TENNESSEE DEPARTMENT

of

TRANSPORTATION

DESIGN DIVISION

DRAINAGE MANUAL

JANUARY 1, 2003

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CHAPTER 1 – INTRODUCTION

The *TDOT Design Division Drainage Manual* discusses Tennessee Department of Transportation (TDOT) policies, practices, and procedures for performing drainage design and hydraulic analyses on projects which are the responsibility of TDOT. The first chapter of the Manual provides the purpose of the manual, background on how the manual was assembled, how the manual is maintained, and provides a general project work flow regarding drainage design for a TDOT project. Chapter 2 covers general drainage policies, practice, and legal issues. Chapter 3 provides the designer information required for drainage plans. Chapter 4 discusses procedures and criteria for TDOT hydrologic analyses. Chapters 5 through 11 will be developed at a later date. Chapter 5 will provide guidelines, procedures, and criteria for channels, roadway ditches, and permanent erosion control. Culvert design guidelines, analysis procedures, and design practices will be included in Chapter 6. Storm drainage systems including storm sewers, curb and gutters, and inlet spacing design guidelines, analyses procedures, and design practices will be covered in Chapter 7. Chapter 8 will explore storage facility design for both detention and retention. Chapter 9 will refer to a separate TDOT publication covering temporary erosion and sediment control. Chapter 10 will refer to a separate TDOT publication covering stormwater management. The permitting application process will be covered in Chapter 11. The Appendix includes the glossary, index, and other multi-chapter reference material.

SECTION 1.01 - PURPOSE

Various legislation, executive orders, and subsequent rules and regulations influence TDOT drainage design components. In most cases, these must be adhered to in order to promote safety and to obtain adequate funding for roadway projects. In order to assist the designer performing drainage and hydrologic design, TDOT has developed this manual to provide a collection of applicable drainage criteria, policies, and examples. All basic design elements are included such that roadway drainage design can be accomplished with minimal assistance. However, this manual cannot provide complete guidance on complex hydrologic or hydraulic problems. This manual is not a substitute for experience or engineering judgement. Additional technical aspects beyond the scope of this manual are referenced throughout the manual.

SECTION 1.02 - BACKGROUND

Proper drainage control is an essential element of highway construction. TDOT originally provided guidance for drainage design in the *TDOT - Roadway Design Guidelines*. Further drainage design needs were recognized by the Department and in 2001 began developing a comprehensive manual in accordance with the Department's needs. Numerous drainage manuals and guides were obtained from other states, municipalities, and organizations. Beneficial aspects of these manuals and guides were used in the production of this manual and referenced when necessary. The American Association of State Highway and Transportation Officials (AASHTO) has produced a *Model Drainage Manual* for use by State Departments of Transportation nationwide. The *Model Drainage Manual* presents design theories, concepts, guidelines, criteria, policies, and procedures for use by the drainage engineer. The *Model Drainage Manual* has been prepared in a format suitable for direct use, with State-specific modifications, by any State DOT. The *TDOT Drainage Manual* has been prepared based on the applicable portion of the *TDOT - Roadway Design Guidelines*, other state and agency guides and manuals, and the *Model Drainage Manual*. Where practical, the text and graphics in the *Model Drainage Manual* have been incorporated into the *TDOT Design Division Drainage Manual* with modifications to reflect TDOT practices.

SECTION 1.03 - MANUAL MAINTENANCE

The manual will be maintained by the Department and notification of the changes will be issued to all registered holders of the manual.

SECTION 1.04 - GENERAL PROJECT WORK FLOW

Roadway drainage design serves two major functions: 1) to maintain surface flows crossing the right-of-way, and 2) to promote safety by efficiently removing storm water from the pavement surface. To meet these goals, the Tennessee Department of Transportation has adopted a process that allows for the orderly development of the drainage design in context with other design elements and administrative functions required for the development of the project. The flowchart presented in Figure 1-1 provides a graphical overview of the process.

The process begins by identifying the overall volume of surface water runoff that flows within and through the project for the required flood frequency. As discussed in Chapter 4, there are several acceptable methods of determining these flows. To the extent possible, existing channels crossing the right-of-way will be maintained in their natural locations. If it is determined that the flows for a 50 year flood frequency at any given point exceed 500 cubic feet per second (cfs), the data related to those locations will be forwarded to the Structures Division Hydraulic Section. The Hydraulic Section is responsible to define the high water elevation and the size and type of structure that will be used to carry these flows through the project. The designer is responsible to size all other cross culverts for the project.

The preliminary plans, based on the approved profile, are used to define the preliminary right-of-way and permanent drainage easement requirements that are presented in a public hearing at the conclusion of the preliminary plans phase.

Detailed elements of the roadway drainage system are designed during the preparation of the Right-of-Way Plans. These elements must include temporary and permanent erosion controls to assure adequate right-of-way is acquired for the project.

Final drainage quantities are tabulated during preparation of the Construction Plans. Any requirements imposed by the environmental permitting agencies should be incorporated before the final Construction Plans are submitted. Detailed guidelines related to this general overview of the drainage design process are presented in the later chapters of this manual. The relationship of these tasks to the stages of TDOT projects is shown in Figure 1-2.

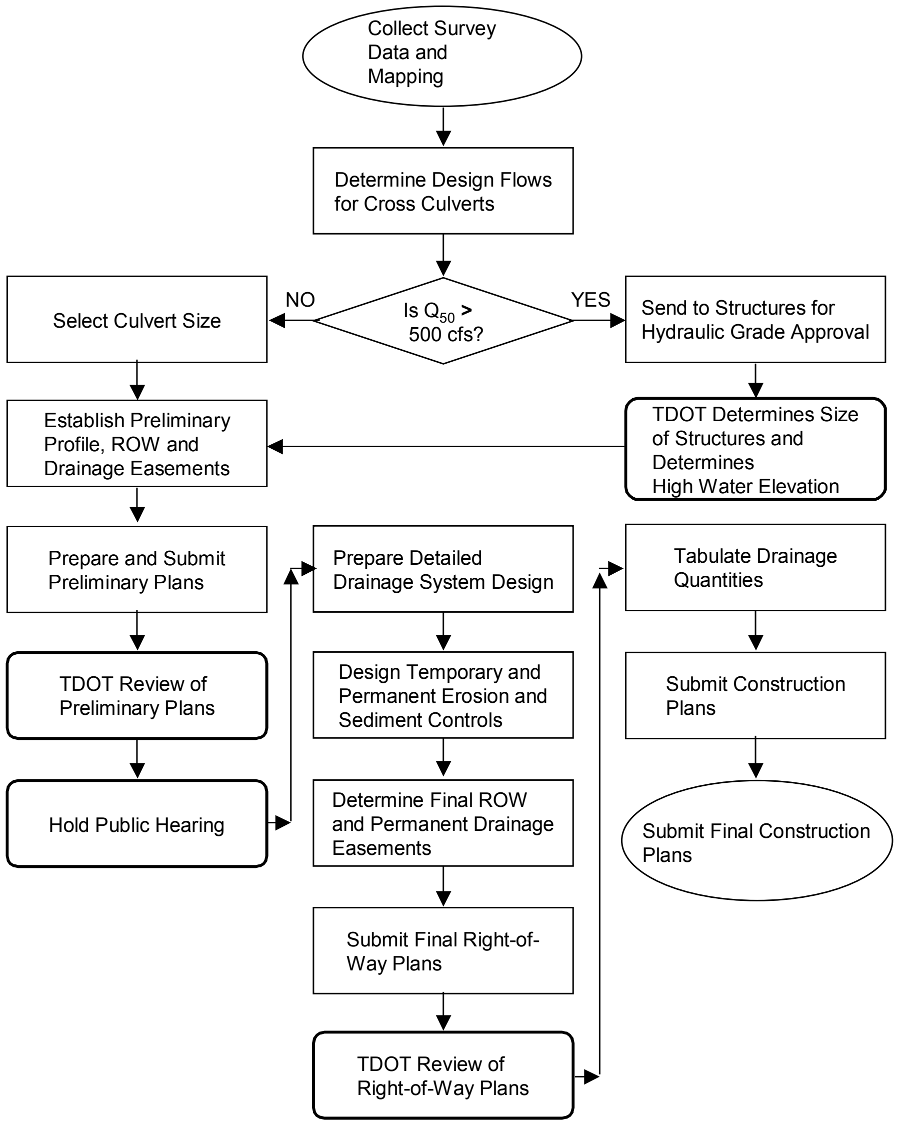

Figure 1-1. TDOT Drainage Design Flowchart

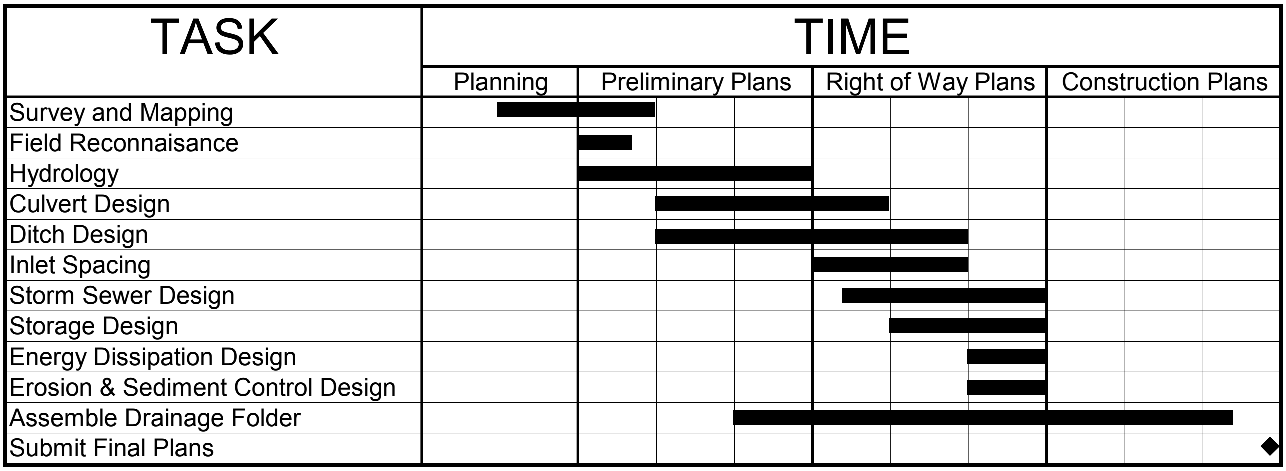

Figure 1-2. Relationship of Drainage Design Tasks to Project Stages

SECTION 1.05 - REFERENCES

American Association of State Highway and Transportation Officials. *Model Drainage Manual [Metric Edition].* Washington, D.C. 1999.

Tennessee Department of Transportation. *Design Guidelines - English*. Nashville, TN. April 2001.

TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER II
GENERAL DRAINAGE POLICIES & PRACTICES

CHAPTER 2 – GENERAL DRAINAGE POLICIES AND PRACTICES

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CHAPTER 2 - GENERAL DRAINAGE POLICIES AND PRACTICE

SECTION 2.01 - INTRODUCTION

2.01.1 PURPOSE

Drainage concerns are one of the most important aspects of roadway design and construction. The purpose of this chapter is to outline policies that guide and influence the practice of drainage design for the Tennessee Department of Transportation. A portion of this chapter will describe legal issues that influence policies and criteria.

2.01.2 POLICY vs CRITERIA

Policy and criteria statements are closely related - criteria being the TDOT's numerical or specific guidance which is founded in broad policy statements. For this manual, the following definitions of policy and criteria apply:

Policy - is a definite course of action or method of action, selected to guide and determine present and future decisions.

Design Criteria - are the standards by which a policy is carried out or placed in action. Thus design criteria are needed for design; policy statements are not.

The following is an example of a policy statement:

> "The designer will size the drainage structure to accommodate a flood compatible with the projected traffic volumes."

The design criteria for designing the structure might be:

> "For a roadway designated as a collector, drainage structures shall be designed for a 10-year flood (exceedance probability of 10%). For a roadway designated as a freeway, a drainage structure shall be designed for a 50-year flood (exceedance probability of 2%)."

SECTION 2.02 – GENERAL LEGAL ISSUES

2.02.1 INTRODUCTION

Various drainage laws and rules are applicable to highway facilities. This portion of the chapter provides information and guidance on the designer's role in the legal aspects of roadway design. After presenting the applicable legal aspects for highway drainage design, federal, state, and local policies will be discussed. This information should not in any way be treated as a manual upon which to base legal advice or make legal decisions. It is also not a summary of all existing drainage laws, and most emphatically, this chapter is not intended as a substitute for legal counsel.

Several generalizations can be made regarding liability. 1) A goal in roadway drainage design should be to perpetuate natural drainage patterns, insofar as practical. 2) The courts look with disfavor upon infliction of injury or damage that could reasonably have been avoided by a prudent designer, even where some alteration in flow is legally permissible. 3) The laws relating to the liability of government entities are undergoing radical change, with a trend toward increased government liability.

The descending order to law supremacy is Federal, State, then local, except as provided for in the statutes of the constitution of the higher level of government. The superior level is not bound by laws, rules, or regulations of a lower level of government.

2.02.2 LEGAL ASPECTS

2.02.2.1 FEDERAL LAWS

Federal law consists of the Constitution of the United States, Acts of Congress, regulations which government agencies issue to implement these acts, Executive Orders issued by the President, and case law. Acts of Congress are published immediately upon issuance and are accumulated for each session of Congress and published in the United States Statutes At Large. Compilations of Federal Statutory Law, revised annually, are available in the United States Code (USC) and the United States Code Service (USCS).

The *Federal Register*, which is published daily, provides a uniform system for making regulations and legal notices available to the public. Presidential Proclamations and Executive Orders, Federal agency regulations and documents having general applicability and legal effect, documents required to be published by an act of Congress and other Federal agency documents of public interest are published in the *Federal Register*. Compilations of Federal regulatory material revised annually are available in the Code of Federal Regulations (CFR).

2.02.2.1.1 Drainage

Federal law does not deal with drainage per se, but many laws have implications which affect drainage design. These include laws concerning:

- Flood insurance and construction in flood hazard areas,
- Navigation and construction in navigable waters,
- Water pollution control,
- Environmental protection, and
- Protection of fish and wildlife.

2.02.2.1.2 Significant Laws

Some of the more significant Federal laws affecting highway drainage are listed below with a brief description of their subject area.

1. Department of Transportation Act (80 Stat. 941, 49 U.S.C. 1651 et seq.). This Act established the United States Department of Transportation and set forth its powers, duties and responsibilities to establish, coordinate and maintain an effective administration of the transportation programs of the Federal Government.
2. Federal-Aid Highway Acts (23 U.S.C. 101 et seq.). The Federal-Aid Highway Acts provide for the administration of the Federal-Aid Highway Program. Proposed Federal-aid projects must be adequate to meet the existing and probable future traffic needs and conditions in a manner conducive to safety, durability and economy

of maintenance, and must be designed and constructed according to standards best suited to accomplish these objectives and to conform to the needs of each locality.

3. Federal-Aid Highway Act of 1970 (84 Sta. 1717, 23, U.S.C. 109 (h)). This act provided for the establishment of general guidelines to insure that possible adverse economic, social and environmental effects relating to any proposed Federal-aid project have been fully considered in developing the project. In compliance with the Act, the Federal Highway Administration issued process guidelines for the development of environmental action plans. These guidelines are contained in the Federal-Aid Highway Program Manual Volume 7, Chapter 7, Section 1 (FHPM 7-7-1), and in 23 CFR 795 et seq.
4. Federal-Aid Highway Act of 1966 (80 Stat. 766), amended by the Act of 1970 (84 Stat. 1713), 23 U.S.C. 109 (g). This act required the issuance of guidelines for minimizing possible soil erosion from highway construction. In compliance with these requirements, the Federal Highway Administration issued guidelines which are applicable to all Federal-aid highway projects. These guidelines are included in FHPM 6-7-1-1, 6-7-3-1, 6-7-3-2. Regulatory material is found in 23 CFR 650.201.
5. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 provided authorization for highways, highway safety and mass transportation for six years. The act intended to develop a National Highway System that is economically efficient and environmentally sound. It created a foundation for the Nation to compete in the global economy and move people and goods in an energy efficient manner. Under the Act, state and local governments have been given more flexibility in determining transportation solutions, whether transit or highways, and the tools on enhanced planning and management systems to guide them in making the best choices. Funding for the new technologies as well as activities for enhancing environment and safety was also available.
6. The Transportation Equity Act for the 21st Century of June 9, 1998 authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 6-year period 1998-2003. The TEA-21 Restoration Act, enacted July 22, 1998, provided technical corrections to the original law. TEA-21 is considered the combined effect of these two laws.

2.02.2.2 NAVIGABLE WATERS REGULATIONS

The Congress of the United States of America is granted Constitutional power to regulate Interstate commerce. This power includes navigable waters and is essentially carried out by four Federal agencies

1. Coast Guard. The United States Coast Guard (USCG) has regulatory authority under Section 9 of the Rivers and Harbors Act of 1899, 33 U.S.C. 401 to approve plans and issue permits for bridges and causeways across navigable rivers. The FHWA has the responsibility to determine whether a USCG permit is required. The USCG has two responsibilities:

   - To determine whether or not a USCG permit is required for the improvement or construction of a bridge over navigable waters except for the exemption exercised by the FHWA.
   - To approve the bridge location, alignment, and appropriate navigational clearances in all bridge permit applications.

2. Corps of Engineers. The United States Army Corps of Engineers (COE or Corps) has regulatory authority over the construction of dams, dikes, or other obstructions which are not considered bridges or causeways under Section 9 (33 U.S.C. 401). The Corps also has authority to regulate Section 10 of the River and Harbor Act of 1899 (33 U.S.C. 403) which prohibits the alteration or obstruction of any navigable waterway with the excavation or deposition of fill material in such waterway.

   Section 404 of the Clean Water Act (33 U.S.C. 1344) prohibits the unauthorized discharge of dredged or fill material into waters of the United States, including navigable waters. Such discharges require a permit. The term "discharges of fill material" means the addition of rock, sand, dirt, concrete, or other material into the waters of the United States incidental to construction of any structure. The Corps has granted a Nationwide General Permit for twenty-six 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 providing such fill has been permitted by the U. S. Coast Guard under Section 9 of the River and Harbor Act of 1899 as part of the bridge permit. Therefore, formal application of the Corps of Engineers for a Section 404 Permit is not required unless bridge approach embankment is located in a wetland area contiguous to said navigable stream. The Corps of Engineers has Section 404 regulatory authority over streams the Coast Guard has placed in the "advance approval" category. This category of navigable streams is defined as navigable in law but not actually navigated other than by logs, log rafts, rowboats, canoes and motorboats. Notably this regulation does not apply to the actual excavation or "dredging of material," provided this material is not reintroduced into any regulated waterway including the one from which it was removed. Section 404 of the Clean Water Act (33 U.S.C. 1344) requires any applicant for a Federal permit for any activity that may affect the quality of waters of the United States to obtain water quality certification from the Tennessee Department of Environment and Conservation.

3. Federal Highway Administration. The Federal Highway Administration (FHWA) has the authority to implement the Section 404 Permit Program (Clean Water Act of 1977) for Federal-aid highway projects processed under 23 CFR 771.115 (b) categorical exclusions. This permit is granted for projects where the activity, work or discharge is categorically excluded from environmental documentation because such activity does not have individual or cumulative significant effect on the human environment.

4. Environmental Protection Agency. The Environmental Protection Agency (EPA) is authorized to prohibit the use of any area as a disposal site when it is determined that the discharge of materials at the site will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife, or recreational areas (Section 404 (c)), Clean Water Act (33 U.S.C. 1344). Also EPA is authorized under the Section 402 of the Clean Water Act (33 U.S.C. 1344) to administer and issue a "National Pollutant Elimination Discharge System" (NPDES) permit for point

source discharges, provided prescribed conditions are met. See Chapter 9 for additional information regarding permits.

Approval of bridge location, alignment, and appropriate navigational clearances in handled by the TDOT Hydraulic Design Section.

2.02.2.3 FISH AND WILDLIFE SERVICE

The Fish and Wildlife Act of 1956 (16 U.S.C. 742 et seq.), the Migratory Game-Fish Act (16 U.S.C. 760c-760g) and the Fish and Wildlife Coordination Act (16 U.S.C. 611-666c) express the concern of Congress with the quality of the aquatic environment as it affects the conservation, improvement, and enjoyment of fish and wildlife resources. The Fish and Wildlife Coordination Act requires that:

> "Whenever the waters of any stream or body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license, such department or agency shall first consult with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular state with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof."

The Fish and Wildlife Service's role in the permit review process is to review and comment on the effects of a proposal on fish and wildlife resources. The regulatory agency (e.g., Corps of Engineers, U.S. Coast Guard) is to consider and balance all factors, including anticipated benefits and costs in accordance with NEPA, in deciding whether to issue the permit (40 FR 55810, December 1, 1975).

2.02.2.4 NATIONAL FLOOD INSURANCE PROGRAM (NFIP)

The Flood Disaster Protection Act of 1973 (Pl 93-234, 87 Stat. 975) denies Federal financial assistance to flood prone communities that fail to qualify for flood insurance. Formula grants to States are excluded from the definition of financial assistance, and the definition of construction in the Act does not include highway construction; therefore, Federal aid for highways is not affected by the Act. The Act does require communities to adopt certain land use controls in order to qualify for flood insurance. These land use requirements could impose restrictions on the construction of highways in floodplains and floodways in communities which have qualified for flood insurance. A floodway, as used here and as used in connection with the National Flood Insurance Program, is that portion of the floodplain required to pass a flood that has a 1-percent chance of occurring in any 1-year period without cumulatively increasing the water surface elevation more than 1 ft.

2.02.2.4.1 Flood Insurance

The National Flood Insurance Act of 1968, as amended, (42 U.S.C. 4001-4127) requires that communities adopt adequate land use and control measures to qualify for insurance. Federal criteria promulgated to implement this provision contain the following requirements which can affect certain highways.

1. In riverine situations, when the Administrator of the Federal Insurance Administration has identified the flood prone area, the community must require that, until a floodway has been designated, no use, including land fill, be permitted within the floodplain area having special flood hazards for which base flood elevations have been provided, unless it is demonstrated that the cumulative effect of the proposed use, when combined with all other existing and reasonably anticipated uses of a similar nature, will not increase the water surface elevation of the 100-year flood more than 1 ft at any point within the community.

2. After the floodplain area having special flood hazards has been identified and the water surface elevation for the 100-year flood and floodway data have been provided, the community must designate a floodway which will convey the 100-year flood without increasing the water surface elevation of the flood more than 1 ft at any point and prohibit, within the designated floodway, fill, encroachments and new construction and substantial improvements of existing structures which would result in any increase in flood heights within the community during the occurrence of the 100-year flood discharge.

The local community with land use jurisdiction, whether it is a city, county, or state, has the responsibility for enforcing National Flood Insurance Program regulations in that community if the community is participating in the NFIP. Consistency with NFIP standards is a requirement for Federal-aid highway actions involving regulatory floodways. The community, by necessity, is the one who must submit proposals to Federal Emergency Management Agency (FEMA) for amendments to NFIP ordinances and maps in that community, should it be necessary. The highway agency should deal directly with the community and, through them, deal with FEMA. Determination of the status of a community's participation in the NFIP and review of applicable NFIP maps and ordinances are, therefore, essential first steps in conducting location hydraulic studies and preparing environmental documents.

For additional information on land use requirements and National Flood Insurance Program regulations please contact the TDOT Hydraulic Design Section.

2.02.2.4.2 National Flood Insurance Program Maps

Where NFIP maps are available, their use is mandatory in determining whether a highway location alternative will include an encroachment on the base floodplain. Three types of NFIP maps are published:

1. Flood Hazard Boundary Map (FHBM),
2. Flood Boundary and Floodway Map (FBFM) and
3. Flood Insurance Rate Map (FIRM).

A FHBM is generally not based on a detailed hydraulic study and, therefore, the floodplain boundaries shown are approximate. A FBFM, on the other hand, is generally derived from a detailed hydraulic study and should provide reasonably accurate information. The hydraulic data from which the FBFM was derived are available through the regional office of FEMA. This is normally in the form of computer input data records for calculating water surface profiles. The FIRM is generally produced at the same time using the same hydraulic model and has appropriate rate zones and base flood elevations added.

Communities may or may not have published one or more of the above maps depending on their level of participation in the NFIP. Information on community participation in the NFIP is provided in the "National Flood Insurance Program Community Status Book" which is published semiannually for each State.

2.02.2.4.3 Federal Emergency Management Agency Coordination

TDOT coordination with FEMA may arise in situations where administrative determinations are needed involving a regulatory floodway or where flood risks in NFIP communities are significantly impacted. The circumstances which would ordinarily require coordination with FEMA include the following:

- When a proposed crossing encroaches on a regulatory floodway and, as such, would require an amendment to the floodway map.
- When a proposed crossing encroaches on a floodplain where a detailed study has been performed but no floodway designated and the maximum 1 ft increase in the base flood elevation would be exceeded.
- When a local community is expected to enter into the regular program within a reasonable period and detailed floodplain studies are under way.
- When a local community is participating in the emergency program and base FEMA flood elevation in the vicinity of insurable buildings is increased by more than 1 ft. Where insurable buildings are not affected, it is sufficient to notify FEMA of changes to base flood elevations as a result of highway construction.

The draft Environmental Impact Statement or Environmental Assessment (EIS/EA) should indicate the NFIP status of affected communities, the encroachments anticipated and the need for floodway or floodplain ordinance amendments. Coordination means furnishing to FEMA the draft EIS/EA and, upon selection of an alternative, furnishing to FEMA, through the community, a preliminary site plan and water surface elevation information and technical data in support of a floodway revision request as required. If a determination by FEMA would influence the selection of an alternative, a commitment from FEMA should be obtained prior to the final environmental impact statement (FEIS) or a finding of no significant impact (FONSI). Otherwise this later coordination may be postponed until the design phase. The designer should be aware that projects processed with a categorical exclusion (CE) provide coordination during design. The outcome of the coordination could change the class of environmental processing.

All TDOT coordination with FEMA should be done through the Hydraulic Design Section.

2.02.2.4.4 Floodways

In many situations it is possible to design and construct highways in a cost effective manner such that their components are excluded from the floodway. This is the simplest way to be consistent with the standards and should be the initial alternative evaluated. If a project element encroaches on the floodway but has a very minor effect on the floodway water surface elevation (such as piers in the floodway), the project may normally be considered as being consistent with the standards, if hydraulic conditions can be improved so that no water surface elevation increase is reflected in the computer printout for the new conditions.

Where it is not cost-effective to design a highway crossing to avoid encroachment on an established floodway, a second alternative would be a modification of the floodway itself. Often, the community will be willing to accept an alternative floodway configuration to accommodate a proposed crossing provided NFIP limitations on increases in the base flood elevation are not exceeded. This approach is useful where the highway crossing does not cause more than a 1 ft rise in the base flood elevation. In some cases, it may be possible to enlarge the floodway or otherwise increase conveyance in the floodway above and below the crossing in order to allow greater encroachment. Such planning is best accomplished when the floodway is first established. However, where the community is willing to amend an established floodway to support this option, the floodway may be revised.

The responsibility for demonstrating that an alternative floodway configuration meets NFIP requirements rests with the community. However, this responsibility may be borne by the agency proposing to construct the highway crossing. Floodway revisions must be based on the hydraulic model which was used to develop the currently effective floodway but updated to reflect existing encroachment conditions. This will allow determination of the increase in the base flood elevation that has been caused by encroachments since the original floodway was established. Alternate floodway configurations may then be analyzed. Base flood elevations increases are referenced to the profile obtained for existing conditions when the floodway was first established.

