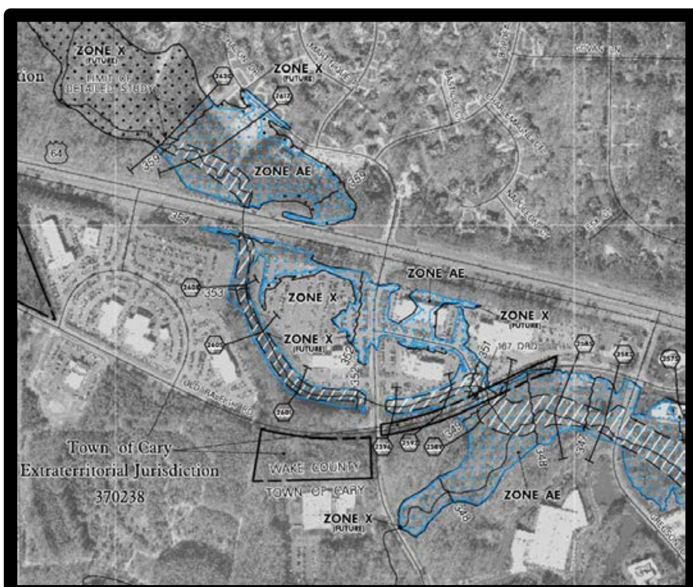
NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

GUIDELINES FOR DRAINAGE STUDIES AND HYDRAULIC DESIGN



DAVID S. CHANG, Ph.D., P.E.
STATE HYDRAULICS ENGINEER

NOVEMBER 21, 2016

Transportation

PAT McCRORY
Governor

NICHOLAS J. TENNYSON
Secretary

November 17, 2016

Mr. John F. Sullivan, III P.E.
Division Administrator
Federal Highway Administration
310 New Bern Avenue, Suite 410
Raleigh, NC 27601

Dear Mr. Sullivan:

Enclosed for your approval is one (1) copy of the 2016 NCDOT *Guidelines for Drainage Studies and Hydraulic Design* manual. Review of this document has been coordinated with Ms. Wendy McAbee of your staff and Ms. Cynthia Nurmi with the FHWA Resource Center, Hydraulics Technical Service Team in Atlanta. All review comments have been addressed. We request that you please return this letter with your signature of approval below for our records. If you have any questions, please contact me at (919)-707-6700.

Sincerely,

David S. Chang

David S. Chang, Ph.D., P.E.
State Hydraulics Engineer
NCDOT Hydraulics Unit

Approval WMcAbee Date 11/21/2016
for FHWA Division Administrator

Enclosure

Cc w/o enclosure:
Ms. Wendy McAbee, Operations (Division Office - Raleigh, NC), Structural Engineer
Ms. Cynthia Nurmi, FHWA Resource Center (Atlanta, GA), Hydraulic Engineer
Mr. Michael L. Holder, PE, NCDOT Chief Engineer
Mr. Rodger Rochelle, PE, NCDOT Technical Services Administrator

Nothing Compares℠

Disclaimer

Guidelines for Drainage Studies and Hydraulic Design is not intended to be a comprehensive design reference. It should be used in accordance with the following criteria:

1. These *Guidelines* are for use in design, analysis, and maintenance of drainage structures and systems designed and constructed by or in association with NCDOT-funded projects.
2. These *Guidelines* are not intended for use on non-NCDOT roads or projects. Any use by non-NCDOT entities is the responsibility of the user and is done at the user's risk.
3. Unless otherwise noted, the design criteria contained herein are guidelines, not policies. A project may have unique circumstances, requiring the design engineer to deviate from them. Should a specific situation require deviation from specified methods, procedures, and criteria presented in these *Guidelines*, approval for a variance is required from the State Hydraulics Engineer.
4. The user assumes the full responsibility in determining applicability for the purposes below:
    - Planning, design and construction of drainage structures and systems
    - Compliance with Federal and State regulatory requirements
    - Use of NCDOT design standards for non-NCDOT roads and projects

The user shall indemnify and hold harmless NCDOT and/or its employees from any claim, demand, suit, liability and/or expense (including attorney's fees and other costs of litigation) arising out of, or relating to injury, damage, or death of persons resulting from the use of these *Guidelines*.

NCDOT Guidelines for Drainage Studies and Hydraulic Design

Contents

1 INTRODUCTION

The 2016 version of the *Guidelines for Drainage Studies and Hydraulic Design,* hereinafter referred to as the "*Guidelines*", is the result of consolidation of the 1999 version of the *Guidelines* and the 1973 *Handbook of Design for Highway Drainage.* It provides design engineers (in-house and consultants) with new guidance to meet emerging environmental, regulatory and design challenges. It includes design policies, procedures, methods, forms, and tools needed to develop the hydrologic and hydraulic designs for NCDOT projects.

This document includes major changes and additions below:

- Legal Aspects, Policies, and Practices in Highway Drainage (revised)
- Preliminary Hydraulic Studies for Planning Document (new)
- Hydrology (revised)
- Stormwater Management (revised)
- Bridge Scour (new)
- Permit Drawings (revised)
- Floodplain Management (new)
- Table of Contents and References (revised)
- Electronic version (single PDF) with internal and external links (new)

It is the responsibility of the design engineer to verify survey and engineering data that are provided by others before using these data in developing the hydraulic design. The responsible engineer is required to affix his or her professional engineering seal to the following documents and reports:

- Construction Plans
- Bridge Survey and Hydraulic Design Report
- Culvert Survey and Hydraulic Design Report
- Hydraulic Design Documentation Summary (Appendix A)
- FEMA documentation:
    - No-rise Certification
    - MT-2 Form
    - As-built Plans Certification Form

This document is not intended to be comprehensive on the practice of hydraulic engineering. The design engineer may reference other materials and should exercise sound engineering judgment in its application to ensure that the design is complete and appropriate. The design engineer is recommended to reference the AASHTO 2007 *Highway Drainage Guidelines* (1) and 2014 *Drainage Manual* (2) for the practice of hydraulic engineering.

The design engineer should follow all policies, specified methods, procedures and tools outlined in this document in developing the drainage plans. However, the design engineer may request approval for variance from the State Hydraulics Engineer for alternative designs.

This document is being published in both hardcopy and electronic (PDF) formats. The electronic version of this document can be accessed and downloaded from the Hydraulics Unit website. The hardcopy version is available for purchase from NCDOT Publications. (See information at https://connect.ncdot.gov/letting/pages/order-publications.aspx.)

A supplementary errata section will be included at the beginning of the electronic version of this document to track minor error corrections, new rules, changes to forms, addenda, etc. which will be rectified in future editions of this publication. To maintain consistency between the hardcopy and electronic versions, no actual changes will be made to the electronic version of the document until such time as a new edition is published. Any updates to forms, appendix items, or addenda will be referenced in the errata section and posted on the Hydraulics Unit website until they are incorporated into a new edition. New editions incorporating full review, update, and incorporation of all revisions and addenda will be issued on a five year cycle and will be coordinated through the FHWA Division Office by the State Hydraulics Engineer.

2 LEGAL ASPECTS, POLICIES, AND PRACTICES IN HIGHWAY DRAINAGE

2.1 Introduction

The purpose of this chapter is twofold:

1. Summarize the relevant federal and state laws which govern NCDOT highway drainage design.
2. Discuss general NCDOT policies and practices pertinent to typical highway drainage designs.

2.2 Federal Laws

2.2.1 Clean Water Act

In 1977, the U. S. Congress amended the Federal Water Pollution Control Act (FWPCA) to regulate the discharge of pollution into waters of the U.S. and it was officially designated the *Clean Water Act*, 33 USC 1344 (CWA) (33). It serves as the cornerstone of federal law for all water quality programs. It directs the Environmental Protection Agency (EPA) and other regulatory agencies to establish standards of water quality for states to follow.

Section 401 of the CWA states that no federal permit or license can be issued that may result in a discharge to waters of the United States unless the State certifies that the discharge is consistent with standards and other water quality goals, or waives certification.

Section 404 of the CWA prohibits the unauthorized discharge of dredged or fill material into waters of the United States, including navigable waters. Such discharges require a permit. The United States Army Corps of Engineers (USACE) has granted Nationwide General Permits for several categories of certain minor activities involving discharge of fill material. Under the provisions of 33 CFR 330.5(a)(15), fill associated with construction of bridges across navigable waters of the United States, including cofferdams, abutments, foundation seals, piers, temporary construction, and access fills, are authorized under the Nationwide Section 404 Permit. Section 404 also requires any federal permit applicant to obtain a Section 401 water quality certification from the appropriate state regulatory agency if the proposed activity may affect the quality of waters of the United States (2).

2.2.2 National Pollutant Discharge Elimination System

In 1987, Congress passed an amendment to the Clean Water Act which added stormwater permits to the National Pollutant Discharge Elimination System (NPDES) program under Section 402. Section 319, which addresses nonpoint source pollution, requires each state to better integrate the Coastal Nonpoint Program and the Statewide Nonpoint Program. In 1997, the NC Legislature passed House Bill 515, which initiated development of a statewide stormwater permit under the National Pollutant Discharge Elimination System (NPDES).

NCDOT was the first statewide agency in the nation to be issued an individual statewide transportation NPDES Stormwater Permit (NCS000250) on June 8, 1998 by the United States Environmental Protection Agency (EPA) through NC Department of Environment and Natural Resources (DENR), which is now NC Department of Environmental Quality (DEQ). This permit is jointly managed by the Hydraulics and Roadside Environmental Units. Requirements contained in the permit address a broad range of NCDOT activities, including the following programs:

- Illicit Discharge Detection and Elimination
- Stormwater System Inventory and Prioritization
- Best Management Practices (BMP) Retrofit
- BMP Toolbox for Post-Construction Runoff
- BMP Inspection and Maintenance
- Post-Construction Runoff Control
- Vegetation Management
- Construction
- Industrial Activities
- Education and Involvement
- Research
- Total Maximum Daily Load (TMDL)

For more details, please see discussion in Chapter 13.

2.2.3 National Environmental Policy Act

The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321–4347) Section 102 requires that all Federal agencies shall ensure that environmental amenities and value be given appropriate consideration in decision making, along with economic and technical considerations (1).

For Federal Aid projects, NCDOT is required to comply with Federal Highway Administration (FHWA) regulations, which are tailored for linear transportation projects and are consistent with NEPA implementation. NCDOT signed an Interagency Agreement in 1977 with the FHWA and the U.S. Army Corps of Engineers (USACE), which integrated Section 404 permit requirements with the NEPA process, constituting the original Merger Process for transportation projects in North Carolina (37). This process, modified most recently in a 2012 Memorandum of Understanding, serves to streamline the project development and permitting processes (67). More information on the Merger Process is provided in Chapter 3, Section 3.3. FHWA guidance on NEPA implementation is provided at https://www.environment.fhwa.dot.gov/projdev/pd2implement.asp.

2.2.4 Executive Order 13653

Executive Order 13653, issued November 1, 2013, requires federal agencies to prepare the nation for the impacts of climate change by promoting (1) engaged and strong partnerships as well as information sharing at all levels of government, (2) risk-informed decision making, (3) adaptive learning, and (4) preparedness planning. Subsequently, FHWA issued Order 5520 on December 15, 2014, to establish policy on preparedness and resilience to climate change and extreme weather events. In this directive, climate change refers to any significant change in the measures of climate, such as temperature, precipitation, wind patterns, etc. lasting for an extended period of time. Changes in climate may manifest as a rise in sea level, as well as increase the frequency and magnitude of extreme weather events (75).

2.2.5 National Flood Insurance Program

The National Flood Insurance Program (NFIP) was established by the National Flood Insurance Act of 1968 (36). NFIP requirements could impose restrictions on the construction of highways in floodplains and floodways in communities that have qualified for flood insurance. It is possible to comply with the federal requirements regarding the encroachment of a highway on a floodplain and still be faced with future legal liabilities because of the impact of the highway on the floodplain and the stream (1). Hydraulics engineers should review the potential for these future liabilities to ensure that they are properly addressed in the development of the proposed hydraulic design. Regulations pertaining to federal flood insurance are contained in 44 CFR 59-80, National Flood Insurance Policy (29).

For information on floodplain management, see Chapter 15.

2.2.5.1 Executive Order 11988

Executive Order 11988, issued in 1977, requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative (31, 32).

2.2.5.2 Executive Order 13690

Executive Order 13690, issued January 30, 2015 amends Executive Order 11988 by establishing a Federal Flood Risk Management Standard, a flexible framework to increase resilience against flooding and help preserve the natural value of floodplains, as part of a national policy on resilience and risk reduction consistent with President Barack Obama's *Climate Action Plan*. (73, 74)

2.2.5.3 Guidance from FHWA

In June 1982, the Federal Highway Administration (FHWA) and the Federal Emergency Management Agency (FEMA) established a Memorandum of Understanding regarding a procedural document entitled "Procedures for Coordinating Highway Encroachments on Floodplains with the Federal Emergency Management Agency". This and additional documentation has subsequently been formally issued in Non-regulatory Supplements 1-3 for Part 650, Subpart A of Title 23 CFR in the Federal Aid Policy Guide (FAPG) (8). These supplements discuss, among other things, recommendations regarding state agencies' and municipalities' responsibility for proposed storm drain installations, design standards for floodplain encroachments, and coordinating proposed highway encroachments on floodplains with FEMA to ensure regulatory compliance. It should be emphasized that Federal Aid projects are required to be in compliance with FHWA regulations or orders, while being consistent with FEMA requirements (including Executive Orders). FHWA regulation applies to all Federal Aid actions in a base floodplain (not just FEMA-regulated floodplains). Detailed guidance on FEMA National Flood Insurance Program compliance as it pertains to specific NCDOT drainage practices is provided in Chapter 15 of these *Guidelines* and in other chapters, as applicable (30).

2.2.5.4 FEMA Hazard Mitigation Grant Program Properties Impacts

Another important FEMA issue of concern relative to highway projects is impact to Hazard Mitigation Grant Program (HMGP) properties (a.k.a. FEMA buyout properties), which may exist pursuant to acquisition under authorization of Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (the Stafford Act), Title 42, United States Code (U.S.C.) 5170c. The Stafford Act requires that such property acquisitions comply with 44 CFR Part 80 FEMA Property Acquisition and Relocation for Open Space. As such, ownership of the acquired property is transferred to the local community government or eligible conservation organization to be maintained for open space purposes in perpetuity in order to restore and/or conserve the natural floodplain functions. Deed restrictions are placed on the property, which prohibit, among other things:

- Addition of any new pavement for roads, highways, bridges and paved parking areas (including asphalt, concrete, oil-treated soil, or other material that inhibits floodplain functions).

- Placement of fill, except where necessary to avoid affecting onsite archeological resources.

Reuse of existing paved surfaces for recreational uses on the acquired property consistent with allowable uses is generally acceptable.

In the development of design alternatives for consideration for a given highway project, it is therefore imperative that HMGP properties be identified early in the planning stage so that every effort can be made to avoid impacts. Identification of HMGP properties and determination of the applicable restrictions associated with them should be coordinated through the NC Department of Public Safety, Division of Emergency Management, Hazard Mitigation Section. Further details regarding HMGP properties are discussed in the FEMA publication *Hazard Mitigation Assistance Guidance; Hazard Mitigation Grant Program, Pre-Disaster Mitigation Program, and Flood Mitigation Assistance Program* (February 27, 2015) (46).

2.3 State Laws and Programs

2.3.1 State Environmental Policy Act

Under the State Environmental Policy Act of 1971 (SEPA) [G.S. 113A, Article 1], State agencies are required to review and report on a proposed project's environmental effect in the form of either an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) document unless the project is covered by minimum criteria. These documents are meant to disclose the direct, secondary, cumulative, long-range, and short-term impacts of the proposed project. An EA is prepared if the project is not anticipated to produce significant adverse environmental impacts, if the impacts can be mitigated to a non-significant level, or if the magnitude of impacts is uncertain. If the project's impacts will be significant or not able to be fully mitigated, an EIS should be prepared. An EIS will provide a more extensive evaluation of the advantages and disadvantages of project alternatives and is written in greater detail than an EA (38).

2.3.2 Coastal Area Management Act

In 1974, the General Assembly passed the Coastal Area Management Act (CAMA) [G.S. 113A, Article 7] to balance economic development and environmental protection in North Carolina’s twenty coastal counties. These counties are subject to the rules and policies of the Coastal Resources Commission (CRC), which administers CAMA regulatory compliance. The Division of Coastal Management (DCM), a division of NCDEQ (formerly NCDENR), serves as staff to the CRC and works to protect, conserve and manage North Carolina's coastal resources through an integrated program of planning, permitting, education and research pursuant to CRC rules and policies.

Areas of Environmental Concern (AEC) are the foundation of the CRC's permitting program for coastal development. An AEC is an area of natural importance: It may be easily destroyed by erosion or flooding; or it may have environmental, social, economic or aesthetic values that make it valuable to our state (39).

The CRC classifies areas as AECs to protect them from uncontrolled development, which may cause irreversible damage to property, public health or the environment. AECs cover almost all coastal waters and about 3 percent of the land in the 20 coastal counties.

The CRC has established four categories of AECs:

- The Estuarine and Ocean System
- The Ocean Hazard System
- Public Water Supplies
- Natural and Cultural Resource Areas.

2.3.3 NC Water Supply Watershed Protection Act

In 1989, the Water Supply Watershed Protection Act was passed by the State Legislature (G.S. 143-214.5) to protect drinking water supplies. It directed the Environmental Management Commission (EMC) to adopt minimum statewide water supply protection standards and implement water quality protection programs (40). It also required classification of the waters of the State based on their quality and significance to the municipalities (41).

2.3.4 Stormwater Management Rules

State highway (NCDOT) development projects are permitted based on a case by case evaluation of each individual project, which are considered to be covered under 15A NCAC 02H .1003, subparagraph (d)(3)(C) "Other Projects", which states: *"otherwise meets the provisions of this Section and has water dependent structures, public roads and public bridges which minimize built-upon surfaces, divert stormwater away from surface waters as much as possible and employ other best management practices to minimize water quality impacts."* Notable among these are the criteria that have been established for determining locations where hazardous spill protection measures must be provided to protect critical water supply watershed areas (see Appendix O). Furthermore, NCDOT is regulated under a separate NPDES Stormwater Permit (see 2.2.2), which covers all NCDOT activities statewide.

2.3.5 Riparian Buffer Rules

Beginning in 1999, EMC adopted Riparian Buffer Rules (G.S. 143-214.20-26; 15A NCAC 02B) to protect existing riparian buffers on nutrient sensitive waters (NSW) and certain water supply watersheds (42). See Chapter 13 Stormwater Management for additional discussion.

2.3.6 State Sedimentation Pollution Control Act

The State Sedimentation Pollution Control Act was adopted in 1973. This promulgated rules and regulations to control accelerated erosion and sedimentation resulting from land disturbing activities. The Department of Transportation has been delegated the authority to administer an erosion and sedimentation control program within the Department. NCDOT's Roadside Environmental Unit is primarily responsible for development of the erosion and sedimentation control plans for state highway projects. Guidance regarding culvert construction phasing considerations with respect to hydraulic design is provided in Chapter 12 of these guidelines.

highway projects. Guidance regarding culvert construction phasing considerations with respect to hydraulic design is provided in Chapter 12 of these guidelines.

2.3.7 State Floodplain Management Policy

Governor James G. Martin issued State Executive Order 123 in July 1990 requiring all state agencies to follow a uniform floodplain management policy and providing guidance for compliance with federal regulations (59). Section 3 of the EO states:

> *The Department of Administration shall administer a Uniform Floodplain Management Policy for State Agencies. By agreement between the Department of Transportation and the Department of Administration, the Department of Transportation shall work directly with the Federal Department of Transportation and the Federal Emergency Management Agency to apply appropriate standards and management to comply with the Floodplain Management Policy relevant to highway construction within floodplains.*

This Executive Order provides the legal basis for NCDOT to enter into a Memorandum of Agreement with the NC Floodplain Mapping Program, as discussed in Chapter 15 (58).

2.3.8 Reasonable Use Rule

North Carolina long adhered to the Civil Law Rule in regard to surface water drainage. This rule obligates owners of lower land to receive the natural flow of surface water from higher lands. It subjects a landowner to liability whenever he or she interferes with the natural flow of surface waters to the detriment of another in the use and enjoyment of his or her land. Since almost any use of land involves some change in drainage and water flow, a strict application of the civil law principles was impracticable in a developing society. Thus, a more moderate application of this rule to allow a landowner reasonable use of his or her property evolved.

In 1977, the North Carolina Supreme Court formally adopted the Rule of Reasonable Use with respect to surface water drainage and abandoned the Civil Law Rule (Pendergrast v. Aiken, 236 S.E.2d 787, 293 N.C. 201). The adopted Reasonable Use Rule allows each landowner to make reasonable use of his or her land even though by doing so, he or she alters in some way the flow of surface water thereby harming other landowners, with liability being incurred only when this harmful interference is found to be unreasonable and causing substantial damage. There are still some unanswered questions in the application of the adopted Reasonable Use Rule to specific areas of state agency activities. However, this rule is more compatible with and adaptable to the realities of modern life and will provide just, fair and consistent treatment. Therefore, NCDOT general drainage policies and practices follow this rule.

The Reasonable Use Rule places responsibility on the landowner to make reasonable use of his or her land. While "reasonable use" is open for interpretation on a case by case basis, the implication for highway drainage is that provisions for, and treatments of, surface waters on properties are to be made in accordance with sound, reasonable, and acceptable engineering practices. Therefore, it is incumbent on engineers to evaluate the potential effects of surface water activities on both upstream and downstream properties and to include provisions in their design to hold these effects to reasonable levels.

2.4 General Drainage Policies and Practices

2.4.1 Augmentation or Acceleration of Peak Rate of Flow

Development of property can cause an increase in the quantity and peak rate of flow by increasing impervious areas and providing more hydraulically efficient channels and overland flow. It is NCDOT policy to develop and make reasonable use of its lands and rights-of-way through sound, reasonable and acceptable engineering practices and to deny responsibility for effects of augmented or accelerated flow caused by its improvements unless determined to cause unreasonable and substantial damages. Likewise, it is NCDOT policy to expect the same practice and acceptance of responsibility of owners and developers of properties adjacent to state highways.

2.4.2 Diversions

Diversions are defined as the act of altering the path of surface waters from one drainage outlet to another. It is NCDOT policy to design and maintain its road systems, so that no diversions are created thereby, insofar as is practicable from sound engineering practice. Anyone desiring to create a diversion into any highway rights-of-way shall not be allowed to do so unless written permission is obtained from the State Hydraulics Engineer. Permission will be granted only after it has been determined that:

- the additional flow can be properly accommodated without causing damage to the highway,
- the cost for any required adjustments to the highway system will be borne by the requester, and
- appropriate consideration and measures have been taken to indemnify and save harmless NCDOT from potential downstream damage claims.

It is NCDOT policy not to become a party to diversions unless refusal would create a considerable and real hardship to the requesting party.

2.4.3 Improvements and Maintenance of Drainage within the Right-of-Way

Drainage structures and ditches shall be maintained such that they do not present an unreasonable level of damage potential for the highway or adjacent properties.

Where the elevation of the flow line of an existing culvert under a highway is not low enough to adequately provide for natural drainage, NCDOT will assume full responsibility for lowering the culvert or otherwise providing needed improvement.

Where a requested culvert invert adjustment is a result of a property owner lowering the flow line of the inlet and outlet ditch in order to improve drainage of his or her property, the following considerations shall be given to the action taken:

- The lowered culvert must have a reasonable expectancy of being functional and maintainable.
- NCDOT participation (up to full cost) must be based on benefit gained by the roadway drainage system as a result of the lowering.
- Where the new installation is of doubtful, or no benefit to highway drainage, the requesting party must bear the entire cost of installation.

Where the size of an existing highway culvert is inadequate as a result of a general overall development of the watershed, it is NCDOT's responsibility to replace the structure or otherwise take appropriate action.

Where such a culvert's inadequacy is the result of a single action or development, it is considered "unreasonable and substantially damaging" under the State's adopted drainage ruling (see 2.3.8). Therefore, the party responsible for the action or development should bear the cost of replacement.

Where a new culvert crossing is requested, if the culvert is required for proper highway drainage or sufficient benefits to the highway drainage system would occur, the full cost will be borne by NCDOT providing there is no diversion of flow involved. Where the new installation is of doubtful or no benefit to highway drainage, the property owner will bear the entire cost. When both parties receive benefit, a joint effort may be negotiated.

Established culvert crossings will be maintained. Requests to eliminate any culvert will require approval of the State Hydraulics Engineer.

When new private drives for single-family residential property are constructed entering the highway, the property owner can furnish, delivered to the site, the amount, type and size pipe designated by NCDOT, to be installed by maintenance forces. This is not applicable for commercial property. For additional guidance on this matter, refer to NCDOT's *Policy on Street and Driveway Access to North Carolina Highways* (60).

No alteration, attachment, extension, nor addition of appurtenance to any culvert shall be allowed on highway rights-of-way without written permission from the State Hydraulics Engineer.

2.4.4 Improvements and Maintenance of Drainage outside the Right-of-Way

While it is the responsibility of NCDOT to provide adequate drainage for constructing and maintaining the State Highway System, it is not its policy nor responsibility to provide improved drainage for the general area traversed by such roads, unless incidental to the drainage of the road or highway itself. Drainage involvement outside the highway rights-of-way is limited to two general areas of justification:

- Sufficient benefit could be gained by such action to warrant the cost. These benefits would be in such areas as reduction in roadway flood frequency or extent, facilitation of maintenance, or a reduction in potential damages.

- Work is required to correct a problem or condition created by some action of NCDOT.

It is not the responsibility of NCDOT to eliminate flooding on private property that is not attributable to acts of the agency or its representative.

In general, outlet ditches will be maintained for a sufficient distance downstream to provide adequate drainage for the highway facility. On large outlets serving considerable areas outside the right-of-way, the maintenance should be done on a cooperative basis, with the benefited properties bearing their proportionate share. Shares will, in general, be based on proportioning of runoff from the areas served by the outlet.

It is not the policy of NCDOT to pipe inlet or outlet drains, natural or artificial, outside the right-of-way, which existed as open drains prior to existence of the highway. Where the property owner wishes to enclose an inlet or outlet, NCDOT may install the pipe adjacent to the right-of-way if justified by reason of reduced maintenance, safety or aesthetics if the pipe is furnished at the site by the property owner. This does not apply to the development of commercial property.

2.4.5 Obstructions

It is the policy of NCDOT that when a drain is blocked downstream of the highway, which is detrimental to highway drainage, if from natural causes, NCDOT will take necessary measures to remove the blockage or obstruction. Where the blockage is caused by wrongful acts of others, it is the policy of NCDOT to take whatever recourse deemed advisable and necessary to cause the party responsible to remove the blockage. Where a blockage occurs downstream of a highway, whether natural or artificial, and is of no consequence to NCDOT, it is the policy to remain neutral in causing its removal.

State Statute (G. S. 136-92) provides that anyone obstructing any drains along or leading from any public road is guilty of a misdemeanor.

2.4.6 Drainage Easements

It is generally preferable that any structural feature such as a drop inlet, catch basin, or pipe end be contained within a permanent easement. Where runoff is discharged from the right-of-way at a point where there is no natural drain or existing ditch, a permanent drainage easement is required to allow construction of a ditch or channel to convey the discharge to an acceptable natural outlet. Where permanent easements are required, sufficient information will be obtained, so that the limits, grade, and cross section may be determined. The easement shall be of sufficient size to contain the spoil and provide working room for equipment.

When the discharge is into a natural drain or existing ditch and the increase in flow would exceed the capacity or otherwise create a problem, a temporary drainage easement can be obtained to allow enlarging or otherwise improving the drain to a point where the increased discharge will not cause damage.

Where diversion of water is made to a natural drain or existing ditch which could increase the discharge considerably above its capacity, an easement is required to enlarge and improve the drain to a point where the increased discharge can be released without causing damage.

Where improvement to an existing drain is required for proper drainage and not covered in the paragraph above, a permanent drainage easement is not required. Even though the drain may be enlarged and deepened, if the property owner is informed of what is to be done and agrees in writing to allow entry onto his or her property for this work, it is all that is required. This should not be construed to mean that in all cases of this nature that only a permit of entry should be obtained. There will be instances where a permanent easement is desirable.

2.4.7 Dams and Impoundments

It is the policy of NCDOT to discourage the location of roadways on dams due to the increase in potential for long term maintenance and replacement cost. In those instances where a defined advantage may be gained or a substantial savings in funds may be realized, the use of a dam for a roadway may be considered.

Where it is determined that a dam will be utilized as a roadway the following criteria must be met:

- It must have approval certification from NCDEQ (formerly NCDENR) pursuant to the State Dam Safety Law of 1967 (G.S. 143-215.23-37), when applicable.
- All pertinent data regarding the design of the embankment and impoundment structure must be presented to NCDOT for review.
- Top section of the dam must be equal to the approach roadway section width (shoulder to shoulder) plus a minimum of 4 feet.
- At a minimum, guardrail will be required on the impoundment side of the roadway.
- The spillway will be designed to provide a minimum freeboard at the roadway shoulder of 2 feet for a 50-year impoundment level.
- Means of draining the lake completely will be provided.

Design acceptance or approval by NCDOT is limited to the use of the dam as a roadway only, and is in no way intended as approval of the embankment as an impoundment structure.

When a section of roadway that also serves as a dam is accepted, responsibility incurred by NCDOT is limited to maintenance of the roadway for highway purposes from shoulder to shoulder only. Responsibility for the impoundment, any damage that may result therefrom, and maintenance of the embankment or appurtenances as may be required to preserve its integrity as an impoundment structure shall remain with the owner of the impoundment. Any maintenance work will be subject to the provisions of G.S. 136-93.

Impoundment of water on highway rights-of-way may be allowed under the following criteria:

- The impoundment does not adversely affect the rights-of-way for highway purposes.
- Adjustments as required (e.g. flattening slopes, rip rap slope protection, structure modifications, etc.) shall be the responsibility of the encroaching party.
- Provision shall be made for draining the impoundment to facilitate highway maintenance.

2.4.8 Subdivision Streets

When roads and streets built by others are accepted onto the State Highway System for maintenance, responsibility for the drainage system, discharge pattern and outlet locations is to maintain them as they exist at the time of acceptance and is limited to the rights-of-way. In general, stormwater treatment facilities should be located outside of the dedicated rights-of-way.

Information on design, review and approval requirements is provided in the NCDOT publication *Subdivision Roads Minimum Construction Standards* (3).

When accepting streets for maintenance, where drainage review is required by Hydraulics Unit, the following information should be furnished for the review:

- Street layout and grades, and if applicable, include proposed catch basins, manholes, stormwater treatment facilities, etc. along with grades (top and invert elevations) of the storm drain system
- Typical Section

- Contour map (if available)
- Pipe sizes and grades
- Drainage areas at each pipe or inlet
- Inlet computations showing gutter spread and bypass for curb and gutter systems.
- Proposed easements
- Vicinity map

The above information should be submitted prior to the beginning of construction of the subdivision, so that if any changes are recommended, these could be incorporated in the original construction, rather than having to make post-construction adjustments.

Where storm drain systems are used, the minimum design for the collector system should be for the 10-year storm frequency; however, for cross-drainage, design for the appropriate storm frequency for the functional classification of the highway facility (usually 25-year or 50-year) should be achieved.

Where roads and streets built by others now exist on the system, NCDOT's responsibility for the drainage system installed by the developer does not extend beyond the right-of-way or easement limits accepted by NCDOT. The acceptance of the streets onto the State Highway System does not include drainage easements outside the right-of-way unless specifically stated that those easements so designated by NCDOT are included in the acceptance.

Where requests for additions to the system arise on roads and streets built by others, the requests shall not be granted until the drainage installations have been inspected and approved by a representative of NCDOT. The representative shall be the Division Engineer or appointed delegate. If desired, or if special treatment is needed, a review by the Hydraulics Unit should be requested. If structures other than pipe installations are included, they shall be approved by the State Hydraulics Engineer.

2.4.9 Adjustments to Pipe Culverts

No alteration, extension nor addition of appurtenance to any pipe culvert shall be allowed on highway right-of-way without the written consent of the Division Engineer or his or her authorized representative.

All requests for alteration, extension or addition of appurtenance to any pipe culvert shall be made in writing to the Division Engineer. Prints shall be furnished showing the location and detail of the proposed work. The print shall include arrows indicating the direction of flow, and approximate acreage drained by the pipe and size and type of the existing pipe. If appurtenances are involved, the type of construction shall be shown. The approximate depth from inlet rim to invert shall be shown when catch basins or drop inlets are proposed. Where only minor drainage alterations are involved, the Division Engineer will have authority to approve the encroachment. If other than minor drainage alterations are involved, the Division Engineer shall provide a drawing and recommendations to the Hydraulics Unit for review and approval. Upon approval by the State Hydraulics Engineer, the request shall be returned to the Division Engineer for preparation and execution of the Encroachment Contract. Any request for alteration to pipe culverts may be submitted to the State Hydraulics Engineer, if the Division Engineer deems it appropriate.

2.4.10 Adjustments to Box Culverts

No alterations of, nor additions to any box culvert on the highway system shall be allowed without written permission from the State Hydraulics Engineer.

All requests for alteration of, or additions to, box culverts shall be made in writing to the Division Engineer. Prints shall be furnished showing in detail the location and nature of the proposed work. The prints shall show sufficient detail such that they may be used as construction drawings. The proposed alteration shall be accomplished within the parameters of good engineering construction and hydraulic design. The Division Engineer shall forward one of these drawings to the State Hydraulics Engineer, with his or her recommendations. After any required revisions and upon approval of the plans by the State Hydraulics Engineer, the request shall be returned to the Division Engineer for preparation and execution of the Encroachment Contract.

2.4.11 Highway Drainage within the Railroad Right-of-Way

When a highway project involves drainage work at a railroad crossing within or adjacent to a railroad right-of-way, every effort should be made to avoid adverse impacts to the railroad, its drainage facilities, and right-of-way. If the impacts to a railroad are unavoidable, any activity within the railroad right-of-way must be coordinated with the owner of the railroad. Resources within NCDOT which may be consulted regarding railroad coordination include the Rail Division and the local Highway Division offices. Railroad companies CSX Transportation and Norfolk Southern Corporation, provide specific guidance regarding their requirements for activities involving culverts and pipelines within their rights-of-way. This guidance is available online for viewing and downloading (see refs. 51 & 52). For new highway bridges over railroads, deck drains should not discharge directly over the railroad tracks.

2.4.12 Stormwater BMP Facilities within NCDOT Rights-of-Way

The following must be observed with respect to stormwater best management practices (BMP) facilities within NCDOT rights-of-way:

- No private stormwater BMP facilities are allowed within NCDOT rights-of-way.
- No private stormwater pipes or other drainage conveyances are allowed to connect to NCDOT BMP facilities.
- Encroachments that impact NCDOT BMP facilities (e.g. construction of a driveway that would reduce a length of an established length of grass swale treatment) should be appropriately accounted for in NCDOT's Stormwater Controls Management System (SCMS).

3 PRELIMINARY HYDRAULIC STUDIES FOR PLANNING DOCUMENT

3.1 Overview

The work performed during the project development (planning) phase is intended to provide needed information required for the selected alternatives in the preparation of the planning document. In the subsequent design phase, much of the data gathered in the earlier phase may need to be verified, updated, and refined. Additional details may be needed prior to the final hydraulic design that were not required in the project development phase.

3.2 Project Development (Planning) Phase

In the planning phase of project development, the design engineer performs preliminary studies and makes recommendations to facilitate and guide decisions made in the project development process. During this planning phase, a Preliminary Design Report (PDR), Appendix D Item 1 should be completed for each major stream crossing (as defined below in Section 3.3).

For bridge replacement projects, the PDR is typically completed prior to the scheduled Field Scoping Meeting (FSM). The preliminary bridge replacement design recommendations are determined at the FSM by a consensus of the multi-disciplinary team of participants. Issues covered at the FSM typically include hydraulic design, geotechnical concerns, roadway design, project development, environmental analysis, traffic safety, structure design, constructability, maintenance access, and local Division concerns. Appendix D Item 2 is a listing of some of the hydraulic design concerns which may need to be discussed at the FSM.

For State Transportation Improvement Program (STIP) projects other than bridge replacement projects, a preliminary field review should be conducted as part of the preliminary hydraulics study, and it would be helpful to complete the PDR for each major stream crossing prior to the preliminary field review. Consult the Natural Resources Technical Report (NRTR), if one has been completed, for consideration of avoidance and minimization of impacts to high quality environmental resources. A checklist is also provided in Appendix D Item 3 of items which should be reviewed during preliminary field reconnaissance. At this time, local highway maintenance personnel should be contacted for input on flood history, problem areas and other pertinent drainage information.

Using data collected in the PDR and preliminary field review, the preliminary hydraulic recommendations for STIP projects are to be developed for every major stream crossing site. The primary purpose of the preliminary hydraulic recommendation is to determine the hydraulic conveyance of the drainage structure that will be needed in order to develop preliminary project cost and estimate of environmental impacts for comparing the project's study alternatives. Existing structures should be evaluated for hydraulic adequacy and structural integrity, and a determination should be made regarding whether they need replacement or can be retained and feasibly modified to accommodate the proposed highway improvements. Any supplemental information regarding the preliminary hydraulic recommendation may be documented in the notes section of the PDR. In the event more space is needed for additional notes, additional pages may be attached. For NCDOT roadway projects, the PDR form is intended to serve as the necessary documentation of the preliminary hydraulic recommendations for use in preparation of the project's planning document. Instructions and an example are included in Appendix D to assist in preparing the PDR form.

3.3 Determination of Major Stream Crossing

For preliminary drainage studies, it is neither practicable nor necessary to study small stream crossings involved with a project; only major stream crossings need be studied. A major stream crossing is defined as one which would require a waterway opening providing hydraulic conveyance greater than that of a single 72-inch diameter pipe (i.e. waterway opening of 30 square feet or more). Any existing crossing with a structure size which may be below, but close to this size and potentially may be undersized, should be included in the preliminary drainage study. Preliminary hydraulic recommendations for major stream crossings should be documented on the form in Appendix D Item 4. It should be noted that overflow drainage structures in the floodplain adjacent to a stream, while not technically conveying a stream, should be considered part of a system of structures comprising a major stream crossing, where applicable, and should thus be accounted for in the hydraulic analyses and documentation.

For NCDOT roadway projects which require concurrence of federal and state agencies through the NEPA 404 Merger Process, the design engineer is responsible for providing preliminary hydraulic recommendations (37, 67). During Concurrence Point 2 (Detailed Study Alternatives Carried Forward), the design engineer offers input regarding any proposed study alternatives which may be problematic for FEMA compliance or difficult for facilitation of drainage. During Concurrence Point 2A (Bridging Decision and Alignment Review), the hydraulic engineer should provide preliminary hydraulic recommendations for the drainage structures required to provide adequate hydraulic conveyance to accommodate the major stream crossings under study for the project, including possibly accompanying the Merger team during a field review of the project area. Appendix D Item 4 form should be used for Concurrence Point 2A documentation.

3.4 Determination of Minimum Length Bridge (for Preliminary Estimates)

Preliminary recommendations for bridge replacements or new location bridges are often based on NCDOT's definition of a minimum length bridge, which is illustrated in Appendix E Item 6. This criterion generally provides for a minimum ten foot wide offset from anywhere along the stream bank to the below-ground projection of the roadway embankment slope (typically 1.5:1 normal to the end bent). This does not necessarily preclude specification of a vertical abutment bridge in the final design stage, which could further reduce bridge length, provided it would meet project requirements. While this is a general rule for preliminary bridge sizing, there also may be unique site constraints which may otherwise affect the recommendation.

3.5 Project Commitments Regarding FEMA Coordination

Planning documents for NCDOT projects usually include formal project commitments (a.k.a. "green sheets"). When a FEMA-regulated stream is involved, the Hydraulics Unit requires that project commitment statements such as the following be included to address FEMA compliance coordination:

Hydraulics Unit commitment:

The Hydraulics Unit will coordinate with the NC Floodplain Mapping Program (FMP) to determine status of project with regard to applicability of NCDOT's Memorandum of Agreement, or approval of a Conditional Letter of Map Revision (CLOMR) and subsequent final Letter of Map Revision (LOMR).*

* If project is in Mecklenburg County, CLOMR submittals should be coordinated with Charlotte-Mecklenburg Storm Water Services.

Highway Division commitment:

This project involves construction activities on or adjacent to FEMA-regulated stream(s). Therefore, the Division shall submit sealed As-built construction plans to the Hydraulics Unit upon completion of structure construction, certifying that the drainage structure(s) and roadway embankment that are located within the 100-year floodplain were built as shown in the construction plans, both horizontally and vertically.

3.6 Project Commitment Regarding Climate Change and Extreme Weather Events

Planning documents for NCDOT projects that may be vulnerable to extreme weather and flooding, such as sea level rise, should also include the following commitment statement in the green sheets:

Hydraulics Unit and Roadway Design Unit commitment:

NCDOT will follow FHWA's policy as set forth in FHWA Order 5520, "Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events" and guidance as set forth in FHWA's publications "Highways in the River Environment-Floodplains, Extreme Events, Risk, and Resilience" June 2016, (FHWA-HIF-16-018) and "Highways in Coastal Environment: Assessing Extreme Events" October 2014, (FHWA-NHI-14-006) to minimize climate and extreme weather risks and protect transportation infrastructure.

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4 PRELIMINARY ROADWAY PLANS REVIEW AND PRE-DESIGN STUDY

4.1 Preliminary Roadway Plans Review

For transportation improvement projects, NCDOT hydraulic design staff initially receive a set of preliminary roadway plans for review from the Roadway Design Unit. The purpose of the preliminary review is to allow the design engineer to determine any potential drainage problems with the design and to provide comment on changes which may be needed. Items which should be evaluated include, but are not limited to, the following:

- overtopping elevation (relative to 100-yr and design event elevations, as applicable)
- effects to floodplain (e.g. lateral floodway encroachment, fill in floodway, etc.)
- project commitments made in planning / project development phase
- potential problems with spread/hydroplaning
- locations of high undercut areas where berm ditches are needed
- superelevation: at rollover locations, on bridge deck(s), at intersections, at sags and crests
- roadway grades, intersection grades
- alignment review for avoidance/minimization efforts
- drainage outlet locations
- effects to existing drainage systems/outlets
- potential diversions
- sag (low point) on bridge or in cut section(s) with no relief
- minimum cover over culverts
- existing level of service for the transportation facility
- physical condition and hydraulic adequacy of existing drainage structures
- preliminary bridge superstructure grade and span arrangement
- typical roadway sections
- embankment slope in wetland areas
- navigational channel requirements
- under-clearance requirement for greenway/animal crossing
- access/vertical clearance under bridge for inspection/maintenance
- sidewalks, bike lanes, multi-use paths

4.2 Pre-Design Study

Prior to commencing detailed final design and associated final field reconnaissance, the project should be reviewed to familiarize the design engineer with the project requirements. Archived field survey records, including Bridge and Culvert Survey and Hydraulic Design Reports (BSRs and CSRs, Appendix E), and office data, including any previous drainage complaints, should be collected and reviewed to determine what additional information is required during the final field reconnaissance and survey stage. As with the project development phase, local highway maintenance personnel should be contacted again prior to commencing final design to update and confirm information on flood history, problem areas and other pertinent drainage information. Specific design methods, procedures and criteria are also addressed at this stage. Design engineers should complete this phase by having a Pre-design Review meeting with the appropriate NCDOT hydraulic design staff. The design engineer is to prepare a list of topics and information, including hydraulic design assumptions, for discussion at the meeting. Any actions and decisions agreed to at the review meeting should be summarized in meeting minutes and included in the final project documentation. Also review project commitments ("green sheets") made in the project development stage to ensure they can be implemented. The first page of Appendix B should be completed and approved by the appropriate NCDOT hydraulic design staff prior to field reconnaissance.

5 FIELD RECONNAISSANCE AND SURVEY

5.1 Overview

The Location and Surveys Unit, in conjunction with the Photogrammetry Unit, provides survey data that are required for the development of hydraulic design plans. The type and presentation format of these data are provided in the Location and Surveys Unit's document *NCDOT Field Surveys for Hydrographic Data* (25).

Typical survey data required for hydrologic and hydraulic studies include:

- existing bridge superstructure and substructure locations and elevations
- existing culvert dimensions (including invert elevations, top slab depth, multi-barrel web thickness, condition, etc.)
- pipe sizes and condition, invert elevations
- existing drainage channels (including, size, slope, stability, etc.)
- drainage structure invert elevations
- streams and ponds (location, geometry, hydraulic characteristics, etc.)
- storm drain system components, etc.
- curb and gutter locations
- topographic features (e.g. paved areas, buildings, wooded areas, etc.)
- digital terrain model (DTM) and LiDAR

Wetlands and jurisdictional streams are delineated by the Natural Environment Section (NES) and verified by the US Army Corps of Engineers (USACE) and/or the NC Department of Environmental Quality (NCDEQ) staff. Survey data for transportation improvement projects are compiled and stored in a single Final Survey Microstation file. For specialty or unusual survey needs, such as bathymetric surveys in sounds, large rivers, ponds or lakes, the Location Engineer may need to coordinate with the design engineer to define the survey coverage area and data requirements during the initial stage of the survey.

It is the primary design engineer's responsibility to verify and supplement the survey data in the field prior to commencing detailed design to ensure that these survey data are accurate for use in developing the hydraulic model analyses, Bridge and Culvert Survey and Hydraulic Design Reports, and drainage plans. The design engineer should consider the level of data needed for the hydrologic and hydraulic analyses to be performed. This should be compared with the survey data provided by Location and Surveys and Photogrammetry Units to determine what additional data must be obtained, such as stream bed slope, channel geometry (at locations where detailed stream cross sections may be needed), etc. If the accuracy of the survey data is in question or if additional field surveys are warranted, assistance from Location and Surveys staff may be requested. Appendix D, Item 4 includes a list of field information that should be collected in the preliminary design phase of the project (which may later be supplemented with more detailed survey information in the final design stage).

5.2 Purpose of a Drainage Survey

The purpose of a drainage survey is to determine how to best convey stormwater runoff, associated with the roadway, to a natural drainage outlet safely, efficiently, aesthetically, and with environmental stewardship. Opportunities to observe live storm runoff events are seldom available. Therefore, the design engineer must rely on expertise, experience and judgment in evaluating site conditions and making appropriate recommendations.

5.3 High Water Marks

Moving water usually leaves marks along the watercourse. Anyone will notice the effects of a great storm on a large stream if it is seen before cleanup operations have been completed and marks removed. But it takes a trained eye to perceive the marks caused by the smaller storms, which leave no visible evidence of damage, but which, nevertheless, might wash out a roadway fill or flood the road.

Indications of the flow of water could include:

- drift (fences are good collectors of drift)
- erosion, such as:
  - cultivated field scoured down to bare clay or gravel in the low areas
  - eroded stream banks
  - scour hole at the outlet of a drainage structure
  - roadway shoulder eroded below the pavement with all the fines washed out
- deposition of streaks of sand and gravel in a field or on pavement
- presence of excessive sediment deposits in a channel
- high water marks on trees and structures
- flow patterns in matted grass

Additionally, it is important to obtain local flood history information from the local Division maintenance personnel and local residents or service personnel (mail carrier, school bus drivers, etc.) who may be familiar with the project site. When conditions are found which indicate potential damage to the road, these should be addressed in the development of the final design recommendations on how to safely convey storm runoff. Reliable high water mark elevations should be recorded on Bridge and Culvert Survey and Hydraulic Design Reports (BSRs and CSRs, Appendix E).

5.4 Drainage Field Reconnaissance

When conducting a field survey for a roadway drainage structure such as a bridge or culvert, it is important to remember that the highway drainage structure must be designed to satisfy the following constraints for the duration of its structural life:

- must safely convey the design flow so as to prevent inundation of the travel way without creating excessive flooding on upstream or downstream properties

- must not create flow velocities causing excessive scour erosion in the outlet channel or on the roadway fill at the inlet
- must structurally support the roadway and traffic loading
- must provide adequate means for terrestrial and aquatic passage

The challenge for the design engineer is to design the most economical structure which will satisfy all of these constraints. More detailed guidance on these topics is provided in Chapters 8 and 9. However, with respect to allowable backwater and scour velocities, certain field data must be collected to establish these parameters. Elevation data on upstream development in the vicinity should be obtained to determine if structures are near the observed or known high water elevation. In order to estimate scouring velocities in a channel, it is necessary to describe the type of material in the stream bed and determine whether scour occurs in the natural channel.

In addition to the above, the field reconnaissance should serve to:

- visually acquaint the design engineer with conditions and constraints of the site (such as obtaining overtopping elevation to determine existing level of service, assessing potential impacts of grade adjustments, etc.)
- identify topographic features missed in prior surveys
- verify data obtained from other sources, such as base mapping or other survey data
- identify ponds, lakes, reservoirs and other stormwater retention areas which may affect discharge rates
- review existing drainage features and obtain information on performance
- review potential outlet facilities and downstream conveyances for performance, adequacy, stability, and condition
- identify sediment-sensitive areas such as lakes, ponds, and channels
- review contributing watershed characteristics (e.g. pasture, wooded, industrial, residential, etc.)
- identify new or planned construction or proposed development
- locate and/or verify wetlands and other environmentally sensitive areas (to note any obvious discrepancies which may need review by the Natural Environment Section)
- obtain by survey or verify from structure inspection reports or Location and Surveys data details of size, location, length, material type and condition of existing drainage structures
    - for existing box culverts to be extended: top slab and vertical interior wall thickness
    - for existing bridges: pier widths, footers, abutments, mud sills
- assess existing structure's condition, and if it is in question (e.g. cracks, perched, spalling, etc.), note to follow up by contacting the Structures Management Unit and/or Materials and Tests Unit, as applicable, to obtain a structural integrity evaluation
- obtain channel data (see Chapter 11)
- obtain historical flood and other stream flow information such as:
    - maximum and other large flood levels at, upstream, and downstream of the study site
    - dates of these occurrences and frequency
    - more frequent flooding levels (examples: annual, 2 year, 5 year)
- note any channel scour and migration
- note drift potential, debris size and quantity
- obtain descriptive photographs of site (e.g. upstream and downstream view from road, face of structure upstream and downstream, evidence of scour, floodplain characteristics, structures in floodplain, etc.), noting location and direction of view

5.5 Drainage Data Collection

Examples of additional drainage survey data and supplemental topographical information which should be collected:

- elevations of flooding (high water marks, historical flood levels)
- elevation of upstream and downstream features which could control the design, such as buildings, roads, yards, fields, and other drainage structures
- stream bed elevations a sufficient distance upstream and downstream to establish the normal stream gradient
- floodplain and channel cross-sections for backwater analysis and channel realignments
- structure geometry and related data needed for hydraulic model analysis (e.g. rail height, pier widths, guardrail, sediment accumulation, etc.)
- development and land cover in floodplain for determination of flow resistance and distribution (e.g. roughness coefficients for hydraulic model analysis)
- general description of stream bed and bank materials (clay, silt, sand, gravel, cobble, rock, etc.)
- depth to rock - if extensive rock is visible, explore extent by probing bed on culvert size streams for possible footing depth. (If warranted, Geotechnical Unit should be contacted for more detailed investigation.)
- locations of high undercut areas where berm ditches are needed.
- locations of top of bank along upstream and downstream channel for sufficient distance to establish riparian buffer limits for assessment of impacts in buffer zones
- location of springs, seeps, or noticeable high water tables
- potential locations for hazardous spill basins (if required)
- verification of wetlands and jurisdictional streams shown in base mapping on Roadway plans, to ensure accuracy for permit application (Coordinate with NES as soon as possible if any significant discrepancies are encountered.)

Additionally in urban areas, where curb and gutter roadway typical section is proposed:

- Locate and obtain elevations of driveways and low areas behind proposed curb where drainage inlets may be needed.
- Locate and obtain elevations of offsite drainage system behind proposed curb
- Locate small inflow systems such as roof and basement drains.

Review and obtain the following information for use in bridge scour analysis:

- Description of floodplain
- Channel bed material (e.g. sand, silt, etc.) and gradation (e.g. fine, medium, coarse)
- Evidence of scour at existing structure, particularly at the abutments and interior bents
- Channel cross-sections at bridge face and at locations of the upstream and downstream toe of the embankment
- Photos to support the selection of roughness coefficient values, hydraulic control features, etc.
- Elevation and location of deepest point in channel (thalweg – not necessarily at center of stream)
- If visible, note type and condition of existing foundation
- Note any visible repairs / bank stabilization.

All pertinent data gathered through this field reconnaissance and survey should be recorded on work plans, field notes, and filed with project documentation. Important hardcopy project documentation should also be preserved in a digital format, such as a MicroStation CADD file or scanned PDF file. Pages 2-4 of Appendix B should be completed while conducting the field study.

5.6 Field Safety

All personnel performing field reconnaissance work for NCDOT must follow the policies and guidance in NCDOT's Safety Policy and Procedure (SPP) Manual (53) and Workplace Safety (Operations Procedures – SOP) Manual (54).

There is no specific published guidance or policy pertaining exclusively to NCDOT roadside work by field survey crews. Roadway Standard Drawings (16) Division 11 contains NCDOT standards for work zone traffic control, which may be consulted as a reference for general information and guidance on such things as flagging traffic and placement of roadside warning signs, cones, and other traffic control devices, as may be applicable. It should be noted that NCDOT requires personnel trained and certified by an approved source to perform traffic flagging, so if required, coordination with the local Division office may be warranted to ensure that appropriate personnel are assigned to serve in this capacity.

If surveys are needed within a railroad right-of-way, a permit of entry must be arranged through coordination with the Location and Surveys Unit and the Rail Division. This work may likely be outsourced to qualified and certified contractors approved by the railroad owners. Under no circumstance should a hydraulic survey field crew enter a railroad right-of-way without an authorized permit of entry.

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6 DRAINAGE PLANS DEVELOPMENT

6.1 Overview of Development Process

Using the preliminary roadway plans as a base, the development of the drainage plans should be done in the MicroStation Drainage (DRN) file, and generally proceeds as follows:

1. Verify and supplement as necessary all existing drainage features (structure type, size, elevations). Contact the Location and Surveys Unit for clarification or revision if major discrepancies or errors are discovered in the field, or if significant supplemental surveys are needed beyond typical scope of a Hydraulics field review.

2. Note all existing drainage divides, flow directions, ditches, channels, etc. (Important notes on hardcopy plans should be transferred to the digital MicroStation plan drawings on the appropriate information levels, such as notes about existing pipe conditions, erosion problems, etc.)

3. Verify and supplement information addressing utilities that may affect drainage features.

4. Sketch any special ditches or other topographical features identified during field surveys and not included on the preliminary plans.

5. Make notes of design controls identified during data collection and field survey stage, such as elevation of lowest adjacent grade of buildings in floodplain, which could potentially be adversely affected.

6. Determine and evaluate the patterns of surface flow as affected and developed by the project construction. (Note flow direction and areas of flow concentration as may be needed for clarity.)

7. Develop a schematic layout of drainage features (bridges, box culverts, pipes, storm drain systems, ditches, channels, etc.) to properly convey surface flow within and adjacent to the project. Note these features on the plans.

8. Perform the design studies required to detail each drainage feature (type, size, location, material, etc.) and document the design detail of each individual feature as directed in the related section of these *Guidelines*.

9. Upon completion of hydraulic design, a final set Redline Drainage Plans (electronic PDF and CADD versions) are to be prepared, and should include, as a minimum, the following items:

    - Drainage areas (label size and show boundary depictions)
    - Existing drainage patterns (see item 6 above)
    - Storm drain system inlets, pipes, etc. with top and invert elevations, structure numbers
    - Ditches and outlet channels (with details, plan/profile views, and computations, as appropriate)

- Topological contours (and flow arrows where needed for clarity)
- Important design notes, including information from field investigation, utility conflicts, commitments, retaining or removing items, etc.
- Sag and crest locations on roadway with flow direction arrows
- Stream tops of banks
- Quantities of excavation, rip rap, geotextile fabric, etc.
- Culvert and cross-pipe hydraulic data
- Permanent and temporary drainage easements
- Limits of shoulder berm gutter at bridges

10. The Checklist for Drainage Study and Hydraulic Design (Appendix B) must also be finished and included with the project documentation upon completion of design.

6.2 Sealing of Drainage Plans and Design Reports by Professional Engineer

Once right-of-way plans are completed by the Roadway Design Unit, they are submitted for review by the Contract Standards and Development Unit, which checks the plans and identifies any corrections needed. After the plans are corrected, the final plans are then signed and sealed by the responsible North Carolina professional engineers who performed or supervised the engineering work. Procedures for electronically sealed plans have recently been implemented within NCDOT. Typically, the design engineer will need to seal the title sheet, any special detail sheets with drainage-related details, and all plan and profile sheets. If Bridge or Culvert Survey and Hydraulic Design Reports (BSRs or CSRs, Appendix E) are included with the project, the design engineer must also certify that the information in these reports and the plans are accurate, as they also are to be signed and sealed by a licensed North Carolina Professional Engineer as part of the official legal design documentation for the project. Additionally, as noted in Chapter 1 Introduction, the Hydraulic Design Documentation Summary (Appendix A), corresponding to the project's documentation package, must be individually sealed by the responsible engineer.

7 HYDROLOGY

7.1 Introduction

The hydrologic analysis phase involves the determination of discharge rates and volumes of runoff that drainage facilities will be required to convey. Acceptable hydrologic methods for highway drainage studies and applicable criteria for their use are discussed in this chapter. When the project site involves a FEMA-regulated stream, discharge methods and values provided in the effective published Flood Insurance Study (FIS) report should be used for determining compliance with National Flood Insurance Program (NFIP) regulations (29). (This may result in the need for additional hydraulic modeling to meet NCDOT design criteria, so there may be both a model for NFIP compliance as well as a design model for the NCDOT project.) The results from any hydrological procedure should be calibrated with historical site information. The design engineer should also consider potential future land use changes within a watershed over the life of a roadway structure and include this effect when estimating design discharges.

7.2 Drainage Area Determination

There are a variety of sources for obtaining drainage area data, including USGS topographic contour maps, published lists of drainage areas from study reports (such as FEMA Flood Insurance Studies and USGS water data reports), archived NCDOT Bridge and Culvert Survey and Hydraulic Design Reports (BSR, CSR; Appendix E), digital elevation data (such as Light Detection and Ranging, or LiDAR, data), and the relatively new USGS StreamStats web-based GIS application for North Carolina, which utilizes Digital Elevation Models (DEMs) based on LiDAR data and a combination of local resolution stream data and National Hydrography Datasets (NHD) for automated computation of drainage areas (and other basin characteristics). Drainage areas should be verified during project field review. The design engineer of record is responsible for verifying the accuracy of the drainage area regardless of the method used to obtain it.

7.2.1 USGS StreamStats

StreamStats is a web-based GIS application (http://water.usgs.gov/osw/streamstats/north_carolina.html) that was released by USGS in 2012. It allows users to easily obtain streamflow statistics, basin characteristics, etc., for USGS gage data collection stations and for user-selected ungaged locations. The application will delineate the drainage area at user-selected stream locations. The website includes comprehensive instructions and associated help files (including *Getting Started* and *Quick Tour* links). Users are advised to review and familiarize themselves with this information before attempting to use the application.

7.2.2 USGS Quadrangle Maps

USGS topographic mapping is available through the *National Map Viewer* website http://nationalmap.gov. Additionally, a GIS web map service (WMS) called USA_Topo_Maps provides a base map of national coverage of USGS topographic contour mapping.

7.2.3 Digital Elevation Data

Several sources of digital elevation data are available. The primary and most current, accurate, and readily available data is in the MicroStation TIN (triangular irregular network) file (supplied by NCDOT Location & Surveys and Photogrammetry Units) for the specific project area. However, this coverage is often inadequate for hydrologic studies, so it may need to be supplemented with other digital elevation data sources, such as LiDAR coverage or USGS Digital Elevation Models. Further details on each of these are discussed below.

7.2.3.1 MicroStation TIN Files

NCDOT's Location and Surveys Unit and Photogrammetry Unit collaborate to produce the final survey files for NCDOT projects, including planimetric mapping, digital terrain models (DTMs), and associated TIN files. The DTM file is first generated from processing the raw survey data; then, the DTM file is used to generate a TIN file to represent the existing ground surface. Often, the original TIN files provided for a project do not provide adequate geographical coverage for hydrologic analyses (e.g. offsite drainage), so supplemental digital elevation data may be used to generate additional TIN file coverage that can be merged with the original TIN.

7.2.3.2 LiDAR Data

One supplemental source of digital elevation data available in North Carolina is the statewide Light Detection and Ranging (LiDAR) coverage that was developed for the NC Floodplain Mapping Program (FMP). The entire state has been mapped using LiDAR techniques to collect digital elevation data. These data and corresponding metadata are available for download, and can be accessed from FMP's website (http://www.ncfloodmaps.com).

7.2.3.3 USGS Digital Elevation Models and Local Government Topographic Data

Digital elevation model (DEM) data are available from the USGS National Elevation Dataset (NED). Procedures on how these data can be downloaded are provided on the *National Map Viewer* website (see 7.2.2). These DEMs may prove most useful for areas in bordering states; however, within the state, NC FMP's LiDAR coverage will likely be more current, higher resolution, and accurate than that available from the NED. Additionally, large municipalities and some counties have developed topographic and elevation data which may be publically available for use in drainage area determination.

7.2.4 Archived NCDOT Bridge and Culvert Survey and Hydraulic Design Reports

There are thousands of bridge and culvert design reports archived at the Hydraulics Unit (hardcopies and PDF electronic copies). They provide valuable hydrologic and hydraulic information, such as drainage area size, as well as discharge rates and associated computed water surface elevations, methods used for computations, flood history records, etc. Information provided on these reports are only as accurate as methods and technology available as of the date of the report. It is the design engineer's responsibility to verify the information on the report before relying on it.

7.2.5 FEMA Flood Insurance Studies

FEMA Flood Insurance Study (FIS) reports' Summary of Discharges Tables are a good source for drainage areas and associated computed discharges for the FEMA hydraulic models. (See Section 7.4.1 for more information.)

7.3 Peak Discharge Design Frequency

Design frequency for NCDOT drainage structures is determined based on the roadway classification, traffic volume, level of service, flooding potential to properties, maintenance cost, etc. A summary of design frequencies that are typically used for NCDOT roadway drainage facilities is provided in Table 7-1. Consideration for site-specific conditions, such as upstream or downstream potential property impacts, existing level of service provided, length of time a temporary detour will be in place, etc. may warrant exceptions to these and should be discussed and agreed upon, preferably during the pre-design review.

	FREQUENCY (years)			
ROADWAY CLASSIFICATION	Bridges, Culverts and Cross Pipes	Storm Drain System		Ditches
		On Grade	At Sags (without relief)	
Major Arterials (e.g. Interstates, US, NC Routes)	50	10	50	10
Minor Arterials, Collectors, and Local Roads	25	10	25	10
Temporary/Detours	10	-	-	10

Table 7-1 Design Frequency

7.4 Peak Discharge Estimates

The design engineer should select from a number of acceptable peak discharge methods, depending upon the site's watershed characteristics. Table 7-2 lists peak discharge methods which are acceptable for NCDOT hydrologic studies. It also references the NCDOT Highway Hydrologic Charts (digitally corrected reproduction of the 1973 State Highway Commission Charts), which are applicable for limited use as discussed in Section 7.4.4 and Appendix C. It is the hydraulic engineer's responsibility to apply sound engineering judgment and to provide documented justification of methods used. Reported discharges should be expressed to two significant figures for 0.1 cfs to 10,000 cfs, and if higher, to three significant figures (examples: round 135.22 to 140; round 13,522 to 13,500), unless specifying discharges cited identically from a published FEMA Flood Insurance Study report.

Feature \ Hydrologic Methods	FIS (for NFIP compliance)	USGS Methods	Rational Method (up to 20 ac)	NCDOT Hwy. Hydrologic Charts	NRCS Method (for routing)
Bridges	X	X			X
Culverts	X	X			X
Storm Drain Systems			X	X	X
Cross Pipes (≤ 72 in. dia.)	X	X	X	X	X
Gutter Spread			X		
Ditches and Channels	X	X	X	X	
BMP Devices			X		X
Natural Stream Design	X	X	X		X
Storage Facilities					X
Floodplain Impacts	X	X			X

Table 7-2 Peak Discharge Method Selection

7.4.1 FEMA Flood Insurance Study

If a project study site is on a FEMA-regulated stream that is included in a published effective FEMA FIS, then the discharges specified in the FIS Summary of Discharges table should be used in the hydraulic model to demonstrate FEMA regulatory compliance. Those streams which were studied by detailed methods will typically list computed discharges for the 10- , 50 - , 100-, and 500-year recurrence intervals. Streams studied by limited detailed methods will only list the 100-year discharge.

Copies of effective FIS reports can be viewed and downloaded online from NC Floodplain Mapping Program's (NC FMP) website (http://www.ncfloodmaps.com).

7.4.2 USGS Stream Gage Analysis

Precedence should be given to analysis of the published stream gage data records when a USGS gage exists at or near the study site. Published North Carolina flood frequency statistics from continuous record USGS gages are available from the Flood-Frequency Statistics USGS Gaged Sites web link (http://nc.water.usgs.gov/flood/floodstats/gaged/index.html) on the NCDOT Hydraulics Unit website (https://connect.ncdot.gov/resources/hydro/pages/default.aspx).

7.4.2.1 Peak Discharge Estimation at Gaged Site

The above USGS website provides three types of statistical peak discharge estimates. The first is computed by fitting the recorded annual regulated peak flows to the log-Pearson Type III distribution using a localized computed sample skew. A second estimate that is provided is computed from the appropriate regionalized regression equation developed for the hydrologic area of the gage station location. The third, and presumably most accurate and reliable estimate provided combines the results of the first two into a weighted estimate for that gage station. Details on how these estimates are computed are discussed in USGS report SIR 2009-5158 (4). This report also discusses how flood-frequency peak discharge estimates at gaged sites can be adjusted (by transposition) to ungaged sites, as summarized in the following guidance.

7.4.2.2 Peak Discharge Estimation at Ungaged Site near Gaged Site

If the study site is not located at the location of a reference stream gage station on the same stream, and the drainage area at the study location is within fifty percent (50%) of that of the reference gage station, it is acceptable to adjust (or transposition) the discharge from the gage station to compute discharge estimates at the study location. The recommended method for peak discharge transposition is detailed in USGS report SIR 2009-5158 (4). This method is not recommended if the difference in drainage areas between the two locations is greater than fifty percent (50%). If the ungaged site is located between two gaged stations on the same stream, two peak discharge estimates can be made using the above procedure and hydrologic judgment applied to determine which is the more appropriate of the two.

7.4.2.3 Peak Discharge Estimation at Ungaged Site

In 2012, USGS launched the North Carolina StreamStats application website. In addition to the recommended use of this application for its automated drainage area delineation capabilities (see 7.2.1), this application is also recommended for use in computing discharges from USGS regression equations at ungaged sites. Rural discharge estimates are computed from the rural regional regression equations presented in SIR 2009-5158 (4). Urban and small rural basin discharge estimates are computed from the regression equations presented in reports SIR 2014-5030 (62), WRI 96-4084 (5), or USGS Fact Sheet 007-00 (63), as applicable. In the event that the StreamStats website is unavailable, refer to guidance in the referenced reports.

7.4.3 Rational Method

The Rational Method estimates the peak discharge (Q) in cubic feet per second (cfs) as a function of drainage area (A) in acres, mean rainfall intensity (I) in inches per hour (for a duration equal to the time of concentration, t_c), and a dimensionless runoff coefficient (C). The Rational Formula is Q = CIA.

NRCS methods (49) for calculating t_c should be used. Minimum value for t_c should be 10 minutes. An upper limit of 20 acres drainage area is recommended for applicability of this method.

7.4.3.1 Rational Runoff Coefficient

The value of the runoff coefficient (C) increases with the imperviousness of the surface cover. Table 7-3 provides some commonly used values for various surface types (7). The higher values in the ranges shown should be used when the terrain slope is steep. Less permeable soils warrant higher range C values. Likewise, areas such as grassed medians and berms behind curb and gutter may also warrant higher C value because of reduced permeability due to soil compaction performed during construction.

TYPE OF SURFACE	C
Pavement	0.7 - 0.9
Gravel surfaces	0.4 - 0.6
Industrial areas	0.5 - 0.9
Residential (Single-family)	0.3 - 0.5
Residential (Apartments, etc.)	0.5 - 0.7
Grassed, steep slopes	0.3 - 0.4
Grassed, flat slopes	0.2 - 0.3
Woods / Forest	0.1 - 0.2

Table 7-3 Typical Rational Runoff Coefficients

7.4.3.2 Rainfall Intensity

Rainfall intensity (I) data can be obtained from the NOAA Atlas 14 published report (47) and corresponding Precipitation Frequency Data Server (PFDS) website, where "I" values are tabulated for a range of durations and storm event frequencies at user-selected locations. In the PFDS table, the duration which is closest to the computed time of concentration (t_c) value will be used to obtain the corresponding "I" value to use in the Rational Formula. A minimum t_c of ten (10) minutes should be used.

The website to access the PFDS is: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html
See Appendix Q for an example of how to use the PFDS to find rainfall intensity values for a given project location.

Intensity values in GEOPAK Drainage (68) are hard coded into the Drainage Library and may not exactly match the NOAA Atlas 14 values for a given location, but should be relatively close. For routine storm drain system design, use the intensity values generated within GEOPAK Drainage.

7.4.4 NCDOT Highway Hydrologic Charts

The NCDOT Highway Hydrologic Charts, corrected and digitally reproduced from the 1973 State Highway Commission charts, are provided in Appendix C. They should primarily be used for sizing of small pipes.

7.4.5 NRCS Method – Storage Routing

Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service) methods, presented in TR-55 (49) and TR-20 (48), are recommended for hydrographic storage routing. The TR-55 manual presents simplified hydrologic procedures for estimating flood hydrographs and peak discharges in small watersheds. The model begins with a rainfall uniformly imposed on the watershed over a specified time. Mass rainfall is then converted to mass runoff by using a runoff curve number (CN) which is based on soil type, land cover, impervious area, surface storage, infiltration rate, etc. Runoff is then converted to a hydrograph to develop peak discharges applying hydrograph routing procedures, runoff travel time, etc. TR-20 provides computer-aided hydrologic analyses for estimating flood hydrograph peak discharges in both small and large watersheds. For current soils data, the NRCS Web Soil Survey website is recommended (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm). Public domain software programs available from the Army Corps of Engineers Hydraulic Engineering Center (HEC) or NRCS are acceptable to perform hydrograph calculations and routing. Other hydrograph methods supported by FHWA and AASHTO (1,2,7) may be used with approval of the State Hydraulics Engineer.

7.5 Accuracy of Hydrologic Estimates

The USGS scientists used various statistical methods to perform hydrologic analysis to develop regression equations for estimating peak discharges for both gaged and ungaged sites. It takes into account the complex geomorphic system of precipitation, evaporation, evapotranspiration, infiltration, overland flow, impoundments, channel flow, etc. The hydrologic analysis is not an exact science. The accuracy of the estimated discharges may vary significantly depending on location and other contributing factors. For example, the average standard error for the 10-year peak discharge in the Piedmont region is 25%; whereas, it is 73% for the 500-year peak discharge in the Sand Hills region (62).

It can be argued that some hydrologic methods are more accurate than others; however, estimated discharges should be calibrated to locally observed or measured events. Methods should be applied within their limits of applicability and with understanding of the underlying assumptions and hydrologic principles supporting them. While detailed hydrologic analysis is not practicable and would be beyond the scope expected in normal NCDOT hydraulic engineering practice, the design engineer is encouraged to calibrate the results from any hydrologic procedure to historical data. For bridge hydraulic analysis (see Chapter 8), these NCDOT *Guidelines* recommend that comparison be made to at least one historical occurrence.

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8 BRIDGES

8.1 Overview

The primary goal of hydraulic design for a bridge is to provide sufficient hydraulic conveyance to safely and efficiently convey the floodwater without adversely affecting channel stability, the floodplain, the roadway facility, or adjoining properties. The design engineer is recommended to reference Chapter 7 (Hydraulic Analysis for the Location and Design of Bridges) of the *AASHTO - Highway Drainage Guidelines* (1), NCDOT *Bridge Policy* (44), FHWA *Hydraulic Design of Safe Bridges* (27), the FHWA floodplain policy statement in *Federal Aid Policy Guide*, *23 CFR 650A* (8), and FHWA *Additional Guidance on 23 CFR 650A* (30).

The design of a bridge at a stream crossing requires a comprehensive engineering approach that involves data collection and documentation, hydrologic analysis, hydraulic analysis, scour evaluation, environmental impact evaluation, economic consideration, and documentation of the final design. The design procedures presented herein will ensure a systematic process that will adequately address most bridge crossing situations.

8.2 Priority for Consideration of Hydraulic Structure Type Recommendation

The recommended hydraulic structure type should be considered in the following priority order:

1. Pipe culvert, circular or arch
2. Box culvert, conventional four-sided reinforced concrete walls or aluminum box
3. Bottomless (three-sided) culvert, founded on scour-resistant rock
4. Bridge

8.3 Data Collection and Documentation

Information gathered during the pre-design study and field survey is to be assembled for the study site.

This process will include:

(a) Review of the Preliminary Design Report (Appendix D), as well as available survey information.

(b) Development of the Bridge Survey and Hydraulic Design Report (BSR, Appendix E). Prior to development of the final design, the following information and guidance should be followed:

1. The drawing scales are normally set at 1 in. = 50 ft. horizontal, 1 in. = 10 ft. vertical. The hardcopy BSR is a standard letter size document (typically 25.5 in. by 11 in. tri-folded). If a larger sheet exceeding the typical BSR size is required, it may be trimmed and folded to the standard letter size. Hardcopy original reports, signed and sealed by the responsible professional engineer, are maintained in the Hydraulics Unit files, in addition to a digital archive of scanned copies of the reports.