Data submitted to FEMA, through the community, in support of a floodway revision request should include the following.

- Copy of current regulatory Flood Boundary Floodway Map, showing existing conditions, proposed highway crossing and revised floodway limits.
- Copy of computer printouts (input, computation, and output) for the current 100-year model and current 100-year floodway model.
- Copy of computer printouts (input, computation, and output) for the revised 100-year floodway model. Any fill or development that has occurred in the existing flood fringe area must be incorporated into the revised 100-year floodway model.
- Copy of engineering certification is required for work performed by private subcontractors.
- Many of the forms are available from FEMA and may be obtained by visiting their web site at http://www.fema.gov.
- To contact a FEMA Flood Insurance Rate Map Specialist (FIRM) please visit the FEMA web site at http://www.fema.gov/mit/tsd/fmc_main.htm
- For detailed FEMA issued Flood Maps please visit the FEMA web site at http://web1.msc.fema.gov/stores/MSC/. These maps include Flood Hazard Boundary Maps (FHBM), Flood Insurance Rate Maps (FIRM), and Conversion Letters that are issued by FEMA.

The revised and current computer data required above should extend far enough upstream and downstream of the floodway revision area in order to tie back into the original floodway and profiles using sound hydraulic engineering practices. This distance will vary depending on the magnitude of the requested floodway revision and the hydraulic characteristics of the stream.

If input data representing the original hydraulic model are unavailable, an approximation should be developed. A new model should be established using the original cross section topographic information, where possible, and the discharges contained in the Flood Insurance

Study which established the original floodway. The model should then be run confining the effective flow area to the currently established floodway and calibrate to reproduce within 0.10 ft of the "With Floodway" elevations provided in the Floodway Data Table for the current floodway. Floodway revisions may then be evaluated using the procedures outlined above.

When it would be demonstrably inappropriate to design a highway crossing to avoid encroachment on the floodway and where the floodway cannot be modified such that the structure could be excluded, FEMA will approve an alternate floodway with backwater in excess of the 1 ft. maximum only when the following conditions have been met.

- A location hydraulic study has been performed in accordance with Federal Aid Highway Program Manual (FHPM) 6-7-3-2, FHWA, "Location and Hydraulic Design of Encroachments on Floodplains" (23 CFR 650, Subpart A) and FHWA finds the encroachment is the only practicable alternative.
- The constructing agency has made appropriate arrangements with affected property owners and the community to obtain flooding easements or otherwise compensate them for future flood losses due to the effects of backwater greater than 1 ft.
- The constructing agency has made appropriate arrangements to assure that the National Flood Insurance Program and Flood Insurance Fund will not incur any liability for additional future flood losses to existing structures which are insured under the Program and grandfathered in under the risk status existing prior to the construction of the structure.
- Prior to initiating construction, the constructing agency provides FEMA with revised flood profiles, floodway and floodplain mapping and background technical data necessary for FEMA to issue revised Flood Insurance Rate Maps and Flood Boundary and Floodway Maps for the affected area, upon completion of the structure.

Highway Encroachment On A Floodplain With A Detailed Study (FIRM) - In communities where a detailed flood insurance study has been performed but no regulatory floodway designated, the highway crossing should be designed to allow no more than 1 ft increase in the base flood elevation based on technical data from the flood insurance study. Technical data supporting the increased flood elevation shall be submitted to the local community and through them to FEMA for their files.

Highway Encroachment On A Floodplain Indicated On A Flood Hazard Boundary Map - In communities where detailed flood insurance studies have not been performed, the highway agency must generate its own technical data to determine the base floodplain elevation and design encroachments in accordance with FHPM 6-7-3-2. Base floodplain elevations shall be furnished to the community, and coordination carried out with FEMA as outlined previously where the increase in base flood elevations in the vicinity of insurable buildings exceeds 1 ft.

Highway Encroachment on Unidentified Floodplains - Encroachments which are outside of NFIP communities or NFIP identified flood hazard areas should be designed in accordance with FHPM 6-7-3-2 of the Federal Highway Administration.

Levee Systems - For purposes of the NFIP, FEMA will only recognize in its flood hazard and risk mapping effort those levee systems that meet, and continue to meet, minimum design operation, and maintenance standards that are consistent with the level of protection sought through the comprehensive floodplain management criteria as outlined in the NFIP. The levee system must provide adequate protection from the base flood. Information supporting this must be supplied to FEMA by the community or other party seeking recognition of such a levee system at the time a flood risk study or restudy is conducted, when a map revision is sought based on a levee system, and upon request by the Administrator during the review of previously recognized structures. The FEMA review will be for the sole purpose of establishing appropriate risk zone determinations for NFIP maps and shall not constitute a determination by FEMA as to how a structure or system will perform in a flood event. For more information on the requirements related to levee systems see "National Flood Insurance Program and Related Regulations", Federal Emergency Management Agency, Revised October 1, 1986 and Amended June 30, 1987 (44 CFR 65.10).

2.02.2.5 EXECUTIVE ORDERS

Presidential Executive Orders (E.O.) have the effect of law in the administration of programs by federal agencies. While executive orders do not directly apply to TDOT, these requirements are usually implemented through general regulations.

2.02.2.5.1 E.O. 11988 (Federal Agency Requirements)

Executive Order 11988, May 24, 1977, requires each federal agency, in carrying out its activities, to take the following actions:

- To reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains.
- To evaluate the potential effect of any actions it may take in a floodplain, to ensure its planning programs reflect consideration of flood hazards and floodplain management.

These requirements are contained in the Federal-Aid Highway Program Manual (FHPM), Volume 6, Chapter 7, Section 3, Subsection 2, and were published in the *Federal Register*, April 26, 1979 (44 FR 24678), and in 23 CFR 650, Subpart A.

2.02.2.5.2 E.O. 11990 (Wetlands)

Executive Order 11990, May 24, 1977, orders each Federal agency to:

- Take action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values to wetlands;
- Avoid undertaking or providing assistance for new construction in wetlands unless the head of the agency finds that there is no practicable alternative and all practicable measures are taken to minimize harm which may result from the action; and
- Consider factors relevant to the proposal's effects on the survival and quality of the wetlands.

These requirements are contained in 23 CFR 771 (FHPM 7-7-1).

2.02.2.6 STATE DRAINAGE LAW

State drainage law is derived mainly from two sources: common law and statutory law.

2.02.2.6.1 Types

Common Law - is that body of principles which developed from immemorial usage and custom and which receives judicial recognition and sanction through repeated application. These principles were developed without legislative action and are embodied in the decisions of the courts.

Statutory Laws of Drainage - are enacted by legislatures to enlarge, modify, clarify, or change the common law applicable to particular drainage conditions. This type of law is derived from constitutions, statutes, ordinances, and codes.

In general, the common law rules of drainage predominate unless they have been enlarged or superseded by statutory law.

2.02.2.6.2 Classification of Waters

The first step in the evaluation of a drainage problem is to classify the water as surface water, stream water, flood water, or ground water. These terms are defined below. Once the classification has been established, the rule that applies to the particular class of water determines responsibilities with respect to disposition of the water.

Surface Waters - are those waters which have been precipitated on the land from the sky or forced to the surface in springs, and which have then spread over the surface of the ground without being collected into a definite body or channel.

Stream Waters - are former surface or ground waters which have entered and now flow in a well defined natural water course, together with other waters reaching the stream by direct precipitation or rising from springs in the bed or banks of the water course. A water course in the legal sense, refers to a definite channel with bed and banks within which water flows either continuously or intermittently.

Flood Waters - are former stream waters which have escaped from a water course (and its overflow channels) and flow or stand over adjoining lands. They remain flood waters until they disappear from the surface by infiltration or evaporation, or return to a natural water course.

Ground Waters - In legal considerations, ground waters are divided into two classes, percolating waters and underground streams. The term "percolating waters" generally includes all waters which pass through the ground beneath the surface of the earth without a definite channel. The general rule is that all underground waters are presumed to be percolating and to take them out of the percolating class; the existence and course of a permanent channel must be clearly shown. Underground streams are waters passing through the ground beneath the surface in permanent, distinct, well-defined channels.

2.02.2.7 STATE WATER RULES

2.02.2.7.1 Basic Concepts

Two major rules have been developed by the courts regarding the disposition of surface waters. One is known as the civil law rule of natural drainage. The other is referred to as the common enemy doctrine. Modification of both rules has tended to bring them somewhat closer together, and in some cases the original rule has been replaced by a compromise rule known as the reasonable use rule. Much of the law regarding stream waters is founded on a common law maxim that states "water runs and ought to run as it is by natural law accustomed to run." Thus, as a general rule, any interference with the flow of a natural watercourse to the injury or damage of another will result in liability. This may involve augmentation, obstruction and detention, or diversion of a stream. However, there are qualifications:

1. In common law, flood waters are treated as a "common enemy" of all people, lands and property attacked or threatened by them.

2. In ground water law, the "English Rule," which is analogous to the common enemy rule in surface water law, is based on the doctrine of absolute ownership of water beneath the property by the landowner.

2.02.2.7.2 Surface Waters

The civil law rule is based upon the perpetuation of natural drainage. The rule places a natural easement or servitude upon the lower land for the drainage of surface water in its natural course and the natural flow of the water cannot be obstructed by the servient owner to the detriment of the dominant owner. Most states following this rule have modified it so that the owner of upper lands has an easement over lower lands for drainage of surface waters and natural drainage conditions can be altered by an upper proprietor provided the water is not sent down in a manner or quantity to do more harm than formerly.

Under the common enemy doctrine, surface water is regarded as a common enemy which each property owner may fight off or control as he will or is able, either by retention, diversion, repulsion, or altered transmission. Thus, there is not cause of action even if some injury occurs causing damage. In most jurisdictions, this doctrine has been subject to a limitation that one must use his land so as not to unreasonably or unnecessarily damage the property of others.

Under the reasonable use rule, each property owner can legally make reasonable use of his or her land, even though the flow of surface waters is altered thereby and causes some harm to others. However, liability attaches when the owner's harmful interference with the flow of surface water is "unreasonable." Whether a landowner's use is unreasonable is determined by a nuisance type-balancing test. The analysis involves the following questions:

1. Was there reasonable necessity for the actor to alter the drainage to make use of his land?
2. Was the alteration done in a reasonable manner?
3. Does the utility of the actor's conduct reasonably outweigh the gravity of harm to others?

2.02.2.7.3 Stream Waters

Where natural watercourses are unquestioned in fact and in permanence and stability, there is little difficulty in application of the rule. Highways cross channels on bridges or culverts, usually with some constriction of the width of the channel and obstruction by substructure within the channel, both causing backwater upstream and acceleration of flow downstream. The changes in regime must be so small as to be tolerable by adjoining owners, or there may be liability of any injuries or damages suffered.

Surface waters from highways are often discharged into the most convenient watercourse. The right is unquestioned if those waters were naturally tributary to the watercourse and unchallenged if the watercourse has adequate capacity. However, if all or part of the surface waters have been diverted from another watershed to a small watercourse, any lower owner may complain and recover for ensuing damage.

2.02.2.7.4 Flood Waters

Considering flood waters as a common enemy permits all affected land-owners including owners of highways, to act in any reasonable way to protect themselves and their property from the common enemy. They may obstruct its flow from entering their land, backing or diverting water onto lands of another without penalty, by gravity or pumping, by diverting dikes or ditches, or by any other reasonable means.

Again, the test of "reasonableness" has frequently been applied, and liability can result where unnecessary damage is caused. Ordinarily, the highway designer should make provision for overflow in areas where it is foreseeable that it will occur. There is a definite risk of liability if such waters are impounded on an upper owner or, worse yet, are diverted into an area where they would not otherwise have gone. Merely to label waters as "flood waters" does not mean that they can be disregarded.

The "English Rule" has been modified by the "Reasonable Use Rule" which states in essence that each landowner is restricted to a reasonable exercise of his own right and a reasonable use of his property in view of the similar right of his neighbors.

The key word is "reasonable." While this may be interpreted somewhat differently from case to case, it can generally be taken to mean that a landowner can utilize subsurface water on his property for the benefit of agriculture, manufacturing, irrigation, etc. pursuant to the reasonable development of his property although such action may interfere with the underground waters of neighboring proprietors. However, it does generally preclude the withdrawal of underground waters for distribution or sale for uses not connected with any beneficial owner-ship or enjoyment of the land from whence they were taken.

A further interpretation of "reasonable" in relation to highway construction would view the excavation of a deep "cut section" that intercepts or diverts underground water to the detriment of adjacent property owners as unreasonable. There are also cases where highway construction has permitted the introduction of surface contamination into subsurface waters and thus incurred liability for resulting damages.

2.02.2.8 STATUTORY LAW

The inadequacies of the common law or court-made laws of drainage led to a gradual enlargement and modification of the common law rules by legislative mandate. In the absence of statute, the common law rules adopted by State courts determine surface water drainage rights. If the common law rules have been enlarged or superseded by statutory law, the statute prevails. In general, statutes have been enacted that affect drainage in one way or another in the subject areas described below.

2.02.2.8.1 Eminent Domain

In the absence of an existing right, public agencies may acquire the right to discharge highway drainage across adjoining lands through the use of the right of eminent domain. Eminent domain is the power of public agencies to take private property for public use.

The Tennessee State Constitution grants TDOT the right of eminent domain which allows that taking of property for public purposes, including the development of watercourse and watershed areas. However, whenever any property is taken under eminent domain, the private landowner must be compensated for the loss.

2.02.2.8.2 Water Rights

The water right which attaches to a watercourse is a right to the use of the flow, not ownership of the water itself. This is true under both the riparian doctrine and the appropriation doctrine. This right of use is a property right, entitled to protection to the same extent as other forms of property, and is regarded as real property. After the water has been diverted from the stream flow and reduced to possession, the water itself becomes the personal property of the riparian owner or the appropriator.

<u>Riparian Doctrine</u> - Under the riparian doctrine, lands contiguous to watercourses have prior claim to waters of the stream solely by reason of location and regardless of the relative productive capacities of riparian and nonriparian lands.

<u>Doctrine of Prior Appropriation</u> - The essence of this doctrine is the exclusive right to divert water from a source when the water supply naturally available is not sufficient for the needs of all those holding rights to its use. Such exclusive right depends upon the effective date of the appropriation, the first in time being the first in right.

Generally, the highway designers must consider that proposed work in the vicinity of a stream should not impair either the quality or quantity of flow of any water rights to the stream.

2.02.2.9 LOCAL LAWS AND APPLICATIONS

Local governments (cities, counties, and improvement districts) have ordinances and codes which require consideration during design. This is described further in the section on Policy (2.02.3.3).

A municipality is generally treated like a private party in State drainage matters. A municipality undertaking a public improvement is liable like an individual for damage resulting from negligence or an omission of duty. As a general rule, municipalities are under no legal duty to construct drainage improvements unless public improvements necessitate drainage - as in those situations in which street grading and paving or construction accelerate or alter storm runoff. In addition, it is generally held that municipalities are not liable for adoption or selection of a defective plan of drainage.

Municipalities can be held liable for negligent construction of drainage improvements, for negligent maintenance and repair of drainage improvements and failing to provide a proper outlet for drainage improvements. In general, in the absence of negligence a municipality will not be held liable for increased runoff occasioned by the necessary and desirable construction of storm drains. Nor will a municipality be held liable for damages caused by overflow of its storm drains occasioned by extraordinary, unforeseeable rains or floods. Municipal liability will attach where a municipality:

1. Collects surface water and casts it in a body onto private property where it did not formerly flow.
2. Diverts, by means of artificial drains, surface water from the course it would otherwise have taken, and casts it in a body large enough to do substantial injury on private land, where, but for the artificial storm drain, it would not go.
3. Fills up, dams back, or otherwise diverts a stream of running water so that it overflows its banks and flows on the land of another.

2.02.3 POLICIES

2.02.3.1 GENERAL POLICIES

Two policies define an adequate drainage structure. The first policy is that the design of the structure meets or exceeds TDOT's standard engineering practice. The second policy is that the design is consistent with what a reasonably competent and prudent designer would do under similar circumstances. To achieve an adequate drainage design, normally a hydrologic and hydraulic analysis and an engineering evaluation of selected alternatives are conducted. The drainage design process includes the following policies:

- The designer is responsible to provide an adequate drainage structure. The designer is not required to provide a structure that will handle all conceivable flood flows under all possible site conditions.
- The detail of the design should be commensurate with the risks associated with the encroachment and with other economic, engineering, social, or environmental concerns.
- The overtopping and/or design flood may serve as criteria for evaluating the adequacy of a proposed design. The overtopping flood and the design flood may vary widely depending on the grade, alignment, and classification of the road and the characteristics of the watercourse and floodplain.
- The predicted value of the 100-year or base flood serves as the present engineering standard for evaluating flood hazards and as the basis for regulating floodplains under the National Flood Insurance Program. The designer must make a professional judgment as to the degree of risk that is tolerable for the base flood on a case-by-case basis.

2.02.3.2 FEDERAL POLICIES

The following sections list the Federal legislation containing the Federal policies which may affect drainage design and construction. These sections give the legislative reference, regulations reference, purpose, applicability, general procedures and agency for coordination and consultation. For more detailed information about specific Federal policies, the applicable legislation should be consulted. Note: Abbreviations are given at the end of these sections.

2.02.3.2.1 Environmental Legislation

1. National Environmental Policy Act: 42 U.S.C. 4321-4347 (P.L. 91-190 and 94-81). Reference - 23 CFR 770-772, 40 CFR 1500-1508, CEQ Regulations, Executive Order 11514 as amended by Executive Order 11991 on NEPA responsibilities.
   Purpose - consider environmental factors through systematic interdisciplinary approach before committing to a course of action.
   Applicability - all highway projects.
   General Procedures - Procedures set forth in CEQ regulations and 23 CFR 771.
   Coordination - appropriate Federal, State, and local agencies.

2. Section 4(f) of the Department of Transportation Act: 23 U.S.C. 138, 49 U.S.C. 303 (P.L. 100-17, 97-449, and 86-670), 23 CFR 771.135.
   Purpose - preserve publicly owned public parklands, waterfowl and wildlife refuges, and all historic areas.
   Applicability - significant publicly owned public parklands, recreation areas, wildlife and waterfowl refuges, and all significant historic sites used for a highway project.
   General Procedures - specific finding required: (1) selected alternative should avoid protected areas, unless not feasible or prudent; and (2) includes all possible planning to minimize harm.
   Coordination - DOI, DOA, HUD, state, or local agencies having jurisdiction, and State Historic Preservation Officer (for historic sites).

3. Economic, Social, and Environmental Effects: 23 U.S.C. 109(h) (P.I. 91- 605), 23 U.S.C. 128, 23 CFR 771.
   Purpose - to assure that possible adverse, economic, social, and environmental effects of proposed highway projects and project locations are fully considered and that final decisions on highway projects are made in the best overall public interest.
   Applicability - to the planning and development of proposed projects on any Federal-aid system for which the FHWA approves the plans, specifications, and estimates, or has the responsibility for approving a program.
   General Procedures - identification of social, economic, and environmental effects; consideration of alternative courses of action; involvement of other agencies and the public; systematic interdisciplinary approach. The report required by Section 128, on the consideration given to the social, economic and environmental impacts of the project, may serve as part of the NEPA compliance document.
   Coordination - appropriate Federal, State, and local agencies.

4. Public Hearings: 23 U.S.C. 128, 23 CFR 771.111.
   Purpose - to ensure adequate opportunity for public hearing(s) on the social, economic and environmental effects of alternative project locations and major design features, as well as the consistency of the project with local planning goals and objectives.
   Applicability - public hearings or hearing opportunities are required for projects described in each State's FHWA approved public involvement procedures.
   General Procedures - public hearings or opportunities for public hearings during the consideration of highway location and design proposals are conducted as described in the State's FHWA-approved, public involvement procedures. States must certify to FHWA that such hearings or the opportunity therefore have been held and must submit a hearing transcript to FHWA.
   Coordination - appropriate Federal, State, and local agencies.

5. Surface Transportation and Uniform Relocation Assistance Act of 1987: Section 123(f) Historic Bridges 23 U.S.C. 144(o) (P.L. 100-17).
   Purpose - complete an inventory of on-and-off system bridges to determine their historic significance. Encourage the rehabilitation, reuse, and preservation of historic bridges.
   Applicability - any bridge that is listed on, or eligible for listing on, the National Register of Historic Places.
   General Procedures - (1) identify historic bridges on and off system, (2) seek to preserve or reduce impact to historic bridges, and (3) seek a recipient prior to demolition.
   Coordination - State Historic Preservation Officer and Advisory Council on Historic Preservation.

6. Surface Transportation and Uniform Relocation Assistance Act of 1987: Section 130 Wildflowers, 23 U.S.C. 319(b) (P.L. 100-17), FHPM 6-2-5-1, 23 CFR 752.
   Purpose - to encourage the use of native wildflowers in highway landscaping.
   Applicability - wildflowers are to be planted on any landscaping project undertaken on the Federal-aid highway system.
   General Procedures - at least 1/4 of 1% of funds expended on a landscaping project must be used to plant wildflowers on that project.
   Coordination - appropriate Federal and State agencies.

2.02.3.2.2 Health

1. Safe Drinking Water Act: 42 U.S.C. 300f - 300j-6 (P.L. 93-523 and 99-339), FHPM 6-7-3-3, 23 CFR 650, Subpart E, 40 CFR 141,149.
   Purpose - ensure public health and welfare through safe drinking water.
   Applicability - (1) all public drinking water systems and reservoirs (including rest area facilities), (2) actions which may have a significant impact on an aquifer or wellhead protection area which is the sole or principal drinking water source, as designated through the *Federal Register* process.
   General Procedures - (1) compliance with national primary drinking water regulations, (2) compliance with State wellhead protection plans, (3) compliance with MOAs between EPA and FHWA covering specific sole source aquifers.
   Coordination - EPA and appropriate State agency.

2. Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976: 42 U.S.C. 6901, et seq., see especially 42 U.S.C. 6961-6964 (P.L. 89-272, 91(P.L. 89-272, 91-512, and 94-580), 23 CFR 751, 40 CFR 256-300.
   Purpose - provide for the recovery, recycling, and environmentally safe disposal of solid wastes.
   Applicability - all projects which necessitate the disposal of solid wastes.
   General Procedures - solid wastes will be disposed of according to the rules for specific waste involved.
   Coordination - EPA.

3. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA): 7 U.S.C. 136-136y (P.L. 92-516), 40 CFR 162-171.
   Purpose - control the application of pesticides to provide greater protection to man and the environment.
   Applicability - all activities which necessitate use of restricted pesticides.

General Procedures - using or supervising "restricted use" pesticides will require certification.
Coordination - EPA.

2.02.3.2.3 Historic And Archeological Preservation

1. Section 106 of the National Historic Preservation Act, as amended: 16 U.S.C. 470f (P.L. 89-665, 91-243, 93-54, 94-422, 94-458, 96-199, 96-244, and 96-515), Executive Order 11593, 23 CFR 771, 36 CFR 60, 36 CFR 63, 36 CFR 800.
   Purpose - protect, rehabilitate, restore, and reuse districts, sites buildings, structures, and objects significant in American architecture, archeology, engineering, and culture.
   Applicability - all properties on or eligible for inclusion on the National Register of Historic Places.
   General Procedures - (1) identify and determine the effects of project on subject properties, (2) afford Advisory Council an early opportunity to comment, in accordance with 36 CFR 800, (3) avoid or mitigate damages to greatest extent possible.
   Coordination - State Historic Preservation Officer, Advisory Council on Historic Preservation, DOI (NPS).

2. Section 110 of the National Historic Preservation Act, as amended: 16 U.S.C. 470h-2 (P.L. 96-515), 36 CFR 65, 36 CFR 78.
   Purpose - protect national historic landmarks and record historic properties prior to demolition.
   Applicability - all properties designated as National Historic Landmarks. All properties on or eligible for inclusion on the National Register of Historic Places.
   General Procedures - (1) identify and determine the effects of a project on subject properties, (2) afford Advisory Council an early opportunity to comment, in accordance with 36 CFR 800.
   Coordination - State Historic Preservation Officer, Advisory Council on Historic Preservation, DOI (NPS).

3. Archeological and Historic Preservation Act: 16 U.S.C. 469-469c (P.L. 93-291) (Moss-Bennett Act), 36 CFR 66 (draft).
   Purpose - preserving significant historical and archeological data from loss or destruction.
   Applicability - any archeological resources discovered as a result of a Federal construction project or federally licensed activity or program.
   General Procedures - (1) notify DOI (NPS) when a Federal project may result in the loss or destruction of a historic or archeological property, (2) DOI and/or the Federal agency may undertake survey or data recovery.
   Coordination - DOI (NPS) departmental consulting archeologist and State Historic Preservation Officer.

4. Act for the Preservation of American Antiquities: 16 U.S.C. 431-433 (P.L. 59-209), 36 CFR 251.50-.64, 43 CFR 3. Archeological Resources Protection Act: 16 U.S.C. 470aa-11 (P.L. 96-95), 18 CFR 1312, 32 CFR 229, 36 CFR 296, 43 CFR 7.
   Purpose - preserve and protect paleontological resources, historic monuments, memorials, and antiquities from loss or destruction.
   Applicability - archeological resources on federally or Indian owned property.

General Procedures - (1) ensure contractor obtains permit, and identifies and evaluates resource, (2) mitigate or avoid resource in consultation with appropriate officials in the State, (3) if necessary, apply for permission to examine, remove, or excavate such objects.
Coordination - Department or agency having jurisdiction over land on which resources may be situated (BIA, BLM, DOA, DOD, NPS, TVA, USFS), State Historic Preservation Officer, recognized Indian tribe, if appropriate.

5. American Indian Religious Freedom Act: 42 U.S.C. 1996 (P.L. 95-341).
Purpose - protect places of religious importance to American Indians, Eskimos, and Native Hawaiians.
Applicability - all projects which affect places of religious importance to Native Americans.
General Procedures - consult with knowledgeable sources to identify and determine any effects on places of religious importance. Comply with Section 106 procedures if the property is historic.
Coordination - BIA, State Historic Preservation Officer, State Indian liaison, Advisory Council on historic Preservation, if appropriate.

2.02.3.2.4 Land And Water Usage

1. Wilderness Act: 16 U.S.C. 1131-1136, 36 CFR 251, 293, 43 CFR 19, 8560, 50 CFR 35.
Purpose - preserve and protect wilderness areas in their natural condition for use and enjoyment by present and future generations.
Applicability - all lands designated as part of the wilderness system by Congress.
General Procedures - apply for modification or adjustment of wilderness boundary by either Secretary of the Interior or Agriculture, as appropriate.
Coordination - Agriculture (USFS), DOI (FWS, NPS, BLM), and State agencies.

2. Wild and Scenic Rivers Act: 16 U.S.C. 1271-1287, 36 CFR 251, 261, 43 CFR 8350.
Purpose - preserve and protect wild and scenic rivers and immediate environments for benefit of present and future generations.
Applicability - all projects which affect designated and potential wild, scenic, and recreational rivers, and/or immediate environments.
General Procedures - submit project plans and reports to appropriate Federal agency.
Coordination - DOI (NPS) and/or Agriculture (USFS), State agencies.

3. Land and Water Conservation Fund Act (Section 6(f)): 16 U.S.C. 460l-4 to l-11 (P.L. 88-578).
Purpose - preserve, develop, and assure the quality and quantity of outdoor recreation resources for present and future generations.
Applicability - all projects which impact recreational lands purchased or improved with land and water conservation funds.
General Procedures - the Secretary of the Interior must approve any conversion of property acquired or developed with assistance under this act to other than public, outdoor recreation use.
Coordination - DOI, State agencies.

4. Executive Order 11990, Protection of Wetlands, DOT Order 5660.1A, 23 CFR 777.

Purpose - to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative.
Applicability - federally undertaken, financed, or assisted construction, and improvements in or with significant impacts on wetlands.
General Procedures - evaluate and mitigate impacts on wetlands. Specific finding required in final environmental document.
Coordination - DOI (FWS), EPA, USCE, NMFS, NRCS, State agencies.

5. Emergency Wetlands Resources Act of 1986: 16 U.S.C. - 3901 note (P.L. 99-645).
Purpose - to promote the conservation of wetlands in the U. S. in order to maintain the public benefits they provide.
Applicability - all projects which may impact wetlands.
General Procedures - (1) preparation of a National Wetlands Priority Conservation Plan which provides priority with respect to Federal and State acquisition, (2) provides direction for the National Wetlands Inventory Project.
Coordination - FWS.

6. National Trails Systems Act: 16 U.S.C. 1241-1249, 36 CFR 251, 43 CFR 8350.
Purpose - provide for outdoor recreation needs and encourage outdoor recreation.
Applicability - projects affecting national recreational, scenic, or side trails designated by Congress and lands through which such trails pass.
General Procedures - (1) apply for right-of-way easement from the Secretary of Interior or Agriculture, as appropriate, (2) ensure that potential trail properties are made available for use as recreational and scenic trails.
Coordination - DOI (NPS) or Agriculture (USFS).

7. Rivers and Harbors Act of 1899: 33 U.S.C. 401, et seq., as amended and supplemented, 23 CFR part 650, Subpart H, 33 CFR 114-115.
Purpose - protection of navigable waters in the U.S.
Applicability - any construction affecting navigable waters and any obstruction, excavation, or filling.
General Procedures - must obtain approval of plans for construction, dumping, and dredging permits (Section 10) and bridge permits (Section 9).
Coordination - USCE, USCG, EPA, State agencies.

8. Federal Water Pollution Control Act (1972), as amended by the Clean Water Act (1977 & 1987): 33 U.S.C. 1251-1376 (P.L. 92-500, 95-217, 100-4), DOT Order 5660.1A, FHWA Notices N5000.3 and N5000.4, FHPM 6-7-3-3, 23 CFR 650, Subpart B, E, 771, 33 CFR 209, 40 CFR 120, 122-125, 128-131, 133, 125-136, 148, 230-231.
Purpose - restore and maintain chemical, physical, and biological integrity of the Nation's waters through prevention, reduction, and elimination of pollution.
Applicability - any discharge of a pollutant into waters of the U.S.
General Procedures - (1) obtain permit for dredge or fill material from USCE or State agency, as appropriate (Section 404), (2) permits for all other discharges are to be acquired from EPA or appropriate State agency (Section 402), (3) water quality certification is required from State water resource agency (Section 401), (4) all projects shall be consistent with the State nonpoint source pollution management program (Section 319).
Coordination - USCE, EPA, designated State water quality control agency, designated State non-point source pollution agency.

9. Executive Order 11988, Floodplain Management, as amended by Executive Order 12148, DOT Order 5650.2, FHPM 6-7-3-2, 23 CFR 650, Subpart A, 771.
Purpose - to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains, and to restore and preserve the natural and beneficial values served by floodplains.
Applicability - all construction of Federal or federally aided buildings, structures, roads, or facilities which encroach upon or affect the base floodplain.
General Procedures - (1) assessment of flood hazards, (2) specific finding required in final environmental document.
Coordination - FEMA, State and local agencies.

10. National Flood Insurance Act: (P.L. 90-448), Flood Disaster Protection Act: (P.L. 93-234) 42 U.S.C. 4001-4128, DOT Order 5650.2, FHPM 6-7-3-2, 23 CFR 650, Subpart A, 771, 44 CFR 59-77.
Purpose - (1) identify flood-prone areas and provide insurance, (2) requires purchase of insurance for buildings in special flood hazard areas.
Applicability - any federally assisted acquisition of construction project in area identified as having special flood hazards.
General Procedures - avoid construction in, or design to be consistent with, FEMA-identified flood-hazard areas.
Coordination - FEMA, State and local agencies.

11. Water Bank Act: 16 U.S.C. (P.L. 91-559, 96-182), 7 CFR 752.
Purpose - preserve, restore, and improve wetlands of the Nation.
Applicability - any agreements with landowners and operators in important migratory waterfowl nesting and breeding areas.
General Procedures - apply procedures established for implementing Executive Order 11990.
Coordination - Secretary of Agriculture, Secretary of Interior.

12. Farmland Protection Policy Act of 1981: 7 U.S.C. 4201-4209 (P.L. 97-98, 99-198), 7 CFR 658.
Purpose - minimize impacts on farmland and maximize compatibility with State and local farmland programs and policies.
Applicability - all projects that take right-of-way in farmland.
General Procedures - (1) early coordination with the NRCS, (2) land evaluation and site assessment, (3) determination on whether or not to proceed with farmland conversion, based on severity of impacts and other environmental considerations.
Coordination - NRCS.

13. Resource Conservation and Recovery Act of 1976 (RCRA), as amended: 42 U.S.C. 690, et seq. (P.L. 94-580, 98-616), 40 CFR 260-271.
Purpose - protect human health and the environment, prohibit open dumping, manage solid wastes, regulate treatment, storage, transportation, and disposal of hazardous waste.
Applicability - any project that takes right-of-way containing a hazardous waste.
General Procedures - coordinate with EPA or State agency on remedial action.
Coordination - EPA or State agency approved by EPA, if any.

14. Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended: 42 U.S.C. 9601-9657 (P.L. 96-510), 40 CFR 300, 43 CFR 11. Superfund Amendments and Reauthorization Act of 1986 (SARA) (P.L. 99-499).
    Purpose - provide for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites.
    Applicability - any project that might take right-of-way containing a hazardous substance.
    General Procedures - (1) avoid hazardous waste sites, if possible, (2) check EPA lists of hazardous waste sites, (3) field surveys and reviews of past and present land use, (4) contact appropriate officials if uncertainty exists, (5) if hazardous waste is present or suspected, coordinate with appropriate officials, (6) if hazardous waste encountered during construction, stop project and develop remedial action.
    Coordination - EPA or State agency approved by EPA, if any.

15. Endangered Species Act of 1973, as amended: 16 U.S.C. 1531-1543 (P.L. 93-205, 94-359, 95-632, 96-159, 97-304), 7 CFR 355, 50 CFR 17, 23, 25-29, 81, 217, 222, 225-227, 402, 424, 450-453.
    Purpose - conserve species of fish, wildlife and plants facing extinction.
    Applicability - any action that is likely to jeopardize continued existence of such endangered/threatened species or result in destruction or modification of critical habitat.
    General Procedures - consult with the Secretary of the Interior or Commerce, as appropriate.
    Coordination - DOI (FWS), Commerce (NMFS).

16. Fish and Wildlife Coordination Act: 16 U.S.C. 661-666c (P.L. 85-624, 89-72, 95-616).
    Purpose - conservation, maintenance, and management of wildlife resources.
    Applicability - (1) any project which involves impoundment (surface area of 4.05 hectares or more), diversion, channel deepening, or other modification of a stream or other body of water, (2) transfer of property by Federal agencies to State agencies for wildlife conservation purpose.
    General Procedures - coordinate early in project development with FWS and State fish and wildlife agency.
    Coordination - DOI (FWS), State fish and wildlife agencies.

2.02.3.3 TDOT DRAINAGE PROCEDURES AND RESPONSIBILITIES

TDOT procedures and responsibilities are described in this section. The drainage designer should check in the particular chapter that deals with each drainage item for further details on TDOT's policies, procedures, practices, and responsibilities.

2.02.3.3.1 Sizing Bridge Waterway Openings

When drainage area runoff flows for 2% exceedance (Q_{50}) is more than 500 cfs or for any structure whose length along the roadway (width of structure) is 20 feet or greater, the Hydraulics Design Section of the Structures Division will furnish all necessary data and hydraulic design to be shown on the plans.

2.02.3.3.2 Hydrologic Responsibilities

Roadway improvements within TDOT lands and rights-of-way should be done through sound, reasonable, and acceptable engineering practices which may include augmented or accelerated flow caused by TDOT improvements unless determined to cause unreasonable and substantial damages. TDOT expects the same practice and acceptance of responsibility by other property owners and those engaged in the development of property. TDOT does not have the responsibility to eliminate flooding on private property that is not attributable to acts of TDOT or its representatives.

2.02.3.3.3 Diversions

Altering the path of surface waters from one drainage area to another is a diversion. Many diversions are made through the use of ditches and open channels; others may be accomplished through closed drainage systems. TDOT practice for drainage system design and maintenance is that diversions be avoided insofar as practical from good engineering practice.

Any person(s) desiring to create a diversion into any TDOT property or right-of-way shall do so only after receiving written permission from TDOT. Permission will be granted only after determination that the diversion flow can be properly handled without damage to the highway and highway drainage system. If any adjustments to the TDOT drainage system are required, the cost will be borne by the requester, and that appropriate consideration and measures have been taken to indemnify and save harmless TDOT from potential downstream damage claims. TDOT will not become a party to diversions unless refusal would create a considerable and real hardship to the requesting party.

2.02.3.3.4 Ditches and Open Channels

Preventive measures against soil erosion and protection of the environment must be considered. Allowable high water elevations for design are identified in the chapter on Channels and Roadway Ditches.

2.02.3.3.5 Storm Drains

The pipe size requirements are identified in the Culvert chapter and the Storm Drainage Systems chapter. No alteration, attachment, extension, nor addition of appurtenance to any culvert, storm sewer, or other drainage structure shall be allowed on highway rights-of-way without written permission from TDOT.

2.02.3.3.6 Erosion and Sediment Control

Permanent Erosion Control procedures and responsibilities are included in the Channels and Roadway Ditches chapter. Refer to the separate TDOT publication for temporary erosion and sediment control for TDOT procedures and responsibilities.

2.02.3.3.7 Floodplain Encroachments

Longitudinal encroachments are to be avoided when possible. If such an encroachment cannot be avoided, the degree of encroachment should be minimized to the greatest extent possible. Transverse encroachments generally cannot be avoided (except for a no-build alternative). The design selected for transverse encroachments should be supported by analysis of design alternatives with consideration given to cost, risk, and potential impacts. "Supported" means that the design is either shown to be cost-effective or justified by another engineering basis.

2.02.3.3.8 Improvements and Maintenance

1. Improvements and Maintenance of Drainage Within the R.O.W.

    - Open channels, ditches, and drainage structures shall be maintained at a functioning level such that they do not present an unreasonable level of damage potential for the roadway or adjacent properties.
    - Where the size of an existing roadway culvert is determined to be of unacceptable adequacy in regard to the roadway drainage system as a result of a single action or development, the party responsible for the action or development will bear the cost of replacement.
    - No alteration, attachment, extension, nor addition of appurtenance to any culvert, storm sewer, or other drainage structure shall be permitted within TDOT right-of-way without written permission from TDOT.

2. Improvements and Maintenance of Drainage Outside of the R.O.W.

    - Drainage involvement outside TDOT right-of-way is limited to two general areas of justification:
        - TDOT would benefit by such an involvement. Benefits that may warrant the cost include would include improvements that reduce the roadway flood frequency, reduce the extent of roadway flooding, facilitates maintenance, or reduces potential damages to TDOT property.
        - TDOT is required to correct a problem or condition created by some action of TDOT.

2.02.3.3.9 Easements

Structural features including items such as inlets, catch basins and pipe ends should be contained in a permanent easement if right-of-way is not available. If runoff is discharged from TDOT 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. A permanent drainage easement would be required to discharge runoff into a natural drain or existing ditch where the increase in flow exceeds the capacity of the drain or ditch or otherwise creates a problem. The permanent drainage easement would allow enlarging or otherwise improving the drain to a point where the increased discharge would not cause damage.

2.02.3.4 DESIGNER'S RESPONSIBILITY

The designer is responsible for following the policies, criteria, procedures, and practices identified in this Drainage Manual and TDOT's other manuals with sections relevant to drainage design. In addition to the TDOT publications, other drainage informational sources are available to the designer. The designer shall use his or her knowledge and judgement to hold paramount the safety, health, and welfare of the public while acting as a faithful agent or trustee to TDOT.

The legal aspects of highway drainage are two-fold for the designer.

1. The designer should know the legal principles involved and apply this knowledge to the design.
2. If legal actions are anticipated on a project, the designer should work closely with the legal staff of his or her organization in the preparation and trial of drainage cases.

2.02.3.5 LOCAL/MUNICIPAL POLICIES

Many local governmental bodies in Tennessee have developed ordinances, codes, guidelines, or other requirements that may influence roadway drainage design. Generally, the State is not legally required to comply with local ordinances except where compliance is required by specific State statute. However, TDOT may consider, as practical, conforming with local ordinances as a courtesy, especially when it can be done without imposing a burden on the State.

SECTION 2.03 – FIELD RECONNAISSANCE

In order for the designer to properly understand the drainage characteristics of the project location, a field reconnaissance is appropriate. The surveyor for the project will have identified many of the drainage features within the project limits. This information is included in the survey data. The designer should review the survey data and perform a field reconnaissance to verify the data and to become familiar with the project's drainage features. The drainage related items included in the survey are identified in the *TDOT Survey Manual*. The field reconnaissance should be performed early in the design of the project

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CHAPTER II
APPENDIX 2A

SECTION 2.04 – APPENDIX

2.04 APPENDIX

2.04.1 REFERENCES

2.04.1.1 PUBLICATIONS

1. American Association of State Highway and Transportation Officials. *Model Drainage Manual [Metric Edition].* Washington, D.C. 1999.
2. Hankins, Jr., A.L. *Guidelines for Drainage Studies and Hydraulic Design North Carolina Department of Transportation.* Raleigh, NC. 1999.
3. Illinois Department of Transportation. *Departmental Policy BBS-7 Drainage Manual*. Springfield, IL 1989.
4. Indiana Department of Transportation. *Indiana Design Manual Part IV Volume I*. Indianapolis, IN. 1999.
5. Tennessee Department of Transportation. *Design Guidelines - English*. Nashville, TN. 2001.

2.04.1.2 ABBREVIATIONS

Following are the abbreviations used in the descriptions of Federal policies:

BIA - Bureau of Indian Affairs
BLM - Bureau of Land Management
CEQ - Council on Environmental Quality
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CFR - Code of Federal Regulations (CFR)
DOA - Department of the Army
DOD - Department of Defense
DOI - Department of the Interior
DOT - Department of Transportation
EPA - Environmental Protection Agency
FEMA - Federal Emergency Management Agency
FHPM - Federal-Aid Highway Program Manual
FHWA - Federal Highway Administration
FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act
FWPCA - Federal Water Pollution Control Act
FEIS - Final Environmental Impact Statement
FWS - Fish and Wildlife Service
HUD - Housing and Urban Development
NFIP - National Flood Insurance Program
NMFS - National Marine Fisheries Service
NPS - National Park Service
NRCS - National Resource Conservation Service; formerly Soil Conservation Service (SCS)
P.L. - Public Law
RCRA - Resource Conservation and Recovery Act
SARA - Superfund Amendments and Reauthorization Act
SEE - Social, Economic, and Environmental
SIP - State Implementation Plan

Stat. - Statute
TVA - Tennessee Valley Authority
UMTA - Urban Mass Transportation Administration
U.S.C. - United States Code
USCE - U.S. Corps of Engineers
USCG - U.S. Coast Guard
USFS - U.S. Forest Service

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CHAPTER III
DRAINAGE PLAN REQUIREMENTS

CHAPTER 3 – DRAINAGE PLAN REQUIREMENTS

SECTION 3.05 – CONSTRUCTION PLANS

SECTION 3.06 – DRAINAGE DESIGN RECORDS

SECTION 3.07 – APPENDIX

CHAPTER 3 – DRAINAGE PLAN REQUIREMENTS

SECTION 3.01 – INTRODUCTION

This chapter discusses the various components of drainage design required to be included on the plans and in the design records. The requirements for each phase of the plan submittal process (preliminary, right-of-way, and construction) is discussed separately. The preliminary plans contain information for use up to and including the public hearing, including preliminary design data for cross culverts, ditches, and channels which will impact the general location of the proposed right-of-way and easements. The right-of-way plans include all completed drainage design information in order to accurately delineate and describe proposed right-of-way and easements necessary for acquisition of the required property. The construction plans contain all tabulated drainage quantities for the project in addition to the information included in the right-of-way plans.

SECTION 3.02 – GENERAL INFORMATION

All current Tennessee Department of Transportation (TDOT) drafting standards (including standard symbols for drainage related items) are to be utilized in developing the plans. The format of notes and general sheet layout for drainage design is presented in later sections of this chapter on the sample drawings.

Sheets in the plans where drainage related information is normally shown include:

- Index Sheet
- Estimated Roadway Quantities Sheet
- Typical Sections Sheet
- General Notes and Special Notes Sheet
- Tabulated Quantities Sheet
- Right-of-Way Acquisition Table Sheet
- Present Layout Sheet
- Proposed Layout Sheet
- Side Road and Ramp Profile Sheet
- Private Drive and Field Ramp Profile Sheet
- Drainage Map Sheet
- Culvert Sections Sheet

Other sheets may contain drainage related information in certain cases.

The following sections contain information which is to be shown on drawings in the design plans. The appendix at the end of this chapter contains samples of portions of the drawings.

SECTION 3.03- PRELIMINARY PLANS

During the Preliminary Plans phase, all cross culverts are designed and preliminary design is performed on other drainage components in order that the profile grade of the proposed roadway improvement and preliminary right-of-way and easement requirements can be established. This information is necessary to develop the plans to a level adequate to be used in the public hearing. The following presents the drainage information required to be shown on the respective sheets in the preliminary plans.

3.03.1 TYPICAL SECTIONS SHEET

The Typical Sections Sheet shows typical road sections and includes details of the standard template ditches in cut sections. Information concerning side slopes, ditch stabilization, and rounding is shown on this sheet. Figure 3A-1 is a sample of a portion of a Typical Sections Sheet showing proposed template ditches. These sheets also show curbs and gutters in curbed streets. Figure 3A-2 is a sample of a portion of a Typical Sections Sheet showing curb and gutter.

3.03.2 PRESENT LAYOUT SHEET

The Present Layout Sheet indicates existing conditions in the area of the proposed road. Also, some of the features of the proposed road are shown, including the proposed cross culverts. The size and type of the cross culverts are shown, but the invert elevations are not. Any drainage features which are to be removed are noted on these sheets. Figure 3A-3 is a sample of a portion of a Present Layout Sheet showing a proposed pipe culvert. Figure 3A-4 is a sample showing a proposed box culvert. Figure 3A-5 is a sample showing a proposed box bridge.

3.03.3 PROPOSED LAYOUT SHEET

The Proposed Layout Sheet contains the geometric design and drainage design data for the proposed project. The proposed cross culverts are shown with size, type, and invert elevations in the plan view. Invert elevations for pipe culverts are shown at the end of the end treatment. The roadway profile shows the graphical location and size of cross culverts, the proposed road centerline station at each culvert, the culvert size, skew angle (from the centerline of the proposed road, 90 degrees or less), type of end treatment, standard drawing numbers for the specified end treatment, and pertinent hydrologic and hydraulic design data. The graphical location and size of existing cross culverts are also shown in the profile. Figure 3A-6 is a sample of a portion of a Proposed Layout Sheet showing a proposed pipe culvert. Also shown on Figure 3A-6 is information required for a driveway culvert. Figure 3A-7 shows a proposed box culvert. Figure 3A-8 shows a proposed box bridge. The box bridge requires additional hydraulic design data and quantities for pay items shown in the profile.

3.03.4 SIDE ROAD AND RAMP PROFILE SHEET

The Side Road and Ramp Profile Sheet contains the same data as required in the roadway profile of the Proposed Layout Sheet.

3.03.5 PRIVATE DRIVE AND FIELD RAMP PROFILE SHEET

The Private Drive and Field Ramp Profile Sheet shows data necessary to construct private drives and field ramps. Drainage information shown is a graphical representation of the culvert under the drive along with the size of the culvert. Invert elevations are not shown. Figure 3A-9 shows a sample private drive profile.

3.03.6 DRAINAGE MAP SHEET

The Drainage Map Sheet shows the approximate limits and general flow patterns of drainage areas along with basic hydrologic design data. The location and sizes of the cross culverts are shown. Other pertinent drainage features such as existing major streams and wetlands and proposed drainage easements are included. The Drainage Map Sheet is a relatively small scale map showing very general drainage features. It is not intended to be used for detailed drainage design. Figure 3A-10 is a sample of a portion of a Drainage Map Sheet.

SECTION 3.04 – RIGHT-OF-WAY PLANS

During the Right-of-Way Plans phase, all remaining detailed drainage design is completed on the project. This allows for the final determination of the limits of proposed right-of-way and required easements. The following presents the drainage information required to be shown on the respective sheets in the right-of-way plans.

3.04.1 TYPICAL SECTIONS AND DETAILS SHEET

(Same as Preliminary Plans).

3.04.2 RIGHT-OF-WAY ACQUISITION TABLE SHEET

The Right-of-Way Acquisition Table Sheet contains information related to property owners and proposed right-of-way and easements to be acquired. Most drainage features will be located inside the areas designated as right-of-way. Permanent drainage easements are required when drainage features are located outside the right-of-way. The necessity for drainage easements will be addressed by the designer and approved by TDOT during the design process. If drainage easements are necessary, they are tabulated on the Right-of-Way Acquisition Table.

3.04.3 PRESENT LAYOUT SHEET

Additional information shown on the Present Layout Sheet includes limits of detention systems. Figure 3A-11 is a sample of a portion of a Present Layout Sheet with an area designated for a detention system.

3.04.4 PROPOSED LAYOUT SHEET

The cross culvert information shown on the Proposed Layout Sheet is the same as shown on the preliminary plans.

Culverts under median openings are shown in the plan view with the structure number of the end treatment, type of end treatment, and invert elevation at the end of the end treatments. The profile shows the graphical location of the culvert along with the structure number and type of end treatment. The top number in the circle labeling the drainage structure denotes the structure number specific to the project. The bottom designation denotes the type of structure used. Figure 3A-12 is a sample of a portion of a Proposed Layout Sheet with a median culvert.

Special ditches required which are not standard template ditches are shown in the plan view along with the type of ditch and specified lining. The profile shows the special ditch slope and elevations at break points along with the station of the break point. Figure 3A-13 is a sample of a portion of a Proposed Layout Sheet with a special ditch. Template ditches are not shown on the Proposed Layout Sheets.

Storm sewer systems are shown in the plan view along with the sizes of pipe, structure numbers, types of structures, grate elevation and invert elevations of each structure. Figure 3A-14 shows a portion of a Proposed Layout Sheet with a storm sewer system in the plan view. The profile for the storm sewers shows the graphical location of the storm sewer system along with the structure number and type of structure and size of pipe. Figure 3A-15 shows a portion of a Proposed Layout Sheet with a storm sewer in the profile view. Figure 3A-16 shows a portion of a Proposed Layout Sheet with a detention system in the plan view. A separate large-scale plan showing details of the detention system should be provided in the plans.

3.04.5 SIDE ROAD AND RAMP PROFILE SHEET

(Same as Preliminary Plans).

3.04.6 PRIVATE DRIVE AND FIELD RAMP PROFILE SHEET

(Same as Preliminary Plans).

3.04.7 DRAINAGE MAP SHEET

(Same as Preliminary Plans).

3.04.8 CULVERT SECTIONS SHEET

The Culvert Sections Sheet shows a profile of the cross culverts on the project. The existing and proposed grades along the centerline of the culvert are shown. The road centerline station where the culvert is located is shown along with the size and material of the culvert, invert elevations, skew angle (from the centerline of the proposed road, 90 degrees or less), type of end treatment, standard drawing numbers for the specified end treatment, and pertinent hydrologic and hydraulic design data. Invert elevations for pipe culverts are shown at the end of the end treatment. Figure 3A-17 is a sample of a portion of a Culvert Sections Sheet showing a pipe culvert. Box culvert and box bridge sections show the same information as pipe culverts along with additional hydraulic design data and pay item quantities for the culvert and end treatment. A box bridge is defined as a box culvert with a total width greater than 20 feet. Figure 3A-18 is a sample of a portion of a Culvert Sections Sheet showing a box culvert. Figure 3A-19 is a sample of a portion of a Culvert Sections Sheet showing a box bridge.

3.04.9 CROSS SECTIONS SHEET

The Cross Sections Sheet includes information for both standard template ditches and special ditches. Figure 3A-20 is a sample of a portion of a Cross Sections Sheet showing both types of ditches. Figure 3A-21 is a sample of a portion of a Cross Sections Sheet showing a detention basin.

SECTION 3.05 - CONSTRUCTION PLANS

The preparation of the Construction Plans involves the tabulation of bid quantities for the project. All drainage design should have previously been completed during the preparation of the Right-of-Way plans. The following presents the drainage information required to be shown on the respective sheets in the construction plans.

3.05.1 INDEX SHEET

In addition to the index of drawing numbers for the plans, the Index Sheet contains a list of Standard Drawings which relate to the project. Some of these are printed with the plans and some are referenced. Drainage related standards are included here.

3.05.2 ESTIMATED ROADWAY QUANTITIES SHEET

The Estimated Roadway Quantities Sheet shows a summary of all the bid items for the project. The item number, description, unit, and total quantity is shown for each bid item.

3.05.3 TYPICAL SECTIONS AND DETAILS SHEET

The drainage related features for the roadway typical sections will be the same as shown on the preliminary plans. In addition, special ditch details and tabulations are included. The special ditches are ditches (other than standard template ditches) required in the drainage design. The location of each ditch, side slopes, bottom width, type of ditch, and specified lining is shown. Also, a typical section of each type of ditch used is shown. Figure 3A-22 is a sample of Tabulated Ditches and Ditch Sections on a Typical Sections Sheet.

3.05.4 GENERAL NOTES AND SPECIAL NOTES SHEET

The General Notes and Special Notes Sheet contains standard and project specific notes related to the project.

3.05.5 TABULATED QUANTITIES SHEET

The Tabulated Quantities Sheets contain the detailed tabulation of various components of the roadway design. Several of these components are drainage related items. Data regarding location, size and/or type, length, pay item quantities, and standard drawing numbers for each component of the drainage system is shown.

3.05.6 RIGHT-OF-WAY ACQUISITION TABLE SHEET

(Same as Right-of-Way Plans).

3.05.7 PRESENT LAYOUT SHEET

(Same as Right-of-Way Plans)

3.05.8 PROPOSED LAYOUT SHEET

(Same as Right-of-Way Plans).

3.05.9 SIDE ROAD AND RAMP PROFILE SHEET

(Same as Right-of-Way Plans).

3.05.10 PRIVATE DRIVE AND FIELD RAMP PROFILE SHEET

(Same as Right-of-Way Plans).

3.05.11 DRAINAGE MAP SHEET

(Same as Right-of-Way Plans).

3.05.12 CULVERT SECTIONS SHEET

(Same as Right-of-Way Plans).

3.05.13 CROSS SECTIONS SHEET

(Same as Right-of-Way Plans).