2. Information to be shown on the profile view includes, but is not limited to, the following:
    - Centerline station, skew, structure (existing and proposed), span arrangement, lowest low chord, and natural ground (upstream and downstream) to accurately depict the floodplain and channel. In event of dual parallel bridges, separate profiles for each bridge may be needed. Inclusion of a typical section detail relating design grade point to centerline elevation is recommended.
    - Design and 100-year water surface elevations.
    - Historical floods data, such as the high water mark (elevation) and date of flood, etc.
    - Existing and proposed features, such as utilities, road grades, drainage structures, bridge superstructure, bent locations, riprap armoring, etc. (Existing bridge and piers should be shown with black dashed lines.)
    - Adjacent structure elevation(s), such as the lowest adjacent grade and finished floor elevation of buildings, etc.
    - Water surface elevation at date of survey and normal water surface (vegetation line – a.k.a. ordinary high water) elevation
    - Theoretical scour depths
    - Design scour depths (added later from Geotechnical report when received)
    - Elevation of rock line (if applicable) from geotechnical subsurface investigation
    - For coastal tidally influenced bridges, also show MHW (mean high water), MTL (mean tide level), and MLW (mean low water) elevations. Tidal datum information can be obtained from the National Oceanic and Atmospheric Administration (NOAA) website: www.noaa.gov.
    - Excavation in floodplain (note elevations), if applicable
    - Sufficient vertical clearance under bridge for maintenance and inspection activities

3. Information to be shown on plan view includes, but is not limited to, the following:
    - Natural features, such as stream channel showing water's edge and top of bank, the existing land use and type(s) of vegetative cover in floodplain, jurisdictional streams, wetland limits, and riparian buffers.
    - Survey benchmark
    - Man-made features in floodplain, such as buildings, houses, roads, utilities, levees, etc.
    - Existing bridge in black dashed lines
    - Roadway superelevation
    - Limits of riprap for spill-through end bents
    - For riverine flow, show direction of flow and stream name
    - In coastal tidal areas, show direction of flood tide (landward/rising) and ebb tide (oceanward/falling)
    - North arrow, stationing and alignment
    - Floodway Boundaries (for FEMA Detailed Study streams only)
    - Pertinent finished floor elevations on adjacent properties

8.4 Hydrologic Analysis

This phase involves the development of a number of discharges on which the performance of alternate designs will be evaluated. While the guidance in this chapter is intended to be specifically related to bridge design, much of the hydrologic analysis information presented here may be applicable to culvert design as well.

The hydrologic analysis for bridge and culvert designs should entail:

(a) Determination of a drainage area, land use, hydrologic region, etc. for the site.
(b) Developing flood discharges for a range of flood events. (See Chapter 7 Hydrology.)
(c) For the stream crossing that is in a FEMA Flood Insurance Study (FIS), the design engineer shall use the FIS discharges to evaluate compliance with FEMA regulations. The design engineer should determine whether the FEMA discharges may be used for developing the hydraulic design. If there is considerable disparity between the FEMA study data and results from hydrological procedures presented in these *Guidelines*, the design engineer should determine the more appropriate method to use for developing the hydraulic design, and document the justification for it on the BSR.

8.5 Hydraulic Analysis

This phase involves hydraulic analysis for review and selection of one or more alternatives. The bridge hydraulic design is typically based on a one-dimensional flow riverine step backwater analysis. HEC-RAS is the most commonly used and widely accepted hydraulic modeling software (22-24) to perform this type of analysis and is therefore the preferred software for most NCDOT bridge hydraulic design applications.

The design engineer should develop the HEC-RAS model with consideration of the following:

- The cross section configuration, as shown in Figure 5-1 of the HEC-RAS *Hydraulic Reference Manual* (23) should be utilized.
- A known starting water surface elevation is preferred to be used as the downstream boundary condition for a subcritical run. Slope conveyance may be used if there is not a known starting water surface elevation.
- The beginning downstream section of the model should be located an adequate distance from the fully expanded flow section (Section 1, exit) to allow the step-backwater computations to converge to a correct water surface elevation before reaching Section 1.
- Intermittent sections may be added to the model to ensure model stability.
- All HEC-RAS hydraulic models should be analyzed as subcritical flow regardless of the channel gradient, unless use of alternate analysis method (e.g. supercritical flow or mixed flow) is approved by the State Hydraulics Engineer.
- Reliable historical flood data, if available, should be used to calibrate the model.

- Publications FHWA TS-84-204 (9) and USGS WSP 1849 (66) are good references for selecting Manning's roughness coefficient (n) values.

- Utilize the HEC-RAS project file system to document all geometric, flow, and hydraulic design data configurations (plans) analyzed, including all water surface profiles, cross section plots, structures, and various output tables. HEC-RAS files submitted for approval should follow established naming and content conventions as specified on the Hydraulics Unit website. Final design recommendations and supporting data from HEC-RAS should be appropriately documented on the BSR.

Bridges in hydrodynamic, complex flow environments or tidally influenced areas may warrant utilization of unsteady or two-dimensional flow analyses methods, which are not discussed here. The design engineer is advised to reference FHWA (27) for guidance and to obtain approval from the State Hydraulics Engineer before commencing design and analysis work using these methods.

8.5.1 General Design Criteria

The selection of an optimal final design alternative is accomplished by evaluating the study results with respect to acceptable design constraints, which are prescribed by both general and specific criteria.

- Avoid creating adverse impact of increased floodwater depth on properties upstream and downstream.
- Flow velocities through the hydraulic structure(s) should not result in channel instability or flood damage to the highway facility or adjacent property.
- Existing channel and floodplain flow patterns are maintained to the extent practicable.
- To the extent practicable, the level of traffic service provided should be consistent with the functional classification of the highway and projected traffic volumes unless a design variance is warranted.
- Project should result in minimal disruption of ecosystems and values unique to the floodplain and stream.
- Assess the floodplain impacts to properties during project construction, such as utilization of temporary causeway, temporary on-site detour and staging areas.
- Pier and abutment location, spacing, and orientation are designed to minimize flow disruption, debris collection and scour potential.
- Ensure compliance with National Flood Insurance Program regulations.

8.5.1.1 Sub Regional Tier Design

In 2008, NCDOT and FHWA approved guidelines establishing controlling design elements for new and reconstructed bridges on the state roads designated as minor collectors, local and secondary roads, which were published in the NCDOT document *Sub Regional Tier Design Guidelines for Bridge Projects* (57). If a bridge project is designed to the standards set forth in that document, no formal design exception approval is required. The design engineer should read and become familiarized with these sub regional tier guidelines to ensure that an appropriate design process is followed.

8.5.2 Specific Design Criteria

8.5.2.1 Climate Change and Extreme Weather Events

Transportation infrastructure is designed to handle impacts of a changing climate, such as sea level rise, increased frequency and magnitude of heavy precipitation and tropical storms, etc. Preparing for extreme weather events is critical to protecting the integrity of transportation and ecological (floodplain and wetland) systems and prudent investment of taxpayer dollars. The NCDOT staff will seek to follow FHWA's policy and guidance to develop cost-effective strategies to minimize climate and extreme weather risks and protect transportation infrastructure. For example, the design engineer will follow the FHWA publication *Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience,* HEC-17 (FHWA-HIF-16-018), June 2016 (26).

8.5.2.2 Design Flood Frequency

This is the specific return period (frequency) flood that has been established as being an acceptable level for roadway overtopping, or when roadway overtopping is not involved, it will be the level of flood used for establishment of freeboard and/or backwater limitations. Overtopping is generally considered to be the point at which the computed water surface elevation overtops the minimum weir flow elevation; however, for bridge scour computations using HEC-RAS, weir flow begins to be computed when the energy grade line elevation exceeds the minimum weir flow elevation. When the energy grade line elevation is used as the basis for determination of when overtopping occurs, this should be noted in the BSR and in the modeling narrative, if applicable. See Table 7-1 for desirable design discharge standards based on accepted inundation levels relative to roadway functional classification. Variation from these or other specific standard values must be justified by an assessment process which reflects consideration for risk of damage to the roadway facility and other properties, traffic interruption, cost, environmental impacts and hazard to the public.

8.5.2.3 Backwater

Backwater is defined as the difference in the upstream water surface elevations between the non-encroached and encroached condition imposed upon the floodplain by the highway embankment and proposed structure. It is measured at the upstream toe of the roadway embankment. Backwater for the 100-year event should be limited to no more than 1.0 foot. If an existing structure already creates a 100-year backwater in excess of 1.0 foot, the design engineer may seek to replace it with a structure that reduces the backwater, provided it will not result in adverse impacts to the receiving channel and downstream properties. The backwater for the design year flood event for the proposed bridge should not exceed that of the existing bridge.

For National Flood Insurance Program (NFIP) regulated floodplains where no regulatory floodway has been established, the cumulative effect of the proposed highway encroachment combined with all other existing and anticipated development shall not result in backwater in excess of 1.0 foot above the established 100-year elevation shown on the effective FEMA Flood Insurance Rate Map (FIRM). It is the policy of NCDOT to compensate the adjoining property owners for the loss of their property value as the result of the proposed transportation facility. For example, an increase in floodway width would reduce a property owner's developable land value. To clarify, "compensate" means to purchase or relocate the property, purchase floodplain (drainage) easement on the property, etc. NCDOT follows the guidance provided in the 1982 Federal Highway Administration (FHWA) Memorandum of Understanding with the Federal Emergency Management Agency entitled "Procedures for Coordinating Highway Encroachments on Floodplains within the Federal Emergency Management Agency (FEMA)", and the September 1992 FHWA NS 23 CFR Part 650A, Transmittal 5 (30). When a detailed flood study area is involved and its regulatory floodway is established, typically no increase in backwater is allowed for the proposed conditions unless a Conditional Letter of Map Revision (CLOMR) proposal is developed and submitted to the community and FEMA for approval. A CLOMR proposal involves a revision in the floodway boundaries to accommodate the proposed transportation facilities without increasing the 100-year flood elevation above the established floodway elevation. All potential CLOMR submittals for NCDOT projects must be reviewed by the State Hydraulics Engineer before submittal will be allowed to the respective regulatory agencies for approval. See Chapter 15 for guidance concerning FEMA NFIP compliance.

8.5.2.4 Minimum Length Bridge

For a bridge with spill-through abutments, the ends of the bridge should typically be located such that, anywhere along the abutment, a linear projection of the spill-through slope face normal to the direction of flow would provide a minimum of ten feet setback from any point on the channel bank or bed. The minimum length bridge is graphically depicted in Appendix E Item 6. Greater setback may be required due to the potential channel migration and scour prediction or other factors, such as greenway or animal passage accommodation. This does not necessarily preclude specification of a vertical abutment bridge, which could further reduce bridge length (which would eliminate the spill-through slope distance, but would still require the ten foot setback).

8.5.2.5 Bridge End Bent Cap

Generally, 4 ft. end bent cap depths are used on new bridge designs; however, 2 ft. 6 in. depth end bent caps may be a viable design option where warranted by site conditions, such as low roadway fill height. Two diagrams are included in Appendix E Item 5 which depict the dimensions for bridge waterway opening for both end bent cap depths. These diagrams should also be utilized to correctly specify the bridge waterway opening and minimum bridge rail (and guardrail) flow obstruction in a HEC-RAS hydraulic model and the associated bridge profile drawing in the BSR.

8.5.2.6 Modeling Bridge Rail and Appurtenances

The design engineer should exercise judgment when coding in the bridge rail, guardrail, and any other appurtenances that may obstruct conveyance of flow (such as attached storm drain system or utilities). The following guidance is typically followed by convention for NCDOT projects, but may not be applicable to every situation. The design engineer should document decisions to justify use of different methods or criteria than these in the modeling narrative:

- Model existing bridge rail based on height and length, and show as blocked.
- Model proposed bridge rail based on height and bridge length, and show as blocked.

- Model, at minimum, the first 12 ft. of guardrail anchor unit at each end of the bridge and show as blocked (see Roadway Standard Drawings 862.03) (16).
- Model other appurtenances, such as an attached storm drain system or utility which may hang below the low chord of the bridge, thus reducing the waterway opening, using the bottom of the obstruction as the effective low chord. Note this clearly in the modeling narrative to specify the adjustments made to the low chord elevations to account for the obstruction.

8.5.2.7 Substructure and Superstructure Determination

The bridge substructure components (drilled piers, piles, spread footings) are determined by the Geotechnical and Structures Management Units based on several factors such as subsurface soil data, loading requirements, navigational clearance, environmental constraints, etc. Early coordination with the Structures Management Unit is recommended at the beginning of the hydraulic design phase on decisions pertaining to the proposed bridge, such as superstructure type and depth, span arrangement, skew angle, longitudinal and cross slopes of deck, deck drainage, etc. Consideration should be given to the roadway overtopping flood level, freeboard, and potential impacts of raising the roadway grade. Piers should generally be aligned in the direction of flood flow. Span lengths and piers should be designed to minimize flow disturbance and drift traps as is consistent to good design and construction principles. Prior to finalizing the design of a bridge, a draft copy of the BSR should be submitted to Structures Management Unit's staff for comment.

8.5.2.8 Freeboard

Standard freeboard design for bridges shall be as follows:

- New location: Provide two (2) feet minimum vertical clearance for bridge superstructure (low chord elevation) above the design flood elevation for primary route structures or secondary route crossings over major rivers. Provide one (1) foot minimum vertical clearance for all other new location bridges (including temporary detour bridges).
- Existing location replacement: If practicable, provide freeboard as stated above for new location crossings. Otherwise, as a minimum, maintain the freeboard provided by the existing bridge.

Greater freeboard may be needed for unique issues, such as heavy debris, climate change consideration, extreme weather (wind, storm surge), navigational clearance, etc. If the bridge deck is in superelevation, the freeboard is measured at the low side of the low chord. Furthermore, it is preferable, where practicable, that the low side of the superelevated bridge deck be set on the upstream side of the bridge. Variance from the freeboard requirement must be approved by the State Hydraulics Engineer prior to completion of the design.

8.5.2.9 Slope Protection

As a minimum, Class II rip rap should be placed on the spill-through abutment slopes through the waterway opening, extending beyond the bridge end bents along the roadway embankment 20 feet and 10 feet on the upstream and downstream sides, respectively. Along the roadway embankment, the top elevation of the rip rap should be placed either one foot above that of the design flood or up to the shoulder point elevation if the road is submerged during the design flood event, whichever is lower. For a lake crossing, the elevation of the rip rap should be at least two feet above the normal pool elevation of the lake, or higher, if so indicated by a wave run-up analysis. At the toe of fill, the rip rap protection should be keyed-in to a depth at least three and a half feet (3.5 ft.) below the ground surface. Additionally, existing and potential stream bank erosion or instability should be considered, and riprap armoring should be provided as needed.

8.5.2.10 Bridge Deck Drainage

A minimum longitudinal gradient of 0.3% is recommended to facilitate adequate drainage of the bridge deck. Standard practice for structural design has typically been to specify six-inch (diameter) deck drains at twelve-foot centers on all girder-type bridges. For cored slab and box beam bridges, flow is discharged horizontally through the bridge rail via rectangular deck drains. The standard dimensions of these deck drain hydraulic openings are 8 in. wide by 4 in. high for cored slabs and 5 in. wide by 4 in. high for box beams. (The actual drain opening is 6 in. high, but will be obstructed by 2 in. pavement overlay.) These deck drains cannot be placed any closer than 5 ft. (measured to center of the opening) from each end of the bridge or from either side of an interior bent and must have a minimum spacing of 3 ft. (center to center). If the bridge is on a heavy skew, a minimum offset of 6 ft. from the ends or interior bents of the bridge may be required. Structures Management Unit staff should also be consulted as early as possible in the design process regarding proposed deck drainage accommodations to verify constructability. Examples of structural concerns which may affect deck drainage could include, but are not limited to, the following:

- deck drains are required for an entire span
- raised median on the bridge
- sidewalk
- barrier rail for protected bicycle/pedestrian lane included on bridge
- particular bridge rail type may affect deck drain locations

If no deck drains are allowed over water, collection of surface runoff from the downgrade end of a bridge is required, and a grated drop inlet should be utilized. If there is inadequate depth for a grated drop inlet, a concrete flume may be used, extending to the toe of fill into a riprap pad.

To the maximum extent practicable, bridge deck drains should not be placed directly over the stream. The additional guidance provided below is recommended:

- <u>Bridges over streams with riparian buffers:</u> Bridges that are located within the promulgated riparian buffer watersheds, such as Randleman Lake, Neuse River, Tar-Pamlico, etc. for which regulatory riparian buffers have been established, shall not have deck drains which discharge directly into the surface water, open channel or buffer zone (typically measured 50 feet from the top of channel banks). Measures such as riprap pads may be provided if needed to ensure that stormwater discharged from bridge deck drains will be released as diffused flow into the buffer. In the event that safety concerns may warrant placement of deck drains within the buffer area, the bridge design will be subject to individual review and approval by the regulatory agencies on a project by project basis.

- Bridges in CAMA Counties: In the 20 coastal counties subject to the jurisdiction of the Coastal Area Management Act (CAMA), bridges shall not have deck drains which discharge directly into surface water. Any direct discharge outside the main stream channel shall also be avoided to the maximum extent practicable (MEP), unless otherwise approved by the regulatory agencies. For bridges over sounds or the Intracoastal Waterway, the volume of stormwater runoff from bridge deck drains is miniscule relative to these immense water bodies, and there typically are no practical locations in which to provide effective treatment. Bridges in these areas may be allowed to discharge directly into the surface waters, unless otherwise advised by the regulatory agencies. Most of these bridges also provide navigational clearance for boating and shipping traffic, so the effects of the high rise and coastal winds would help to diffuse and diminish any detrimental impact of stormwater from bridge decks.

- Bridges over Outstanding Resource Waters and Water Supply Waters: Stream crossings may pose an increased risk of hazardous material spills into sensitive waters. For this reason, bridges over Outstanding Resource Waters (ORW) and Water Supply (WS) waters WS-I, WS-II, WS-III, and WS-IV may be subject to hazardous spill basin requirements. Hazardous Spill Basins (HSBs) are structural stormwater controls designed to temporarily store hazardous materials from accidental spills. If an HSB is required for a stream crossing, the bridge drainage system should route all bridge runoff through the HSB prior to discharging into the receiving water. More information about the application and design of HSBs is available in Appendix O of these Guidelines and in Chapter 8 of the NCDOT *Stormwater Best Management Practices Toolbox* (34).

- Enclosed drain system for a bridge deck: If a closed drainage system is designed for a bridge deck, its outlet should be placed as far away as practicable from the protected surface water. A preformed scour hole is recommended at the outlet to help diffuse and infiltrate the stormwater, unless other BMP devices are used. Closed drainage systems are only specified for pre-stressed girder type bridges and will typically be comprised of 6-inch diameter PVC deck drains installed vertically through the deck connected to a longitudinal drainage system (typically an 8-inch diameter UVL-proof PVC pipe) beneath the deck. To ensure positive drainage, a minimum 0.3% slope is desirable for the drainage system. Such closed systems are not desirable and should only be considered as a last resort if no other practicable alternatives are available.

- Grade separation structures: Bridges over roadways or railways shall not have deck drains which discharge directly over travel lanes, sidewalks, or railroad tracks. The gutter spread along the structure must be evaluated for issues affecting the safety of the traveling public, such as hydroplaning. This acceptable spread is dependent on shoulder or additional width provided on a structure, but generally should not extend into the through-travel lane (see Chapter 10, Section 10.3). Considering the potentially significant quantity of flow from the deck, it is very important to check the adequacy of the end drains and provide recommendations for additional measures when warranted.

The above guidelines must also be balanced with the safety need to limit the spread of storm runoff to minimize hazards such as hydroplaning and ice accumulation. (See guidance in Chapter 10, Section 10.3 and Table 10-1). Provision must be made at the down grade end of all bridges to adequately convey any storm runoff not intercepted by deck drains to a storm drain system or outlet. Further detailed guidance on bridge deck drainage design is provided in HEC-21 (10).

8.5.2.11 Channel Relocation

The alignment of the proposed bridge and its piers should be designed to accommodate the existing channel. Prudent design consideration should be given to bridge crossings over unstable channels susceptible to high levels of bank erosion and channel migration. Repairing an unstable channel may be warranted to determine the proposed bridge length and location of end and interior bents. A major channel modification or relocation in and around a bridge crossing requires a thorough environmental assessment review, sound engineering design, cost analysis, and approval by the State Hydraulics Engineer.

8.5.2.12 Detour Structures

The design for a detour structure is site-specific. In general, the detour bridge and roadway grade are designed to convey flood water during a ten-year flood event. These temporary structures may be lower and shorter than their permanent counterparts. They may result in potential risks, such as traffic interruption, flood damages to the roads and adjoining properties, etc. Generally the detour bridges sit on two end bents that are supported by steel piles. The minimum length of a detour bridge is the width of the main channel plus a minimum of five-foot setback from each bank. On a site by site basis, the five-foot setback may be adjusted to ensure the integrity of channel banks and need of construction access. The bottom of the detour bridge deck (low chord) should allow at least one foot clearance over the flood elevation during the10-year flood event. The theoretical scour analysis for the detour bridges may be limited only to the contraction scour during a ten-year flood event. For detour structures on FEMA-regulated streams, see additional guidance in Chapter 15, Section 15.6. When developing the detour bridge design, the Division Bridge Construction Engineer should be consulted regarding the potential type of temporary detour bridge structure anticipated to be utilized for the project.

Detour Survey and Hydraulic Design Report (Appendix E, Item 3) should be used to document design criteria used for detour bridges. Sketch proposed structure(s) and roadway grade in plan and profile showing roadway grade elevation, minimum low chord elevation, structure location and size, limits and elevations of any required scour protection (if applicable), and any channel modifications. These should be scanned and compiled into a single document to be distributed and filed appropriately.

8.5.2.13 Multiple Bridge Openings

Roadways over streams or rivers with wide floodplains may warrant multiple openings in the floodplain to provide better conveyance through the embankment. Where it is evident that multiple openings may be required, the design engineer should develop hydraulic models to assess the location and performance of each hydraulic opening structure. The results of the modeling and performance of these structures should be documented in the BSR. The guidance outlined in the *HEC-RAS Hydraulic Reference Manual* (23) should be utilized.

8.6 Bridge Scour Evaluation

An estimate of potential scour depth is required for all new bridge designs. FHWA has issued a set of three Hydraulic Engineering Circulars (HECs) to provide guidance for bridge scour and stream stability analyses:

- HEC-18 *Evaluating Scour at Bridges* (11)
- HEC-20 *Stream Stability at Highway Structures* (13)
- HEC-23 *Bridge Scour and Stream Instability Countermeasures* (43)

Bridge scour evaluation requires a multidisciplinary analysis that involves input from the design engineer, the Geotechnical Engineering Unit and the Structures Management Unit. The design engineer's role in evaluating scour involves the following three steps:

1. Stream stability and geomorphic assessment
2. Scour analysis
3. Bridge scour and stream instability countermeasures

8.6.1 Stream Stability and Geomorphic Assessment

The design engineer should evaluate the stream stability and make a geomorphic assessment of the stream crossing. This part of the process includes office data collection, a site visit evaluation and an overall assessment of the stream stability.   This information must be documented and will be used in the overall scour evaluation.

Office data collection specific to the scour evaluation includes but is not limited to:

- Bridge Routine Inspection Reports
- Historical Bridge Survey Reports
- FHWA Scour Program reports
- Aerial photography
- Old structure plans
- Available Geotechnical information

Information collected specific to the scour evaluation during the site visit includes but is not limited to:

- Stream characteristics - straight, meandering, braided, anastomosed, engineered
- Floodplain characteristics – natural, agricultural, urban, suburban, rural, industrial etc. and susceptibility to change

- Overall stream stability:
  - Lateral stream stability (plan form) - bank material, bank slope, bank vegetation, bank erosion, leaning trees, debris potential, floodplain material. Any past or possible channel migration should be noted.
  - Vertical stream stability (profile) - bed material, degrading, aggrading, stable, scour holes, pools, riffles, etc.
  - Stream response - stable or subject to change.
- Debris potential - leaning or undercut trees along banks, size and quantity.
- Scour at existing bridge to be replaced (if applicable) - observed conditions around existing piers and spill-through slopes, indication of previous scour, depth etc., foundation type – is footing visible?

Based on the above evaluations, the design engineer should make an overall assessment of the stream stability. In particular, the design engineer should note the potential for lateral shifting (migration) of the channel when evaluating scour of piers and or abutments close to the channel banks. Potential for lateral shifting (migration) of the channel should be considered in the layout of the bridge (location of piers and or ends of bridge). See following guidance for calculating pier scour and abutment scour. A statement addressing the overall assessment of the stream stability and its determination in the scour evaluation should be noted on the BSR with the scour computations.

8.6.2 Scour Analysis

Evaluate scour design flood frequency as follows:

Regional Tier and Statewide Tier Projects

1. If the overtopping flood is less than the 100 year flood, analyze scour for the overtopping flood only. Show and plot overtopping scour calculations on the Bridge Survey Report.
2. If the overtopping flood is greater than the 100 year flood but less than the 500 year flood, analyze scour for the 100 year and overtopping floods. Show and plot both scour calculations on the Bridge Survey Report.
3. If the roadway is not overtopped by the 500 year flood, analyze scour for both the 100 year and 500 year floods. Show and plot both scour calculations on the Bridge Survey Report.

Sub Regional Tier Projects

1. If the overtopping flood is less than the 100 year flood, analyze scour for the overtopping flood only. Show and plot overtopping scour calculations on the Bridge Survey Report.
2. If the overtopping flood is greater than the 100 year flood, analyze scour for the 100 year flood only. Show and plot 100 year scour calculations on the Bridge Survey Report.

8.6.2.1 Contraction Scour

The design engineer should evaluate contraction scour for all bridges. Normally, NCDOT bridge length provides a minimum 10 ft. setback from any point on the channel bank or bed, as described in Chapter 3, Section 3.5. Standard practice is to use spill-through sloped abutments lined with Class II rip rap keyed into the overbank area under the bridge a minimum depth of 3.5 ft. This is described as contraction scour Case 1c in HEC-18. Contraction scour typically should only be computed for the main channel and not the overbank areas between the main channel and the abutments; however, computing overbank contraction scour may be appropriate for a bridge spanning a very wide floodplain.

Live-bed contraction scour occurs at a stream when there is transport of bed material from the upstream reach into the bridge cross section. With live bed contraction scour, the area of the contracted section increases until a state of equilibrium occurs, at which the transport of sediment out of the contracted section equals the sediment transported in (11).

Clear-water contraction scour occurs when (a) there is no bed material transport from the upstream reach into the downstream reach, or (b) the material transported in the upstream reach is transported through the downstream reach mostly in suspension and at less than capacity of flow. With clear-water contraction scour, the area of the contracted section increases until, in the limit, the velocity of flow or the shear stress on the bed is equal to the critical velocity or the critical shear stress of a certain particle size in the bed material (11).

Design guidance for calculating contraction scour is as follows:

Determine if the scour design flood frequency water surface elevation results in non-pressure flow scour conditions (water surface elevation is below the low chord elevation of the bridge) or pressure flow scour conditions (water surface elevation is above the low chord elevation of the bridge).

For non-pressure flow scour conditions, calculate contraction scour using the live bed contraction scour equation 6.2 in Chapter 6 of HEC-18 with a k_1 exponent of 0.69. The equation is:

$$y_2 / y_1 = (Q_2 / Q_1)^{6/7} (W_1 / W_2)^{k_1}$$

$$y_s = y_2 - y_0 = \text{(average contraction scour depth)}$$

Where:

- y_1 = Hydraulic depth in the upstream main channel, ft.
- y_2 = Hydraulic depth in the contracted section channel, ft. (this is computed by the equation)
- y_0 = Hydraulic depth in the contracted section channel before scour (Use the upstream internal bridge section in HEC-RAS), ft.

Q_1 = Flow in upstream main channel, ft^3/s

Q_2 = Flow in contracted channel (use the upstream internal bridge section in HEC-RAS), ft^3/s

W_1 = Top width of upstream main channel, ft. (See note 4 in HEC-18 Section 6.3)

W_2 = Top width of main channel in contracted section (use the upstream internal bridge section in HEC-RAS), ft.

k_1 = 0.69 (for worst case scenario)

To ensure accuracy of bridge contraction scour computations, the values of y_1, Q_1 and W_1 of the upstream main channel to be used in the contraction scour equations should be taken at the upstream approach section (fully effective unconstricted section). The approach section must be properly located and the channel geometry correctly verified by field surveys. The approach section should be located at a point upstream of the bridge just before the flow begins to contract due to the bridge opening. This may require adding another upstream section in developing the Corrected Effective HEC-RAS model, especially in the case of Limited Detailed Study models, which may have been created with an upstream approach section that is not within a reasonable distance upstream to correctly represent the location at which flow contraction begins. It also may have only an approximated channel configuration not based on field surveys. In some instances, the channel width and floodplain geometry at the approach section may be considerably different than the channel nearer the bridge, in which case it would not be appropriate to use the approach section geometry for the contraction scour calculation. If this is the case, then the values of y_1, Q_1 and W_1 may be taken from the upstream toe section of the natural conditions model at the bridge location.

The design engineer should also carefully identify the channel section through the internal bridge opening. The top of bank stations should accurately define the channel through the bridge opening in the HEC-RAS model.

Non-pressure flow contraction scour conditions for overflow bridges should be calculated using clear water contraction scour equation 6.4 in chapter 6 of HEC-18. The equation is:

$$y_2 = [(K_u Q^2) / (D_m^{2/3} W^2)]^{3/7}$$

$$y_s = y_2 – y_0 = \text{average contraction scour depth}$$

Where:

y_2 = Average equilibrium depth in the contracted section after scour, ft.

Q = Discharge through the bridge associated with the width W, ft^3/s

D_m = Diameter of the smallest non-transportable particle in the bed material ($1.25D_{50}$) in the contracted section, ft.

D_{50} = Median diameter of bed material, ft.

W = Top width of the contracted section less pier widths, ft.

y_0 = Hydraulic depth in the contracted section channel before scour (use the upstream internal bridge section in HEC-RAS), ft.

K_u = 0.0077 for English Units

If the D_{50} bed material for the overflow bridge is not known, use D_{50} for very coarse sand (.007ft.). If the overflow bridge is part of a braided river system then the design engineer should use the live bed contraction scour equation.

Pressure flow scour conditions should be calculated as outlined in section 6.10 of chapter 6 of HEC 18. NCDOT practice is to only compute pressure flow scour conditions up to the point of roadway overtopping. Therefore Q_{ue} (effective channel discharge for live bed conditions and overtopping flow) is not required to be computed. The pressure flow scour equations should be used with the live bed contraction scour equation and/or the clear water contraction scour (for overflow bridges) as noted above.

The pressure flow scour equations are as follows:

$y_s = y_2 - h_b$

Where:

y_s = pressure flow scour depth, ft

y_2 = average depth in the contracted section as determined from the live bed contraction scour equation or contraction scour equation noted above, ft.

h_b = vertical height of bridge opening (bed to low chord) prior to scour, ft.

Contraction scour at bottomless culverts ("three-sided") is not required since NCDOT requires that these be founded on scour resistant rock.

8.6.2.2 Pier Scour

Evaluate pier scour for all internal piers. The design engineer should reference Equation 7.3 of HEC-18 to compute the pier scour as shown below:

$y_s / a = 2 K_1 K_2 K_3 (y_1/a)^{0.35} Fr_1^{0.43}$

Where:

y_s = Scour depth, ft.

y_1 = Flow depth directly upstream of the pier, ft (use the upstream toe section in HEC-RAS).

K_1 = Correction factor for pier nose shape from figure 7.3 and table 7.1 in HEC-18

K_2 = Correction factor for angle of attack of flow from table 7.2 or equation 7.4 in HEC-18

K_3 = Correction factor for bed condition from table 7.3 in HEC-18

a = Pier width, ft

L = Length of pier, ft

Fr_1 = Froude Number directly upstream of the pier=$V_1/(gy_1)^{1/2}$

V_1 =Mean velocity of flow directly upstream of pier, ft/s.

g = Acceleration of gravity (32.2 ft/s^2)

For complex pier foundations, the design engineer should use the procedures outlined in HEC-18. An Excel spread sheet developed for Florida DOT (FDOT) is also available for use in calculating complex pier foundations. It can be downloaded from FDOT's website (http://www.dot.state.fl.us/rddesign/Drainage/Bridge-Scour-Policy-Guidance.shtm).

Based on the stream stability and geomorphic assessment of the bridge site, a note is to be added on the BSR with the pier scour calculations stating whether or not the local pier scour was calculated based on potential channel migration or no channel migration. If there is potential for channel migration such that the channel could migrate to the pier location, then the pier scour should be calculated based on the depth of flow from the channel bottom prior to scour. If there is no potential for channel migration, then the pier scour should be calculated based on the depth of flow at the pier location prior to scour.

8.6.2.3 Abutment Scour

Evaluate abutment scour for all vertical abutment bridges or spill-through abutment bridges that have less than the minimum 10 ft. setback from any point on the channel bank or bed as noted above in 8.6.2.1. Abutment scour evaluation is not required for spill through bridges that are designed based on the minimum bridge length or greater unless it is determined through the overall assessment of the stream stability that abutment scour may be a concern.

The NCHRP 24-20 *Estimation of Scour Depth at Bridge Abutments* (69) method outlined in Chapter 8 of HEC-18 should be used. It should be noted that the NCHRP 24-20 method calculates both abutment and contraction scour. The equations and procedure are as follows:

$$y_{max} = \alpha_A\, y_c$$

$$y_c = y_1(q_2/q_1)^{6/7}$$

$y_s = y_{max} - y_0$

where:

y_{max} = Maximum flow depth resulting from abutment scour, ft.

y_c = Flow depth including live bed contraction scour, ft.

$\propto_A$ = Amplification factor for live bed conditions.

y_1 = Hydraulic depth in the upstream (approach) main channel, ft.

q_1 = Upstream unit discharge, ft^2/s. Estimate by dividing the upstream channel discharge by the upstream channel top width.

q_2 = Unit discharge in the constricted opening accounting for non-uniform flow distribution, ft^2/s. Estimate by dividing the total bridge opening discharge by the total bridge opening width.

y_s = Abutment scour depth, ft.

y_0 = Flow depth prior to scour, ft.

After calculating q_2/q_1, the design engineer should use Figures 8.9 and 8.10 of HEC-18 to compute $\propto_A$. The values of y_c, y_{max} and y_s may then be calculated based on the equations above.

Froehlich's Abutment Scour Equation or the HIRE Abutment Scour Equation as outlined in HEC-18 may be used if determined to be more applicable and approved by the reviewing engineer.

8.6.3 Plotting Scour

The cone of influence (scour hole side slopes) for total scour to be shown on the bridge profile view of the BSR should be at least 1.4 H: 1 V; however, HEC-18 suggests using 2 H: 1 V (ref. 11, Section 7.8). If only contraction scour is calculated, the design engineer may plot scour depth from channel bottom prior to scour. The width of the bottom of the contraction scour should match the channel bottom width. If there is an existing scour hole under the existing bridge, do not add the calculated scour depth to the existing scour depth, unless the existing scour depth was used in the y_2 calculation of scour and in the bridge hydraulic analysis. Show the depth of calculated scour relative to the projected natural stream bed; an example is illustrated in Appendix R.

Based on the location of piers, the theoretical scour may be plotted as follows:

- Pier is in main channel

  Add contraction and pier scours as the maximum scour and plot it below the thalweg elevation at the pier location. Depth of flow and velocity for pier scour should be based on channel bottom elevation prior to scour. The width of the bottom of the pier scour should be the width of the pier. Plot both the side slopes of the pier and the contraction scours at 1.4:1.

- Pier is not in main channel, but may be later due to channel migration

  Add contraction and pier scours as the maximum scour at the pier location and plot it from the thalweg elevation. Depth of flow and velocity for pier scour should be based on channel bottom prior to scour. The width of the bottom of the pier scour should be the width of the pier. Plot both the side slopes of the pier and the contraction scour at 1.4:1.

- Pier is not in main channel with little potential for migration

  Plot contraction scour as noted above. Plot pier scour based on depth of flow at pier location prior to scour. If cone of influence of contraction scour intersects pier location below natural ground at pier, plot pier scour from this point. The width of the bottom of the pier scour should be the width of the pier. Plot both the side slopes of the pier and the contraction scours at 1.4:1.

- Abutment scour

  Use NCHRP 24-20 Method to plot the abutment scour. Begin the plot of the scour at the lowest point in the stream bed out to the ends of the bridge end bents. Note that the NCHRP 24-20 Method computes both contraction and abutment scour. If Froehlich's or Hire Abutment scour equations are used, plot abutment scour from ground elevation at abutment.

8.6.4 Documentation of Scour on the BSR

The design engineer should include the following information in the "Additional Information and Computations" section of the BSR:

- The overall assessment of the stream stability and its determination in the scour evaluation
- If pier is subjected to potential channel migration.
- Appropriate scour computations during each flood event
- Evidence of existing scours in and around the main channel, interior and end bents

The design engineer calculates the theoretical scour based on the guidelines outlined in this section. This information must be documented on the BSR, which is provided to the Geotechnical Engineering Unit for their use in developing the Design Scour Elevations. Based on the Geotechnical Engineering Unit's Subsurface Investigation Report, the Design Scour Elevation may be adjusted from the Theoretical Scour Elevation on the BSR. The Geotechnical Engineering Unit and/or the Structures Management Unit may consult with the Hydraulics Engineer throughout the scour evaluation process as necessary. (76)

8.6.5 Scour for Coastal/Tidal Bridges

The scour equations developed for inland rivers are also recommended for use in estimating and evaluating scour for tidal flows and storm surge (HEC-18, Chapter 9). The design engineer should reference section 8.9 of this chapter for guidance in modeling coastal/tidal bridges.

Generally the tide-influenced rivers are characterized by river flows, tidal fluctuations, waves and storm surges. If a structure is affected by both riverine flooding and tidal/storm surge flooding, the design engineer should determine if the worst case conditions of discharge, depths and velocities occur due to tides and storm surge or by inland floods. FEMA, USGS, NOAA and USACE records, maintenance records and local interviews are good source of flood records, such as precipitations, flood discharge, durations, depths and velocities, etc. In some instances it may be necessary to evaluate scour based on the flooding that would occur from storm surge backwater runoff and the scour that would occur due to riverine flooding conditions and use the worst case. There may be other cases where the hydrodynamic force is mainly driven by tide, wind and storm surge. An example is the design of transportation facilities along the coast over tidal inlets and estuaries that warrant the use of more detailed hydraulic models.

If the specific variables required for the scour analysis are available from the hydraulic model used in the design of the bridge, then the design engineer should use these.

The design engineer may use one of the following two methods for the scour calculation due to storm surge - Simplified Storm Surge or Level III Wave Vulnerability Study Method:

<u>Simplified Storm Surge Method</u>

1. Compute the volume of storm surge by multiplying the design basin area by the average depth of storage, i.e. the difference of the ground and design flood elevations or overtopping elevation, whichever is lower.
2. Determine the flood discharge which is the volume of storage divided by the duration of surge; available from nearby rain gage sites, or a minimum of 6 hours.

$$Q = A \times d \times 43{,}560 / (t \times 3600)$$

Where:
Q = discharge, cubic feet per second
A = drainage area, acres
d = average depth of storage, ft
t = duration of surge, hrs.

3 Determine average flow velocity through the bridge opening by dividing the discharge by the bridge opening area (for the design scour flood frequency depth).

4. Determine discharge in the upstream channel section using the depth of flow (for the design scour flood frequency depth), channel geometry, channel slope and Manning's n values. This will require the use of a single section hydraulic analysis of the upstream channel section.
5. Calculate scour using the applicable scour equations for contraction, pier, and abutment scour outlined in the previous sections, as applicable.

Level III Wave Vulnerability Study Method

In July 2013 NCDOT entered into a contract with Dr. Max Sheppard, Ph.D., P.E. of Ocean Engineering Associates to develop the *NCDOT Bridge Superstructure Level III Wave Vulnerability Study* (56). This study provides Level III storm surge and wave analyses for use by structure design engineers to compute design water levels and wave parameters, which are needed to analyze the forces and moments which act against the dead weight of the bridge members. The study includes hindcasting 62 of the most severe storms in the state over the last 160 years; developing extreme value analyses on water elevations, wave heights, and depth averaged current velocities in the state's coastal areas. A complete list of these design parameters is available on the Hydraulics Unit website. The design engineers should use them in the development of a BSR, unless a site-specific flood model is deemed more appropriate. The design engineer should develop the following tidal scour design parameters based on data available from the Wave Study:

- Velocity of flow and depth of flow (for the design scour flood frequency) at the bridge crossing.
- Discharge through the bridge opening based on the area of the bridge opening (for the design scour flood frequency depth) multiplied by the velocity of flow.
- Discharge in the upstream channel section using the depth of flow (for the design scour flood frequency depth), channel geometry, channel slope and manning's n values. This may require the use of a single section hydraulic analysis of the upstream channel section.

The Hydraulics Unit should be contacted to obtain the site-specific GIS data associated with this study, which includes the 5-, 10-, 25-, 50-, and 100-year return intervals. (If bridge overtops below 5-year interval, use 5-year data as minimum for scour analysis.)

Computation of scour can then be performed using the applicable scour equations for contraction, pier, and abutment scour outlined in the previous sections, as applicable.

8.7 Economic Consideration

When more than one alternate will satisfy all control factors for a site, the evaluation and selection of an optimal alternate should include a cost analysis to ensure that the selected alternate will be the most cost effective over the structure's life cycle.

8.8 Documentation of Design

All information pertinent to the selection of the optimal final design alternate shall be documented in a manner suitable for review and retention, including:

- Complete the BSR (Appendix E). In addition to the information already included at the beginning of the BSR preparation, also show the proposed structure(s) and roadway grade in plan and profile, including crown grade elevation, superstructure, low chord, bent locations, limits of shoulder berm gutter (if applicable), riparian buffer zone (outer limit only, where applicable), specification of deck drainage accommodations, limits and elevations of rip rap and any channel modifications, typical bridge section, and any necessary details. In the bridge profile drawing, it is also important to show water surface elevations for Q_{design}, and Q_{100}. All water surface elevations should be expressed to nearest tenth of a foot (0.1 ft.).
- Provide (in the interior gridded area of the BSR) a performance table of the natural, existing (if applicable) and proposed conditions water surface elevations at the upstream toe section for the following discharges: Q_{10}, Q_{design}, Q_{100}, and Q_{500} (or $Q_{overtopping}$, if less). The distance upstream of the bridge face at which the proposed conditions water surface elevations are referenced should be specified.
- Include scour analysis computations on the BSR. Plot estimated scour depths on the profile view for both the 100-year and 500-year return intervals (or for the overtopping discharge, if less, respectively).
- If applicable, the following note should be included in the Additional Information and Computations section of the BSR: "No upstream or downstream structures that were in place at the time this project was designed will be adversely impacted by this bridge project."
- Provide digital scan of sealed and approved BSR for digital archive record.
- Provide copies of hydraulic computer model data files, with complete input and output, supporting (and consistent with) corresponding design documentation.

8.9 Coastal / Tidal Bridges

Design and analysis of stream crossings in the coastal region that are subject to the effects of tidal flows and storm surge follow a similar procedure to that outlined for riverine crossings. However, there are major differences in the hydrologic and hydraulic analysis phases. The design engineer is referred to the basic Tidal Prism procedure discussed in HEC-18 (11), as well as more information on this and other more detailed one and two dimensional tidal crossing modeling guidance presented in HEC-25 (12, 72). Crossings of tidal inlets, bays and estuaries present special design challenges, and hydraulic design of such bridges should be closely coordinated with the State Hydraulics Engineer. A map showing approximate coastal limits of tidal influence is provided in Appendix K (61). Tidal influence should also be confirmed by field evidence and reports from local residents familiar with the project site. For information on calculating bridge scour for coastal / tidal bridges, refer to section 8.6.5.

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9 CULVERTS

9.1 Overview

A culvert in this chapter is defined as a hydraulic conduit that conveys flow through a roadway embankment. The most commonly used culvert shapes are circular, rectangular, elliptical, and arches. They range in size from large multiple barrel culverts to a single 18-inch diameter pipe, which is the minimum size for cross-drainage. The design process for culverts is similar to that for bridge crossings in that it involves: design documentation, data collection, hydrologic analysis, hydraulic analysis and design, and economic consideration.

9.2 Design Documentation

Development of a Culvert Survey and Hydraulic Design Report (CSR, Appendix E), is required for any structure that is on a FEMA regulated stream, or has a hydraulically effective total waterway opening of thirty (30) square feet or more, excluding any area of the culvert that is buried below the streambed. For culverts with a waterway opening of less than 30 square feet, design data should be summarized on the Pipe Data Sheet (Appendix G). All design data in the CSR or Pipe Data Sheet should be based on either HEC-RAS (22-24) hydraulic models or HDS-5/HY-8 (55) results, as applicable.

Documentation on the CSR should include, but is not limited to, the following:

(a) Plot and label the proposed structure in plan and two profile views: along roadway alignment and along the structure alignment. Note roadway centerline station, skew, and grade point elevation. Box culvert dimensions are typically specified in terms of the number of barrels at a given span dimension by rise dimension (e.g. 2 @ 10 ft. x 6 ft. RCBC). The drawing scales in the CSR are typically 1 inch = 50 feet horizontal and 1 inch = 10 feet vertical. Information should be limited to that which is pertinent to the structure sizing and location.

(b) Show centerline invert elevation (or top of footing elevation for "bottomless" culvert) and slope. Note: Precise length and end invert elevations are determined by Structures Management Unit.

(c) Show normal, design and 100-yr. water surface elevations on all views.

(d) Enter all required data for selected structure as completely as possible on the CSR. It is helpful to enter "N/A" in data fields which are not applicable. Use the Additional Information and Computations section to document pertinent important design information not covered elsewhere in the CSR.

(e) Note software and versions used for computations. Supporting computer data files (e.g. HEC-RAS, HY-8, HDS-5) and summaries must be included in project documentation.

(f) Complete the performance table for the proposed structure with a comparison to the natural and existing conditions (if applicable) stage-discharge relations.

9.3 Culvert Data Collection

Information gathered during the pre-design study (see Chapter 3) and field survey (see Chapter 5) relative to each particular crossing or all crossings in general is to be assembled. Prior to development of the final design, the following information and guidance should be followed to begin preparing the appropriate documentation.

9.3.1 Culvert Data – Profiles Views

There are two profiles that are included in the CSR. One is the longitudinal profile of the roadway showing the floodplain section and the roadway vertical alignment grades for both the existing and proposed conditions. On this profile, conventionally, the culvert opening and natural ground are depicted at the upstream face; if different convention is used, label for clarification. The other profile is along the centerline of the structure, depicting the layout of the culvert relative to the stream.

(1) The longitudinal profile along the roadway alignment:

The longitudinal profile should include: natural ground lines upstream (and downstream also, if significantly different), channel base and banks, roadway grade for both the existing and proposed conditions, existing and proposed culverts, water surface elevations (as of date of survey, and normal - if different), 100-year floodplain limits, historical flood elevations (including dates of occurrence, and estimated frequency), utility elevations, controlling backwater feature elevations (buildings -finished floor elevations and lowest adjacent grade, roadways, driveways, other drainage structures, overtopping controls, etc.), and general classification of stream bed and bank materials (clay, sand, gravel, etc.). The low point of the roadway profile is the point at which roadway overtopping will occur. It is prudent to note this location and elevation on the profile.

(2) The centerline profile of the structure:

This profile should include: stream bed, top of banks, existing and proposed roadway cross-sections, existing and proposed culverts, normal water surface (vegetation line – a.k.a. ordinary high water) profile, historical flood levels, controlling feature elevations properly positioned along the profile, and rock line, if identified. The purpose of the centerline profile is to establish the length and inverts of the proposed culvert by superimposing the culvert barrel on the roadway cross section and stream bed profile. If an existing culvert is to be retained and extended, its type, condition, top slab and interior web thickness, slope, and opening, should also be noted.

Any additional stream details utilized for design or needed for channel realignments are to be plotted on the CSR. Note: These also need to be included on details sheets in the roadway plans to ensure they will be followed and utilized during construction.

9.3.2 Culvert Data – Plan View

Information to be provided on the plan view includes, but is not limited to:

(1) Natural features – stream/water edges, banks, ground cover, wetland boundary, buffers
(2) Manmade features - buildings, houses, roads, driveways, existing drainage, utilities, etc.
(3) Proposed roadway and fill slope limits, retaining walls, easements, right-of-way
(4) Proposed drainage structure(s), channels, rip-rap, etc.
(5) Floodway Boundaries designated and regulated by FEMA
(6) Other information, such as flow direction, north arrow, survey line and stations, land cover, etc.

9.3.3 Cross Pipe Data

For any culvert with total waterway opening of less than 30 square feet and on a stream that is not regulated by FEMA, its design data can be summarized on the Pipe Data Sheet (Appendix G). The design engineer will also need to reference the drainage plans for topographical and proposed layout information.

Note that driveway pipes in roadside ditches should be sized to convey the same discharge as that for which the ditch is designed (see Chapter 11 Roadside Ditches and Channels). Generally, for driveway pipes, design documentation on Pipe Data Sheets is not required; however, the design engineer may elect to do so for those which are 48 inches in diameter or larger.

9.4 Hydrologic Analysis

The hydrologic analysis for a culvert differs from that for bridges primarily due to the smaller drainage areas involved; however, they may be similar for larger culverts. For more guidance regarding hydrologic analysis, please refer to Chapter 7 Hydrology.

The hydrologic analysis for culvert design entails:

(a) Determination of the drainage area for the site.
(b) Developing flood discharges:
    1. Q_d - design discharge, as listed in Table 7-1
    2. Q_{10} - 10 year discharge
    3. Q_{100} – 100 year discharge
    4. Q_{ot} – overtopping discharge, if less than Q_{500}
    5. Q_{500} – 500 year discharge, if less than Q_{ot}

If the stream crossing is in a FEMA Flood Insurance Study (FIS), the Base Flood discharge in the FIS shall be used to assess the flood impact and compliance with FEMA's NFIP. If an error is found in the FEMA hydrologic analysis, an alternate analysis method may be warranted. The design engineer may request a review from NCFMP and/or the State Hydraulics Engineer for guidance and approval of an alternative for determining the discharge rates.

(c) Record pertinent hydrologic analysis data on the CSR, such as land use change, stream gage, physical changes (dam, impoundment, etc.).
(d) Provide a performance table of the natural, existing (if applicable), and proposed conditions flood elevations at the upstream toe section for the following discharges: Q_{10}, Q_d , Q_{100}, and Q_{500} (or Q_{ot}, if less). The location of the flood elevations that are compared should be clearly identified (for example: "at section 1001, 15 ft. upstream of culvert inlet").
(e) Include details and typical cross sections inside and outside the culvert that depict the design features necessary to mimic the natural channel, such as back fill of native bed materials, benches, sills and baffles, energy dissipators, etc.

9.5 Hydraulic Analysis and Design

9.5.1 Design Criteria

The first step in developing a CSR is to establish the applicable design criteria and constraints prior to commencing actual structural sizing and location. To the maximum extent practicable, every effort should be made to avoid or minimize adverse impacts to the natural and human environments. A sound culvert design should include consideration for proper location and alignment, adequate opening, safety of the traveling public, debris loading, channel stability, sediment transport, post-construction maintenance, outlet channel protection, life cycle of material, etc. The design engineer may reference Appendix F Item 3 – Culvert Avoidance and Minimization Design for guidance.

9.5.1.1 Material Selection

The selection of a culvert may vary depending on its location, subsurface materials, and constructability. The most commonly used structures are reinforced concrete box culverts (RCBC), reinforced concrete pipes (RCP), corrugated steel pipes (CSP), and corrugated aluminum alloy pipes (CAAP). Of those structures, the most common shapes are rectangular, circular and arch. Depending on the site constraints as well as the size and type of structure that are needed, the design engineer should follow the applicable guidance below:

Pipe culverts:

Material selection, associated fill-height limitations, and pipe installation methods should follow the applicable guidance prescribed in the NCDOT Pipe Material Selection Guide (Appendix H), Chapter 5 of the NCDOT Roadway Design Manual (15), and Standard No. 300.01 "Method of Pipe Installation", NCDOT Roadway Standard Drawings (16).

Box culverts:

Box culverts are typically comprised of reinforced concrete, either precast or cast in place. There are also large metal structures, arches and box shapes, with and without bottom plates that can be considered for sites requiring large opening and/or spans. However, unless site constraints dictate other culvert type, the design of the culvert should be developed based on a four-sided, cast-in-place reinforced concrete box culvert. Any culvert design alternates to the approved CSR proposed by the contractors during construction should be reviewed and approved by the State Hydraulics Engineer. Maximum fill height tables for some standard size metal arch structures are provided in Appendix H.

9.5.1.2 End Treatment

Headwalls are generally used on the inlet end of a 36-inch diameter pipe culvert or larger. Maximum height of headwalls shall be one foot above the pipe structure. Neither Mechanically Stabilized Earth (MSE) nor Modular Block walls are considered appropriate for culvert headwall application. If the culvert is 150 feet or more in length and functions in inlet control, an improved inlet design may be considered. The outlet end of a pipe does not require an endwall, unless an exception is warranted, such as limited right-of-way, buoyancy on metal pipes, eroded channel, pipe-disjoint potential, etc. For guidance on end treatment of parallel pipes, reference section 5-20, of the *Roadway Design Manual* (15).

9.5.1.3 Allowable Headwater

The allowable headwater elevation is established based on an evaluation of flood elevation, freeboard, upstream structures, and proposed roadway elevations. The headwater depth is measured from the design flood elevation to the invert of the inlet of the culvert and generally should not exceed the lowest upstream shoulder (overtopping) point elevation of the roadway or an elevation about twenty percent higher than the height of the culvert, whichever is lower. For routes functionally classified as Major Arterials (Interstates and primary routes), a minimum freeboard of 1.5 feet is recommended. Other factors to consider include impacts to adjacent properties, potential damage to the culvert and roadway, level of service, cost, safety, channel stability, floodplain regulations, available detour routes, etc.

For a culvert replacement, the headwater of the proposed culvert should not exceed that of the existing culvert during the design flood and 100-year events. An exception may be allowed when it is located in a rural area with no appreciable flood damage impact to the floodplain or adjoined properties. For a road project on new location, the new culvert should not result in more than one (1) foot of backwater over the natural condition. Also refer to guidance regarding backwater in Chapter 8, Section 8.5.2.2.

If the replacement or new culvert is on a FEMA regulated stream, FEMA's base flood elevation (BFE) should be used as the allowable headwater elevation to size the culvert. If the proposed design would result in a change in BFE, the design engineer should obtain a Conditional Letter of Map Revision (CLOMR) or Memorandum of Agreement (MOA) approval.

9.5.1.4 Multiple Barrels

Often, multiple barrels may need to be considered such as when roadway embankment is low in height or the channel is shallow and wide. The recommended minimum barrel dimension for a box culvert is five (5) feet in both width and height. A multiple barrel box culvert is more economical than a single barrel of the same hydraulic conveyance, due to its structural requirements for the top slab member. When the total width of the multiple barrels is larger than that of the channel, a review should be made to evaluate the need for barrels to be set at different elevations to minimize head cut, channel instability, and aggradation.

9.5.1.5 Sills and Baffles

Sills are vertical walls attached to the culvert bottom, placed at both the inlet and outlet of the culvert to mimic the natural channel opening. Baffles are vertical walls attached to the culvert bottom placed at designed intervals inside the culvert to maintain a low flow channel for aquatic organism passage. In general, one barrel passes normal flow and the others collect sediment and debris. Normally all multiple barrels are built on the same elevation. The low-flow barrel(s) is (are) buried one foot below the streambed and aligned with the natural channel; other barrels are installed with engineered sills to mimic the existing channel width.

The force of the high floods may result in a natural flushing of sediment and debris out of the barrels, depending on the available headwater, vegetation growth, backwater from the receiving stream, etc. If there is heavy accumulation of sediment in the barrels of an existing culvert, the cause and source of the sediment accumulation should be investigated, and mechanical removal of sediment should be considered. If site conditions clearly indicate that excess sediment inside the barrel would be flushed out of the barrel in high water events, the design engineer may perform the hydraulic analysis on the basis of the total clear width and height of the barrel (excluding the buried portion) being available for flow conveyance. Conversely, if a culvert is in an aggregated channel and no stream restoration is planned, the total clear width and height should not be assumed effective for flow conveyance in the design. Sills are normally placed in each barrel of multiple barreled culverts to retain the native material in the culvert as well as to minimize head cutting.

Normally, native material is preferred to be used for backfilling culverts. Refer to guidance provided in Appendix F Item 1 for design details for sills and baffles. For additional information and guidance regarding accommodations to facilitate aquatic organism passage and habitat, see Appendix N Stream Crossing Guidelines for Anadromous Fish Passage and FHWA *Culvert Design for Aquatic Organism Passage* HEC-26 (35). Appendix N also includes a reference guide which shows the distribution of potential anadromous fish habitat streams in North Carolina.

9.5.1.6 Length and Alignment

Culverts must generally be long enough to accommodate the proposed roadway section with a 2:1 fill slope, or flatter, from shoulder point to the top of pipe or top of roof slab of box (not headwall). To the extent practicable, a culvert should be aligned with the natural channel with minimum transitions made between the opening ends of the culvert and natural channel. When significant channel realignment (other than minor alignment adjustments at the inlet and outlet) is required, a natural channel design may be utilized (see Chapter 11). In general, pipes and box culverts should be aligned with the existing channel. The skew that is referenced in the CSR is defined as the angle measured clockwise from the centerline roadway alignment in the direction of progressing stations (i.e. “line ahead”) to the centerline of the culvert. The culvert should be skewed to align with the direction of flow. If a culvert extension requires a bend to better align with the stream, the existing culvert should be extended a minimum of five feet along the existing structure alignment before applying the bend. Note that an added bend in the culvert will incur an energy loss which must be accounted for in the hydraulic computations. Bends in culverts should be avoided if the potential for debris to become lodged is apparent.

9.5.1.7 Slope and Sediment

Pipe or box culverts should be constructed on slopes that are consistent with the existing channel to minimize channel aggradation or degradation. Most culverts are constructed on slopes that are less than ten percent (10%). For concrete pipes on steep slopes, a junction box and/or an end wall is recommended at the outlet. Culverts on steep slopes may result in major maintenance issues, such as deformation from negative pressure, seepage, joint separation, outlet scour hole, sink hole, etc.

Normally the inverts of a culvert should be set at an appropriate depth below the natural bed to ensure the passage of aquatic organisms. This depth may range from a few inches for small pipes to one (1) foot for large culverts (refer to Appendix H, Pipe Bury Depths table). All box culvert inverts should be set a minimum of one (1) foot below the natural bed (unless extending an existing culvert that is not buried). If shallow, non-erosive bedrock is found three (3) feet or less below the streambed, proposal of a bottomless ("three-sided") culvert may be considered. Confirmation from the Geotechnical Unit on the depth of the rock line along the length of the proposed culvert is required.

Most culverts do not encounter sedimentation or head cut problems if they conform to and are aligned with the natural channel. A stable channel is expected to balance erosion and deposition of sediment, achieving equilibrium over time. If a culvert is in a degrading channel, it may result in upstream head cutting and scour holes downstream. Examples are entrenched downstream channel, urbanized channelization, channel straightening, etc. If a culvert is in an aggrading channel, it may accumulate sedimentation inside and outside the barrel, which may require periodic channel and culvert cleanout to maintain design conveyance. Examples are erosion from development in the watershed, flow blockage, ponding downstream, etc. If the culvert and/or channel are heavily silted, the design engineer should account for the resulting reduction in hydraulic conveyance, unless the excessive sediment is proposed to be removed from both the channel and the culvert and measures provided to prevent recurrence of the heavy siltation. The design engineer may use HEC-RAS to perform sediment transport and mobile bed computations to determine the available hydraulic conveyance of the culvert during the flood event of interest.

9.5.1.8 Tailwater

The computed normal water depth for each discharge level being evaluated generally establishes the tailwater depth. For culverts which are not on FEMA-regulated streams, tailwater depth may be determined by a simple single section normal depth calculation, such as that provided in HY-8 (55). For those on FEMA-regulated streams, tailwater should be determined using HEC-RAS (discussed below). Effects of downstream controls and constrictions must also be considered. Tailwater calculations should be documented in the Additional Information and Computations section of the CSR or on the Pipe Data Sheet, as applicable.

9.5.2 Culvert Design

Culverts which are not on FEMA regulated streams may be analyzed using the FHWA's *Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5* (HDS-5) (14) methodology or by HEC-RAS (22-24), as appropriate. HEC-RAS should be used if proposing to replace a bridge with a culvert or in situations where a more detailed step backwater analysis is needed.

Special design situations that may affect the load bearing of the structure should be coordinated with the Structures Management Unit as early as possible in the design process. Examples are pipe connecting to the culvert, traverse utility lines inside or adjacent to the culvert, "Y" culvert junction, bend in culvert, etc.

9.5.2.1 HEC-RAS

HEC-RAS should typically be used when any of the following apply:

- Stream is in a regulated FEMA flood zone
- Need to assess flood impact by the proposed crossing to structures on adjoining properties
- Establish water surface elevations (by step backwater analysis) for a culvert design
- Determine backwater caused by a bridge for the existing and proposed conditions

9.5.2.1.1 General Modeling Guidance

The culvert hydraulic analysis routine in HEC-RAS is similar to that for bridge hydraulics, except that the equations for inlet control in FHWA's HDS-5 (14) are used where applicable to compute the energy losses. HEC-RAS can model many different culvert shapes. However, it does not include a shape corresponding to that of a corrugated aluminum box culvert, which is commonly used in North Carolina. The design engineer may refer to Appendix F Item 4 for modeling guidance for a corrugated aluminum box culvert. Bottomless ("three-sided") culvert structures typically have either a flat top or arched top waterway opening. (An arched-top structure may be modeled as a flat-top structure, ignoring flow area in the arched-top portion of the opening in HEC-RAS runs.)

As a one-dimensional flow modeling tool in culvert analysis, HEC-RAS computes the energy grade elevation with the initial assumption that all flow is going through the culvert. The culvert will typically be flowing full and will be submerged, before the flow overtops the road. If the computed energy grade elevation is greater than the weir (overtopping) elevation, then weir flow occurs, and HEC-RAS performs an iterative procedure to balance weir and culvert flows to determine the water surface elevation. However, the weir (overtopping) flow may not occur at the roadway location directly above the culvert. The design engineer should review the roadway profile and floodplain to determine where the minimum elevation for weir flow (overtopping) will occur. For example, a culvert may not be flowing full due to a low lying bank that allows the water move away from the culvert, through a ditch and across the road.

9.5.2.2 Debris Consideration

The culvert opening should be reasonably sized to provide for debris passage. The general limitation of design headwater depth to not exceed the culvert opening height by more than about twenty percent has proven to limit debris problems to acceptable levels. Where experience or physical evidence indicates the watercourse will transport excessive debris, special debris controls (e.g. deflectors) may need to be developed or the estimated capacity of the structure reduced to reflect the potential for debris blockage.

9.5.2.3 Evaluation of Outlet Velocity

All stormwater outlets must be in compliance with NC Statute 15A NCAC 04B.0109 regarding stormwater outlet protection. After a given culvert size has been determined to be adequate for conveyance of the design discharge, it is important to evaluate the ten-year outlet velocity to ensure the culvert will not result in an adverse effect downstream. If the partial flow outlet velocity for the ten-year discharge (Q_{10}) exceeds the scour velocity for the receiving stream, placement of rip rap or other acceptable outlet protection is required. Refer to the ditch stability charts (Appendix J) to determine acceptable flow velocity. Use the greater of tailwater depth or normal flow depth in the culvert to determine the partial flow outlet velocity. In HEC-RAS, use the downstream culvert velocity (Culv Vel DS) for this evaluation. Chapter 11 Roadside Ditches and Channels provides more detailed guidance regarding ditch and channel analysis and design criteria.

9.6 Economic Consideration

When more than one alternate will satisfy all control factors for a site, the evaluation and selection of an optimal alternate should include a cost analysis to ensure that the selected alternate will be the most cost effective over the structure's life cycle.

9.7 Construction Sequence

See Chapter 12 Erosion and Sedimentation Control, Section 12.3 regarding the culvert construction sequence plan.

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10 STORM DRAIN SYSTEM

10.1 Overview

The purpose of a storm drain system is to prevent adverse impacts to the existing drainage and to remove water from the roadway surface, subgrade, and embankment. It consists of pavement drainage, inlet structures, storm drain pipes, junctions, manholes, stormwater storage facilities, hazardous spill basins, and outfalls. The design process for storm drain systems usually follows the basic steps of planning/data collection, hydrologic/hydraulic design, and outlet analysis. The pavement and inlet design may be accomplished by a computer program which follows the procedures of HEC-22 (6). GEOPAK Drainage (68) is an acceptable software application for storm drain system design. GEOPAK Drainage is the current hydraulic design application that runs within the MicroStation environment. In the event it is replaced by the manufacturer, refer to the Hydraulics Unit web page for any updates.

10.2 Determination of Design Constraints

Information gathered from the planning document and/or early project coordination during the pre-design study and field surveys relevant to the storm drain system should be assembled for design reference, and design constraints identified, including the following:

10.2.1 Drainage of Adjacent Properties

The roadway storm drain system may involve or affect adjacent properties along the roadway. Sometimes improvement of an existing storm drain system may be warranted to alleviate an existing drainage problem. For example adding storage basins or augmenting cross drain conveyance may be needed to facilitate conveyance of increased runoff from offsite drainage. Additional improvements for public health and safety must also be considered, such as providing trash racks, fencing, and warning signage on storage basins or large cross drains where there may be potential drowning or other safety hazards.

10.2.2 Design Frequency and Rainfall Intensity

Roadway inlet locations, capacities, gutter spread, and storm drain pipe system should be analyzed and designed using a ten-year discharge (Q_{10}) with a minimum time of concentration of 10 minutes. An intensity of 4 inches/hour should be used for calculating spread and determination of appropriate locations for inlet placement to collect roadway pavement runoff. For the overall storm drain system and non-roadway inlets (such as yard inlets and drop inlets collecting offsite runoff) design should be developed using the rainfall intensity guidance provided in Chapter 7 Section 7.4.3.2. In sag areas where relief by curb overflow is not provided, the roadway design discharge level (Table 7-1, Ch. 7) should be used for analysis to ensure level of service for anticipated traffic volume is maintained.

10.2.3 Gutter Grade and Pipe Slopes

A minimum gutter gradient of 0.2 percent (0.3 percent desirable) should be utilized. When a lesser gradient is encountered, the gutter must be warped to provide the minimum gradient required for positive drainage. This minimum slope criteria may also be considered to be applicable to pipe slopes in the storm drain system. HEC-22 (6) recommends using the minimum slope required to maintain a minimum full-flow pipe velocity of 3 ft/sec in order to promote self-cleaning. An alternative inlet system, such as a slotted or trench drain, or elongated throat catch basin may be considered for use in sag or low gradient gutter sections. Refer to NCDOT Standard 846.01 for standard gutters used on NCDOT roadways (16).

10.2.4 Inlet types

The standard inlet for typical 2 ft. – 6 in. curb and gutter is a combination grate and curb opening (commonly referred to as a “catch basin” or “CB”), std. no. 840.01 of Roadway Standard Drawings (16). Use of other than standard inlet types for curb sections requires project specific approval. Otherwise, standard grated drop inlets (DIs, 2GIs, etc.) are to be used in shoulder sections, roadway and median ditches, and other appropriate locations. Angled vane grates are recommended for gradients exceeding three percent. Grates with two-inch or less opening width shall be used in areas subject to pedestrian traffic. Traffic bearing inlets and grates (e.g. TB 2GI, TB DI) are to be specified for drop inlets which are placed in or within four feet of a permanent or temporary travel lane. This does not apply to Catch Basins (CBs), which are considered to be traffic bearing. A useful summary of NCDOT standard inlet types with box depths for various pipe sizes is posted on the Hydraulics Unit website in the GEOPAK Applications section. Consideration should also be given to the potential likelihood of a paved shoulder being utilized as a temporary travel lane in deciding whether to call for a traffic-bearing structure. Additional guidance is provided in Section 5-13 of the NCDOT Roadway Design Manual (15).

10.3 Inlet Analysis and Design Criteria

The following specific criteria apply to inlet analysis and design:

- On grades, the curb opening can be ignored in determining inlet capacity. The grate efficiency may be assumed to equal that of a parallel bar grate.
- Inlet capacity at sags should allow for debris blockage by providing twice the required computed opening (i.e. assume 50% blockage). Use design frequency from Table 7-1.
- Inlet spacing shall be sufficient to limit spread as required for safe vehicle maneuverability. Acceptable design spread criteria are specified in Table 10-1. Allowable spread into the travel lane during temporary conditions (detours, phased construction, etc.) should be evaluated based on factors such as traffic volume, road classification, posted speed limit, and lane width, etc. For curb and gutter sections (with no side parking or bike lanes, etc.) the width of the gutter pan is considered the “shoulder” width in Table 10-1.

Roadway Classification	Design speed (on grade) or Sag (low point)*	Design Frequency (yr)	Intensity (in/hr)	Allowable Spread (ft)
Major Arterials (e.g. Interstate, US, NC routes)	≤ 45 mph	10	4	Shoulder * + 3
	> 45 mph	10	4	Shoulder *
	Sag (low point)†	50	4	Shoulder * + 3
Minor Arterials, Collectors, and Local Streets	≤ 45 mph	10	4	½ travel lane
	> 45 mph	10	4	Shoulder *
	Sag (low point)†	25	4	½ travel lane

*Applies to shoulder width 6 ft or greater; for narrower shoulder widths, design spread should not exceed 6 ft. † Sag (low point) criteria is applicable where there is no overland relief.

Table 10-1 Design Frequency and Spread Criteria for Inlet Placement

- On bridges or when the typical roadway section includes a full shoulder (six feet or wider), bike lane, or parking lane, any spread into the travel lane should be avoided. For spread on bridges on urban curb and gutter section roadways, spread may be allowed into the travel lane consistent with that allowed along the approaches to the bridge.
- In evaluating spread for maximum efficiency and safety, remember to consider the height of curb, as flow should not be allowed to exceed the curb height. For standard 6-inch high curb, it is preferable that the design flow depth not exceed 5 inches.
- While there is generally no maximum spacing requirement for inlets, no trunk line pipe should extend more than 500 feet without access on a curb and gutter typical section. For median and side ditch systems in shoulder sections, 700 feet is an acceptable upper limit.
- Longitudinal runs of pipe beneath roadway travel lanes should be avoided.
- A minimum vertical clearance of 0.5 foot from the hydraulic grade line to top of inlet grate or junction is recommended.
- It is desirable that inlets be designed for 100% interception of runoff; however, minor bypass discharge to a downstream inlet is acceptable, provided it is accounted for in design computations.
- Bypass discharge at a superelevation rollover should not exceed 0.1 cfs.
- False sumps should be used downstream of median ditch inlets to provide 100% interception of runoff, analyzed as a low point (sag) inlet.
- Review preliminary design plans for low point (sag) locations in roadway cut sections, which should be avoided if practicable, as they are usually difficult to drain and easily clogged.
- For high volume multilane arterial routes (such as interstates) with more than three lanes sloped in one direction, it may be necessary to break the superelevation to eliminate potential hydroplaning hazard. This should be coordinated with Roadway Design Unit as early as possible.

- On high volume arterial and collector routes with raised median, it may be useful to call for a 2 ft. – 9 in. curb and gutter (requires special detail – not NCDOT standard) in areas where the pavement is sloped toward the high side of the median, with inlets placed to limit spread to no more than 3ft. into the adjacent travel lane.
- Standard Drawings 560.01 and 560.02 (16) should be referred to in evaluating median drainage, as the direction of pavement drainage will differ depending on whether the width of the median paved shoulder is greater or less than 10 ft.

10.4 Pipe System Analysis and Design Criteria

- Storm drain pipes should typically be concrete unless a site limitation, such as grade, corrosive condition, or other reasonable justification can be made to support use of an alternate material. Refer to Appendix H, Item 1 regarding criteria for acceptability of alternate pipe material specification.
- The minimum pipe size to serve a single inlet is 12 inch diameter. For pipes connecting to more than one inlet, pipe under pavement, side drains (driveway pipes), or pipes having a length of more than 100 feet, a 15 inch diameter is the minimum size which should be used. (Minimum size for an open-ended cross pipe functioning as a culvert is 18 inches, excluding driveway pipes). Use of 12 inch or smaller diameter pipe (other than to serve a single inlet or driveway) should be approved by the Hydraulics Unit.
- When differing size pipes enter and exit a junction the desired practice is to match the crown elevations of the pipes when practicable.
- Pipe systems shall not decrease in size in the downstream direction.
- See additional guidance on pipe material selection in Section 10.6.
- Due consideration must be given to method of pipe installation (Standard 300.01) (16) and fill height requirements (Appendix H), as may be warranted.
- Driveway pipes must comply with NCDOT's *Policy on Street and Driveway Access to North Carolina Highways* (60).
- Avoid placement of storm drain systems where it would disturb contaminated soils (identified on the plans) for which the contamination is to be managed by containment rather than removal. If unavoidable, as a minimum, specify a sealed (watertight) system through the contaminated area, which would warrant an exception to the standard Pipe Material Selection Guide (Appendix H). Consult the Geotechnical Unit for guidance concerning any additional measures needed.

10.5 Hydrologic and Hydraulic Design

Storm drain system design is a two phase process involving first a selection of the required surface inlets, followed by the design of a subsurface pipe system to serve the surface inlets. GEOPAK Drainage is an acceptable software application for storm drain system design, which is consistent with the following general design procedure based on HEC-22 (6) guidance:

10.5.1 Inlet Selection and Placement Procedure

1. Prior to commencing the hydrologic/hydraulic analysis of the surface system, a layout of locations requiring inlets should be developed on a set of plans. This would include sag points, upstream of intersections, upgrade of superelevation rollovers, and at locations requiring junction back-of-curb inlets. On curved alignments, it may be necessary to add intermediate inlets to avoid having to construct pipes on a curve, and coordination with the Division is recommended regarding this.
2. With the above noted locations determined, the next step is to analyze the runoff and gutter spread along the roadway to establish additional required inlet locations to meet spread and depth criteria. The hydrologic method used will typically be the Rational Method and follows the guidance in Chapter 7 (Hydrology). The general procedure, as outlined in Chapter 6 (Drainage Plans), should be used to confirm drainage boundaries, flow paths, outlet conditions and other project special design features.
3. The design is to be documented on a form similar to Appendix I Item 1. The inlets, junctions, and outlets or other features (as applicable) should be numbered in a logically ascending order and their location referenced to a project station. If the storm drain system numbering changes by time plans are let for construction, the revised construction numbers should be documented on the design forms for future reference. Some computer programs (such as GEOPAK Drainage) (68) may also require the outlet of a storm drain system, as well as pipe elbows, pipe collars, etc. to be assigned a structure number. Further guidance regarding structure numbering for NCDOT projects is posted on the Hydraulics Unit website in the GEOPAK Applications section.

10.5.2 Storm Drain Design Procedure

1. Following the above inlet selection and location procedure, lay out the pipe system to provide a connecting route of flow from the inlet(s) to the proper outlet point(s).

2. Once initial system layout is completed, the next step is to size the individual pipes.

3. The storm drain design computation form (Appendix I Item 2 – see Section 10.5.2.1 below) follows a systematic design process of developing the pipe network from upstream to downstream. Selection of pipe sizes is accomplished utilizing Manning's flow capacity equation, with the limitations on maximum pipe capacity presented in Appendix I Item 6. Sizing of most systems by this procedure is generally sufficient, and may be automated by a software application (e.g. GEOPAK Drainage).