SECTION 3.06 - DRAINAGE DESIGN RECORDS

3.06.1 OVERVIEW

3.06.1.1 INTRODUCTION

An important part of the design or analysis of any hydraulic facility is the documentation. Appropriate documentation of the design of any hydraulic facility is essential because of:

- The importance of public safety
- Justification of expenditure of public funds
- Future reference by engineers (when improvements, changes, or rehabilitations are made to the highway facilities)
- Information leading to the development of defense in matters of litigation
- Public information

Frequently, it is necessary to refer to plans, specifications and analysis long after the actual construction has been completed. Documentation permits evaluation of the performance of structures after flood events to determine if the structures performed as anticipated or to establish the cause of unexpected behavior, if such is the case. In the event of a failure, it is essential that contributing factors be identified in order that recurring damage can be avoided.

3.06.1.2 DEFINITION

The definition of hydrologic and hydraulic documentation as used in this chapter is the compilation and preservation of the design and related details as well as all pertinent information on which the design and decisions were based.

3.06.1.3 PURPOSE

This purpose of the drainage documentation is to support the development of plans and to serve as a diary of the drainage design process for TDOT projects. This portion of the manual focuses on the documentation of the findings obtained in using the other chapters of this manual, and thus designers should be familiar with all the hydrologic and hydraulic design procedures associated with these chapters. In this portion of the manual, TDOT's system for organizing the documentation of hydraulic designs is presented. The documentation will provide as complete a history of the drainage design process as is practical.

The major purpose of providing good documentation is to define the design procedure that was used and to show how the final design and decisions were arrived at. Often there is expressed the myth that avoiding documentation will prevent or limit litigation losses as it supposedly precludes providing the plaintiff with incriminating evidence. This is seldom if ever the case and documentation should be viewed as the record of reasonable and prudent design analysis based on the best available technology. Thus, good documentation can provide the following:

- Protection for TDOT by proving that reasonable and prudent actions were, in fact, taken;
- Identifying the situation at the time of design;
- Documenting that rationally accepted procedures and analysis were used at the time of the design which were commensurate with the perceived site importance and flood hazard;
- Providing a continuous site history to facilitate future reconstruction;
- Providing the file data necessary to quickly evaluate any future site problems that might occur during the facilities service life; and
- Expediting plan development by clearly providing the reasons and rationale for specific design decisions.

3.06.1.4 TYPES

There are three basic types of documentation which will be considered: preconstruction, design, and construction / operation.

1. Preconstruction documentation includes the following if available:

   a. Aerial photographs

b. Contour mapping
c. Watershed map or plan including:
    - Flow directions
    - Watershed boundaries
    - Watershed areas
    - Natural storage areas
d. Surveyed data reduced to include:
    - Existing hydraulic facilities
    - Existing controls
    - Profiles - roadway, channel, driveways
    - Cross sections - roadway, channels, faces of structures
e. Flood insurance studies and maps by FEMA
f. National Resource Conservation Service soil maps (if used during design)
g. Field reconnaissance report(s) which may include:
    - Video cassette recordings
    - Audio tape recordings
    - Still camera photographs
    - Movie camera films
    - Written analysis of findings with sketches
h. Reports from other agencies (local, State or Federal), TDOT personnel, newspapers, and abutting property owners.

2. Design documentation includes all the information used to justify the design, including:

a. Reports from other agencies
b. Hydrological report
c. Hydraulic report
d. Approvals

3. Construction or operation documentation includes:

a. Plans
b. Revisions
c. Record drawings
d. Photographs
e. Record of operation during flooding events, complaints and resolutions

It is very important to prepare and maintain in a permanent file the record drawings plans for every drainage structure to document subsurface foundation elements such as footing types and elevations, pile types and (driven) tip elevations, etc. There may be other information which should be included or may become evident as the design or investigation develops. This additional information will also be incorporated at the discretion of the designer.

3.06.1.5 SCHEDULING

Documentation shall not be considered as occurring at specific times during the design or as the final step in the process which could be long after the final design is completed. Documentation should rather be an ongoing process and part of each step in the hydrologic and hydraulic analysis and design process. This will increase the accuracy of the documentation, provide data for future steps in the plan development process, and provide consistency in the design even when different designers are involved at different times of the plan development process. The drainage design records and documentation will be assembled appropriately for permanent storage. The notebook will be retained by the designer.

3.06.1.6 RESPONSIBILITY

The designer will be responsible for determining what hydrologic analyses, hydraulic design, and related information will be documented during the plan development process. These hydrologic analyses, hydraulic designs, related information, and procedures are covered in depth in the remainder of this manual. The designer will make a determination that complete documentation has been achieved during the plan development process which will include the final drainage design.

3.06.2 PROCEDURES

3.06.2.1 INTRODUCTION

A complete hydrologic and hydraulic design and analysis documentation file for each waterway encroachment or crossings will be developed. Where applicable this file will include such items as:

1. Identification and location of the facility
2. Photographs (ground and aerial)
3. Hydrology investigations
4. Drainage area maps, vicinity maps and topographic maps
5. Contour maps
6. Interviews (local residents, adjacent property owners and maintenance forces)
7. Newspaper clippings
8. Design notes and correspondence relating to design decisions
9. History of performance of existing structure(s)
10. Assumptions

The documentation file will contain design/analysis data and information which influenced the facility design.

3.06.2.2 PRACTICES

Following are the Department's practices related to documentation of hydrologic and hydraulic designs and analyses.

1. Hydrologic and hydraulic data, preliminary calculations and analyses and all related information used in developing conclusions and recommendations related to drainage requirements, including estimates of structure size and location, will be compiled in a documentation file.

2. The designer will document all design assumptions and selected criteria including the decisions related thereto.
3. The amount of detail of documentation for each design or analysis will be commensurate with the risk and the importance of the facility.
4. Documentation will be organized to be as concise and complete as practicable so that knowledgeable designers can understand years hence what was done by predecessors.
5. In cases where there are potential unknown design factors, this should be stated in the design assumptions.
6. Provide all related references in the documentation file to include such things as published data and reports, memos and letters and interviews. Include dates and signatures where appropriate.
7. Documentation will be organized to logically lead the reader from past history through the problem background, into the findings and through the performance.
8. A summary at the beginning of the documentation will provide an outline of the documentation file to assist users in finding detailed information.

3.06.3 DOCUMENTATION COMPONENTS

3.06.3.1 ASSEMBLY

The following sections discuss the items that will be included in the drainage design records. The intent is not to limit the data to only those items listed, but rather to establish a minimum requirement consistent with the hydraulic design procedures as outlined in TDOT manuals. If circumstances are such that the drainage facility is sized by other than normal procedures or if the size of the facility is governed by factors other than hydrologic or hydraulic factors, a narrative summary detailing the design basis will be included in the records. Additionally, the designer will include in the documentation items not listed below but which are useful in understanding the analysis, design, findings and final recommendations.

The design records will be assembled in a manner that will allow the various components to be found as readily as possible.

1. Each section of the drainage records that contains computations will start with all assumptions used by the designer(s).
2. Copies of reports, meetings, or correspondence regarding the drainage design will be included in the design records.
3. All pages larger than 8 1/2 x 11 inches will be neatly folded and labeled to allow the contents of the page and its station(s) to be identified without unfolding the page. The quantity of folded pages should be kept to a minimum.
4. Computer calculations require both the input files and the computer output.
5. Sheets that contain manual calculations, non-departmental forms, and any other material which support the hydraulic results should be included.
6. Drainage items designed or analyzed should be identified such that they may be readily found in the construction plans.

All hand calculations will be initialed and dated by the designer. Computer inputs and outputs will be initialed by the person entering the data and running the computer program. Such initialing will be construed as a check of the computer output to be a reasonable result. Appropriate quality control procedures should be documented by the designer.

3.06.3.2 HYDROLOGY

Detailed requirements are presented in Chapter 4 of this manual. To aid in assembling the design records these categories should be reviewed for inclusion:

1. List all assumptions used in the design or analysis.
2. Maps or data used to delineate drainage areas.
3. How methods for design or analysis were selected.
4. Criteria selected for design or analysis.
5. Findings of analysis or design.

3.06.3.3 CULVERTS

Documentation should be provided indicating the amount of runoff estimated for each structure. When the estimation indicates a flow greater than 500 cfs, TDOT's Structures Hydraulics Section performs the design. Copies of correspondence informing TDOT's Structures Hydraulics Section of these structures will be included. For structures receiving less than or equal to 500 cfs, detailed design and documentation requirements are presented in Chapter 6 of this manual. To aid in assembling the design records these categories should be reviewed for inclusion:

1. Allowable headwater elevation and basis for its selection.
2. Roughness coefficient assignments ("n" values).
3. Observed high water, dates and discharges.
4. Calculated headwater elevations, outlet velocities, and scour (if applicable) and any historical floods.
5. Type of culvert entrance condition and whether outlet or inlet control.
6. Culvert outlet appurtenances and energy dissipation calculations and designs (if applicable).
7. Copies of all computer analyses.
8. Potential flood hazard to adjacent properties.

3.06.3.4 OPEN CHANNELS

All channels on the project shall be analyzed hydraulically. This includes roadway cut ditches, surface ditches, special ditches, interceptor ditches, inlet and outlet ditches, and channels. Detailed requirements are presented in Chapter 5 of this manual. To aid in assembling the design records these categories should be reviewed for inclusion:

1. Cross section(s) used in the design water surface determinations and their locations.
2. Roughness coefficient assignments ("n" values).
3. Information on the method used for design water surface determinations.
4. Observed high water, dates and discharges.
5. Channel velocity measurements or estimates and locations.
6. Design or analysis of materials proposed for the channel bed and banks.
7. Energy dissipation calculations and designs.
8. Copies of all computer analyses.

3.06.3.5 STORM DRAINAGE SYSTEM

Detailed requirements for storm drainage systems are presented in Chapter 7 of this manual. To aid in assembling the design records these categories should be reviewed for inclusion:

1. Computations for inlets and pipes, including hydraulic grade lines.
2. Copies of storm sewer computation sheets or computer analyses.
3. Complete drainage area map (addresses inlet spacing).
4. Design frequency.
5. Information concerning outfalls, existing storm drains, and other design considerations including connecting structures.
6. Calculations for any special drainage details.
7. A schematic indicating the storm drainage system layout with design information.

3.06.3.6 STORM WATER DETENTION

Detailed requirements for storm water detention and/or retention design are presented in Chapter 8 of this manual. To aid in assembling the design records these categories should be reviewed for inclusion:

1. Computations indicating the hydraulic design of the system, including routing the specified storms through the detention/retention system.
2. Design frequencies.
3. Sketches and/or reduced scale plans showing the layout and dimensions of the pond(s).
4. Information concerning the discharge pipe(s) or weir(s), including energy dissipation calculations and design.
5. Copies of all computer analyses.

3.06.3.7 DESIGN RECORDS EXCLUSIONS

To clarify the information included in the design records and to reduce the overall size, several specific items should **not** be included:

1. Full set of plans
2. Full size present and proposed layout sheets
3. Intermediate computer runs (input and output files)

3.06.3.8 SEQUENCE OF DESIGN RECORDS COMPONENTS

The following order should be followed by the designer when assembling the drainage design records:

1. Reports and Correspondence
2. Hydrology
3. Culverts
4. Open Channels
5. Storm Sewers/Inlet Spacing

6. Special Drainage Structures
7. Detention / Retention

Photographs can be included in an appendix or in the section in which they are referenced.

TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER III
APPENDIX 3A

SECTION 3.07 – APPENDIX

3.07 APPENDIX

3.07.1 FIGURES AND TABLES

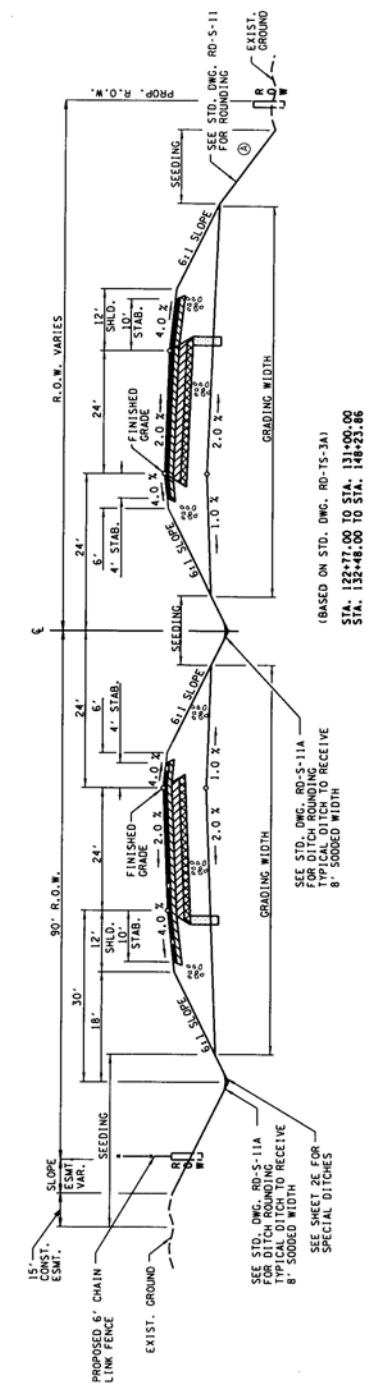


Figure 3A-1. Portion of Typical Sections Sheet (Road Section)

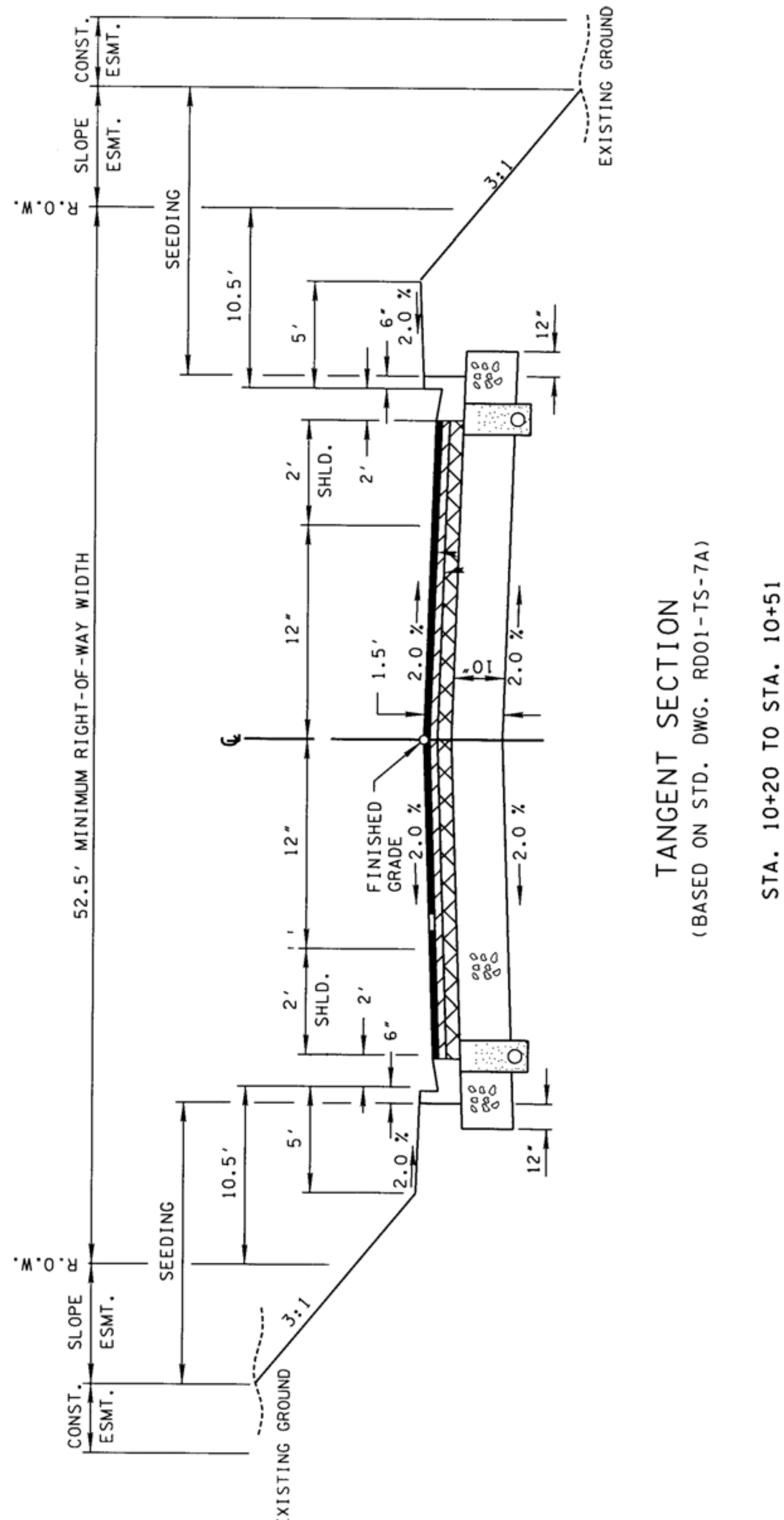


Figure 3A-2. Portion of Typical Sections Sheet (Curb and Gutter)

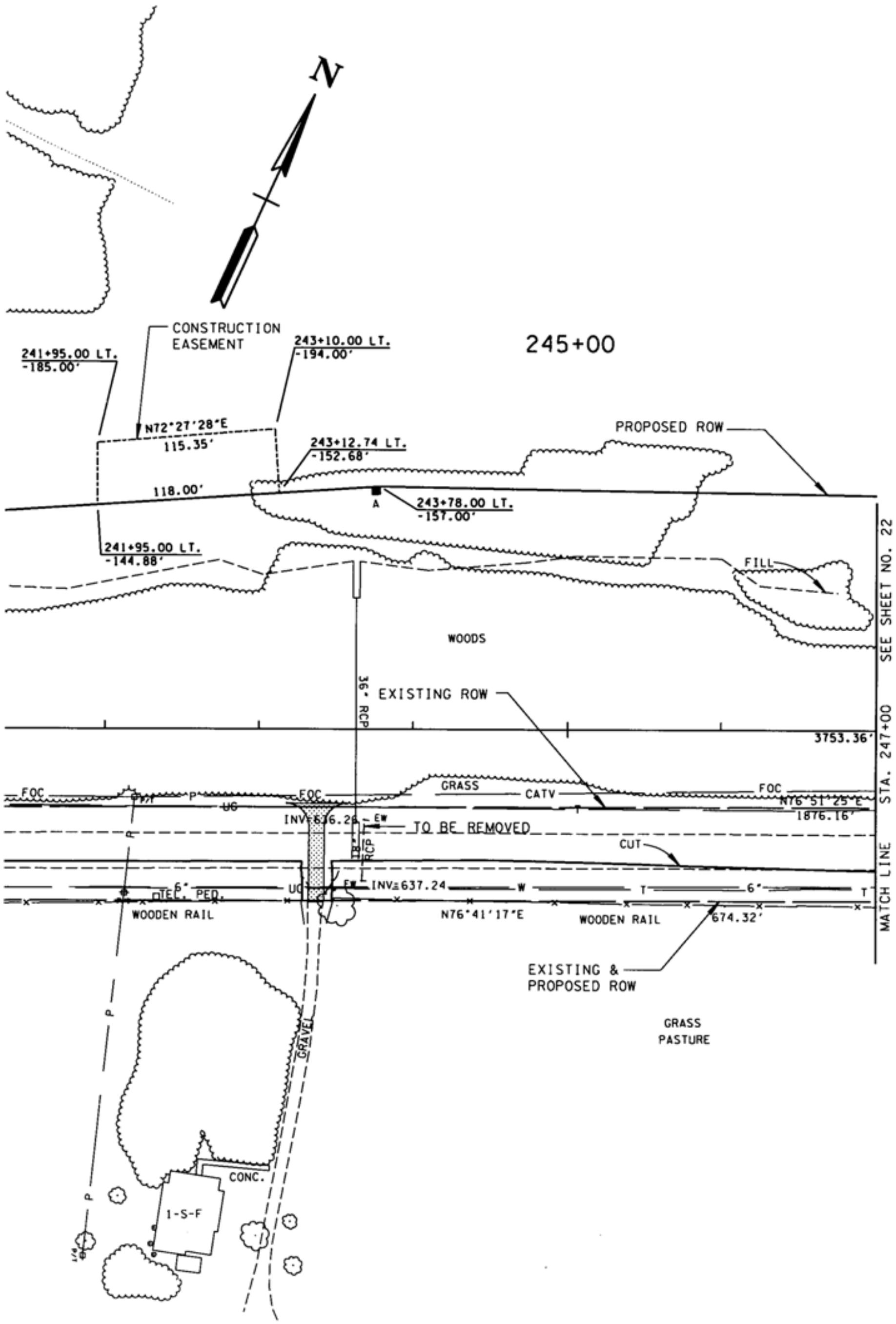


Figure 3A-3. Portion of Present Layout Sheet (Pipe Culvert)

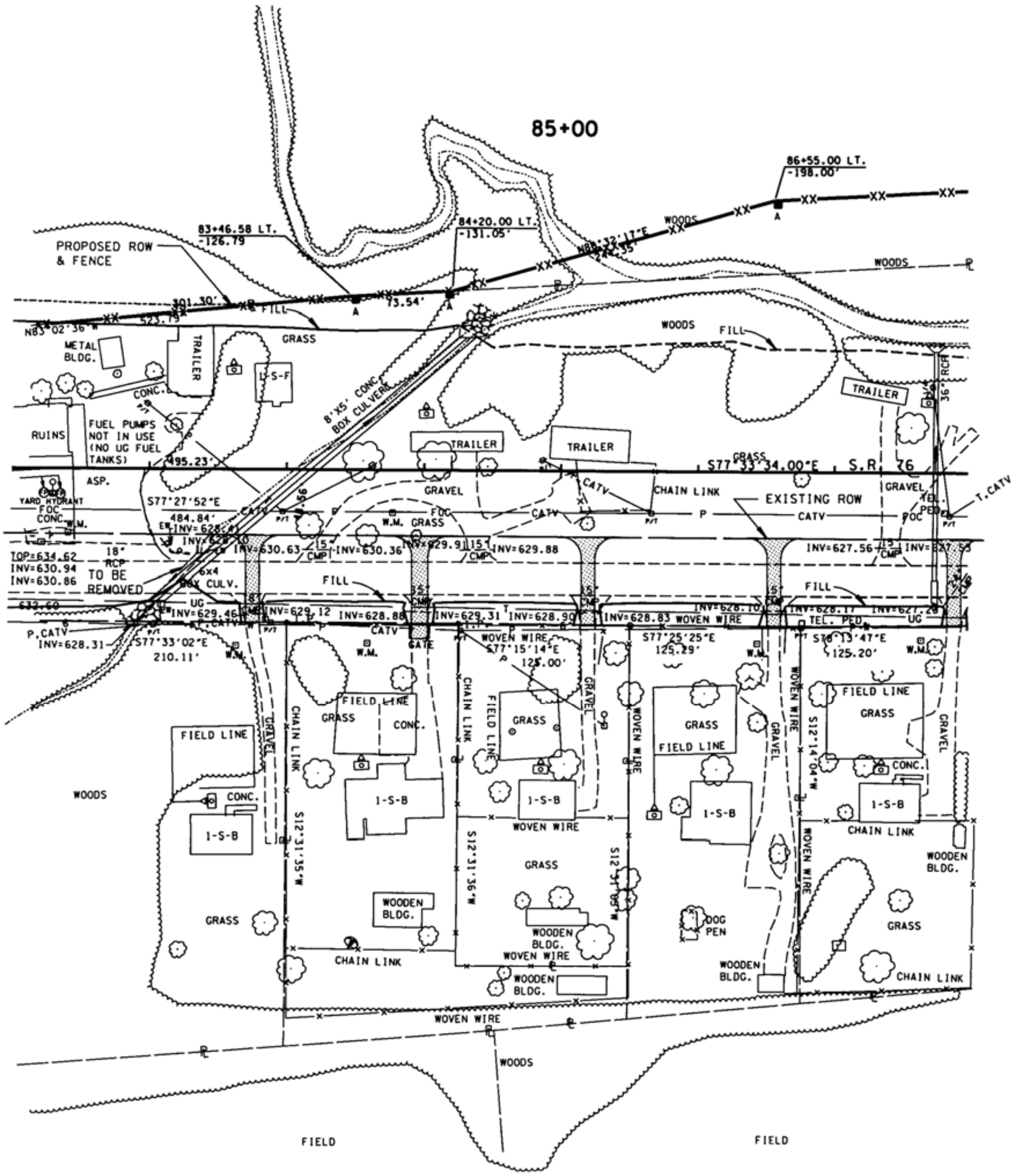


Figure 3A-4. Portion of Present Layout Sheet (Box Culvert)

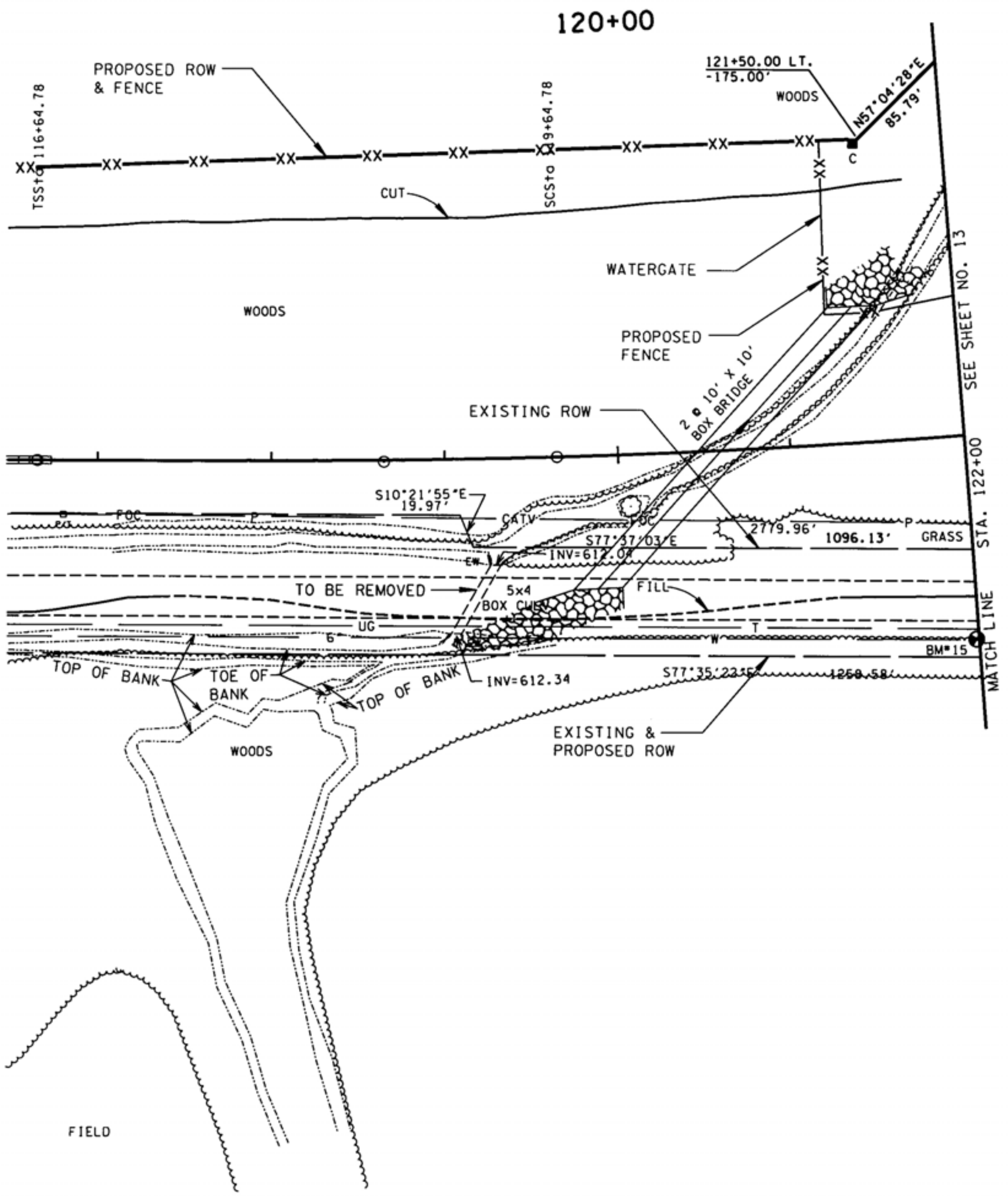


Figure 3A-5. Portion of Present Layout Sheet (Box Bridge)