4. The procedure for hydraulic grade line development is outlined below in Section 10.5.2.2. A check of the system by development of hydraulic grade line is recommended, and can be checked relatively quickly if using software to perform the computations. However, calculating hydraulic grade line manually can be very time consuming. Therefore, if hand computations are being used, the design engineer should consider whether the time and effort needed to perform a hydraulic grade line check of a system is warranted. Conditions that may warrant undertaking this additional design analysis are:
    - Systems with outlets that are subject to high tailwater conditions.
    - Systems that transition from a steep to flat gradient.
    - Systems on a flat gradient, especially if they have substantial junction or bend losses.

10.5.2.1 Storm Drain Design Computations Procedure

Reference Appendix I Item 2, for storm drain system design documentation, as outlined below in order of columns from left to right:

1. Inlet number at upstream end of pipe, corresponding to inlet computation sheet (design number/construction number).
2. Inlet numbers at downstream end of pipe, corresponding to inlet computation sheet.
3. Total cumulative drainage area served by the section of pipe.
4. Cumulative sum of the incremental product of the incremental drainage area multiplied by the corresponding runoff coefficient (Sum CA) for each inlet contributing flow to that location.
5. Length of the pipe between study points.
6. Time of concentration for contributing drainage area to inlet at upstream end of pipe.
7. Flow time for first pipe equals inlet time. Flow time for subsequent sections is a sum of the time of concentration of the previous reach (minimum t_c = 10 minutes) plus time of flow in subject pipe.
8. Enter larger value from items 6 and 7 as the design time. Use 10 minutes as minimum value. For design time greater than 30 minutes, a flood hydrograph or other routing procedure is recommended.
9. Design storm rainfall intensity for duration equal to design time.
10. Design discharge for pipe reach. (Rational method: multiply Sum CA by design intensity.)
11. Invert elevation of pipe inlet.
12. Invert elevation of pipe outlet.
13. Invert slope of pipe.
14. Diameter of pipe. This size is to be selected based on pipe flow capacity (item 16)
15. Pipe material (e.g. M – metal, C – concrete).
16. Capacity is computed using Manning's full flow capacity equation: $Q = (0.46/n)\,(D^{2.67})(S_o^{0.5})$. A nomograph solution for this equation is provided in Appendix I, Item 3. The capacity utilized for design cannot exceed the values contained in Appendix I, Item 6. Manning's roughness coefficient (n) corresponds to the pipe material specified in item 15.
17. Velocity based on design discharge and selected pipe size (can use charts Appendix I, Item 4 or calculate with Manning Equation and Continuity Equation, Q=VA).
18. Upstream box depth.
19. Remarks – Use to document unusual design conditions, restrictions, allowable pipe material, etc.

10.5.2.2 Hydraulic Grade Line Development Procedure

A hydraulic grade line will provide the potential elevation, under design conditions, to which water will rise in the various inlets and junctions. This can serve as a check for potential unacceptable outflow or pressure problem areas within the system dictating a change in the system design.

Reference Appendix I, Item 7 for hydraulic grade line computations, as outlined below in order of columns from left to right:

1. The inlet or junction number immediately upstream of the outlet (design number / construction number).
2. Water surface elevation at outlet, or 0.8 (D_o) + invert elevation of the outflow pipe, whichever is greater.
3. Diameter (D_o) of outflow pipe.
4. Design discharge (Q_o) for the outflow pipe.
5. The length (L_o) of the outflow pipe.
6. Friction loss (H_f) for full pipe flow. Loss due to flow in the pipe can be computed by multiplying pipe length (L_o) by friction slope (S_f). Friction slope can be determined from pipe flow charts or by using the formula: $S_f = (Q/K)^2$, where $K = (1.486/n)(A)(R^{0.67})$. Sheet 4 - Appendix I, sheet 5 provides values of (K) for various pipe sizes.
7. Contraction loss (H_c). Loss due to contraction of flow at inlet of outflow pipe. Computed by the formula: $H_c = 0.25\ (V_o^2/2g)$, where: V_o = flow velocity in outlet pipe (full flow); $g = 32.2$ ft/sec^2 (gravitational acceleration constant).
8. Expansion loss (H_e). Loss due to expansion of flow into the junction. Use expansion loss from primary inflow line, given by $He = 0.35\ (V_i^2/2g)$, where: V_i = flow velocity in inlet pipe (full flow)
9. Bend loss (H_b) loss due to change in direction of flow. Use change in angle of primary flow line. Bend loss is given by $H_b = K\ (V_i^2/2g)$, where K is the bend loss coefficient from the following list:

90 º K = 0.70	40 º K = 0.38
80 º K = 0.66	30 º K = 0.28
70 º K = 0.61	25 º K = 0.22
60 º K = 0.55	20 º K = 0.16
50 º K = 0.47	15 º K = 0.10

10. Total losses (H_t), sum of friction, contraction, expansion, and bend losses.
11. Inlet water surface elevation. This is the potential water surface elevation within the inlet or junction. (Outlet water surface elevation plus total losses.)
12. Inlet rim elevation or top of junction. It is desirable for the water surface elevation to be a minimum of 0.5 feet below this elevation. If not, the pipe size should be increased or other measures taken as practicable to lower the water level.
13. Remarks.

Repeat the procedure for the upstream junction and plot the potential water surface elevation if above the crown elevation of the outlet pipe.

10.5.3 Storm Drain System Outlet Analysis

The storm drain system design must include an evaluation to determine that the downstream receiving channel and property (including its associated drainage features) will not be adversely affected by increased discharge or erosion from the upstream runoff and is in compliance with NC Statute 15A NCAC 04B.0109 regarding Stormwater Outlet Protection. The design engineer should bear in mind that the intent of this statute, as it relates to NCDOT actions, is to ensure, to the maximum extent practicable, every effort is made to avoid or minimize adverse impact to the downstream channel and the adjacent downstream property as a result of stormwater runoff exiting from NCDOT's right-of-way.

This evaluation should address:

- Potential effects on the receiving stream when identified as an environmentally sensitive stream (reference Chapters 11 and 13).
- Potential effects on the highway facility due to downstream outlet inadequacies.
- Potential effects to other properties due to outlet inadequacies.
- Effect of the highway improvements on the downstream facility. (Percent increase in quantity, velocity, depth, etc.) Typically the two-year, five-year, and ten-year event discharges are evaluated for this analysis.
- Potential corrective measures (with estimate of associated cost).
- Recommended actions.

10.6 Pipe Material Selection

In 2009, NCDOT developed requirements and guidance to foster competition with respect to the specification of alternate types of culvert and storm drain system pipes. These were intended to be commensurate with similar competitive requirements for other construction materials, in compliance with federal law. Current guidance is outlined in Appendix H in a table labeled "NCDOT Pipe Material Selection Guide". This table is also posted on the Hydraulics Unit website. If the hydraulic engineer requires a specific pipe material and class for a given pipe, this should be clearly specified on the design plans. Supplemental tables in Appendix H are provided for reference; however, the "NCDOT Pipe Material Selection Guide" should take precedence if information in the supplemental tables differ.

10.7 Drainage Summary Sheet

The Drainage Summary Sheet in the roadway design plans contains a detailed listing of all the quantities for various pay items associated with the drainage design for the project. This sheet is generally prepared by Roadway Design Unit and checked by the design engineer. To facilitate production, a program has been developed to generate automated quantities from data stored in GEOPAK Drainage (68). Documentation for this is posted on the Hydraulics website in the GEOPAK Applications section.

10.8 Treatment of Existing Pipes

When existing pipe is to be removed, or removed and replaced, this should be noted in the drainage plans. Pipe removal is warranted when the existing pipe is deteriorated and unusable or if it is being replaced in the same location. If the existing pipe is no longer needed for flow conveyance, but it is deemed advantageous to leave in place under the pavement, the design engineer may call for pipe plugs (NCDOT Standard 840.71) (16) at both ends of the pipe. If the structural integrity of the abandoned pipe is a concern with respect to support of the overlying fill material (e.g. a corroded metal pipe), the design engineer may alternatively call for filling the pipe with flowable material. If an existing pipe within the project construction limits is deemed to be in good condition and is recommended to be retained, this also should be called out on the drainage plans.

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11 ROADSIDE DITCHES AND CHANNELS

11.1 Overview

A channel is a conveyance in which water flows with a free surface and may be natural or manmade. A roadside ditch is a man-made channel generally paralleling the roadway surface and distinguished by a regular geometric shape. The design process and analysis requirements for roadside ditches and channels differ. Roadside ditches are roadside and median drainage conveyances that carry surface stormwater off away from the roads and their subgrade drains. For the purpose of this chapter, "channel" shall refer to all open conveyance facilities not classified as roadside ditches or requiring more than a two foot wide base. Although the design procedure presented is general, the guidance provided is intended to address specific criteria and analysis requirements. The design engineer should reference FHWA's HEC-11, (17), HEC-14 (28), HEC-15 (18), Chapter 6 of the *AASHTO Highway Drainage Guidelines* (1), and Chapter 10 of the *AASHTO Drainage Manual* (2) for more detailed design guidance.

11.2 Roadside Ditches

11.2.1 Establishment of Ditch Plan

Establish a ditch plan which shows the proposed ditch locations and flow patterns. This ditch plan is a part of the drainage plan (Chapter 6, Section 6.1 – item 7).

11.2.2 Determination of Typical Ditch Cross Section

Determine the standard or typical ditch cross sections for the project. This is provided by the roadway plans typical sections. When a ditch is required along the construction limits and is not shown in the roadway typical section, the following criteria should be followed in establishing a typical section:

- A standard berm ditch section should be specified at the top of a cut section where required as depicted in Roadway Standard Drawing 240.01 (16). In the event it is necessary to bring water down cut slopes into the highway drainage system when the roadway grade is at a lower elevation than the natural drain which it crosses, it may be necessary to intercept runoff from the berm ditch into a berm drainage outlet, as depicted in Roadway Standard Drawing 850.10-11 (16), to convey the runoff from the top of the cut slope to a storm drain inlet located in the typical roadway cut ditch. Safety bars over the pipe opening may be warranted in neighborhoods where safety of small children is a concern.
- Toe of fill ditches adjacent to shallow fills and flat slopes (4:1 or flatter) should be formed by continuation of the fill slope to a desired ditch depth, provision of a base width, if required, then a stable back slope (2:1 minimum).
- Toe of fill ditches adjacent to high steep slopes should be constructed with a minimum two (2) foot berm. A wider berm is desirable for very high fills to prevent embankment from filling the ditch and for maintenance if access is limited from opposite the roadway side.

11.2.3 Determination of Ditch Gradient

Determine the gradient to be used on all proposed ditches. Roadside ditches included in the typical roadway section should have a grade corresponding to the roadway profile. When the roadway profile grade is less than 0.3%, special roadway ditch grades may be established and noted on the plans. Ditches along the toe of fill will generally parallel the grade of the natural ground at an established acceptable depth. Ditch grades are to be established and plotted on the roadway plans in the profile view.

11.2.4 Investigation of Capacity of Ditch

Roadside ditches are to be designed to contain, as a minimum, the Q_{10} discharge (including temporary detour ditches). The typical roadside ditch section should be established with sufficient depth to drain the pavement subbase and provide flat side slopes for safe vehicle maneuverability. This generally provides very generous capacity for the design flow requirements. Therefore, actual capacity determination can be evaluated on a selective basis at sites on common project grades to verify adequacy and establish limitations on the length of ditch run. If there is a likelihood of future pavement widening toward the median, this should be accounted for in the median ditch drainage analysis and design. Driveway pipes in ditches should typically be sized to convey the same design discharge as that for which the ditch is designed.

The size requirements of the project special side ditches along the toes-of-fill will be established based on an analysis of the design flood. This ditch capacity analysis will be performed using Manning's equation: $Q = (1.49/n)\ A(R^{2/3})\ (S^{1/2})$, where Q is discharge in cubic feet per second (cfs), A is flow area in square feet, S is slope (feet of fall per feet of length), and R is the hydraulic radius in feet.

Discharge determination shall follow the requirements of Chapter 7 - Hydrology. The roadway section including shoulders and slopes shall be considered an urban watershed. This capacity analysis is usually worked in conjunction with the next step of lining evaluation.

11.2.5 Evaluation of Ditch Lining for Stability

The stability of vegetative ditch linings is to be analyzed by use of Charts 1 and 2 in Appendix J. These charts are based on the commonly used 'V' and base ditch sections. However, a procedure and example are included for evaluating other channel configurations. The stability limitation is based on an established acceptable velocity. When applying the chart, if conditions at a particular site are such that the resulting chart value is located to the left of the stability line (velocity under 4.5 ft/sec), a vegetative cover would not be expected to erode. Conversely, if it is to the right of the line, the ditch would be expected to be unstable and erode when subjected to the design flow; therefore, some type of armoring (such as rip rap) should be used.

Charts 3 and 4 in Appendix J are provided to analyze the stability of rip rap ditch linings (Types A, B, and Class I rip rap). They are used in the same manner as Charts 1 and 2 to determine the stability of stone lining under differing ditch shape and flow conditions.

The Appendix J ditch stability design charts were developed in accordance with the procedures in HEC-15 (18) which determine the acceptability of given lining type by comparing the maximum shear stress of the flow to the permissible shear stress of the lining.

The maximum shear stress of the flow in a ditch can be established by the following equation:

$$\tau_d = \gamma d S_o$$

Where,

- τ_d is the maximum shear stress of the flow (lb/ft^2).
- is the unit weight of water (lb/ft^3). (Typically 62.4 lb/ft^3)
- d is the depth of flow (ft)
- S_o is the channel longitudinal slope (ft/ft)

As the Appendix J charts demonstrate, grass-lined ditches tend to become unstable when flow velocity approaches 4.5 ft/sec or greater. Table 11-1 lists permissible shear stress values for typical non-vegetative ditch liners used by NCDOT:

Liner	d_{50} (in)	τ_p (lb/ft^2)
Class A riprap	4	1.6
Class B riprap	8	3.2
Class I riprap	10	4.0
Class II riprap	12	4.8

Table 11-1 Permissible Shear Stress (τ_p)

Another channel liner used by NCDOT is Permanent Soil Reinforcement Matting (PSRM), which is a synthetic geotextile product typically used for permanent erosion control or in conjunction with certain stormwater control devices, as specified in the Stormwater Best Management Practices Toolbox (34). PSRM should not typically be specified as the primary liner for a roadside ditch or channel; however it may be specified as an alternative liner where Type A rip-rap may not be acceptable, such as within the clear recovery zone or in a homeowner's front yard. PSRM has a permissible shear stress of 3 lb/ft^2.

Type and dimensions of ditch liner are to be specified in the ditch details shown in the plans. Roadway Standard Drawings 876.01-04 (16) depict standards for riprap placement in channels, drainage ditches, and at pipe outlets. For concrete ditch behind a retaining wall, note that Geotechnical Unit has established standard cells and details which must be included, as applicable, in the design plans. (https://connect.ncdot.gov/resources/Geological/Pages/Geotech_Forms_Details.aspx)

11.2.6 Analysis of Ditch Outlet

Determine any special measures that may be required to mitigate or avoid scour or degradation at or downstream of the ditch outlet. A check should be made of the transition of flow from a ditch to the receiving outlet.

Factors to be considered are:

(a) Is there provision for a smooth transition of flow from the ditch to the outlet?
(b) Will the outlet adequately handle the quantity of flow? Is improvement required?
(c) Is the velocity of flow at the outlet too high for the condition of the receiving channel? Is riprap or other means of energy dissipation justified? (Refer to Chapter 10, Section 10.5.3.)
(d) When the receiving outlet is sheet overland flow, is concentration of flow by the ditch a potential problem? Is some form of flow diffusion required?
(e) Is access to the outlet provided for inspection and maintenance?

11.3 Channels

Channel analysis differs from roadway ditch analysis in that it involves establishing a channel configuration to meet specific site hydrologic, and geomorphic requirements. The requirements for analysis can range from simple sizing of small ditches constructed adjacent to the roadway fill for interception and conveyance of discharge to acceptable outlets, to complex studies of extensive natural stream and river relocation. In addition to the guidance provided in this document, the design engineer should follow FHWA's Hydraulic Engineering Circular No. 15 (18) and Chapters 10 and 16 of the AASHTO *Drainage Manual* (2), for further guidance for small ditch and channel analysis. For larger stream involvement, FHWA's *Highways in the River Environment* (19), *Applied River Morphology* (20), NC Wildlife Resources Commission's *Guidelines for Mountain Stream Relocation and Restoration in North Carolina* (21), NCDEQ (formerly NCDENR) *Stream Mitigation Guidelines* (45), and *Stream Restoration, A Natural Channel Design Handbook* (50) are suggested references. It should also be noted that individual NCDOT Division offices may have established criteria for ditch and channel design which are applicable to construction practices within their own Division; therefore the design engineer should consult with the division to ensure that appropriate and acceptable ditch and channel designs are specified and constructed.

11.3.1 Channel Lining for Stabilization

Rip rap lining may be needed to control erosion. A supplemental geotextile liner may be specified underneath the standard riprap liner where warranted and should be shown and quantified in the ditch details and quantity estimates provided on the roadway plans. For channel capacity and stability analysis, follow the same guidance used for ditch design provided in Sections 11.2.4 and 11.2.5, utilizing the design charts provided in Appendix J.

11.3.2 Realignment of Natural Channels

Realignment of natural streams should be designed and configured to match as near as practicable to the natural channel in alignment and gradient. Minimum disturbance to the natural flow is always the aim of good hydraulic design, except in areas where natural flow is unstable or detrimental, requiring restoration or mitigation measures, which can be incorporated in the highway drainage design.

For minor stream realignment at the inlet and outlet of structures (less than 100 feet total, approximately 50 feet each end), the design engineer should follow guidance provided in "Stream Relocation Guidelines" developed jointly by representatives of the NCDOT and the NC Wildlife Resources Commission in 1993 (Appendix M).

11.3.2.1 Morphological Stream Classification

If relocation of a stream channel is unavoidable, the design of the replacement channel should provide dimension, pattern and profile that affords natural stability. A process of stream classification developed by Dave Rosgen, detailed in *Applied River Morphology* (20), has been widely used and accepted for effective analysis of natural streams and rivers. The objective of classifying streams on the basis of channel morphology is to set categories of discrete stream types, so that consistent, reproducible descriptions and assessments of conditions and potential can be developed.

Some specific objectives of a classification system are:

- Provide methodology for predicting a stream's behavior from its appearance (classification).
- Guide development of specific hydraulic and sediment transport relationships for stream type and state.
- Provide mechanism for comparison of data for stream reaches having similar characteristics.
- Provide a consistent frame of reference for communicating stream conditions and morphology across disciplines.

The general guidance provided in the following sections should be followed in analysis of natural channels.

11.3.2.2 Data Collection for Stream Studies

Data collection includes office study as well as a field survey. Much of the information needed for initial classification can be obtained from topographic mapping and aerial photography. The field survey provides more detailed information for refinement of the initial classification as well as the analysis and design process. It should include as a minimum the collection of the following data:

11.3.2.2.1 Data Needed for Stream Classification

- channel width (bankfull)
- channel depth (section mean)
- maximum depth (at bankfull)
- bankfull cross section area
- slope (average for at least 20-30 channel width reach)
- stream length (20-30 bankfull channel widths in length)
- valley length (20-30 bankfull channel widths in length)
- bed material (type, size [D_{50}])
- bank material (type, size [D_{50}])
- width of flood-prone area

11.3.2.2.2 Data Needed for Stream Analysis and Design

- Channel Dimension
    - pool depth
    - pool width
    - pool area
    - riffle depth
    - riffle area
    - maximum pool depth
- Channel Pattern
    - meander length
    - amplitude
    - radius of curvature
    - belt width
- Channel Profile
    - valley slope
    - riffle slope
    - average water surface slope
    - pool slope
    - pool to pool spacing
    - pool length

11.3.2.3 Establishment of Stream Type Classification

With the above data collected and further determination of stream features such as entrenchment ratio, width/depth ratio, and sinuosity, a stream type classification can be established following the procedure discussed in Chapter 3 of *Applied River Morphology* (20).

11.3.2.4 Evaluation of Existing Conditions

It is important to assess the existing condition of the stream as it relates to stability, state, and causes of changes, potential future impacts, and hydrologic and hydraulic requirements. This assessment process should address:

- the watershed,
- flow regime,
- riparian vegetation,
- bank stability,
- bed stability,
- meander patterns,
- sediment supply and transport,
- debris,
- aggradation/degradation,
- aquatic and terrestrial habitat,
- discharge levels and conveyance requirements
- evolutionary trend.

Stream conditions gathered through the assessment process apply only to the reach of the stream studied, and may vary considerably upstream and downstream as the character of the valley changes. Some stream study reaches may be at such an altered state that existing conditions data are of little value in developing recommendations for a relocated or restored channel. In such a case, a reference stream of similar classification and morphological characteristics can be used as a guide for developing study proposals.

11.3.2.5 Development and Documentation of Proposed Channel Design

The above evaluation process should provide the design engineer with sufficient information and knowledge necessary to develop a recommended channel relocation or restoration proposal that meets hydrological and ecological requirements and provides a natural, stable system. A wildlife resource specialist should be consulted for input during the design process. All information pertinent to the channel design should be documented in an appropriate design report format.

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12 EROSION AND SEDIMENT CONTROL

12.1 Overview

NCDOT was first delegated an erosion and sediment control program by the North Carolina Sedimentation Control Commission in 1974. Controlling accelerated erosion and sedimentation is critical for the protection of water quality in streams and water bodies receiving drainage from NCDOT projects. This chapter addresses erosion and sediment control on NCDOT projects and compliance with applicable state and federal regulations.

12.1.1 Effects of Accelerated Erosion and Sedimentation

Erosion and sedimentation can cause or contribute to a number of water quality related problems including:

- Elevated turbidity
- Increased water temperature
- Decreased dissolved oxygen
- Increased algae growth
- Loss of aquatic habitat
- Reduction in stream conveyance
- Increased flooding
- Reduced storage volume in reservoirs
- Increased filtration costs for municipal water supplies

12.1.2 Erosion and Sediment Control Requirements

- The North Carolina Sedimentation Pollution Control Act of 1973 and Administrative Rules are enforced by the Division of Energy, Minerals and Land Resources - Land Quality Section in the NC Department of Environmental Quality (NCDEQ, formerly NCDENR). The Act applies to land-disturbing activities for public or private development and highway construction and maintenance. Because of the magnitude of land-disturbance conducted by the NCDOT, the Sedimentation Control Commission within NCDEQ delegated authority to the Division of Highways to implement an erosion and sediment control program with periodic project inspections and an annual audit by the Land Quality Section. The NCDOT has responsibility to comply with all statutory and administrative rules and all requirements stipulated in the program delegation.

- The Federal Clean Water Act (CWA) and the National Pollutant Discharge Elimination System (NPDES) require that construction activities control the discharge of pollutants in stormwater runoff including sediment. They are enforced by the United States Environmental Protection

Agency (USEPA) and by the Division of Energy, Minerals and Land Resources (DEMLR) and the Division of Water Resources (DWR) within the NCDEQ (formerly NCDENR) through delegation of authority from the USEPA. An NPDES permit is required in order to discharge stormwater, and in North Carolina, construction activities are covered under NPDES General Permit – NCG 010000. The permit incorporates compliance with State erosion and sediment control requirements along with other stormwater pollution prevention requirements. NCDOT must comply with a specific NPDES stormwater permit (NCS000250), which incorporates the requirements NCG 010000, and state nutrient management strategy rules. Both are discussed in Chapter 13.

12.2 NCDOT Erosion and Sediment Control Program

The Roadside Environmental Unit (REU) within the Division of Highways has primary responsibility for implementing the delegated NCDOT erosion and sediment control program. The REU prepares erosion control plans, develops and maintains erosion and sediment control standards, details, specifications, develops project special provisions, produces training materials for erosion and sediment control and monitors active work-sites for compliance with the Sedimentation Pollution Control Act and NCG 010000.

12.2.1 Erosion and Sediment Control Plans

Within the REU, the Soil and Water Engineering Section is responsible for designing and approving erosion and sediment control plans for land-disturbing activities of one or more contiguous acres associated with NCDOT highway construction. Plan designs consider a number of factors including construction sequencing, existing topography, proposed land grades, soil type, hydrology, design storm, required trapping efficiency for certain devices, classification of receiving waters, critical habitat areas, and other identified environmental concerns.

More information regarding the NCDOT erosion and sediment control program including design requirements for devices used on highway construction projects can be found at:

http://www.ncdot.gov/doh/operations/dp_chief_eng/roadside/soil_water/

12.2.2 Riparian Buffer Rules

At present, riparian buffer rules have been adopted by the NC Environmental Management Commission (EMC) in the Neuse River Basin, the Randleman Lake Water Supply Watershed, the Tar-Pamlico River Basin, along the Catawba River main stem, the Goose Creek Water Supply Watershed and the Jordan Lake Water Supply Watershed. Highway construction projects are subject to these rules and must preserve vegetated riparian buffer zones along streams and rivers. These regulatory buffers provide for only certain types of minimally invasive encroachments. More extensive encroachments must be permitted by the NC Division of Environmental Quality (NCDEQ, formerly NCDENR) DWR. The rules that are currently in effect can be found in 15A NCAC 02B.0233, 15A NCAC 02B.0250, 15A NCAC 02B.0259, 15A NCAC 02B.0243, 15A NCAC 02B.0607, 15A NCAC 02B.0267 respectively. As new buffer rules are adopted or existing rules are modified by the EMC, these regulatory codes will be updated accordingly.

12.2.3 Erosion and Sediment Control Inspections

NCDOT Project Inspectors and the REU Field Operations Sections perform inspections of highway construction activities to ensure compliance with all erosion and sediment control requirements. Plan implementation as well as installation, maintenance and effectiveness of devices are evaluated. A report is generated for all inspections noting corrective actions if needed.

Project Inspectors perform inspections at least weekly and more often after periods of rainfall. Findings are recorded in the inspector’s daily report. A list of all needed corrections is given to the contractor with a copy provided the Resident Engineer or the District Engineer for maintenance projects.

REU Field Operations staff inspect monthly. If significant problems or potential violations are observed, an Immediate Corrective Action (ICA) is issued to the Resident or District Engineer. Corrective actions must begin within 24 hours, and grading operations can be suspended until are problems are resolved. Field Operations staff will revisit the site within five (5) working days or seven (7) calendar days (whichever is shorter). Serious violations can result in the issuance of a Notice of Violation (NOV) by the NCDEQ (formerly NCDENR) Land Quality Section and possible enforcement actions.

12.3 Culvert Construction Sequence

The design engineer should provide a culvert construction sequence plan for each culvert that provides a total waterway opening of thirty (30) square feet or greater. These plans are provided to Structures Management, Roadside Environmental, and Traffic Management Units to assist with culvert construction. The construction sequence plan is comprised of a construction sequence narrative and figure, which provide a description of the phases required to construct the culvert to manage water conveyance and erosion control. The construction sequence plan is intended to serve as a reasonable and acceptable method to accomplish construction; however, there may be other methods that are found to be more appropriate and acceptable. Construction sequencing should be discussed and agreed upon during the field inspection. The final construction sequence plan will be developed by the REU and included in the project’s erosion control plans.

The design engineer is responsible for the calculations required for the construction sequence plan, including stream diversion flows, pipe and diversion channel sizing for stream flows, volumes for sediment basin and sediment bags, and excavation quantities for diversion channels.

Temporary stream diversions and pipes are to be sized for the mean daily flow, which should be computed based on the normal water surface elevation (vegetation line – a.k.a. ordinary high water) in the channel as determined from field review.

Volume needed for temporary basins or sediment bags for treatment of dewatering effluent from construction areas are calculated using the following formula:

$$V_b = [L \text{ x } W \text{ x } (NWS+1)]/27$$

Where:

V_b = Volume needed for temporary basin or sediment bags (yd^3)

L= Length of culvert plus required construction access (ft)

W = Width of culvert plus required construction access (ft)

NWS = Normal Water Surface depth (ft)

Note that 1 ft depth is added to the NWS depth to account for base excavation.

Basin volume (V_b) and trapezoidal basin dimensions for a temporary stilling basin per Standard Drawing 1630.04 (16) necessary to provide the target volume can be calculated using the Temporary Stilling Basin Dimensions and Volume Calculator shown in Appendix F Item 5, which can be downloaded from the Hydraulics Unit website.

Required excavation volumes for temporary diversion channels should be estimated by taking the largest excavation cross-section area and multiplying by the length of the diversion channel.

An example of a culvert construction sequence plan is provided in Appendix F Item 6.

The culvert construction sequence plan should include:

1. Narrative describing culvert construction phasing and other noteworthy information
2. A figure depicting the following:
   - culvert construction phases
   - diversion channels or pipes with sizing calculations
   - drainage ditch excavation volume
   - sediment basin or bags with location and temporary drainage easement
   - temporary dikes
   - roadway drainage and roadway features as shown on plans

13 STORMWATER MANAGEMENT

13.1 Highway Stormwater Program

Stormwater runoff is a cause of water pollution in North Carolina and is regulated federally by the Clean Water Act (CWA) and also by state regulations. NCDOT has a delegated stormwater program from the NC Department of Environmental Quality (NCDEQ), formerly the NC Department of Environment and Natural Resources, which covers the requirements of both state and federal regulations. The Department's Highway Stormwater Program (HSP), managed by the Hydraulics Unit, is responsible for maintaining stormwater compliance for the Department. The design engineer is responsible for complying with all state and federal stormwater regulations during project delivery.

13.2 National Pollutant Discharge Elimination System Permit and Stormwater Regulations

The Department's National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (NCS000250) and associated state laws and administrative codes define the requirements for NCDOT stormwater management. NCDOT was the first in the nation to receive a statewide transportation NPDES Stormwater permit on June 8, 1998. This permit is renewed by NCDEQ, NC Division of Energy, Mineral, and Land Resources (NCDEMLR) every five years. The current permit covers from October 1, 2015 to September 30, 2020. The permit allows discharge of stormwater from NCDOT facilities both in the construction and post-construction periods.

The NCDEQ regulates specific pollutants of concern that impair waters of the state, and it also regulates practices that protect water quality or endangered species. Nutrient Sensitive Waters (NSW) have been identified in the state, which include the Neuse and Tar Pamlico River Basins and associated special watershed programs for Falls Lake and Jordan Lake. Riparian Buffer Rules have been promulgated, which provide both Nutrient Management Strategies and water quality protection strategies throughout the state. There are currently six (6) watersheds or river basins for which Riparian Buffer Rules have been established:

- Neuse River Basin (includes Falls Lake)
- Tar-Pamlico River Basin
- Catawba River Basin
- Jordan Lake Water Supply Watershed
- Randleman Lake Water Supply Watershed
- Goose Creek Watershed

NCDOT also protects water quality through hazardous spill prevention with the installation of Hazardous Spill Basins along designated road facilities in certain water classification areas. Guidance on Hazardous Spill Basins is provided in Appendix O.

13.3 Post-Construction Stormwater Program – Compliance for Transportation Projects

Stormwater management occurs during construction and post-construction activities. Construction stormwater runoff is regulated by the State Sedimentation Control Act and the Federal NPDES stormwater permit. The Roadside Environmental Unit manages erosion and sedimentation control requirements on NCDOT projects. More information about the erosion and sedimentation control plans and requirements may be found on the Roadside Environmental Unit, Soil and Water Section website and in Chapter 12 of these *Guidelines*.

Stormwater runoff after construction is known as post-construction runoff. Since the post-construction period exists perpetually, the importance of implementing effective controls is imperative. NCDOT manages post-construction stormwater through the Post-Construction Stormwater Program (PCSP).

Stormwater is required to be managed to the "maximum extent practicable" (MEP)* for NCDOT projects as directed by the document titled Post-Construction Stormwater Controls for Roadway and Non-Roadway Projects (64). This policy document has been approved by NCDEQ for NCDOT projects and guides the design engineer in compliance requirements. The NCDOT Best Management Practices Toolbox (BMP Toolbox) (34) is used with the PCSP to provide guidance on stormwater control design requirements. Regulatory interaction and coordination is imperative to achieve the MEP standard.

> * The Federal Register, Volume 64, page 68754, December 8, 1999, states: "Maximum extent practicable (MEP) is the statutory standard that establishes the level of pollutant reductions that operators of regulated MS4s [TS4s in NCDOT's case] must achieve. The CWA requires that NPDES permits for discharges from MS4s 'shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods.' CWA Section 402 (p) (3) (B) (iii)."

MEP for transportation projects considers the following:

- right-of-way costs
- existing mature trees and buffers that provide water quality and ecological benefits
- topography limitations such as steep slopes, cut sections, etc.
- geological limitations such as rock, high ground water table, etc.
- environmental justice
- utility conflicts
- costs of construction and maintenance of a control device
- applicability and effectiveness of non-structural controls

Stormwater compliance is required for all NCDOT development and re-development projects that add new built upon area (BUA). BUA is generally defined as impervious surface or partially impervious surface that does not allow water to infiltrate through the surface into the subsoil. A more specific definition is available in the PCSP document. The PCSP document identifies the workflows for stormwater management compliance and applicability to a project.

Stormwater management decisions are made during the planning and design phases of a project. Decisions during these two phases are documented in the Stormwater Management Plan (SMP), which demonstrates the Department's stormwater compliance to MEP. After the project contract let date, the construction of stormwater Best Management Practices (BMP) devices may require the oversight of the design engineer. Following construction, the Hydraulics Unit, in cooperation with the Roadside Environmental Unit and the Division, coordinates inspection and maintenance of BMPs (65).

13.4 Roadway Projects vs. Non-Roadway Projects

In general, transportation projects are classified as either roadway or non-roadway projects. Projects that are incorporated into the Department's right-of-way (ROW) are considered roadway projects. Those that are off the ROW, such as industrial facilities and Division offices, are considered non-roadway projects. Information about Roadway Projects and Non-Roadway Projects are discussed separately below.

13.4.1 Roadway Projects

13.4.1.1 Planning

Considerations for stormwater management begin in the planning phase of a roadway project while it is being scoped and the planning document is being completed. Section 2.2 of the PCSP document identifies minimum planning measures to be considered for all projects. During this phase, when alignment alternatives are being discussed and environmental features are being identified for avoidance and mitigation, the design engineer should identify the watershed, any associated regulations along with the water quality classification, and impairment status of any potentially impacted water resources (70, 71). In addition, information about the new BUA to be added should be noted along with type of facility and whether the project typical section is shoulder or curb and gutter. As part of the preliminary hydraulic study, the design engineer should identify any existing stormwater controls from previous NCDOT project permits or those which may be owned by others.

13.4.1.2 Design: Stormwater Management Plan

Stormwater management requirements and the MEP standard may differ depending on the project type. Bridge, safety, widening, or new location projects may have different requirements with respect to the stormwater controls. Minimum measures for the drainage design phase as outlined in Section 2.3 of the PCSP document should be considered for every project. These include adequate ground cover, stabilizing embankments and slopes, providing adequate energy dissipation, utilizing natural features and drainage pathways, maximizing vegetative conveyance, encouraging diffuse flow, and avoiding directly connected impervious areas. These measures should be included in the design regardless of whether a Stormwater Management Plan (SMP) is required. If a SMP is required, the measures employed should be identified in the narrative.

Most projects will require a SMP since new BUA is being added. The SMP is the NPDES compliance document of record for the MEP standard. SMPs must be completed and submitted to the Hydraulics Unit prior to the contract let date.

Once the design engineer receives the Roadway Preliminary Plans and the drainage design is started, stormwater controls should be considered an integral component of the design. As stated above, MEP is context sensitive and varies with project type and location. Decisions on project stormwater controls should be made in cooperation with the resource agencies and Department staff around the 30% design phase or the 4B Concurrence Point if the project is following the Merger Process. If project constraints are limiting BMPs, especially if the project is not following Merger, the design engineer may coordinate with the resource agencies to achieve MEP. All determinations should be recorded in the SMP. While design of vegetative slopes, swales, and other conveyance controls are practical in the majority of conditions along roadway shoulder sections, more structurally based controls may be needed when there is a high concentration of impervious areas, curb and gutter systems are used, or high quality resource waters are present. Stormwater controls should be considered as mitigation measures for outlets that are determined to be critical to downstream receiving areas as discussed in the outlet analysis section in Chapter 10 (Section 10.5.3). Coordination with the Geotechnical Unit, Right-of-Way Unit, and Plans and Standards Management Unit or other units may be needed to complete stormwater control designs without delaying project delivery.

The design of all stormwater controls, identification of adequate ROW requirements for maintenance access and constructability, and any details and associated special provisions needed shall be completed by the design engineer prior to the combined field inspection (CFI) or the final design field inspection (FDFI). Following the CFI or FDFI, the design engineer should begin to develop the SMP for the project. The design engineer should use the latest version of the SMP formatted for Microsoft Excel. The Excel version of the SMP includes guidance on content to include in the plan to ensure consistency across projects. For projects which include one or more structural stormwater BMPs, worksheets (tabs) are provided in the Excel version of the SMP which allow the design engineer to enter the pertinent design information specific to each BMP type. Commonly used structural BMP types are swales, filter strips, level spreaders, preformed scour holes, and detention or retention basins. The BMP worksheets are integrated with the latest version of the BMP Toolbox. If a BMP design deviates from the criteria in the BMP Toolbox, the design engineer should document the justification for the design deviation, such as any project constraints or other considerations.

Completed SMPs shall be submitted via email (NCDOT_Hydraulics_SMP@ncdot.gov) to the Hydraulics Unit for the NPDES compliance report and archiving purposes. This email submittal is separate from the SMP submittal required for stream and wetlands and riparian buffers permit packages. SMPs and their associated revisions are required to be submitted at least three (3) months prior to the contract let date. Additional information on SMPs is available in chapter 4 of the PCSP document.

13.4.1.3 Construction

When a project design requires stormwater controls that include outlet control structures, media filters, wetlands, or other non-routine construction techniques handled by roadway contractors, coordination with the Division Construction Engineer and Resident Engineer is recommended. As stated above, coordination during the CFI or FDFI regarding constructability should be discussed. The design engineer should participate in the pre-construction meeting and be available to offer guidance during construction.

13.4.1.4 Maintenance

Upon completion of a project, the stormwater BMPs are recorded in the Departments Stormwater Control Management System (SCMS). SCMS provides information about the inspection and maintenance of the BMPs.

13.4.2 Non-Roadway Projects

Non-roadway projects can originate from a number of different sources within NCDOT's organization, such as one of the 14 highway Divisions, Facilities Management Division, Rail Division, Ferry Division, or Bicycle and Pedestrian Division. They also may constitute or be part of a scheduled STIP project (e.g., rest area or weigh station). Regardless of the source of the non-roadway project's origination, all design engineers shall follow the same process for compliance with the PCSP.

The PCSP Manual guides the hydraulics engineer through the more prescriptive requirements of non-roadway projects as outlined in Chapter 3 of the PCSP Manual (64). Coordination with the resource agencies similar to that identified for roadway projects is also required for non-roadway projects. Non-roadway projects should be coordinated with the DWR Transportation Permitting Branch.

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14 PERMIT DRAWINGS

14.1 Overview

The drainage study and hydraulic design process includes the development of permit drawings and completion of pertinent application forms for State and Federal environmental permits. These drawings and accompanying information show the anticipated impacts to natural resources associated with the proposed project design.

14.2 General Procedure

The procedure for development of the drawings and application should generally be as follows:

14.2.1 Review of Planning Document and Field Verification of Impacts

Review the planning document and associated Natural Resources Technical Report (NRTR), which lists and identifies wetland areas and jurisdictional streams likely to be impacted by the project and provides preliminary estimates of impact quantities. The planning document includes delineation of wetland area limits and estimated lengths of impacts to jurisdictional streams; however the information presented in the planning document is not sufficiently accurate for the final permit application.

The impacts must be verified and updated during the final hydraulic design stage in accordance with the protocol specified in Appendix P (See Section 14.2.3 below).

14.2.2 Compilation of Environmental Impacts Data

Through the final design phase, environmental data collected from field review and office analysis is to be compiled and organized to be presented in the permit application documentation, including:

- Location, quantity, and classification of wetlands and streams impacted
- Topography and elevation data at impact sites
- Drainage structure and/or channel design data
- Contributing watershed areas
- Flow data (e.g. average, low, bankfull)

14.2.3 Preparation of Permit Drawings

When the permit application is being prepared, considerable time may have elapsed since the time the drainage design and hydraulic recommendations were completed. It is important that the permit drawings be consistent with the project's final roadway plans and drainage design. Appendix P provides specific procedural guidance regarding permit drawing preparation, consistency review, and subsequent electronic delivery protocol for final submittal. NCDOT posts copies of recently issued permits online, and a link to this site is provided on the Hydraulics Unit webpage for reference.

14.2.4 Completion of Forms to Include with Permit Drawing

Documentation associated with each permit application will vary depending on the requirements of the specific project, its location, and the particular natural environmental resources which may be impacted. Therefore, not all of the forms listed below will be required for every project; however, all applicable forms should be fully completed and checked for accuracy and consistency with the associated permit drawings. Permit forms which may be required are listed below, and reference copies are provided in Appendix L.

The needed forms should be downloaded from the Hydraulics Unit website:

- Wetland and Surface Water Impacts Summary
- Riparian Buffer Impacts Summary
- Stormwater Management Plan (SMP)
- CAMA Major Permit Application (multiple forms)

15 FLOODPLAIN MANAGEMENT

15.1 Overview

Any NCDOT road and/or structure that crosses a Federal Emergency Management Agency (FEMA) regulated Special Flood Hazard Area (SFHA), as shown on the effective Flood Insurance Rate Maps (FIRMs) and/or the Flood Risk Information System (FRIS) website (http://rfris.nc.gov/fris/), will require coordination and approval from FEMA, or its designees in North Carolina, which are the North Carolina Division of Emergency Management Floodplain Mapping Program (NCFMP) and Charlotte-Mecklenburg Storm Water Services (CMSWS). NCFMP is authorized to issue the Flood Insurance Rate Maps statewide, except for CMSWS, which issues its own. Furthermore, it should be emphasized that Federal Aid projects are required to be in compliance with FHWA regulations or orders, while being consistent with FEMA requirements (including Executive Orders). FHWA regulation applies to all Federal Aid actions in a base floodplain (not just FEMA-regulated floodplains).

Approximately 85% of the streams across the state are designated as having SFHAs. There are three types of flood studies performed and promulgated in North Carolina: Detailed Study (DS), Redelineated Detailed Study (RDS) and Limited Detailed Study (LDS). It is the policy of NCDOT to abide by federal and state floodplain management regulations and rules. These include:

- FEMA's National Flood Insurance Program (NFIP) (29)
- FHWA's *Federal Aid Policy Guide, Location and Hydraulic Design of Encroachments on Flood Plains* (23 CFR 650 Subpart A) (8)
- Memorandum of Understanding by FHWA and FEMA (June 1982) (30),
- Presidential Executive Order 11988 (32)
- Presidential Executive Order 13690 (73),
- North Carolina Governor's Executive Order 123 (July 1990) (59)

To streamline the coordination with the two FEMA-delegated agencies (NCFMP and CMSWS), NCDOT and NCFMP entered into a Memorandum of Agreement (MOA) in 2008, which was subsequently modified in 2009, 2013, 2015 and 2016 (58).

It is the policy of NCDOT to encourage a broad and unified effort to:

1. Employ a practical and reasonable approach to the design of transportation facilities located within floodplains.
2. Avoid lateral encroachments into floodplains to the extent practicable.
3. Minimize and mitigate unavoidable adverse impacts on adjoining properties in floodplains.

4. Restore and preserve natural floodplain value and function to the extent practicable.
5. Avoid rise in Base Flood Elevation (BFE) greater than one (1) foot in the floodplain of a FEMA regulated stream, unless a variance is granted by the State Hydraulics Engineer to proceed with regulatory agencies' approval for a Conditional Letter of Map Revision (CLOMR).

When a bridge or a culvert crosses a regulated SFHA, the design engineer shall use FEMA's hydrologic data and hydraulic models to assess the impact by the proposed project to the floodplain in accordance with NFIP regulations. The design engineer shall develop optimal roadway encroachment, structure types, and hydraulic openings in a floodplain that are cost effective and least damaging to the human and natural environments.

15.2 Design Data Documentation

To develop the optimal floodplain management, the design engineer shall follow 44 CFR 60.1 through 77.2 (29) of the NFIP, FHWA *Location and Hydraulic Design of Encroachments on Flood Plains 23CFR 650A* (8, 36) and NCDOT's MOA with NCFMP (58). The design engineer should document pertinent floodplain design data in the Bridge Survey and Hydraulic Design Report (BSR) and Culvert Survey and Hydraulic Design Report (CSR) and in the hydraulic modeling narrative included in the submittal package.

These design data include, but are not limited to:

- Geometry, orientation, and hydraulic conveyance of existing and proposed structures
- Profile of the floodplain
- Hydrologic methodology
- Hydraulic model version used
- Corrections made to the effective FEMA models
- Methods used in computing the hydraulic losses through structures
- Roughness coefficients of channel and overbanks
- Limits of the floodway or non-encroachment width
- Location of adversely affected structures and the elevation of the lowest floor (including basement) and lowest adjacent grade to the structure
- Drainage structure's hydraulic performance with respect to any change in the Base Flood Elevation (BFE), which is defined as the elevation of the flood having a one-percent chance of being equaled or exceeded in any given year

15.3 Coordination With Regulatory Agencies

Depending on the nature and the magnitude of the changes in BFE between the proposed and existing structures, the design engineer shall follow the guidance below:

1. <u>FEMA Consultation in Planning Stage</u>: During the project planning stage, the design engineer may consult with FEMA, NCFMP, or CMSWS, as applicable, on NCDOT's planning documents, such as the Draft Environmental Impact Statement (DEIS) or Environmental Assessment (EA). If a determination by FEMA, NCFMP, or CMSWS may affect the selection of the Least Environmentally Damaging Practical Alternative (LEDPA), a written statement regarding such determination should be obtained from them prior to the completion of the final EIS or Finding of No Significant Impact (FONSI). An example of this would be a proposed roadway alignment that would result in a longitudinal encroachment of a FEMA regulated floodway, thus causing potential flood damage to insurable structures. For projects that are processed with a Categorical Exclusion, this coordination may not be warranted, or it may be carried out during the design stage.

2. <u>MOA Types 1, 2a or 2b</u>: If the proposed structure results in either no change or a decrease in BFE, the design engineer shall coordinate with NCFMP in accordance with the MOA. This applies to all the streams that are in a DS, RDS or LDS statewide. The State Hydraulics Engineer approves the MOA Types 1 and 2a projects; the NCFMP approves Type 2b projects.

3. <u>MOA Type 2c</u>: If the input data for the effective FEMA hydraulic models are unavailable, incomplete, illegible, or have erroneous hydrologic and/or topographic data, etc., an approximation of the effective model may be developed. The design engineer shall coordinate with NCFMP in accordance with the MOA. This applies to all streams that are in a DS or RDS statewide, provided the proposed structure does not result in an increase in BFE over the existing conditions. If NCFMP concurs with pursuing as a Type 2c MOA candidate, documentation of this pre-consultation concurrence by NCFMP must be included with the MOA submittal packet.

4. <u>MOA Types 2d or 2e</u>: If the proposed structure is over an LDS stream and results in an increase in BFE, the design engineer shall coordinate with NCFMP in accordance with the MOA. This applies to all the streams that are in an LDS statewide. The State Hydraulics Engineer and NCFMP approve the MOA Type 2d and 2e, respectively.

5. <u>MOA Type 2f</u>: If the proposed structure is over an LDS stream and results in a BFE increase of greater than one foot in the area that is within the Department's rights-of-way, the design engineer may request approval from the State Hydraulics Engineer and NCFMP for the project to be processed as an MOA Type 2f candidate. The design engineer shall assess flood risk impacts to properties and to the traveling public. This application is only limited to projects where no practical alternatives exist to meet backwater limitations as outlined in the NFIP regulations. As an MOA Type 2f candidate, such a project requires special approval from both the State Hydraulics Engineer and the NCFMP Director. This approval needs to be documented in the hydraulic modeling narrative included in the MOA submittal packet.

6. MOA Type 2g: The State Hydraulics Engineer and NCFMP may approve projects that result in a rise in BFE and/or increase and modification to the regulatory floodway caused by a proposed structure over a FEMA regulated stream at or near the bridge deck or culvert face, provided these changes are contained solely within the Department's rights-of-way. The design engineer shall assess flood risk impacts to properties and to the traveling public. This application is only limited to projects where no practical alternatives exist to meet backwater limitations as outlined in the NFIP regulations. As an MOA Type 2g candidate, such a project requires special approval from both the State Hydraulics Engineer and the NCFMP Director. This approval needs to be documented in the hydraulic modeling narrative included in the MOA submittal packet.

7. MOA Types 3a and 3b: For approved CLOMR projects, within six (6) months after project completion, NCDOT shall submit the associated certified As-built plans to NCFMP for inclusion for future DFIRM mapping updates. MOA Type 3a applies to streams for which DFIRM mapping is still current after issuance of the CLOMR approval. MOA Type 3b applies to streams for which the hydrologic and hydraulic models were restudied and DFIRM mapping modified since the issuance of the CLOMR approval.

8. MOA Type 3c: For clarification and guidance on the hydrologic analysis and hydraulic models associated with the effective flood study, the design engineer may request a pre-design consultation with NCFMP in accordance with the MOA. For example, the design engineer may request an approval from NCFMP to use alternative engineering methods or applications that are more appropriate and may result in more scientifically and technically correct estimates of flood elevations of the regulated streams. The design engineer should provide appropriate documentation in the BSR, CSR, or pipe design report, as applicable, and in the hydraulic modeling narrative included with the MOA submittal packet. If NCFMP concurs with pursuing as a Type 3c MOA candidate, documentation of this pre-consultation concurrence by NCFMP must also be included with the MOA submittal packet.

9. As-built Plans Review and Final MOA Submittal: Within the six (6) months of completion of a structure over a FEMA regulated stream, the Hydraulics Unit staff should coordinate with the Division Operations staff in obtaining the sealed As-built plans. An engineering review is required to determine whether the surveyed structure geometry data on its As-built plans match what is specified on the BSR or CSR. Upon certification of the As-built Plans, final submittal is made to NCFMP for all MOA types.

10. MOA Type 4a: If the As-built plans do not match the model, BSR/CSR and MOA packet must be revised accordingly. If the revision results in a BFE change, a flood damage assessment to the adjacent properties is required, and appropriate mitigation measures shall be determined. Submittal of a LOMR may be required. The Hydraulics Unit may

coordinate with NCFMP for consultation and to apply for an MOA Type 4a candidate. This As-built plans submittal requirement applies to all CLOMR and MOA projects that were reviewed and approved by FEMA, CMSWS, NCFMP and the State Hydraulics Engineer, as applicable.

11. CLOMR Submittals: If a proposed structure is over a DS or RDS stream and results in an increase in BFE greater than 0.1 ft., the design engineer shall coordinate through Hydraulics Unit with the respective regulatory agencies and apply for a Conditional Letter of Map Revision (CLOMR) approval. If the structure is located within Mecklenburg County, its CLOMR packet shall be sent to CMSWS. For the other 99 counties of the state, the CLOMR packet will be submitted to NCFMP. CLOMR approval will be issued by FEMA after all review comments are satisfactorily addressed. All projects anticipated to require a CLOMR must be reviewed by the State Hydraulics Engineer before submittal will be allowed to the respective regulatory agencies for approval.

15.4 Avoidance of FEMA Buyout Properties

Any construction or alteration of the transportation facilities (roadway embankment, side walk, stormwater BMPs, roadside ditches, etc.) on the FEMA buyout properties shall be avoided to the extent practicable. A FEMA buyout property is defined as any land that was purchased by FEMA under its Hazard Mitigation Grant Program or Flood Mitigation Assistance Program and title-transferred to the local government for the restoration and preservation of the floodplain (46). If encroachment by the proposed transportation facility cannot be avoided, the design engineer shall coordinate with FEMA, through NCFMP, for consultation, coordination, and approval prior to the project letting. For additional information, see Chapter 2, Section 2.2.5.4.

15.5 Encroachment in Floodplain and Regulatory Floodway or Non-Encroachment Area

No road or structure including its members, is allowed to be constructed within the designated regulatory floodway or non-encroachment area without a regulatory review and approval. A longitudinal encroachment, such as a roadway that is constructed parallel to a stream, encroaching into the stream's floodplain, does not require a regulatory review or approval as long as the encroachment is not within the designated regulated floodway or non-encroachment area. However, the design engineer should consider performing a hydraulic study and flood damage assessment to the adjoining properties that are located in the floodplain to protect the Department from lawsuits or liability claims.

15.6 Temporary Encroachment in Regulatory Floodway

Temporary roads for construction activities and on-site detour traffic that last longer than one year and encroach into the floodway must be reviewed and coordinated with NCFMP and the community's floodplain administrators. The design engineer should perform hydraulic analysis and work with Division Operations staff to include a provision in the project's contract to stipulate the following, as applicable:

1. Boundary of the regulatory floodway
2. Duration of construction within the floodway
3. Installation of on-site stream gages
4. Installation of a flood warning system
5. Designated staging areas for equipment that are at least one (1) foot above the BFE
6. Notification of the affected property owners of the potential risk of flooding from the temporary encroachment
7. Department commitment assuming liability for any flood damages resulting from the temporary encroachment

No CLOMR or LOMR approvals will be required for the temporary encroachment into the FEMA regulated floodway.

15.7 Rest Area Buildings in Floodplain

Rest area buildings and related water and wastewater treatment facilities shall be located outside the base floodplain where practicable. Rest area buildings which are located in the base floodplain shall be floodproofed or constructed two (2) feet above the BFE.

15.8 Replacement of Emergency Flood-Damaged Structures

If the Department's drainage structures are damaged by flooding due to extreme weather events, Department personnel should follow the protocol below:

Emergency Replacement of Drainage Structures:

1. Pipe Replacement:

    - Pipe can either be concrete pipe or metal of any shape (circular, arch, elliptical, etc.)
    - Guiding documents are MOA and NCDOT *Guidelines for Drainage Studies and Hydraulic Design*.
    - The State Hydraulics Engineer approves the design and/or NFIP compliance.

- NCDOT submits design information to FMP for the inclusion of future NFIP flood maps. No hydraulic (HEC-RAS) model or formal MOA submittal is required.

2. Reinforced Concrete Box Culvert or Bridge Replacement:

    - RCBC can be either precast or cast-in-place box culvert.
    - Guiding documents are MOA and NCDOT *Guidelines for Drainage Studies and Hydraulic Design*.
    - The State Hydraulics Engineer approves the design and notifies Division for construction.
    - For structures that are on FEMA regulated streams, the Hydraulics Unit staff follows MOA to submit design reports to FMP for compliance review during or post construction. FMP Director or the State Hydraulics Engineer approves the design reports per MOA.
    - For structures that are not on FEMA regulated streams, the State Hydraulics Engineer or his staff approves the design reports.

15.9 Acceptable Level of Precision for Base Flood Elevations

In the BSR, CSR, and pipe design report, the design engineer should follow the specific rules of rounding guidance below to document the design flood elevations:

1. All flood elevations are to be rounded to the nearest one tenth of a foot (0.1 ft.).
2. If the first digit to be dropped (i.e. in the hundredth decimal place) is less than 5, the last digit retained is not changed. For example, a BFE of 100.14 ft. is rounded to 100.1 ft.
3. If the first digit to be dropped (i.e. in the hundredth decimal place) is greater than or equal to 5, the last digit retained is increased by 1 (or "rounded up"). For example, a BFE of 100.15 ft. is rounded to 100.2 ft.

The rounded flood elevations are then compared to determine the applicability for MOA candidates. If the difference in BFE between the proposed and existing NCDOT structure is 0.1 ft. or less, it is considered as no change, or no rise in BFE. For example, if the HEC-RAS model for a bridge that is over a FEMA regulated stream has a Corrected Effective BFE of 100.25 ft., rounded to 100.3 ft., and has a Revised BFE of 100.44 ft., rounded to 100.4 ft., the difference of these two rounded BFEs is 0.1 ft.; therefore, it qualifies for an MOA Type 1 candidate. This applies to all streams in the state regardless of types of the flood study (DS, RDS or LDS).

All proposed floodway and non-encroachment width dimensions should be rounded to the nearest foot. Likewise, a similar rounding rule applies to the floodway width. Examples: If the proposed floodway width from a HEC-RAS output is 300.49 ft., it is rounded to 300 ft.; if the floodway width is 301.58 ft., it is rounded to 302 ft.

15.10 Documentation for FEMA Submittals

The following information is primarily related to the specific project documentation required for NCDOT projects involving bridges (or culverts) on FEMA-regulated streams:

15.10.1 NCFMP-NCDOT Memorandum of Agreement (MOA) Projects

Most of the bridge replacement projects will require a regulatory approval via the MOA process. The MOA and associated documentation requirements for project submittals to NCFMP are maintained and updated on the Hydraulics Unit website in the FEMA/FMP Coordination section. Also posted on the website is the current checklist of Common MOA HEC-RAS Issues, which should be utilized to facilitate timely MOA project approvals. (58)

15.10.2 FEMA Conditional Letter of Map Revision (CLOMR) Projects

For projects which will result in an increase in the 100-year base flood elevation (BFE), requiring a floodway revision and corresponding approval of a CLOMR, the additional required documentation will include (but is not limited to) the following:

- Completion of the applicable CLOMR application (MT-2) forms (The latest version of these forms are available on the FEMA.gov website).
- Hydraulic analyses (computer models - input and output) which duplicate the hydraulic analyses (Duplicate Effective model) used for the effective Flood Insurance Study (FIS) for the following frequency floods (as applicable): 10-, 50-, 100- and 500-year floods and the 100-year floodway.
- New/revised hydraulic analyses (computer models - input and output) for existing conditions (Corrected Effective model) for the following frequency floods (as applicable): 10-, 50-, 100-, and 500-year floods and floodway. (This involves adding cross sections for the crossing site without the proposed structure and for any changes in the floodplain.)
- New/revised hydraulic analyses (computer models - input and output) for proposed conditions (revised model) for the following frequency floods: 10-, 50-, 100-, and 500-year floods and floodway. (This involves the addition of the crossing features and any proposed floodway changes.)
- Certified topographic work map (sealed by professional engineer) with existing and proposed topography and contours (maximum 5 ft. contour interval), showing revised

existing and/or proposed 100- and 500-year flood boundaries, 100-year floodway, base flood (100-yr) elevations, cross sections, stream alignment, road alignment, etc.

- Annotated Flood Insurance Rate Map (FIRM) showing revised existing and/or proposed 100- and 500-year flood boundaries, 100-year floodway, corporate limits, etc.
- Annotated Flood Insurance Study (FIS) flood profile(s) showing revised existing and/or proposed 10-, 50-, 100-, and 500-year flood profiles (as applicable).
- Annotated FIS Floodway Data Table(s) showing corrected existing and/or proposed floodway data.
- Documentation demonstrating compliance with Sections 9 and 10 of the Endangered Species Act. This documentation needs to be attached to the Riverine Hydrology and Hydraulics Form (MT-2 Form 1) of the CLOMR packet.
- List of the affected property owners (including their mailing addresses and the proposed changes in BFE and floodway widths). The affected property owners will be notified by the community of these changes. If development that has occurred in the existing flood fringe area since the adoption of the community's floodway ordinance will now be located within the revised floodway area, NCDOT will ensure that adversely affected adjacent property owners are compensated for the loss.
- Sample letter of property owner notifications.
- Within six (6) months of completion of construction of a drainage structure for which a CLOMR was approved, the above documentation must be updated, as applicable, and submitted along with As-built plans and the corresponding hydraulic model for approval of the final Letter of Map Revision (LOMR) by FEMA.

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17 APPENDICES

- A – Hydraulic Design Documentation Summary
- B – Checklist for Drainage Study and Hydraulic Design
- C – NCDOT Hydrologic Charts
- D – Preliminary Design Forms
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- E – Major Hydraulic Structures Forms and Information
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    - Item 5 – HEC-RAS Bridge Opening Guide
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- F – Supplemental Culvert Design Guidance
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- G – Pipe Data Sheet
- H – Supplemental Pipe Information
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- L – Permit Forms
    - Item 1 – Wetland Impacts Summary
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    - Item 3 – Stormwater Management Plan (SMP)
    - Item 4 – CAMA Permit Application (multiple forms)
- M – NCWRC Stream Relocation Guidelines
- N – Stream Crossing Guidelines for Anadromous Fish Passage
    - Reference Guide to Distribution of Anadromous Fishes in NC Rivers
- O – Guidelines for the Location and Design of Hazardous Spill Basins
- P – Permit Drawings Guidelines
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- Q – Using NOAA Atlas 14 Website to Find Rainfall Intensity Values
- R – Diagram of Bridge Scour Depth Relative to Projected Natural Stream Bed

HYDRAULIC DESIGN DOCUMENTATION SUMMARY

I.D. NO. _______________ COUNTY: __________________ PROJECT NO: _________________

DESCRIPTION:

PROJECT ENGINEER:__________________ DESIGN ENGINEER:________________ DATE:___________

THE FOLLOWING CHECKED DESIGN ITEMS HAVE BEEN DEVELOPED IN ACCORDANCE WITH THE CURRENT NCDOT *GUIDELINES FOR DRAINAGE STUDIES AND HYDRAULIC DESIGN* AND ARE INCLUDED IN THE PROJECT DOCUMENTATION FILES:

1. _______ PRELIMINARY DESIGN REPORT(S) (APPENDIX D)
2. _______ CHECKLIST FOR DRAINAGE STUDY AND HYDRAULIC DESIGN (APPENDIX B)
3. _______ STRUCTURE SURVEY RECOMMENDATIONS (APPENDIX E)
4. _______ PIPE DATA SHEETS (NUMBER _______) (APPENDIX G)
5. _______ STORM DRAINAGE COMPUTATION SHEETS (NUMBER _______) (APPENDIX I)
6. _______ OUTFALL ANALYSIS
7. _______ CULVERT SURVEY REPORT(S) (NUMBER _______) (APPENDIX E)
8. _______ CONSTRUCTION SEQUENCE FOR BOX CULVERTS
9. _______ BRIDGE SURVEY REPORT(S) (NUMBER _______) (APPENDIX E)
10. _______ DETOUR STRUCTURE SURVEY REPORT(S) (NUMBER _______) (APPENDIX E)
11. _______ CULVERT / BRIDGE SURVEY FIELD NOTES
12. _______ STORMWATER MANAGEMENT PLAN (APPENDICES L, P)
13. _______ MOA / CLOMR PACKAGE REQUIRED
14. _______ OTHER:____

NORTH CAROLINA PE SEAL:

NORTH CAROLINA PE CERTIFICATION:

____

SIGNTURE DATE

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CHECKLIST FOR DRAINAGE STUDY AND HYDRAULIC DESIGN

THIS PAGE SHOULD BE COMPLETED AND APPROVED PRIOR TO FIELD RECONNAISSANCE VISIT

APPROVED BY: ______________________________ **DATE :** ________

I.D.: ________ **COUNTY:** ________________ **PROJECT ENGINEER:** __________ **DATE:** __________

1. REVIEW PLANNING REPORT AND NATURAL RESOURCES TECHNICAL REPORT (NRTR). IDENTIFY COMMITMENTS OR REQUIREMENTS WHICH WOULD AFFECT THE DESIGN.

2. IDENTIFY PRIOR SURVEYS AT STREAM CROSSINGS, INCLUDING UPSTREAM AND DOWNSTREAM STRUCTURES. INCLUDE STRUCTURE NUMBER, SIZE, AND LOCATION.

3. IDENTIFY FLOOD ZONE STATUS.

4. IDENTIFY STREAM GAGES IN AREA. (DATES AND FREQUENCIES OF MAJOR FLOODS)

5. LIST DRAINAGE AREA(S) AND SOURCE(S).

6. PROVIDE DESCRIPTION OF EXISTING STRUCTURES.

7. DEVELOP PRELIMINARY DESIGN DISCHARGES.

8. ESTIMATE PROPOSED STRUCTURE TYPE(S) AND SIZE(S).

9. DETERMINE POSSIBLE PERMIT REQUIREMENTS.

10. REVIEW AVAILABLE SURVEY DATA.

11. IDENTIFY ANY HYDROLOGIC / HYDRAULIC STUDIES WITHIN THE PROJECT AREA BY AGENCIES SUCH AS: THE CORPS OF ENGINEERS, TVA, NRCS, CITIES OR COUNTIES.

FIELD INVESTIGATIONS

THE FOLLOWING INFORMATION IS TO BE INCLUDED IN THE FIELD SURVEY NOTES: (CHECK LOCATION AND SURVEY NOTES AND SUPPLEMENT WITH ANY ADDITIONAL INFORMATION THAT MAY BE REQUIRED) ANSWER YES, NO, N/A, OR COMMENT AS APPLICABLE

1. TOPO IS TO INCLUDE BUT NOT LIMITED TO:

a. _________ CHANNEL BANKS AND WATERS EDGES

b. _________ EXISTING STRUCTURES (BRIDGES, CULVERTS, AND STORM DRAINAGE SYSTEMS)

c. _________ UTILITIES (POWER, WATER, GAS, TELEPHONE, SANITARY SEWER, ETC.)

d. _________ ROADWAY PAVEMENT, SHOULDERS AND TOE OF FILL

e. _________ ANY DEVELOPMENT ADJACENT TO SITE, UPSTREAM AND DOWNSTREAM

f. _________ LIMITS OF FLOODPLAIN

g. _________ DRAINAGE COURSES AND DRAINAGE DITCHES

2. LEVELS

a. _________ CENTERLINE PROFILES OF NATURAL GROUND AND EXISTING HIGHWAY (WHERE APPLICABLE) ACROSS FLOODPLAIN

b. _________ SECTION UNDER BRIDGE

c. _________ SIZE, DEPTHS, AND INVERTS OF ALL CULVERTS AND STORM DRAINAGE SYSTEMS

d. _________ STREAM BED, NATURAL GROUND, AND WATER SURFACE PROFILE ELEVATIONS (NORMAL, AT DATE OF SURVEY, AND ORIDINARY HIGH WATER) UPSTREAM AND DOWNSTREAM FOR A SUFFICIENT DISTANCE BEYOND LIMITS OF CONSTRUCTION. (EXTEND OUTLET DITCH PROFILES AS FAR AS NECESSARY TO REACH ADEQUATE CAPACITY).

e. _________ FLOODPLAIN CROSS-SECTIONS AS DEEMED NECESSARY FOR PERFORMING BACKWATER ANALYSIS

f. _________ ELEVATION OF ANY UPSTREAM OR DOWNSTREAM DEVELOPMENT THAT WOULD BE CONSIDERED IN DESIGN (EXAMPLE: FINISHED FLOOR ELEVATION AND LOWEST ADJACENT GRADE OF HOUSES, BASEMENTS, YARDS, GARDENS, BARNS, AND PONDS)

g. _________ ELEVATION OF ANY DEBRIS OR OTHER HIGH WATER MARKS

3. SCOUR POTENTIAL: OBTAIN THE FOLLOWING FIELD INFORMATION IN ADDITION TO THE NORMAL BRIDGE CROSSING DATA

a. _________ WHAT IS THE STREAM BED AND FLOODPLAIN MATERIAL? IF SAND, IS IT FINE ,MEDIUM, OR COARSE?

b. _________ ARE THE STREAM BANKS STABLE? ARE THERE VISIBLE SLUMPS, VERTICAL BANKS, LEANING TREES, OR UNDERCUT BANKS?

AT EXISTING CROSSING SITES:

c. _________ OBTAIN A TYPICAL CHANNEL SECTION AT SUFFICIENT DISTANCE UP OR DOWNSTREAM BEYOND CROSSING EFFECTS

d. _________ OBTAIN BED PROFILE EXTENDING WELL BEYOND SCOUR AREA

e. _________ IDENTIFY THE TYPE FOUNDATION OF THE EXISTING STRUCTURE

IF FOOTING IS VISIBLE, NOTE CONDITION

f. _________ OBSERVE GROUND CONDITIONS AROUND EXISTING PIERS AND ABUTMENTS IS THERE INDICATION OF PREVIOUS SCOUR? IF SO, NOTE APPROXIMATE DEPTH.

4. RECONNAISSANCE

a. _________ DRIFT POTENTIAL, SIZE, AND QUANTITY. (QUESTION SOURCES WHEN HIGH-WATER INFORMATION IS OBTAINED).

b. _________ IDENTIFY CULTURE IN FLOODPLAIN FOR DETERMINATION OF FLOW RESISTANCE AND DISTRIBUTION (ESTIMATE "N" VALUES)

c. _________ IDENTIFY DEVELOPMENT IN FLOODPLAIN THAT COULD BE AFFECTED BY BACKWATER, DOWNSTREAM EROSION OR REDUCTION OF FLOW

d. _________ IDENTIFY STORAGE AREAS SUCH AS PONDS, LAKES, ETC., FOR POSSIBLE ADJUSTMENT OF DISCHARGE RATES WHERE APPLICABLE

e. _________ REVIEW ADEQUACY OF DOWNSTREAM CHANNELS FOR CONVEYANCE OF INCREASED DISCHARGE RATES

f. _________ PHOTOGRAPHS OF SITE(S)

g. _________ IDENTIFY POTENTIAL WETLAND / JURISDICTIONAL STREAMS

5. OBTAIN HISTORICAL H.W. INFORMATION SOURCES: (NAMES, ADDRESSES, AND PERIOD OF KNOWLEDGE OF PROVIDER).

   a. _________ LOCAL RESIDENTS

   b. _________ BRIDGE MAINTENANCE PERSONNEL

   c. _________ ROADWAY MAINTENANCE PERSONNEL

   d. _________ FREQUENT ROAD USERS (EX. MAILMAN, DELIVERY PEOPLE)

   QUESTIONS:

   a. _________ MAXIMUM H.W. WHEN IT OCCURRED?, WHAT DAMAGE OCCURRED?,

   b. _________ OTHER LESSER FLOOD LEVELS, HOW OFTEN?

   c. _________ YEARLY OCCURRENCE

6. DATA ON UPSTREAM AND DOWNSTREAM CROSSINGS

   a. _________ SIZE

   b. _________ RELATIVE LEVELS OF STRUCTURE AND ROADWAY

   c. _________ EXISTING ISSUES (DEBRIS, SCOUR, ETC.)

HYDRAULIC STUDY

THE FOLLOWING INFORMATION IS TO BE COMPLETED BY THE DESIGN ENGINEER AT THE COMPLETION OF THE PROJECT DESIGN.

1. WHAT DESIGN FREQUENCIES WERE USED FOR DRAINAGE STRUCTURES? WHY?

2. WHAT ALTERNATES HAVE BEEN CONSIDERED FOR THE MAJOR DRAINAGE STRUCTURES?

3. HAS AN ECONOMIC ANALYSIS BEEN MADE FOR ANY CROSSING DESIGN?
   HAS A LESSER DESIGN STANDARD BEEN CONSIDERED?

4. HAS PROPOSED STRUCTURE OR DESIGN BEEN CHANGED FROM WHAT WAS RECOMMENDED IN PLANNING DOCUMENT? IF SO, HAS PDEA BEEN NOTIFIED OF CHANGES?

5. HAVE PROVISIONS BEEN MADE FOR UTILITY CONFLICTS?

6. HAVE EVALUATIONS BEEN MADE OF OUTLET CHANNELS FOR POTENTIAL EFFECT OF PROJECT DEVELOPMENT?

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NCDOT Hydrologic Charts

(Revised and digitally reproduced from 1973 State Highway Commission charts)

List of Charts:

Chart number	Description
C200.1	Hydrologic Contour (HC) Map
C200.2	Rural Runoff
C200.3	Urban Runoff
C200.4	Rural Drainage Area (DA) Shape Correction
C200.5	Rural Drainage Area (DA) Land Cover Correction

Procedure for rural watersheds:

1. Verify DA < 1 sq. mi.; otherwise, SHC charts not applicable.
2. Determine HC from C200.1 to nearest 0.5 interval. In highly channelized areas, particularly in coastal areas, a value of 1.0 above that shown in C200.1 should be used. Thus, it is unlikely that a value less than 4.0 would ever be used.
3. In C200.2, determine 50-yr discharge (Q_{50}) for the given HC and DA values. For other frequencies, apply the appropriate frequency factor listed. These values may need to be adjusted further for DA shape and land cover, as outlined in following steps 4 and 5.
4. Determine shape parameter W/L. From this and the DA, the shape correction factor can be determined in C200.4.
5. With the DA and percentage forest cover, use C200.5 to determine the land cover correction factor. Do not use this factor to reduce discharge unless future development in the watershed is not anticipated, such as in certain mountainous, wetland, or designated preservation areas.
6. Acceptable values for the multiple of shape and land cover correction factors are limited to the range of 0.7 to 1.5. Apply the adjustment factors to the discharge values determined from step 3.