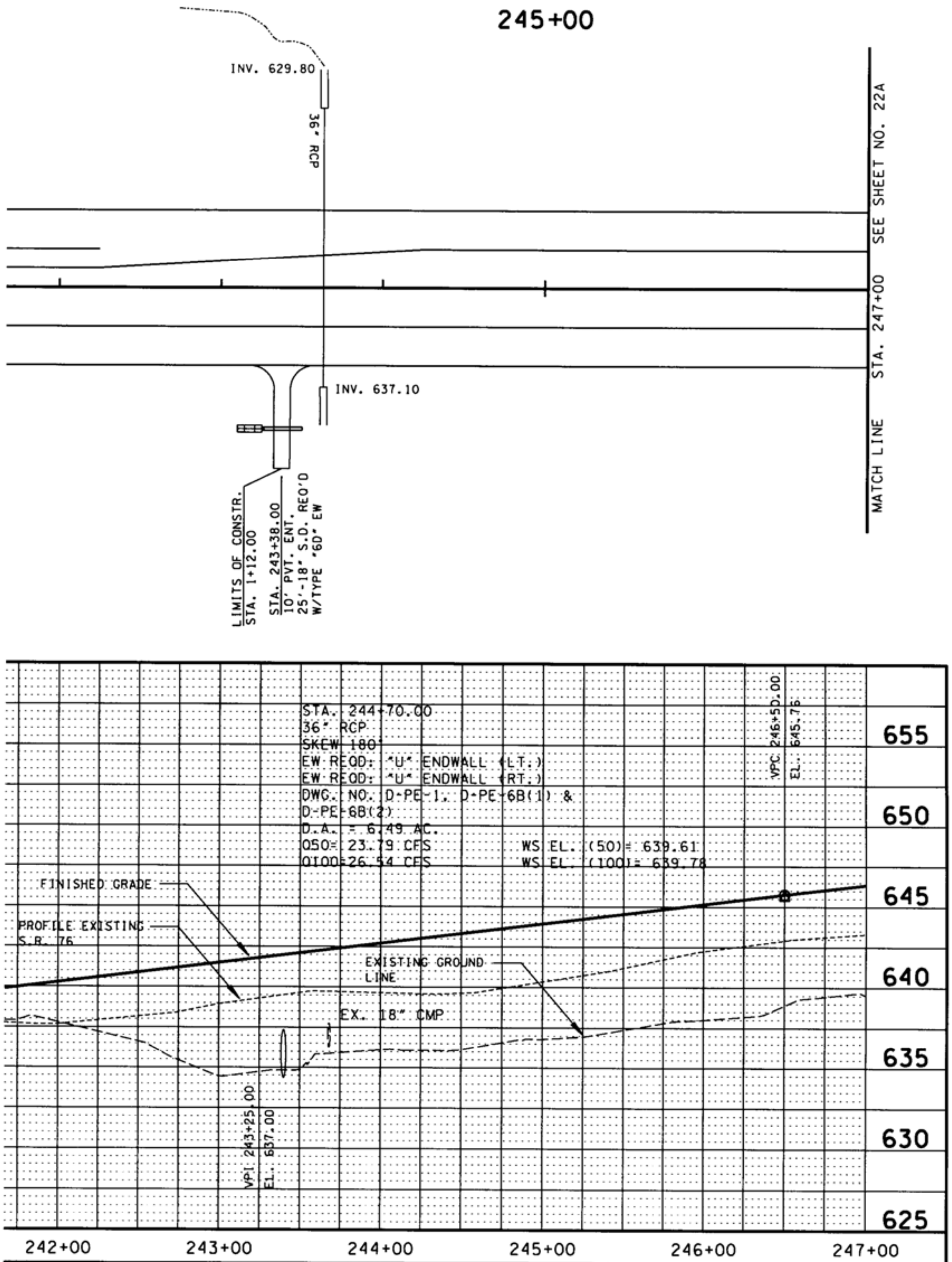


Figure 3A-6. Portion of Proposed Layout Sheet (Pipe Culvert)

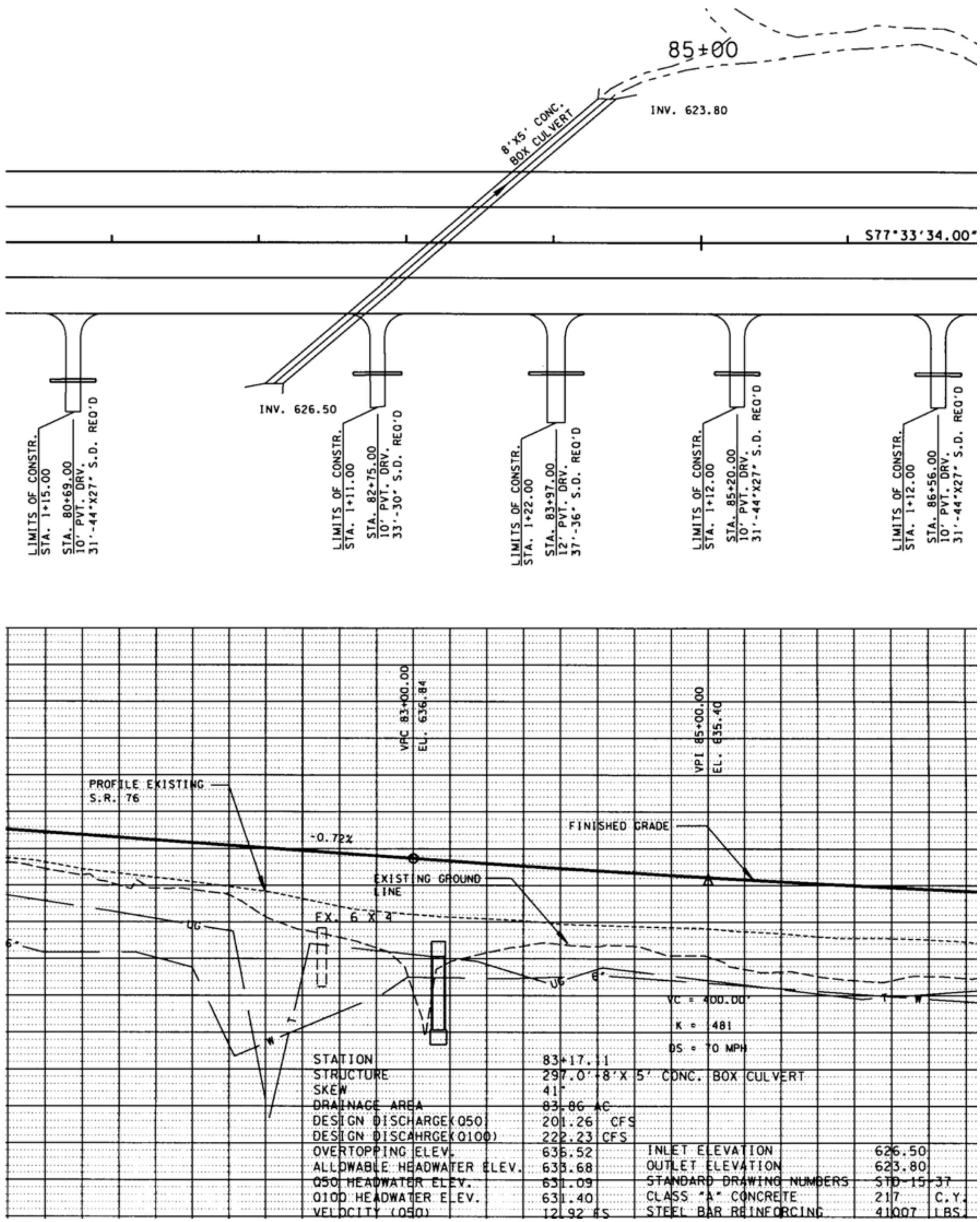


Figure 3A-7. Portion of Proposed Layout Sheet (Box Culvert)

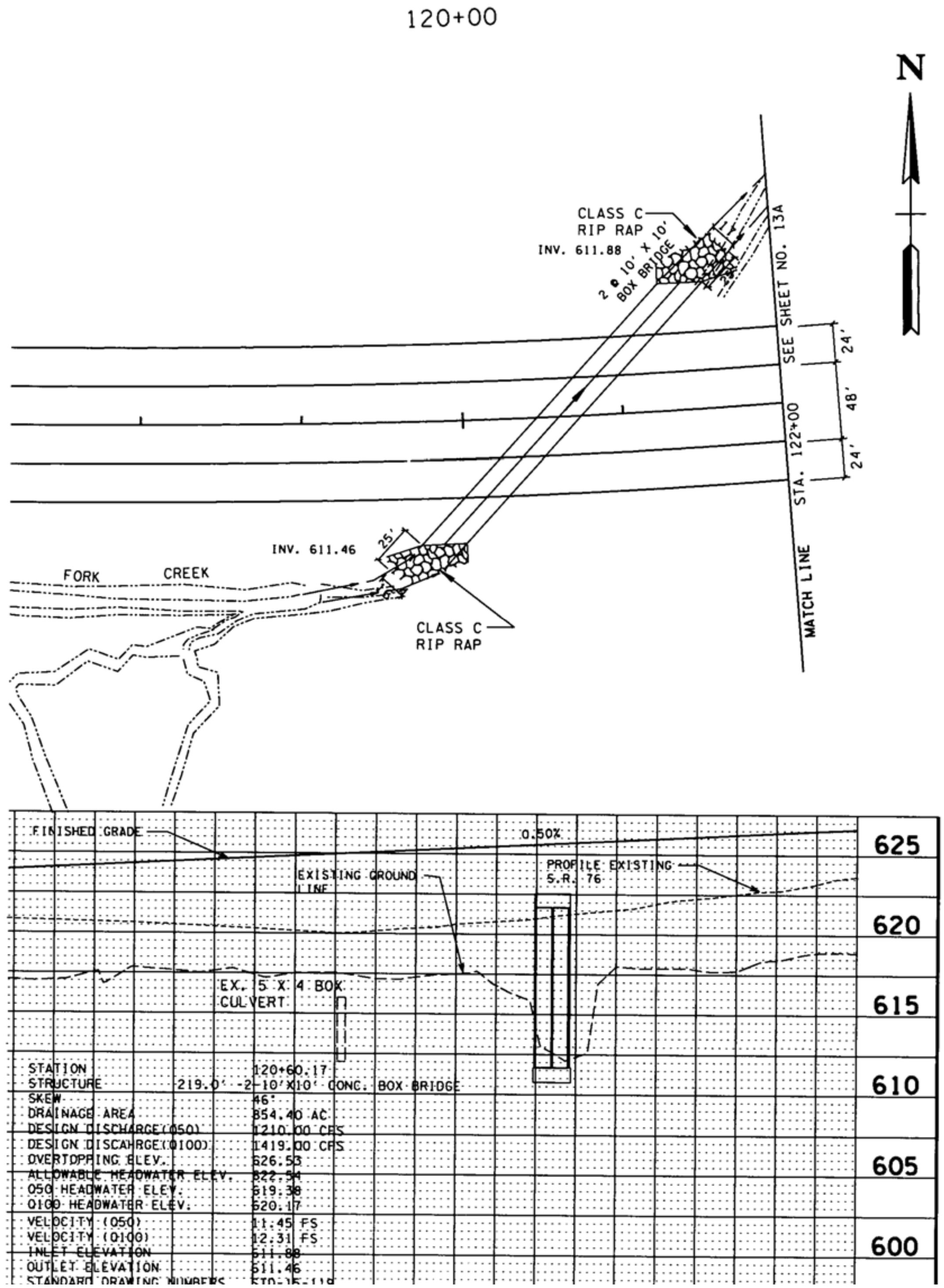


Figure 3A-8. Portion of Proposed Layout Sheet (Box Bridge)

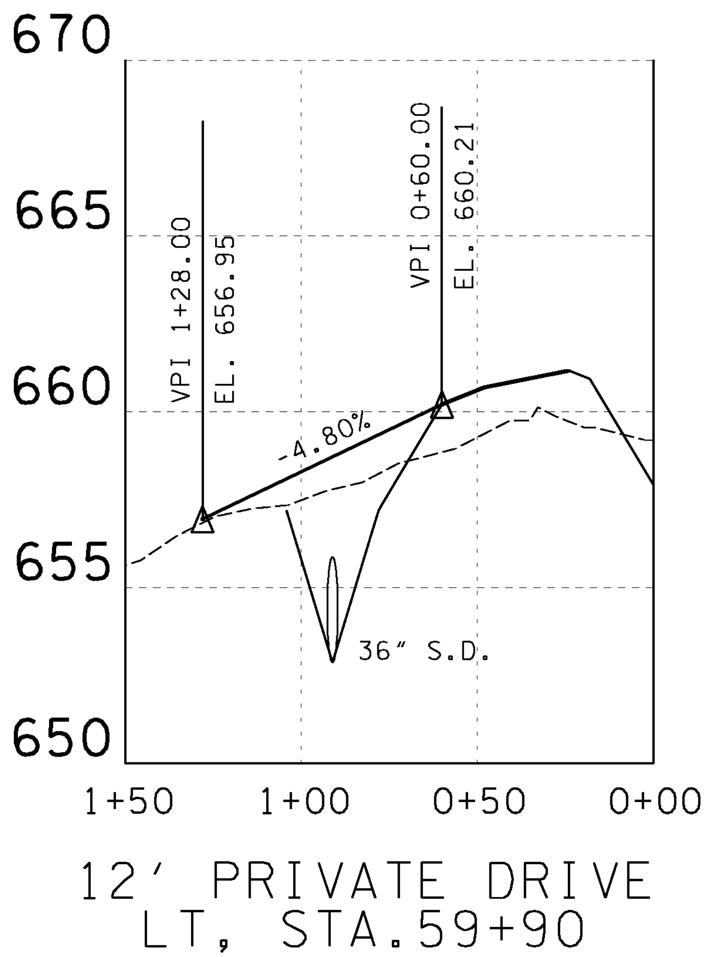
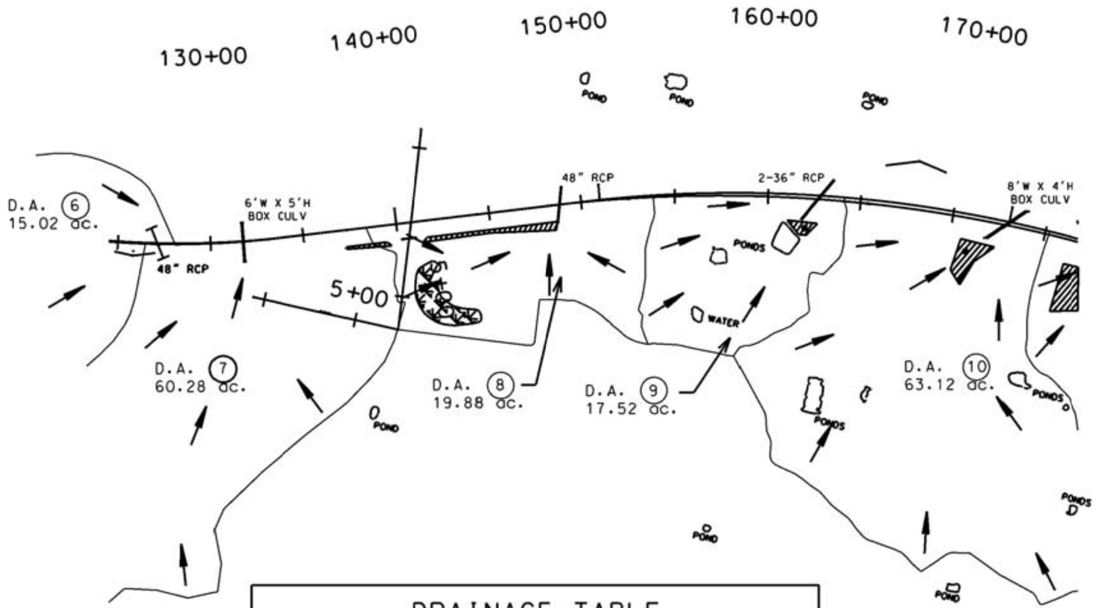


Figure 3A-9. Portion of Private Drive and Field Ramp Profile Sheet



DRAINAGE TABLE

DRAINAGE AREA	AREA* (ac)	Q_{50} (cfs)	Q_{100} (cfs)	C COEFFICIENT OF RUNOFF	T_c (min.)
6	15.02	54.82	60.08	0.50	8.5
7	75.30	176.96	192.02	0.50	23.2
8	19.88	64.11	68.39	0.43	7.5
9	17.52	63.51	68.32	0.50	8.1
10	63.12	151.49	157.80	0.50	21.0
11	22.38	74.97	82.69	0.50	9.7
12	24.79	80.57	86.77	0.50	10.9

*CULVERT'S TOTAL CUMULATIVE DRAINAGE AREA.

WETLANDS

PERMANENT DRAINAGE EASEMENT

DIRECTION OF FLOW

Figure 3A-10. Portion of Drainage Map Sheet

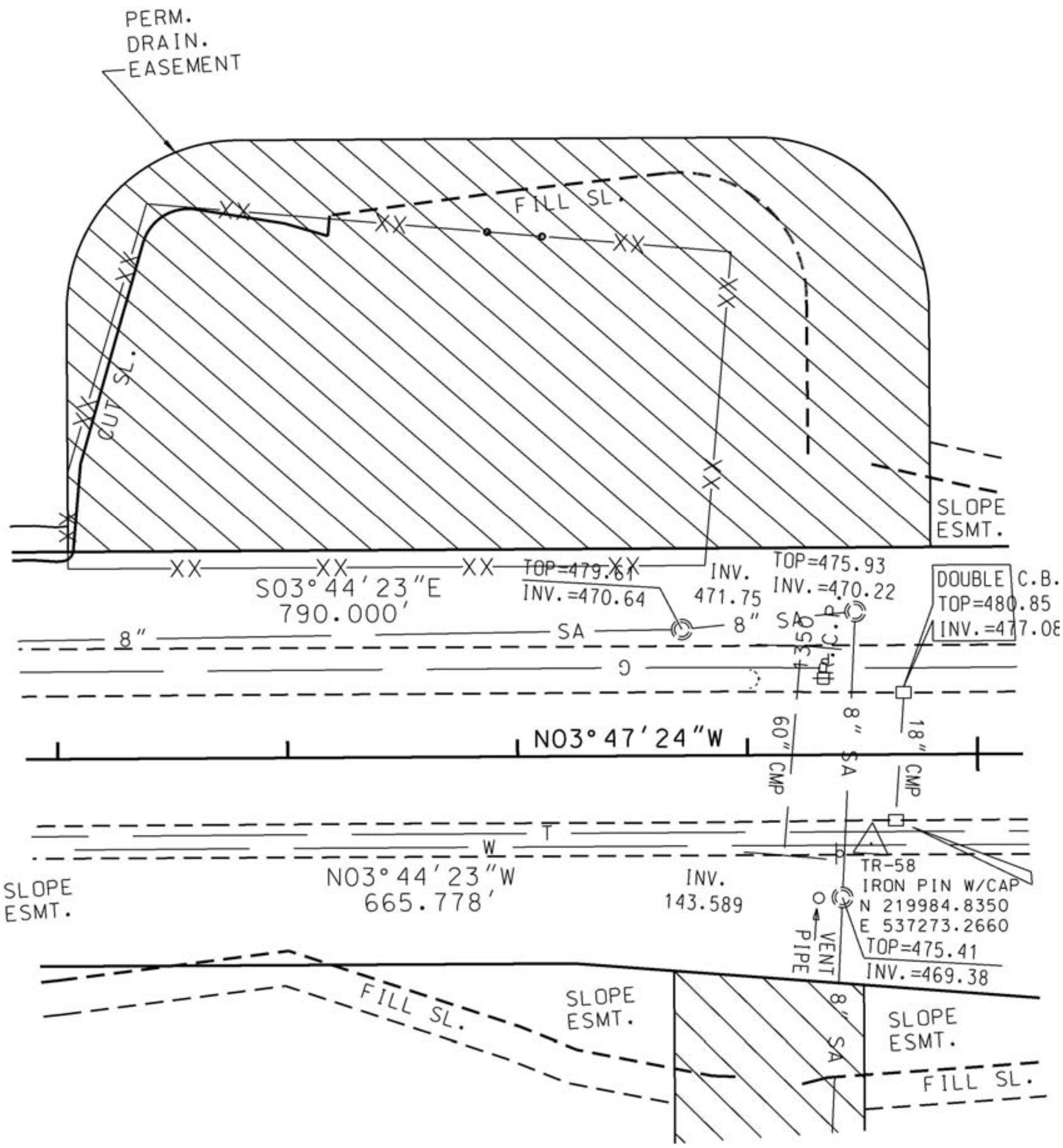


Figure 3A-11. Portion of Present Layout Sheet (Detention System)

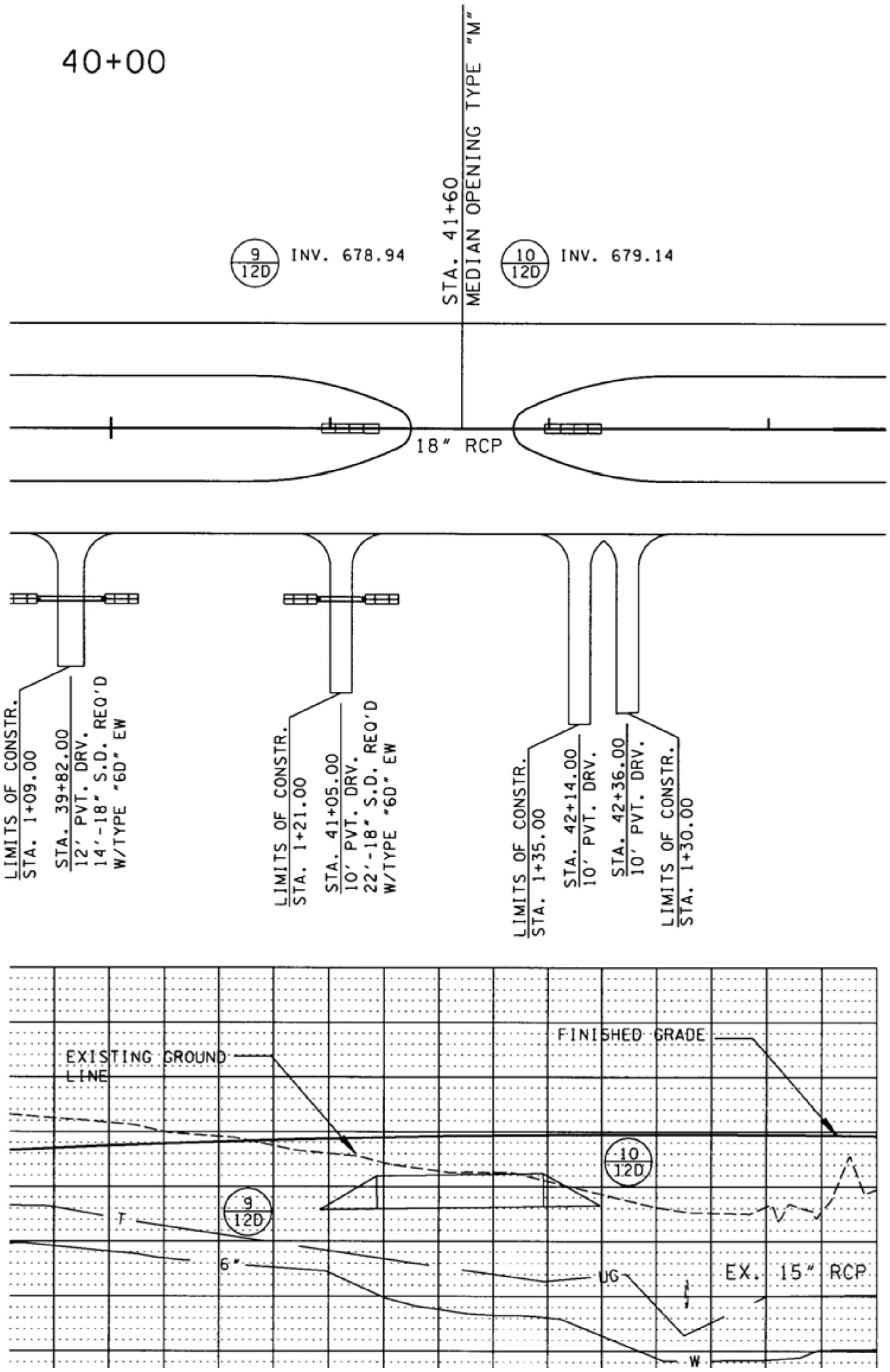


Figure 3A-12. Portion of Proposed Layout Sheet (Median Culvert)

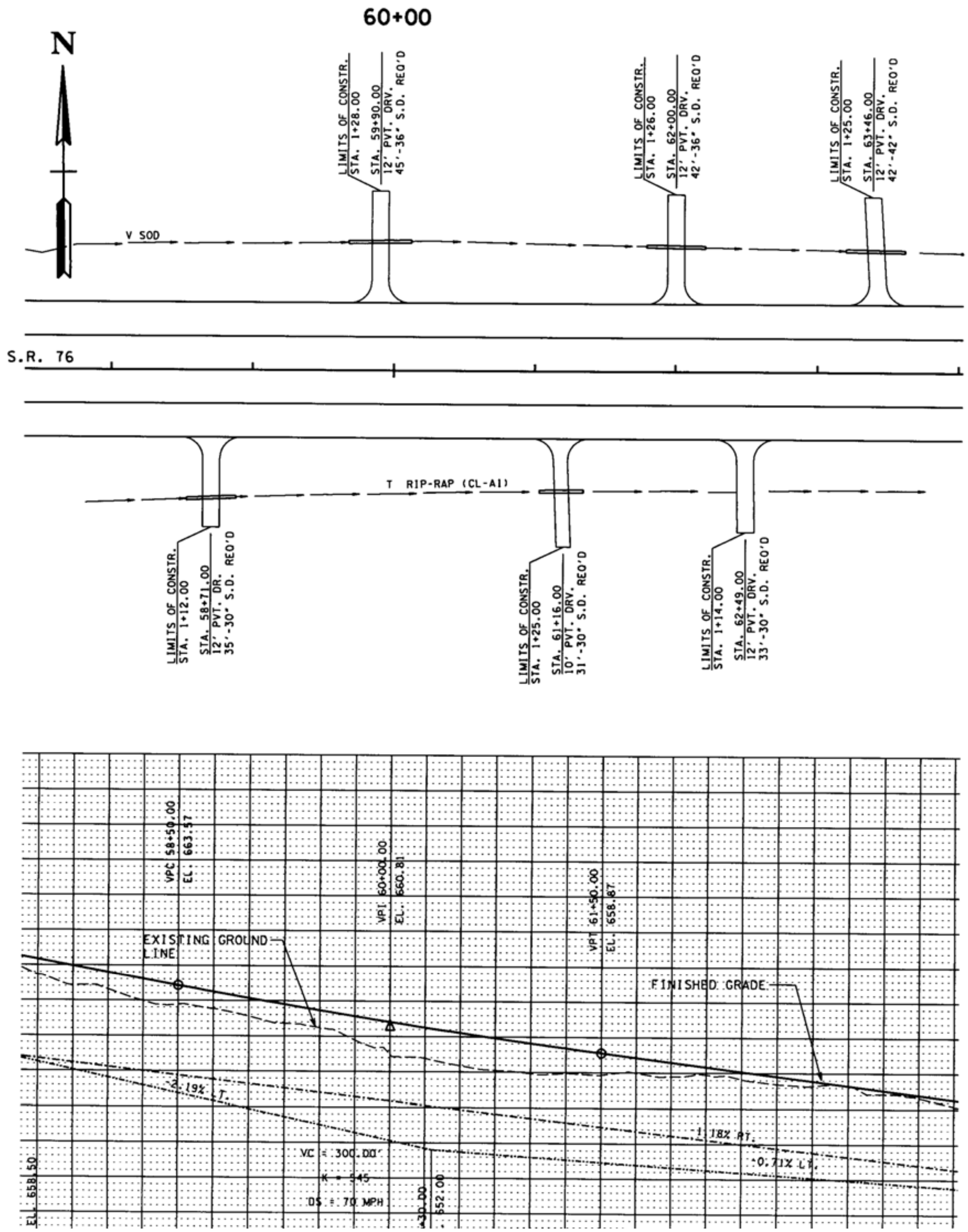


Figure 3A-13. Portion of Proposed Layout Sheet (Special Ditch)