Procedure for urban watersheds:

1. If DA < 20 acres, verify whether Rational Method would be more appropriate to use instead of the SHC charts. Also, if DA > 1000 acres, C200.3 is not applicable. If uncertain whether watershed is urban, calculate discharges for both urban and rural conditions, then apply appropriate engineering judgment and document which results are deemed appropriate for study site.
2. If the watershed is has more than 50% impervious land cover, SHC chart is not applicable, and other hydrologic methods, such as storage routing (e.g. NRCS TR-20), should be considered.
3. Determine HC from C200.1.
4. Determine type and relative density of development to determine the appropriate development density adjustment factor.
    a. Residential – high type: lot sizes > 0.5 acres
    b. Average Development: small lots < 0.5 acres, or mixed residential / small business
    c. Large area – full business: DA >75 acres (up to 50% impervious)
    d. Small area – full business: DA < 75 acres (up to 50% impervious)
5. In C200.3, use HC and DA to obtain 10 yr. discharge (Q_{10}). Apply appropriate adjustment factor for other frequency events and development density adjustment from step 4

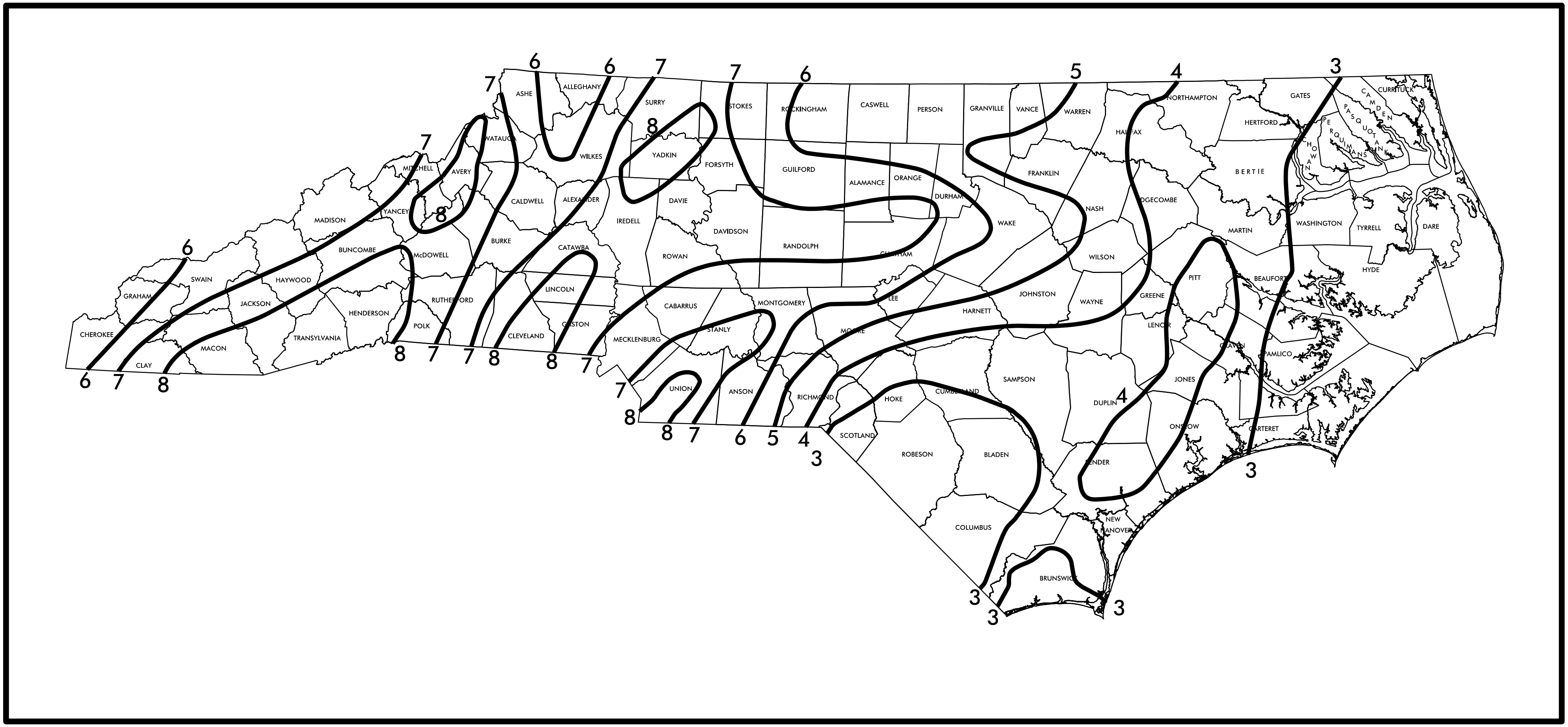
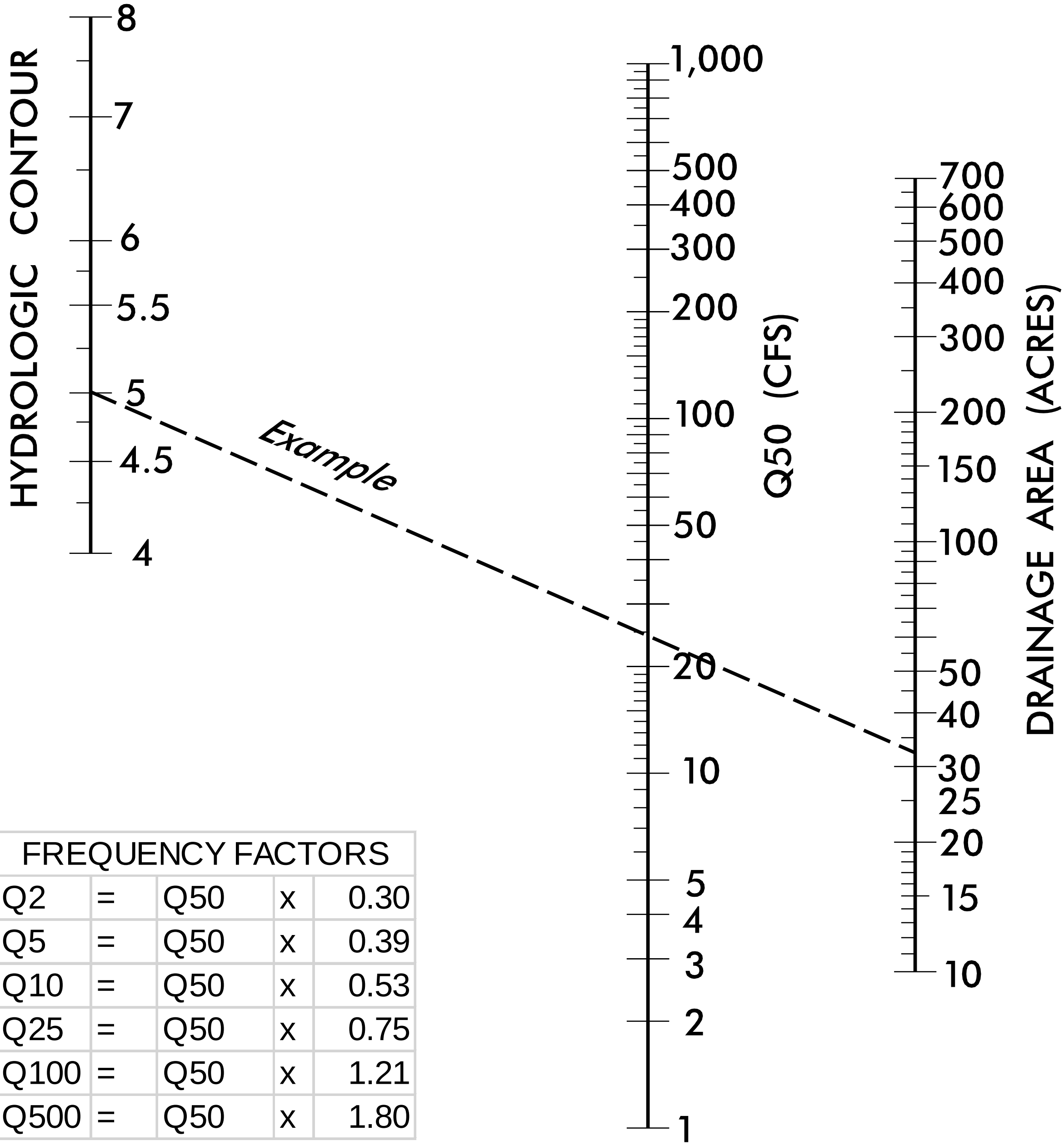


Chart C200.1 NC Hydrologic Contours

APPENDIX C

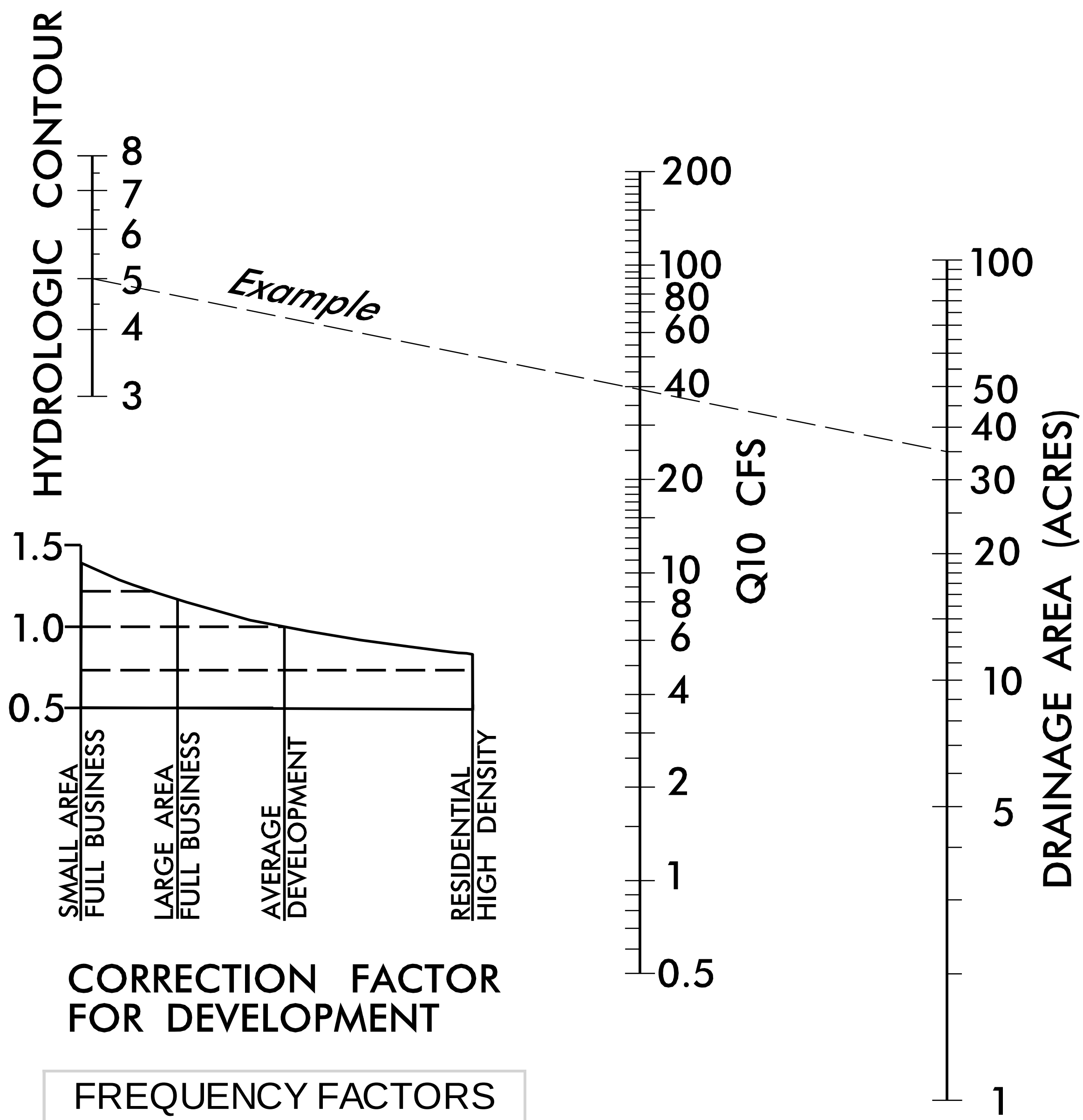
Example:
Hydrologic Contour = 5.0
Drainage Area = 32 acres
Read Q50 = 24 cfs



FREQUENCY FACTORS				
Q2	=	Q50	x	0.30
Q5	=	Q50	x	0.39
Q10	=	Q50	x	0.53
Q25	=	Q50	x	0.75
Q100	=	Q50	x	1.21
Q500	=	Q50	x	1.80

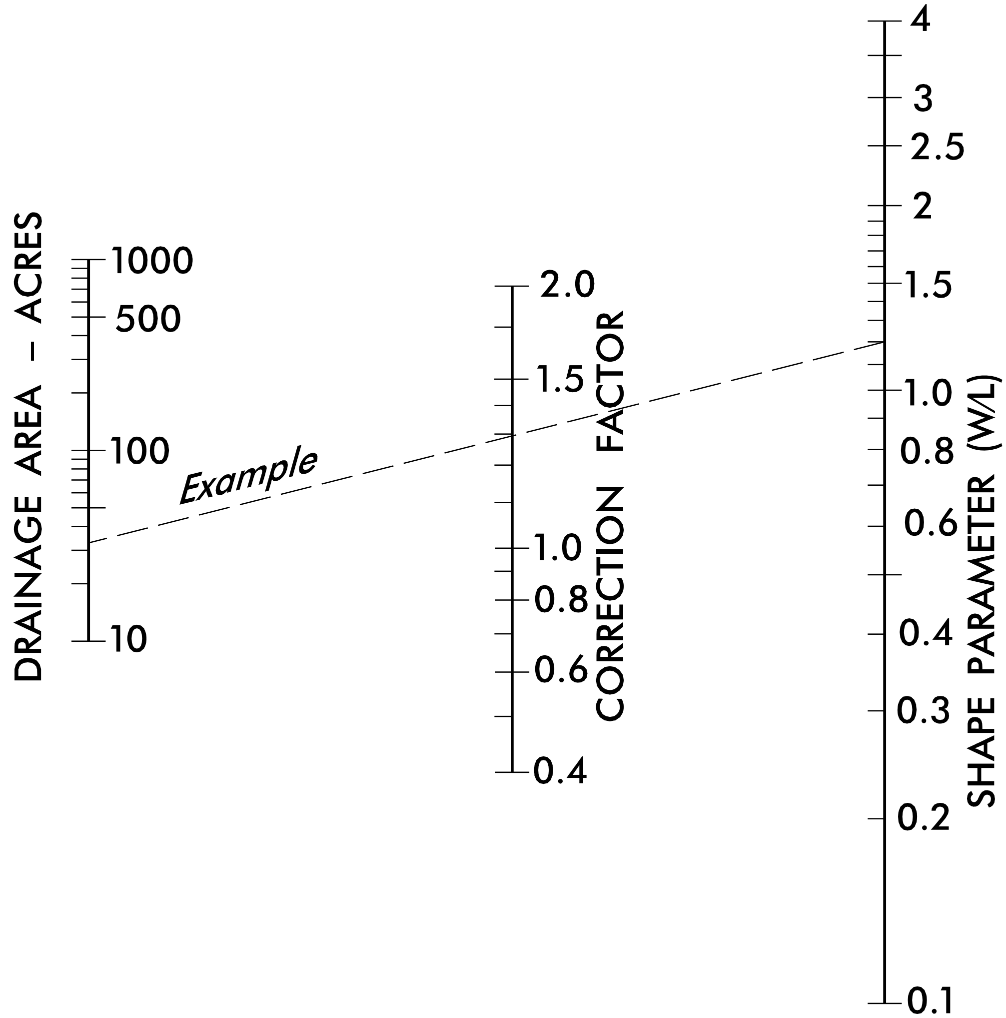
C200.2 RURAL RUNOFF CHART (REVISED)

Example:
Hydrologic Contour 5.0
Drainage Area 35 ac
Small Area – Full Business
Q10 = 39x1.4 = 55 cfs



FREQUENCY FACTORS				
Q2	=	Q10	x	0.50
Q5	=	Q10	x	0.75
Q25	=	Q10	x	1.35
Q50	=	Q10	x	1.85
Q100	=	Q10	x	2.15
Q500	=	Q10	x	3.10

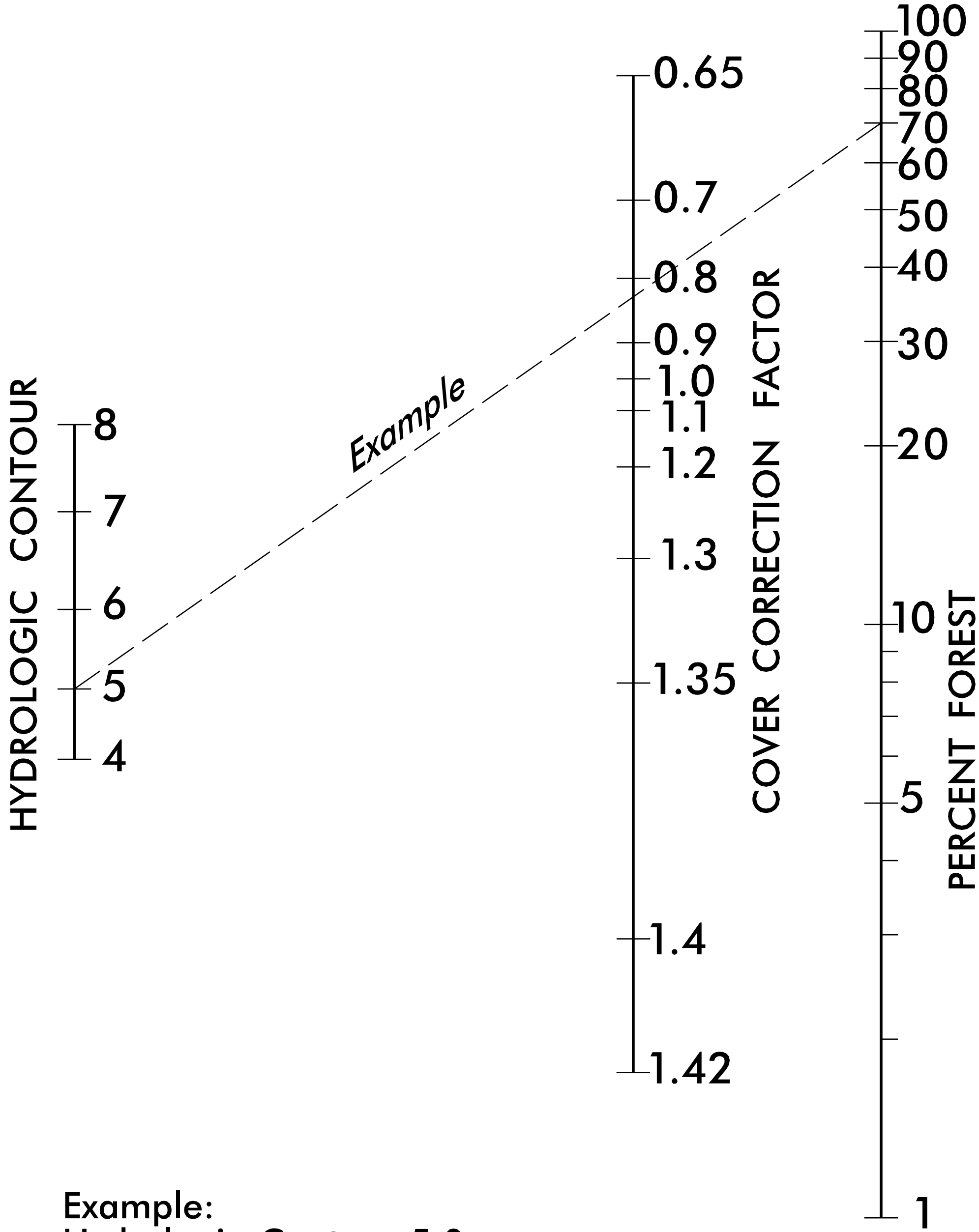
C200.3 URBAN RUNOFF CHART (REVISED)



Example:
Drainage Area 32 ac
W/L = 1.2
Q50 = 25 cfs (from Chart C200.2)
Corrected Q50 = 25x1.3 = 33 cfs

DRAINAGE AREA SHAPE PARAMETER
CORRECTION FACTORS

C200.4



Example:
Hydrologic Contour 5.0
Drainage Area 35 ac
70% forest cover
Q50 = 25 cfs (from C200.2)
Corrected Q50 = 25x0.84 = 21 cfs

DRAINAGE AREA COVER PARAMETER
CORRECTION FACTORS

C200.5

Pre-Design Report (PDR) Instructions

The **Pre-Design Report (PDR)** package typically may include, but is not limited to:

- Cover Sheet (Item 1) – form filled in with all relevant data
- Location map (typically from NCDOT county/bridge map)
- Map of watershed (drainage area) on USGS quad topo map or from USGS StreamStats website
- USGS StreamStats Basin Characteristics table
- Excerpts from NCDOT Structure Inspection Report
- FEMA DFIRM panel with structure site location noted

An example Cover Sheet (Item 1) is provided with sample data. The PDF fill-in form for the PDR Cover Sheet must be downloaded from the Hydraulics Unit Website. An example of a full PDR package is also available from the Hydraulics Unit website.

Cover Page

Hydraulics Unit Pre-Design Report (Pre-Scoping) for Structure #: ________ Date:

County: | **Stream:** | Assigned to:
Road #: | **Road Name:** | Prepared By
Division: | **Location:** | Hydro Mgr: | Hydro Reviewer:
Latitude: | **Longitude:** | Decimal degrees, a min of 5 decimal points | Project Type:

Existing Structure

Structure Type | Yr Built:
Span Arrangement: | OAL (ft): | Skew: | Abutment Type:
Number of Barrels: | @ Span (ft): | x Rise (ft):
Bed to Crown (ft): | Clear Roadway (ft): | Water Depth (ft) | Superstructure Depth:
ADT: | Year ADT: | Scour Code (item113): | Prior Survey Completed: ☐ | Survey Date:
Drainage Area: | Drainage Area Source: | Roadway Overtops at Q100: ☐
Discharge Method: | USGS Region: | Stream Gage Number(if applicable):
Q10 (cfs): | Q25 (cfs): | Q50 (cfs): | Q100 (cfs): | QBFE (cfs):
☐ Structure in Flood Hazard Zone | Panel #: | Panel Date: | Type of FIS: | Date of FIS:

Enviromental

Quad Map: | River Basin: | Buffer Rule:

Primary Stream Classification

☐ Class B ☐ Class C ☐ SA ☐ SB
☐ SC ☐ SWL ☐ WL ☐ WS I
☐ WS II ☐ WS III ☐ WS IV ☐ WS V

Supplemental Stream Classification

☐ FWS ☐ HQW ☐ NSW ☐ ORW
☐ Sw ☐ Tr ☐ UWL ☐ w/in 0.5mi. of CA

Other Stream Classification

☐ Anadromous Fish ☐ Area of Envronmental Concern
☐ CAMA County ☐ Federal Wild & Scenic Rivers
☐ HSB Requried ☐ NC Natural & Scenic Rivers
☐ Impaired [303d] ☐ Primary Nursery Area
☐ TVA ☐ Designated Shellfish Harvesting Area
☐ Designated Public Mountain Trout Waters

Up/Down Stream Features

Upstream Feature: | Structure Type:
Location: | Span Arrangement: | OAL (ft):
Structure #: | Route: | Number of Barrels: | @ Span (ft): | x Rise (ft):
Latitude: | Longitude: | Decimal degrees, a min of 5 decimal points
Prior Survey Completed: ☐ | Survey Date: | Bed to Crown (ft): | Year Built: (yyyy)

Downstream Feature: | Structure Type:
Location: | Span Arrangement: | OAL (ft):
Structure #: | Route: | Number of Barrels: | @ Span (ft): | x Rise (ft):
Latitude: | Longitude: | Decimal degrees, a min of 5 decimal points
Prior Survey Completed: ☐ | Survey Date: | Bed to Crown (ft) | Year Built: (yyyy)

Preliminary Structure Estimate [Office Estimate]

Structure Type: | Skew:
Dimensions/Spans:

Notes

This form can be downloaded from the Hydraulics Unit website.

Cover Page

Responses for outlined fields are available from dropdown menus

APPENDIX D - ITEM 1 PDR

Hydraulics Unit Pre-Design Report (Pre-Scoping)for Structure #: 220229

Date: 1/6/2016

County: Cleveland | Stream: GRASSY BRANCH
Road #: SR 1504 | Road Name: SHOFFORD LAKE RD
Division: 12 | Location: .04 MI S OF SR 1509
Latitude: | Longitude: Decimal degrees, a min of 5 decimal points

Assigned to: Firm Name or In-House
Prepared By WHS
Hydro Mgr: PFF | Hydro Reviewer: MTS
Project Type: B-5861

Existing Structure

Structure Type: Timber Deck/ I Beams | Yr Built: 1955
Span Arrangement: 2 @ 30' | OAL (ft): 60 | Skew: 90 | Abutment Type: Sloped-2:1
Number of Barrels: | @ Span (ft): | x Rise (ft):
Bed to Crown (ft): 13 | Clear Roadway (ft): | Water Depth (ft): 1 | Superstructure Depth: 2
ADT: 300 | Year ADT: 2013 | Scour Code (item113): 8 | Prior Survey Completed: ☑ | Survey Date: 9/5/2002
Drainage Area: 3.1 Sq. Mi. | Drainage Area Source: USGS Stream Stats | Roadway Overtops at Q100: ☐
Discharge Method: USGS Regression Equations | USGS Region: 1 | Stream Gage Number(if applicable): 456954
Q10 (cfs): 400 | Q25 (cfs): 1050 | Q50 (cfs): 1300 | Q100 (cfs): 1500 | QBFE (cfs): 1457
☐ Structure in Flood Hazard Zone | Panel #: 2622 | Panel Date: 2/20/2008 | Type of FIS: LIMITED | Date of FIS: 2/20/2008

EXAMPLE Only (data not accurate)

Enviromental

Quad Map: ALARKA, NC | River Basin: Broad | Buffer Rule: NA

Primary Stream Classification

☑ Class B ☐ Class C ☐ SA ☐ SB
☐ SC ☐ SWL ☐ WL ☐ WS I
☐ WS II ☐ WS III ☑ WS IV ☐ WS V

Supplemental Stream Classification

☐ FWS ☐ HQW ☐ NSW ☐ ORW
☐ Sw ☐ Tr ☐ UWL ☐ w/in 0.5mi. of CA

Other Stream Classification

☑ Anadromous Fish ☐ Area of Envronmental Concern
☐ CAMA County ☐ Federal Wild & Scenic Rivers
☐ HSB Requried ☐ NC Natural & Scenic Rivers
☐ Impaired [303d] ☑ Primary Nursery Area
☐ TVA ☐ Designated Shellfish Harvesting Area
☐ Designated Public Mountain Trout Waters

Up/Down Stream Features

Upstream Feature: Culvert
Location: 0.3 MI S OF SR 1509
Structure #: 220221 | Route: SR 1505
Latitude: 35.40235 | Longitude: -81.65787
Prior Survey Completed: ☐ | Survey Date: | Bed to Crown (ft): 7 | Year Built: 1955
Structure Type: CMP
Span Arrangement: 2 LINES 0F 96" | OAL (ft):
Number of Barrels: | @ Span (ft): | x Rise (ft):

Downstream Feature: Confluence w/ Stream(s)
Location:
Structure #: | Route:
Latitude: | Longitude:
Prior Survey Completed: ☐ | Survey Date: | Bed to Crown (ft): | Year Built:
Structure Type:
Span Arrangement: | OAL (ft):
Number of Barrels: | @ Span (ft): | x Rise (ft):

Preliminary Structure Estimate [Office Estimate]

Structure Type: Cored Slab | Skew: 90
Dimensions/Spans: 2@35

Notes

Stream gage 5ft downstram

This form can be downloaded from the Hydraulics Unit website.

<u>Items to consider discussing at bridge replacement field scoping meeting</u>:

STRUCTURE

- Bridge replacement with culvert (or vice versa)
- Culvert sills, baffles, bottomless (3-sided) structure, native bed material
- Precast or cast-in-place
- Recommended structure, possible span arrangement
- Existing bents, abutments – offsets for new bent locations, removal or not?
- Vertical abutments proposed?
- Alternate structure recommendation
- Box beam, cored slab, concrete girder, steel girder, etc.
- Fill height
- Bridge rail height and type
- 10 ft. offset – provided or waived?
- Drilled shafts or piles
- Is Geotechnical information available? Does it affect design?
- Bed to crown height
- Superstructure depth
- Step-caps vs. consistent depth superstructure spans
- Low chord adjustment vs. raising grade
- Freeboard considerations
- Vertical clearance needed under bridge for maintenance/inspection access
- End bent caps depth – 4 ft. or 2 ft.-6 in.?
- Skew considerations, flow direction, bent alignment and location (in water?)

FEMA

- FEMA permit required?
- Will MOA apply? (CLOMR anticipated?)
- Status of effective hydraulic model (Redelineated study?)
- In FEMA Special Flood Hazard Area (SFHA), does 100-yr overtop road?
- Lowest adjacent grade on potentially affected properties

SCOUR

- Unusual scour potential? Protection needed?
- Are banks stable? Protection needed?
- Debris potential
- Riprap on excavated bench and/or stream banks

STREAM

- Design event (frequency), level of service, (low-water bridge?)
- Normal water surface depth
- High water information (if available)
- Stream channel width, banks, slope, flow velocity, etc.
- Jurisdictional environmental features (wetlands, tributaries, etc.)

OTHER

- Sidewalk, bike lanes, raised median
- Deck drains, 2GI or concrete flume, limits of shoulder berm gutter, guardrail
- Potential driveway relocations
- Allowable spread
- Temporary causeway needed? Related issues
- Construction staging issues
- Temporary onsite detour needed? If so, what alignment and elevation?
- Greenway, pedestrian, bike, farming access accommodation

PRELIMINARY HYDRAULIC FIELD VISIT CHECKLIST

1. MEASUREMENTS OF BRIDGE/CULVERT, WATERWAY, APPROACHES
    - Soundings for bridge opening, incl. bridge seats, low chord, toe of abutment, natural ground, tops of banks, water's edge, water surface elevation
    - Measure/locate each span
    - Measure size of culvert opening(s) (width x height)
    - Measure cover over pipe/culvert
    - Measure skew of structure
    - Plot location of channel and tops of banks relative to structure
    - Note abutment type and condition
    - Note any evidence of scour/erosion/bank instability; for culverts, also note the following:
        - Scour hole at outlet (depth, length, width)
        - Is invert perched? If so, measure how much
    - Note bed material and condition
    - Review existing land use for determination of Manning roughness coefficient values
    - Determine approximate location/elevation for roadway overtopping
    - Note any identifiable migration of stream
    - Identify and sketch potential stream relocations
    - Note condition of existing bridge/box culvert (cracks, spalling, etc)
    - Measure normal depth of water (beyond influence of existing structure), recent high water, Ordinary High Water (OHW – mud or vegetation line)
    - Note signs of high water and elevation
    - Note if flow is confined to a single barrel (if culvert is multi-barrel)
    - Measure width of channel (base, water's edge to water's edge, top of bank to top of bank) and plot channel alignment/skew relative to structure (at approximate crossing location if new location)
    - Note debris potential
    - Note and locate as appropriate anything that may affect proposed structure (remnant piers, etc.)
    - Note whether USGS stream gage is attached to or near bridge
    - Note utilities concerns (overhead, attached to structure, adjacent to roadway, etc.)

2. NEARBY PROPERTY, STRUCTURES, ETC. AFFECTED
    - Note any structures upstream that may be in the floodplain
    - Note nearby utilities
    - Note potential environmentally sensitive areas (including wetlands, parks, ponds, lakes, reservoirs)
    - Note Right-of-Way acquisition concerns (especially for recommended alignment)
    - Measurements of building offsets, driveway location, etc. if directly adjacent to bridge/culvert
    - Describe floodplain characteristics upstream and downstream

3. PHOTOGRAPHICAL INFORMATION
    - Upstream channel and banks
    - Downstream channel and banks
    - Bridge face showing approaches
    - Left and right approach alignments
    - Abutments and typical interior bent
    - Any special conditions that warrant a photograph
    - Document/label photos taken in field notes for identification purposes

4. FIELD NOTES/DELIVERABLES

- Date and note personnel on field notes
- Plan view sketch at 1"=50' scale (or other convenient scale)
  Plan view sketch should include ex. structure/bents (incl. remnant piles, if applicable), channel alignment with water's edge and tops of banks, and include road, and any pertinent adjacent features (building, drive, woods line, utilities, ditch, pipe etc.), North arrow and flow direction. After field visit, proposed structure should be added at appropriate skew and include preliminary span arrangement.
- Profile view at 1"=10' scale (or other convenient scale).
  Profile view should include ex. structure/bents, WE & TB, etc. After the field visit, prop. structure should be added and include preliminary superstructure and span arrangement.
- Record of historical flooding information from locals (w/name, address, phone no., years in residence): ever overtopped, highest level reached, flooding frequency etc.
- Show recommendation for replacement or for new structure
- Note any advantages or disadvantages with respect to various alternatives
- Note recommendation for proposed structure/road alignment, and temp. on-site detour
- Record of photographical information

Obtained from Routine Inspection Report:

- Superstructure type and depth (top of deck to low chord)
- Substructure type
- Year built
- Clear roadway width
- Overall (out to out) bridge deck width
- Note bridge sounding data for historical migration of streambed or developing scour
- Review photos and notes about debris
- Note any maintenance performed due to scour

PRELIMINARY HYDRAULIC RECOMMENDATIONS FOR MAJOR(1) CROSSINGS

DATE:
PROJECT NUMBER:
WBS ELEMENT #:
PROJECT DESCRIPTION:
NAME:

SITE NUMBER	ALT ID (2)	ROUTE	STATION	LAT	LONG	STREAM/ WETLAND ID	STREAM NAME	FEMA STUDY TYPE	DRAINAGE AREA (Mi^2)	EXISTING STRUCTURE	MINIMUM RECOMMENDED STRUCTURE	Notes
										Number, Size, Structure Type	Number, Size, Structure Type	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

NOTES:
(1) Major Crossings - conveyance greater than 72" pipe (This table should be used for Merger CP2A concurrence.)
(2) Provided in planning document

THE EXCEL SPREADSHEET FOR THIS FORM SHOULD BE DOWNLOADED FROM THE HYDRAULICS UNIT WEBSITE.

https://connect.ncdot.gov/resources/hydro/pages/default.aspx

APPENDIX D
ITEM 4

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Bridge Survey & Hydraulic Design Report Key

1. **I.D. No. -** Specify ID No. Example: B-4494 (for TIP projects) BD-5112K (For Low Impact bridge project), SF-890095 (State funded bridge projects), FA-770077(Division Force Account projects).

2. **Project No.** - Specify Project Number.

3. **Proj. Station -** Specify centerline bridge station to the nearest foot along survey line (typically –L- or -Y- line).

4. **County -** Specify County Name

5. **Bridge Over -** Specify name of stream or body of water

6. **Bridge Inv. No.** - Specify four digit bridge number, e.g., 0078.

7. **On Highway** - Specify Route number bridge is located on and for SR routes specify road name if there is one. (e.g., NC 211, SR 1742 (N. McMullen Rd)).

8. **Between________ and _______ -** Specify Route bridge is located between. For SR routes specify road name if there is one. (e.g., **Between** NC 211 **and** SR 1742 (N. McMullen Rd))

9. **Recommended Structure -** Specify number of spans and length, type of structure, overall length, and depth of cap. (e.g., 1@40', 1@55' 21" cored slab, w/4.0' deep caps). Note: Overall length no longer specified, so as not to be confused with length specified by Structures Management Unit in plans.

10. **Recommended Width of Roadway -** Specify clear roadway width on the bridge (e.g., 27'-10" clear roadway). Note: "Out to out" width no longer need be specified.

11. **Skew -** Specify skew of bridge (angle based on line ahead to the right).

12. **Recommended Location is -** circle either Up, At, or Down based on location relative to existing bridge.

    12a. Specify location of proposed bridge in relation to existing bridge, e.g., 50 ft. downstream, At Existing, New Location.

13. **Longitude/Latitude Coordinates:** Specify as decimal degrees (preferably to the 5th decimal place), e.g. -79.74686, 36.01297. This is useful for locating on GIS maps.

14. Specify Statewide, Regional, or Sub-Regional Tier based on transportation facility.

15. **Bench Mark** - Specify Bench mark description, should be located outside of the construction limits. Can use L&S Bench marks, preferably referenced to -L- or -Y- line (rather than to -BL- line). Also Specify the Northing and Easting State Plane coordinates of the benchmark.

16. **Elev**. - Specify bench mark elevation.

17. **Datum** - Specify Vertical Datum used for this project, e.g., NAVD 88, NGVD 29.

18. **Temporary Crossing** - Specify whether or not a temporary crossing is required at the project site. e.g., Not Required, Off-Site detour provided, or Required 60' detour bridge downstream of existing bridge.

19. **Photo** - Place picture of existing upstream bridge face looking downstream (if no existing bridge use photo of proposed bridge location looking downstream). Include directional arrows for the road alignment and stream flow. See Photo below. If not practicable to provide photo, explain.

20. **Designed by** - Specify Design Engineer. (Prefer at least initials and last name for #20 - #21)

21. **Assisted by** - Specify people who assisted with surveying or CADD work.

22. **Project Engineer** - Specify Project Engineer.

23. **Reviewed by** - The reviewer will sign after printed and reviewed.

24. **Date**- Date project is sealed.

25. **P.E. Seal** - of responsible NC-licensed Design or Project Engineer

26. **Stream** - Specify name of stream or body of water

27. **Struc. Inv. No.** - Specify the four digit bridge designation, e.g., 0078.

28. **I.D. No**. – See #1

29. **Project No**. - Specify Project Number.

30. **PDF File** - Specify file PDF file name using the appropriate naming convention, e.g., 6 digit structure number_I.D. No._Stream_ Route Name.pdf.

31. **Drainage Area** - Specify Drainage Area at stream crossing. Specify in Square miles if area is 1.0 Square miles or greater. Specify in Acres if less than 1 square mile.

32. **Source** - Specify Source of Drainage Area. Typically from USGS Quad Maps or Stream Stats. Can also come from, LIDAR data, drainage areas of Selected Sites verified with Quad Maps, or FEMA FIS. Drainage areas should always be verified for accuracy.

33. **River Basin** - Specify River Basin

34. **Character** - Specify the character of the drainage area, e.g., Region 3-Sand Hills, rural, urban, etc.

35. **Stream Classification** - Specify any classifications listed on the DWR website or in the NRTR, e.g., B, WS-II, NSW

36. **Data on Existing Structure** - Specify the number of spans and length, overall length, type of structure, and pile type.

37. **Total Waterway Opening** - Specify total square foot of waterway opening between the low chord of the existing bridge and the stream bed.

38. **Waterway Opening below 100yr WSEL** - Specify total square foot of waterway opening between 100yr WSEL and stream bed. If overtopped, specify area of weir flow also (in additional information section, if necessary).

39. **Debris Potential** - Specify possible debris severity based on Bridge Inspectors rating of item 41 on the Bridge Inspection Record and Summary and observations made in the field such as large trees leaning on banks, debris build up on the bents, or foliage in existing bridge joists.

40. **Data on Structures Up and Down Stream -** Specify distance up or down stream from proposed structure if relatively close (within 1000') otherwise list location by feature carried (eg. SR 1005), type of structure, number of spans, substructure information, and overall length if bridge; if culvert, number of barrels, size, and type. Include 6-digit bridge number, if in NCDOT inventory.

41. **Design Control Elev. -** Specify the design control elevation based on Chapter 8 in *Guidelines* concerning backwater, freeboard, FEMA compliance, etc. Provide justification.

42. **Gage Station No. -** If available, report nearest USGS gage station I.D. number.
    Data and location of nearest gage stations can be found using the quick check feature at **NC USGS Water Resources** (http://nc.water.usgs.gov/). Gage station locations can also be found using **North Carolina StreamStats** (http://water.usgs.gov/osw/streamstats/north_carolina.html) or **HSP Environmental Sensitivity Map** (https://gis13.services.ncdot.gov/esm/).

43. **Period of Records -** Specify the stream gage periods of activity and total number of active years. (e.g., May 1974 to May 1981, 7 yrs.)

44. **Max. Discharge -** Specify the maximum discharge recorded by the stream gage.

45. **Date -** Specify the date of the maximum discharge recorded by the stream gage.

46. **Frequency -** Specify the frequency of the storm event for maximum discharge recorded by the stream gage.

47. **Historical Flood Information -** Record any reliable information on flooding or overtopping events obtained from local residents, county maintenance or bridge inspectors, or other local individuals familiar with area. Also previous Bridge Inspection Reports, past Bridge Survey and Hydraulic Design Reports, or local news sources can be utilized to determine any flood or overtopping events. Record as much information as is available. Also note if all sources report no overtopping.

47a. **Date -** Specify date of the flood event.

47b. **Elev. -** Specify estimated WSEL of the flood event.

47c. **Est. Freq. -** Specify the estimated storm event frequency of the flood event.

47d. **Source-** Specify individual (name, title, address, etc.) or source of flood event information.

47e. **Period of Knowledge-** If information is from an individual, specify the total number of years the source has been acquainted with the bridge location.

48. **Historical Scour Info-** Historical scour information can be obtained from the Field Inspection section of the Bridge inspection Report or, if available, the Bridge Scour Report. Examining historical stream bed soundings can also be used to discover any scour trends.

48a. **General -** Specify any general scour reported for the existing bridge.

48b. **Contraction -** Specify any contraction scour reported for the existing bridge.

48c. **Local -** Specify any local scour reported for the existing bridge.

49. **Channel Slope -** Specify the slope of the channel. The slope can be measured from, but not limited to, USGS Quad maps, LiDAR, FEMA Detailed Flood study models, or field surveys.

50. **Source -** Specify source of channel slope.

51. **Normal Water Surface Elev. -** Specify the Normal WSEL (vegetation line) observed during the field inspection. If unavailable report WSEL during day of survey.

52. **Manning's n: Left** -Specify Manning's 'n' for the left overbank.

53. **Channel -** Specify Manning's 'n' for the channel.

54. **Right -** Specify Manning's 'n' for the right overbank.

55. **Source** - Specify source of Manning's 'n' value. (e.g., Flood Insurance Study or Field Observation)

56. **Flood Study/Status** - Specify the type of Flood Insurance Study (FIS) the bridge crossing is within (e.g., Detailed, Limited), the date of the FIS, and FIRM panel number. State 'Not in Flood Study' if bridge crossing is not within a study.

57. **Floodway Established** - Specify whether a floodway has been established in the FIS or hydraulic model.

58. **Flood Study 100yr. Discharge -**Specify the 100yr discharge at the published section upstream of the bridge crossing used in the FIS.

59. **With Floodway / With Non-Encroachment -** Specify the published FIS 100yr floodway WSEL for Detailed and Redelineated studies. Specify the Duplicate Effective Model 100yr encroached WSEL for Limited Detailed studies.

60. **Without Floodway / Without Non-Encroachment** - Specify the published FIS 100yr WSEL for Detailed, Limited Detailed and Redelineated studies.

61. **@ River Station** - Specify the published river station upstream of the bridge used to obtain 'With Floodway / With Non-Encroachment' and 'Without Floodway / Without Non-Encroachment' elevations.

62. **Hydrological Method** - Specify the Hydrological Region and method used for the hydraulic design of the bridge, e.g., FEMA Discharges, USGS SIR 2014-5030.

63. **Hydraulic Design Method -** Specify the Hydraulic Design method used for design of the bridge, e.g. HEC-RAS 4.1.0.

64. **Floods Evaluated-** A comparison of the various discharge frequencies used for the hydraulic design.

    64a. **@ River Station?** - Specify the river station at the upstream toe used to obtain the hydraulic design quantities for the various discharges and WSELs. (Needs to match item 74)

    64b. **Freq.** - Specify the flood frequency.

    64c. **Q** - Specify the flood discharge, rounded per convention in *Guidelines* Chapter 7, Section 7.4.

    64d. **Elev.** - Specify the event's WSEL (to nearest tenth of a foot for all reported).

    64e. **Backwater** - Specify the increase in the WSEL caused by the highway encroachment relative to the normal computed WSEL under non-encroached conditions, round to the tenth. (e.g., Proposed WSEL minus Natural WSEL at upstream River Station)

    64f. **Bridge Opening Velocity** - Specify the bridge opening velocity at the upstream face, round to the tenth (ft/sec).

65. **Waterway Opening Provided Below**: **Design W.S. Elev**. - Specify total square foot of waterway opening between Design WSEL and stream bed. If overtopped, also include area of weir flow.

66. **Waterway Opening Provided Below**: **100yr W.S. Elev**. - Specify total square foot of waterway opening between 100yr WSEL and stream bed. If overtopped, also include area of weir flow.

67. **Waterway Opening Provided Below**: **Total** - Specify total square foot of waterway opening between the low chord of the proposed bridge and the stream bed.

68. **Average Channel Velocity (Design) -** Specify the average upstream channel velocity for the design frequency.

69. **Average Overbank Velocity (Design) -** Specify the average upstream overbank velocity for the design frequency.

70. **Computed Scour: General -** Specify the calculated long term degradation scour for the 100yr storm event and any additional required frequencies (per *Guidelines* 8.6.2).

71. **Computed Scour: Contraction -** Specify the calculated contraction scour for the 100yr storm event and any additional required frequencies (per *Guidelines* 8.6.2). (Equations to be shown in Additional Information and Computations, see item 86)

72. **Computed Scour: Local -** Specify the calculated local scour for the 100yr storm event and any additional required frequencies. (Equations to be shown in Additional Information and Computations, see item 87)

73. **Is a Floodway Revision Required?** - Specify the type of floodway revision that is required (e.g., CLOMR, MOA type 1, MOA type 2e). Specify the maximum increase or decrease of the BFE and river station location. (e.g., Maximum decrease of 0.4 ft. at River Station 15003)

74. **WS EL. Taken @ River Station -** Specify the river station upstream of the bridge used to obtain the Hydraulic design quantities for the various discharges and WSELs. (Needs to match item 64a)

75. **Design: Discharge -** Specify discharge for the design frequency.

76. **Design: Frequency -** Specify the design frequency per *Guidelines* (Table 7-1).

77. **Design: Elev. -** Specify the WSEL for the design frequency, round to tenth ft.

78. **Base Flood: Discharge -** Specify the discharge for the base flood (100yr event).

79. **Base Flood: Elev. -** Specify the WSEL for the base flood (100yr event), round to tenth ft.

80. **Overtopping: Discharge -** Specify the discharge for the overtopping event. If greater than a 500yr event, state 500yr+ and note >500yr discharge (e.g.: 10,000cfs) and state "overtopping exceeds 500yr flood event"

81. **Overtopping: Frequency -** Specify the overtopping frequency.

82. **Overtopping: Elev. -** Specify the elevation for the overtopping event, round to tenth ft.

83. **Additional overtopping information -** Specify the roadway overtopping location, e.g., left shoulder at STA. 15+69 -L- .

84. **Discharge Equations used for Hydrological Method -** Specify the method and equations used to calculate the various frequency discharges.

85. **FEMA Discharges -** Specify discharges used in the FIS.

86. **Contraction Scour Computations -** Specify the equations/variables used (cite HEC-18 version) to calculate the contraction scour for the 100yr storm event and any additional required frequencies. (reported on item 71) Specify type - live bed or clear water. Include River Station from which parameters obtained.

87. **Local Scour Computations -** Specify the equations/variables used (cite HEC-18 version) to calculate the local scour for the 100yr storm event and any additional required frequencies. (reported on item 72) Include River Station from which parameters obtained.

88. **Any other information -** Specify any additional information (e.g. regulatory requirements, datum adjustments, etc.) or other pertinent information related to the H&H design.

BRIDGE SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. ....1.......... Project No. ....2.......... Proj. Station ....3..........

County ....4.......... Bridge Over ....5.......... Bridge Inv. No. .....6.....

30 On Highway ....7.......... Between ....8.......... and ....

Recommended Structure ....9..........

....

Recommended Width of Roadway ....10.......... Skew .....11.....

Recommended Location is 12 (Up, At, Down) Stream from Existing Crossing ....12a..........

Longitude .... 13 Latitude ....

Statewide Tier ☐ Regional Tier ☐ Sub–Regional Tier ☐ 14

Bench Mark is ....15..........

29 Northing .... Easting .... Elev. .....16..... ft. Datum: .....17.....

Temporary Crossing .....18..........

28

19

27

26

Designed by: ....20..........

Assisted by: ....21..........

Project Engineer : ....22..........

Reviewed by: ....23..........

Date .....24.....

25

Stream .... Struc. Inv. No. .... I.D. No. .... Project No. .... PDF File

SITE DATA

Drainage Area ....(31).... Source ....(32)....

River Basin ....(33).... Character ....(34)....

Stream Classification (Such as Trout, High Quality Water, etc.) ....(35)....

Data on Existing Structure ....(36)....

.... Total Waterway Opening ....(37).... s.f.

Waterway Opening Below 100yr. WS EL. ....(38).... s.f.

Debris Potential: Low .... Moderate .... High ......(39)

Data on Structures Up and Down Stream ....(40)....

....

....

Design Control Elev. ....(41).... ft.

Gage Station No. ....(42).... Period of Records ....(43).... yrs.

Max. Discharge ....(44).... c.f.s. Date ....(45).... Frequency ....(46)....

Historical Flood Information: (47)

Date .... Elev. .... ft. Est. Freq. .... yr. Source .... Period of Knowledge .... yrs.

Date ..(47a).. Elev. ..(47b).. ft. Est. Freq. ..(47c).. yr. Source ..(47d).. Period of Knowledge ..(47e).. yrs.

Date .... Elev. .... ft. Est. Freq. .... yr. Source .... Period of Knowledge .... yrs.

(48) Historical Scour Info. : General ....(48a).... ft. Contraction ....(48b).... ft. Local ....(48c).... ft.

Channel Slope ....(49).... ft/ft Source ....(50).... Normal Water Surface Elev. ....(51).... ft.

Manning's n: Left O.B. ....(52).... Channel ....(53).... Right O.B. ....(54).... Source ....(55)....

Flood Study /Status ....(56).... Floodway Established? ....(57)....

Flood Study 100yr. Discharge ....(58).... c.f.s. WS Elev.: With Floodway ....(59).... ft. Without Floodway ....(60).... ft.

@ River Station ? (61)

DESIGN DATA

Hydrological Method ....(62)....

Hydraulic Design Method ....(63)....

(64) Floods Evaluated:

@ River Station ? (64a)

Freq. (yr.)	Q (c.f.s)	Elev. (ft.)	Backwater (ft.)	Bridge Opening Velocity (f.p.s.)
....	....	....	....	....
(64b)	(64c)	(64d)	(64e)	(64f)
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

Waterway Opening Provided Below: Design W.S. Elev. ....(65).... s.f., 100yr W.S. Elev. ....(66).... s.f., Total ....(67).... s.f.,

Average Channel Velocity (Design) ....(68).... f.p.s. Average Overbank Velocity (Design) ....(69).... f.p.s.

Computed Scour : General ....(70).... ft. Contraction ....(71).... ft. Local ....(72).... ft.

Is a Floodway Revision Required? ....(73)....

INFORMATION TO BE SHOWN ON PLANS

WS EL. Taken @ River Station ? 74

Design: Discharge ....75........ c.f.s. Frequency ....76........ yr. Elev. ....77........ ft.

Base Flood: Discharge ....78........ c.f.s. Frequency ....100........ yr. Elev. ....79........ ft.

Overtopping: Discharge ....80........ c.f.s. Frequency ....81........ yr. Elev. ....82........ ft.

83 *STATE LOCATION OF OVERTOPPING

ADDITIONAL INFORMATION AND COMPUTATIONS

84 USGS REGRESSION EQUATIONS

SOURCE

$Q_{10} =$

$Q_{25} =$

$Q_{50} =$

$Q_{100} =$

$Q_{500} =$

85 FEMA DISCHARGES

$Q_{10} =$

$Q_{25} =$

$Q_{50} =$

$Q_{100} =$

$Q_{500} =$

CONTRACTION SCOUR: 86

$Y_2 = Y_1 [Q_2/Q_1]^{6/7} [W_1/W_2]^{K1}$ $\quad$ $Y_2 = Y_1 [Q_2/Q_1]^{6/7} [W_1/W_2]^{K1}$

$Ys = Y_2 - Yo$ $\quad$ $Ys = Y_2 - Yo$

LOCAL SCOUR: (CSU EQUATION) 87

$Ys = 2.0(K_1)(K_2)(K_3)(a)^{0.65} (Y_1)^{0.35} (Fr_1)^{0.43}$ $\quad$ $Ys = 2.0(K_1)(K_2)(K_3)(a)^{0.65} (Y_1)^{0.35} (Fr_1)^{0.43}$

Ys = ? $\quad$ Ys = ?

88

DRAWING SCALE SHALL TYPICALLY BE:
1 IN. = 50 FT. HORIZONTAL, 1 IN. = 10 FT. VERTICAL.

LABEL STATIONS AT 100 FT INCREMENTS

XX XX XX XX XX

Bridge Label at ℄
(IN PROFILE VIEW)
Center Line Station(to nearest foot)
Center Line Elevation
Skew Angle
Proposed Structure Size, Type and Span Arrangement

NCDOT PERFORMANCE TABLE

	FREQUENCY				
	10yr.	25yr.	50yr.	100yr.	500yr.
NATURAL	?	?	?	?	?
EXISTING	?	?	?	?	?
PROPOSED	?	?	?	?	?

@SECTION ?
? FT FROM US FACE OF BRIDGE

FEMA PERFORMANCE TABLE

	100yr.
DUPLICATE EFFECTIVE	?
CORRECTED EFFECTIVE	?
REVISED	?

@SECTION ?
? FT FROM US FACE OF BRIDGE

SPREAD ANALYSIS
DA = ?
I = ?
C = ?
Q = ?
LONGITUDINAL SLOPE = ? ft/ft
CROSS SLOPE = ? ft/ft
SHOULDER WIDTH = ? FT.
SPREAD = ? FT.

SUPPLEMENTAL PROFILE VIEW

This area may be used to provide a scaled view to show extents of 100-year floodplain or other information supplemental to the Roadway Profile View.

LABEL ELEVATIONS
AT
10 FT INCREMENTS

XX
XX
XX

ROADWAY PROFILE VIEW

(Bridge should be centered on sheet and aligned with Plan View)

Include (but not limited to) the following

Existing/Proposed Bridge (and Piers), Existing/Proposed Roadway Grade with proposed Vertical Curve Information, Natural Ground with Proposed/Existing Bridge Opening, Excavation (Include Quantity(CY) and Elevation), Remnant Pile Locations (from old bridge),Class of Rip Rap, Slope and Key In Depth of the Sloping Abutment, Proposed Design And 100yr WSEL, Normal (or day of survey) WSEL, Floodplain Boundaries Right/Left, Theoretical Scour, etc.

BASED ON SPREAD ANALYISIS INCLUDE EITHER OF THE FOLLOWING:

DECK DRAINS REQUIRED
? X ? SLOTS ON ? CENTERS
FROM STA. ? TO STA. ? LT.
FROM STA. ? TO STA. ? RT.

NO DECK DRAINS REQUIRED

PLAN VIEW

(Must align with Roadway Profile View)

Include (but not limited to) the following

Existing/Proposed Bridge (and Piers), Proposed Roadway Design, Existing Roadway and Topography, Proposed Drainage (2-GIs, pipes, ditches, etc.), Proposed Slope Stakes, Rip Rap (Label Class), Land Use Description, Proposed/Existing R/W, Wetland Boundaries, Buffers Zones, Name of Steam and Direction of Flow, Location Description (Arrows to Nearest Intersecting Road or City), North Directional Arrow, etc.

TYPICAL SECTION ON STRUCTURE

(NOT TO SCALE)

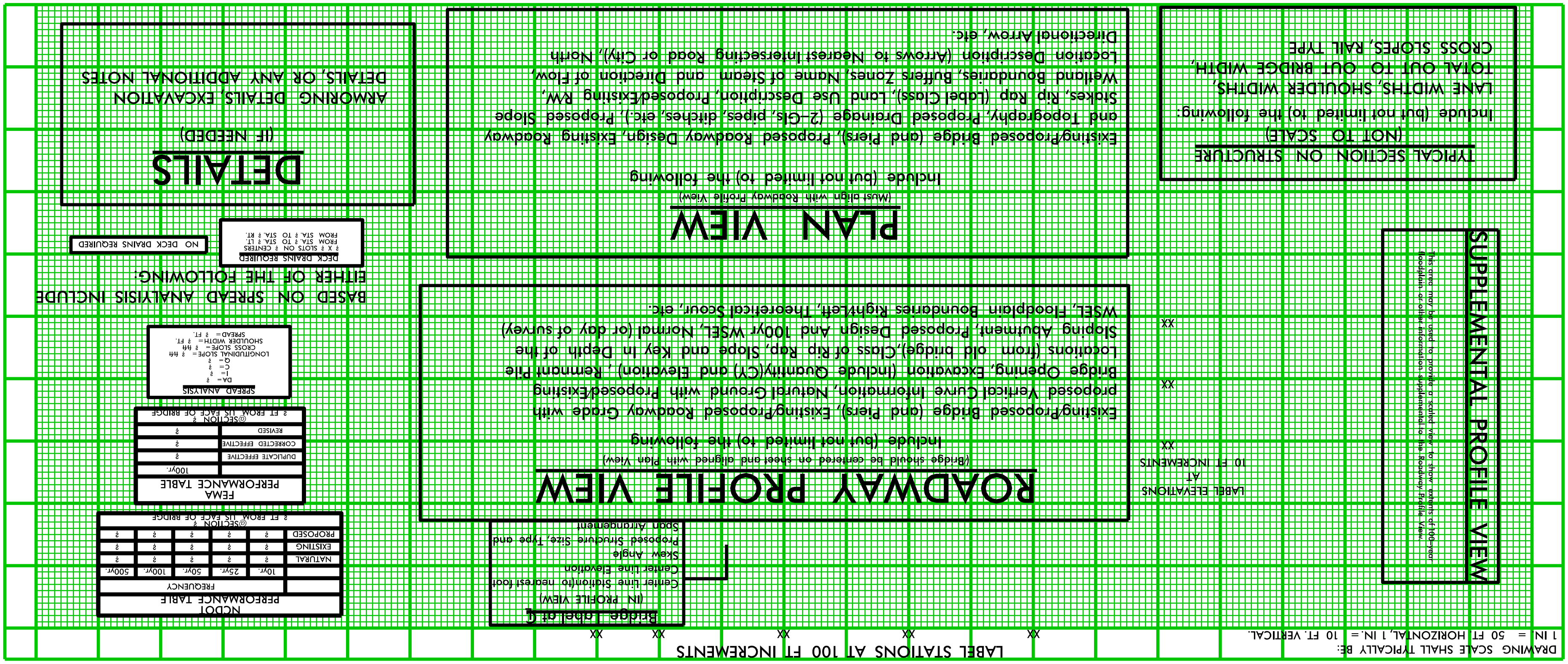
Include (but not limited to) the following:

LANE WIDTHS, SHOULDER WIDTHS, TOTAL OUT TO OUT BRIDGE WIDTH, CROSS SLOPES, RAIL TYPE

DETAILS

(IF NEEDED)

ARMORING DETAILS, EXCAVATION DETAILS, OR ANY ADDITIONAL NOTES



INFORMATION TO BE SHOWN ON PLANS

WS EL. Taken @ River Station ? (74)

Design: Discharge (75) c.f.s. Frequency (76) yr. Elev. (77) ft.

Base Flood: Discharge (78) c.f.s. Frequency 100 yr. Elev. (79) ft.

Overtopping: Discharge (80) c.f.s. Frequency (81) yr. Elev. (82) ft.

(83) *STATE LOCATION OF OVERTOPPING

ADDITIONAL INFORMATION AND COMPUTATIONS

USGS REGRESSION EQUATIONS (84) — SOURCE

Q_{10} =
Q_{25} =
Q_{50} =
Q_{100} =
Q_{500} =

FEMA DISCHARGES (85)

Q_{10} =
Q_{25} =
Q_{50} =
Q_{100} =
Q_{500} =

CONTRACTION SCOUR: (86)

$Y_2 = Y_1 [Q_2/Q_1]^{6/7} [W_1/W_2]^{K_1}$ $Y_2 = Y_1 [Q_2/Q_1]^{6/7} [W_1/W_2]^{K_1}$

$Ys = Y_2 - Yo$ $Ys = Y_2 - Yo$

LOCAL SCOUR: (CSU EQUATION) (87)

$Ys = 2.0(K_1)(K_2)(K_3)(a)^{0.65}(Y_1)^{0.35}(Fr_1)^{0.43}$ $Ys = 2.0(K_1)(K_2)(K_3)(a)^{0.65}(Y_1)^{0.35}(Fr_1)^{0.43}$

Ys = ? Ys = ?

(88)

SITE DATA

Drainage Area (31) (33) Source (32)

River Basin (33) Character (34)

Stream Classification (Such as Trout, High Quality Water, etc.) (35)

Data on Existing Structure (36)

Total Waterway Opening (37) s.f.

Waterway Opening Below 100yr. WS EL. (38) s.f.

Debris Potential: Low Moderate High (39)

Data on Structures Up and Down Stream (40)

Design Control Elev. (41) ft.

Gage Station No. (42) Period of Records (43) yrs.

Max. Discharge (44) c.f.s. Date (45) Frequency (46)

Historical Flood Information: (47)

Date (47a) Elev. (47b) ft. Est. Freq. (47c) yr. Source (47d) Period of Knowledge (47e) yrs.

Date Elev. ft. Est. Freq. yr. Source Period of Knowledge yrs.

Date Elev. ft. Est. Freq. yr. Source Period of Knowledge yrs.

(48) Historical Scour Info. : General (48a) ft. Contraction (48b) ft. Local (48c) ft.

Channel Slope (49) ft/ft Source (50) Normal Water Surface Elev. (51) ft.

Manning's n: Left O.B. (52) Channel (53) Right O.B. (54) Source (55)

Flood Study /Status (56) Floodway Established? (57)

Flood Study 100yr. Discharge (58) c.f.s. WS Elev.: With Floodway (59) ft. Without Floodway (60) ft. @ River Station ? (61)

DESIGN DATA

Hydrological Method (62)

Hydraulic Design Method (63)

(64) Floods Evaluated:

Freq. (yr.)	Q (c.f.s)	Elev. (ft.)	Backwater (ft.)	Bridge Opening Velocity (f.p.s.)
@ River Station (64a) (64b)	(64c)	(64d)	(64e)	(64f)

Waterway Opening Provided Below Design W.S. Elev. (65) s.f., 100yr W.S. Elev. (66) s.f., Total (67) s.f.,

Average Channel Velocity (Design) (68) f.p.s. Average Overbank Velocity (Design) (69) f.p.s.

Computed Scour : General (70) ft. Contraction (71) ft. Local (72) ft.

Is a Floodway Revision Required? (73)

BRIDGE SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. (1) Project No. (2) Proj. Station (3)

County (4) Bridge Over (5) Bridge Inv. No. (6)

(30) On Highway (7) Between (8) and

Recommended Structure (9)

Recommended Width of Roadway (10) Skew (11)

Recommended Location (12) (Up, At, Down) Stream from Existing Crossing (12a)

Longitude (13) Latitude

Statewide Tier ☐ Regional Tier ☐ Sub-Regional Tier ☐ (14)

(29) Bench Mark is (15)

Northing Easting Elev. (16) ft. Datum: (17)

Temporary Crossing (18)

PDF File

Project No. (28)

I.D. No. (27)

Struc. Inv. No.

(19)

Stream (26)

Designed by: (20)

Assisted by: (21)

Project Engineer : (22)

Reviewed by: (23)

Date (24)

(25)

APPENDIX E - ITEM 1
SHEET 11 OF 11

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Culvert Survey & Hydraulic Design Report Key

1. **I.D. No. -** Specify ID No. Example: B-4494 (for TIP projects) BD-5112K (For Low Impact Structure project), SF-890095 (State funded projects), FA-770077(Division Force Account projects).

2. **Project No.** - Specify Project Number.

3. **Proj. Station -** Specify Roadway station along survey line (typically –L- or -Y- line) where the project intersects the structure centerline.

4. **County -** Specify County Name

5. **Stream -** Specify name of stream or body of water

6. **Structure No.** - Specify four digit Structure number, e.g., 0078.

7. **On Highway** - Specify Route number Structure is located on and for SR routes specify road name if there is one. (e.g., NC 211, SR 1742 (N. McMullen Rd).

8. **Between________ and _______ -** Specify Route Structure is located between. For SR routes specify road name if there is one. (e.g., **Between** NC 211 **and** SR 1742 (N. McMullen Rd))

9. **Recommended Structure -** Specify the number, size and type of culvert(s) proposed; additionally, include any other design features, e.g., sill height, embedded depth, baffle placement. If structure is being extended, specify extension length and direction of extension (up and/or downstream). Note culvert sizing is listed as Width x Height .

10. **Recommended Width of Roadway -** Specify shoulder point to shoulder point width (e.g., 72'-0" shld. pt. to shld. pt.)

11. **Skew -** Specify skew of Structure (angle based on line ahead to the right of the proposed alignment). For existing culverts that will be extended, report the skew with as much precision as necessary, including to DDMMSS. For proposed new locations, generally reporting to the nearest degree is sufficient.

12. **Recommended Location is -** circle either Up, At, or Down based on location.

    12a. Specify location of proposed Structure in relation to existing Structure, e.g., 50ft downstream, At Existing, New Location.

13. **Longitude/Latitude Coordinates:** Specify as decimal degrees (preferably to the 5th decimal place), e.g. -79.74686, 36.01297. This is useful for locating on GIS maps.

14. Specify Statewide, Regional, or Sub-Regional Tier based on transportation facility.

15. **Bench Mark** - Specify Bench mark description, should be located outside of the construction limits. Can use L&S Bench marks, preferably referenced to -L- or -Y- line (rather than to -BL- line). Also Specify the Northing and Easting State Plane coordinates of the benchmark.

16. **Elev**. - Specify bench mark elevation.

17. **Datum** - Specify Vertical Datum used for this project, e.g., NAVD 88, NGVD 29.

18. **Temporary Crossing** - Specify whether or not a temporary crossing is required at the project site. e.g., Not Required, Off-Site detour provided, or Required (note size and type of) detour Structure and location (upstream or downstream of existing Structure).

19. **Photo** – Use this space for photograph of proposed site, showing centerline, direction of flow and other important points on photograph.

20. **Designed by** - Specify Design Engineer. (Prefer at least initials and last name for #20 - #21)

21. **Assisted by** - Specify people who assisted with surveying or CADD work.

22. **Project Engineer** - Specify Project Engineer.

23. **Reviewed by** - The reviewer will sign after printed and reviewed.

24. **Date**- Date project is sealed.

25. **P.E. Seal** - of Design Engineer.

26. **Stream** - Specify name of stream or body of water

27. **Struc. Inv. No.** - Specify the four digit Structure designation, e.g., 0078.

28. **I.D. No**. – See #1.

29. **Project No**. - Specify Project Number.

30. **PDF File** - Specify file PDF file name using the appropriate naming convention: 6 digit structure number_Year sealed_I.D. No._Stream_ Route Name.pdf. Example:

    970012_2010_B5800_MuddyCreek_NC8.**PDF**

31. **Drainage Area** - Specify Drainage Area at stream crossing. Specify in Square miles if area is 1.0 Square miles or greater. Specify in Acres if less than 1 square mile.

32. **Source** - Specify Source of Drainage Area. Typically from USGS Quad Maps or Stream Stats. Can also come from, LIDAR data, drainage areas of Selected Sites verified with Quad Maps, or FEMA FIS. Drainage areas should always be verified for accuracy.

33. **River Basin** - Specify River Basin

34. **Character** - Specify the character of the drainage area, e.g., Region 3-Sand Hills, rural, urban, etc.

35. **Stream Classification** - Specify any classifications listed in the NRTR, e.g., B, WS-II, NSW and any additional classification such as Tr, HQW, NSW, OWR

36. **Data on Existing Structure** - Specify existing structure detail. Bridges include the number of spans and length, type of structure, and pile type, shape, and width. Culverts include number of barrels, structure size, and type.

37. **Total Waterway Opening** - Specify total square foot of waterway opening for the existing Structure.

38. **Waterway Opening below 100yr WSEL** - Specify total square foot of waterway opening between 100yr WSEL and stream bed. If overtopped, specify area of weir flow also (in additional information section, if necessary).

39. **Debris Potential** - Specify possible debris severity based on Structure Inspectors rating of item 41 on the Structure Inspection Record and Summary and observations made in the field such as large trees leaning on banks, debris build up on the bents, or foliage in existing Structure joists.

40. **Data on Structures Up and Down Stream -** Specify distance up or down stream from proposed structure if relatively close (within 1000') otherwise list location by feature carried (eg. SR 1005), type of structure, number of spans, substructure information, and overall length if bridge; if culvert, number of barrels, size, and type. Include 6-digit bridge number, if in NCDOT inventory.

41. **Gage Station No. -** If available, report nearest USGS gage station I.D. number.
Data and location of nearest gage stations can be found using the quick check feature at **NC USGS Water Resources** (http://nc.water.usgs.gov/). Gage station locations can also be found using **North Carolina StreamStats** (http://water.usgs.gov/osw/streamstats/north_carolina.html) or **HSP Environmental Map** (http://ncdotesm.ursokr.com/default.html).

42. **Period of Records -** Specify the stream gage periods of activity and total number of active years. (e.g., May 1974 to May 1981, 7 yrs.)

43. **Max. Discharge -** Specify the maximum discharge recorded by the stream gage.

44. **Date -** Specify the date of the maximum discharge recorded by the stream gage.

45. **Frequency -** Specify the frequency of the storm event for maximum discharge recorded by the stream gage.

46. **Historical Flood Information -** Record any reliable information on flooding or overtopping events obtained from local residents, county maintenance or Structure inspectors, or other local individuals familiar with area. Also previous Structure Inspection Reports, past Structure Survey and Hydraulic Design Reports, or local news sources can be utilized to determine any flood or overtopping events. Record as much information as is available. Also note if all sources report no overtopping.

    46a. **Date -** Specify date of the flood event.

    46b. **Elev. -** Specify estimated WSEL of the flood event.

    46c. **Est. Freq. -** Specify the estimated storm event frequency of the flood event.

    46d. **Source-** Specify individual (name, title, address) or source of flood event.

    46e. **Period of Knowledge-** If information is from an individual, specify the total number of years the source has been acquainted with the culvert location.

47. **Allowable HW Elev. -** Specify the allowable HW elevation based on Chapter 9 *Guidelines* concerning allowable headwater, freeboard, FEMA compliance, etc. Provide justification.

48. **Normal Water Surface Elev. -** Specify the Normal WSEL (vegetation line) observed during the field inspection. If unavailable report WSEL during day of survey.

49. **Manning's n: Left** -Specify Manning's 'n' for the left overbank.

50. **Channel -** Specify Manning's 'n' for the channel.

51. **Right -** Specify Manning's 'n' for the right overbank.

52. **Obtained From** - Specify source of Manning's 'n' value. (e.g., Flood Insurance Study or Field Observation)

53. **Flood Study/Status** - Specify the type of Flood Insurance Study (FIS) the Structure crossing is within (e.g., Detailed, Limited) and the date of the FIS. State 'Not in Flood Study' if Structure crossing is not within a study.

54. **Floodway Established** - Specify whether a floodway has been established in the FIS or hydraulic model.

55. **Flood Study 100yr. Discharge -**Specify the 100yr discharge at the Structure crossing used in the Flood Insurance Study.

56. **With Floodway / With Non-Encroachment -** Specify the published FIS 100yr floodway WSEL for Detailed and Redelineated studies. Specify the Duplicate Effective Model 100yr floodway for Limited Detailed studies.

57. **Without Floodway / Without Non-Encroachment** - Specify the published FIS 100yr WSEL for Detailed, Limited Detailed and Redelineated studies.

58. **@ River Station** - Specify the river station upstream of the Structure used to obtain 'With Floodway / With Non-Encroachment' and 'Without Floodway / Without Non-Encroachment' elevations.

59. **Hydrological Method** - Specify the Hydrological method used for the hydraulic design of the Structure, e.g., FEMA Discharges, USGS SIR 2014-5030.

60. **Hydraulic Design Method -** Specify the Hydraulic Design method used for design of the Structure, e.g. HEC-RAS 4.1.0, HDS-5.

61. **Design Tailwater -**Specify tailwater

62. **Culvert Hydraulic Design Computations –** Default form corresponds to HDS-5 methodology. Cell level can be turned off to replace with an alternate table, such as one showing HEC-RAS output.

63. **Is a Floodway Revision Required? -** Specify the type of floodway revision that is required (e.g., CLOMR, MOA type 1, MOA type 2e). Specify the maximum increase or decrease of the BFE and river station location. (e.g., Maximum decrease of 0.4 ft. at River Station 15003) Use additional information and computations section, if necessary.

64. **Total Proposed Waterway Opening** - Specify total square feet of waterway opening provided in structure.

65. **Outlet Velocity (V_{10}) -** Specify the outlet velocity for the 10yr event. To ensure this number is accurately accounting for channel stability requirements, use partial depth velocity.

66. **Natural Channel Velocity (V_{10}) -** Specify the natural channel velocity for the 10yr event.

67. **Required Outlet Protection - I**f needed, specify type (eg.: "Class I rip rap along banks only" or "Energy dissipator basin required, see detail" and provide detail and quantity inside report. If none required, state "none required".

68. **WS EL. Taken @ River Station -** Specify the river station upstream of the Structure used to obtain the Hydraulic design quantities for the various discharges and WSELs. Give approximate distance from upstream face.

69. **Design: Discharge -** Specify discharge for the design frequency.

70. **Design: Frequency -** Specify the design frequency based on the roadway classification. If a lesser design frequency is used, state the frequency and state whether the design maintains the level of service for the facility.

71. **Design: Elev. -** Specify the WSEL for the design frequency. (Round all flood elevations to tenth of a foot.)

72. **Base Flood: Discharge -** Specify the discharge for the base flood (100yr event). Round per convention in *Guidelines* Chapter 7 Section 7.4.

73. **Base Flood: Elev. -** Specify the WSEL for the base flood (100yr event).

74. **Overtopping: Discharge -** Specify the discharge for the overtopping event. If greater than a 500yr event, state 500yr+ and note >500yr discharge (e.g.: 10,000cfs) and state "overtopping exceeds 500yr flood event"

75. **Overtopping: Frequency -** Specify the overtopping frequency.

76. **Overtopping: Elev. -** Specify the elevation for the overtopping event.

77. **Additional overtopping information -** Specify the roadway overtopping location, e.g., left shoulder at STA. 15+69 -L- .

78. **Discharge Equations used for Hydrological Method -** Specify the method and equations used to calculate the various frequency discharges.

79. **FEMA Discharges -** Specify discharges used in the FIS.

80. **Any other information -** Specify any additional information (e.g. regulatory requirements, datum adjustments, etc.) or other pertinent information related to the H&H design.

CULVERT SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. .... 1 .... Project No. .... 2 .... Proj. Station .... 3 ....

County .... 4 .... Stream .... 5 .... Stru. No. ..... 6 ....

30 On Highway .... 7 .... Between .... 8 .... and ....

Recommended Structure .... 9 ....

....

Recommended Width of Roadway .... 10 .... Skew ..... 11 .....

Recommended Location is 12 (Up, At, Down) Stream from Existing Crossing. ..... 12a .....

Longitude .... 13 Latitude ....

Statewide Tier ☐ Regional Tier ☐ Sub–Regional Tier ☐ 14

Bench Mark is ..... 15 ....

29 .... Elev. ..... 16 ..... ft. Datum: ..... 17 .....

Temporary Crossing ..... 18 ....

28

19

27

26

Designed by: .... 20 .... Date ..... 24 .....

Assisted by: .... 21 ....

Project Engineer : .... 22 ....

Reviewed by: .... 23 ....

25

PDF File. .... Project No. .... I.D. No. .... Struc. Inv. No. .... Stream ....

SITE DATA

Drainage Area ....(31)........ Source ....(32)........

River Basin ....(33)........ Character ....(34)........

Stream Classification (Such as Trout, High Quality Water, etc.) ....(35)........

Data on Existing Structure ....(36)........

Total Waterway Opening ....(37)....s.f. Waterway Opening Below 100yr. WS EL. ....(38)....s.f.

(39) Debris Potential: Low ☐ Moderate ☐ High ☐

Data on Structures Up and Down Stream ....(40)........

....

Gage Station No. ....(41)........ Period of Records ....(42)........yrs.

Max. Discharge ....(43)........ c.f.s Date ....(44)........ Frequency ....(45)........

Historical Flood Information: (46)

Date .... Elev. ....ft. Est. Freq. ....yr. Source .... Period of Knowledge ....yrs.

Date ...(46a)... Elev. ...(46b)...ft. Est. Freq. ...(46c)...yr. Source ....(46d)........ Period of Knowledge ...(46e)...yrs.

Allowable HW Elev. ....(47)........ft. Normal Water Surface Elev. ....(48)....ft.

Manning's n : Left O.B. ...(49)... Channel ...(50)... Right O.B. ...(51)... Obtained From ....(52)....

Flood Study /Status ....(53)........ Floodway Established? ...(54)...

Flood Study 100 yr. Discharge ...(55)... c.f.s. ; WS Elev.: With Floodway ...(56)...ft. Without Floodway ...(57)...ft.
@River Station ? (58)

DESIGN DATA

Hydrological Method ....(59)........

Hydraulic Design Method ....(60)........

Design Tailwater : Q_{10} ...(61)...ft.; Q_{25} ....ft.; Q_{50} ....ft.; Q_{100} ....ft.; Q_{500} ....ft.

Size & Type	Q (c.f.s.)	K e	Inlet Control HW/D	Inlet Control H.W. (ft.)	Outlet Control dc	Outlet Control $\frac{dc+D}{2}$	Outlet Control h_o	Outlet Control H	Outlet Control LS_o	Outlet Control H.W. (ft.)	Remarks
				62							

Is a Floodway Revision Required? ....(63)........ Total Proposed Waterway Opening ....(64)....s.f.

Outlet Velocity (V_{10}) ....(65)........f.p.s. Natural Channel Velocity (V_{10}) ....(66)........f.p.s.

Required Outlet Protection ....(67)........

INFORMATION TO BE SHOWN ON PLANS

WS EL. Taken @ River Station ? (68)

Design: Discharge ...(69)...(72)... c.f.s. Frequency ....(70)....yr. Elev. ....(71)....ft.

Base Flood: Discharge .... c.f.s. Frequency ....100....yr. Elev. ....(73)....ft.

Overtopping: Discharge ...(74)... c.f.s. Frequency ....(75)....yr. Elev. ....(76)....ft.

(77)

ADDITIONAL INFORMATION AND COMPUTATIONS

78

USGS REGRESSION EQUATIONS

SOURCE

Q_{10} =

Q_{25} =

Q_{50} =

Q_{100} =

Q_{500} =

79

FEMA DISCHARGES

Q_{10} =

Q_{25} =

Q_{50} =

Q_{100} =

Q_{500} =

80

PROFILE VIEW

EXISTING AND PROPOSED ROADWAY GRADE; NATURAL GROUND
ALONG CENTERLINE; NATURAL GROUND RIGHT AND LEFT
(IF NEEDED TO DEFINE FLOODPLAIN)
EXISTING STRUCTURE(S) (IF PRESENT)
VERTICAL CURVE INFORMATION
PROPOSED WS ELEVATIONS, NORMAL WS, UPSTREAM
PROPOSED CULVERT PLOTTED AT THE UPSTREAM FACE.
PLOT EXISTING IF EXTENDING DOWNSTREAM

LABEL ELEVATIONS
AT
10 FT INCREMENTS
XX

XX

XX

Culvert Label at Roadway Station

(Cross Section View, along culvert centerline)
Roadway I.D. Station (example –L– 10+00.0)
Skew Angle
Proposed Structure Type and Size
Roadway Grade Point Elevation

NCDOT
PERFORMANCE TABLE

	FREQUENCY				
	10yr.	25yr.	50yr.	100yr.	500yr.
NATURAL	?	?	?	?	?
EXISTING	?	?	?	?	?
PROPOSED	?	?	?	?	?

@SECTION ?
? FT FROM US FACE OF BRIDGE

FEMA
PERFORMANCE TABLE

	100yr.
DUPLICATE EFFECTIVE	?
CORRECTED EFFECTIVE	?
REVISED	?

@SECTION ?
? FT FROM US FACE OF BRIDGE

Roadway Cross Section/Culvert Profile View

EXISTING AND PROPOSED ROADWAY CROSS SECTION, CULVERT AND
STREAM BED PROFILE, TOP OF BANKS LEFT/RIGHT,
PROPOSED/NORMAL WS AT INLET, CENTER LINE STATION,
SIZE, TYPE, SKEW ANGLE, CULVERT INVERT,
INVERT ELEVATION AT ROADWAY I.D. STATION AND SLOPE

PLAN VIEW

(Culveret Must align with Cross Section View as much as practicable)

Include (but not limited to) the following

Existing/Proposed Structures, Proposed Roadway Design, Existing Roadway, Existing Topography, Proposed Slope Stakes, Rip Rap (Label Class), Land Use Description, Proposed/Existing R/W, Wetland Boundaries, Buffers Zones, Name of Steam and Direction of Flow, Location Description (Arrows to Nearest Intersecting Road or City), North Directional Arrow

DETAILS

(IF NEEDED)

ARMORING DETAILS, EXCAVATION DETAILS, SILL DETAILS

APPENDIX E -
ITEM 2
SHEET 9 OF 10

PROFILE VIEW

EXISTING AND PROPOSED ROADWAY GRADE, NATURAL GROUND ALONG CENTERLINE, NATURAL GROUND RIGHT AND LEFT (IF NEEDED TO DEFINE FLOODPLAIN)
EXISTING STRUCTURE(S) (IF PRESENT)
VERTICAL CURVE INFORMATION
PROPOSED WS ELEVATIONS, NORMAL WS UPSTREAM
PROPOSED CULVERT PLOTTED AT THE UPSTREAM FACE
PLOT EXISTING IF EXTENDING DOWNSTREAM

PLAN VIEW

(Culvert Must align with Cross Section View as much as practicable)

Include (but not limited to) the following

Existing/Proposed Structures, Proposed Roadway Design, Existing Roadway, Existing Topography, Proposed Slope Stakes, Rip Rap (Label Class), Land Use Description, Proposed/Existing RW, Wetland Boundaries, Buffers Zones, Name of Steam and Direction of Flow, Location Description (Arrows to Nearest Intersecting Road or City), North Directional Arrow

DETAILS

(IF NEEDED)

ARMORING DETAILS EXCAVATION DETAILS, SILL DETAILS

Roadway Cross Section/Culvert Profile View

EXISTING AND PROPOSED ROADWAY CROSS SECTION, CULVERT AND STREAM BED PROFILE, TOP OF BANKS LEFT/RIGHT, PROPOSED/NORMAL WS AT INLET, CENTER LINE STATION, SIZE, TYPE, SKEW ANGLE, CULVERT INVERT, INVERT ELEVATION AT ROADWAY I.D. STATION AND SLOPE

XX
XX
XX

LABEL ELEVATIONS AT 10 FT INCREMENTS

Culvert Label at Roadway Station
Roadway I.D. Station (example -L- 10+00.0)
(Cross Section View, along culvert centerline)
Skew Angle
Proposed Structure Type and Size
Roadway Grade Point Elevation

FEMA PERFORMANCE TABLE

	100yr.
DUPLICATE EFFECTIVE	?
CORRECTED EFFECTIVE	?
REVISED	?

? FT. FROM U/S FACE OF BRIDGE @SECTION ?

NCDOT PERFORMANCE TABLE

FREQUENCY	10yr.	25yr.	50yr.	100yr.	500yr.
NATURAL	?	?	?	?	?
EXISTING	?	?	?	?	?
PROPOSED	?	?	?	?	?

? FT. FROM U/S FACE OF BRIDGE @SECTION ?

ADDITIONAL INFORMATION AND COMPUTATIONS

78 USGS REGRESSION EQUATIONS
SOURCE
Q_{10} =
Q_{25} =
Q_{50} =
Q_{100} =
Q_{500} =

79 FEMA DISCHARGES
Q_{10} =
Q_{25} =
Q_{50} =
Q_{100} =
Q_{500} =

80

SITE DATA

Drainage Area 31 .... Source 32 ....
River Basin 33 .... Character 34 ....
Stream Classification (Such as Trout, High Quality Water, etc.) 35 ....
Data on Existing Structure 36 ....
Total Waterway Opening 37 s.f. Waterway Opening Below 100yr. WS EL. 38 s.f.
39 Debris Potential: Low ☐ Moderate ☐ High ☐
Data on Structures Up and Down Stream 40 ....

Gage Station No. 41 .... Period of Records 42 .... yrs.
Max. Discharge 43 c.f.s Date 44 Frequency 45

Historical Flood Information: 46

Date 46a Elev. 46b ft.Est. Freq. 46c yr. Source 46d Period of Knowledge 46e yrs.
Date 46a Elev. 46b ft.Est. Freq. 46c yr. Source 46d Period of Knowledge 46e yrs.

Allowable HW Elev. 47 ft. Normal Water Surface Elev. 48 ft.
Manning's n : Left O.B. 49 Channel 50 Right O.B. 51 Obtained From 52
Flood Study /Status 53 Floodway Established? 54
Flood Study 100 yr. Discharge 55 c.f.s.; WS Elev.: With Floodway 56 ft. Without Floodway 57 ft.
@River Station ? 58

DESIGN DATA

Hydrological Method 59 ....
Hydraulic Design Method 60 ....
Design Tailwater : Q_{10} 61 ft.; Q_{25} ft.; Q_{50} ft.; Q_{100} ft.; Q_{500} ft.

Size & Type	Q (c.f.s.)	Ke	Inlet Control HW/D	Inlet Control H.W. (ft.)	Outlet Control dc	Outlet Control (dc+D)/2	Outlet Control h_o	Outlet Control H	Outlet Control LS_o	Outlet Control H.W. (ft.)	Remarks
				62							

Is a Floodway Revision Required? 63 Total Proposed Waterway Opening 64 s.f.
Outlet Velocity (V_{10}) 65 f.p.s. Natural Channel Velocity (V_{10}) 66 f.p.s.
Required Outlet Protection 67

INFORMATION TO BE SHOWN ON PLANS

WS EL. Taken @ River Station ? 68

Design: Discharge 69 72 c.f.s. Frequency 70 yr. Elev. 71 ft.
Base Flood: Discharge c.f.s. Frequency 100 yr. Elev. 73 ft.
Overtopping: Discharge 74 c.f.s. Frequency 75 yr. Elev. 76 ft.
77

CULVERT SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. 1 Project No. 2 Proj. Station 3
County 4 Stream 5 Stru. No. 6
On Highway 7 Between 8 and
Recommended Structure 9

Recommended Width of Roadway 10 Skew 11
Recommended Location 12 is (Up, At, Down) Stream from Existing Crossing 12a
Longitude 13 Latitude
Statewide Tier ☐ Regional Tier ☐ Sub-Regional Tier ☐ 14
Bench Mark is 15
Elev. 16 ft. Datum: 17
Temporary Crossing 18

19

Designed by: 20
Assisted by: 21
Project Engineer : 22
Reviewed by: 23
Date 24
25

Stream 26 Struc. Inv. No. 27 I.D. No. 28 Project No. 29 PDF File 30

APPENDIX E - ITEM 2
SHEET 10 OF 10

DETOUR STRUCTURE SURVEY & HYDRAULIC DESIGN REPORT

N.C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N.C.

I.D. NO. ________ **Project No.** ________ **Proj. Station** ________

County ________ **Stream** ________ **Str. No.** ________

On Highway ________ **Between** ________ **and** ________

Recommended Structure ________

Recommended Roadway Width ________ **Skew** ________

Recommended Location is (Up, At, Down) Stream from Existing Crossing ________

Benchmark is ________

Elev. ________ **ft.** **Datum** ________ **ft.**

Superstructure Depth (3' assumed unless otherwise noted) ________ **ft.**

Recommended Grade Point at Structure ________ **ft.**

DESIGN DATA

Frequency	Discharge	Elevation (U/S)	Velocity (D/S)
yr.	c.f.s.	ft.	ft/s

SITE DATA

Drainage Area ________ **Normal Water Surface Elev.** ________ **ft.**

Allowable HW Elev. ________ **ft.**

ADDITIONAL INFORMATION

____

____

____

Note: See attached drawing for any additional notes

Designed by: ________

Assisted by: ________

Project Engineer: ________

Reviewed by: ________

North Carolina Department of Transportation

Division of Highways   Hydraulics Unit

Raleigh, N.C.

Structure Survey Recommendations

I.D. No. *Date:*
Project No.:
County: *Surveyed by:*

Description:

Shipping pt.: RR: Distance from project:

Station	Structure	Skew	Bed Elevation	Min.Subgrade Required	Final Grade Elevation	Drainage Area

Remarks:

Remarks:

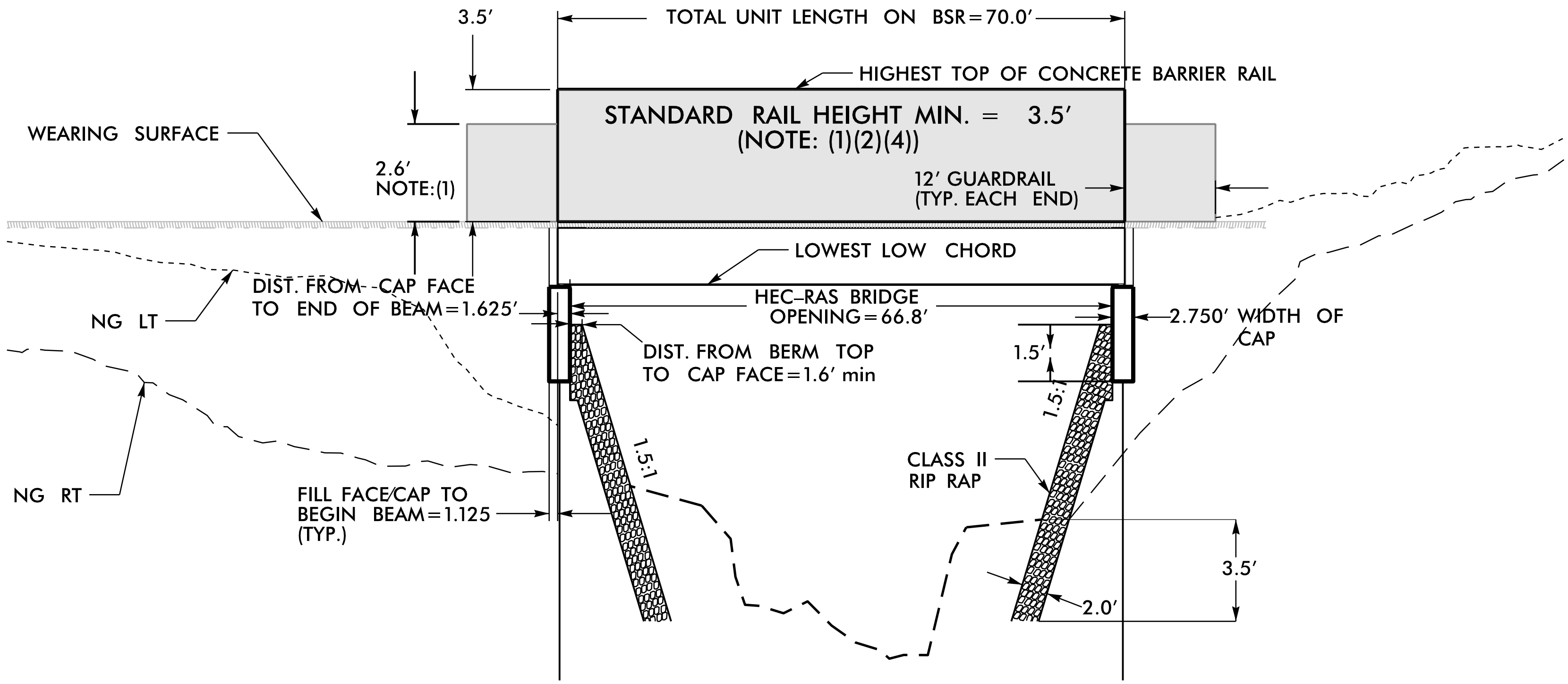
Remarks:

Remarks:

This form can be downloaded from the Hydraulics Unit website.

NCDOT BSR – HEC–RAS BRIDGE OPENING GUIDE

(2.5′ CAP, 90 DEGREE SKEW, CORED SLAB and BOX BEAM)



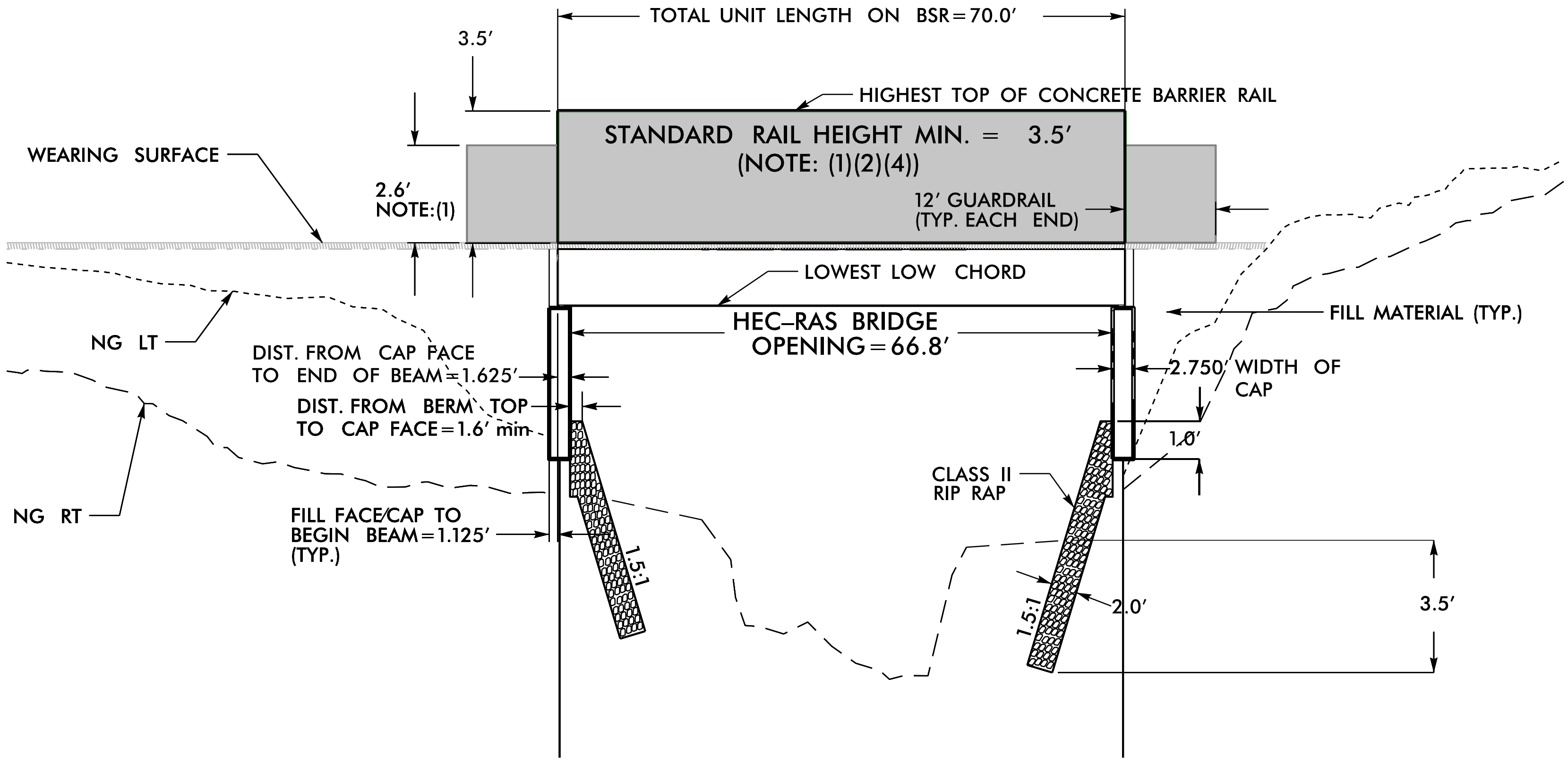
"NCDOT BSR – HEC–RAS BRIDGE OPENING GUIDE"
The attached bridge profile view reflects how to determine the location of the interior face of the cap (1.625′ inside end of beam). It also reflects 1.6′ as the latest minimum top of berm width (includes class II RIP RAP).

NOTES:
(1) ACCOUNT FOR CROWN DROP AS NEEDED
(2) CONCRETE BARRIER RAIL HEIGHT MUST MAINTAIN 3.5′ ABOVE WEARING SURFACE
(3) DIMENSIONS ARE ROUNDED
(4) DIMENSIONS MAY VARY DEPENDING ON STRUCTURE
(5) EXAMPLE IS FOR A STANDARD SINGLE SPAN 70′ UNIT LENGTH.
(6) THIS IS A GUIDE. ENGINEER IS RESPONSIBLE FOR VERIFYING CORRECT DIMENSIONING

12/10/13, HEC–RAS_Bridge_Opening_2013_12_10.pdf

NCDOT BSR – HEC–RAS BRIDGE OPENING GUIDE

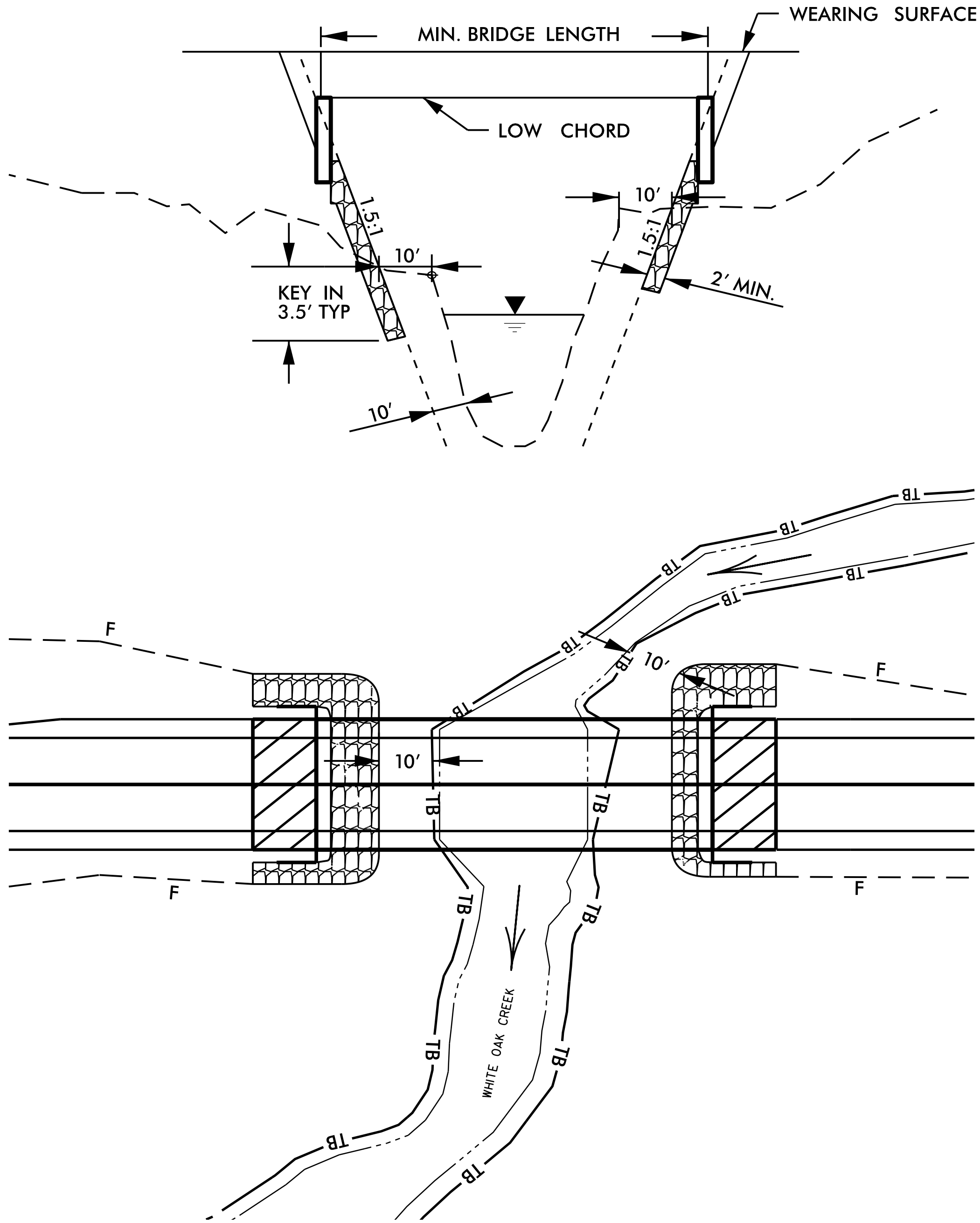
(4.0′ CAP, 90 DEGREE SKEW, CORED SLAB and BOX BEAM)



"NCDOT BSR – HEC–RAS BRIDGE OPENING GUIDE"
The attached bridge profile view reflects how to determine the location of the interior face of the cap (1.625′ inside end of beam). It also reflects 1.6′ as the latest minimum top of berm width (includes class II RIP RAP).

NOTES:
(1) ACCOUNT FOR CROWN DROP AS NEEDED
(2) CONCRETE BARRIER RAIL HEIGHT MUST MAINTAIN 3.5′ ABOVE WEARING SURFACE
(3) DIMENSIONS ARE ROUNDED
(4) DIMENSIONS MAY VARY DEPENDING ON STRUCTURE
(5) EXAMPLE IS FOR A STANDARD SINGLE SPAN 70′ UNIT LENGTH.
(6) THIS IS A GUIDE. ENGINEER IS RESPONSIBLE FOR VERIFYING CORRECT DIMENSIONING

12/10/13, HEC_RAS_Bridge_Opening_2013_12_10.pdf



NCDOT MINIMUM LENGTH BRIDGE

APPENDIX E - ITEM 6

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Guidance for When to Use Sills/Baffles in Box Culverts

The following is to be used as a guide to help the engineer in determining when to use sills/baffles in box culverts. The guide is intended primarily for reinforced concrete box culverts but may also be applicable to larger Aluminum Box Culverts, Corrugated Steel Pipes and Corrugated Steel Pipe Arches. The *Culvert Avoidance and Minimization Design Guidance* memo dated 4/24/12 should be referenced for criteria to evaluate in culvert design. The *Native Material Specification* Memo dated 1/6/14 should also be referenced for material to be used to backfill sills/baffles.

Sills are vertical extensions attached to the culvert bottom placed at the inlet and outlet of the culvert. Baffles are vertical extensions attached to the culvert bottom placed at designed intervals inside the culvert beyond the sills located at the inlet and outlet. Sills can be used to retain the native material in the culvert as well as to help prevent head cutting. Sills may be used at the inlet and outlet of the higher flow barrels of multiple barreled culverts to help maintain the natural stream width and depth through one or more of the barrels. Baffles can be used together with sills to help retain native material in culverts on steeper slopes. Sills and baffles may also be used to help slow velocities in very steep culverts. Baffles can also be used together with sills to help create a low flow channel in the culvert by varying the dimensions (height and width) of the sills/baffles. See figure 1 below for example of sill/baffle detail:

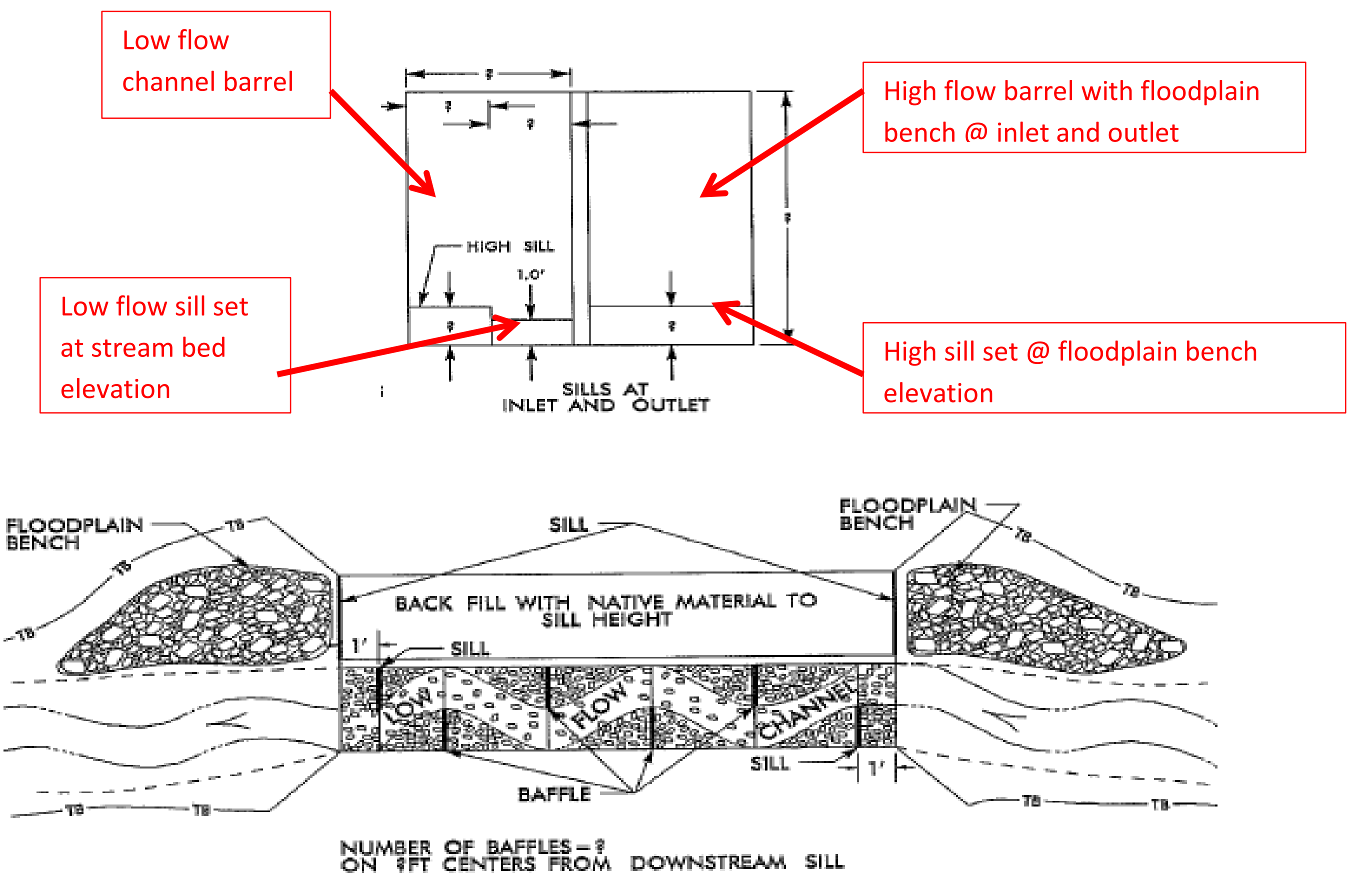


Figure 1-Sill/Baffle detail

It should be noted that baffles and sills do not have to be alternating as shown in the above detail. Each stream crossing should be evaluated by the engineer to determine the appropriate design. The engineer should evaluate the need for using sills/baffles based on factors such as culvert width, stream width, culvert slope, stream slope, culvert length, stream stability, bed material, propensity to head cut and the need for floodplain benches. The following criteria may be used as a guide in determining when to use sills/baffles in box culverts.

Evaluate Culvert Width vs. Stream Width

Designing the culvert width to match the stream's low flow width is preferred if possible. The designer should look up and down stream of an existing structure to determine the stream's low flow width, as the width of the stream close to the existing structure is in many cases wider. If the culvert barrel width when compared to the existing streams low flow width is such that the stream's low flow width and depth cannot be maintained through the culvert, then the use of sills and baffles will be required to establish a continuous low flow channel through the culvert barrel. The height of the sills and baffles should vary across the width of the culvert barrel to provide a continuous low flow channel through the culvert similar to the natural streams low flow width and depth. See Figure 2 for reference. The sills and baffles should be spaced throughout the length of the culvert to hold the bed material and maintain adequate flow depth during low flow conditions. The culvert should be buried a minimum of 1 foot and backfilled with native material. The top of the low flow sills/baffles should match the stream bed elevation in the low flow channel.

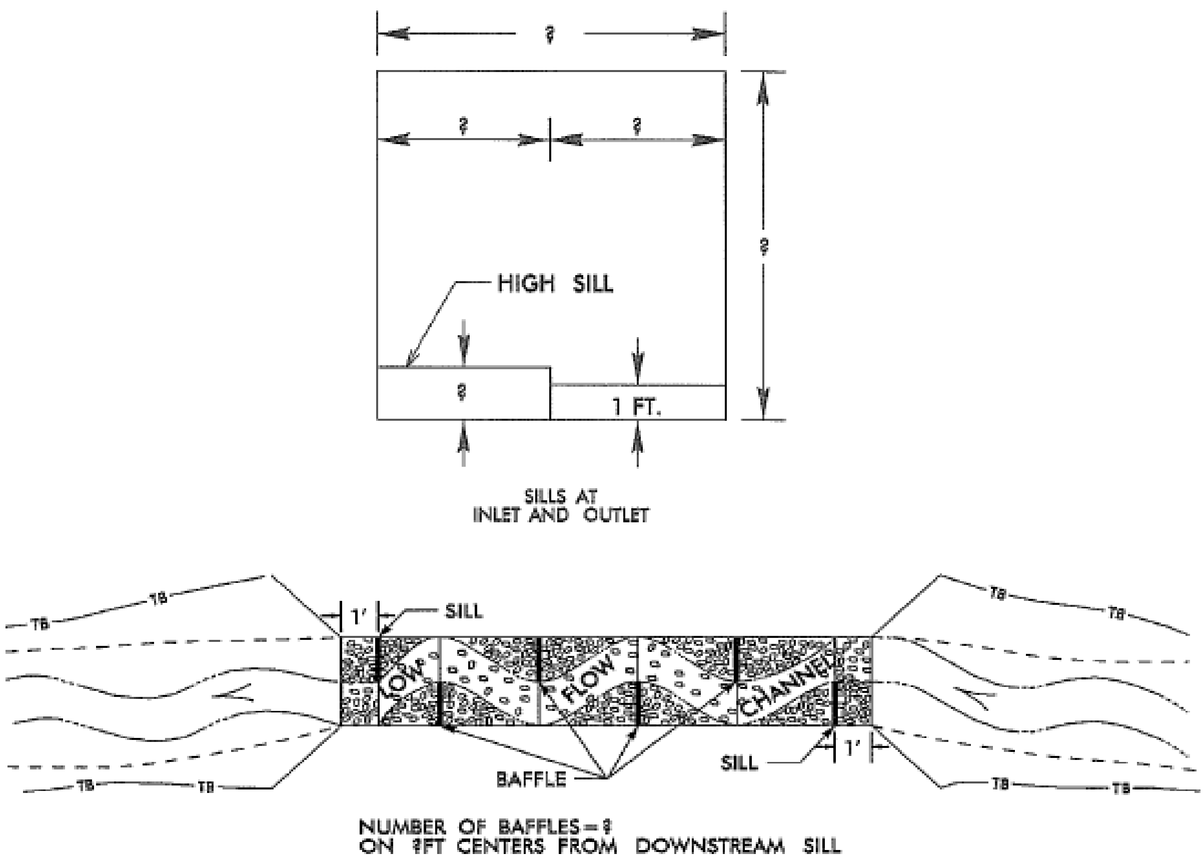


Figure 2- Sills and Baffles used to create a low flow channel through culvert

Evaluate Culvert Slope vs. Stream Slope

If the culvert barrel dimensions are such that the stream's low flow width and depth can be maintained through the culvert, then the culvert slope/stream slope should be evaluated to determine if sills and or baffles are required to help retain the bed material in the culvert. In this case the dimensions of the sills/baffles does not need to vary since the width and slope of the culvert will maintain the stream's low flow width and depth. The purpose of the sills and baffles is to hold the bed material in the culvert and help prevent head cutting. The following general guidance may be used when determining the need for sills and baffles based on culvert slope/stream slope (stream stability and bed material should be considered also as noted below).

- If the culvert slope/stream slope is less than 1%, then sills and baffles are generally not required. Burying the culvert a minimum of 1 foot below the stream bed and allowing it to fill in on its own should suffice. If the stream is very unstable and the stream slope varies up and downstream of the culvert then the engineer should evaluate if sills and baffles should be used. Typically unstable streams with less coarse bed materials (sand and silt) may require the use of sills and baffles at slopes less than 1%.

- If the culvert slope/stream slope is between 1% and 2% then sills and baffles are generally required to help retain the native material in the culvert barrel. The culvert should be buried a minimum of 1 foot below the stream bed with sills and baffles. The sill and baffle height should match the burial depth and they should be backfilled with native material. If the stream is very stable and if the stream slope is constant throughout the length of the culvert as well as up and downstream of the culvert then the use of sills and baffles may not be required. Typically stable streams with coarser bed materials (gravel, cobbles and boulders) would be more likely to not require sills and baffles until you reach slopes above 2%.

- If the culvert slope/stream slope is greater than 2%, then sills and baffles are required to help retain the native material in the culvert barrel. The culvert should be buried a minimum of 1 foot below the stream bed with sills and baffles. The sill and baffle height should match the burial depth and they should be backfilled with native material.

Floodplain Benches

For multiple barrel culverts where high flow barrels are required with floodplain benches at the inlet and outlet, sills should be used. Sills should be placed at the inlet and outlet of the high flow barrel(s) and the barrel(s) should be backfilled to the sill height with native material. The sill height at the inlet and outlet of the high flow barrel should be above the low flow normal water surface elevation. See Figures 3 for reference. Figure 3 shows a multi barrel culvert with one barrel that matches the low flow stream width and the other barrel with sills and floodplain benches at the inlet and outlet. The low flow barrel for this detail matches the streams low flow width and does not require sills to retain the bed material. Figure 4 below is a picture of a multiple barrel culvert with floodplain bench.

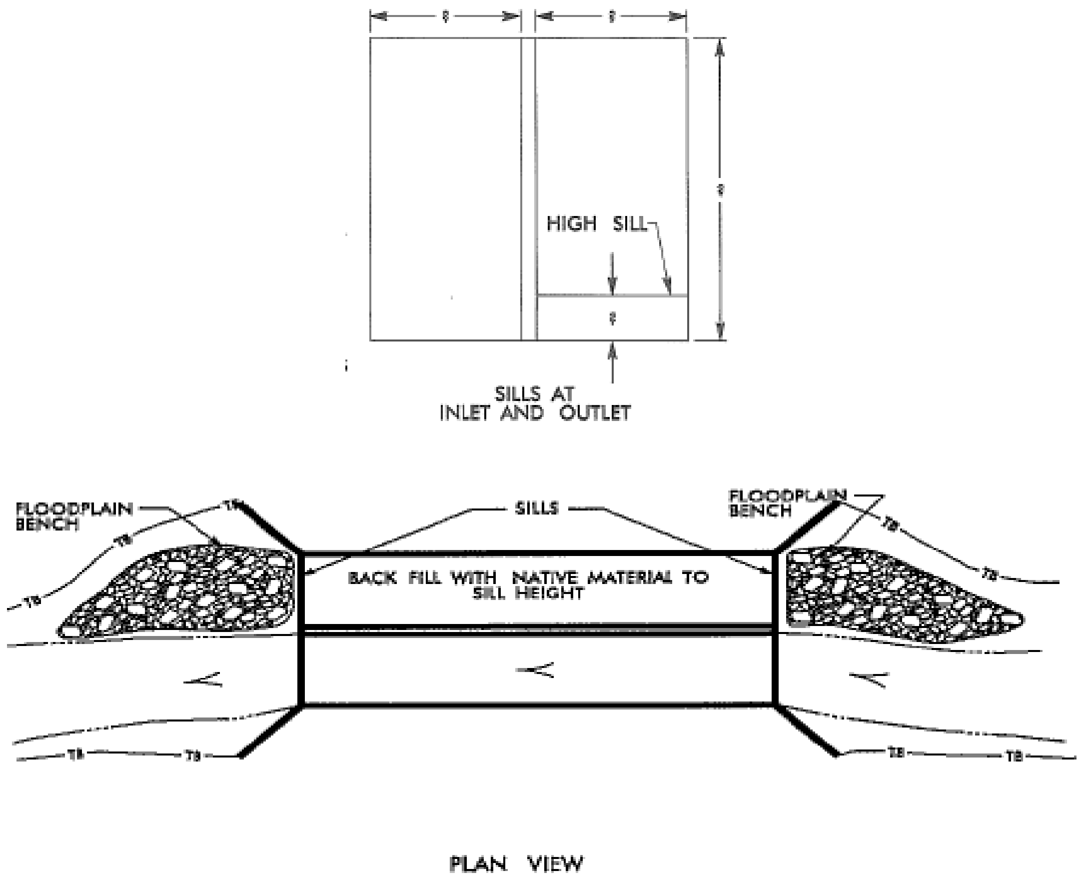


Figure 3-Sills in high flow barrel with floodplain bench

Figure 4-Culvert with floodplain bench

Wide single span culverts such as Aluminum Box Culverts may require floodplain benches at the inlet and outlet to maintain the natural stream width up and downstream of the culvert. The sills for these types of structures should be detailed to provide a low flow notch to match the stream's low flow width. See figure 5 below for example detail:

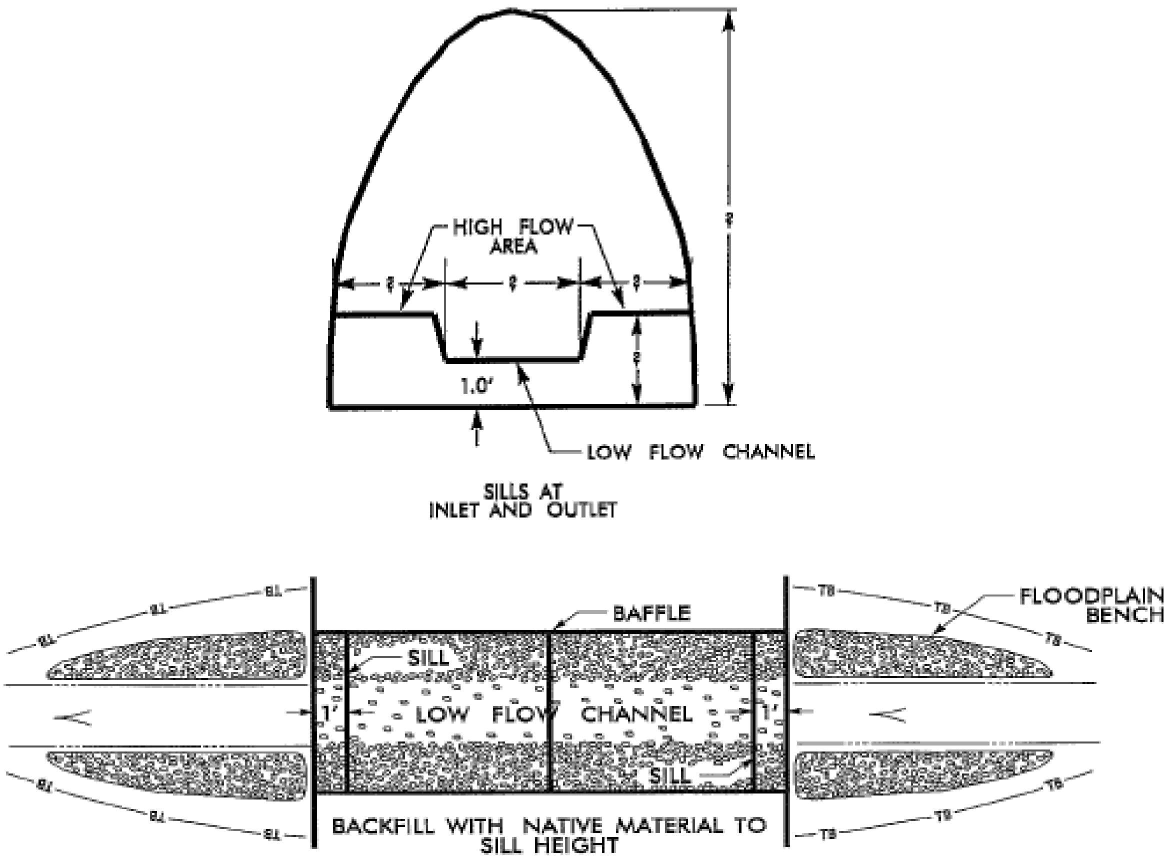


Figure 5-Sill with notch on wide single span culvert with floodplain bench

Sill Spacing

Sills/baffles in culverts are typically spaced at approximately 25' intervals. On slopes steeper than 2%, the spacing may be shortened to an interval length of 0.5' divided by the slope of the culvert or as deemed appropriate by the engineer. 10' is typically the minimum spacing used. The engineer should space the sills to hold the bed material and maintain adequate flow during low flow conditions.

The engineer should detail the dimensions, locations and spacing of the sills/baffles on the CSR (or on a detail to be included with the CSR) and note which culvert barrels should be backfilled with native material.

Native Material Specification (Use only when called for on plans)

- Native Material consists of material that is excavated from the stream bed or floodplain at the project site during culvert construction. Only material that is excavated from the stream bed may be used to line the low flow culvert barrel. Rip rap may be used to supplement the Native Material in the high flow culvert barrel(s). If rip rap is used to line the high flow culvert barrel(s), Native Material should be placed on top to fill voids and provide a flat surface for animal passage. Native Material is subject to approval by the engineer and may be subject to permit conditions.

The above note may be modified as follows if there is no high flow culvert barrel:

- Native Material consists of material that is excavated from the stream bed at the project site during culvert construction. Native Material is subject to approval by the engineer and may be subject to permit conditions.

The above note may be modified as follows if native material is only required in the high flow culvert barrel:

- Native Material consists of material that is excavated from the stream bed or floodplain at the project site during culvert construction. Rip rap may be used to supplement the Native Material in the high flow culvert barrel(s). If rip rap is used to line the high flow culvert barrel(s), Native Material should be placed on top to fill voids and provide a flat surface for animal passage. Native Material is subject to approval by the engineer and may be subject to permit conditions.

The appropriate note above should be placed on the Culvert Survey Report (CSR) when backfilling the culvert with Native Material between sills and/or baffles is recommended. The engineer should detail the dimensions, locations and spacing of the sills/baffles on the CSR (or on a detail to be included with the CSR) and note which culvert barrels should be backfilled with native material.

Native material should be paid for as incidental to the culvert construction. Additional rip rap, if needed, will be paid at the contract price of rip rap or negotiated price if not already in the contract.

CULVERT AVOIDANCE AND MINIMIZATION DESIGN GUIDANCE

When designing a culvert, the engineer should ensure that the following avoidance and minimization design criteria have been evaluated and implemented as much as practicable.

- Proposed culvert slope is consistent with the existing stream slope.

- Proposed low flow dimensions through the culvert are consistent with the existing low flow channel dimensions in the stream. Alternating low flow sills/baffles may be required to achieve this.

- Proposed low flow velocities through the culvert are consistent with the existing low flow velocities in the stream.

- Proposed culvert is appropriately buried such that the bed material will be retained throughout the culvert length. The use of alternating low flow sills/baffles should be evaluated based on culvert slope, bed material and stream stability.

- The dimension and profile of the stream above and below the culvert should not be modified by widening the stream channel or by reducing the depth of the stream in the vicinity of the culvert. Establishment of a low flow floodplain bench should be evaluated at the inlet and outlet of multiple barrel culverts.

- Culvert length has been minimized as much as possible.

- Culvert alignment avoids sharp bends at the inlet and outlet as much as practicable to avoid bank erosion at the inlet and outlet. Stream realignment and/or armoring may be warranted to improve culvert alignment and/or to mitigate potential stream bank erosion. The amount of stream work to be done up and down stream should be minimized as much as possible.

Guidance for Modeling Aluminum Box Culvert (ABC) in HEC-RAS

April 2012

Since the Corrugated Metal Box Culvert shape in HEC-RAS does not match the actual area of the ABC when the span and rise of the ABC is input into the HEC-RAS model, the following methodology should be used to model the ABC. The span of the ABC should be reduced while maintaining the rise until the effective area of the ABC is approximated in the HECRAS model. It should be noted that although this methodology is not considered to be exact, for most situations it should provide a more conservative answer.

ABCs should be modeled in HEC-RAS as Corrugated Metal Box Culverts using the Culvert Data Editor as follows:

Select culvert Shape as Box. The Span should be reduced as necessary (by trial and error) to provide a culvert area opening that is reflective of the effective open area of the culvert. Use the ABC Size Chart (attached) to determine the actual area of the ABC. If the culvert is buried or altered by other means such as sills/baffles, low flow floodplain benches etc., then determine the effective open area by subtracting out the blockage from the actual area of the ABC. The Rise should be the actual rise of the proposed ABC and should not be adjusted. The computed open area of the culvert can then be compared to the effective open area of the ABC. Chart # should be 16, 17, 18 or 19 depending on the rise/span ratio noted in HDS-5 for the particular chart. The rise/span ratio should be based on the actual dimensions of the ABC (do not use the reduced span length). Scale # 1 should be used based on 90 degree headwall. All other information should be appropriately filled in based on the proposed culvert.

Example: 15’-9” X 8’-0” ABC, buried 1’ below stream bed.

Actual culvert area from ABC Chart = 111.8 ft^2, rise/span ratio = 0.5079, use Chart # 19, 90 degree headwall, use scale #1.

Effective open area of culvert = Actual Culvert area – blockage.

15.75’ bottom span x 1’ (bury depth) = 15.75 ft^2 blockage.

Effective open area = 111.8 ft^2 -15.75 ft^2 = 96.05 ft^2, say 96 ft^2

Computed open area in HEC-RAS if modeled as a 15’-9” x 8’-0’ Corrugated Metal Box Culvert buried 1’ (1’ blocked in Culvert Data Editor) = 110.25 ft^2 (Note effective open area of culvert over estimated by 14 ft^2)

Adjust span length by trial and error to reach effective open area of culvert = 96 ft^2

Use span length = 13.72’, Computed open area in HEC-RAS = 96.04 ft^2, say 96 ft^2

Therefore, Model in HEC-RAS as a 13.72’ x 8’ Corrugated Metal Box Culvert buried 1’

APPENDIX F
ITEM 4

Box Culvert Shell-Plate and Rib Data (H-25, HS-25)

TABLE 49. SHELL DATA – H-25, HS-25 LOADING
PLATE AND RIB COMBINATIONS WITH ALLOWABLE HEIGHT OF COVER

Structure Number	Span "A" (Ft.-In.)	Rise "B" (Ft.-In.)	Area (Sq. Ft.)	D6 HG\CG (Gauge)	D6 HRS/CRS (Inches)	D6 Min. (Feet)[9]	D6 Max. (Feet)[9]	E6 HG\CG (Gauge)	E6 HRS/CRS (Inches)	E6 Min. (Feet)[9]	E6 Max. (Feet)[9]	F6 HG\CG (Gauge)	F6 HRS/CRS (Inches)	F6 Min. (Feet)[9]	F6 Max. (Feet)[9]	Max. Shell Wt./Ft. (Lbs.)
STRUCTURES 1 THROUGH 20 HAVE TYPE II HAUNCH AND TYPE IV CROWN RIBS																
1	8-9	2-6	18.4	2\2	54/18	1.7	5.0	3\3	54/18	1.4	5.0					49
2	9-2	3-3	25.4	2\2	54/18	2.0	5.0	3\3	54/18	1.4	5.0					57
3	9-7	4-1	32.6	2\2	54/18	2.0	5.0	3\3	54/18	1.4	5.0					62
4	10-0	4-10	40.2	2\2	54/18	2.5	5.0	2\2	54/9	1.4	5.0					67
5	10-6	5-7	48.1	2\2	54/18	2.5	5.0	2\2	54/9	1.4	5.0					71
6	10-11	6-4	56.4	2\2	54/18	3.0	5.0	2\2	54/9	2.0	5.0	3\3	54/9	1.4	5.0	85
7	11-4	7-2	65.0	2\2	54/18	3.0	5.0	2\2	27/18	2.5	5.0	3\3	54/9	1.4	5.0	90
8	10-2	2-8	23.0	2\2	54/18	2.5	5.0	3\3	54/18	1.7	5.0	4\4	54/18	1.4	5.0	66
9	10-7	3-5	31.1	2\2	54/18	3.0	5.0	3\3	54/18	2.0	5.0	3\3	27/18	1.4	5.0	73
10	10-11	4-3	39.5	2\2	54/18	3.0	5.0	3\3	54/18	2.5	5.0	3\3	54/9	1.4	5.0	84
11	11-4	5-0	48.2	2\2	54/18	3.0	5.0	3\3	54/18	2.5	5.0	3\3	54/9	1.4	5.0	88
12	11-8	5-9	57.2	2\2	54/18	3.0	5.0	3\3	54/18	2.5	5.0	3\3	54/9	1.4	5.0	93
13	12-1	6-7	66.4	3\3	54/18	3.0	5.0	3\3	27/18	2.5	5.0	3\3	27/9	1.4	5.0	105
14	12-5	7-4	76.0	2\2	27/18	3.0	5.0	2\2	27/9	2.0	5.0	3\3	27/9	1.4	5.0	110
15	11-7	2-10	28.1	2\2	54/18	3.0	5.0	3\3	54/18	2.5	5.0	3\3	54/9	1.4	5.0	85
16	11-11	3-7	37.4	3\3	54/18	3.0	5.0	3\3	27/18	2.5	5.0	3\3	54/9	1.4	5.0	90
17	12-3	4-5	46.9	3\3	54/18	3.0	5.0	4\4	54/18	2.5	5.0	4\4	54/9	1.4	5.0	104
18	12-7	5-2	56.6	3\3	54/18	3.0	5.0	3\3	27/18	2.5	5.0	4\4	54/9	1.4	5.0	109
19	12-11	6-0	66.6	3\3	27/18	3.0	5.0	2\2	27/9	2.0	5.0	4\4	27/9	1.4	5.0	123
20	13-3	6-9	76.9	2\2	18/18	3.0	5.0	2\2	27/9	2.5	5.0	3\3	18/9	1.4	5.0	125
STRUCTURES 21 THROUGH 39 HAVE TYPE II HAUNCH AND TYPE VI CROWN RIBS[10]																
21	13-0	3-0	33.8	3\3	54/18	2.3	5.0	2\2	27/18	1.6	5.0	3\3	27/18	1.4	5.0	100
22	13-4	3-10	44.2	3\3	54/18	2.5	5.0	2\2	27/18	1.7	5.0	4\4	27/18	1.4	5.0	114
23	13-7	4-7	54.8	3\3	54/18	2.7	5.0	2\2	27/18	1.9	5.0	3\3	18/18	1.4	5.0	118
24	13-10	5-5	65.6	3\3	54/18	2.9	5.0	2\2	27/18	2.0	5.0	3\3	18/18	1.4	5.0	122
25	14-1	6-2	76.6	2\2	27/18	2.3	5.0	2\2	18/18	1.7	5.0	3\3	18/18	1.4	5.0	126
26	14-5	3-3	40.0	2\2	27/18	2.5	5.0	2\2	18/18	1.8	5.0	4\4	18/18	1.4	5.0	121
27	14-8	4-1	51.5	2\2	27/18	2.8	5.0	2\2	18/18	2.0	5.0	4\5	18/18	1.4	5.0	140
28	14-10	4-10	63.2	2\2	27/18	2.8	5.0	2\2	18/18	2.0	5.0	4\6	18/18	1.4	5.0	137
29	15-1	5-8	75.1	2\2	27/18	3.0	5.0	2\2	18/18	2.1	5.0	4\7	18/18	1.4	5.0	145
30	15-4	6-5	87.2	3\3	27/18	2.6	5.0	2\2	18/18	2.3	5.0	5\7	18/18	1.4	5.0	157
31	15-6	7-3	99.4	3\3	27/18	2.6	5.0	2\2	18/18	2.3	5.0	5\7	18/18	1.4	5.0	163
32	15-9	8-0	111.8	3\3	27/18	2.6	5.0	2\2	18/18	2.5	5.0	5\7	18/18	1.4	5.0	169
33	15-10	3-6	46.8	2\2	18/18	2.4	5.0	6\2	18/18	1.7	5.0	7\5	18/18	1.4	5.0	149
34	16-0	4-3	59.5	2\2	18/18	2.5	5.0	6\2	18/18	1.8	5.0	7\6	18/18	1.4	5.0	159
35	16-2	5-1	72.3	2\2	18/18	2.5	5.0	6\2	18/18	1.8	5.0	7\7	18/18	1.4	5.0	170
36	16-4	5-11	85.2	2\2	18/18	2.6	5.0	6\2	18/18	1.9	5.0	7\7	18/18	1.4	5.0	176
37	16-6	6-8	98.3	2\2	18/18	2.6	5.0	6\2	18/18	2.0	5.0	4\5	9/18	1.4	5.0	178
38	16-8	7-6	111.5	2\2	18/18	2.7	5.0	6\2	18/18	2.0	5.0	4\7	9/18	1.4	5.0	197
39	16-10	8-3	124.8	2\2	18/18	2.8	5.0	6\2	18/18	2.1	5.0	4\7	9/18	1.4	5.0	202
STRUCTURES 40 THROUGH 87 USE ALL TYPE VI RIBS[10]																
40	17-9	3-10	54.4	2\2	54/18	2.8	5.0	2\2	27/18	2.0	5.0	2\2	18/18	1.4	5.0	135
41	18-2	4-7	68.3	2\2	27/18	2.2	5.0	2\2	18/18	1.5	5.0	2\3	18/18	1.4	5.0	147
42	18-7	5-4	82.5	2\2	27/18	2.3	5.0	2\2	18/18	1.6	5.0	2\5	18/18	1.4	5.0	163
43	19-0	6-1	97.1	2\2	27/18	2.4	5.0	2\2	18/18	1.8	5.0	2\6	18/18	1.4	5.0	174
44	19-5	6-11	111.9	2\2	27/18	2.6	5.0	2\2	18/18	1.8	5.0	2\7	18/18	1.4	5.0	186
45	19-10	7-8	127.1	2\2	27/18	2.7	5.0	2\2	18/18	1.9	5.0	2\7	18/18	1.4	5.0	181
46	20-3	8-5	142.6	2\2	27/18	2.9	5.0	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	214
47	19-1	4-2	63.3	2\2	27/18	2.6	5.0	2\2	18/18	1.8	5.0	2\2	18/9	1.4	5.0	194
48	19-5	4-11	78.3	2\2	27/18	2.6	5.0	2\2	18/18	1.8	5.0	2\2	18/9	1.4	5.0	203
49	19-9	5-8	93.6	2\2	27/18	2.7	5.0	2\2	18/18	1.9	5.0	2\2	18/9	1.4	5.0	211
50	20-1	6-6	109.2	2\2	27/18	2.9	5.0	2\2	18/18	1.9	5.0	2\2	18/9	1.4	5.0	218
51	20-6	7-3	125	2\2	27/18	3.0	5.0	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	222
52	20-10	8-1	141.2	2\2	27/18	3.2	4.5	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	225
53	21-2	8-10	157.6	2\2	18/18	2.1	5.0	2\7	18/18	1.7	5.0	2\2	18/9	1.4	5.0	229
54	20-4	4-6	73.1	2\2	27/18	3.0	5.0	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	211
55	20-7	5-3	89.2	2\2	27/18	3.1	4.9	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	220
56	20-11	6-1	105.5	2\2	27/18	3.2	4.3	2\2	18/18	2.0	5.0	2\2	18/9	1.4	5.0	229
57	21-3	6-10	122.1	2\2	18/18	2.1	5.0	2\7	18/18	1.7	5.0	2\2	18/9	1.4	5.0	233
58	21-6	7-8	139.0	2\2	18/18	2.2	5.0	2\7	18/18	1.8	5.0	2\2	18/9	1.4	5.0	236
59	21-10	8-5	156.0	2\2	18/18	2.2	5.0	2\7	18/18	1.9	5.0	2\2	18/9	1.4	5.0	240
60	22-1	9-3	173.3	2\2	18/18	2.3	5.0	2\7	18/18	2.0	5.0	2\2	18/9	1.4	5.0	243
61	21-7	4-11	83.8	2\2	18/18	2.2	5.0	2\7	18/18	1.8	5.0	2\2	18/9	1.4	5.0	225
62	21-10	5-8	101	2\2	18/18	2.2	5.0	2\7	18/18	1.9	5.0	2\2	18/9	1.4	5.0	234
63	22-1	6-6	118.4	2\2	18/18	2.3	5.0	2\7	18/18	2.0	5.0	2\2	18/9	1.4	5.0	243
64	22-3	7-3	135.9	2\2	18/18	2.4	5.0	2\7	18/18	2.0	5.0	2\2	18/9	1.4	5.0	247
65	22-6	8-1	153.7	2\2	18/18	2.5	5.0	2\7	18/18	2.0	5.0	2\2	18/9	1.4	5.0	251
66	22-9	8-10	171.6	2\2	18/18	2.6	5.0	2\7	18/18	2.0	5.0	2\2	18/9	1.4	5.0	254
67	23-0	9-8	189.8	2\2	18/18	2.6	5.0	2\7	18/18	2.2	5.0	2\2	18/9	1.4	5.0	258
68	22-9	5-4	95.5	2\2	18/18	2.4	5.0	2\7	18/18	2.1	5.0	2\2	18/9	1.4	5.0	240
69	23-0	6-1	113.7	2\2	18/18	2.5	5.0	2\7	18/18	2.1	5.0	2\2	18/9	1.4	5.0	249
70	23-2	6-11	132.1	2\2	18/18	2.5	5.0	2\7	18/18	2.2	5.0	2\2	18/9	1.4	5.0	258
71	23-4	7-8	150.6	2\2	18/18	2.6	5.0	2\7	18/18	2.2	5.0	2\2	18/9	1.4	5.0	262
72	23-6	8-6	169.3	2\2	18/18	2.6	5.0	2\7	18/18	2.2	5.0	2\2	18/9	1.4	5.0	265
73	23-8	9-3	188.1	2\2	18/18	2.7	4.9	2\7	18/18	2.3	5.0	2\2	18/9	1.4	5.0	269
74	23-10	10-1	207.0	2\2	18/18	2.7	4.8	2\7	18/18	2.3	5.0	2\2	18/9	1.4	5.0	272
75	24-0	5-9	108.2	2\2	18/18	2.7	4.6	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	254
76	24-1	6-6	127.5	2\2	18/18	2.7	4.6	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	263
77	24-3	7-4	146.8	2\2	18/18	2.8	4.4	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	272
78	24-4	8-2	166.2	2\2	18/18	2.8	4.3	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	276
79	24-5	8-11	185.7	2\2	18/18	2.9	4.2	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	280
80	24-7	9-9	205.3	2\2	18/18	2.9	4.1	2\7	18/18	2.4	5.0	2\2	18/9	1.4	5.0	283
81	24-8	10-6	225	2\2	18/18	3.0	4.0	2\7	18/18	2.5	5.0	2\2	18/9	1.4	5.0	287
82	25-2	6-2	122.0	3\5	18/18	2.7	4.3	2\2	18/9	1.4	5.0					272
83	25-2	7-0	142.2	3\5	18/18	2.7	4.3	2\2	18/9	1.4	5.0					278
84	25-3	7-9	162.4	3\5	18/18	2.7	4.3	2\2	18/9	1.4	5.0					287
85	25-4	8-7	182.6	3\5	18/18	2.7	4.2	2\2	18/9	1.4	5.0					291
86	25-4	9-5	202.9	3\5	18/18	2.7	4.2	2\2	18/9	1.4	5.0					294
87	25-5	10-2	223.3	3\5	18/18	2.8	4.2	2\2	18/9	1.4	5.0					298

See Notes page 67

STILLING BASIN DIMENSIONS AND VOLUME

STILLING BASIN DIMENSIONS | **TIP:** ______ | **Station:** ______ | **Calculated by:** ______

DIMENSIONS FOR BASIN VOLUME

Culvert Length + Access =	21 ft
Culvert Width + Access =	11 ft
Normal Water Surface Depth =	ft

INSIDE BASIN DIMENSIONS

Length =	16 ft
Width =	8 ft

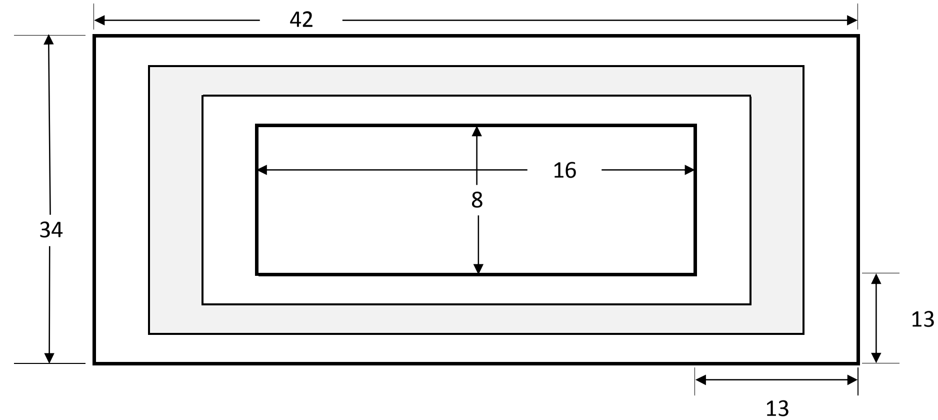
OUTSIDE BASIN DIMENSIONS

Length =	42 ft
Width =	34 ft

BASIN WATER VOLUME [Vb]

V_b = 18 cu yd

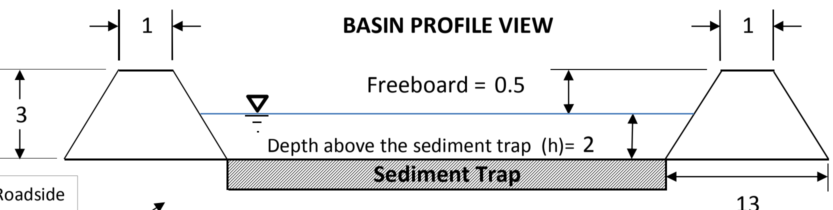
BASIN PLAN VIEW



BASIN PROFILE VIEW

Stilling Basin Height = 3

Side Slope = 1.5 :1



Sediment Trap to be sized by Roadside Environmental Unit.
Sediment Trap volume not included in basin volume calculation.

All dimensions are in units of feet

This form can be downloaded from the Hydraulics Unit website.

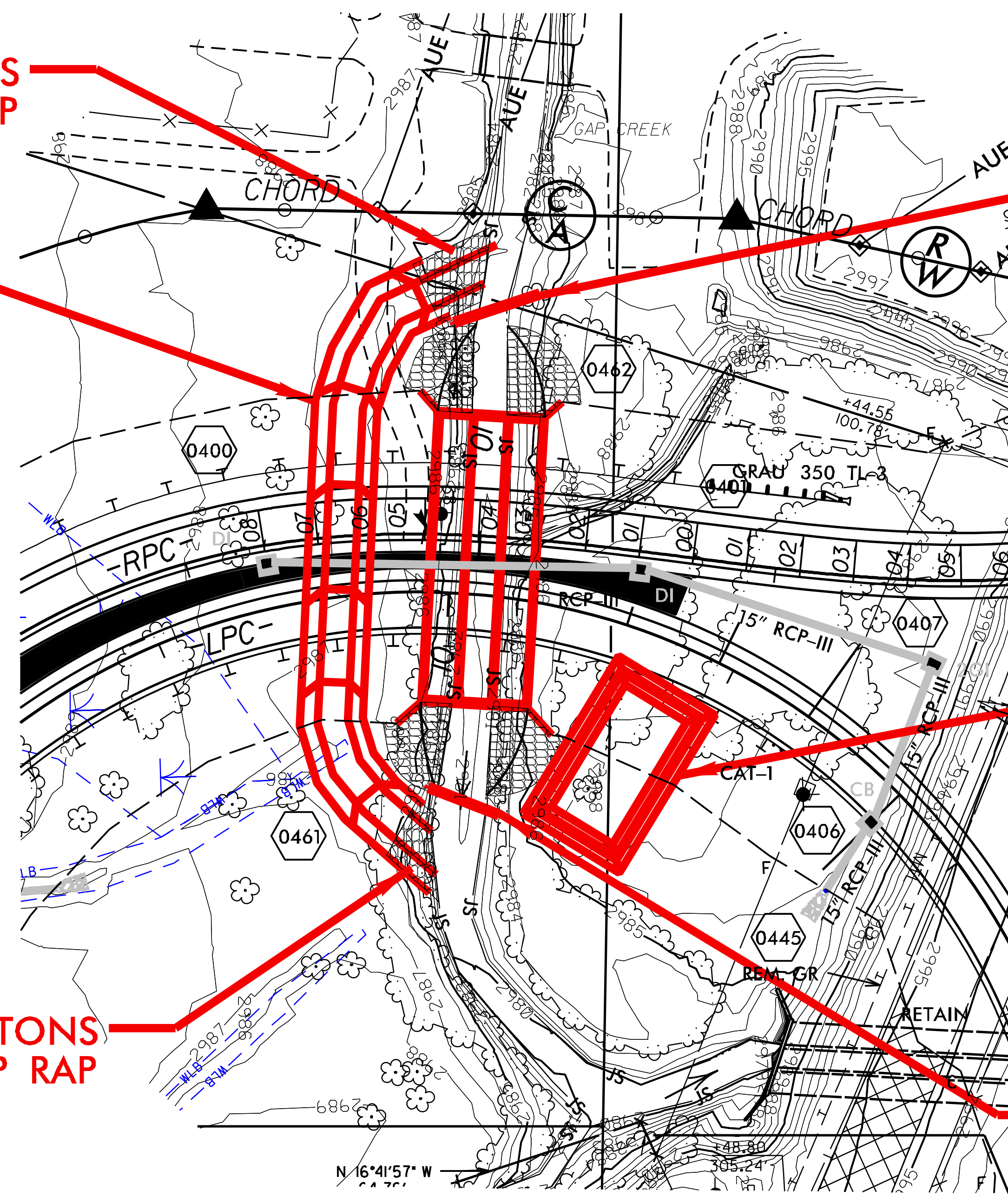
PROJECT REFERENCE NO.	SHEET NO.
R-2915A	
RW SHEET NO.	
ROADWAY DESIGN ENGINEER	HYDRAULICS ENGINEER

GAP CREEK
CULVERT CONSTRUCTION SEQUENCE
–RPC– STA. 9+99 –LPC– STA. 9+89

1. CONSTRUCT STILLING BASIN PER NCDOT STANDARD DRAWING 1630.04 TO SIZE SPECIFIED AND AT LOCATION SHOWN.
2. CONSTRUCT IMPERVIOUS DIKES AND TEMPORARY DIVERSION CHANNEL AS SHOWN.
3. DIVERT CHANNEL FLOW THROUGH TEMPORARY DIVERSION CHANNEL.
4. CONSTRUCT PROPOSED CULVERT AND CHANNEL IMPROVEMENTS.
5. REMOVE IMPERVIOUS DIKES AND ALLOW FLOW THROUGH RCBC.
6. REMOVE STILLING BASIN AND FILL TEMPORARY DIVERSION CHANNEL.
7. COMPLETE PROPOSED ROADWAY CONSTRUCTION.

EST. 41 TONS
CL I RIP RAP

TEMPORARY DIVERSION
CHANNEL LINED W/GEOTEXTILE



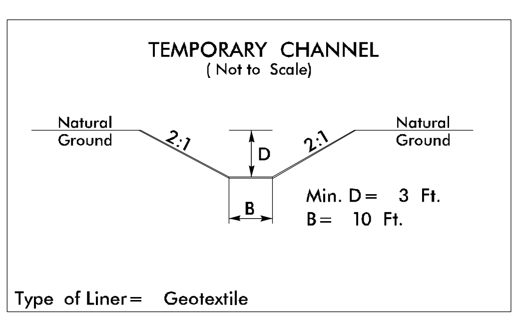
IMPERVIOUS DIKE

STILLING BASIN FOR
PUMPED EFFLUENT
BASE L=48', W=24'
H=2' DIKE, 1.5:1 SLOPES
TOTAL H=3.5'
REQUIRED VOL=134 CY
PROVIDED VOL=137 CY

EST. 29 TONS
CL I RIP RAP

IMPERVIOUS DIKE

TEMPORARY DIVERSION
CHANNEL DETAIL
EST. EXCAVATION=410 CY
EST GEOTEXTILE=560 SY



APPENDIX F - ITEM 6

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PIPE DATA SHEET

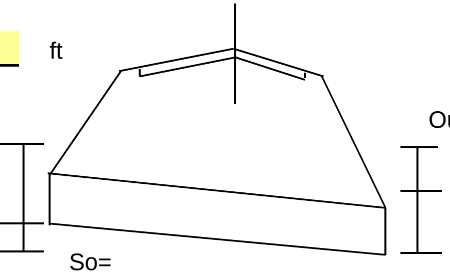
Date: ______ Sheet ______ of ______

Project Number: ______ I.D. No.: ______ County: ______ Designed By: ______ Reviewed By: ______

Alignment: ______
Station: ______
Skew: ______
Size/Type Pipe: ______
Type Entrance: ______
Direction of Flow: ______
Hydrologic Method: ______
H.W. Control Elevation: ______
H.W. Control Feature: ______

GP Elev.: ______ ft

Shoulder Elev.: ______ ft



Inlet Ground Elev. ______ ft

H.W.

LS_o

Outlet Ground Elev.

H ______ ft

T.W.

Inlet Invert Elev.: ______ ft

So= ______

L= ______ ft

Outlet Inv. Elev. ______ ft

Plan Summary Data

Drainage Area: ______
Design Freq.: ______
Design Disch.: ______
Design H.W. Elev.: ______
Q100 Disch.: ______
Q100 Elev.: ______
Overtopping Freq.: ______
Overtopping Disch.: ______
Overtopping Elev.: ______

RCP=.012, CMP=.024
n= ______

TW Channel Specs.: Slope: ______ Lt. Side Slope= ______
Base Width= ______ n= ______ Rt. Side Slope= ______

BARRELS			TW	Q	Nat.	Allow.	Inlet Control			Outlet Control							HW	V_o*	
SIZE	No. Of	FREQ			H.W.	H.W.	HW/D	HW (ft)		Ke	d_c	$(d_c+D)/2$	h_o	H	LS_O	HW	ELEV.		Remarks
in	Pipes	YR	ft	ft^3/s	ft	ft	ft/ft	ft			ft	ft	ft	ft	ft	ft		ft/s	

Notes & Calculations

*V_o is partial flow velocity.