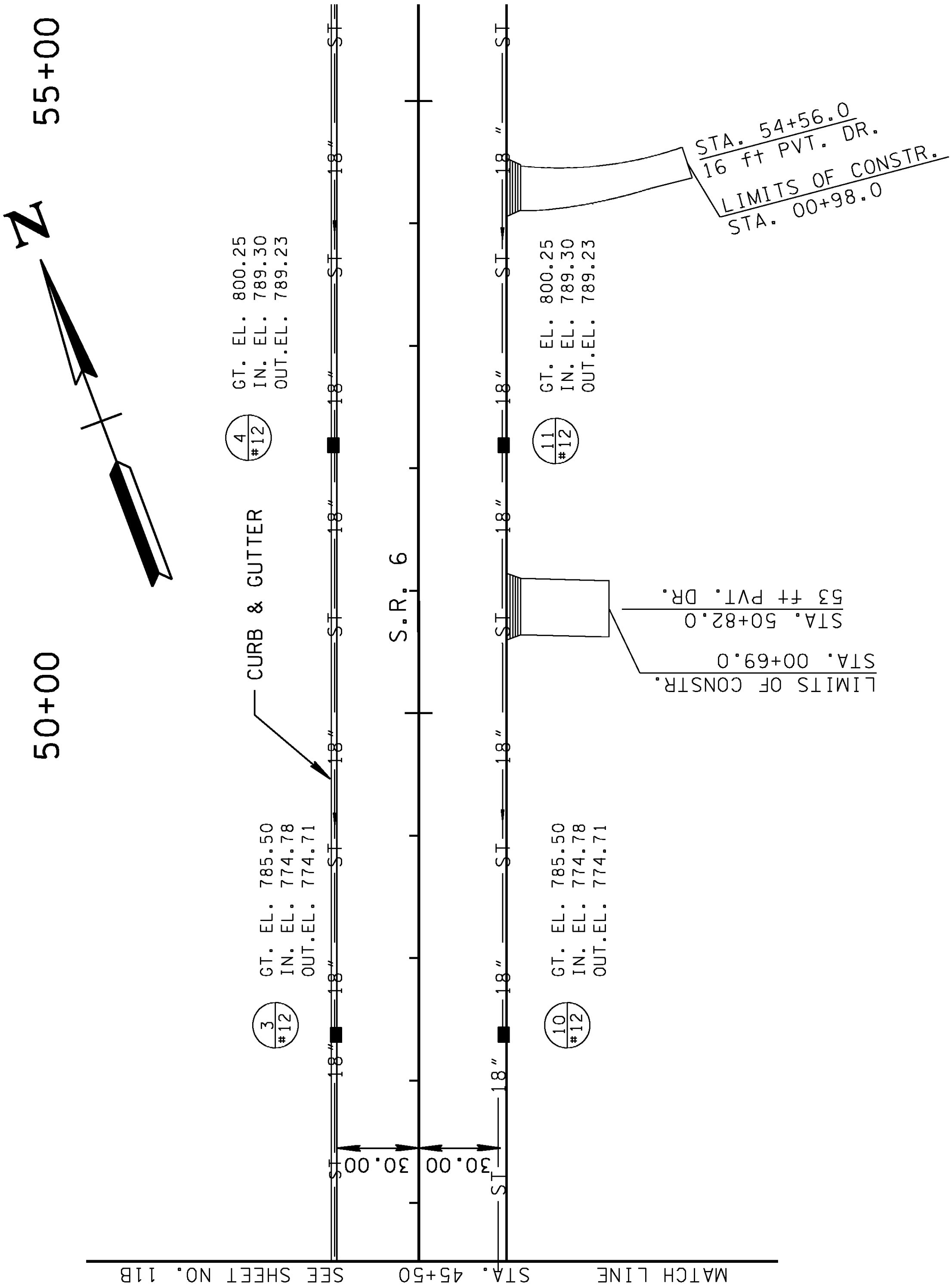


Figure 3A-14. Portion of Proposed Layout Sheet (Storm Sewer Plan)

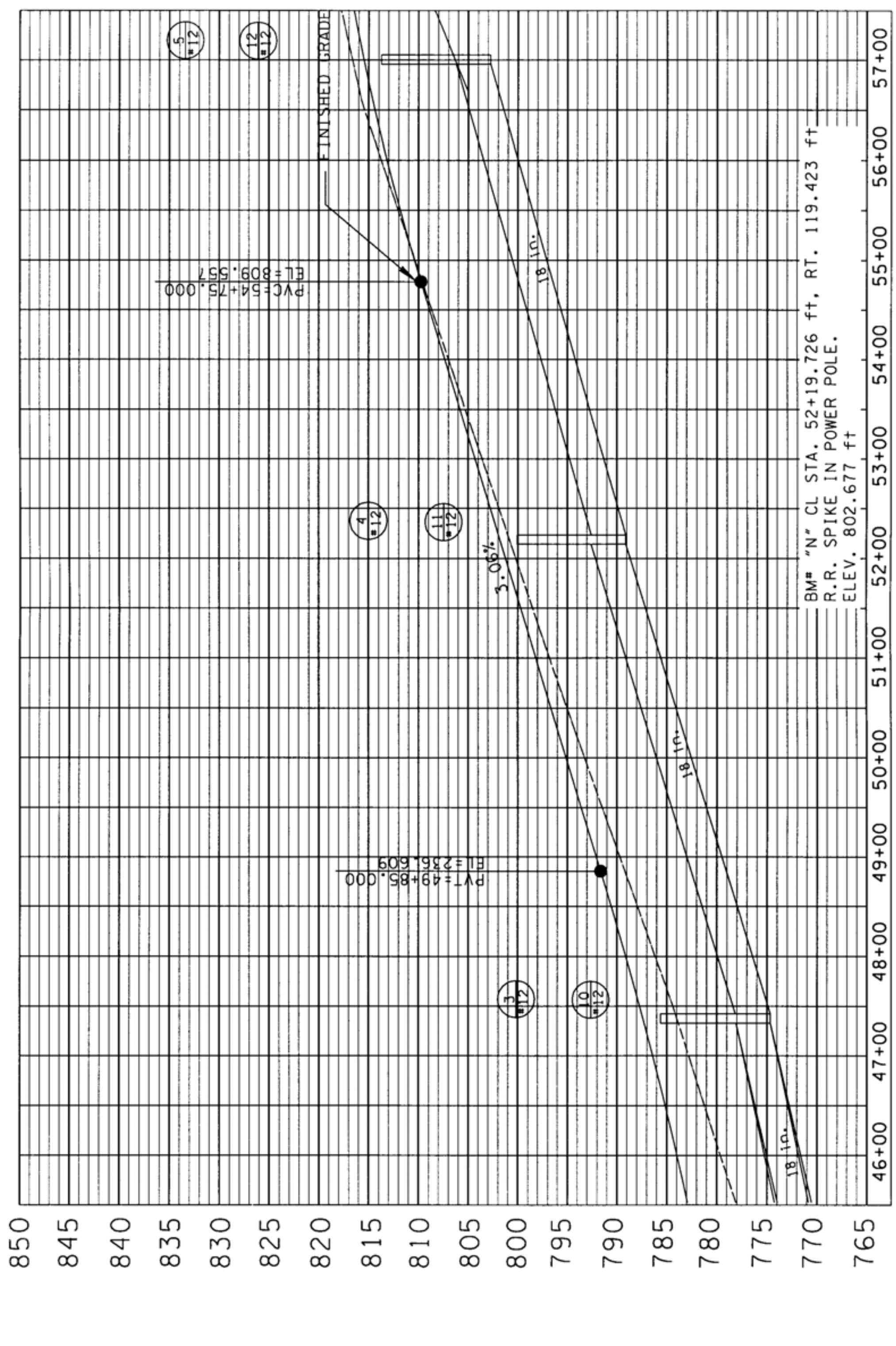


Figure 3A-15. Portion of Proposed Layout Sheet (Storm Sewer Profile)

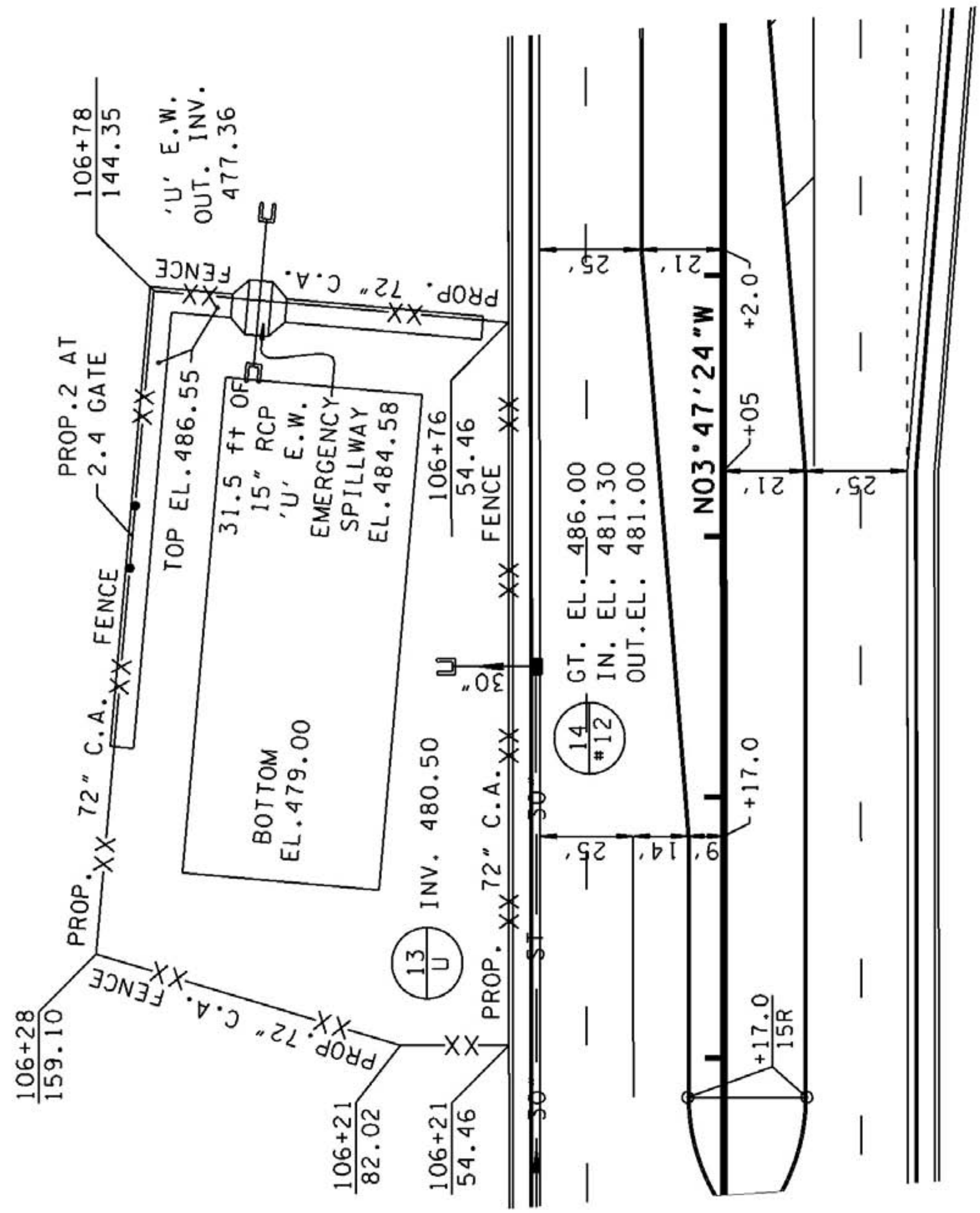


Figure 3A-16. Portion of Proposed Layout Sheet (Detention System)

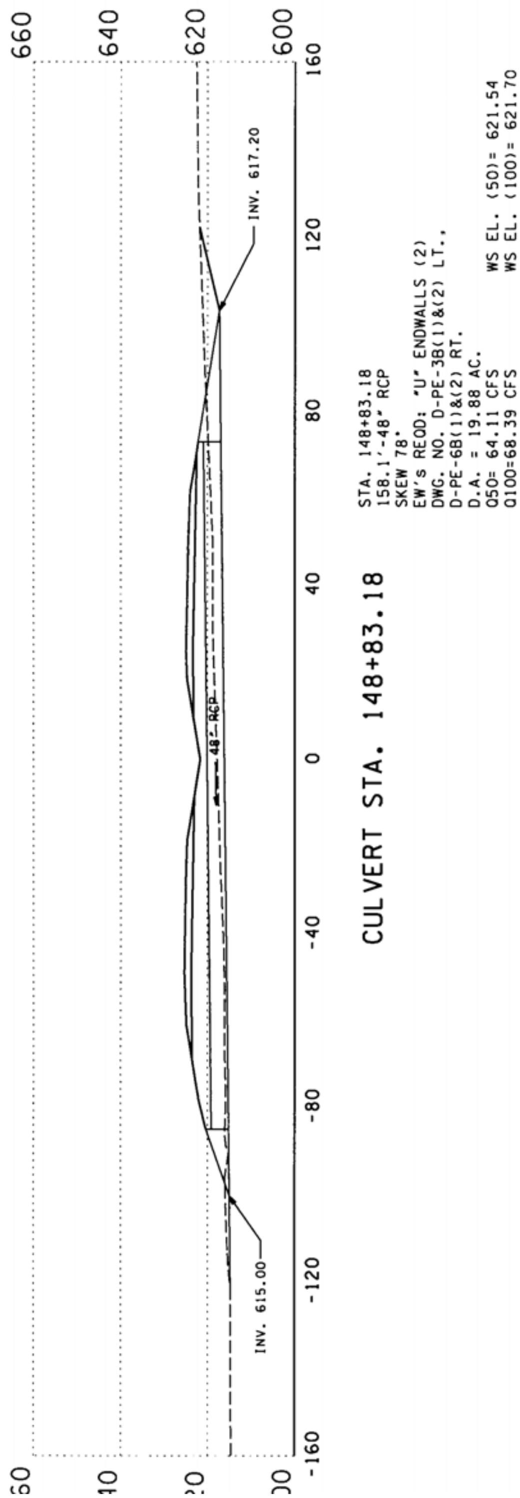


Figure 3A-17. Portion of Culvert Sections Sheet (Pipe Culvert)

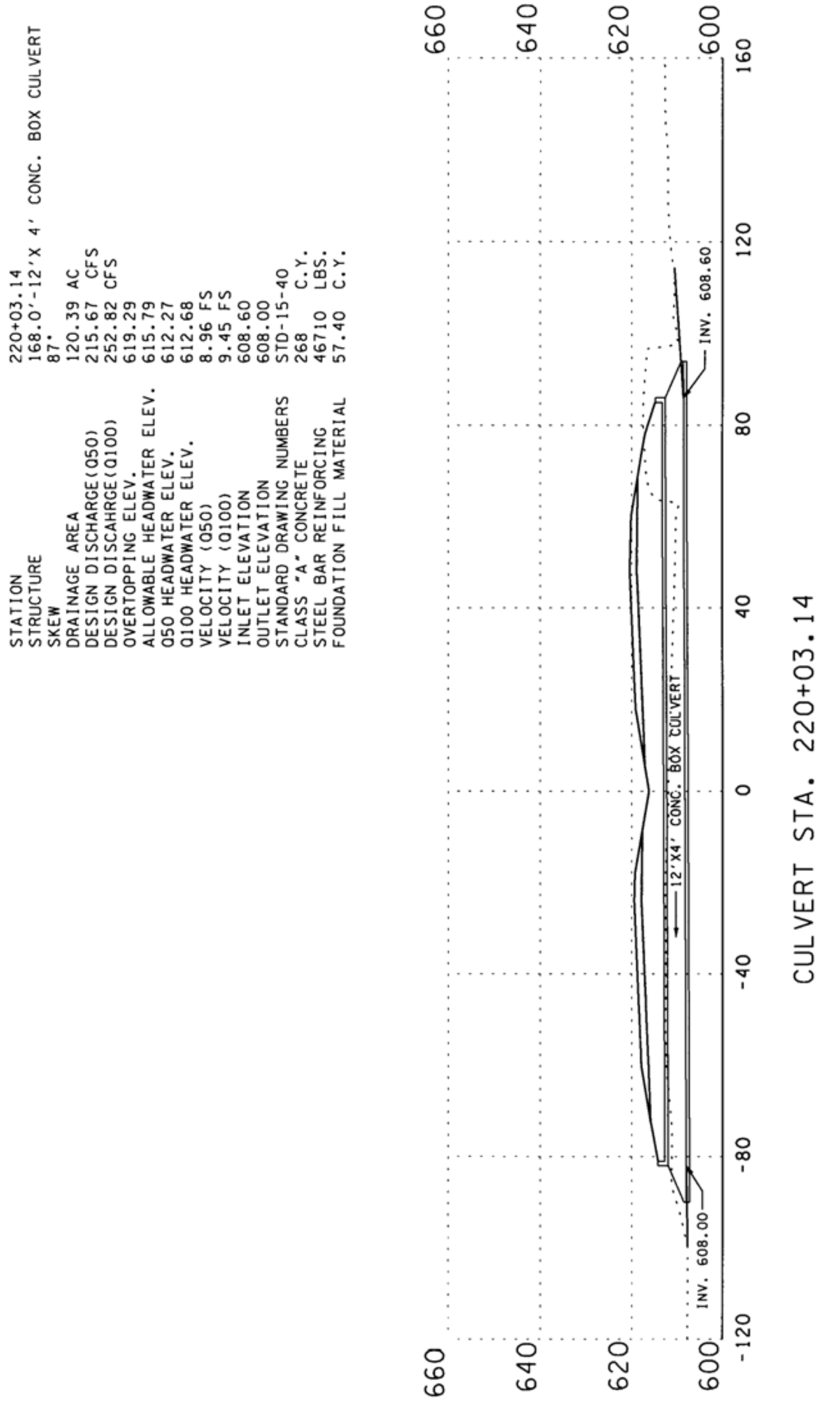


Figure 3A-18. Portion of Culvert Sections Sheet (Box Culvert)

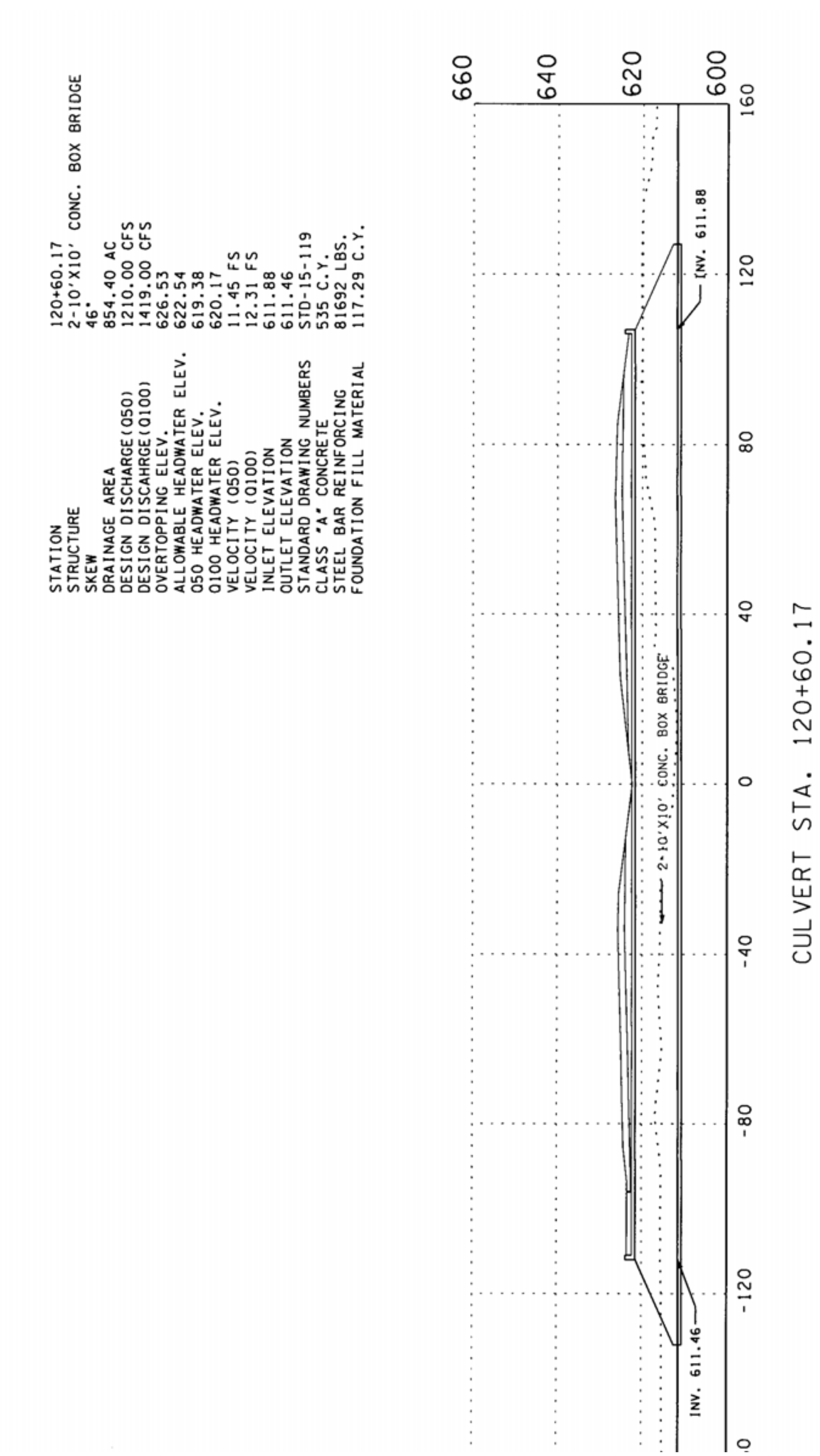


Figure 3A-19. Portion of Culvert Sections Sheet (Box Bridge)

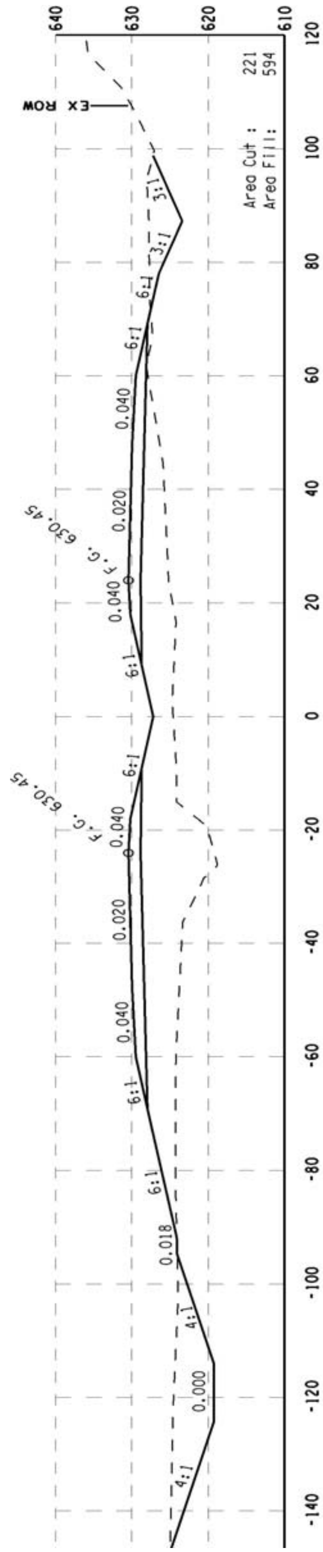


Figure 3A-20. Portion of Cross Section Sheet (With Template Ditch and Special Ditch)

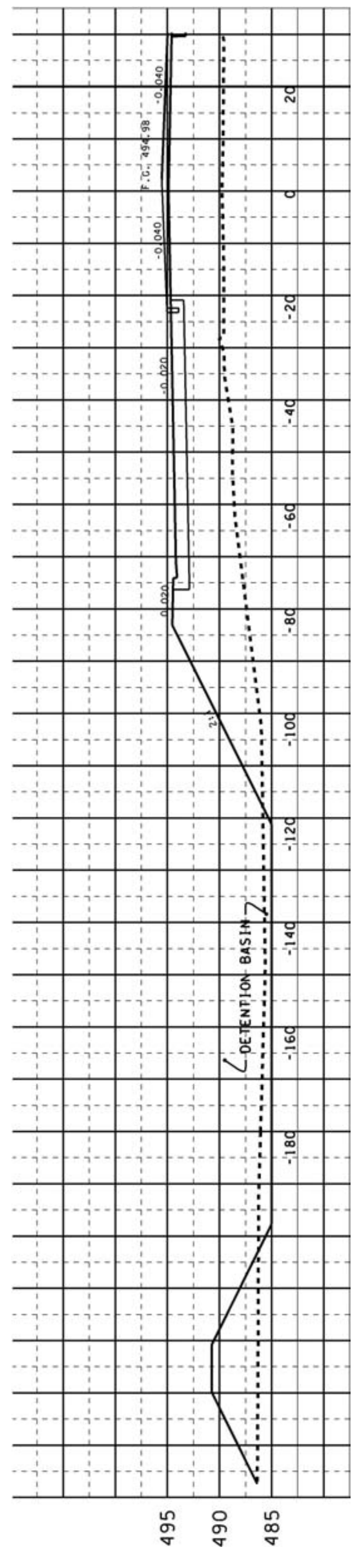
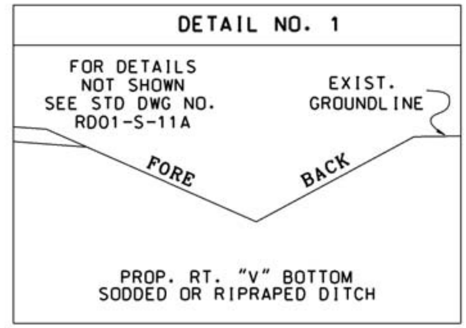
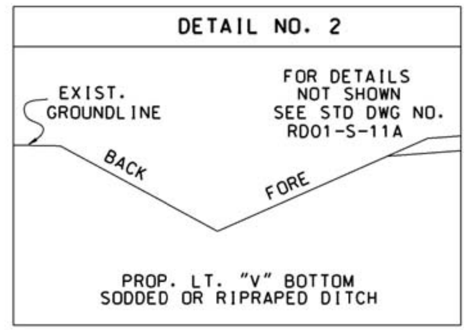


Figure 3A-21. Portion of Cross Section Sheet (Detention Basin)

SPECIAL DITCHES

ROAD	STATION		SLOPE			DETAIL NUMBER	TYPE
	FROM	TO	FORE (h/v)	BOT WIDTH (ft)	BACK (h/v)		
SR 76	220+00	226+00	3:1	0	3:1	1	SOD
SR 76	226+00	229+75	3:1	0	3:1	1	RIP-RAP (A-1)
SR 76	229+75	230+25	3:1	0	3:1	1	RIP-RAP (A-1)
SR 76	230+25	235+75	3:1	2	3:1	3	RIP-RAP (A-1)
SR 76	235+75	236+75	3:1	0	3:1	1	RIP-RAP (A-1)
SR 76	242+30	243+25	6:1	0	4:1	2	SOD
SR 76	243+25	244+75	6:1	0	4:1	2	SOD
SR 76	244+50	250+00	4:1	0	4:1	1	RIP-RAP (A-1)
SR 76	244+75	245+75	6:1	0	4:1	2	SOD
SR 76	250+00	251+50	4:1	0	4:1	1	RIP-RAP (A-1)
SR 76	257+00	262+25	3:1	2	3:1	3	SOD
SR 76	262+25	265+00	3:1	0	3:1	1	SOD
SR 76 EX. E. CONN.	1+80	7+67	3:1	0	3:1	1	SOD
SR 76 EX. E. CONN.	1+90	3+65	3:1	0	3:1	2	SOD
GIBBS ROAD	1+40	2+20	3:1	0	4:1	1	SOD
GIBBS ROAD	1+40	2+70	3:1	0	4:1	2	SOD
LIVERPOOL ROAD	1+90	2+20	3:1	0	3:1	1	RIP-RAP (A-1)
LIVERPOOL ROAD	2+70	3+80	3:1	0	3:1	1	SOD
LIVERPOOL ROAD	3+80	5+15	3:1	0	3:1	2	SOD
LIVERPOOL ROAD	3+80	5+15	3:1	0	3:1	1	SOD





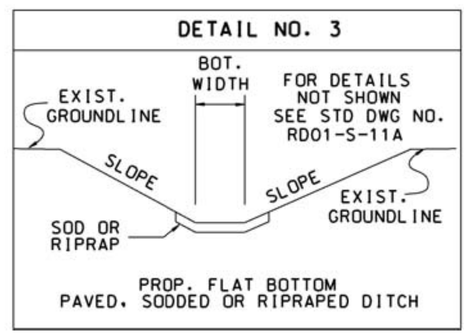


Figure 3A-22. Portion of Tabulated Ditches and Ditch Section Sheet

3.07.2 REFERENCES

3.07.2.1 PUBLICATIONS

American Association of State Highway and Transportation Officials. *Model Drainage Manual [Metric Edition]*. Washington, D.C. 1999.