SUMMARY AND RECOMMENDATIONS: ______

______

______

APPENDIX G

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NCDOT PIPE MATERIAL SELECTION GUIDE

*SWT: ALTERNATE PIPE APPLICABLE ONLY FOR SIDE AND SLOPE DRAINS FOR SIZES 12" TO 48"

*RT AND SRT: ALTERNATE PIPE APPLICABLE ONLY FOR FILL HEIGHTS >2.0' & <20.0' FOR SIZES 12" TO 48"

FILL TABLES

RCP (REINFORCED CONCRETE) AASHTO M170

CLASS II		CLASS III		CLASS IV		CLASS V	
*MIN.	MAX.	*MIN.	MAX.	*MIN.	MAX.	*MIN.	MAX.
2.0'	10.0'	2.0'	20.0'	1.0'	30.0'	1.0'	40.0'

(FOR FILLS >40' & <80' USE LRFD DIRECT DESIGN METHOD

WHEN FILL HEIGHTS (NOT INCLUDING THE PAVEMENT STRUCTURE AND CURB) FOR RCP RUNNING PARALLEL TO AND UNDER CURB AND GUTTER, EXPRESSWAY GUTTER, SHOULDER BERM GUTTER AND ADJACENT TO MEDIAN BARRIER ARE 1' OR LESS, SPECIFY CLASS IV RCP.

WHEN THE FILL HEIGHTS (NOT INCLUDING THE PAVEMENT STRUCTURE) FOR RCP RUNNING UNDER/ACROSS THE ROADWAY ARE 1' OR LESS, SPECIFY CLASS V RCP.

SPECIFY A SINGLE CLASS OF RCP BETWEEN DRAINAGE STRUCTURES.

SPECIFY A SINGLE CLASS OF RCP IN A SINGLE RUN OF PIPE THAT TERMINATES WITH AN OUTLET OR A DRAINAGE STRUCTURE ON EACH END.

CSP (CORRUGATEDSTEEL) AASHTO M36 2 2/3 x 1/2 CORRUGATION **

SIZE	*MIN.	MAXIMUM					
		(Ga)	16	14	12	10	8
12"	12"		204'	256'			
15"	12"		162'	204'			
18"	12"		135'	169'	239'		
24"	12"		100'	126'	178'		
30"	12"		79'	100'	142'		
36"	12"		65'	83'	117'	152'	
42"	12"		55'	70'	100'	130'	160'
48"	12"		48'	61'	87'	113'	139'
54"	12"			54'	77'	100'	123'
60"	12"				69'	90'	111'
66"	12"					81'	100'
72"	12"					74'	91'
78"	12"						81'
84"	12"						69'

CAAP (CORRUGATED ALUMINUM) AASHTO M196 2 2/3 x 1/2 CORRUGATION **

SIZE	*MIN.	MAXIMUM					
		(Ga)	16	14	12	10	8
12"	12"		123'	155'	218'	281'	344'
15"	12"		98'	123'	174'	224'	275'
18"	12"		81'	102'	144'	187'	228'
24"	12"		60'	76'	108'	139'	171'
30"	12"			60'	85'	111'	136'
36"	12"			50'	71'	92'	113'
42"	12"				60'	78'	96'
48"	12"				52'	68'	84'
54"	12"				46'	50'	74'
60"	12"					50'	62'
66"	12"						51'
72"	12"						41'

HDPE ASSHTO M294

SIZE	*MIN.	MAX.
12"	2.0'	20'
15"	2.0'	20'
18"	2.0'	20'
24"	2.0'	20'
30"	2.0'	17'
36"	2.0'	17'
42"	2.0'	17'
48"	2.0'	17'
54"	2.0'	17'
60"	2.0'	17'

PVC–ASTM F949 ASSHTO M304

SIZE	*MIN.	MAX.
12"	2.0'	30'
15"	2.0'	30'
18"	2.0'	30'
24"	2.0'	30'
30"	2.0'	30'
36"	2.0'	30'

APPLICATIONS

		RCP (REINFORCED CONCRETE) AASHTO M170	CSP (CORRUGATEDSTEEL) AASHTO M36	CAAP (CORRUGATED ALUMINUM) AASHTO M196	HDPE ASSHTO M294	PVC–ASTM F949 ASSHTO M304
OPEN END CROSS PIPES	SWT	CAN BE USED	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE	DO NOT USE
	RT & SRT	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
STORM DRAIN SYSTEMS	SWT	CAN BE USED	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE	DO NOT USE
	RT & SRT	CAN BE USED	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	CAN BE USED	CAN BE USED
TRANSVERSE MEDIAN PIPES	SWT	CAN BE USED	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE	DO NOT USE
	RT & SRT	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
SLOPE DRAINS	SWT	DO NOT USE	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
	RT & SRT	DO NOT USE	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
SIDE DRAINS	SWT	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
	RT & SRT	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED

*MINIMUM FILL HEIGHT IS MEASURED FROM TOP OF PIPE TO BOTTOM OF PAVEMENT STRUCTURE

** FOR DIFFERENT CORRUGATIONS AND ARCH PIPES REFER TO ROADWAY DESIGN MANUAL AND MANUFACTURERS SPECIFICATION.

NOTES: FILL HEIGHTS SHOWN WERE CALCULATED USING AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

1' MINIMUM COVER FOR ALL SIDE DRAIN PIPE IN ACCORDANCE WITH STANDARD SPECIFICATIONS

ALL PIPE TYPES ARE SUBJECT TO THE MAXIMUM AND MINIMUM FILL HEIGHT REQUIREMENTS AS FOUND IN CHAPTER 5 OF THE ROADWAY DESIGN MANUAL. THE APPROPRIATE CLASS OF PIPE FOR RCP AND GAGE THICKNESS FOR CSP/CAAP SHOULD BE SELECTED BASED ON FILL HEIGHT. RCP IS NOT ALLOWED FOR GRADES >10%.

FOR COUNTIES LISTED IN ARTICLE 310–2 OF THE STANDARD SPECIFICATIONS CSP IS NOT ALLOWED. IN OTHER COUNTIES CSP REQUIRES AN ACCEPTABLE COATING IN ACCORDANCE WITH 1032–4.

SITE SPECIFIC CONDITIONS MAY LIMIT A PARTICULAR MATERIAL BEYOND WHAT IS IDENTIFIED IN THE TABLE. THESE CONDITIONS INCLUDE, BUT ARE NOT LIMITED TO, ABRASION, ENVIRONMENTAL, SOIL RESISTIVITY AND PH, HIGH GROUND WATER, AND SPECIAL LOADING CONDITIONS. THE HYDRAULIC DESIGN ENGINEER WILL DETERMINE IF ADDITIONAL RESTRICTIONS ARE NECESSARY.

ONLY PIPE WITH SMOOTH WALL INSIDE WALLS WILL BE ALLOWED FOR STORM DRAIN SYSTEMS.

DO NOT USE ALTERNATE PIPE WHEN FILL HEIGHT IS <2' OR >20'.

DEFINITIONS:

STATEWIDE TIER (SWT)–THE STRATEGIC HIGHWAY CORRIDOR NETWORK AS APPROVED BY THE BOARD OF TRANSPORTATION.

REGIONAL TIER (RT)– US AND NC ROUTES NOT ON THE STATEWIDE TIER.

SUBREGIONAL TIER (SRT)– SR ROUTES

SIDE DRAINS– STORM DRAIN PIPES RUNNING PARALLEL TO THE ROADWAY TO INCLUDE PIPES IN THE MEDIANS, OUTSIDE DITCHES, DRIVEWAYS, AND UNDER SHOULDER BERM GUTTER ALONG OUTSIDE SHOULDERS GREATER THAN 4 FEET WIDE. MAY OR MAY NOT BE OPEN ENDED.

STORM DRAIN SYSTEMS– LATERAL DRAIN PIPE UNDER CURB AND GUTTER, EXPRESSWAY GUTTER, AND SHOULDER BERM GUTTER (WITH SHOULDERS 4 FEET WIDE OR LESS) THAT CONNECT DRAINAGE STRUCTURES AND IS NOT OPEN ENDED. ALSO INCLUDES CROSS DRAIN CONNECTING TWO OR MORE SYSTEMS OR SYSTEM OUTLETS.

TRANSVERSE MEDIAN DRAINS– SHALLOW CROSS DRAIN PIPE THAT COLLECTS DRAINAGE IN A MEDIAN DITCH OR CURB SECTION AND DEPOSITS IT OUTSIDE DITCHES OR NATURAL DRAINAGE CHANNELS. MAY OR MAY NOT BE OPEN ENDED.

09/21/15

STRUCTURAL PLATE STEEL PIPE ARCHES
6"x2" Corrugation
18" Corner Radius

Span	Rise	Area	Minimum Cover	Minimum Gage	Maximum Fill Height (ft.) for Corner Pressure 4000 lb/ft^2	6000 lb/ft^2
6'-1"	4'-7"	22	2'	12	16	24
6'-4"	4'-7"	24	2'	12	15	23
6'-9"	4'-11"	26	2'	12	14	21
7'-0"	5'-1"	28	2'	12	14	21
7'-3"	5'-3"	31	2'	12	13	20
7'-8"	5'-5"	33	2'	12	12	19
7'-11"	5'-7"	35	2'	12	12	18
8'-2"	5'-9"	38	2'	12	12	18
8'-7"	5'-11"	40	2'	12	11	17
8'-10"	6'-1"	43	2'	12	11	16
9'-4"	6'-3"	46	2'	12	10	16
9'-6"	6'-5"	49	2'	12	10	15
9'-9"	6'-7"	52	2'	10	10	15
10'-3"	6'-9"	55	3'	10	9	14
10'-8"	6'-11"	58	3'	10	9	13
10'-11"	7'-1"	61	3'	10	9	13
11'-5"	7'-3"	64	3'	10	8	13
11'-7"	7'-5"	67	3'	10	8	12
11'-10"	7'-7"	71	3'	10	8	12
12'-4"	7'-9"	74	3'	8	8	12
12'-6"	7'-11"	78	3'	8	8	12
12'-8"	8'-1"	81	3'	8	7	11
12'-10"	8'-4"	85	3'	8	7	11
13'-5"	8'-5"	89	3'	8	7	11
13'-11"	8'-7"	93	3'	8	7	10
14'-1"	8'-9"	97	4'	8	7	10
14'-3"	8'-11"	101	4'	8	6	10
14'-10"	9'-1"	105	4'	8	6	10
15'-4"	9'-3"	109	4'	8	6	9
15'-6"	9'-5"	113	4'	8	6	9
15'-8"	9'-7"	118	4'	8	6	9
15'-10"	9'-10"	122	4'	8	6	9
16'-5"	9'-11"	126	4'	8	6	9
16'-7"	10'-1"	131	4'	8	6	9

STRUCTURAL PLATE STEEL PIPE ARCHES
6"x2" Corrugation
31" Corner Radius

Span	Rise	Area	Minimum Cover	Minimum Gage	Maximum fill Height (ft) for Corner Pressure 4000 lb/ft²	6000 lb/ft²
13'-3"	9'-4"	97	4'	8	12	19
13'-6"	9'-6"	102	4'	8	12	19
14'-0"	9'-8"	105	4'	8	12	18
14'-2"	9'-10"	109	4'	8	12	18
14'-5"	10'-0"	114	4'	8	11	17
14'-11"	10'-2"	118	4'	8	11	17
15'-4"	10'-4"	123	4'	8	11	16
15'-7"	10'-6"	127	4'	8	10	16
15'-10"	10'-8"	132	4'	8	10	16
16'-3"	10'-10"	137	4'	8	10	15
16'-6"	11'-0"	142	4'	8	10	15
17'-0"	11'-2"	146	4'	8	10	15
17'-2"	11'-4"	151	4'	8	9	14
17'-5"	11'-6"	157	4'	8	9	14
17'-11"	11'-8"	161	4'	8	9	14
18'-1"	11'-10"	167	4'	8	9	14
18'-7"	12'-0"	172	4'	8	9	13
18'-9"	12'-2"	177	4'	8	9	13
19'-3"	12'-4"	182	4'	8	8	13
19'-6"	12'-6"	188	4'	8	8	13
19'-8"	12'-8"	194	4'	8	8	12
19'-11"	12'-10"	200	4'	8	8	12
20'-5"	13'-0"	205	4'	8	8	11
20'-7"	13'-2"	211	4'	8	8	11

STRUCTURAL PLATE ALUMINUM PIPE ARCH
9"x2 1/2" Corrugations
28.8 Corner Radius

Span	Rise	Area	Minimum Cover	Minimum Thickness	Maximum fill Height (ft) for Corner Pressure 4000 lb/ft^2	6000 lb/ft^2
5'-11"	5'-4"	25	2'	0.100"	24	32*
6'-8"	5'-7"	29	2'	0.100"	22	29*
7'-4"	5'-11"	34	2'	0.100"	20	26*
8'-0"	6'-2"	39	2'	0.100"	18	24*
8'-7"	6'-6"	45	2'	0.100"	17	22*
9'-0"	6'-8"	48	2'	0.100"	16	21*
9'-4"	6'-10"	50	2'	0.125"	17	20
10'-0"	7'-1"	56	3'	0.125"	16	19
10'-5"	7'-3"	60	3'	0.125"	15	18
11'-2"	7'-6"	66	3'	0.125"	14	17
11'-8"	7'-10"	73	3'	0.125"	13	16
12'-2"	8'-0"	76	3'	0.150"	13	19
12'-10"	8'-3"	83	3'	0.150"	12	18
13'-7"	8'-7"	91	3'	0.150"	11	17
14'-3"	8'-10"	98	4'	0.150"	11	16
14'-9"	9'-2"	107	4'	0.150"	10	16
15'-3"	9'-4"	111	4'	0.150"	10	15
16'-0"	9'-7"	119	4'	0.150"	10	14
16'-8"	9'-11"	128	4'	0.150"	9	12
16'-11"	10'-1"	132	4'	0.150"	9	12

* 0.125" Minimum Thickness Required

STRUCTURAL PLATE ALUMINUM PIPE
9"x2 1/2" Corrugation
Maximum Height of Cover Limits in Feet

Size	Area	Minimum Cover	Thickness in Inches														
			0.10		0.125		0.15		0.175		0.20		0.225		0.25	
			Cir.	El.	Cir.	El.	Cir.	El.	Cir.	El.	Cir.	El.	Cir.	El.	Cir.	El.
72	28	1'	24		26	32	28	41	30	48	32	55	34	61	36	66
84	38	1.5'	20		23	27	24	35	25	41	26	47	28	52	29	57
96	50	1.5'	18		21	24	22	30	22	36	23	41	24	45	25	50
108	64	2'			19	21	20	27	21	32	21	37	22	40	22	44
120	78	2'			19	19	19	24	20	29	20	33	20	36	21	40
132	95	2'					18	22	19	26	19	30	19	33	20	36
144	113	2.5					18	20	18	24	19	27	19	30	19	33
156	133	2.5					18	18	18	22	18	25	18	28	19	30
168	154	2.5					17		18	20	18	23	18	26	18	28
180	177	2.5					16		17	19	18	22	18	24	18	26

CORRUGATED ALUMINUM PIPE
3"x1" Corrugation
Maximum Height of Cover Limits in Feet

Size	Area	Minimum Cover	Thickness in Inches							
			.075		.105		.135		.164	
			Cir.	El.	Cir.	El.	Cir.	El.	Cir.	El.
36	7.1	1	24	37	27	51	30	61	34	68
42	9.6	1			23	44	25	51	27	55
48	12.6	1			21	38	22	45	24	48
54	15.9	1			20	34	21	42	22	44
60	19.6	1			19	31	20	40	20	41
66	23.8	1			18	28	19	38	19	39
72	28.3	1			18	25	18	37	19	38
78	33	1			18	23	18	31	18	37
84	38	1.5			17	19	18	25	18	31
90	44	1.5			15		17	20	18	25
96	50	1.5			12		16		17	21
102	57	2					14		17	
108	64	2					11		14	
114	71	2							12	
120	78	2							10	

D. Minimum and Maximum Fill Over Pipes

The following tables provide acceptable minimum and maximum earthfill heights over the pipe for several different types of pipe materials.

Table 1. Minimum Gauge for Corrugated Metal Pipe (CMP) *(Reference 1)*

Diameter, in.	Acceptable Fill Height, ft		Minimum Gauge CMP			
			Steel (corrugations)		Aluminum (corrugations)	
	Minimum	Maximum	2 2/3 x ½ in.	3 x 1 in.	2 2/3 x ½ in.	3 x 1 in.
≤18	2	25	16	16	16	16
21	2	25	16	16	16	16
24	2	23	16	16	16	16
	>23	25	16	16	12	16
30	2	18	16	16	14	16
	>18	25	16	16	12	16
36	2	15	16	16	14	16
	>15	25	16	16	12	16
42	2	22	16	16	12	16
	>22	23	16	16	10	16
	>23	24	16	16	---	16
	>24	25	14	16	---	14
48	2	19	16	16	12	16
	>19	20	16	16	10	16
	>20	21	16	16	---	16
	>21	23	14	16	---	14
	>23	25	12	16	---	14
54	2	17	14	16	12	16
	>17	18	14	16	10	16
	>18	20	14	16	---	14
	>20	23	12	16	---	14
	>23	25	12	16	---	12
60	2	16	12	16	10	16
	>16	20	12	16	---	14
	>20	23	12	16	---	12
	>23	25	10	16	---	12
66	2	15	10	16	---	16
	>15	19	10	16	---	14
	>19	22	10	16	---	12
	>22	25	---	16	---	12

Table 1. Minimum Gauge for Corrugated Metal Pipe (CMP) *(Reference 1)*

Diameter, in.	Acceptable Fill Height, ft		Minimum Gauge CMP			
			Steel (corrugations)		Aluminum (corrugations)	
	Minimum	Maximum	2 2/3 x ½ in.	3 x 1 in.	2 2/3 x ½ in.	3 x 1 in.
72	2	13	10	16	---	16
	>13	17	10	16	---	14
	>17	20	10	16	---	12
	>20	24	---	16	---	10
	>24	25	---	14	---	10
78	2	16	---	16	---	14
	>16	22	---	16	---	12
	>22	25	---	14	---	10

Table 2. Minimum Thickness for Welded Steel Pipe *(Reference 1)*

Pipe Diameter, in	Acceptable Fill Height, ft		Minimum Pipe Wall Thickness, in
	Minimum	Maximum	
≤10	2	30	0.187
12	2	25	0.187
14, 16	2	30	0.25
18	2	23	0.25
	>23	25	0.375
20	2	18	0.25
	>18	25	0.375
24	2	12	0.25
	>12	25	0.375
30	2	8	0.25
	>8	18	0.375
	>18	25	0.5
36	2	6	0.25
	>6	12	0.375
	>12	23	0.5
42	2	5	0.25
	>5	9	0.375
	>9	16	0.5
48	2	4	0.25
	>4	7	0.375
	>7	12	0.5

Table 3. Minimum Acceptable PVC Pipe *(Reference 1)*

Nominal Pipe Diameter, in	Acceptable Fill Height, ft		Minimum Acceptable PVC Type[1]	
	Minimum	Maximum	Schedule	Standard Dimension Ratio (SDR)
4	2	10	40	26
	>10	16	40	21
	>16	21	40	---
	>21	25	80	---
6	2	10	40	26
	>10	12	40	21
	>12	16	80	21
	>16	25	80	---
8	2	10	40	26
	>10	16	80	21
	>16	25	80	---
10	2	8	40	21
	>8	16	80	21
	>16	24	80	---
12 -14	2	7	40	26
	>7	10	80	26
	>10	16	80	21
	>16	22	80	---
16	2	7	40	26
	>7	10	80	26
	>10	16	80	21
	>16	21	80	---
18	2	7	40	26
	>7	10	80	26
	>10	16	80	21
	>16	20	80	---
20	2	6	40	26
	>6	10	80	26
	>10	16	80	21
	>16	20	80	---

Table 3. Minimum Acceptable PVC Pipe *(Reference 1)*

Nominal Pipe Diameter, in	Acceptable Fill Height, ft		Minimum Acceptable PVC Type[1]	
	Minimum	Maximum	Schedule	Standard Dimension Ratio (SDR)
24	2	<3	---	26
	3	6	40	26
	>6	10	80	26
	>10	16	80	21
	>16	19	80	---
30 - 36	2	10	---	26
	>10	16	---	21

[1] Polyvinyl Chloride Pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241.

Table 4. Corrugated Plastic Tubing[2] (CPT) *(References 1,2,3)*

Trench Width, in	Max Fill Height, ft	Maximum Diameter CPT (in) per Installation Type	
		Tile Machine	Open Trench
12	any	8”	6”
16	8.4	12”	10”
20	6.8	15”	12”
24	6.0	18”	18”
28	5.6	24”	18”
32	5.3	24”	24”

[2]Single wall corrugated polyethylene (PE) pipe conforming to ASTM F405 or F667

References:

1. USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.

2. American Society of Agricultural and Biological Engineers. 2008. Standard ASAE EP480. Design of Subsurface Drains in Humid Areas.

3. Spangler, M.G. and R.L. Handy. 1982. Soil Engineering. 4th Edition.

D. Minimum and Maximum Fill Over Pipes

The following tables provide acceptable minimum and maximum earthfill heights over the pipe for several different types of pipe materials.

Table 1. Minimum Gauge for Corrugated Metal Pipe (CMP) *(Reference 1)*

Diameter, in.	Acceptable Fill Height, ft		Minimum Gauge CMP			
			Steel (corrugations)		Aluminum (corrugations)	
	Minimum	Maximum	2 2/3 x ½ in.	3 x 1 in.	2 2/3 x ½ in.	3 x 1 in.
≤18	2	25	16	16	16	16
21	2	25	16	16	16	16
24	2	23	16	16	16	16
	>23	25	16	16	12	16
30	2	18	16	16	14	16
	>18	25	16	16	12	16
36	2	15	16	16	14	16
	>15	25	16	16	12	16
42	2	22	16	16	12	16
	>22	23	16	16	10	16
	>23	24	16	16	---	16
	>24	25	14	16	---	14
48	2	19	16	16	12	16
	>19	20	16	16	10	16
	>20	21	16	16	---	16
	>21	23	14	16	---	14
	>23	25	12	16	---	14
54	2	17	14	16	12	16
	>17	18	14	16	10	16
	>18	20	14	16	---	14
	>20	23	12	16	---	14
	>23	25	12	16	---	12
60	2	16	12	16	10	16
	>16	20	12	16	---	14
	>20	23	12	16	---	12
	>23	25	10	16	---	12
66	2	15	10	16	---	16
	>15	19	10	16	---	14
	>19	22	10	16	---	12
	>22	25	---	16	---	12

Table 1. Minimum Gauge for Corrugated Metal Pipe (CMP) *(Reference 1)*

Diameter, in.	Acceptable Fill Height, ft		Minimum Gauge CMP			
	Minimum	Maximum	Steel (corrugations)		Aluminum (corrugations)	
			2 2/3 x ½ in.	3 x 1 in.	2 2/3 x ½ in.	3 x 1 in.
72	2	13	10	16	---	16
	>13	17	10	16	---	14
	>17	20	10	16	---	12
	>20	24	---	16	---	10
	>24	25	---	14	---	10
78	2	16	---	16	---	14
	>16	22	---	16	---	12
	>22	25	---	14	---	10

Table 2. Minimum Thickness for Welded Steel Pipe *(Reference 1)*

Pipe Diameter, in	Acceptable Fill Height, ft		Minimum Pipe Wall Thickness, in
	Minimum	Maximum	
≤10	2	30	0.187
12	2	25	0.187
14, 16	2	30	0.25
18	2	23	0.25
	>23	25	0.375
20	2	18	0.25
	>18	25	0.375
24	2	12	0.25
	>12	25	0.375
30	2	8	0.25
	>8	18	0.375
	>18	25	0.5
36	2	6	0.25
	>6	12	0.375
	>12	23	0.5
42	2	5	0.25
	>5	9	0.375
	>9	16	0.5
48	2	4	0.25
	>4	7	0.375
	>7	12	0.5

Table 3. Minimum Acceptable PVC Pipe *(Reference 1)*

Nominal Pipe Diameter, in	Acceptable Fill Height, ft		Minimum Acceptable PVC Type[1]	
	Minimum	Maximum	Schedule	Standard Dimension Ratio (SDR)
24	2	<3	---	26
	3	6	40	26
	>6	10	80	26
	>10	16	80	21
	>16	19	80	---
30 - 36	2	10	---	26
	>10	16	---	21

[1] Polyvinyl Chloride Pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241.

Table 4. Corrugated Plastic Tubing[2] (CPT) *(References 1,2,3)*

Trench Width, in	Max Fill Height, ft	Maximum Diameter CPT (in) per Installation Type	
		Tile Machine	Open Trench
12	any	8”	6”
16	8.4	12”	10”
20	6.8	15”	12”
24	6.0	18”	18”
28	5.6	24”	18”
32	5.3	24”	24”

[2]Single wall corrugated polyethylene (PE) pipe conforming to ASTM F405 or F667

References:

1. USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.

2. American Society of Agricultural and Biological Engineers. 2008. Standard ASAE EP480. Design of Subsurface Drains in Humid Areas.

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	Minimum	Maximum	Schedule	Standard Dimension Ratio (SDR)
24	2	<3	---	26
	3	6	40	26
	>6	10	80	26
	>10	16	80	21
	>16	19	80	---
30 - 36	2	10	---	26
	>10	16	---	21

[1] Polyvinyl Chloride Pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241.

Table 4. Corrugated Plastic Tubing[2] (CPT) *(References 1,2,3)*

Trench Width, in	Max Fill Height, ft	Maximum Diameter CPT (in) per Installation Type	
		Tile Machine	Open Trench
12	any	8”	6”
16	8.4	12”	10”
20	6.8	15”	12”
24	6.0	18”	18”
28	5.6	24”	18”
32	5.3	24”	24”

[2]Single wall corrugated polyethylene (PE) pipe conforming to ASTM F405 or F667

References:

1. USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.

2. American Society of Agricultural and Biological Engineers. 2008. Standard ASAE EP480. Design of Subsurface Drains in Humid Areas.

3. Spangler, M.G. and R.L. Handy. 1982. Soil Engineering. 4th Edition.

PIPE BURY DEPTHS

18-Mar-04

NON-CAMA COUNTIES

Jurisdictional Streams			Non-Jurisdictional Streams	
Pipe Dia.	Bury Depth		Pipe Dia.	Bury Depth
18"	3.6" (20%)	=0.3'	18"	Not Req'd
24"	4.8" (20%)	=0.4'	24"	Not Req'd
30"	6.0" (20%)	=0.5'	30"	Not Req'd
36"	7.2" (20%)	=0.6'	36"	Not Req'd
42"	8.4" (20%)	=0.7'	42"	Not Req'd
48"	9.6" (20%)	=0.8'	48"	Not Req'd
54"	12.0"	=1.0'	54"	Not Req'd
60"	12.0"	=1.0'	60"	12.0"
66"	12.0"	=1.0'	66"	12.0"
72"	12.0"	=1.0'	72"	12.0"

CAMA COUNTIES

Jurisdictional Streams		Non-Jurisdictional Streams	
Pipe Dia. *	Bury Depth	Pipe Dia.	Bury Depth
		18"	Not Req'd
		24"	Not Req'd
		30"	Not Req'd
36"	12.0"	36"	Not Req'd
42"	12.0"	42"	Not Req'd
48"	12.0"	48"	Not Req'd
54"	12.0"	54"	Not Req'd
60"	12.0"	60"	12.0"
66"	12.0"	66"	12.0"
72"	12.0"	72"	12.0"

* Since the minimum bury depth is 12", a 36" diameter pipe is considered the smallest practical pipe to use.

PIPE BURY DEPTHS

MINIMUM EQUIVALENT PIPE DIA (in.)

BURIED Pipe Dia.	Equivalent Inlet Ctrl. Pipe Dia.	Equivalent Outlet Ctrl. Pipe Dia.
18	15	12
24	18	15
30	24	18
36	30	24
42	36	30
48	42	36
54	48	42
60	54	48
66	60	54
72	66	60

INLET COMPUTATION SHEET

DATE: ________ SHEET ____ OF ____

I.D. NO. ________ PROJ. NO.: ______________ COUNTY: _______________________ DESIGNED BY: _______________

DESCRIPTION:____ REACH: _____________________ CHECKED BY: _______________

LOCATION			ROADWAY		RUNOFF							INLET			
INLET NO.	**STATION**	**ELEVATION**	**GRADE**	**CROSS SLOPE**	**DRAINAGE AREA**	**RUNOFF COEFF.**	**TIME OF CONC.**	**RAINFALL INTENSITY**	**DISCHARGE FROM D.A.**	**DISCHARGE CARRYOVER**	**TOTAL DISCHARGE**	**SPREAD**	**INTERCEPT**	**BYPASS**	REMARKS
DES./ CONST.					D.A.	C	T_C	I	$Q_{D.A.}$	Q_C	$Q_T = Q_{D.A.} + Q_C$		Q_I	Q_B	

This form can be downloaded from the Hydraulics Unit website.

STORM DRAIN DESIGN COMPUTATIONS

[SEE ALSO HYDRAULIC GRADE LINE SHEETS]

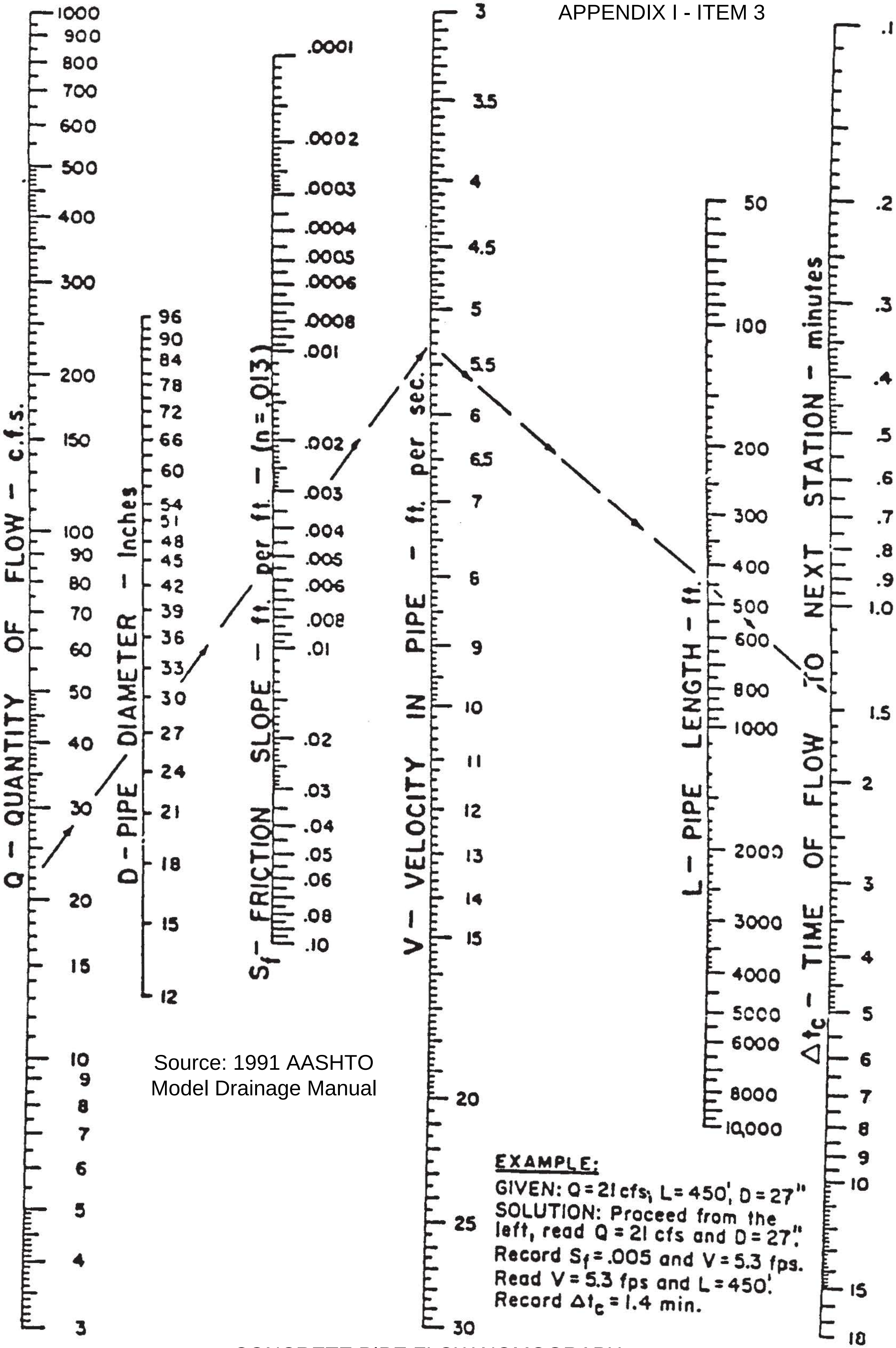
DATE: SHEET ____ OF ____

I.D. NO. _____________ PROJ. NO. ___________________ COUNTY: ______________________ DESIGNED BY: _______________

DESCRIPTION: ____ CHECKED BY: _______________

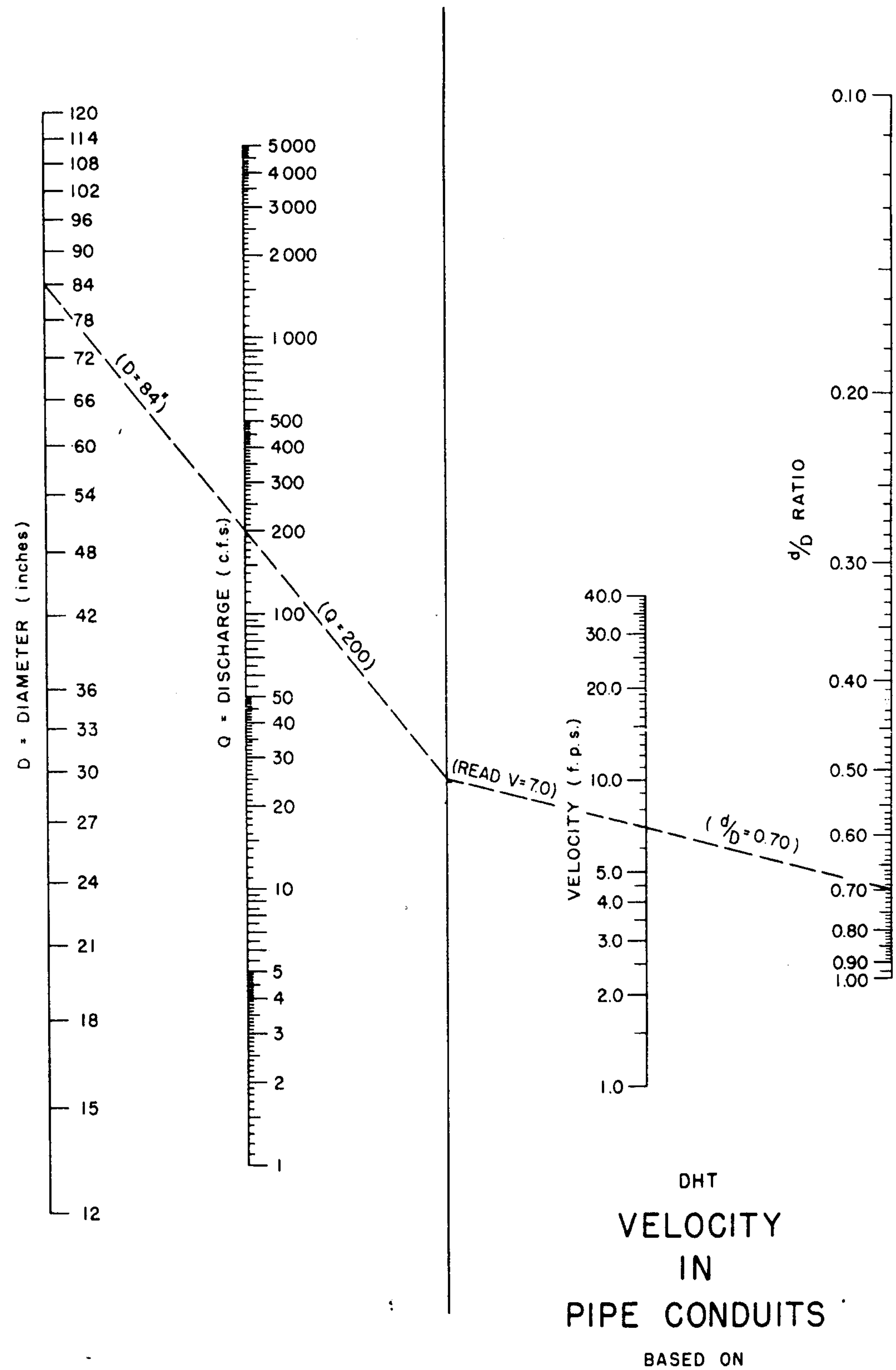
LOCATION		RUNOFF								PIPE DESIGN								
FROM	TO				TIME OF CONCENTRATION min.					INLET ELEV.	OUTLET ELEV.							
DES./ CONST.	DES./ CONST.	CUM. D.A. ac	SUM CA	PIPE L (ft)	INLET TIME	FLOW TIME	DESIGN TIME	INT I (in/hr)	DISCH. Q (cfs)	INV	INV	SLOPE ft/ft	DIA. in	MATERIAL	CAP. cfs	VEL. ft/s	UPSTREAM BOX DEPTH	REMARKS

This form can be downloaded from the Hydraulics Unit website.



Source: 1991 AASHTO
Model Drainage Manual

CONCRETE PIPE FLOW NOMOGRAPH



DHT

VELOCITY IN PIPE CONDUITS

BASED ON

$Q = VA$

NOMOGRAPH H

6/90

HYDRAULIC PROPERTIES - CIRCULAR PIPES

Pipe Diam. (Inch)	A Pipe Area (sq. ft.)	R Hydraulic Radius (feet)	Value of K = $1.486/n \times A \times R^{2/3}$ (n = 0.012)	Value of K = $1.486/n \times A \times R^{2/3}$ (n = 0.024)
8	0.349	0.167	13.1	6.5
10	0.545	0.208	23.7	11.9
12	0.785	0.250	38.6	19.3
15	1.227	0.313	70.0	35.0
18	1.767	0.375	113.8	56.9
21	2.405	0.438	171.7	85.8
24	3.142	0.500	245.1	122.5
27	3.976	0.563	335.5	167.8
30	4.909	0.625	444.4	222.2
33	5.940	0.688	572.9	286.5
36	7.069	0.750	722.6	361.3
42	9.621	0.875	1090	545.0
48	12.566	1.000	1556	778.1
54	15.904	1.125	2130	1065
60	19.635	1.250	2821	1411
66	23.758	1.375	3638	1819
72	28.274	1.500	4588	2294
78	33.183	1.625	5680	2840
84	38.485	1.750	6921	3460
90	44.179	1.875	8319	4159
96	50.265	2.000	9881	4940
102	56.745	2.125	11615	5807
108	63.617	2.250	13527	6763
114	70.882	2.375	15625	7812
120	78.540	2.500	17915	8958
126	86.590	2.625	20404	10202
132	95.033	2.750	23099	11550
138	103.869	2.875	26006	13003
144	113.097	3.000	29132	14566

STORM DRAIN PIPE

MAXIMUM CAPACITY TABLE

(1) PIPE SIZE	(2) MAXIMUM CAPACITY
12"	6
15"	9
18"	13
24"	25
30"	43
36"	64
42"	90
48"	120
54"	160
60"	200
66"	250

(1) CONCRETE PIPE

(2) CAPACITY (c.f.s.) BASED ON INLET CONTROL
FOR MAXIMUM DEPTH IN STANDARD CATCH BASIN

6/90

HYDRAULIC GRADE LINE

DATE: __________ **SHEET** ____**OF**____

ID NO. __________ **PROJECT:** ______________________ **COUNTY:** ______________ **DESIGNED BY:** ______________

DESCRIPTION: ____ **CHECKED BY:** ______________

INLET OR JUNCT. NO. DES. / CONST.	OUTLET W.S. ELEV.	D_O	Q_O	L_O	HEAD LOSSES					INLET W.S. ELEV.	RIM ELEV.	REMARKS
					H_f	H_c	H_e	H_b	H_t			

This form can be downloaded from the Hydraulics Unit website.

Reinforced Concrete Pipes (RCP)
Wall "B" Thickness

Diameter (inches)	Thickness (inches)
12	2.00
15	2.25
18	2.50
24	3.00
30	3.50
36	4.00
42	4.50
48	5.00
54	5.50
60	6.00
66	6.50
72	7.00
78	7.50
84	8.00
90	8.50
96	9.00
102	9.50
108	10.00

'V' DITCH WITH GRASS
6:1 SIDE SLOPES

For ditch with side slopes other than 6:1 multiply the discharge by a factor 6/Z, where Z is side slope

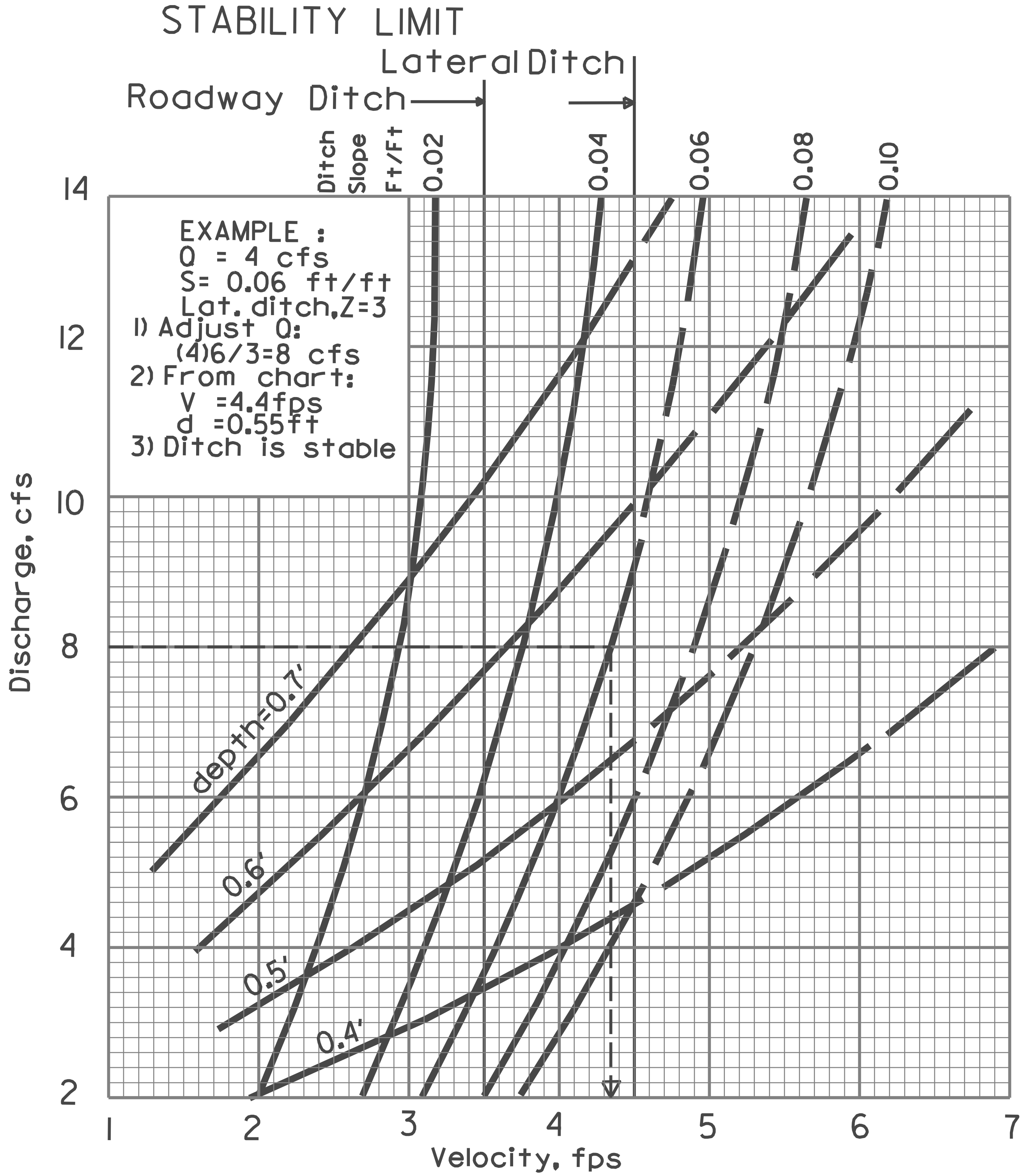


CHART 1

2 FT. BASE DITCH WITH GRASS
2:1 SIDE SLOPES

base width (ft)	Multiply Q by:
3	0.7
4	0.6
5	0.5
6	0.4

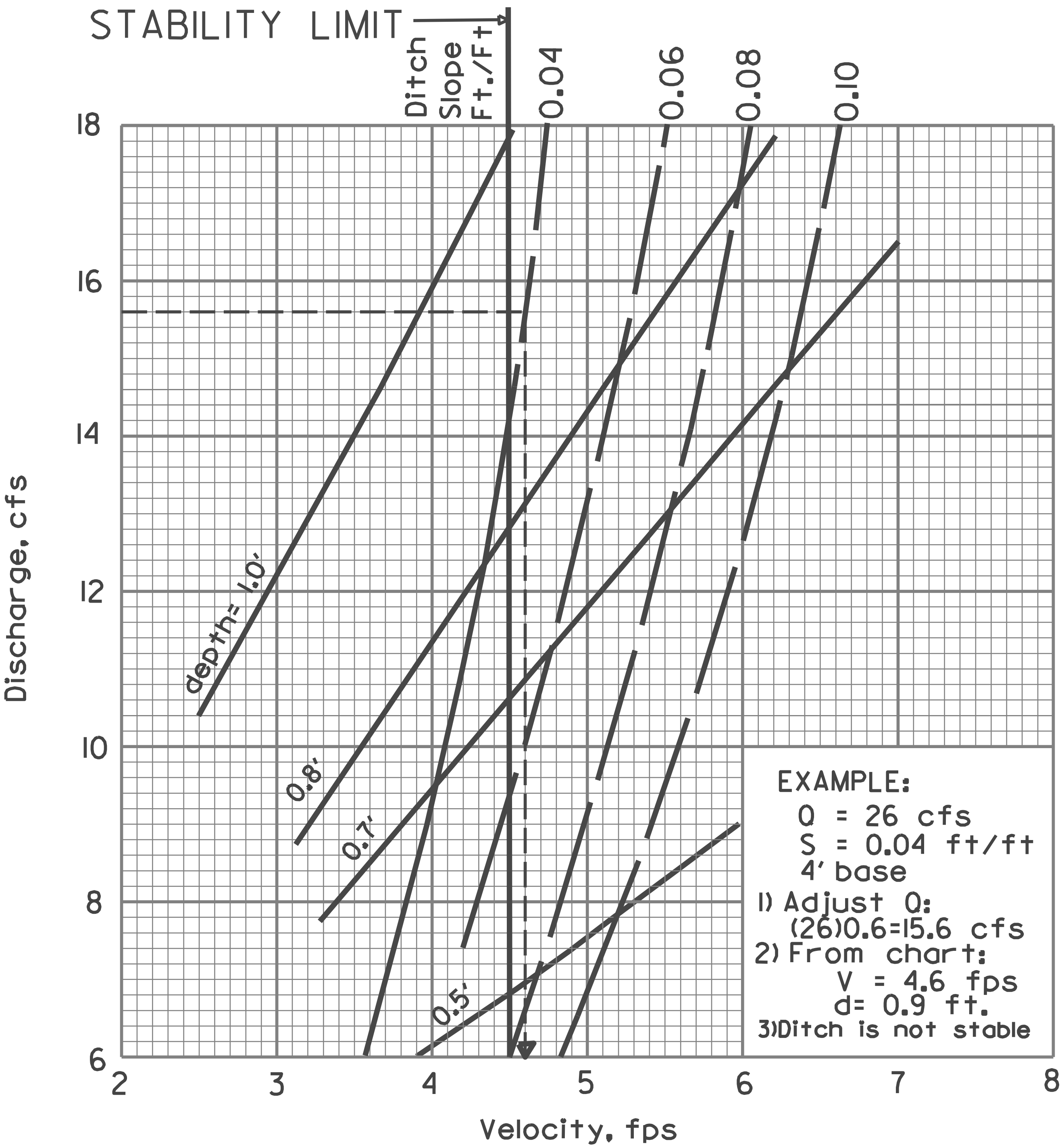


CHART 2

'V' DITCH WITH RIP RAP
2:1 SIDE SLOPES

For ditch with side slopes other than 2:1, multiply the discharge by a factor 2/Z where Z is the side slope.

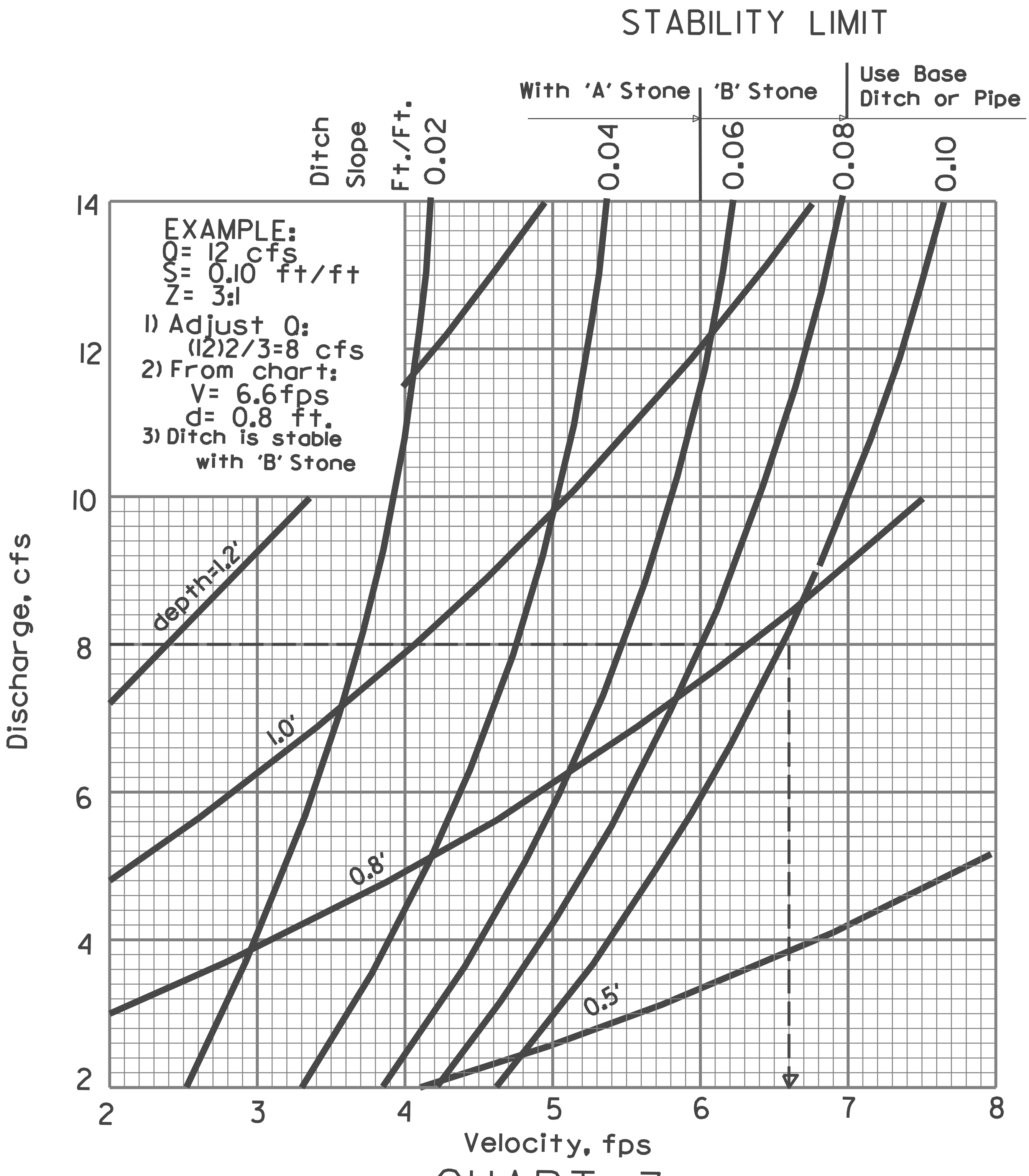


CHART 3

2 FT. BASE DITCH WITH RIPRAP LINING 2:1 SIDE SLOPES

base width (ft)	Multiply Q by:
3	0.7
4	0.6
5	0.5
6	0.4

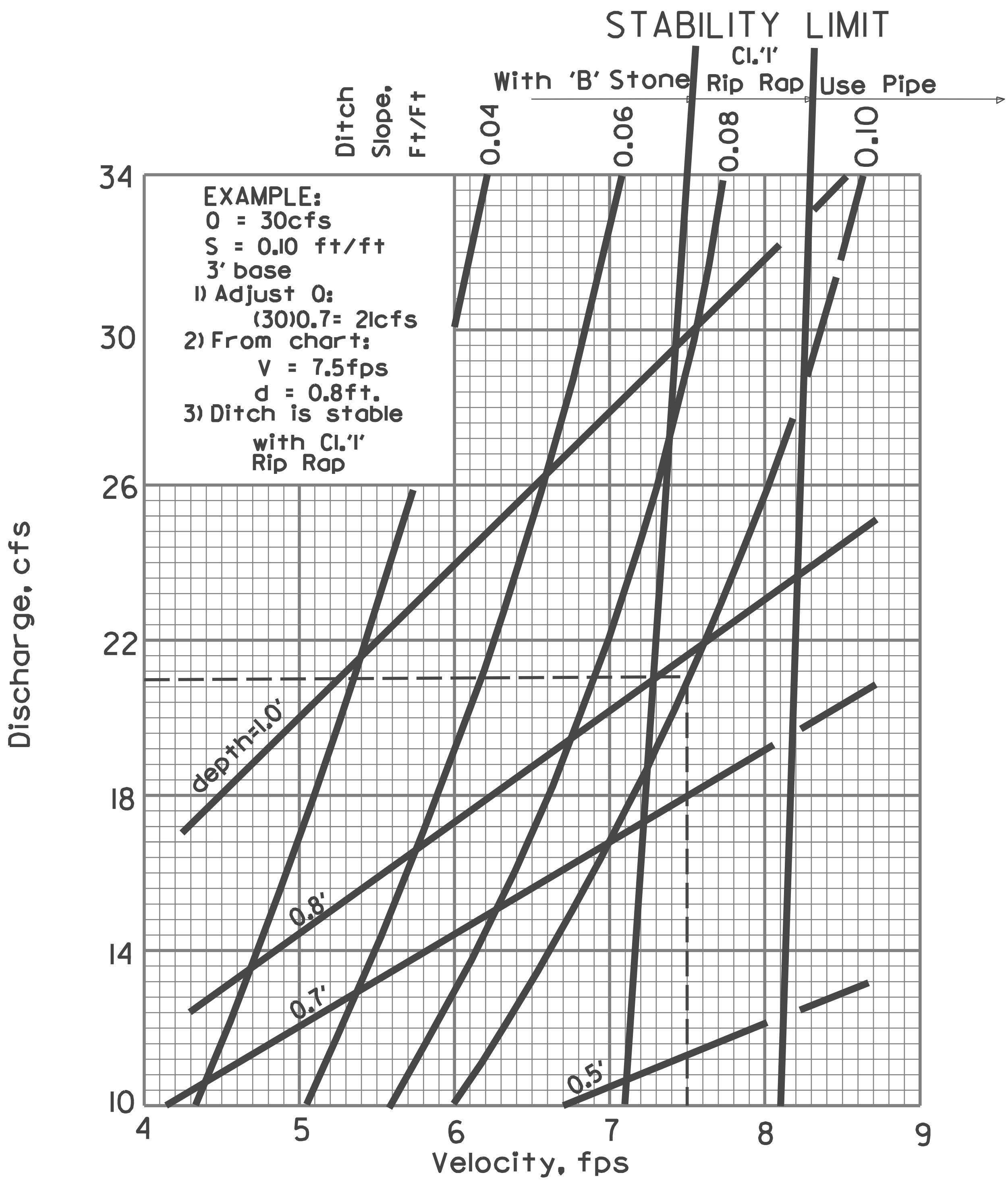
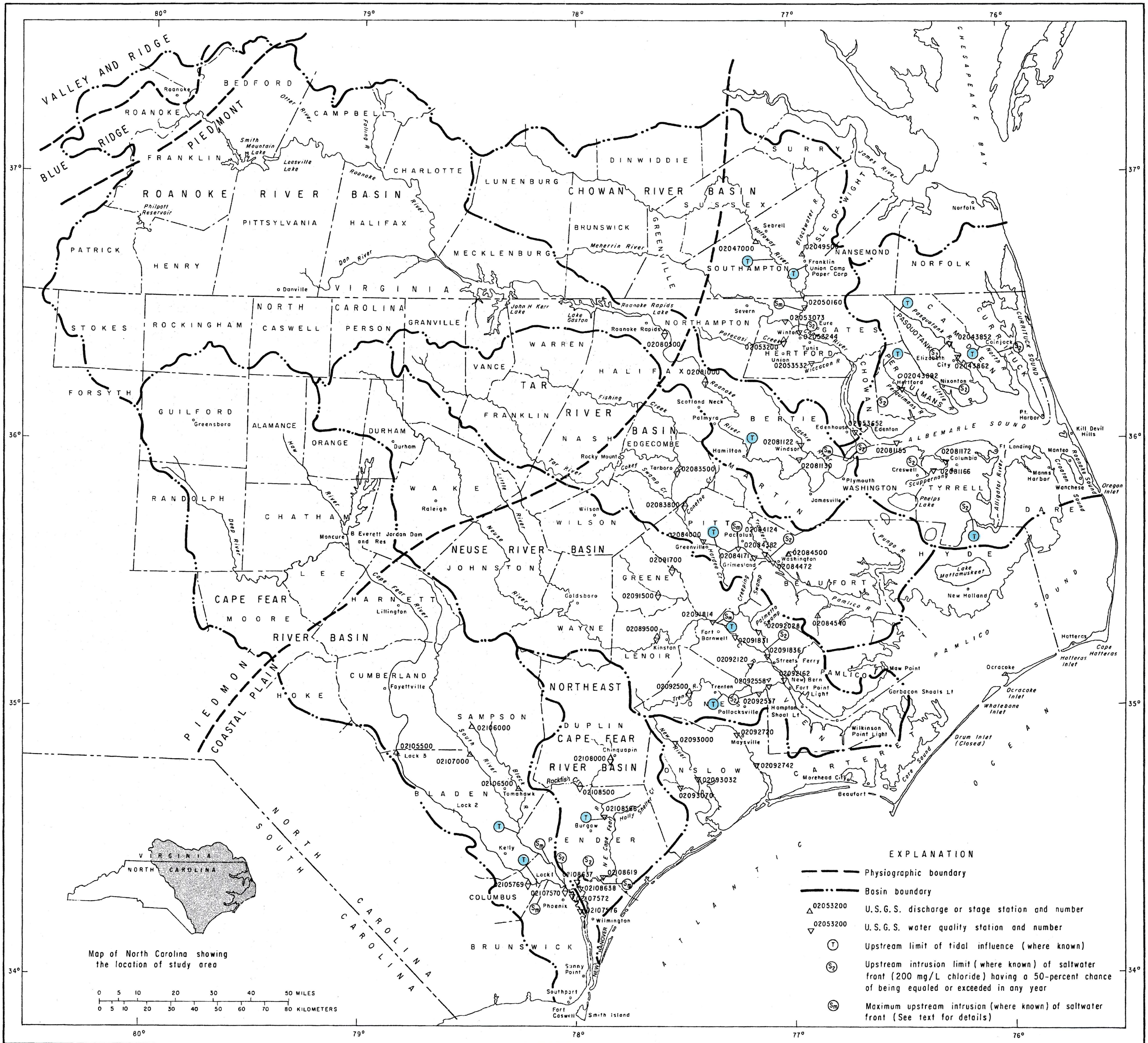


CHART 4

PREPARED IN COOPERATION WITH THE
NORTH CAROLINA DEPARTMENT OF NATURAL RESOURCES AND COMMUNITY DEVELOPMENT



Base from U. S. Geological Survey
State base map, 1975

MAJOR ESTUARIES AND SOUNDS OF NORTH CAROLINA

APPENDIX K

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PERMIT APPLICATION FORMS

- **Wetland and Surface Water Impacts Summary**
- **Riparian Buffer Impacts Summary**
- **Stormwater Management Plan (SMP)**
- **CAMA Major Permit Application (multiple forms)**

NOTE: These are intended for reference. Actual forms should be downloaded from Hydraulics website.

WETLAND AND SURACE WATER IMPACTS SUMMARY

			WETLAND IMPACTS					SURFACE WATER IMPACTS				
Site No.	Station (From/To)	Structure Size / Type	Permanent Fill In Wetlands (ac)	Temp. Fill In Wetlands (ac)	Excavation in Wetlands (ac)	Mechanized Clearing in Wetlands (ac)	Hand Clearing in Wetlands (ac)	Permanent SW impacts (ac)	Temp. SW impacts (ac)	Existing Channel Impacts Permanent (ft)	Existing Channel Impacts Temp. (ft)	Natural Stream Design (ft)
TOTALS*:												

*Rounded totals are sum of actual impacts

NOTES:

NC DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
ENTER DATE HERE
ENTER COUNTY HERE
ENTER TIP # HERE
ENTER WBS # HERE
SHEET XXX OF XXX

Revised 2016 09 09

APPENDIX L

RIPARIAN BUFFER IMPACTS SUMMARY

			IMPACT									BUFFER REPLACEMENT	
			TYPE			ALLOWABLE			MITIGABLE				
SITE NO.	STRUCTURE SIZE / TYPE	STATION (FROM/TO)	ROAD CROSSING	BRIDGE	PARALLEL IMPACT	ZONE 1 (ft^2)	ZONE 2 (ft^2)	TOTAL (ft^2)	ZONE 1 (ft^2)	ZONE 2 (ft^2)	TOTAL (ft^2)	ZONE 1 (ft^2)	ZONE 2 (ft^2)
					TOTALS:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

N.C. DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS

COUNTY
PROJECT: *WBS # (STIP #)*

DATE mm/dd/yyyy

SHEET OF

Rev. SEP 2016

APPENDIX L

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North Carolina Department of Transportation
Highway Stormwater Program
STORMWATER MANAGEMENT PLAN
FOR NCDOT PROJECTS

Overview

Introduction
The Stormwater Management Plan (SMP), is used to evaluate and present mitigation efforts for potential stormwater runoff impacts to surface waters. The SMP summarizes project stormwater management information including post-construction stormwater best management practices (BMPs) selected to mitigate stormwater impacts. This information is used to support compliance with the department's NPDES permit as well as other federal and state environmental permit applications during the design stage of a project.

This SMP form was developed for use on NCDOT roadway and bridge replacement projects and is being made available for non-road projects; however, some fields and sheets may not apply.

Instructions
Some general guidelines for filling out the SMP follow:

The workbook has been distributed with some cells protected in order to preserve formatting and formulas. Cell protection may be removed from each tab by selecting "Unprotect Sheet" under the Excel "Review" ribbon or by clicking "File" on the Excel ribbon and deactivating the "Protect Current Sheet" button under the "Protect Workbook" dropdown.

Fill out the applicable worksheets (not all sheets are required for all projects) with yellow tabs as completely as possible. The yellow cells within each worksheet should be filled in by the user. Some fields contain a pull-down list of options, but allow unique values to be entered. Further explanation of terms is provided in one of two ways: (1) click on the yellow cell of interest to display a message that describes what should be entered, or (2) click on the Guidance tab and scroll to the term and corresponding definition of interest for a more complete explanation.

Space is provided at the bottom of each worksheet or at the end of each row to include any additional comments that apply to a given section of the SMP. If needed, additional space can be created by unprotecting the sheet as described above, or by simply attaching additional documentation to the SMP.

The SMP should be saved using the following convention: [Project/TIP No.]_HYD_SMP_[YYYYMMDD].

Submittal of SMP To Hydraulics Unit
Please submit all completed SMP's to the Hydraulics Unit at the following address for archival and records retention as required by the Department's NPDES permit: **NCDOT_Hydraulics_SMP@ncdot.gov**
Submission of the SMP in the Microsoft Excel file format is preferred.
******* Note that submittal of the SMP to the Hydraulics Unit is not part of any permit approval process.***

Version Number	Revision Date	Revision Summary
2.0	September 29, 2014	Released for use.
2.01	December 1, 2014	Minor typographic corrections.
2.02	April 1, 2015	Clarified Swale and Filter Strip measurement instructions
2.03	October 7, 2015	Addition of Submittal Instructions on Overview Tab
2.04	November 23, 2015	Clarified fields and instructions on Bridge to Culvert Tab
2.05	April 4, 2016	Modified Dissipator Types on PSHs, Energy Diss. Tab
2.06	June 9, 2016	Updated Reference Website Links
2.07	September 12, 2016	Minor clarifications on Overview and Guidance Tabs

(Version 2.07; Released September 2016)

Note: For more information or guidance on the definitions provided below, reference the NCDOT Hydraulics Unit website,
https://connect.ncdot.gov/resources/hydro/Pages/default.aspx

General Guidance	
Referenced Documents	
North Carolina Department of Transportation (NCDOT) Stormwater Best Management Practices (BMP) Toolbox (2014) https://connect.ncdot.gov/resources/hydro/Pages/HSPProgramPages.aspx?PGM=BMPT	
Federal Highway Administration (FHWA) Hydraulic Engineering Circular No. 14 (HEC-14), Third Edition, July 2006 http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf	
General Project Information	
WBS Element:	The Work Breakdown Structure (WBS) Element is a unique project identifying number used by NCDOT's SAP management system. All projects have a WBS element.
TIP No.:	If the project is a Transportation Improvement Program (TIP) project, provide the TIP Project Number. If the project is not part of a TIP project, leave the cell blank.
Project Type:	Provide type of project activity.
NCDOT Contact:	Provide contact information for the project NCDOT representative.
Contractor/Designer:	Provide contact information for the project contractor or designer.
City/Town:	Provide either the municipality where the project takes place, or the nearest municipality to the project.
County(ies):	Provide the county where the project takes place. Include more than one county if necessary.
River Basin(s):	Provide the river basin in which the project takes place, from the 17 major river basins identified in North Carolina. Provide more than one river basin if necessary. More information on river basins, including interactive mapping tools, can be found on the North Carolina Department of Environment and Natural Resources (NCDENR) website, http://www.ncwater.org/?page=4
CAMA County:	Indicates whether the project occurs in a county subject to the Coastal Area Management Act (CAMA), administered by the Coastal Resources Commission. Cell populates based on selection in "County(ies)" cell. The "CAMA Map" tab illustrates these counties. A list of CAMA counties is provided on the North Carolina Division of Coastal Management website, http://deq.nc.gov/about/divisions/coastal-management/about-coastal-management/cama-counties
Wetlands within Project Limits?	Using the dropdown menu, indicate whether wetlands are present within the project limits.
Project Length:	Provide linear length of entire project. Enter "N/A" for non-road projects.
Surrounding Land Use:	Provide general information on the project area surrounding land uses.
Project Built-Upon Area (BUA):	The portion of a project that is covered by impervious or partially impervious surface including, but not limited to buildings; pavement and gravel areas such as roads, parking lots and paths; and recreation facilities such as tennis courts. Refer to NC Session Law 2006-246 for full definition.
Typical Cross Section:	Provide a brief description of the design or existing typical cross section, including median types and dimensions, if applicable. Enter "N/A" for non-road projects.
Annual Average Daily Traffic (design/future):	Provide the estimated design Annual Average Daily Traffic (AADT) within the project area (20-yr projection, typ.). Provide the year for which this estimation was made. The proposed AADT may be found as part of preliminary roadway design documents. Enter "N/A" for non-road projects.

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General Guidance	
General Project Information (Continued)	
Annual Average Daily Traffic (existing):	Provide the existing Annual Average Daily Traffic (AADT) for the project area and the year in which the estimate was performed. Enter "N/A" for non-road projects. AADT for a roadway may be obtained from NCDOT's Traffic Survey Unit website. http://www.ncdot.gov/projects/trafficsurvey/
General Project Narrative: (Description of Minimization of Water Quality Impacts)	Provide a summary of the current project area, including reference to NCDOT and non-NCDOT roadways in the project area, and facility type. Describe proposed improvements. Provide a brief description of any stormwater and water quality impacts as well as minimization efforts or mitigation measures utilized as part of the project design. Such efforts may include maximizing vegetative conveyance, minimizing directly connected impervious area (DCIA), minimizing diversion of stormwater, etc. Pressing 'alt + enter' will create a carriage return within the cell and advance the cursor to the next line.
Surface Water Body:	Provide the first named surface water to which runoff from the project area drains. If runoff from the project area drains to an unnamed tributary, provide the first named stream downstream of the unnamed tributary. Surface waters within the project area can be found from 7.5-minute USGS Topographic Maps, among other resources. If there are multiple water bodies, they should each be documented in the additional spaces provided in order according to station.
NCDWR Stream Index:	Provide the North Carolina Division of Water Resources' (NCDWR) stream index number for the water body (previously identified). The stream index can be found in the NCDWR Waterbody Reports. To download Waterbody Reports, refer to the NCDWR Classifications and Standards Unit (CSU) website. https://deq.nc.gov/river-basin-classification-schedule
NCDWR Surface Water Classification:	Designations applied to surface water bodies by NCDWR which define the best uses to be protected within these waters and carry with them an associated set of water quality standards to protect those uses. Surface water classifications can be found through the environmental documents for the project, as well as from NCDWR's Classifications and Standards Unit (CSU) website. https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/classifications
Primary (Surface Water Body Classification):	Provide primary classifications for the water body (previously defined). For example, water bodies classified as WS-I are also protected as Class C. All classifications should be listed in the spaces provided. For more information on primary surface water classifications, refer to. https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/classifications
Supplemental (Surface Water Body Classification):	Provide any supplemental classifications for the water body (previously identified) per NCDWR's Classifications and Standards Unit (CSU). For more information on supplemental surface water classifications, refer to, https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/classifications
Other Stream Classification:	Provide any surface water classifications as determined by agencies other than NCDWR, including The NC Division of Parks and Recreation, NC Wildlife Resources Commission, the NC Division of Coastal Management, the NC Division of Environmental Health, and the Marine Fisheries Commission. Other surface water classifications are generally listed in the project's environmental documents.
Impairment:	If the water body is impaired, provide the type of water quality impairment. Provide all impairments if more than one exists. Impaired waters and associated type of water quality impairment(s) are listed in the North Carolina Integrated Report. For more information, refer to the following section of NCDWR's website, http://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/water-quality-data-assessment/integrated-report-files

Note: For more information or guidance on the definitions provided below, reference the NCDOT Hydraulics Unit website,
https://connect.ncdot.gov/resources/hydro/Pages/default.aspx

General Guidance	
General Project Information (Continued)	
Aquatic Threatened/Endangered Species:	If threatened or endangered aquatic species (not terrestrial species) are present (indicate "Yes" or "No"), provide a brief description of the species and any related stormwater management measures used to protect the species of concern. Consult the project's Environmental Impact Statement (EIS) or Environmental Assessment (EA).
NRTR Stream ID, if available:	If available, provide the ID assigned to the water body in the Natural Resource Technical Report (NRTR). If the ID includes a superscript, denote it by selecting the character and checking the "Superscript" box in the "Font" dialogue box. Or, use the carat symbol (^). Note that NRTRs are not completed for all projects. "N/A" may be entered for such cases.
Buffer Rules in Effect:	Select the Riparian Area Buffer Rule that applies to your project, if applicable. Otherwise, select "N/A." For more information, refer to the following section of NCDWR's website, http://deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/401-wetlands-buffer-permitting/riparian-buffers-protection
Project Includes Bridge Spanning Water Body?	Using the dropdown menu, indicate whether a bridge spanning the listed water body is included as part of the project. If "Yes," be sure to describe all bridge BMPs that were used in the General Project Narrative. Refer to Chapter 9 of the Toolbox for additional information.
Deck Drains Discharge Over Water Body?	Using the dropdown menu, indicate whether deck drains discharge over the listed water body. Note that this cell will automatically be populated with "N/A" if "No" was selected in the previous cell. If "Yes" is selected, provide justification in the General Project Narrative section. Specifically, indicate why direct discharge could not be avoided.
Deck Drains Discharge Over Buffer?	Using the dropdown menu, indicate whether deck drains discharge over the riparian buffer. Note that this cell will automatically be populated with "N/A" if "N/A" is selected for "Buffer Rules in Effect" or if "No" was selected under "Project Includes Bridge Spanning Water Body." If "Yes" is selected, provide justification in the General Project Narrative section and then indicate whether dissipator pads were used.
Dissipator Pads Provided in Buffer?	Using the dropdown menu, indicate whether dissipator pads were provided in the buffer underneath deck drains. Note that this cell will automatically be populated with "N/A" if "No" or "N/A" is contained in the previous cell. If "Yes" is selected, describe the dimensions and materials used for the pads. If "No" was selected, provide justification for why dissipator pads were not provided.
Swales	
If a swale is designed for water quality treatment per the BMP Toolbox, it should be identified as a BMP on the Swales tab. Any swale that should be included in the I&M program should be identified on the Swales tab. Use of vegetated conveyance is also beneficial for water quality. Roadside channels that do not meet the aforementioned swale criteria should be described in the General Project Narrative area.	
Sheet No.:	Provide the plan sheet number on which the applicable swale section begins.
Station & Coordinates (Road and Non Road Projects):	Road and Non Road Projects: provide the project station (i.e., alignment, station, and right or left; e.g., -L- 12+73 Rt.) and coordinates (latitude/longitude, decimal degrees) for the downslope end of the swale (e.g., 35.764498 / -78.578803).
Surface Water Body:	Select the water body that the swale eventually drains to. Refer to the water bodies listed on the General Project Information sheet (drop down values are based on these). If only one water body was listed, that water body will be entered automatically after a Sheet No. is entered (via the "IF" formula that resides in the cell unless it is replaced by the user with a value from the drop down list). Note that water body names do not automatically synchronize with those on the General Project Information sheet and that they will need to be updated if any revisions are made to the water body names on the General Project Information sheet.
Base Width:	Provide base width of swale. Base width is equal to zero for V-ditch geometry.