Indiana Department of Transportation. *Indiana Design Manual Part IV Volume 1*. Indianapolis, IN, 1999.

Kentucky Transportation Cabinet, *Drainage Guidance Manual* - Proposed Revisions. Frankfort, KY. September 29, 2000.

Tennessee Department of Transportation. *Design Guidelines - English*, Nashville, TN 2001.

3.07.2.2 ABBREVIATIONS

Following are the abbreviations used in the descriptions of Federal policies:

AC. – Acres
C.Y. – Cubic Yards
CFS – Cubic Feet Per Second
CMP – Corregated Metal Pipe
D.A. – Drainage Area
DS – Design Speed
EL. – Elevation
ESMT. – Easement
EW – Endwall
FEMA – Federal Emergency Management Agency
FS – Feet Per Second
GT. – Gutter
h/v – Horizontal to Vertical
INV. – Invert
PVT. DRV. – Private Drive
R.O.W – Right-of-Way
RCP – Reinforced Concrete Pipe
S.D. – Storm Drain
SHLD. – Shoulder
SL. – Slope
STAB – Stabilized
TDOT – Tennessee Department of Transportation
VC – Vertical Curve
VPC- Vertical Point of Curvature
VPI – Vertical Point of Intersection
WS – Water Surface

TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER IV
HYDROLOGY

CHAPTER 4 – HYDROLOGY

SECTION 4.01 – INTRODUCTION

SECTION 4.02 – DOCUMENTATION PROCEDURES

SECTION 4.03 – DESIGN CRITERIA

SECTION 4.04 – APPLICABLE METHODS

SECTION 4.05 – ACCEPTABLE SOFTWARE

SECTION 4.06 – APPENDIX

SECTION 4.01 - INTRODUCTION

This chapter presents the Tennessee Department of Transportation (TDOT) procedures and accepted methodologies for hydrologic analyses for roadway design. The procedures and methodologies presented in this chapter assume that the designer has a basic understanding of the science of hydrology and its principles. The designer should also be familiar with the regulations and requirements of the State and Federal agencies that regulate water-related construction as they may affect TDOT projects.

Hydrology is generally defined as the science dealing with the interrelationship between water on and under the earth and in the atmosphere. For this manual, hydrology will consist of estimating storm water runoff discharge rates and/or volumes from precipitation for the design of the highway drainage system and any required cross drainage structures. In general, only computed peak flow rates will be required from the hydrologic analyses. Runoff hydrographs and volumes will be required only under special circumstances.

In urban or urbanizing areas, the designer should consider the impact changing land use conditions would have on the size and capacity of the roadway drainage system and cross drainage structures.

This chapter is organized into sections. These sections will present the hydrologic design criteria for the components of the roadway drainage system and cross drainage structures, recommended methods, approved software, and examples. References and definitions are included to assist the designer during the design process.

SECTION 4.02 – DOCUMENTATION PROCEDURES

The designer will be responsible to document the hydrologic analyses performed for the roadway design. The documentation should contain drainage area maps, hand calculations, and hardcopy and electronic files of the computer model input and output. The documentation should be organized by drainage type design (ditch design, culvert, storm sewer, etc.) and by roadway station from the beginning to the end of the improvement.

Two drainage area maps will be required in the documentation. The drainage areas should be delineated on the project aerial mapping. The scale of the drainage area map should be at an adequate scale to be legible and show sufficient detail to document the assumptions in the hydrologic analyses. For drainage areas that extend beyond the limits of the project aerial mapping, the drainage areas should be delineated on USGS 7.5-minute topographic maps. The project alignment should be plotted on the USGS topographic map. In addition to the drainage area boundaries, the maps should also include information supporting the calculations for time of concentration, NRCS curve number, runoff coefficient, etc.

All hand calculations prepared for the hydrologic analyses should be initialed and dated by the designer. The hand calculations should be neat and legible. Each sheet should have a header that includes the project descriptor, a description of the type of calculation, and project station and off-set.

The computer model input and output should be clearly labeled as to the project descriptor, type of calculation, and project station and offset. Comments should be included in the input file to explain any assumptions (i.e. existing conditions, future land-use, data sources, etc.) regarding the input data.

For unusual project features or designs, the designer should include in the documentation a description of the hydrologic analyses performed and any assumptions made during the analysis.

SECTION 4.03 – DESIGN CRITERIA

4.03.1 INTRODUCTION

The design frequency for the roadway drainage facilities is based on achieving a balance between construction cost, maintenance needs, amount of traffic, potential flood hazard to adjacent property, and expected level of service. The design frequencies presented are the minimum that achieve this balance for the types of drainage facilities and the various road classifications.

The design criteria presented in Table 4-1 have been developed based on road classification and type of drainage facility.

The design frequencies shown in Table 4-1 for cross drainage structures:

a. Shall not significantly increase the flood hazard for adjacent property and
b. Shall permit maintenance of traffic on roads and streets under design flood conditions.

The design frequencies shown in Table 4-1 for roadway storm drainage structure design:

a. Shall not significantly increase the flood hazard for adjacent property and
b. Shall limit the encroachment onto the traveled lanes which could cause a hazard to traffic.

The design frequency for a given flood is the reciprocal of the probability that a flood will be equaled or exceeded in a given year. If a flood event has a 10 percent chance of being equaled or exceeded in a year, the flood event will be equaled or exceeded on average every 10 years. The designer should note that the 10-year flood event will not be equaled or exceeded once every 10 years, but has a 10 percent chance of being equaled or exceeded in any year. Therefore, the 10-year flood event could conceivably occur in consecutive years, or possibly more frequently.

Table 4-1. Hydrologic Design Criteria

	Freeway and Multi-Lane Divided Arterial	Arterial	Collector	Local Road
Inlet Design Frequency	50-yr.	10-yr.[1]	10-yr.[1]	10-yr.
Sewer Design Frequency	50-yr.	10-yr.[1]	10-yr.[1]	10-yr.
Culvert Design Frequency	50-yr. Check for 100-yr.	50-yr. Check for 100-yr.	50-yr. Check for 100-yr.	50-yr. Check for 100-yr.
Roadway Freeboard[2]	50-yr.	50-yr.	50-yr.	50-yr.
Ditch Design Frequency	50-yr.	10-yr.[1]	10-yr.[1]	10-yr.

[1] 50-year in Roadway Sag Sections

[2] The design high water elevation should be at or below the bottom of the roadway subgrade.

SECTION 4.04 – APPLICABLE METHODS

This section of the manual describes the hydrologic methods that are approved for use by the Tennessee DOT. The designer should be familiar with the limitations of each of the methods so that appropriate methods are applied. There will be some projects where the approved methodologies are not applicable. The designer will need to be familiar with a variety of hydrologic methods to ensure the correct methodology is selected for these isolated circumstances. Any methodology not described in this section of the manual must be approved by the Tennessee DOT design manager prior to any hydrologic analyses using the methodology.

Other hydrologic methods and software may be considered for use on TDOT projects at the discretion of the TDOT design manager at the request of the designer. For other hydrologic methods and software to be considered, the designer will have to demonstrate that the method is appropriate for the intended application.

A flow chart to assist the designer in selecting the appropriate hydrologic method is shown in Figure 4-1. The first decision point is strictly based on drainage area. The rational method is the preferred method for all drainage areas less than 100 acres. The USGS and TDOT regression equations for rural and urban areas are the preferred methods for drainage areas larger than 100 acres. These methods should be used for all projects unless they are not applicable due to the watershed conditions or the need for a runoff hydrograph.

The primary reason the preferred methods (Rational and USGS Regression Equations) would not be applicable is due to man-made modifications in the watershed or to the stormwater conveyance system. A natural lake or man-made reservoir with sufficient storage volume to attenuate the peak flow rate for the design frequency is one example of when the preferred methods would not be applicable. The limitations of each method will be discussed in this chapter.

HEC-HMS, or TR-20 will be required for any TDOT drainage design where the project will include stormwater storage (existing or proposed). HEC-1 may be used if there is an existing HEC-1 model.

If the design peak flow rate computed by the selected method is greater than 500 cfs, the designer should indicate the location of the structure on the proposed roadway layout drawing. This drawing along with the related drainage survey and hydrologic calculations should be forwarded to the Hydraulics Design Section of the Structures Division. The Hydraulics Design Section will furnish all of the necessary data to be shown on the plans for this structure.

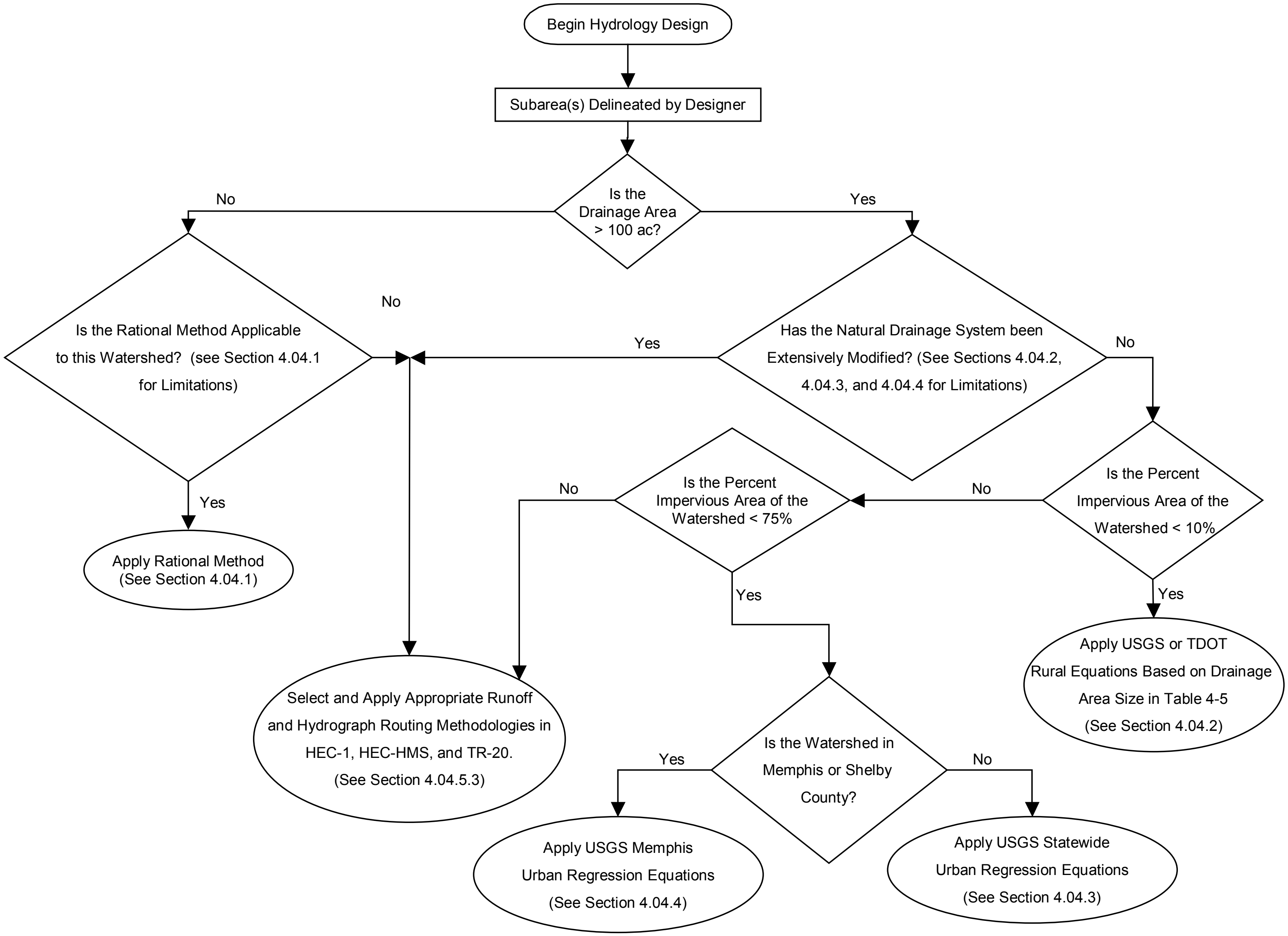


Figure 4-1. Hydrologic Method Selection Flow Chart

4.04.1 RATIONAL METHOD

The rational method is recommended for estimating the design storm runoff for drainage areas less than 100 acres as indicated in the previous section. The rational method is the preferred method to be used when all of the required data is available. The rational formula is expressed as follows:

$$Q = CIA \qquad (4\text{-}1)$$

Where:
- Q = peak rate of runoff (ft.^{3}/s.)
- C = weighted runoff coefficient representing a ratio of runoff to rainfall
- I = average rainfall intensity for a duration equal to the time of concentration, for a selected return period (in./hr.)
- A = drainage area tributary to the point under design (acres)

Although the formula is not dimensionally correct (ft.^{3}/s vs. ac*in/hr), the conversion coefficient of 1.008 is ignored as being insignificant. For further technical information and details, refer to the 1965 and 1997 publications *Hydraulic Design Series 4 (HDS 4)* by the FHWA. The results of using the rational formula to estimate peak discharges is very sensitive to the parameters that are used. Under some conditions, peak runoff occurs before all of the drainage area contributes. The likelihood of error in the runoff estimate increases as the drainage area increases. This likelihood of error is why the limit is set at 100 acres for applying the Rational Method by TDOT. The designer must use engineering judgment in estimating values that are used in the method.

4.04.1.1 RUNOFF COEFFICIENT

The runoff coefficient represents the relationship between the rainfall intensity and the peak discharge, as only a certain percentage of the total precipitation on a given area will reach the drainage structure. The amount of water reaching the drainage structure is reduced by evaporation, transpiration, infiltration, and ponding. Two methods are commonly used for calculating the runoff coefficient. The first is to utilize known soil properties, infiltration rates, and land slopes. This method requires information from the Soil Conservation Service and/or other agencies for pervious and impervious surface soil conditions. The second method for calculating the runoff coefficient is to utilize tables developed for various types of surface conditions and land use. The runoff coefficients used on TDOT projects are shown in Table 4-2.

Complex watersheds with several different types of land use will require a weighted runoff coefficient be computed. The weighted runoff coefficient is computed by multiplying the runoff coefficient for each land use type by the area of each land use and summing and then dividing the sum by the total area. An example of how to compute a weighted runoff coefficient is shown on page 4A-20.

Table 4-2. Runoff Coefficients

VALUES OF RUNOFF COEFFICIENTS (C) FOR USE IN THE RATIONAL METHOD	Runoff Coefficient (C)
Rural Areas	
Concrete or sheet asphalt pavement	0.8 - 0.9
Asphalt macadam pavement	0.6 - 0.8
Gravel roadways or shoulders	0.4 - 0.6
Bare earth	0.2 - 0.9
Steep grassed areas (2:1)	0.5 - 0.7
Turf meadows	0.1 - 0.4
Forested areas	0.1 - 0.3
Cultivated fields	0.2 - 0.4
Urban Areas	
Flat residential, with about 30 percent of area impervious	0.40
Flat residential, with about 60 percent of area impervious	0.55
Moderately steep residential, with about 50 percent of area impervious	0.65
Moderately steep developed area, with about 70 percent of area impervious	0.80
Flat commercial/industrial, with about 90 percent of area impervious	0.80

NOTES: For flat slopes and/or permeable soil, use the lower values. For steep slopes and/or impermeable soil, use the higher values.
For areas where there is a shallow bedrock surface, use the higher values.

Sources: *Introduction to Highway Hydraulics Hydraulic Design Series Number 4*. FHWA. April 1997 by James D. Schall and Everitt V. Richardson
Design of Roadside Channels - HDS 4. FHWA. May 1965 by James K. Searcy

4.04.1.2 INTENSITY

Rainfall intensity (I) is the average rainfall rate (in./hr.) for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and the time of concentration is calculated for the drainage area, the rainfall intensity can be determined from Rainfall Intensity Duration Frequency Curves. The designer should select the appropriate curve based on the location of the project (refer to Figure 4A-1 in the chapter appendix). The curves are identified on four charts and designated by the major Tennessee cities (Knoxville, Chattanooga, Nashville, and Memphis) located in each area. The intensity-duration-frequency (IDF) curves are shown in Figures 4A-2, 4A-3, 4A-4, and 4A-5 in the chapter appendix.

4.04.1.3 TIME OF CONCENTRATION (t_c)

Time of Concentration is the time it takes water from the most distant point (hydraulically) to reach a drainage basin outlet or the drainage structure being designed. The time of concentration may consist of overland flow (including sheet flow and shallow concentrated flow), pipe flow, channelized flow or a combination thereof. If there is a combination of flow types in the drainage basin, the time for each portion is identified as an individual travel time (t_t). Summing up the travel times for each reach will yield the time of concentration. As a general guideline, if the time of concentration is calculated to be less than 5 minutes, a minimum value of 5 minutes should be used.

$$t_c = t_{t1} + t_{t2} + t_{t...} \quad (4\text{-}2)$$

Several methods have been studied and proposed to compute the travel time for overland flow. TDOT has selected several methods acceptable for their projects. The preferred method is the Kinematic Wave equation described in HDS 4 (1997). Another acceptable method for TDOT is the NRCS TR-55 methodology (Mannings' Kinematic Solution for overland flow travel time and NRCS Upland Method for shallow concentrated flow). These methods are included in this section.

Methods for determining travel time for pipe flow, gutter flow, and channel flow have also been studied. The acceptable methods for TDOT projects include the Manning equation or a modified Manning equation for gutter flow. When the average water velocity is known, travel time can be calculated. This is the equation used to calculate travel time when an average water velocity is available:

$$t_t = \frac{L}{60 * V} \quad (4\text{-}3)$$

where: t_t = travel time (min.)
L = length of flow (ft.)
V = average velocity (ft./s.)
60 = conversion factor from seconds to minutes

4.04.1.3.1 Travel Time - Overland Flow

The overland flow time consists of the time required for runoff to flow over the ground surface to a channel, gutter, inlet, or pipe. The first portion of overland flow is termed sheet flow. After the water concentrates and collects in indentations in the ground such as swales, the flow becomes shallow concentrated flow. The sum of the two is overland flow. Some publications indicate that the Kinematic Wave Equation accounts for both the sheet flow travel time and the shallow concentrated flow travel time. TDOT follows the *HDS 4* (1997) approach and limits the equation's use to sheet flow. The components of overland flow are best shown by the following equation:

$$t_t(\text{overland flow}) = t_t(\text{sheet flow}) + t_t(\text{shallow concentrated flow}) \quad (4\text{-}4)$$

4.04.1.3.1.1 Travel Time - Sheet Flow

A portion of overland flow may be categorized as sheet flow. Friction in sheet flow is usually comprised of drag over the plane surface which may include obstacles such as litter, vegetation, sediment, and rocks. Sheet flow is normally considered when water flows at a depth of 0.1 feet (1.2 inches) or less. The time of concentration for sheet flow is approximated by utilizing the Kinematic Wave method or the NCRS Runoff Method. It is not always apparent when flow changes from sheet flow to shallow concentrated flow. If shallow ridges, swales, or small channels are not evident in the field, it is reasonable to assume the water stays in sheet flow for a maximum of 300 feet. After 300 feet, it is presumed that the water will find shallow ridges or swales on the ground's surface in which to collect. Once to this point, the water is termed shallow concentrated flow.

Kinematic Wave Method for Sheet Flow Travel Time

The Kinematic Wave Method for calculating sheet flow travel time was developed for flow on a plane surface. Some publications have added assumptions to the equation and have permitted its use for shallow concentrated flow travel time and small channel or pipe travel time. TDOT chooses not to make these same assumptions and limits its use to sheet flow. For sheet flow, the Kinematic Wave method is the most physically correct approach according to *HDS 4* (1997). The Kinematic Wave equation follows:

$$t_t = C\frac{n^{0.6}L^{0.6}}{i^{0.4}s^{0.3}} \qquad (4\text{-}5)$$

Where:
- t_t = Sheet flow travel time (min.)
- C = 0.938 (constant)
- n = Manning roughness coefficient (Table 4-3)
- L = Sheet flow length (ft.) (Maximum is 300 ft.)
- i = rainfall rate (in./hr.)
- s = slope of the surface (ft./ ft.)

Solving the Kinematic Wave equation requires the designer to go through an iterative process since both the travel time and rainfall intensity are unknown. Start by assuming a travel time, determine the rainfall intensity from the charts provided in the chapter appendix (Figures 4A-2 to 4A-5), and then insert the rainfall intensity in the equation. When the assumed travel time approaches the travel time generated by the equation, the designer should use this value as the solution for the sheet flow travel time. If the equation is used for sheet flow estimation in a grassy area, the n value should be quite large (e.g., 0.45 for Bluegrass). As per the *HDS 4* (1997), "This is necessary to account for the large relative roughness resulting from water running through grass rather than over it as compared to channel flow conditions." A smaller n value should be used for smooth paved conditions (e.g., 0.011 for concrete). The Manning's n values applicable for overland applications are included in Table 4-3. The designer should use an n-value based on the season of the year when the greatest likelihood of heavy rainfall will occur. This is especially pertinent to agricultural areas and roadside ditches. Farming practices alter the ground throughout the year and often different crops are planted over the years. The designer will need to make a judgement based on knowledge of farming practices in the area or from available aerial photos. In the case of roadside ditches and other maintained land, the designer will need to use engineering judgement to select an average condition based on mowing practices and channel lining material for when the greatest likelihood of heavy rainfall would occur. In infrequently mowed areas, tall grass should be considered.

Table 4-3. Manning's n Values for Overland Flow

Type of Surface	Minimum	Normal	Maximum
Concrete	0.010	0.011	0.013
Asphalt	0.010	0.012	0.015
Bare Soil	0.010	0.011	0.030
Bare Sand	0.010	0.010	0.016
Graveled Surface	0.011	0.012	0.030
Bare Clay-Loam (eroded)	0.012	0.020	0.033
Packed Clay		0.030	
Fallow (no residue)	0.006	0.050	0.160
Cultivated (till) (residue ≤ 20%)	0.006	0.060	0.120
Cultivated (till) (residue > 20%)	0.070	0.170	0.470
No Till (no residue)	0.030	0.040	0.100
No Till (20% - 40% residue)	0.010	0.070	0.170
No Till (>60% residue)	0.016	0.300	0.470
Plow (fall)	0.020	0.020	0.100
Range (natural)	0.100	0.130	0.320
Pasture	0.300	0.350	0.400
Pasture (sparse vegetation)	0.053	0.070	0.130
Grass (bluegrass sod)	0.390	0.450	0.630
Grass (Bermuda)	0.300	0.410	0.480
Lawns	0.200	0.250	0.300
Woods and Shrubbery	0.400	0.400	0.800

Sources: American Society of Civil Engineers and Water Environment Federation. *Design and Construction of Urban Stormwater Management Systems*. ASCE Manuals and Reports of Engineering Practice No. 77 and WEF Manual of Practice FD-20. New York, New York and Alexandria, Virginia. 1992.

Indiana Department of Transportation. *Indiana Design Manual Part IV Volume I*. Indianapolis, IN. 1999.

Kentucky Transportation Cabinet, *Drainage Guidance Manual - Proposed Revisions*. Frankfort, KY. September 29, 2000.

Metropolitan Government of Nashville and Davidson County Department of Public Works Engineering Division. *Stormwater Management Manual*. Nashville, Tennessee. Sept. 1999.

United States Department of Agriculture. Soil Conservation Service. Engineering Division. *Urban Hydrology for Small Watersheds - Technical Release 55*. June 1996.

Virginia Department of Transportation. *Drainage Manual*. Richmond, Virginia. February 1989.

NRCS Runoff Method For Sheet Flow

The NRCS runoff method for calculating sheet flow is applicable to depths of approximately 0.1 foot (1.2 inches) or less. As with the Kinematic Wave method, the Manning's n value is taken from Table 4-3 which has been developed for shallow flow depths.

$$t_t = \frac{0.007(nL)^{0.8}}{P_{2-24}^{0.5} s^{0.4}} \tag{4-6}$$

Where:
- t_t = Sheet flow travel time (hr.)
- n = Manning sheet flow roughness coefficient (Use Table 4-3)
- L = Sheet flow length (ft.)
- P_{2-24} = 2-year, 24-hour rainfall (in.) (Use Figure 4A-65)
- s = slope of hydraulic grade line, assumed to be the surface (ft./ft.)

Note: P_{2-24} should be used in this equation even if the design storm under investigation for determining the peak discharge is for a different return period.