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General Guidance	
Swales (Continued)	
Front Slope:	Provide the front slope (nearest the road) of swale. Enter only the horizontal change as it relates to 1 unit of vertical change. For example, for a 3:1 slope, enter "3" into the cell.
Back Slope:	Provide the back slope (furthest from road) of swale. Enter only the horizontal change as it relates to 1 unit of vertical change. For example, for a 3:1 slope, enter "3" into the cell.
Drainage Area:	Provide the total drainage area flowing to the listed swale section in acres.
Length Recommended for Treatment:	A treatment length of 100 feet for every one acre of drainage area, as is recommended by the NCDOT Stormwater Best Management Practices Toolbox (2014), is automatically calculated.
Actual Length:	Input actual linear length of swale.
Longitudinal Slope:	Input longitudinal slope of swale.
Q2:	Provide the 2-year storm event peak flow rate (in cubic feet per second) through the swale section listed.
V2:	Provide the 2-year storm event velocity (in feet per second) through the swale section listed.
Q10:	Provide the 10-year storm event peak flow rate (in cubic feet per second) through the swale section listed.
V10:	Provide the 10-year storm event velocity (in feet per second) through the swale section listed.
Rock Check Dams Used:	Indicate if rock check dams are installed within swale channel.
Swale Installed for Buffer Compliance?	Use the dropdown menu to indicate whether the swale was used for buffer compliance. If "Yes," use the Additional Comments box to describe how the swale was used to meet buffer protection requirements.
Filter Strip	
If a filter strip is designed for water quality treatment per the BMP Toolbox, it should be identified as a BMP on the Filter Strip tab. Any filter strip that should be included in the I&M program should be identified on the Filter Strip tab. Any filter strips not documented on the Filter Strip tab, should be described in the General Project Narrative area.	
Sheet No.:	Provide the plan sheet number on which the applicable filter strip begins.
Station & Coordinates (Road and Non Road Projects):	Road and Non Road Projects: provide the project station (i.e., alignment, station, and right or left; e.g., -L- 12+73 Rt.) and coordinates (latitude/longitude, decimal degrees) for the downslope end mid-point of the filter strip (e.g., 35.764498 / -78.578803).
Surface Water Body:	Select the water body that the filter strip eventually drains to. Refer to the water bodies listed on the General Project Information sheet (drop down values are based on these). If only one water body was listed, that water body will be entered automatically after a Sheet No. is entered (via the "IF" formula that resides in the cell unless it is replaced by the user with a value from the drop down list). Note that water body names do not automatically synchronize with those on the General Project Information sheet and that they will need to be updated if any revisions are made to the water body names on the General Project Information sheet.
Drainage Area:	Provide the total drainage area flowing to the listed filter strip section in acres.
Surface Area:	Provide the estimated surface area of the filter strip section in acres.

Note: For more information or guidance on the definitions provided below, reference the NCDOT Hydraulics Unit website,
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General Guidance	
Filter Strip (Continued)	
Drainage Area: Surface Area Ratio	The ratio of drainage area to surface area is automatically calculated and should be less than 10:1 as is recommended by the NCDOT Stormwater Best Management Practices Toolbox (2014).
Actual Length:	Input length of filter strip in feet.
Longitudinal Slope:	Input longitudinal slope of filter strip in percent.
Filter Strip Installed for Buffer Compliance?	Use the dropdown menu to indicate whether the filter strip was used for buffer compliance. If "Yes," use the Additional Comments box to describe how the filter strip was used to meet buffer protection requirements.
Preformed Scour Holes and Energy Dissipators	
PSHs not used solely for energy dissipation (e.g., PSHs used in associated with buffer compliance) should be listed on this tab. PSHs used solely for energy dissipation may be described in the general project narrative. Any PSH that should be included in the I&M program should be identified on this tab. Any PSHs not documented on this tab, should be described in the General Project Narrative area. Preferably, energy dissipators should be entered on this tab; however, describing them in the general project narrative is also acceptable.	
Sheet No.:	Provide the plan sheet number on which the applicable energy dissipator is shown.
Station & Coordinates (Road and Non Road Projects):	Road and Non Road Projects: provide the project station (i.e., alignment, station, and right or left; e.g., -L-12+73 Rt.) and coordinates (latitude/longitude, decimal degrees) for the downslope end of the energy dissipator (e.g., 35.764498 / -78.578803).
Surface Water Body:	Select the water body that the energy dissipator eventually drains to. Refer to the water bodies listed on the General Project Information sheet (drop down values are based on these). If only one water body was listed, that water body will be entered automatically after a Sheet No. is entered (via the "IF" formula that resides in the cell unless it is replaced by the user with a value from the drop down list). Note that water body names do not automatically synchronize with those on the General Project Information sheet and that they will need to be updated if any revisions are made to the water body names on the General Project Information sheet.
Energy Dissipator Type:	Provide the energy dissipator type located at the listed station. Refer to FHWA HEC-14 for descriptions of types.
Riprap Type:	Provide riprap size used in energy dissipator. Refer to NCDOT Standard Specification 1042 for riprap sizes.
Drainage Area:	Provide the total drainage area flowing to the listed energy dissipator in acres.
Conveyance Structure:	List the hydraulic structure directly flowing to energy dissipator, including equalizer pipes.
Pipe/Structure Dimensions:	If conveyance structure is pipe, select the pipe diameter from the pull down list. If not listed, manually input the pipe diameter. For structures other than pipes, dimensions and standard acronyms are to be included, i.e., 2-8x8 RCBC
Q10:	Provide the 10-year storm event peak flow rate (in cubic feet per second) flowing to energy dissipator listed.
V10:	Provide the 10-year storm event velocity (in feet per second) exiting energy dissipator listed.
PSH Installed for Buffer Compliance?	Use the dropdown menu to indicate whether the PSH was used for buffer compliance. If "Yes," use the Additional Comments box to describe how the PSH was used to meet buffer protection requirements.

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General Guidance	
Level Spreaders, Hazardous Spill Basins, and Forebays	
All level spreaders, hazardous spill basins, and forebays included in the project should be listed on this tab.	
Dual-purpose BMPs (such as hazardous spill basins that also function as dry detention basins) should be listed on both applicable worksheets. Fields documenting BMP type that utilize dropdown menus can be overwritten with manual entries. Users may enter "HSB/DDB," for example. Include any necessary notes in the comment boxes to cross-reference entries and define the BMP's configuration. Record only the portion of the BMP's volume that pertains to its function on the worksheet. Note that a HSB/DDB must be designed to capture the WQv plus the spill volume in the event that a spill occurs during or following a rain event. *For example, consider a HSB/DDB with a drainage area of 0.75 ac that is entirely NBUA. The total volume of the HSB/DDB is 5,200 ft ^{3}, the required HSB volume is 2,360 ft ^{3}, the HSB volume provided is 2,500 ft ^{3}, and the dry detention portion (WQv) is 2,700 ft ^{3}. On the Level Spreaders, Hazardous Spill Basin, and Forebays tab, enter 2,360 for the Required/Minimum Treatment and 2,500 for the Treatment Achieved. Add notes in the Additional Comments field discussing the BMP's configuration, documenting the total BMP volume of 5,200 ft ^{3}, and referring to other applicable sheets (i.e., the Other BMPs sheet).*	
Sheet No.:	Provide the plan sheet number on which the applicable stormwater best management practice (BMP) is shown.
Station & Coordinates (Road and Non Road Projects):	Road and Non Road Projects: provide the project station (i.e., alignment, station, and right or left; e.g., -L-12+73 Rt.) and coordinates (latitude/longitude, decimal degrees) for the downslope end* (e.g., 35.764498 / -78.578803). * LS = Center of Level Spreader Weir * HSB = On the Outlet Structure * Forebay = Center of the Forebay
Surface Water Body:	Select the water body that the BMP eventually drains to. Refer to the water bodies listed on the General Project Information sheet (drop down values are based on these). If only one water body was listed, that water body will be entered automatically after a Sheet No. is entered (via the "IF" formula that resides in the cell unless it is replaced by the user with a value from the drop down list). Note that water body names do not automatically synchronize with those on the General Project Information sheet and that they will need to be updated if any revisions are made to the water body names on the General Project Information sheet.
Level Spreader, Hazardous Spill Basin, or Forebay:	Indicate whether the BMP located at the listed station is a level spreader, hazardous spill basin, or forebay.
Drainage Area:	Provide the total drainage area flowing to the listed BMP in acres.
New Built-Upon Area (NBUA):	The amount of added impervious or partially impervious surface draining to the BMP including, but not limited to buildings; pavement and gravel areas such as roads, parking lots and paths; and recreation facilities such as tennis courts. Refer to NC Session Law 2006-246 for full definition.
Required / Minimum Treatment:	Provide the required/minimum design treatment (including units) for the listed BMP type. For more information on the stormwater treatment calculation refer to the document, NCDOT Stormwater Best Management Practices Toolbox (2014). Minimum treatment criteria will automatically populate based on BMP type selection.
Treatment Achieved:	Provide the actual treatment achieved (including units). For more information on the stormwater treatment calculation refer to the document, NCDOT Stormwater Best Management Practices Toolbox (2014).
BMP Installed for Buffer Compliance?	Use the dropdown menu to indicate whether the BMP was used for buffer compliance. If "Yes," use the Additional Comments box to describe how the BMP was used to meet buffer protection requirements.
Other BMPs	

Note: For more information or guidance on the definitions provided below, reference the NCDOT Hydraulics Unit website,
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General Guidance
All bioretention basins, dry detention basins, filtration basins, infiltration basins, stormwater wetlands, wet detention basins, and BMP variations similar to these that are not listed on other sheets should be listed on this tab.
Dual-purpose BMPs (such as hazardous spill basins that also function as dry detention basins) should be listed on both applicable worksheets. Fields documenting BMP type that utilize dropdown menus can be overwritten with manual entries. Users may enter "HSB/DDB," for example. Include any necessary notes in the comment boxes to cross-reference entries and define the BMP's configuration. Record only the portion of the BMP's volume that pertains to its function on the worksheet. Note that a HSB/DDB must be designed to capture the WQv plus the spill volume in the event that the spill occurs during or following a rain event. *For example, consider a HSB/DDB with a drainage area of 0.75 ac that is entirely NBUA. The total volume of the HSB/DDB is 5,200 ft^3, the required HSB volume is 2,360 ft^3, the HSB volume provided is 2,500 ft^3, and the dry detention portion (WQv) is 2,700 ft^3. On the Other BMPs sheet, enter 0.062 ac-ft (2,700 ft^3) under Volume Treated which results in 1.04" of precipitation treated. Add notes in the Additional Comments field discussing the BMP's configuration, documenting the total BMP volume of 5,200 ft^3, and referring to other applicable sheets (i.e., the Level Spreader, HSB, & Forebay sheet).*
Sheet No.: Provide the plan sheet number on which the applicable BMP is shown.

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General Guidance	
Other BMPs (Continued)	
Station & Coordinates (Road and Non Road Projects):	Road and Non Road Projects: provide the project station (i.e., alignment, station, and right or left; e.g., -L- 12+73 Rt.) and coordinates (latitude/longitude, decimal degrees) for the downslope end* (e.g., 35.764498 / -78.578803). *On the Outlet Structure *If no Outlet Structure, use Center of Basin
BMP Type:	Provide the BMP type located at the listed station. Refer to the document, NCDOT Stormwater Best Management Practices Toolbox (2014), for approved NCDOT post-construction BMPs.
Drainage Area:	Provide the total drainage area flowing to the listed BMP in acres.
New Built-Upon Area (NBUA):	The amount of added impervious or partially impervious surface draining to the BMP including, but not limited to buildings; pavement and gravel areas such as roads, parking lots and paths; and recreation facilities such as tennis courts. Refer to NC Session Law 2006-246 for full definition.
Volume Treated:	Provide the treatment volume achieved and the associated units of measure.
Precipitation Depth Treated over NBUA:	Provide the precipitation depth treated (in inches) as calculated relative to the new built-upon area (i.e., [P = WQv/(3,450 A_{NBU})] with unit conversions as appropriate).
BMP Installed for Buffer Compliance?	Use the dropdown menu to indicate whether the BMP was used for buffer compliance. If "Yes," use the Additional Comments box to describe how the BMP was used to meet buffer protection requirements.
Bridge to Culvert Avoidance and Minimization	
The "Bridge to Culvert Avoidance and Minimization" sheet should be filled out for any project in the state involving a bridge converted to culvert(s).	
Sheet No.:	Provide the plan sheet number on which the culvert is shown.
Station:	Provide the project station of the culvert.
Drainage Area:	Provide the total area (in acres or square miles) draining to the culvert and indicate units of measure using the dropdown options.
Surface Water Body:	Select the water body associated with the culvert. Refer to the water bodies listed on the General Project Information sheet (drop down values are based on these). If only one water body was listed, that water body will be entered automatically (via the "IF" formula that resides in the cell unless it is replaced by the user with a value from the drop down list). Note that water body names do not automatically synchronize with those on the General Project Information sheet and that they will need to be updated if any revisions are made to the water body names on the General Project Information sheet.
Culvert Type:	Indicate the type and material of construction for the culvert (e.g., "Reinforced concrete box culvert).
Number of Culverts:	Indicate the number of culverts to be installed.
Culvert Width/Diameter (ft):	Provide the culvert width if rectangular or the diameter if circular.
Culvert Height (ft):	Provide the culvert height if rectangular or type "N/A" if circular.
Culvert Length (ft):	Provide the culvert length.

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https://connect.ncdot.gov/resources/hydro/Pages/default.aspx

General Guidance	
Bridge to Culvert Avoidance and Minimization (Continued)	
Avoidance and Minimization Efforts: (Bridge to Culvert)	Provide a brief overview of bridge to culvert avoidance and/or minimization efforts and describe, in detail, any efforts that will not be captured in the remainder of the form. Some examples of minimization efforts include: culvert burial, low flow sill/baffles, slope considerations, velocity considerations, and culvert angle and stream bend considerations.
Existing Average Stream Slope (%):	Provide the existing average slope (%) of the stream along the distance of the proposed culvert.
Proposed Culvert Slope (%):	Provide the proposed culvert slope, in %.
Existing Low Flow Channel Dimensions in the Stream:	Provide a description of the approximate average existing low flow channel dimensions for the stream. Indicate units of measure (typically feet).
Proposed Low Flow Dimensions Through the Culvert:	Provide a description of the proposed low flow dimensions for the culvert. Indicate units of measure (typically feet).
Existing Low Flow Velocities in the Stream (ft/s):	Provide the existing low flow velocities in the section of stream to be impacted by the culvert. Use the average spring flow if available. If unavailable, use bankfull flow.
Proposed Low Flow Velocities Through the Culvert (ft/s):	Provide the proposed low flow velocities through the culvert. Use the average spring flow if available. If unavailable, use bankfull flow.
Alternating Low Flow Sills/Baffles:	Indicate whether the culvert will have low flow sills and/or baffles and provide justification.
Proposed Culvert Burial Depth (ft):	Provide the depth of burial of the culvert (i.e., the distance from the invert of the culvert to the elevation of the natural streambed).
Existing Streambed Material:	Describe the existing streambed material (e.g., boulders, cobbles, gravel, sand).
Proposed Sills/Baffles:	Describe the proposed sills and/or baffles in detail, including spacing, dimensions, and justification.
Stream Patterns Up and Downstream of Culvert that Could Affect Fish Passage and Bank Stability:	Describe any characteristics of the stream and culvert that may prevent fish passage or bank stability (e.g., bends in the stream or changes in slope).
Bed Forms Impacted by Culvert (riffles, pools, glides, etc.):	Describe the bed forms that will be affected by the culvert.
Low Flow Floodplain Bench Required?	Indicate whether a low flow floodplain bench is required (yes/no) and provide justification.
Sharp Bends at Inlet/Outlet?	Indicate whether there are any sharp bends at the inlet or outlet of the culvert (yes/no) and describe the general alignment of the culvert with the stream.
Stream Realignment Necessary?	Indicate whether stream realignment is necessary (yes/no) and provide justification.
Bank Stabilization:	Describe bank stabilization measures, including distances up and downstream where appropriate.
Natural Stream Channel 2-yr Velocity (ft/s):	Provide the 2-year natural stream channel velocity.
Proposed Culvert 2-yr Outlet Velocity (ft/s):	Provide the 2-year culvert outlet velocity.
Natural Stream Channel 10-yr Velocity (ft/s):	Provide the 10-year natural stream channel velocity.
Proposed Culvert 10-yr Outlet Velocity (ft/s):	Provide the 10-year culvert outlet velocity.
Evaluate/Describe Roadway Geometric Constraints:	Describe any roadway constraints that prevent ideal culvert design and installation.

North Carolina Department of Transportation

Highway Stormwater Program

STORMWATER MANAGEMENT PLAN

FOR NCDOT PROJECTS

(Version 2.07; Released September 2016)

General Project Information

WBS Element:		TIP Number:		Project Type:		Date:	
NCDOT Contact:				Contractor / Designer:			
Address:				Address:			
Phone:				Phone:			
Email:				Email:			
City/Town:				County(ies):			
River Basin(s):				CAMA County?			
Wetlands within Project Limits?							

Project Description

Project Length (lin. miles or feet):		Surrounding Land Use:		
	Proposed Project		Existing Site	
Project Built-Upon Area (ac.)	ac.		ac.	
Typical Cross Section Description:				
Annual Avg Daily Traffic (veh/hr/day):	Design/Future:	Year:	Existing:	Year:
General Project Narrative: (Description of Minimization of Water Quality Impacts)				

Waterbody Information

Surface Water Body (1):		NCDWR Stream Index No.:			
NCDWR Surface Water Classification for Water Body		Primary Classification:			
		Supplemental Classification:			
Other Stream Classification:					
Impairments:					
Aquatic T&E Species?		Comments:			
NRTR Stream ID:				Buffer Rules in Effect:	
Project Includes Bridge Spanning Water Body?		Deck Drains Discharge Over Buffer?		Dissipator Pads Provided in Buffer?	
Deck Drains Discharge Over Water Body?		(If yes, provide justification in the General Project Narrative)		(If yes, describe in the General Project Narrative; if no, justify in the General Project Narrative)	
(If yes, provide justification in the General Project Narrative)					

APPENDIX L

Highway Stormwater Program

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North Carolina Department of Transportation

Highway Stormwater Program

STORMWATER MANAGEMENT PLAN

FOR NCDOT PROJECTS

WBS Element: **TIP No.:** **County(ies):** **Page** **of** **1**

Swales

Sheet No.	Station & Coordinates (Road and Non Road Projects)	Surface Water Body	Base Width (ft)	Front Slope (H:1)	Back Slope (H:1)	Drainage Area (ac)	Recommended Treatm't Length (ft)	Actual Length (ft)	Longitudinal Slope (%)	Q2 (cfs)	V2 (fps)	Q10 (cfs)	V10 (fps)	Rock Checks Used	BMP Associated w/ Buffer Rules?

Additional Comments

APPENDIX L

North Carolina Department of Transportation

Highway Stormwater Program

STORMWATER MANAGEMENT PLAN

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WBS Element: **TIP No.:** **County(ies):** **Page** **of** **1**

Filter Strips

Sheet No.	Station & Coordinates (Road and Non Road Projects)	Surface Water Body	Drainage Area (ac)	Surface Area (ac)	Drainage Area: Surface Area Ratio	Actual Length (ft)	Longitudinal Slope (%)	BMP Associated with Buffer Rules?

Additional Comments

APPENDIX L

North Carolina Department of Transportation

Highway Stormwater Program

STORMWATER MANAGEMENT PLAN

FOR NCDOT PROJECTS

(Version 2.07; Released September 2016)

WBS Element: TIP No.: County(ies): Page of 1

Preformed Scour Holes and Energy Dissipators

Sheet No.	Station & Coordinates (Road and Non Road Projects)	Surface Water Body	Energy Dissipator Type	Riprap Type	Drainage Area (ac)	Conveyance Structure	Pipe/Structure Dimensions (in)	Q10 (cfs)	V10 (fps)	BMP Associated w/ Buffer Rules?

Additional Comments

* Refer to the NCDOT Best Management Practices Toolbox (2014), NCDOT Standards, the Federal Highway Administration (FHWA) Hydraulic Engineering Circular No. 14 (HEC-14), Third Edition, Hydraulic Design of Energy Dissipators for Culverts and Channels (July 2006), as applicable, for design guidance and criteria.

APPENDIX L

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WBS Element:	TIP No.:	County(ies):	Page	of	1

Level Spreaders, Hazardous Spill Basins, and Forebays

Sheet No.	Station & Coordinates (Road and Non Road Projects)	Surface Water Body	Level Spreader, Hazardous Spill Basin, or Forebay?	Drainage Area (ac)	New Built-Upon Area (ac)	Required / Minimum Treatment		Treatment Achieved		BMP Associated w/ Buffer Rules?

*Hazardous spill basins are pollution prevention measures designed for spill containment rather than stormwater treatment. Under Required / Minimum Treatment and Treatment Achieved, provide the minimum required volume and the actual HSB volume, respectively. Refer to the NCDOT Stormwater Best Management Practices Toolbox (2014) for design guidance.

Additional Comments

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North Carolina Department of Transportation

Highway Stormwater Program

STORMWATER MANAGEMENT PLAN

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(Version 2.07; Released September 2016)

WBS Element: **TIP No.:** **County(ies):** **Page** **of** **1**

Other Best Management Practices

Sheet No.	Station & Coordinates (Road and Non Road Projects)	Surface Water Body	BMP Type	Drainage Area (ac)	New Built-Upon Area (ac)	Volume Treated (ac-ft)	Precipitation Depth Treated over NBUA (in)	BMP Associated w/ Buffer Rules?

Additional Comments

APPENDIX L

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STORMWATER MANAGEMENT PLAN

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WBS Element:	TIP No.:	County(ies):	Page	of	1

Bridge to Culvert Avoidance and Minimization

Proposed Structure Summary

Sheet No. & Station	Sheet No.:		Station:	Number of Barrels:	
Drainage Area (ac or sq mi):				Barrel Width/Diameter (ft):	
Surface Water Body:				Barrel Height (ft):	
Culvert Type:				Culvert Length (ft)	
Avoidance and Minimization Efforts: (Bridge to Culvert)					

Stream Slope			Fish and/or Aquatic Life Passage	
Existing Average Stream Slope (%):		%	Existing Low Flow Channel Dimensions in the Stream:	
Proposed Culvert Slope (%):		%		
Culvert Burial				
Proposed Culvert Burial Depth (ft):				
Existing Streambed Material:			Proposed Low Flow Dimensions Through the Culvert:	
Proposed Sills/Baffles:			Existing Low Flow Velocities in the Stream (ft/s):	
			Proposed Low Flow Velocities Through the Culvert (ft/s):	
			Alternating Low Flow Sills/Baffles:	

Culvert/Stream Alignment

Stream Patterns Upstream and Downstream of the Culvert that Could Affect Fish Passage and Bank Stability:		
Bed Forms Impacted by Culvert (riffles, pools, glides, etc.):		
Low Flow Floodplain Bench Required? (provide justification)		
Bends at Inlet/Outlet? (describe culvert alignment with stream)		
Stream Realignment Necessary? (provide justification)		
Bank Stabilization:		

Outlet Velocities

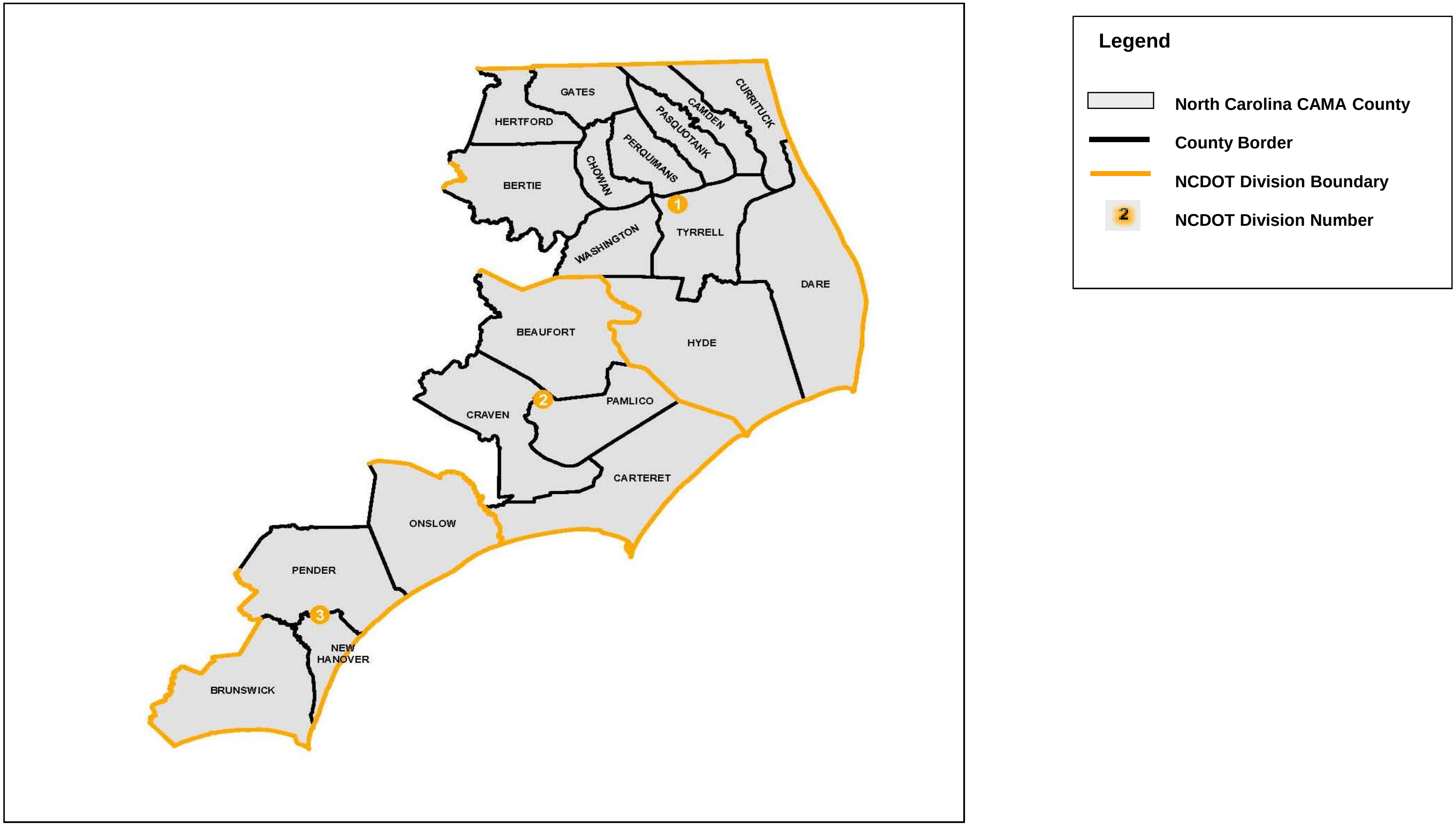
Natural Stream Channel 2-yr Velocity (ft/s):		Natural Stream Channel 10-yr Velocity (ft/s):	
Proposed Culvert 2-yr Outlet Velocity (ft/s):		Proposed Culvert 10-yr Outlet Velocity (ft/s):	

Roadway Geometric Considerations

Evaluate/Describe Roadway Geometric Constraints:

APPENDIX L

Map A. North Carolina Coastal Counties subject to the Coastal Area Management Act (CAMA)



Note: Map prepared using NCDOT's Environmental Sensitivity Maps (ESM).

APPENDIX L

DCM MP-1

APPLICATION for
Major Development Permit

(last revised 12/27/06)

North Carolina DIVISION OF COASTAL MANAGEMENT

1. *Primary Applicant/ Landowner Information*					
Business Name			Project Name (if applicable)		
Applicant 1: First Name		MI	Last Name		
Applicant 2: First Name		MI	Last Name		
If additional applicants, please attach an additional page(s) with names listed.					
Mailing Address			PO Box	City	State
ZIP	Country	Phone No. - - ext.		FAX No. - -	
Street Address *(if different from above)*			City	State	ZIP -
Email					

2. *Agent/Contractor Information*					
Business Name					
Agent/ Contractor 1: First Name		MI	Last Name		
Agent/ Contractor 2: First Name		MI	Last Name		
Mailing Address			PO Box	City	State
ZIP		Phone No. 1 - - ext.		Phone No. 2 - - ext.	
FAX No.		Contractor #			
Street Address *(if different from above)*			City	State	ZIP -
Email					

<Form continues on back>

3. Project Location

County (can be multiple)	Street Address			State Rd. #
Subdivision Name		City	State	Zip -

Phone No. - - ext.	Lot No.(s) *(if many, attach additional page with list)* , , , ,
a. In which NC river basin is the project located?	b. Name of body of water nearest to proposed project
c. Is the water body identified in (b) above, natural or manmade? ☐Natural ☐Manmade ☐Unknown	d. Name the closest major water body to the proposed project site.
e. Is proposed work within city limits or planning jurisdiction? ☐Yes ☐No	f. If applicable, list the planning jurisdiction or city limit the proposed work falls within.

4. Site Description

a. Total length of shoreline on the tract (ft.)	b. Size of entire tract (sq.ft.)
c. Size of individual lot(s) , , , *(If many lot sizes, please attach additional page with a list)*	d. Approximate elevation of tract above NHW *(normal high water)* or NWL *(normal water level)* ☐NHW or ☐NWL
e. Vegetation on tract	
f. Man-made features and uses now on tract	
g. Identify and describe the existing land uses <u>adjacent</u> to the proposed project site.	
h. How does local government zone the tract?	i. Is the proposed project consistent with the applicable zoning? (Attach zoning compliance certificate, if applicable) ☐Yes ☐No ☐NA
j. Is the proposed activity part of an urban waterfront redevelopment proposal?	☐Yes ☐No
k. Has a professional archaeological assessment been done for the tract? If yes, attach a copy. If yes, by whom?	☐Yes ☐No ☐NA
l. Is the proposed project located in a National Registered Historic District or does it involve a National Register listed or eligible property?	☐Yes ☐No ☐NA

<Form continues on next page>

m. (i) Are there wetlands on the site?	☐Yes ☐No
(ii) Are there coastal wetlands on the site?	☐Yes ☐No
(iii) If yes to either (i) or (ii) above, has a delineation been conducted? *(Attach documentation, if available)*	☐Yes ☐No

n. Describe existing wastewater treatment facilities.	
o. Describe existing drinking water supply source.	
p. Describe existing storm water management or treatment systems.	

5. Activities and Impacts	
a. Will the project be for commercial, public, or private use?	☐Commercial ☐Public/Government ☐Private/Community
b. Give a brief description of purpose, use, and daily operations of the project when complete.	
c. Describe the proposed construction methodology, types of construction equipment to be used during construction, the number of each type of equipment and where it is to be stored.	
d. List all development activities you propose.	
e. Are the proposed activities maintenance of an existing project, new work, or both?	
f. What is the approximate total disturbed land area resulting from the proposed project?	☐Sq.Ft or ☐Acres
g. Will the proposed project encroach on any public easement, public accessway or other area that the public has established use of?	☐Yes ☐No ☐NA
h. Describe location and type of existing and proposed discharges to waters of the state.	
i. Will wastewater or stormwater be discharged into a wetland?	☐Yes ☐No ☐NA
If yes, will this discharged water be of the same salinity as the receiving water?	☐Yes ☐No ☐NA
j. Is there any mitigation proposed? If yes, attach a mitigation proposal.	☐Yes ☐No ☐NA

<Form continues on back>

6. Additional Information *In addition to this completed application form, (MP-1) the following items below, if applicable, must be submitted in order for the application package to be complete. Items (a) – (f) are always applicable to any major development application. Please consult the application instruction booklet on how to properly prepare the required items below.*
a. A project narrative.
b. An accurate, dated work plat (including plan view and cross-sectional drawings) drawn to scale. Please give the present status of the proposed project. Is any portion already complete? If previously authorized work, clearly indicate on maps, plats, drawings to distinguish between work completed and proposed.
c. A site or location map that is sufficiently detailed to guide agency personnel unfamiliar with the area to the site.

d. A copy of the deed (with state application only) or other instrument under which the applicant claims title to the affected properties.
e. The appropriate application fee. Check or money order made payable to DENR.
f. A list of the names and complete addresses of the adjacent waterfront (riparian) landowners and signed return receipts as proof that such owners have received a copy of the application and plats by certified mail. Such landowners must be advised that they have 30 days in which to submit comments on the proposed project to the Division of Coastal Management. Name Phone No. Address Name Phone No. Address Name Phone No. Address
g. A list of previous state or federal permits issued for work on the project tract. Include permit numbers, permittee, and issuing dates.
h. Signed consultant or agent authorization form, if applicable.
i. Wetland delineation, if necessary.
j. A signed AEC hazard notice for projects in oceanfront and inlet areas. *(Must be signed by property owner)*
k. A statement of compliance with the N.C. Environmental Policy Act (N.C.G.S. 113A 1-10), if necessary. If the project involves expenditure of public funds or use of public lands, attach a statement documenting compliance with the North Carolina Environmental Policy Act.

7. Certification and Permission to Enter on Land

I understand that any permit issued in response to this application will allow only the development described in the application. The project will be subject to the conditions and restrictions contained in the permit.

I certify that I am authorized to grant, and do in fact grant permission to representatives of state and federal review agencies to enter on the aforementioned lands in connection with evaluating information related to this permit application and follow-up monitoring of the project.

I further certify that the information provided in this application is truthful to the best of my knowledge.

Date ____________________________ Print Name ____________________________

Signature ____________________________

Please indicate application attachments pertaining to your proposed project.

☐DCM MP-2 Excavation and Fill Information

☐DCM MP-5 Bridges and Culverts

☐DCM MP-3 Upland Development

☐DCM MP-4 Structures Information

Form DCM MP-2

EXCAVATION and FILL

(Except for bridges and culverts)

Attach this form to Joint Application for CAMA Major Permit, Form DCM MP-1. Be sure to complete all other sections of the Joint Application that relate to this proposed project. Please include all supplemental information.

Describe below the purpose of proposed excavation and/or fill activities. **All values should be given in feet.**

	Access Channel (NLW or NWL)	Canal	Boat Basin	Boat Ramp	Rock Groin	Rock Breakwater	Other (excluding shoreline stabilization)
Length							
Width							
Avg. Existing Depth					NA	NA	
Final Project Depth					NA	NA	

1. EXCAVATION

☐*This section not applicable*

a. Amount of material to be excavated from below NHW or NWL in cubic yards.

____

b. Type of material to be excavated.

____

c. (i) Does the area to be excavated include coastal wetlands/marsh (CW), submerged aquatic vegetation (SAV), shell bottom (SB), or other wetlands (WL)? If any boxes are checked, provide the number of square feet affected.

☐CW _____ ☐SAV _____ ☐SB _____
☐WL _____ ☐None

(ii) Describe the purpose of the excavation in these areas:

____

____

d. High-ground excavation in cubic yards.

____

2. DISPOSAL OF EXCAVATED MATERIAL

☐*This section not applicable*

a. Location of disposal area.

____

b. Dimensions of disposal area.

____

c. (i) Do you claim title to disposal area?

☐Yes ☐No ☐NA

(ii) If no, attach a letter granting permission from the owner.

d. (i) Will a disposal area be available for future maintenance?

☐Yes ☐No ☐NA

(ii) If yes, where?

____

e. (i) Does the disposal area include any coastal wetlands/marsh (CW), submerged aquatic vegetation (SAV), shell bottom (SB), or other wetlands (WL)? If any boxes are checked, provide the number of square feet affected.

☐CW _____ ☐SAV _____ ☐SB _____
☐WL _____ ☐None

(ii) Describe the purpose of disposal in these areas:

____

____

f. (i) Does the disposal include any area in the water?

☐Yes ☐No ☐NA

(ii) If yes, how much water area is affected?

____

3. SHORELINE STABILIZATION

(If development is a wood groin, use MP-4 – Structures)

☐*This section not applicable*

a. Type of shoreline stabilization:
☐Bulkhead ☐Riprap ☐Breakwater/Sill ☐Other: _____

b. Length: _____
Width: _____

c. Average distance waterward of NHW or NWL:

d. Maximum distance waterward of NHW or NWL:

e. Type of stabilization material:

f. (i) Has there been shoreline erosion during preceding 12 months?
☐Yes ☐No ☐NA
(ii) If yes, state amount of erosion and source of erosion amount information.

g. Number of square feet of fill to be placed below water level.
Bulkhead backfill _____ Riprap _____
Breakwater/Sill _____ Other _____

h. Type of fill material.

i. Source of fill material.

4. *OTHER FILL ACTIVITIES*

(Excluding Shoreline Stabilization)

☐*This section not applicable*

a. (i) Will fill material be brought to the site? ☐Yes ☐No ☐NA
If yes,
(ii) Amount of material to be placed in the water _____
(iii) Dimensions of fill area _____
(iv) Purpose of fill

b. (i) Will fill material be placed in coastal wetlands/marsh (CW), submerged aquatic vegetation (SAV), shell bottom (SB), or other wetlands (WL)? If any boxes are checked, provide the number of square feet affected.
☐CW _____ ☐SAV _____ ☐SB _____
☐WL _____ ☐None
(ii) Describe the purpose of the fill in these areas:

5. *GENERAL*

a. How will excavated or fill material be kept on site and erosion controlled?

b. What type of construction equipment will be used (e.g., dragline, backhoe, or hydraulic dredge)?

c. (i) Will navigational aids be required as a result of the project?
☐Yes ☐No ☐NA
(ii) If yes, explain what type and how they will be implemented.

d. (i) Will wetlands be crossed in transporting equipment to project site? ☐Yes ☐No ☐NA
(ii) If yes, explain steps that will be taken to avoid or minimize environmental impacts.

Date

Project Name

Applicant Name

Applicant Signature

Form DCM MP-5

BRIDGES and CULVERTS

Attach this form to Joint Application for CAMA Major Permit, Form DCM MP-1. Be sure to complete all other sections of the Joint Application that relate to this proposed project. Please include all supplemental information.

1. BRIDGES

☐*This section not applicable*

a. Is the proposed bridge:
☐Commercial ☐Public/Government ☐Private/Community

b. Water body to be crossed by bridge:

____

c. Type of bridge (construction material):

____

d. Water depth at the proposed crossing at NLW or NWL:

____

e. (i) Will proposed bridge replace an existing bridge? ☐Yes ☐No
If yes,
(ii) Length of existing bridge: ______
(iii) Width of existing bridge: ______
(iv) Navigation clearance underneath existing bridge: ______
(v) Will all, or a part of, the existing bridge be removed? (Explain)

____

____

f. (i) Will proposed bridge replace an existing culvert? ☐Yes ☐No
If yes,
(ii) Length of existing culvert: ______
(iii) Width of existing culvert: ______
(iv) Height of the top of the existing culvert above the NHW or NWL: ______
(v) Will all, or a part of, the existing culvert be removed? (Explain)

____

____

g. Length of proposed bridge: ______

h. Width of proposed bridge: ______

i. Will the proposed bridge affect existing water flow? ☐Yes ☐No
If yes, explain:

____

____

j. Will the proposed bridge affect navigation by reducing or increasing the existing navigable opening? ☐Yes ☐No
If yes, explain:

____

____

k. Navigation clearance underneath proposed bridge: ______

l. Have you contacted the U.S. Coast Guard concerning their approval? ☐Yes ☐No
If yes, explain:

____

____

m. Will the proposed bridge cross wetlands containing no navigable waters? ☐Yes ☐No
If yes, explain:

____

____

n. Height of proposed bridge above wetlands: ______

2. CULVERTS

☐*This section not applicable*

a. Number of culverts proposed: ______

b. Water body in which the culvert is to be placed:

____

< Form continues on back>

c. Type of culvert (construction material):

____

d. (i) Will proposed culvert replace an existing bridge? ☐Yes ☐No

If yes,

(ii) Length of existing bridge: ______

(iii) Width of existing bridge: ______

(iv) Navigation clearance underneath existing bridge: ______

(v) Will all, or a part of, the existing bridge be removed? (Explain)

____

____

____

e. (i) Will proposed culvert replace an existing culvert? ☐Yes ☐No

If yes,

(ii) Length of existing culvert(s): ______

(iii) Width of existing culvert(s): ______

(iv) Height of the top of the existing culvert above the NHW or NWL: ______

(v) Will all, or a part of, the existing culvert be removed? (Explain)

____

____

____

f. Length of proposed culvert: ______

g. Width of proposed culvert: ______

h. Height of the top of the proposed culvert above the NHW or NWL. ______

i. Depth of culvert to be buried below existing bottom contour. ______

j. Will the proposed culvert affect navigation by reducing or increasing the existing navigable opening? ☐Yes ☐No

If yes, explain:

____

____

____

k. Will the proposed culvert affect existing water flow? ☐Yes ☐No

If yes, explain:

____

____

____

3. *EXCAVATION and FILL*

☐*This section not applicable*

a. (i) Will the placement of the proposed bridge or culvert require any excavation below the NHW or NWL? ☐Yes ☐No

If yes,

(ii) Avg. length of area to be excavated: ______

(iii) Avg. width of area to be excavated: ______

(iv) Avg. depth of area to be excavated: ______

(v) Amount of material to be excavated in cubic yards: ______

b. (i) Will the placement of the proposed bridge or culvert require any excavation within coastal wetlands/marsh (CW), submerged aquatic vegetation (SAV), shell bottom (SB), or other wetlands (WL)? If any boxes are checked, provide the number of square feet affected.

☐CW _____ ☐SAV _____ ☐SB _____

☐WL _____ ☐None

(ii) Describe the purpose of the excavation in these areas:

____

____

____

c. (i) Will the placement of the proposed bridge or culvert require any high-ground excavation? ☐Yes ☐No

If yes,

(ii) Avg. length of area to be excavated: ______

(iii) Avg. width of area to be excavated: ______

(iv) Avg. depth of area to be excavated: ______

(v) Amount of material to be excavated in cubic yards: ______

d. If the placement of the bridge or culvert involves any excavation, please complete the following:

(i) Location of the spoil disposal area: ______

(ii) Dimensions of the spoil disposal area: ______

(iii) Do you claim title to the disposal area? ☐Yes ☐No (*If no, attach a letter granting permission from the owner.)*

(iv) Will the disposal area be available for future maintenance? ☐Yes ☐No

(v) Does the disposal area include any coastal wetlands/marsh (CW), submerged aquatic vegetation (SAVs), other wetlands (WL), or shell bottom (SB)?

☐CW ☐SAV ☐WL ☐SB ☐None

If any boxes are checked, give dimensions if different from (ii) above. ______

(vi) Does the disposal area include any area below the NHW or NWL? ? ☐Yes ☐No

If yes, give dimensions if different from (ii) above. ______

e. (i) Will the placement of the proposed bridge or culvert result in any fill (other than excavated material described in Item **d** above) to be placed below NHW or NWL? ☐Yes ☐No

If yes,

(ii) Avg. length of area to be filled: ______

(iii) Avg. width of area to be filled: ______

(iv) Purpose of fill: ______

f. (i) Will the placement of the proposed bridge or culvert result in any fill (other than excavated material described in Item **d** above) to be placed within coastal wetlands/marsh (CW), submerged aquatic vegetation (SAV), shell bottom (SB), or other wetlands (WL)? If any boxes are checked, provide the number of square feet affected.

☐CW ______ ☐SAV ______ ☐SB ______
☐WL ______ ☐None

(ii) Describe the purpose of the excavation in these areas: ______

g. (i) Will the placement of the proposed bridge or culvert result in any fill (other than excavated material described in Item **d** above) to be placed on high-ground? ☐Yes ☐No

If yes,

(ii) Avg. length of area to be filled: ______

(iii) Avg. width of area to be filled: ______

(iv) Purpose of fill: ______

4. GENERAL

a. Will the proposed project require the relocation of any existing utility lines? ☐Yes ☐No

If yes, explain: ______

If this portion of the proposed project has already received approval from local authorities, please attach a copy of the approval or certification.

b. Will the proposed project require the construction of any temporary detour structures? ☐Yes ☐No

If yes, explain: ______

< Form continues on back>

c. Will the proposed project require any work channels? ☐Yes ☐No

If yes, complete Form DCM-MP-2.

d. How will excavated or fill material be kept on site and erosion controlled? ______

e. What type of construction equipment will be used (for example, dragline, backhoe, or hydraulic dredge)?

____

____

____

f. Will wetlands be crossed in transporting equipment to project site? ☐Yes ☐No

If yes, explain steps that will be taken to avoid or minimize environmental impacts.

____

____

____

g. Will the placement of the proposed bridge or culvert require any shoreline stabilization? ☐Yes ☐No

If yes, complete form MP-2, Section 3 for Shoreline Stabilization only.

____

Date

____

Project Name

____

Applicant Name

____

Applicant Signature

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Stream Relocation Guidelines

NOTE: These guidelines are for the piedmont and coastal regions. While these guidelines are similar to the trout county requirements, they do not replace the existing process for trout counties. This guidance is to be followed **prior to the permit process** to facilitate that process and to minimize impacts

"Minor Relocations"

Applicable when:

- Less than 100 feet of total relocation is required at a given crossing (from the end of the structure, inluding headwalls), and no more than 50 feet is relocated on any one side (upstream or downstream)

Technical guidelines:

-Relocation should be similar to original channel in

Width
Depth
Gradient
Substrate

-Bank vegetation should be re-established, but no specific planting regime is required

Co-ordination with WRC field staff:

-No coordination is required unless in High Quality Waters(HQW), critical habitat(as mapped by WRC), or at locations involving Federal/State listed species. Treat these cases as "Standard Relocations".

Note: WRC coordination will be welcomed even on "Minor"projects.

"Standard Relocations"

Applicable when:

- Greater than 100 feet of total relocation is required at a given crossing (from the end of the structure inluding headwalls), Or more than 50 feet is relocated on any one side (upstream or downstream)

Technical guidelines:

-Relocation should be similar to original channel in

Width
Depth
Gradient
Substrate

For the following items, site specific requirements will be determined through coordination with the WRC field staff. These items will follow WRC's established guidelines and will incorporate any highway specific guidance jointly developed between WRC, Hydraulics, and Roadside Environmental:

- Re-etablishment of bank vegetation with planting regime required
- Meanders and habitat structures (root wads, wing deflectors, etc.) approximating the original stream

Co-ordination with WRC field staff:

-Coordinate the relocation with the appropriate WRC district fisheries biologist

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General Guidance: Minimize instream activities during peak spawning periods (April-June)

- Schedule instream activities during periods of low flow as much as possible
- Use vegetation to stabilize streambank vs. riprap to the maximum extent practicable
- Minimize use of fertilizer adjacent to stream
- Use native woody/shrub like species with small basal width within 25-50 ft. of the structure to reduce clogging. Beyond that distance use native tree species.
- It is preferred that bank vegetation be re-established prior to introducing flow into the channel.
- For reference utilize NC Wildlife Res. Comm. document "NC Stream Protection and Improvement Guidelines"

NOTE: Coordination with WRC on projects covered by nationwide permits (outside the 25 trout counties) is voluntary. This is a proactive effort by NCDOT and WRC minimize habitat impacts from highway projects and to facilitate communication and understanding at the field level.

STREAM CROSSING GUIDELINES

FOR ANADROMOUS FISH PASSAGE

Anadromous Fish are a valuable resource and their migration must not be adversely impacted. The purpose of this document is to provide guidance to the North Carolina Department of Transportation to ensure that replacement of existing and new highway stream crossing structures will not impede the movement of Anadromous Fish.

Applicable When:

- Project is in the coastal plain defined by the "Fall Line" as the approximate western limit (see attached figure).
- For perennial and intermittent streams delineated on most recent USGS 7.5 minute quadrangle maps.

General Guidelines:

- Design and scheduling of projects should avoid the necessity of instream activities during the spring migration period. For the purposes of these guidelines "Spring" is considered to fall between February 15 and June 15. (In areas where the shortnose sturgeon may be present, the Cape Fear, Brunswick and Waccamaw Rivers, spring shall be defined as February 1 to June 15).
- Bridges and other channel spanning structures are preferred where practical.

Technical Guidelines:

- In all cases, the width, height and gradient of the proposed opening shall be such as to pass the average historical spring flow without adversely altering flow velocity. Spring flow should be determined from gage data if available. In the absence of this data, bankfull flow can be used as a comparative level. (Reference, "Fisheries Handbook of Engineering Requirements and Biological Criteria", Bell 1973, for fish swimming limitations.)
- The invert of culverts shall be set at least one foot below the natural stream bed.

This is a general guideline, with applicable exceptions. See Chapter 9 on Culverts.

- Crossings of perennial streams serving watersheds greater than one square mile shall provide a minimum of four (4) feet of additional opening width (measured at spring flow elevation) to allow for terrestrial wildlife passage.

- In stream footings for bridges will be set one foot below the natural stream bed when practical.

For crossing sites which require permit review the following information will be provided as a minimum to facilitate resource agency review.

- Plan and profile views showing the existing and proposed crossing structures in relation to the stream bank and bed.

- Average historical spring flow (or bankfull flow) for the site.

- How the proposed structure will affect the velocity and stage of the spring flow (bankfull).

- Justification for any variance from the guideline recommendations.

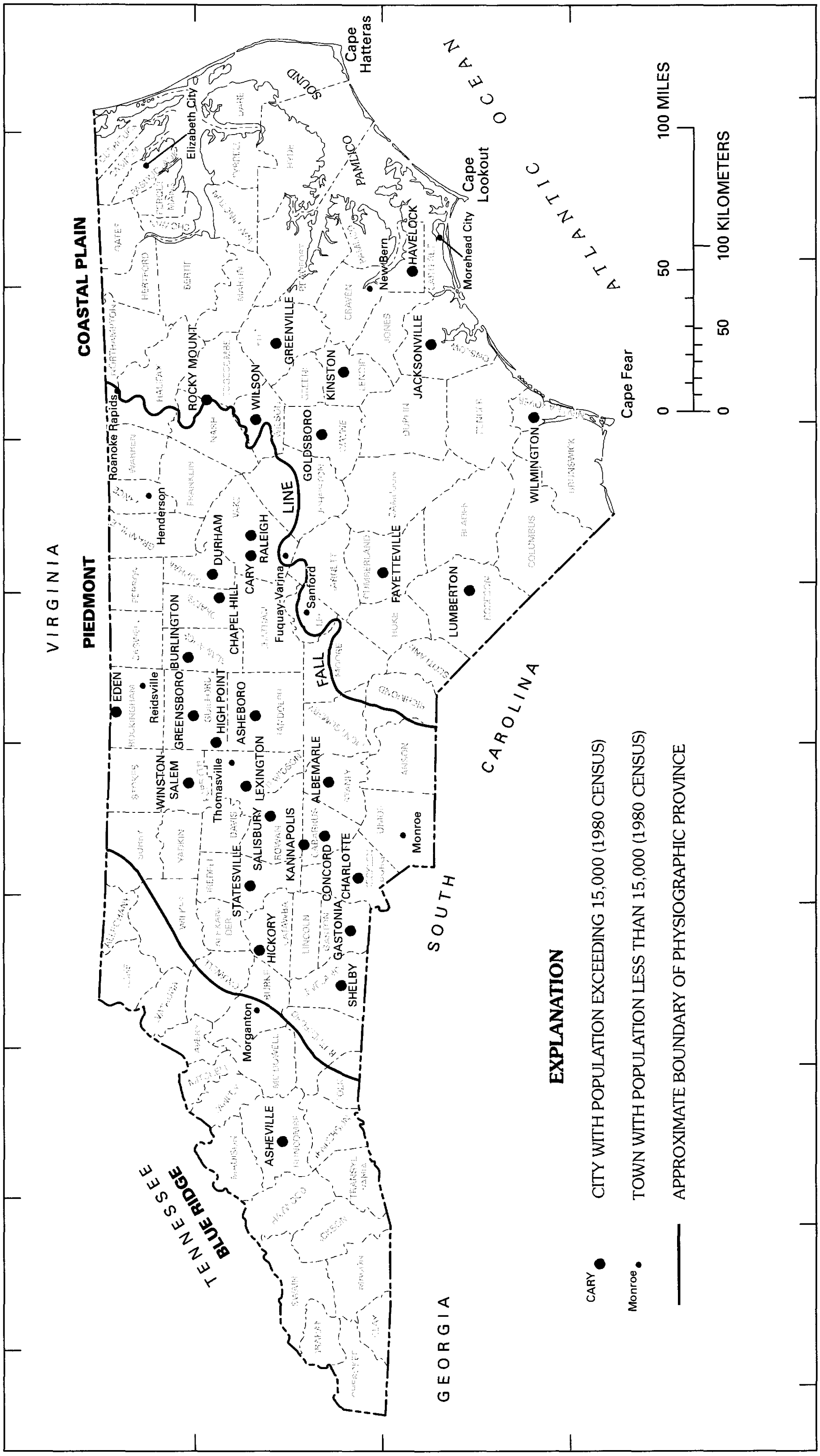


Figure 2. Counties and major population centers of North Carolina.

A Reference Guide to the Distribution of Anadromous Fishes in North Carolina Rivers

Prepared for the Wilmington and Charleston Districts, U.S. Army Corps of Engineers

September 2010

Prepared by:

National Marine Fisheries Service
Habitat Conservation Division
101 Pivers Island Road
Beaufort, NC 28516

The purpose of this guide is to provide an easy reference to the present and potential distribution of anadromous fishes in North Carolina. The guide can be used by project managers during review of applications for nationwide or individual permit applications. The anadromous fish species include the federally-endangered shortnose sturgeon, Atlantic sturgeon, American shad, hickory shad, blueback herring, alewife, and striped bass. The American eel is a catadromous species which is widely distributed in all of the river basins.

The distribution limits shown on the map were derived from two sources. The areas in pink are areas designated by rule by the North Carolina Division of Marine Fisheries and the Wildlife Resources Commission as Anadromous Fish Spawning Areas. These areas are also listed in Table 1. The rivers/streams in blue represent reaches where one or more of these anadromous species could occur based on sufficient water flow in April (mean of 100 cfs).

The distribution limits described here in this guide are subject to revision as new information becomes available and as restoration efforts continue. Removal of dams or installation of fish passage facilties will expand the distribution limits as restoration efforts continue.

For additional information regarding site specific project reviews and protective measures for anadromous species, particularly the shortnose sturgeon, please contact the Atlantic Branch, Habitat Conservation Division, Anadromous Fish Coordination: Fritz Rohde, 252-838-0828 or by email at: fritz.rohde@noaa.gov

Table 1. North Carolina Anadromous Fish Spawning Areas as defined by the North Carolina Division of Marine Fisheries and the Wildlife Resources Commission.

1. Northwest River
   Anadromous fish waters within the Northwest River System extend from Tull Bay northwest to the Virginia state line, including Moyock Run (Shingle Landing Creek). It also includes Tull Creek and its tributaries: Roland Creek, New Bridge Creek, Cowells Creek, and Buckskin Creek.

2. North River
   Anadromous fish waters within the North River System extend from Albemarle Sound northwest to the US 158 bridge and includes all tributaries: Indiantown Creek, Crooked Creek, Bump Landing Creek, Narrow Ridges Creek, Great Creek, Deep Creek, and Public Creek.

3. Pasquotank River
   Anadromous fish waters within the Pasquotank River System extend from Albemarle Sound northwest to the US 17 bridge near South Mills and includes all tributaries: Joyce Creek, Sawyers Creek, Knobbs Creek, Charles Creek, Areneuse Creek, Mill Dam Creek, Portohonk Creek, and New Begun Creek.

4. Big Flatty Creek
   Anadromous fish waters within the Big Flatty Creek System extend from Albemarle Sound northwest to the headwaters and include Chapel Creek and Mill Dam Creek.

5. Little River
   Anadromous fish waters within the Little River System extend from Albemarle Sound northwest to the US 17 bridge and includes Halls Creek, Deep Creek, and Symonds Creek.

6. Perquimans River
   Anadromous fish waters within the Perquimans River System extend from Albemarle Sound northwest approximately 4 miles upstream of the NC 37 bridge at Belvidere and includes Goodwin Creek, Mill Creek, Walter's Creek, Suttons Creek, Jackson (Cove) Creek, and Muddy Creek.

7. Yeopim River
   Anadromous fish waters within the Yeopim River System extend from Albemarle Sound northwest and include Yeopim Creek, Bethel Creek, Burnt Mill Creek, and Middleton Creek.

8. Edenton Bay
   Anadromous fish waters within the Edenton Bay System extend from Albemarle Sound north to the headwaters of Queen Anne Creek and Pembroke Creek, including Pollock Swamp.

9. Chowan River
   Anadromous fish waters within the Chowan River System extend from Albemarle Sound north to the Virginia state line and includes Buckhorn Creek (Hertford County), Somerton Creek, Mud Creek, Catherine Creek (Hertford County), Buckhorn Creek (Run Off Swamp) (Gates County), Spikes Creek, Barnes Creek, Shingle (Island) Creek, Sarem Creek, Hodges Creek, Wiccacon River, Ahoskie Creek, Chinkapin Creek, Beef Creek, Goose Creek, Swain Mill (Taylor Pond) Creek, Bennetts Creek, Catherine Creek (Gates County), Trotman Creek, Warwick Creek, Stumpy Creek, Dillard (Indian) Creek, Keel (Currituck) Creek, and Rocky Hock Creek. Included in this also is the Merherrin River to the Virginia state line, Vaughan's Creek (Kirby's Creek), Turkey Creek, Potecasi Creek, Old Tree Swamp, and Cutawhiskie Creek.

10. Cashie River
    Anadromous fish waters within the Cashie River System extend from Batchelor Bay northwest to the US 17 bridge and includes Connarista Swamp, Whiteoak swamp, Chiska Creek, Hoggard Mill Creek, Roquist Creek, Wading Place Creek, Broad Creek, Grennel Creek, and Cashoke Creek.

11. Salmon Creek

Anadromous fish waters include Salmon Creek and extend from the confluence with the Chowan River northwest to the US 17 bridge.

12. Middle and Eastmost Rivers
    Anadromous fish waters within the Middle and Eastmost River Systems extend from Batchelor Bay west to the Roanoke River.

13. Roanoke River
    Anadromous fish waters within the Roanoke River System extend from Batchelor Bay northwest to the Roanoke Rapids Dam in Roanoke Rapids. This includes the lower Roanoke River tributaries of Bridgers Creek, Kehukee Swamp, Wire Gut, Apple Tree Creek, Indian Creek, Prices Gut, Rainbow Gut, Coniott Creek, Frog level Swamp, Conoho Creek, Sweetwater Creek, Peter Swamp, Old Mill Creek, Gardner Creek, Cut Cypress Creek, Roses Creek, Broad Creek, Welch Creek, Conaby Creek, Warren Neck Creek, Thoroughfare, Devils Gut, and Conine Creek.

14. Mackeys (Kendrick Creek)
    Anadromous fish waters include Mackeys Creek and extend from Albemarle Sound south to the US 64 bridge.

15. Scuppernong River
    Anadromous fish waters within the Scuppernong River System extend from Bull Bay south to include Lake Phelps and its main canals as well as First (Rider's) Creek, Second Creek, Deep Creek, and Banton (Bunton or Maybell) Creek.

16. Alligator River
    Anadromous fish waters within the Alligator River System extend from Albemarle Sound south and include Little Alligator River, East lake, Second Creek, Milltail Creek, Whipping Creek and Lake, Swan Creek and Lake, and Northwest Fork. Also included are the adjacent Tom Mann Creek and Peter Mashoes Creek.

17. Spencer Creek
    Anadromous fish waters include Spencer Creek and extend from Croatan Sound northwest to the headwaters.

18. Callaghan Creek
    Anadromous fish waters include Callaghan Creek and extend from Croatan Sound southwest to the headwaters.

19. Lake Mattamuskeet
    Anadromous fish waters include all waters and inland manmade tributaries of Lake Mattamuskeet.

20. Pamlico River

Anadromous fish waters within the Pamlico River System extend from Pamlico Sound west to the US 17 bridge and includes Durham Creek, Blounts Creek, Chocowinity Creek, Little Goose Creek, Broad Creek, and Runyon Creek.

21. Tar River
    Anadromous fish waters within the Tar River System extend from the US 17 bridge northwest to the Rocky Mount Mill Pond Dam in Rocky Mount and includes Tranters Creek, Aggie Run, Cherry Run, Bear Creek, Old Grindle Creek, Chicod Creek, Hardee Creek, Conetoe Creek, Tyson Creek, Otter Creek, Town Creek, Fishing Creek; Deep Creek, and Swift Creek.

22. Trent Creek
    Anadromous fish waters include Trent Creek and extend from its confluence with Bay River south to State Route 1316 bridge.

23. Neuse River
    Anadromous fish waters within the Neuse River System extend from Pamlico Sound west to Milburnie Dam in Raleigh. The following tributaries are included: Smith Creek; Kershaw Creek; Dawson Creek; Beard Creek; Upper Broad Creek; Hancock Creek; Slocum Creek (Southwest and East Prongs); Trent River including its tributaries Jumping Creek, Mill Run, Mill Creek, and Brice Creek; Swift Creek; Little Swift Creek; Bachelor Creek; Pine Tree Creek; Taylor Creek; Turkey Quarter Creek; Greens Creek; Pitchkettle Creek; Core Creek; Kitten Creek; Village Creek; Halfmoon Creek; Contentnea Creek; Falling Creek; Bear Creek; Walnut Creek; Little River; Mill Creek; and Middle Creek.

24. White Oak River
    Anadromous fish waters within the White Oak River System extend from the Atlantic Ocean north to the US 17 bridge and includes Holston Creek and Grant's Creek.

25. New River
    Anadromous fish waters within the New River System extend from the Atlantic Ocean north to State Route 1316 bridge and include Northeast Creek and Little Northeast Creek.

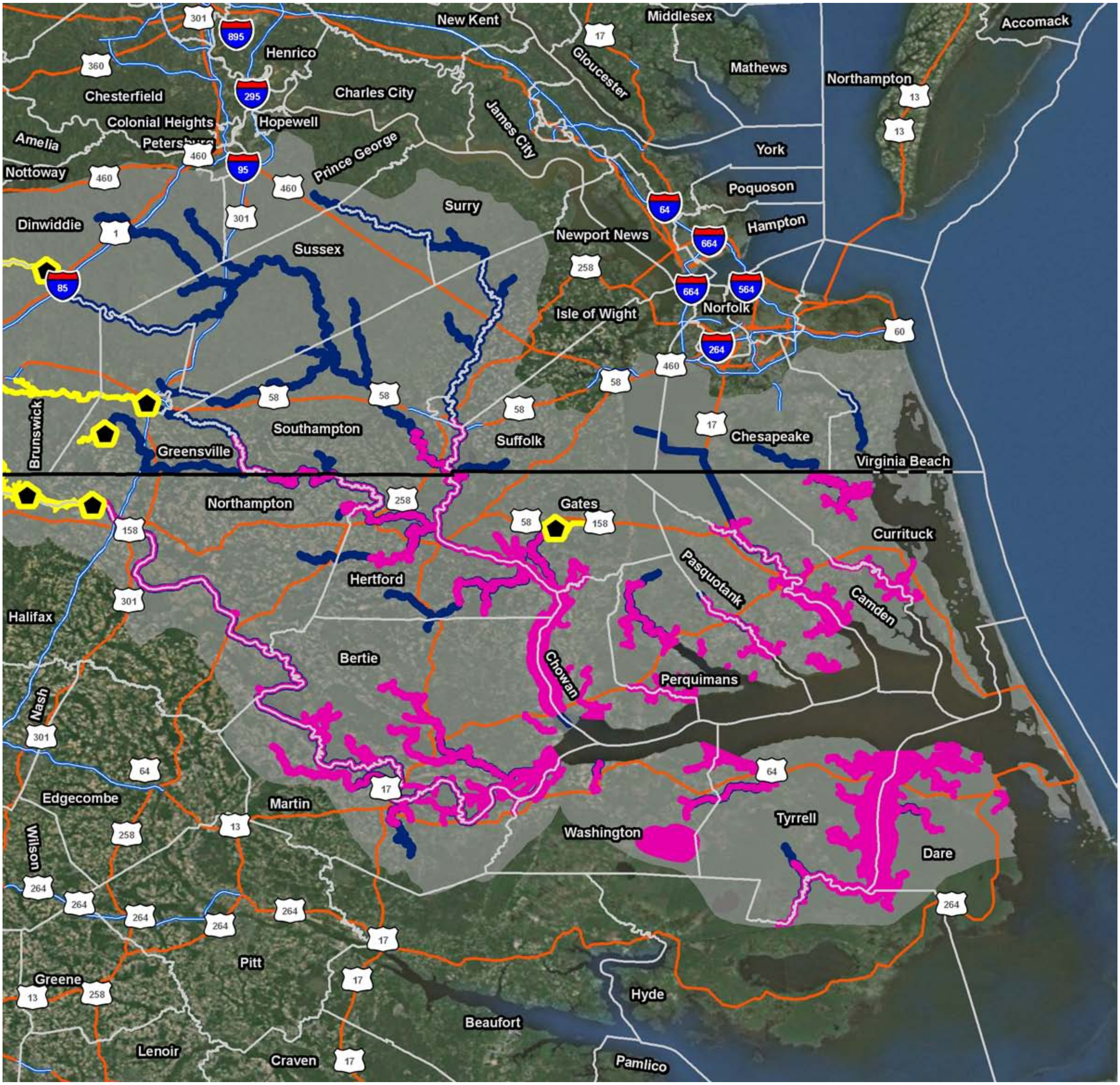
26. Northeast Cape Fear River
    Anadromous fish waters within the Northeast Cape Fear River System extend from the confluence with the Cape Fear River north to State Route 1318 bridge and include Long Creek, Turkey Creek, Prince George Creek, Island Creek, Merrick (Harrisons) Creek, Pike Creek, and Burgaw Creek.

27. Black River
    Anadromous fish waters within the Black River System extend from the confluence with the Cape Fear northwest to include Six Runs Creek and Great Coharie Creek at the NC 24 bridges. Included in this system is the South River up to State Route 1007 bridge.

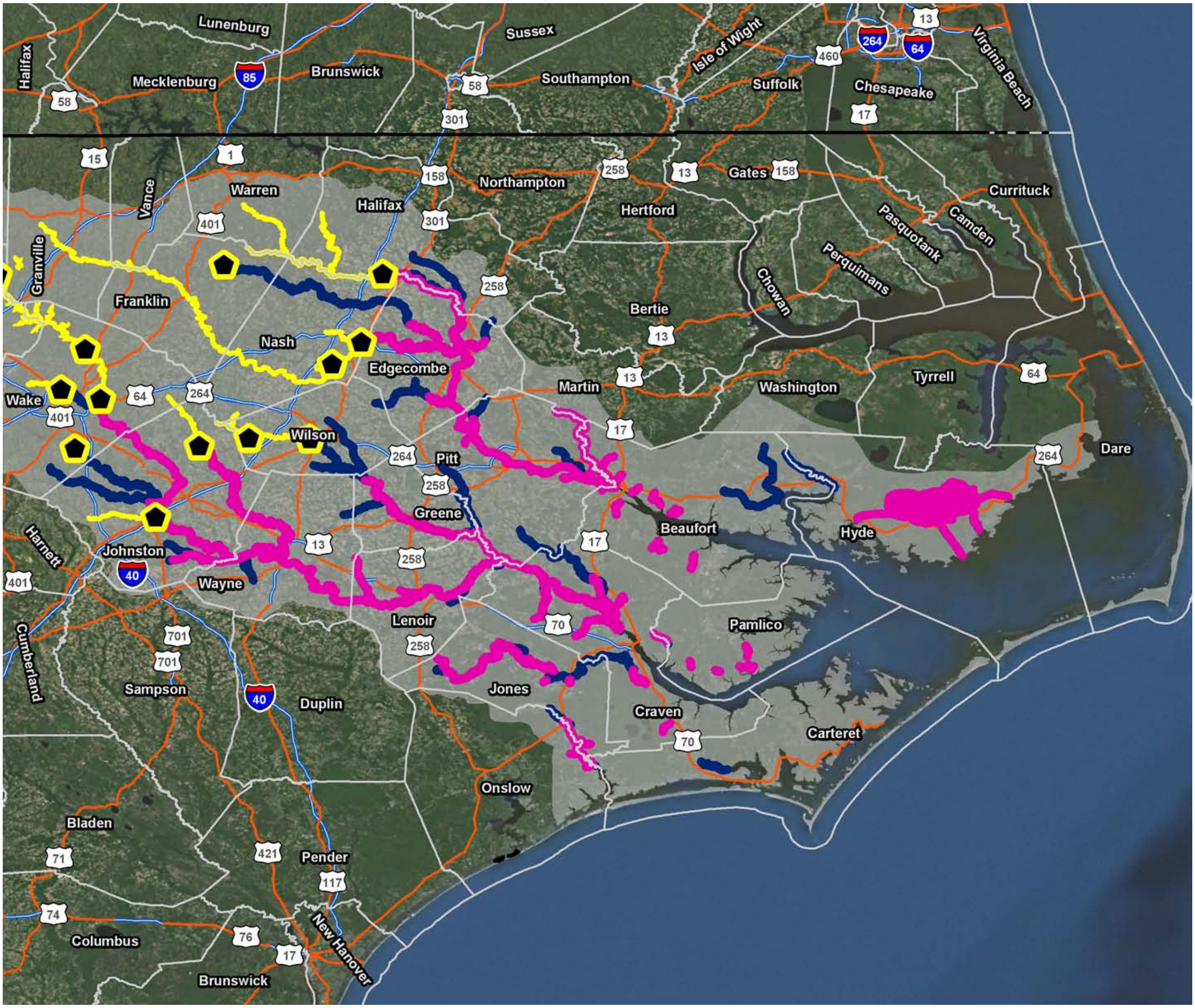
28. Cape Fear River

Anadromous fish waters within the Cape Fear River System extend from the Atlantic Ocean north and northwest to Buckhorn Dam and includes Lilliput Creek, Town Creek, Mallory Creek, Jackeys Creek, Brunswick River, Alligator Creek, Mill Creek, Sturgeon Creek, Indian Creek, Hood Creek, Livingston Creek, Wayman's Creek, Steep Run, Hammond Creek, and Brown's Creek.

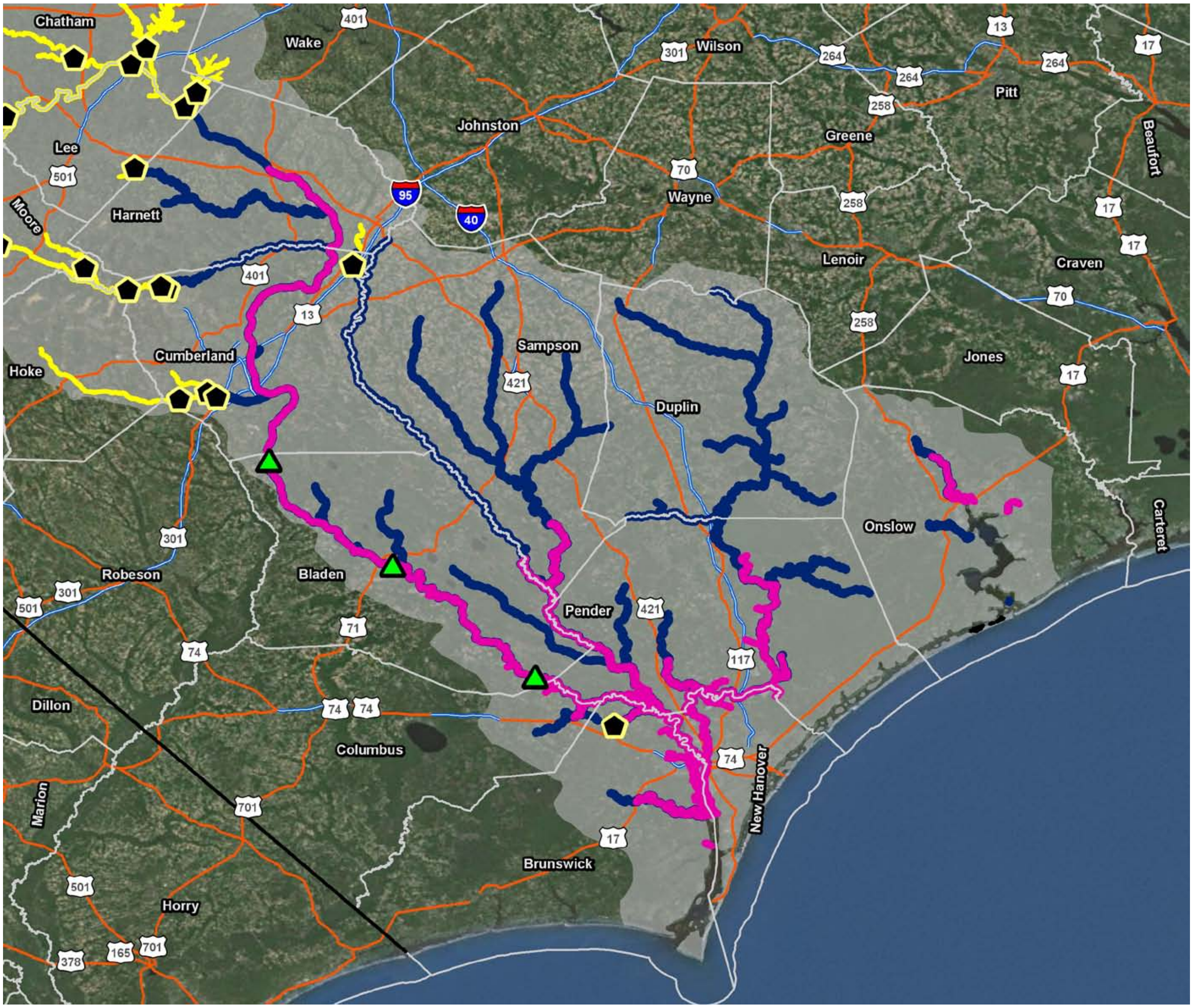
29. Pee Dee River
    Anadromous fish waters within the Pee Dee River system extend from South Carolina state line north to Blewett Falls Dam and include Marks Creek, Jones Creek, Hitchcock Creek, and Cartledges Creek.



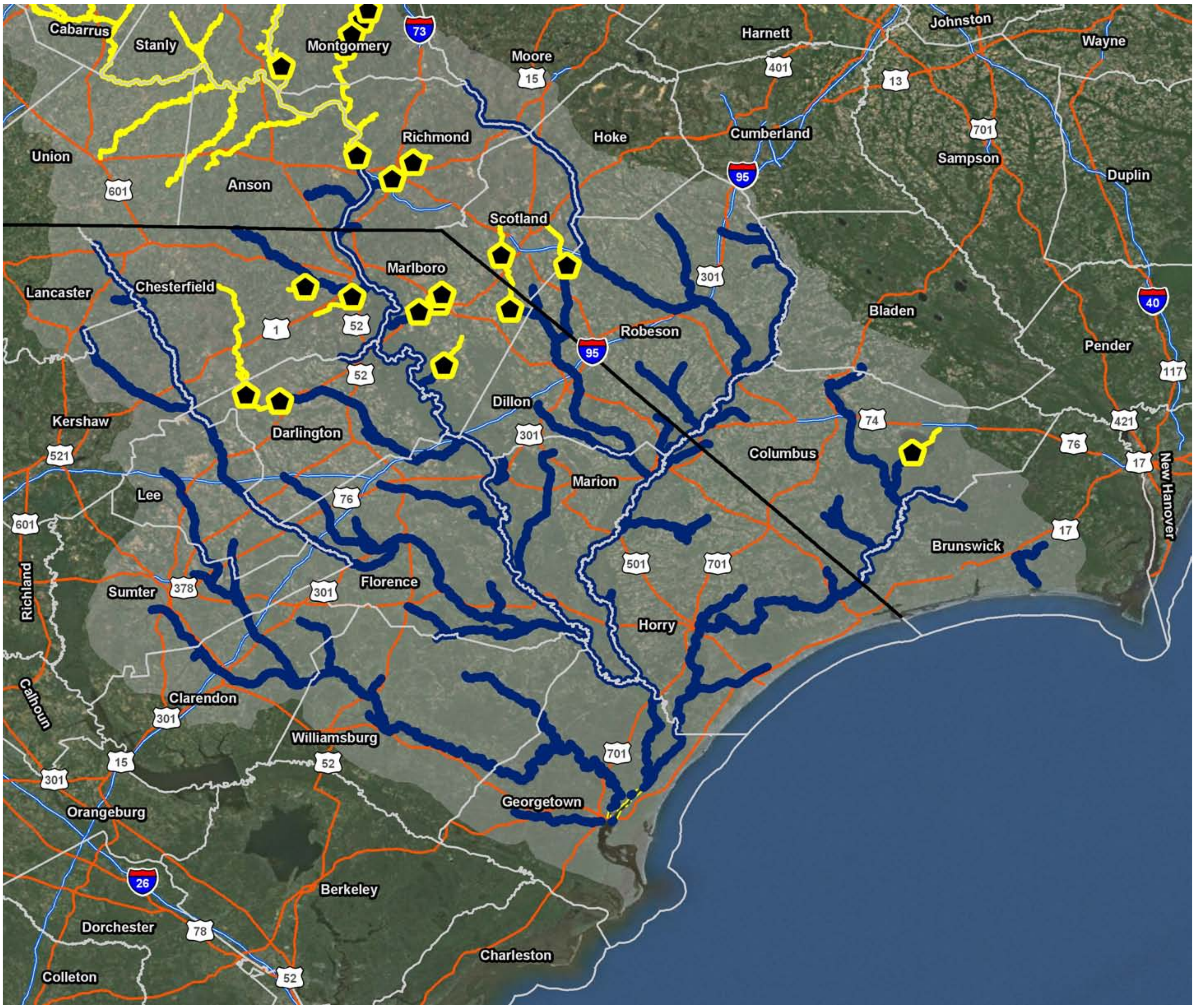
Waters in the Roanoke-Chowan River basins that support or potentially support anadromous fishes. Pink represents designated Anadromous Fish Spawning Areas, blue is potential anadromous fish habitat, yellow/black symbols are dams, and yellow represents potential habitat that is currently blocked by dams.



Waters in the Tar-Neuse River basins that support or potentially support anadromous fishes.

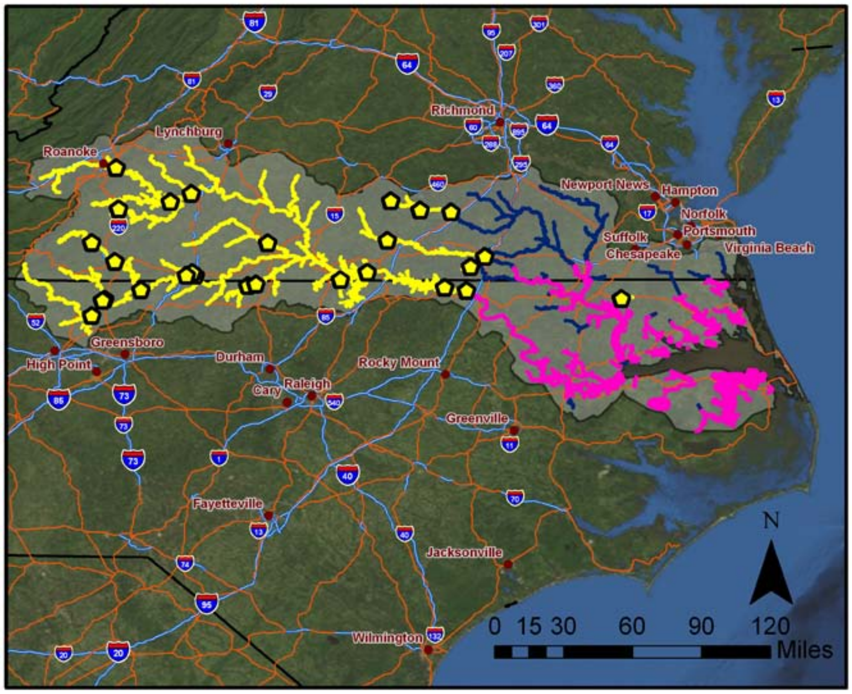


Waters in the Cape Fear River Basin that support or potentially support anadromous fishes. Green triangles represent dams with some fish passage.

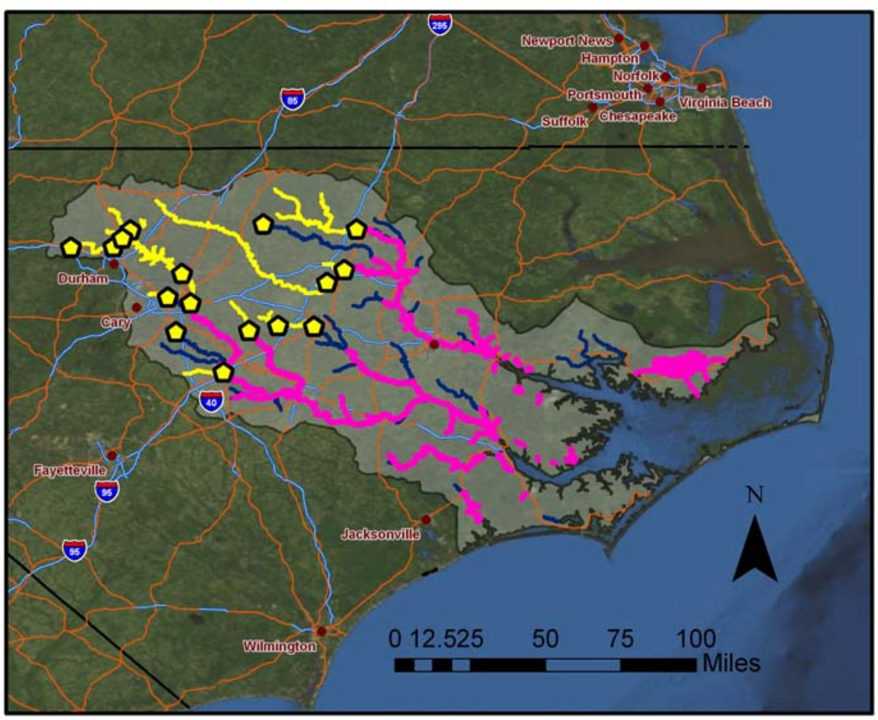


Waters in the Yadkin-Pee Dee River Basin that support or potentially support anadromous fishes.

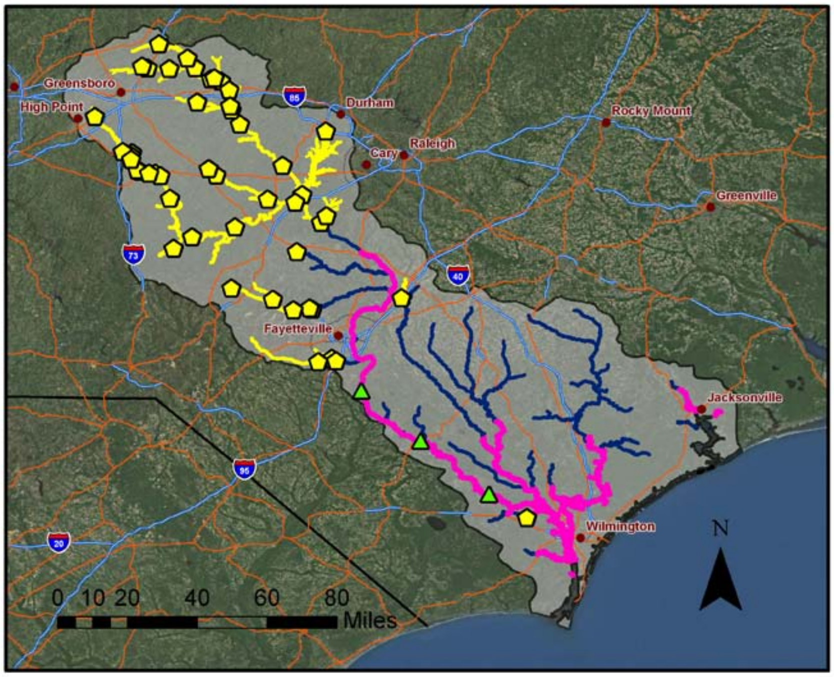
Maps of the entire river basins with waters that could support anadromous fish based on spring flows.



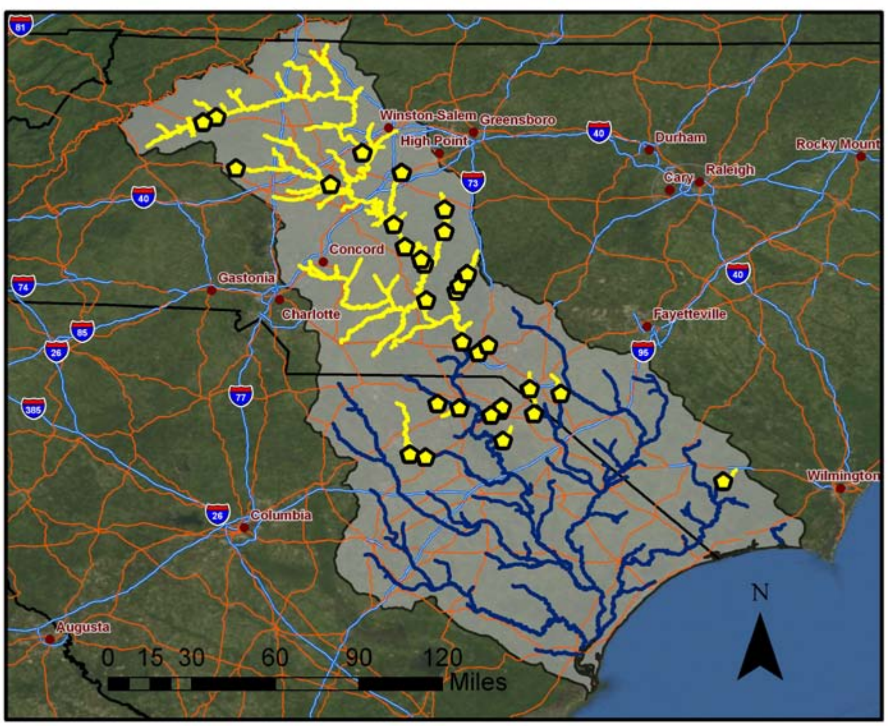
Roanoke-Chowan



Tar-Neuse



Cape Fear



Yadkin-Pee Dee

GUIDELINES FOR THE LOCATION AND DESIGN OF HAZARDOUS SPILL BASINS

Hazardous Spill Basins are provided in new highway construction and major improvment projects at strategic locations along arterial system highways to aid in containment and clean up of accidental spills. The determination of these strategic locations is based on concentrated truck usage areas such as; parking sites at rest areas, weight stations, and runaway ramps, as well as for highway segments in close proximity to particularly sensitive waters such as; outstanding resource waters and water supply sources.

The strategy is to configure the highway segment of concern such that any potential spill runoff would be directed through a facility (basin) where the flow could be interrupted and temporarily stored to prevent hazardous material from reaching a receiving stream.

The use of these basins and other management practices to protect receiving waters is in accordance to the general policies and criteria presented in the departments document “Best Management Practices for Protection of Surface Waters”. The following is additional specific guidance in the location and design of the basins:

APPLICABLE LOCATIONS

- Basins will be provided **at stream crossings** on highways functionally classified as a rural or urban arterials and,
  - The stream(1) is identified as an Outstanding Resource Water (ORW) or a WS-I watersupply, or
  - The stream(1) crossing is within 1/2 mile of the critical area(2) of a water supply source classified as WS-II, WS-III and WS-IV.
- Provision of basins at crossings of those streams on highways functionally classified as collectors and local streets and roads can be evaluated on a site by site basis with consideration for: traffic volume, traffic type, accident potential related to the highway geometrics, receiving water quality, and the feasibility of basin construction at the site.

(1) *For the purpose of these guidelines "stream" will be defined as those depicted as blue lines on 7-1/2 minute (1:24000 scale) United States Geological Survey (USGS) quadrangles.*

(2) *Critical area is defined as extending 1/2 mile from the normal pool elevation of a reservoir; or 1/2 mile upstream of , and draining to an intake. This would make the effective area for hazardous spill basins placement, within 1.0 mile of the normal pool or upstream of an intake.*

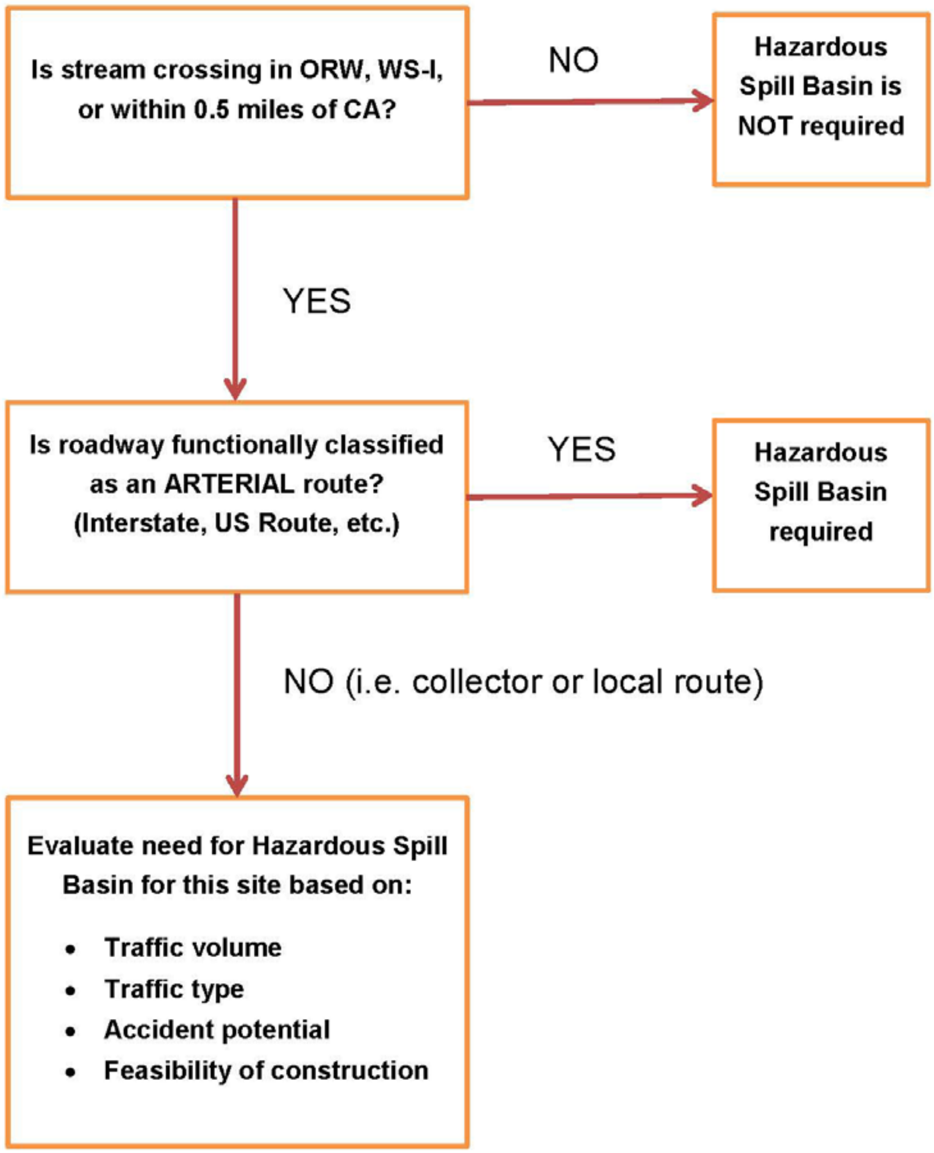
DESIGN REQUIREMENTS

- The volume of spill containment storage provided will be approximately 10,000 gallons plus the estimated runoff volume from a rainfall intensity equating to a two year return period event.

- A means will be provided such that the normal free flow of runoff at the basin outlet can be interrupted to cause containment of hazardous runoff. This can be accomplished by providing a mechanical control gate or by constructing a minimum control section in the outlet channel that could be readily blocked by such simple mean as shoveled earth material or stacked bags.

- The mechanical gate alternative will generally be utilized in areas where normal operational activities would allow close scrutiny and control, reducing the potential for problems with vandalism. Examples would be rest areas, weight stations and within controlled access.

HAZARDOUS SPILL BASIN FLOWCHART



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PERMIT DRAWINGS GUIDELINES
(July 2016)

Table of Contents

* Merged with Division of Water Resources in August 2013

PERMIT DRAWING GUIDELINES

PERMIT DRAWING CADD FILE SETUP

Using the Design File Generator, create the following files (if needed) and place in the "Hydraulics/PERMITS_Environmental/Drawings" directory:

- "TipNo_Hyd_prm_wet.dgn" (where wetland and stream impact hatching will be drawn)
- "TipNo_Hyd_prm_buf.dgn" (where buffer impact hatching will be drawn)

Open the "*wet.dgn" or "*buf.dgn" file above and reference in all roadway plan sheets that have impact areas. Hatch impact areas as needed noting site numbers at each impact location. ("B" projects generally do not require site numbers but depending on the number of resources impacted, separate site numbers may be required. Ex. More than one stream or more than one wetland would require separate site numbers). Site locations should be labeled numerically (1, 2, 3, etc.).

Next, create a plan sheet file for each plan sheet having impact areas. Reference in the "*wet.dgn" or "*buf.dgn" noted above. Each plan sheet should have a "Permit Drawing Sheet _ of _" cell, a plan scale, date/user name/ file name label, and a legend for each different impact type shown on the sheet. (A separate legend sheet is not required.) IPLOT Organizer may facilitate plotting of multiple permit plan sheets.

Note: When adding "date/user name/file name label", drop the cell in the bottom left hand corner of the plan sheet. The cell will appear as "$date$ $(username)$ $filel$".
DO NOT manually replace this text with your own information. The cell will automatically populate the text when you print or export the file to PDF.

If wetland impacts are on the project, at least one representative cross section will need to be plotted, per site. The cross section "xpl" files should be used for this purpose. Simply copy and rename the file ""TipNo_Hyd_prm_xpl.dgn" and place in the "Hydraulics/PERMITS_Environmental/Drawings" directory.

The Department's current levels, logical names, and symbology for permit CADD work must be followed. The Hydraulics Workspace for MicroStation provides a Hydraulics Toolbar to facilitate this. The Workspace should be updated regularly to ensure it is current. The permit drawings must be in color, using red for all proposed drainage, blue for all jurisdictional features, gray for contours, and black for all impacts. This same color format is to be used for preliminary permit drawings reviewed during the "4C" Merger Meeting, if applicable.

<u>PERMIT DRAWINGS</u> (for Natural Environment Section, NES, submittal)

General guidance and requirements:

- The required naming convention for this single PDF will be *"TIP_Permit Drawings_Current Date (YEARmoDAY) .pdf"*. The PDF will need to be placed at

"Hydraulics\PERMITS_Environmental\Drawings". If both Wetland/Stream and Buffer Permit Drawings are required, the separate Buffer drawings package should be named *"TIP_Permit Drawings_BUFFER_Current Date (YEARmoDAY) .pdf"*.

- Include "*Permit Drawing Sheet__of __*" cell on all sheets (excluding the Stormwater Management Plan, SMP) for NES use with respective sheet numbers reflected. If both Wetland/Stream and Buffer Permit Drawings are required, each type is separately packaged and should be numbered as an individual set.
- Excel versions of the wetland/stream and buffer impact tables as well as the Storm Water Management Plan will need to reside in the "Hydraulics\PERMITS_Environmental\Forms" directory.
- For Merger Projects, "4B" & "4C" Merger Meeting Minutes will need to be sent with the Permit Drawings. The minutes reside in the "Hydraulics\PERMITS_Environmental" directory.
- Private Engineering Firms: Please submit CADD and Excel files along with the PDF of the permit drawings.

ITEMS TO OMIT (IF POSSIBLE) TO DE-CLUTTER PLAN SHEETS

DRN file:

- Structure numbers, ditch details (except swales or ditches near jurisdictional areas), rip rap, and geotextile quantities.
- Approach slab, embankment cut and pavement removal hatching since it can be confused with wetland or buffer impact hatching.

ROW file:

- Station and offsets for R/W, PDE, TDE, and E
- Right of Way marker symbols
- Property line bearings

DSN file:

- Superelevations
- Pavement and shoulder widths
- Guardrail and Guardrail text
- Traffic flow arrows
- Begin and End Bridge Stations
- Begin and End Approach Slab Stations
- Approach Slab Single Hatch must be turned off
- Any other hatching that could be confused with impact hatching should be turned off as well.
- Curve Data Info, PT, PC, etc.

FS file:

- Baseline
- Deed book reference and/or Map page
- Bearing and Distance for property lines
- Datum Description

The submittal to NES should be a single PDF containing the following (where applicable), in this order:

1. **<u>Stormwater Management Plan (SMP)*</u>**

   (https://connect.ncdot.gov/resources/hydro/pages/default.aspx) under "Highway Stormwater Program (HSP)."

***<u>Submission of Completed SMPs to Hydraulics Unit</u>**

NCDOT's NPDES Permit requires that all completed SMPs be archived for a minimum period of five years. The Hydraulics Unit has set up a service account email to make this archiving process convenient and to answer any SMP related questions. All SMPs must be submitted (in their original Excel format) to the following service account email upon completion and submittal of the Permit Drawing Package. Note that submittal of the SMP to the service account email is not part of the permit drawing package approval process.

NCDOT_Hydraulics_SMP@ncdot.gov

2. **<u>Wetland & Stream Permit Drawings</u>**

   Wetland & Stream Permit Drawings Should Contain:

   - PROJECT TITLE SHEET- 11"x17" Titled "Wetland & Stream Impacts". Site locations should be labeled numerically (1, 2, 3, etc.). Verify that Let and Right of Way dates are current.
   - PLAN SHEETS WITH IMPACTS HATCHED - 11"x17" (only those sheets with impacts, one with and one without contours plotted) Show hatched area impacts in wetlands and streams within the project footprint as well as those areas needed for demolition of the existing structure or construction of the proposed structure. Such areas could include limits of construction phasing, work bridges, work pads or causeways. A legend for the hatched area type and sheet scale should be placed on each sheet.
     - If enlargement view is necessary on an additional plan sheet, include it on an 11" x 17" sheet directly behind the respective plan view.
     - If applicable, Riparian Buffer Zones should be reflected on the wetland/stream permit plan view.

Sheets Should Include:

1. Show the existing and proposed bridge/interior bents and/or box culverts.
2. Stormwater treatment data; Show Q_{10} and V_{10} data for all ditch outlets that drain directly into wetlands. V_{10} must be non-erosive (2.0 fps or less) entering wetlands. For preformed scour holes, show Q_{10}.
3. Temporary work bridges and rock work pads or causeways. See Work Pad section below.
4. Details for features affecting impact areas: bank stabilization, swales, structure inlet/outlets, etc.
5. Roadway centerline, stations with tick marks, sheet match lines, north arrow and parcel numbers & names.
6. Top of bank lines for major stream crossings.

- PERMIT PROFILE SHEETS FOR BRIDGES (11"x17", located directly behind respective permit plan view) Use Roadway's centerline profile sheet, show existing and proposed bridges including interior bents. The bridge and bridge opening profile should match the bridge opening contained in the Bridge Survey Report. Any required excavation and the Normal Water Surface (NWS) should also be shown on the profile sheets. For CAMA Permits, indicate rip rap under bridges on profile (should match what is shown on the BSR). For tidally influenced crossings, show Mean High Water (MHW) and Mean Low Water (MLW) or only Normal Water Level (NWL) if the difference between daily high and low tides is less than six inches.
- PERMIT PROFILE SHEETS FOR CULVERTS (11"x17", located directly behind respective permit plan view) Profiles along culverts are required for pipes and box culverts that have the conveyance of a 60" pipe or greater in Jurisdictional Streams (JS). Show flow line profile of culvert and stream. (Flow Line Profile from Culvert Survey Report can be used). Indicate the Normal Water Surface (NWS) and slope of the culvert. (See example provided on page 10)
- ROADWAY CROSS SECTIONS (one representative cross section per site in wetland impact areas) half sized with at least one cross section shown per each wetland impact area. Wetland boundaries should be indicated on the cross section(s) by a thick vertical line labeled "Wetlands". Separate cross sections are not needed for buffer permit drawings if they are already included in wetland/stream permit drawings.
- HYDRAULIC DESIGN DETAIL SHEET (if not included on project plan sheets) Note: For culvert sites with sills and/or baffles, provide culvert detail(s) and any associated notes such as native bed material.
- WORK PADS & CAUSEWAYS: If required, copy layout from Structure Management's General Drawing (SMGD) onto permit plan view (check the plotted limits of the work pad/causeway and correct if needed). Include cross-sectional detail of the work pad/ causeway if needed for clarity and if not provided on SMGD. If the cross-sectional detail will not

fit on the permit plan view sheet, a separate detail sheet can be added. Verify that the top of the work pad/causeway has been drawn at least 2 feet above the NWS. (See example plan and profile sheets provided on pages 11 &12.) It is also acceptable to directly include Structure Management's General Drawing with the work pad/causeway cross sectional detail as a part of the Permit Drawings. The sheet number cell would need to be added directly to SMGD.

- WETLAND & STREAM IMPACT SUMMARY SHEET (Excel file) - 11" by 17". (The latest "Wetland Permit Impact Summary" form can be found on the Hydraulics Unit Web Site under "Environmental Permit Forms")**.** Individual site impacts should be entered to the nearest 0.001 acres on the Excel Wetland Permit Impact Summary Form "Data Entry Page" tab. The Wetland Permit Impact Summary to be included in the permit package should be printed from the "Print Page" tab which rounds data to the nearest 0.01 acres or will show as "<0.01 acres" if applicable. Surface water impacts should be shown to the nearest linear foot. Permanent bank stabilization should be reported as a separate linear impact to the nearest foot. Temporary bank stabilization should be reported as a linear foot and acreage impact. The Structures Management Unit will supply the Hydraulics Unit with permanent impact calculations for the proposed bents in the water. This data should be reflected below the Wetland Permit Impact Summary Table in the "Notes" section. If more than one summary sheet is required, include a subtotal for each sheet and on the last sheet have both a subtotal for that sheet and a total line for the entire project.

Wetland Permit Impact Summary Sheet Key

1. Site No. - Site number referenced on the permit drawing plan view.
2. Station (From/To) - the project station where the impacts occur. Does not have to be from/to unless it is a very long linear impact. Will want to reference left or right of the centerline if applicable.
3. Structure Size/Type - type of structure if applicable. Examples: box culvert, bridge, pipe, temporary work bridge, temporary rock causeway, bank stabilization, etc.
4. Permanent fill in wetlands, temporary fill in wetlands, excavation in wetlands, mechanized clearing in wetlands, hand clearing in wetlands, and isolated wetlands report impact in acres of wetlands. For an isolated wetland site, place an asterisk with the quantity to reference a note below the summary table on the impact summary sheet.
5. Permanent SW Impacts - quantity in acres of surface waters impacted permanently. Surface waters include streams, lakes and ponds (ponds that are connected to surface water streams or wetlands. Does not include isolated ponds). Examples: culverts in streams, permanently placed riprap in streams, bank stabilization, any part of the surface water of the stream that is permanently relocated, permanent roadway fill in the surface water, any part of the surface water that is permanently dewatered or drained, etc.

(Note that bank stabilization should be noted separately, for each site in the impact table.) Permanent bank stabilization should be reported as a separate linear impact to the nearest foot. Where permanent bank stabilization is proposed on opposing sides of the channel, do not double-count impacts in areas of overlap. (Length is total length of channel impacted, regardless of whether impacts are on one bank or both.)

6. Temporary SW Impacts - quantity in acres of surface waters impacted temporarily. Surface waters include streams, lakes and ponds (ponds that are connected to surface water streams or wetlands). Does not include isolated ponds. Examples: temporary fills due to temporary rock causeways required for bridge construction or construction access, temporary detour fills in surface water, temporary dewatering impacts required for construction. Temporary bank stabilization (grading of the bank where rip rap will not be placed) should be reported as a linear foot and acreage impact.
7. Existing Channel Impacts Permanent - length of stream that is permanently impacted as noted in 5 above. Report to nearest foot.
8. Existing Channel Impacts Temporary - length of stream that is temporarily impacted as noted in item 6 above. This distance should be a minimum of 10 feet beyond each end of the proposed drainage structure for pipe and culvert crossings, but may need to extend to the limit of construction phasing. Report to nearest foot.
9. Natural Stream Design - length of stream that is relocated (due to project impacting it) using natural stream design techniques. Report to nearest foot.

Note that other impacts the permitting agencies require may be reported at the bottom of the sheet in the “Notes” section. Examples would be impacts due to bridge piers (provided by Structure Management Unit) in the wetlands (temporary and permanent), CAMA wetlands, etc.

3. <u>Buffer Permit Drawings</u>

Current basins and watersheds that require buffer permit drawings:
Neuse River Basin, Tar-Pamlico River Basin, Catawba River (Main Stem and Main Stem Lakes), Goose Creek, Randleman Lake Watershed, Jordan Lake Watershed

Buffer Permit Drawings Should Contain;

- PROJECT TITLE SHEET- 11”x17” Titled “Buffer Impacts”. Site locations should be labeled numerically (1, 2, 3, etc.). Verify that Let and R/W dates are current.
- PLAN SHEETS WITH IMPACTS HATCHED (without contours) 11”x17” (for only those sheets with impacts), showing hatched area impacts for buffers and access for work bridges/work pads or causeways

needed for demolition of the existing structure or construction of the proposed structure. A legend for the hatched area type and sheet scale should be placed on each sheet.

- If enlargement view is necessary on an additional plan sheet, include it on an 11” x 17” sheet directly behind the respective plan view.
- If applicable, wetland/stream boundaries should be reflected on the buffer permit plan view.
- For existing transportation facilities with jurisdictional stream crossings, riparian buffer zones will need to be reflected as arcs around the ends of the existing cross line. If both ends of the existing cross line are jurisdictional, the arcs should extend until they overlap where they should merge. Impacts should not be reflected for the portion of the riparian buffer zones that are within the footprint of the existing transportation facility. The guidance above is based on the March 10, 2008 Buffer Interpretation/Clarification Memo from the Division of Water Quality (Division of Water Resources as of 8/1/2013) provided on page 13 or at: http://portal.ncdenr.org/c/document_library/get_file?uuid=79a7802c-de83-4e83-b012-cbb949d8ebb3&groupId=38364

  To review other Riparian Buffer Clarification Memos published by DWR, please refer to “DOT and Other Road Projects” on the following link: https://deq.nc.gov/riparian-buffer-clarification-memos

Sheets Should Include:

1. Show the existing and proposed bridge/interior bents and/or box culverts.
2. Grass swale ditch data at buffer areas: Show Q_{2}, V_{2} and Q_{10}, V_{10} data as well as all other pertinent data described in BMP Toolbox, Stormwater Management Plan and grass swale data table cell under Microstation main menu/Permits/Buffer Rules/Data Tables/Grass Swale.
3. Temporary work bridges and rock work pads or causeways. See example work pad plan and profile sheets on pages 11 & 12.
4. Details for features affecting impact areas; bank stabilization, swale, structure inlet/outlets, etc.
5. Roadway centerline, stations with tick marks, sheet match lines, north arrow and parcel numbers & property owners.

- HYDRAULIC DESIGN DETAIL SHEET (if not included on Project Plan Sheets) Note: For culvert sites with sills and/or baffles, provide culvert detail(s) and any associated notes such as Native Material.
- STORMWATER CONTROL DETAILS (if details are on separate sheets, include those sheets)

- BUFFER IMPACT SUMMARY SHEET - 11" x 17". (The latest "Buffer Impact Summary" form can be found on the Hydraulics Unit Web Site under "Environmental Permit Forms"**.** Riparian Buffer (Zone 1 and Zone 2) Impacts are shown to the nearest square foot. Note that there is another worksheet in this file (see Excel tab) where "wetlands in buffer" square footage needs to be reported if applicable. This is for NES's use so that impacts are not counted twice. Note that a line drawn through and skewed with each end of the proposed bridge serves as the break between Road Crossing and Bridge Crossing Impacts.

  * For coastal counties, riparian buffers extend from the limit of the established CAMA Coastal Wetland boundary. See the Division of Water Quality (changed to Division of Water Resources as of 8/1/2013) buffer clarification memo dated May 25, 2007: http://portal.ncdenr.org/c/document_library/get_file?uuid=a65ef197-5af3-4c18-92e7-96ab37e2cafe&groupId=38364 (copy provided on page 14).

Buffer Permit Impact Summary Sheet Key
(For Items Not Explained Above)

1. SITE NO.: site number referenced on the buffer drawing plan view.
2. TYPE*: Type of impact - Road Crossing, Bridge or Parallel Impact - Place an "x" in the appropriate column
3. ALLOWABLE IMPACT: Zone 1, Zone 2 and totals (Zone 1 plus Zone 2)
4. MITIGABLE IMPACT: Zone 1, Zone 2 and totals.
5. BUFFER REPLACEMENT: Zone 1, Zone 2 and totals.
6. WETLANDS IN BUFFERS (see tab at bottom of spreadsheet): To ensure impacts are not counted twice in both wetlands and buffers impacts summaries, report the wetlands within buffer zones in units of square feet for NES's use.

   *Note: The three most common types of impacts are road crossing, bridge or parallel impacts; however, other types of impacts may exist (e.g. temporary road). A column that is not being used may be used for reporting these impacts, or a new column may need to be added.

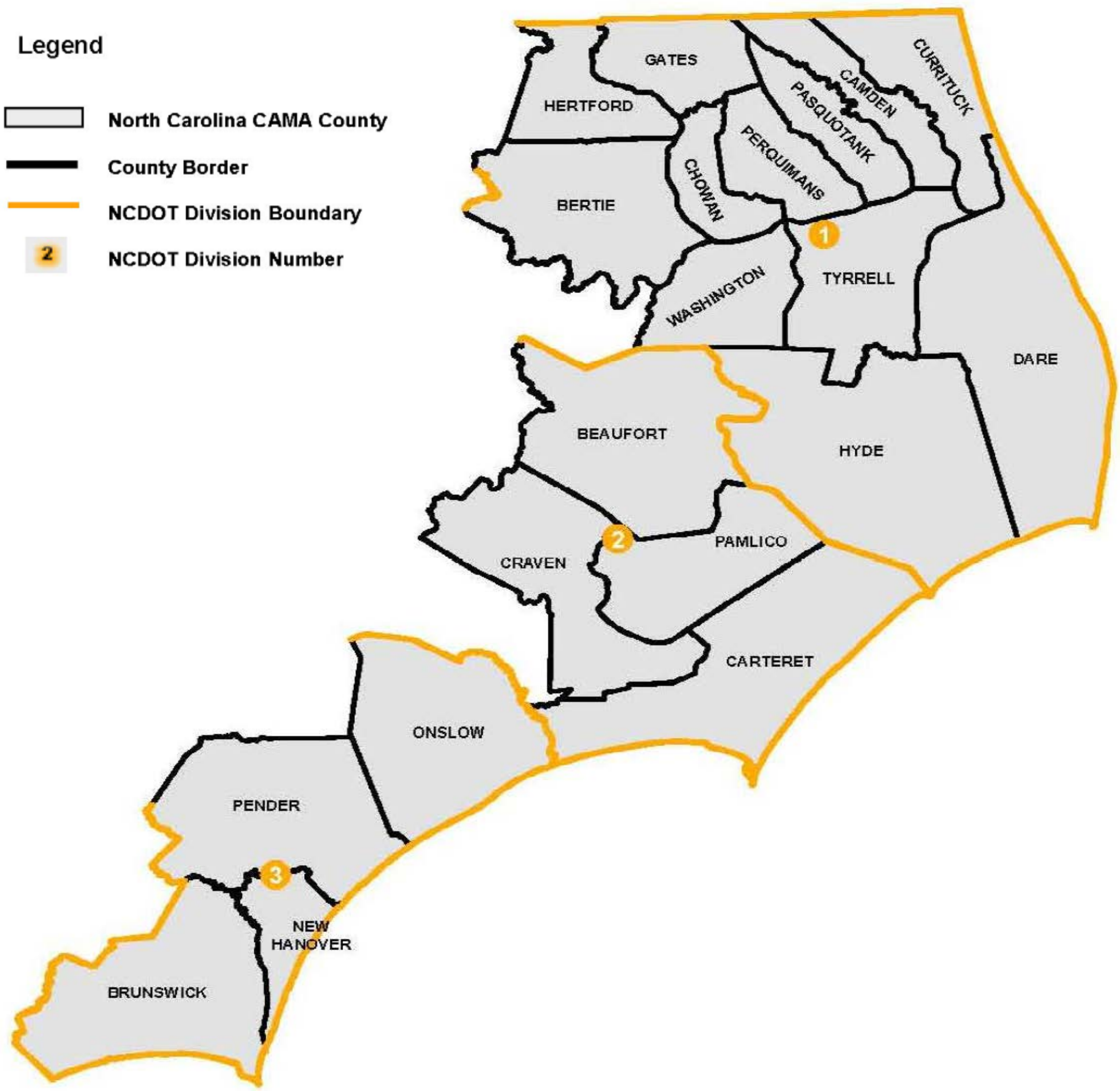
4. CAMA Major Permit (MP) Application Forms (only if required).
A map of the 20 CAMA Counties is provided on page 9.

For CAMA Permits:

- If CAMA Wetlands are indicated in the NES WET file, show combined quantity in table but indicate separate CAMA Wetland Quantity in a note at the bottom of the impact summary sheet.
- CAMA Major Permit (MP) Application Forms as needed. The forms can be downloaded from https://deq.nc.gov/about/divisions/coastal-management/coastal-management-permits/major-permit-applications .

CAMA COUNTIES

If your project is one of these 20 counties reflected below and within an Area of Environmental Concern (AEC), a CAMA Permit may be required.



PROJECT REFERENCE NO. | SHEET NO.

R/W SHEET NO.

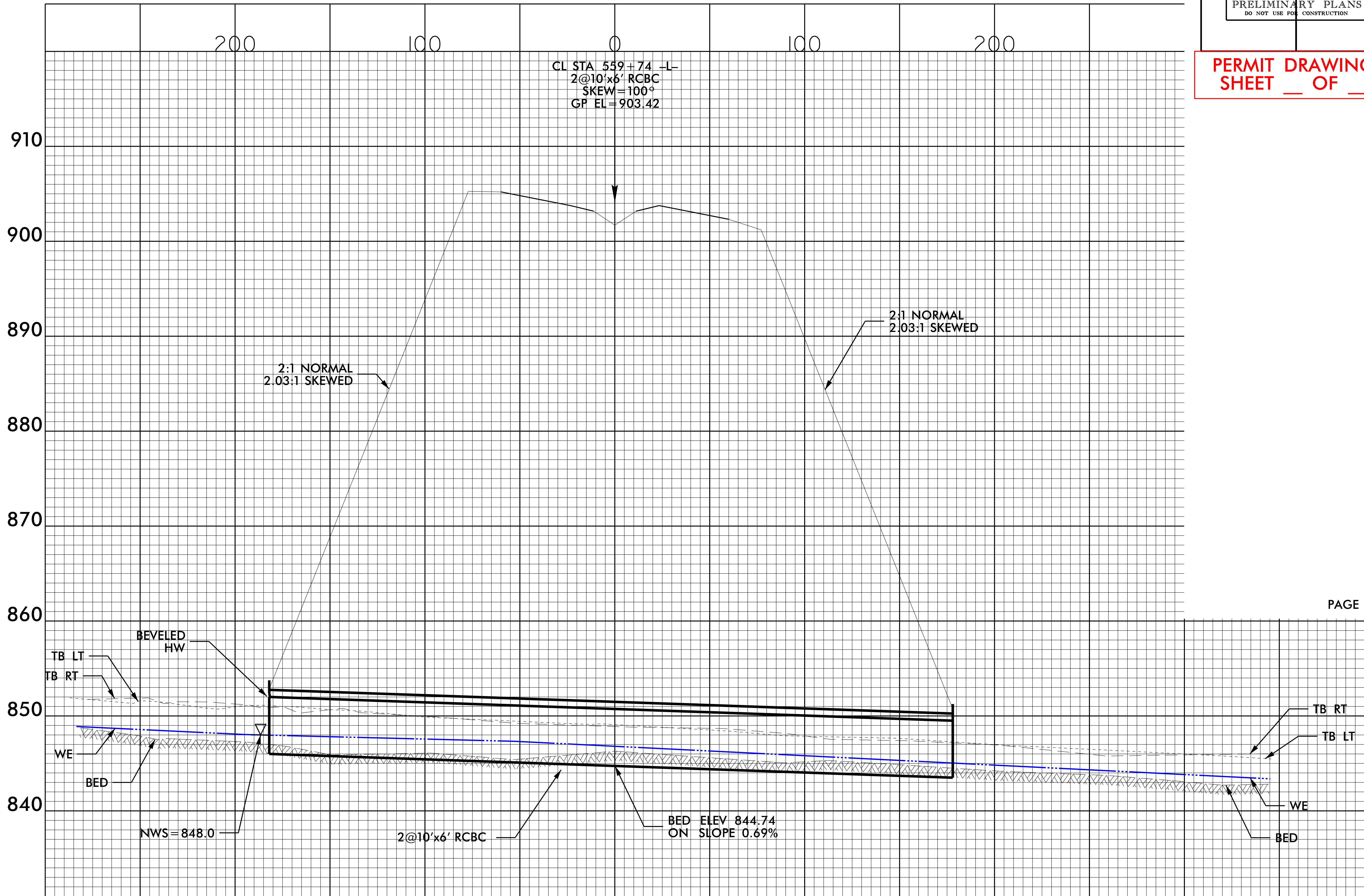
ROADWAY DESIGN ENGINEER | HYDRAULICS ENGINEER

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION

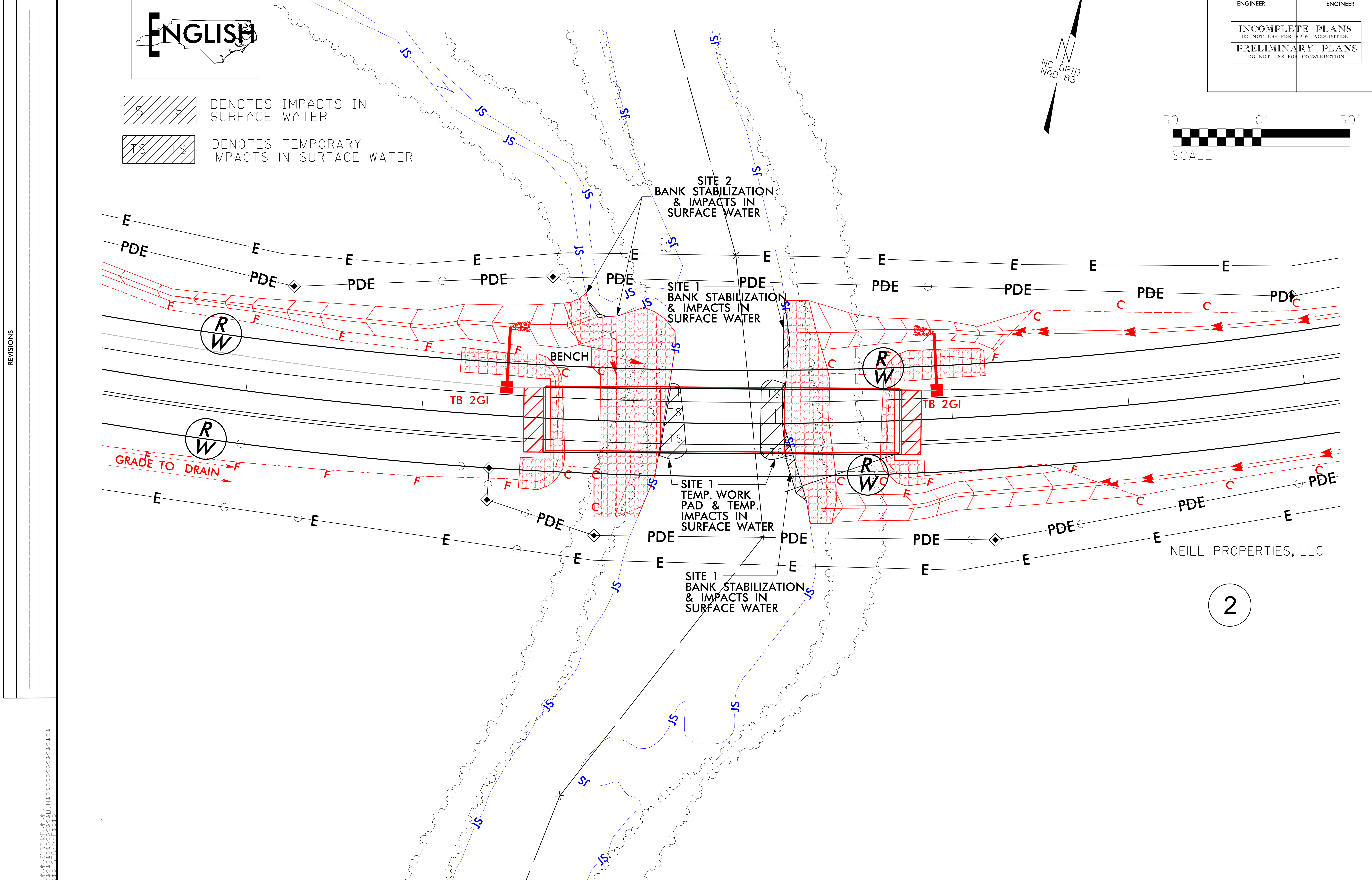
PERMIT DRAWING
SHEET __ OF __

REVISIONS



$$$$SYSTIME$$$$
$$$$DGN$$$$
$$$$USERNAME$$$$

WORK PAD EXAMPLE



WETLAND/SURFACE WATER PERMIT DWG.

PROJECT REFERENCE NO.	SHEET NO.
	6
ROADWAY DESIGN ENGINEER	HYDRAULICS ENGINEER

BEGIN GRADE -L- STA 10+00
EL = 841.45

-L- STA 14+50 =
-Y1- STA 11+87.62
EL = 815.49'

BRIDGE HYDRAULIC DATA

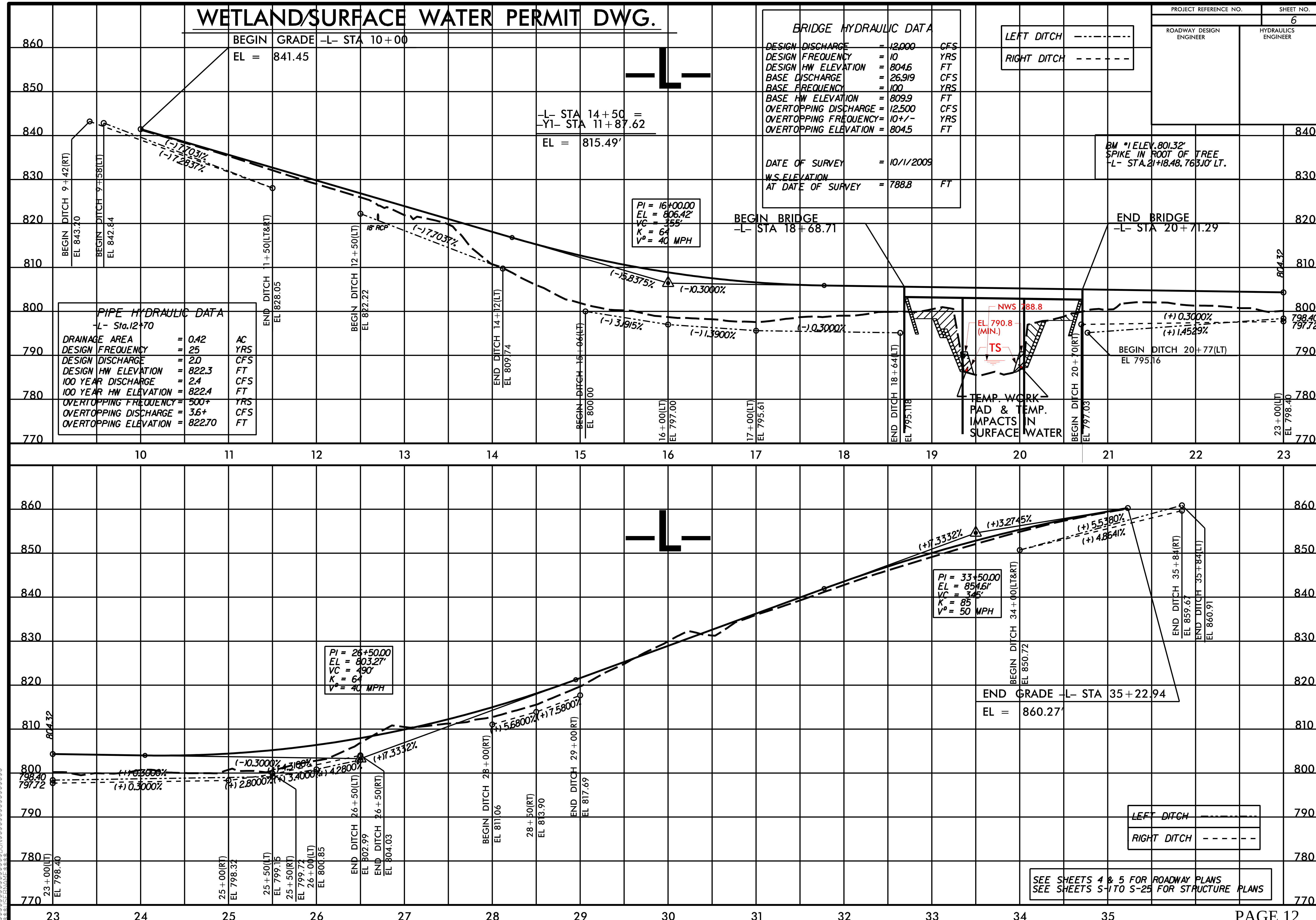
DESIGN DISCHARGE	=	12,000	CFS
DESIGN FREQUENCY	=	10	YRS
DESIGN HW ELEVATION	=	804.6	FT
BASE DISCHARGE	=	26,919	CFS
BASE FREQUENCY	=	100	YRS
BASE HW ELEVATION	=	809.9	FT
OVERTOPPING DISCHARGE	=	12,500	CFS
OVERTOPPING FREQUENCY	=	10+/-	YRS
OVERTOPPING ELEVATION	=	804.5	FT
DATE OF SURVEY	=	10/1/2009	
W.S. ELEVATION AT DATE OF SURVEY	=	788.8	FT

LEFT DITCH	- · - · - · -
RIGHT DITCH	- - - - - -

BM #1 ELEV. 801.32'
SPIKE IN ROOT OF TREE
-L- STA. 21+18.48, 76.10' LT.

PIPE HYDRAULIC DATA
-L- Sta. 12+70

DRAINAGE AREA	=	0.42	AC
DESIGN FREQUENCY	=	25	YRS
DESIGN DISCHARGE	=	2.0	CFS
DESIGN HW ELEVATION	=	822.3	FT
100 YEAR DISCHARGE	=	2.4	CFS
100 YEAR HW ELEVATION	=	822.4	FT
OVERTOPPING FREQUENCY	=	500+	YRS
OVERTOPPING DISCHARGE	=	3.6+	CFS
OVERTOPPING ELEVATION	=	822.70	FT



SEE SHEETS 4 & 5 FOR ROADWAY PLANS
SEE SHEETS S-1 TO S-25 FOR STRUCTURE PLANS

Michael F. Easley
Governor

William G. Ross, Jr., Secretary
Department of Environment and Natural Resources

Coleen, H. Sullins, Director
Division of Water Quality

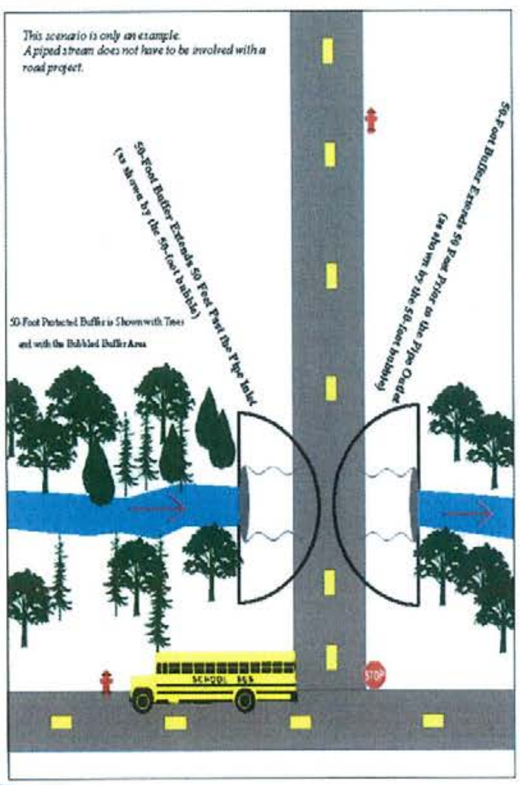
March 10, 2008
Buffer Interpretation/Clarification #2008-018

MEMORANDUM

RE: There has been a need to clarify how to measure the 50-foot buffer at the point where a stream ceases to be piped or "daylights" (the start point of a stream) as well as how to measure the 50-foot buffer at the point where a "daylighted" stream becomes piped (the stop point of a stream), per the Neuse River Basin Buffer Rule 15A NCAC 2B.0233(4), the Tar-Pamlico River Basin Buffer Rule 15A NCAC 2B.0259(4), the Randleman Lake Water Supply Watershed Buffer Rule 15A NCAC 2B.0250(3), and the Catawba River Basin Buffer Rule 15A NCAC 2B.0243(4).

Solution: In the case where a stream has been piped and then daylights, the buffer start point of that stream is a "bubble" arcing 50-feet upstream of the pipe. In the case where a daylighted stream becomes piped, the buffer stop point is a "bubble" arcing 50-feet downstream from the pipe.

**The drawing below illustrates the 50-foot buffer "bubble" at the start and stop points of a stream that is subject to the above-mentioned buffer rules*.*



Signature: [signature] Date: 3-13-08

One NorthCarolina Naturally

401 Wetlands Certification Unit
1650 Mail Service Center, Raleigh, North Carolina 27699-1650
2321 Crabtree Boulevard, Suite 250, Raleigh, North Carolina 27604
Phone: 919-733-1786 / FAX 919-733-6893 / Internet: http://h2o.enr.state.nc.us/ncwetlands

Michael F. Easley
Governor

William G. Ross, Jr., Secretary
Department of Environment and Natural Resources

Alan W. Klimek, P.E., Director
Division of Water Quality

May 25, 2007
Buffer Interpretation/Clarification #2007-009

MEMORANDUM

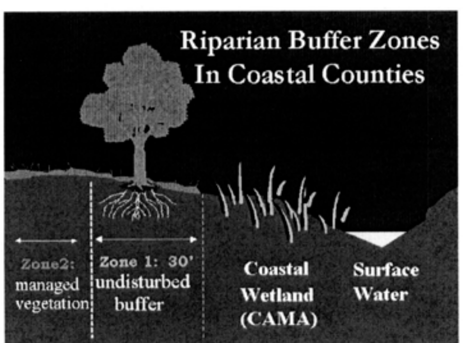
The Division of Water Quality's (DWQ's) stance on riparian buffers in the 20 Coastal Counties per the Neuse River Basin Buffer Rule 15A NCAC 02B.0233 and the Tar-Pamlico River Basin Buffer Rule 15A NCAC 02B.0259.

According to the Neuse River Basin Buffer Rule 15A NCAC 02B.0233(4)(a)(iii) and the Tar-Pamlico River Basin Buffer Rule 15A NCAC 02B.0259(4)(a)(iii), for surface waters within the 20 Coastal Counties (defined in 15A NCAC 2B.0202) within the jurisdiction of the Division of Coastal Management (DCM), Zone 1 shall begin at the most landward limit of:

(A) the normal high water level;
(B) the normal water level; or
(C) the landward limit of coastal wetlands as defined by the DCM.

In some instances, the Coastal Shoreline Rule's (15A NCAC 07H.0209(e) 30- foot shoreline buffer is being confused with the DCM's coastal wetland line. The Coastal Shoreline Rule requires new development to be located a distance of 30 feet landward of the normal water level or normal high water level. Zone 1 for the Neuse and Tar-Pamlico Buffer Rules begins at the same point as this Coastal Shoreline Rule buffer. Zone 2 for the Neuse and Tar-Pamlico Buffer Rules extends 20 feet past the Zone 1 buffers.

However, if DCM flags a coastal wetland boundary line, the Neuse and Tar-Pamlico Buffers shall begin landward of the coastal wetland boundary line (see diagram below). Coastal wetlands are defined as marshlands in G.S. 113-229(n)(3) as "any salt marsh or other marsh subject to regular or occasional flooding by tides, including wind tides (whether or not the tidewaters reach the marshland areas through natural or artificial watercourses), provided this shall not include hurricane or tropical storm tides."



Signature: ______________________ Date: 5/29/07

401 Wetlands Certification Unit
1650 Mail Service Center, Raleigh, North Carolina 27699-1650
2321 Crabtree Boulevard, Suite 250, Raleigh, North Carolina 27604
Phone: 919-733-1786 / FAX 919-733-6893 / Internet: http://h2o.enr.state.nc.us/ncwetlands

One NorthCarolina *Naturally*

Protocol for Electronic Delivery of Permit Drawings
February 18, 2013

1. The Natural Environment Section (NES) Project Management Group Leader sends an email request for Draft and Final Permit Drawings to the Hydraulics Project Manager and copies Roadway Design, Structures Management, Roadside Environmental, and Utilities.

2. The Hydraulics Engineer will then complete the Draft Permit Drawings (hereafter referred to as the Draft Permit Package). The Draft Permit Package will consist of a single PDF containing the following documents, in this order; Stormwater Management Plan (SMP), Permit Drawings and Impact Summary Sheets (Wetland, Stream, and Buffer if applicable). The required naming convention for this PDF will be "*TIP_Permit Package_Current Date (year month day).pdf*".

3. When the Draft Permit Package is complete, the Hydraulics Engineer will send a notification email to the respective Roadway Project Design Engineer indicating that the Draft Permit Package has been placed at "Hydraulics\PERMITS_Environmental\Drawings" and ask for their consistency review. After the consistency review is complete, the Roadway Project Design Engineer will send an email to the Hydraulics Engineer to confirm that the Permit Drawings agree with the Roadway Plans. The Roadway Project Design Engineer will then prepare and place the "PER" PDF files in the "Roadway\PDF Distribution\Current_Plans" directory on the Project Store.

4. The Hydraulics and Roadway Project Design Engineer will then send separate notification emails to the appropriate NES Regional Manager, copying the NES Project Management Group Leader, indicating that a PDF of the Draft Permit Package and the Roadway Plans, respectively, are available on the Project Store. The subject line of the email should be *"B-1234 Permit Info from Hydraulics".* The respective Hydraulics and Roadway Project Engineer should be copied on these notification emails. A paper copy of the Draft Permit Package and the Roadway Plans will not be sent.

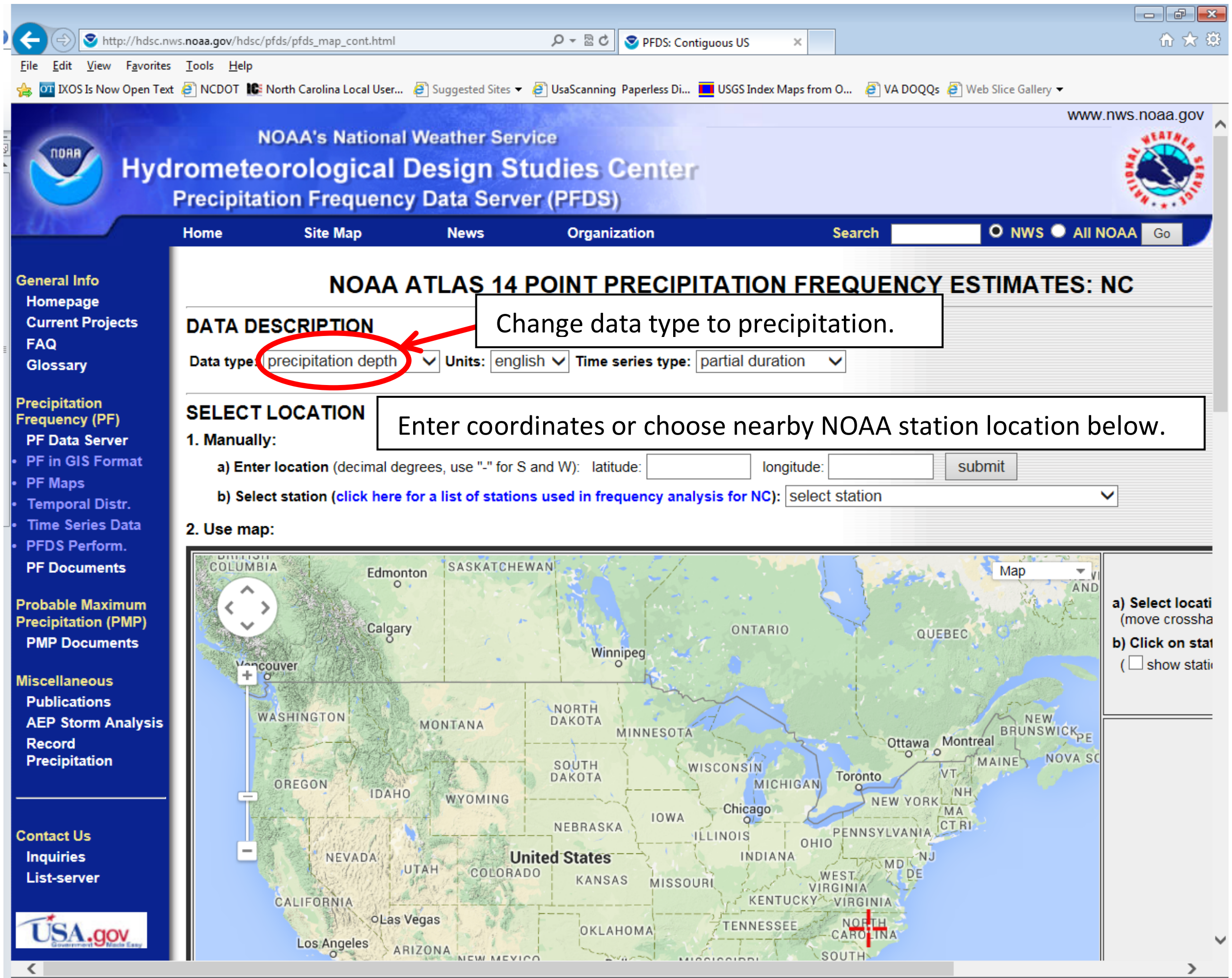
5. After receipt and review of the Draft Permit Package, the NES Regional Manager will send the respective Hydraulics Engineer and Roadway Project Design Engineer a confirmation email that indicates whether or not the Draft Permit Drawings are acceptable and will be used as the Final Permit Drawings in the Permit Application.

6. If the Draft Permit Package is not acceptable, the respective NES Regional Manager will send an email back to the Hydraulics Engineer, Hydraulics Project Manager, and Roadway Project Design Engineer that describes what revisions are necessary. The respective Hydraulics Engineer will address comments from NES as needed and update the single PDF of the Permit Package.

USING NOAA ATLAS 14 WEBSITE TO FIND RAINFALL INTENSITY VALUES

Website: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

Opening page will look similar to the image shown below. Drag the red cross-hair pointer over North Carolina on the map and click on it once.



See next page for sample results for a location in Raleigh, NC.

For this example, use the NOAA Station “RALEIGH NC STATE UNIV (31-7079)” location.

Selecting this station generates the following table (scroll down to view table) of precipitation intensity values for specified recurrence intervals and durations:

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

PFDS: Contiguous US

File Edit View Favorites Tools Help

IXOS Is Now Open Text NCDOT North Carolina Local User... Suggested Sites UsaScanning Paperless Di... USGS Index Maps from O... VA DOQQs Web Slice Gallery

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

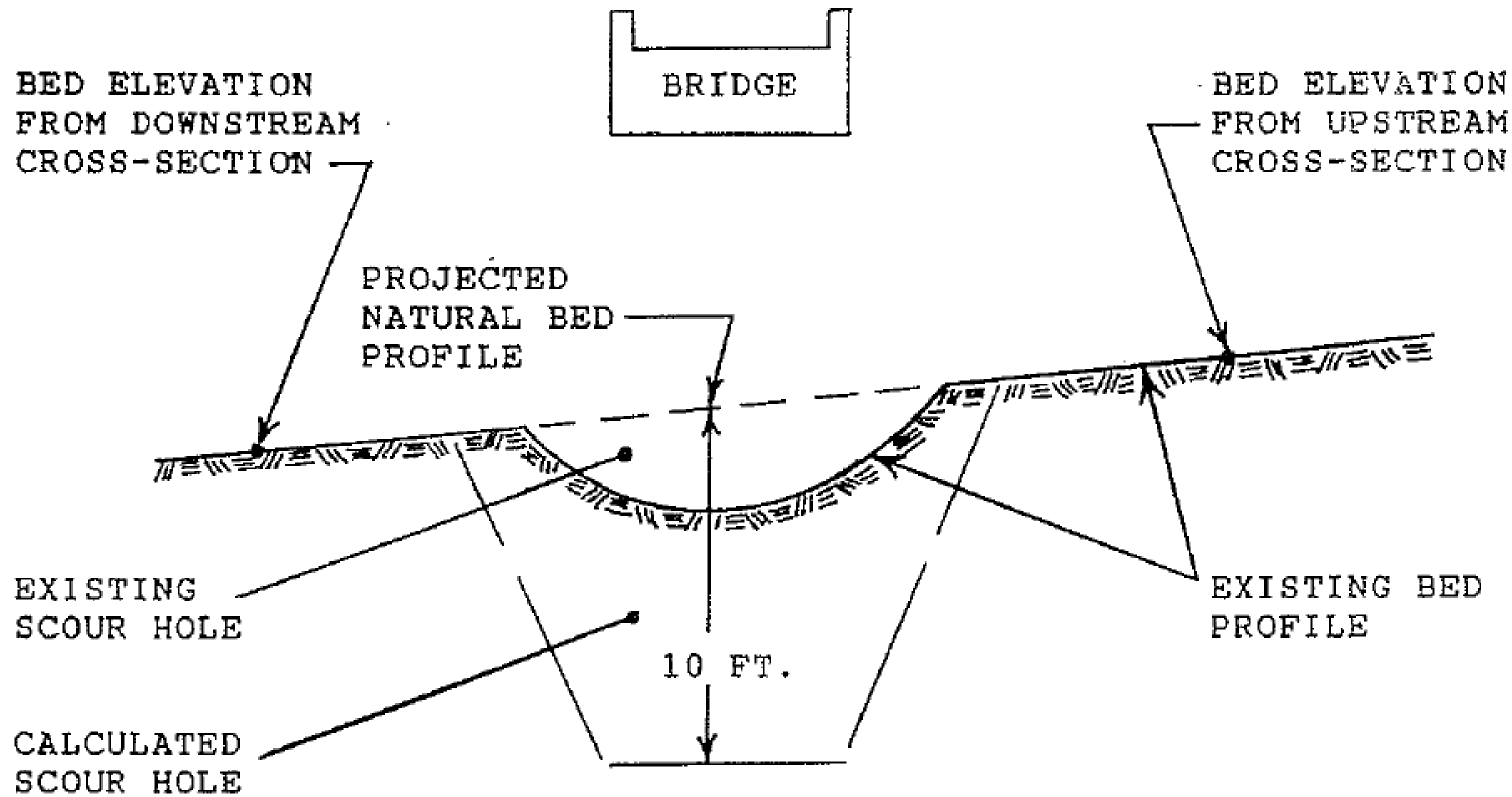
WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION

NOAA Atlas 14, Volume 2, Version 3

PF tabular | PF graphical | Supplementary information | Print Page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	4.84 (4.43–5.27)	5.64 (5.18–6.16)	6.49 (5.98–7.08)	7.21 (6.61–7.85)	7.96 (7.26–8.66)	8.50 (7.72–9.24)	8.98 (8.11–9.77)	9.38 (8.44–10.2)	9.84 (8.77–10.7)	10.2 (9.02–11.1)
10-min	3.86 (3.54–4.21)	4.51 (4.15–4.93)	5.20 (4.78–5.67)	5.77 (5.29–6.28)	6.34 (5.78–6.90)	6.76 (6.14–7.36)	7.13 (6.44–7.76)	7.44 (6.69–8.11)	7.79 (6.94–8.48)	8.04 (7.10–8.77)
15-min	3.22 (2.95–3.50)	3.78 (3.47–4.13)	4.38 (4.03–4.78)	4.86 (4.46–5.30)	5.36 (4.89–5.83)	5.71 (5.19–6.21)	6.01 (5.43–6.54)	6.26 (5.63–6.82)	6.53 (5.82–7.12)	6.72 (5.94–7.34)
30-min	2.20 (2.02–2.40)	2.61 (2.40–2.85)	3.12 (2.86–3.40)	3.52 (3.23–3.84)	3.97 (3.62–4.32)	4.30 (3.91–4.68)	4.60 (4.16–5.01)	4.87 (4.38–5.31)	5.20 (4.63–5.67)	5.45 (4.81–5.94)
60-min	1.37 (1.26–1.50)	1.64 (1.51–1.79)	2.00 (1.84–2.18)	2.29 (2.10–2.50)	2.64 (2.41–2.88)	2.91 (2.65–3.17)	3.17 (2.86–3.45)	3.42 (3.07–3.72)	3.73 (3.32–4.06)	3.98 (3.51–4.34)
2-hr	0.801 (0.730–0.880)	0.958 (0.876–1.05)	1.18 (1.08–1.30)	1.37 (1.24–1.50)	1.59 (1.44–1.74)	1.78 (1.60–1.94)	1.95 (1.74–2.14)	2.13 (1.89–2.33)	2.36 (2.08–2.58)	2.55 (2.22–2.79)
3-hr	0.564 (0.516–0.620)	0.676 (0.620–0.743)	0.837 (0.763–0.919)	0.975 (0.887–1.07)	1.15 (1.04–1.26)	1.30 (1.16–1.42)	1.44 (1.28–1.57)	1.59 (1.41–1.73)	1.79 (1.56–1.95)	1.95 (1.69–2.13)
6-hr	0.341 (0.313–0.373)	0.409 (0.375–0.448)	0.506 (0.463–0.553)	0.589 (0.538–0.644)	0.698 (0.633–0.760)	0.789 (0.711–0.858)	0.881 (0.787–0.956)	0.975 (0.863–1.06)	1.10 (0.964–1.20)	1.21 (1.05–1.32)
12-hr	0.200 (0.184–0.219)	0.240 (0.220–0.262)	0.298 (0.273–0.325)	0.349 (0.318–0.381)	0.416 (0.377–0.453)	0.474 (0.426–0.513)	0.532 (0.474–0.577)	0.594 (0.523–0.642)	0.679 (0.588–0.733)	0.752 (0.641–0.812)
24-hr	0.120 (0.112–0.129)	0.144 (0.135–0.156)	0.181 (0.169–0.195)	0.210 (0.195–0.226)	0.249 (0.231–0.268)	0.281 (0.260–0.302)	0.313 (0.288–0.336)	0.345 (0.318–0.372)	0.390 (0.358–0.421)	0.426 (0.388–0.459)
2-day	0.069 (0.064–0.074)	0.083 (0.078–0.089)	0.104 (0.097–0.111)	0.120 (0.111–0.128)	0.141 (0.131–0.152)	0.158 (0.146–0.170)	0.176 (0.162–0.189)	0.194 (0.178–0.208)	0.218 (0.200–0.235)	0.237 (0.216–0.256)
3-day	0.049 (0.046–0.052)	0.059 (0.055–0.063)	0.073 (0.068–0.078)	0.084 (0.078–0.090)	0.099 (0.092–0.106)	0.111 (0.102–0.118)	0.123 (0.113–0.132)	0.135 (0.124–0.145)	0.152 (0.139–0.163)	0.165 (0.151–0.178)
4-day	0.039 (0.036–0.041)	0.046 (0.043–0.050)	0.057 (0.053–0.061)	0.066 (0.061–0.070)	0.077 (0.072–0.083)	0.087 (0.080–0.093)	0.096 (0.089–0.103)	0.106 (0.098–0.113)	0.119 (0.109–0.128)	0.129 (0.118–0.139)
7-day	0.026 (0.024–0.027)	0.031 (0.029–0.033)	0.037 (0.035–0.040)	0.043 (0.040–0.045)	0.050 (0.046–0.053)	0.056 (0.052–0.059)	0.061 (0.057–0.065)	0.067 (0.062–0.072)	0.076 (0.070–0.081)	0.082 (0.075–0.088)
10-day	0.020 (0.019–0.022)	0.024 (0.023–0.026)	0.029 (0.027–0.031)	0.033 (0.031–0.035)	0.038 (0.036–0.041)	0.042 (0.040–0.045)	0.047 (0.043–0.050)	0.051 (0.047–0.054)	0.056 (0.052–0.060)	0.061 (0.056–0.065)
20-day	0.014 (0.013–0.015)	0.016 (0.015–0.017)	0.019 (0.018–0.020)	0.021 (0.020–0.023)	0.025 (0.023–0.026)	0.027 (0.025–0.029)	0.030 (0.027–0.031)	0.032 (0.030–0.034)	0.035 (0.033–0.038)	0.038 (0.035–0.041)
30-day	0.011 (0.011–0.012)	0.013 (0.013–0.014)	0.016 (0.015–0.016)	0.017 (0.016–0.018)	0.019 (0.018–0.021)	0.021 (0.020–0.022)	0.023 (0.021–0.024)	0.025 (0.023–0.026)	0.027 (0.025–0.029)	0.028 (0.026–0.030)
45-day	0.010 (0.009–0.010)	0.011 (0.011–0.012)	0.013 (0.012–0.014)	0.014 (0.013–0.015)	0.016 (0.015–0.017)	0.017 (0.016–0.018)	0.018 (0.017–0.019)	0.019 (0.018–0.021)	0.021 (0.020–0.022)	0.022 (0.021–0.024)
60-day	0.009 (0.008–0.009)	0.010 (0.010–0.011)	0.011 (0.011–0.012)	0.012 (0.012–0.013)	0.014 (0.013–0.015)	0.015 (0.014–0.016)	0.016 (0.015–0.017)	0.017 (0.016–0.018)	0.018 (0.017–0.019)	0.019 (0.018–0.020)



EXAMPLE SHOWN IS FOR A TOTAL CALCULATED SCOUR DEPTH (CONTRACTION + PIER) EQUAL TO 10 FEET. THE SCOUR DEPTH IS MEASURED FROM THE PROJECTED NATURAL BED PROFILE, NOT FROM THE BOTTOM OF THE EXISTING SCOUR HOLE.

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