4.04.1.3.1.2 Travel Time - Shallow Concentrated Flow

After sheet flow, the water usually becomes shallow concentrated flow. The shallow concentrated flow normally has a depth greater than 0.1 feet (1.2 inches). After some distance, the shallow concentrated flow further concentrates to a ditch, gutter, channel, or drainage structure. Once the water has reached a more concentrated flow such as in a gutter, pipe, or channel, the travel time in the channel will be calculated and added to the overland flow travel time. If a shallow concentrated flow time is required, then the nomograph found in the chapter appendix as Figure 4A-6 should be used to approximate this travel time. Alternately, the designer may use the equations represented by this nomograph. The following equations are based on Manning's equation with assumptions for Manning's roughness coefficient and hydraulic radius which permit a calculation of an average shallow concentrated flow velocity. The assumptions include for unpaved areas a Manning's n equal to 0.05 and hydraulic radius equal to 0.4 feet and for paved areas a Manning's n equal to 0.025 and hydraulic radius equal to 0.2 feet. Once the velocity is known, travel time can be calculated with equation 4-3.

$$V_{unpaved} = 16.1345(s)^{0.5} \tag{4-7}$$

$$V_{paved} = 20.3282(s)^{0.5} \tag{4-8}$$

where V = average velocity (ft./s.)
s = slope of hydraulic grade line (assumed to be watercourse slope in ft./ft.)

4.04.1.3.2 Travel Time - Pipe, Gutter & Channel Flow

Travel time for pipe, gutter, or channel flow can be estimated from the hydraulic properties of the conduit or channel. After first determining the average velocity in the pipe or channel, the travel time is obtained by dividing the pipe or channel length by the determined velocity. In watersheds with gutters, storm drains, pipes, or channels, the travel time for these items must be added to the overland flow travel time to find the total time of concentration. Manning's equation can be used to determine water velocity for these types of flow. When calculating the velocity for channels, the designer should presume bank full conditions. For an engineered channel that has been well maintained or is in the process of design, then the designer may assume one foot of freeboard. In special situations, additional design information may be available and a different depth of flow may be used.

$$V = \frac{1.49}{n} * R_h^{0.67} * S_c^{0.5} \qquad (4\text{-}9)$$

Where:
- V = Average Velocity (ft./s.)
- R_h= Hydraulic Radius (ft.)
- S_c= Friction Slope (assumed to be average slope, ft./ft.)
- n = Manning's Roughness Coefficient

A detailed discussion of the Manning's equation is included in Chapter 5 where open channel flow is presented. The Manning's Roughness Coefficient (n-value) used in Equation 4-9 is not the same as those presented in Table 4-3. The appropriate table in Chapter 5 should be used to determine the n value for Equation 4-9.

Triangular Gutter Section

A modified version of the Manning's equation may be applied to triangular gutter sections. The modified equation describes the flow in wide, shallow, triangular channels. The area of the gutter and the hydraulic radius are a function of the water's spread and the roadway cross slope. This assumes that the gutter cross slope and the roadway cross slope are equal. This would lead to the following assumed channel shape:

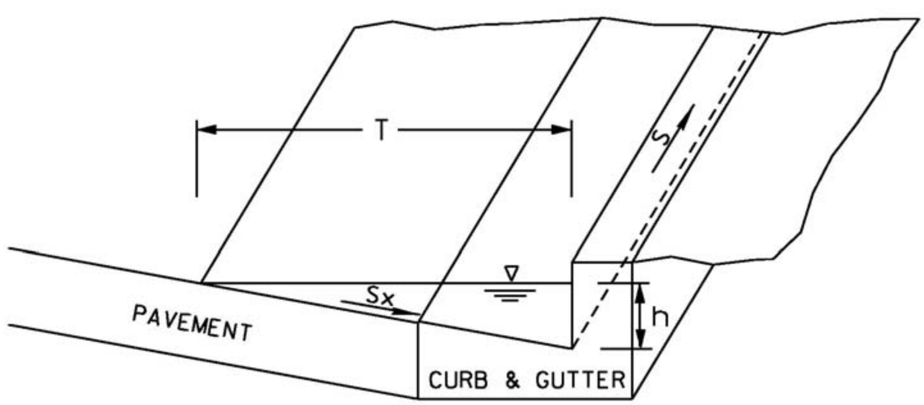


Figure 4-2. Triangular Gutter Section

With this assumed gutter section, the velocity of the water in the gutter can be calculated with equation 4-10.

$$V = \frac{1.12}{n * h} * S_x^{1.67} * S^{0.5} * T^{1.67} \quad (4\text{-}10)$$

Where:
- V = Flow Velocity (ft./s.)
- n = Manning Roughness Coefficient (See Table in Chapter 5)
- S_x = Cross Slope (ft./ft.)
- S = Longitudinal Slope (ft./ft.)
- h = Water Depth at Curb (ft.)
- T = Width of Flow Spread (ft.)

If the gutter cross section is different from the shape shown in Figure 4-2 (especially the pavement cross slope and gutter cross slope), then the designer should use methods described in Chapter 6 for composite gutter sections.

4.04.1.4 DRAINAGE AREA

The drainage area contributing to the point in question can be determined in the field or measured from a topographic map. Data needed to determine the required variables in the rational equation should be noted at the time of the field reconnaissance. Many drainage areas are straight-forward (i.e., in a fill section where only pavement area may be considered for an inlet). For other occasions the drainage area is complex. Example problems are provided for the designer's use. One is a simple drainage area example and the other is for a more complex drainage area. These example problems are included in the Chapter Appendix. According to *HDS 4* (1997):

> [I]t is possible that the maximum rate of runoff will be reached from the higher intensity rainfall periods less than the time of concentration for the whole area, even though only a part of the drainage area is contributing. This might occur where a part of the drainage area is highly impervious and has a short time of concentration, and another part is pervious and has a much longer time of concentration. Unless the areas or times of concentration are considerably out of balance, the accuracy of the method does not warrant checking the peak flow from only a part of the drainage area. This is particularly true for the relatively small drainage areas associated with highway pavement drainage facilities.

Often the designer uses USGS 7.5 minute quad maps to help identify drainage areas, elevations, and channels. With the availability of electronic quad maps, the proposed project can be represented superimposed over the quad map in a Microstation file. Although not required, this electronic representation is suggested. The designer also develops runoff coefficients, structure locations, and other design information for each area on the map, which develops into a drainage map.

4.04.1.5 PROCEDURES

Once the designer has identified the rational method for determining design discharge, the following steps are applicable:

Step 1 – Determine drainage area.
Step 2 – Calculate runoff coefficient.

Step 3 – Find time of concentration. If the designer chooses the NRCS–TR-55 Time of Concentration Method, a useful worksheet is included in the chapter appendix as Figure 4A-7.
Step 4 – Determine rainfall intensity.
Step 5 – Calculate storm runoff (design discharge).
Step 6 – Verify that any sub-area does not provide higher runoff.

Rational Method example problems are presented in the chapter appendix. These examples begin on page 4A-19.

4.04.2 USGS REGRESSION EQUATIONS FOR RURAL AREAS

4.04.2.1 BACKGROUND

The United States Geological Survey (USGS) developed regression equations for rural areas of Tennessee in 2002. The rural regression equation development is described in Water-Resources Investigations Report 02-4165, "Flood Frequency of Streams in Rural Basins of Tennessee". The study was based on stream flow data gathered from 453 gaging stations. Of these, 297 gages were located in Tennessee. The remaining gages were on streams near the Tennessee border. All of the gages had a minimum of ten years of stream flow data. Stream gages where the historical discharge record had been significantly impacted by urbanization, dredging, or other man-made watershed changes were not included in the analysis.

A regional flood frequency analysis was performed on these gages. This regional flood frequency analysis identified drainage area as the only consistently significant variable in predicting peak flow for the range of flood frequencies. Four hydrologically similar areas were identified during the regional flood frequency analysis that improved the predictive capability of the regression equations. These four Hydrologic Areas are shown in Figure 4-3. The rural regression equations for each of the four Hydrologic Areas of the state are shown in Table 4-4. The only variable in the equation is the drainage area in acres, represented by A. The resulting flow in cubic feet per second can be obtained by using these equations.

Table 4-4. USGS Rural Regression Equations by Hydrologic Area (CFS)

Recurrence Interval (years)	Hydrologic Area 1	Hydrologic Area 2	Hydrologic Area 3	Hydrologic Area 4
2	$119(CDA)^{0.756}$	$207(CDA)^{0.725}$	$348(CDA)^{0.661}$	$431(CDA)^{0.529}$
5	$197(CDA)^{0.740}$	$344(CDA)^{0.715}$	$555(CDA)^{0.650}$	$615(CDA)^{0.545}$
10	$258(CDA)^{0.731}$	$444(CDA)^{0.711}$	$700(CDA)^{0.646}$	$735(CDA)^{0.554}$
25	$343(CDA)^{0.721}$	$578(CDA)^{0.708}$	$885(CDA)^{0.643}$	$883(CDA)^{0.563}$
50	$412(CDA\ )^{0.715}$	$682(CDA)^{0.706}$	$1,020(CDA)^{0.642}$	$991(CDA)^{0.568}$
100	$485(CDA)^{0.709}$	$788(CDA)^{0.705}$	$1,160(CDA)^{0.642}$	$1,100(CDA)^{0.573}$
500	$675(CDA)^{0.698}$	$1,050(CDA)^{0.702}$	$1,470(CDA)^{0.644}$	$1,340(CDA)^{0.583}$

A – Drainage Area in acres.
Source: "Flood Frequency of Streams in Rural Basins of Tennessee" Water-Resources Investigations Report 92-4165. USGS. 1993.

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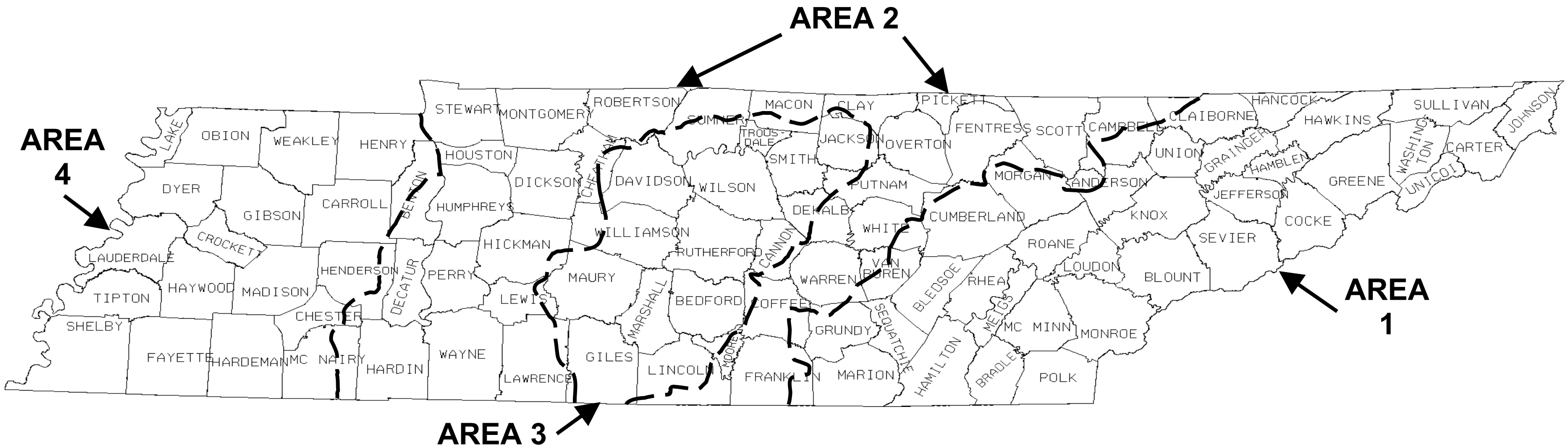

Source: "Flood Frequency of Streams in Rural Basins of Tennessee" Water-Resources Investigations Report 92-4165. USGS. 1993.

NOTE: DASHED LINES IDENTIFY HYDROLOGIC BOUNDARIES

Figure 4-3. Hydrologic Area Map

The USGS and TDOT rural regression equations described below should be applied to rural watercourses with drainage areas greater than 100 acres as indicated in Figure 4-1. The stream flow in these drainage areas should be unregulated or not significantly altered by man-made structures or activities and the impervious area within the drainage area should be less than 10% of the entire drainage area. According to the USGS report, the basic forms of the rural regression equations are applicable for the drainage area ranges shown in Table 4-5. TDOT has determined that the USGS rural regression equations should be applied when the drainage area is greater than TDOT area limits shown in Column 3 of Table 4-5.

Table 4-5. USGS Rural Regression Equation Drainage Area Range Limitations (CFS)

Hydrologic Area	USGS Area Limits (ac.)	TDOT Area Limit (ac.)
1	230 to 13,696,000	230
2	300 to 452,480	300
3	20 to 570,880	100
4	186 to 1,477,120	186

Source: "Flood Frequency of Streams in Rural Basins of Tennessee" Water-Resources Investigations Report 92-4165. USGS. 1993.

TDOT has developed regression equations for rural drainage areas between 100 acres and the lower drainage area limit of the USGS rural regression equations for each Hydrologic Area shown in Column 3 of Table 4-5. Hydrologic Area 3 does not have TDOT developed regression equations since the USGS equations are applicable for drainage areas greater than 100 acres. The TDOT regression equations shown in Tables 4-6, 4-7, and 4-8 should be used for drainage areas greater than 100 acres, but less than the TDOT Area Limit shown in Column 3 of Table 4-5.

Table 4-6. TDOT Hydrologic Area 1 Regression Equations for Areas Between 100 Acres and 230 Acres (CFS)

Recurrence Interval (years)	Equation
2	$Q_2 = Q_{25} (1 – 0.5 A^{0.052})$
5	$Q_5 = Q_{25} (1 – 0.4 A^{0.014})$
10	$Q_{10} = Q_{25} (1 – 0.2 A^{0.034})$
25	$Q_{25} = 33.6 A – 31.1 A^{1.01}$
50	$Q_{50} = Q_{25} (1 + 0.2 A^{0.015})$
100	$Q_{100} = Q_{25} (1 + 0.5 / A^{0.019})$

Table 4-7. TDOT Hydrologic Area 2 Regression Equations for Areas Between 100 Acres and 300 Acres (CFS)

Recurrence Interval (years)	Equation
2	$Q_2 = Q_{25} (1 – 0.5 A^{0.055})$
5	$Q_5 = Q_{25} (1 – 0.4 A^{0.013})$
10	$Q_{10} = Q_{25} (1 – 0.2 A^{0.035})$
25	$Q_{25} = 18A – 15 A^{1.02}$
50	$Q_{50} = Q_{25} (1 + 0.2 A^{0.001})$
100	$Q_{100} = Q_{25} (1 + 0.5 / A^{0.034})$

Note: Hydrologic Area 3 does not have TDOT developed regression equations. The USGS rural regression equations are applicable to all areas greater than 100 acres.

Table 4-8. TDOT Hydrologic Area 4 Regression Equations for Areas Between 100 Acres and 186 Acres (CFS)

Recurrence Interval (years)	Equation
2	$Q_2 = Q_{25} (1 – 0.5 A^{0.017})$
5	$Q_5 = Q_{25} (1 – 0.4 A^{0.075})$
10	$Q_{10} = Q_{25} (1 – 0.2 A^{0.056})$
25	$Q_{25} = 5A – 0.6 A^{1.30}$
50	$Q_{50} = Q_{25} (1 + 0.2 / A^{0.121})$
100	$Q_{100} = Q_{25} (1 + 0.5 / A^{0.164})$

4.04.2.2 PROCEDURES

The procedures for applying the rural regression equations are described in the following steps. The designer should follow these steps for all rural watersheds.

Step 1 - The designer determines the drainage area in acres using detailed project mapping and/or the USGS 7.5-minute topographic maps.

Step 2 – The designer determines in which Hydrologic Area the majority of the watershed lies. A map of the Hydrologic Area boundaries is shown in Figure 4-3.

Step 3 – Select the appropriate regression equation based on the hydrologic area (Figure 4-3), design frequency (Table 4-1), and drainage area.

Step 4 – Compute the peak discharge using the appropriate regression equation for the desired design frequency, drainage area, and hydrologic area.

USGS regression equation method example problems for rural areas are included in the chapter appendix. These examples begin on page 4A-33.

4.04.3 USGS REGRESSION EQUATIONS FOR URBAN AREAS

4.04.3.1 BACKGROUND

The USGS developed regression equations for small urban streams of Tennessee in 1984. The process is described in Water-Resources Investigations Report 84-4182, "Synthesized Flood Frequency for Small Urban Streams in Tennessee". Twenty-two streams were studied statewide in urban areas with populations between 5,000 and 100,000. The drainage areas for these twenty-two sites ranged from 0.21 to 24.3 square miles. The impervious percentage in the watersheds for the study, ranged from 4.7 to 74.0 percent.

The stream flow record for the gages ranged from four to eight years. Due to the short record for the gages, rainfall-runoff models were calibrated for each of the watersheds. Flood magnitudes for selected recurrence intervals were then estimated for each of the watersheds using the calibrated models. These flood magnitudes were then used in a regional regression analysis to develop the regression equations. Three basin characteristics were determined to be significant in the regional regression analysis. These characteristics are drainage area, percent impervious, and the 2-year, 24-hour rainfall. The urban regression equations developed from this analysis are as follows:

$$Q_2 = 1.76\,(A/640)^{0.74}\,I_{IMP}^{0.48}\,P_{2\text{-}24}^{3.01} \qquad (4\text{-}11)$$

$$Q_5 = 5.55\,(A/640)^{0.75}\,I_{IMP}^{0.44}\,P_{2\text{-}24}^{2.53} \qquad (4\text{-}12)$$

$$Q_{10} = 11.8\,(A/640)^{0.75}\,I_{IMP}^{0.43}\,P_{2\text{-}24}^{2.12} \qquad (4\text{-}13)$$

$$Q_{25} = 21.9\,(A/640)^{0.75}\,I_{IMP}^{0.39}\,P_{2\text{-}24}^{1.89} \qquad (4\text{-}14)$$

$$Q_{50} = 44.9\,(A/640)^{0.75}\,I_{IMP}^{0.40}\,P_{2\text{-}24}^{1.42} \qquad (4\text{-}15)$$

$$Q_{100} = 77.0\,(A/640)^{0.75}\,I_{IMP}^{0.40}\,P_{2\text{-}24}^{1.10} \qquad (4\text{-}16)$$

Where:
Q_r = Estimated Discharge for the Recurrence Interval Indicated (cfs)
A = Drainage Area of the Watershed (acres)
I_{IMP} = Percentage of Impervious Area in Watershed (%)
$P_{2\text{-}24}$ = 2-year, 24-hour Rainfall (in.)
Note: The 2-year, 24-hour rainfall amounts for Tennessee are shown in Figure 4A-26 found in the chapter appendix.

The USGS urban stream regression equations should be applied to all urban drainage areas greater than 100 acres. The impervious area for the watershed should be between 10 and 75 percent of the total watershed area. The stream flow should be unregulated. The peak flow magnitude should not be affected by in-channel storage or overbank detention storage. These equations should not be used in the City of Memphis or Shelby County. The USGS has developed regression equations specifically for urban watersheds in the City of Memphis and Shelby County.

4.04.3.2 PROCEDURES

The procedures for applying the urban regression equations are described in the following steps.

Step 1 – The designer determines the drainage area in acres using the detailed project mapping and/or the USGS 7.5-minute topographic maps.

Step 2 – The designer determines the 2-year, 24-hour rainfall amount by interpolating Figure 4A-26.

Step 3 – Determine the amount of the impervious area in the watershed. The designer then computes the impervious percentage by dividing the impervious area by the total drainage area.

Step 4 – Compute the peak discharge using the appropriate regression equation for the desired frequency (see Equations 4-11 to 4-16.)

USGS regression equation method example problems for urban areas are included in the chapter appendix. These examples begin on page 4A-36.

4.04.4 USGS REGRESSION EQUATIONS FOR THE CITY OF MEMPHIS AND SHELBY COUNTY URBAN AREAS

4.04.4.1 BACKGROUND

A method for estimating the magnitude and frequency of peak discharges in the urban areas of the City of Memphis and Shelby County was developed by the USGS in 1984. The methodology development is described in Water-Resources Investigations Report 84-4110, “Flood Frequency and Storm Runoff of Urban Areas of Memphis and Shelby County, Tennessee.” The study was based on stream flow and rainfall records from 27 stream gaging stations and 37 rainfall gages. The drainage areas for the 27 gages ranged from 0.043 to 19.4 square miles.

Eight years of stream flow and rainfall records were gathered at the gages. This data was used to calibrate a rainfall-runoff model for each gage for about 30 storms. The Lichty and Liscum map model procedure (1978) was used to develop peak discharge frequency curves for each of the gages using parameters optimized in the rainfall-runoff model calibration. These peak discharge frequency curves were used in a regional frequency analysis to identify physical basin characteristics that were significant in estimating peak flows. Two physical characteristics were identified in the regional frequency analysis as being significant predictors of peak flow rates. These basin characteristics are drainage area in square miles and channel condition. Channel condition represents how much of the channel at four points in the watershed is paved.

The use of the regression equations is not allowed for any project designed for or constructed by TDOT.

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4.04.5 OTHER HYDROLOGIC METHODS

4.04.5.1 INTRODUCTION

This section presents other hydrologic methods that may be used by the designer when the preferred methods discussed previously are not applicable due to watershed conditions or where other hydrologic data is available for the stream crossing location. Examples of other hydrologic data are published peak flow rates from FEMA Flood Insurance Studies or other agencies. Hydrologic models utilizing hydrograph routing techniques may be required for some watersheds due to the presence of existing or proposed storage reservoirs. This section will discuss other sources of existing flow data and hydrologic models.

4.04.5.2 SOURCES OF EXISTING FLOW DATA

The designer should check for existing published flow data for the project site. A typical source of flow data is Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS). These studies are generally published by FEMA for each community. As a minimum the appropriate design storm published FIS flows should be used for the project site for the design of a structure. Other sources of existing flow data are stormwater management or flood control studies conducted by Federal, State, or local government agencies.

4.04.5.3 HYDROLOGIC MODELS INVOLVING DETENTION (HEC-1, HEC-HMS, AND TR-20)

The hydrologic models and methods described in this section are to be used by the designer when detention storage will be included in the highway drainage design or for watersheds where the rational method or regression equations are not applicable. These methods should also be used for watersheds that have significant existing reservoir storage, diversions, and other significant man-made changes that have made TDOT preferred hydrologic methods inapplicable to the watershed. The hydrologic models for this purpose are the U.S. Army Corps of Engineers' HEC-1 and HEC-HMS and the Natural Resource Conservation Service's TR-20. When using one of these models, the designer should be familiar with hydrologic modeling concepts. HEC-1 and HEC-HMS are more versatile and provide a wider variety of modeling techniques for watershed features. The user’s manuals for these models should be consulted for the specifics on how to use the models and the data input requirements.

4.04.5.3.1 Hydrologic Model Loss Rate and Unit Hydrograph Methodology

The NRCS curve number loss rate and unit hydrograph methodology are the preferred methods to be used by the designer in computing runoff hydrographs in HEC-1, HEC-HMS, and TR-20. The NRCS TR-55 time of concentration methodology described in the Rational Method Section 4.04.1.3 should be used by the designer. The following paragraphs describe the methodology for determining the NRCS curve number for a watershed.

The principle factors that determine the Runoff Curve Number (CN) are the hydrologic soil group, ground cover type, treatment, hydrologic condition, antecedent runoff condition, and how the flow enters the drainage system. This design methodology assumes that the runoff potential before a storm event is at "average" conditions. This pre-storm runoff potential is also described as the Antecedent Runoff Condition. Tables 4A-1 to 4A-3 found in the chapter appendix list runoff curve numbers for various land uses and hydrologic soil groups. A worksheet for determining the composite runoff curve number and runoff is included in the chapter appendix as Figure 4A-8.

In determining the NRCS curve number, soils are classified into four hydrologic soil groups (A, B, C, and D). The classifications are based on bare soil infiltration rates after prolonged wetting. The infiltration rates are affected by subsurface permeability and surface intake rates. The soils in the project or study area can be identified from a soil survey report which can be obtained from a soil and water conservation district office or local National Resource Conservation Service office. A summary of common Hydrologic Soil Groups in Tennessee are included in Table 4A-4 found in the chapter appendix. If the soil group is not included in Table 4A-4, then the designer should refer to the appendix included in the TR-55 document.

Even though urban areas have more impervious areas (i.e., buildings, roadways, and, sidewalks) than rural areas, soil remains an important factor in estimating the amount of runoff. According to TR-55, "Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates." The designer should be aware that natural soils may have been disturbed by prior projects. Native soils may be mixed with soils introduced from other areas (fill material) or may be removed (excavation). Hydrologic Soil Groups for disturbed soils can be characterized by the soil texture as identified in Table 4-9.

Table 4-9. Disturbed Soil Hydrologic Soil Group

Hydrologic Soil Group	Soil Textures
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Source: TR-55 Second Edition, June 1986.

Tables 4A-1 to 4A-3 address the most common ground cover types. The preferred method for determining the type of ground cover is from the field reconnaissance. Aerial photography and land use maps are also useful sources.

Ground Treatment describes a modification to the ground cover made by management practices on agricultural land. The treatments are bare soil, crop residue cover, straight row, contoured, and contoured & terraced. These are each identified in Table 4A-2.

The hydrologic condition indicates the effects of the ground cover and any given ground treatment on runoff and water infiltration. The hydrologic condition is generally classified as either "good" or "poor." "Good" hydrologic conditions indicate that the soil would have low runoff potential. According to the NRCS, the designer should consider five factors when estimating the effect of the cover on infiltration and runoff:

1. Density of lawns, crops, or other vegetative areas,
2. Amount of year-round cover,

3. Amount of grass or close-seeded legumes in rotations,
4. Percent of residue cover, and
5. Degree of surface roughness.

4.04.5.3.2 Rainfall Distributions

The 24-hour rainfall amounts for the desired design frequency are available in the NWS Technical Paper No. 40 and are included in the chapter appendix as Figures 4A-64 to 4A-70. A balanced rainfall distribution should be used by the designer. A balanced rainfall distribution is where the greatest rainfall intensity occurs during the central portion of the storm. The balanced storm distribution is shown in Figure 4-4 and Table 4-10. For TR-20, the NRCS Type II rainfall distribution may be used.

Table 4-10. Balanced Storm Rainfall Distribution (P/P_{24} Ratio)

Hour	Quarter - Hour			
	0.0000	0.2500	0.5000	0.7500
0	0.0000	0.0003	0.0005	0.0008
1	0.0010	0.0015	0.0020	0.0025
2	0.0030	0.0039	0.0048	0.0056
3	0.0065	0.0074	0.0083	0.0091
4	0.0100	0.0138	0.0175	0.0213
5	0.0250	0.0288	0.0325	0.0363
6	0.0400	0.0450	0.0500	0.0550
7	0.0600	0.0650	0.0700	0.0750
8	0.0800	0.0870	0.0940	0.1010
9	0.1080	0.1185	0.1290	0.1395
10	0.1500	0.1675	0.1850	0.2025
11	0.2200	0.2450	0.2800	0.3900
12	0.5000	0.6080	0.7150	0.7570
13	0.7900	0.8075	0.8250	0.8425
14	0.8600	0.8688	0.8775	0.8863
15	0.8950	0.9008	0.9065	0.9123
16	0.9180	0.9226	0.9273	0.9319
17	0.9365	0.9411	0.9458	0.9504
18	0.9550	0.9581	0.9613	0.9644
19	0.9675	0.9706	0.9738	0.9769
20	0.9800	0.9819	0.9837	0.9856
21	0.9875	0.9894	0.9912	0.9931
22	0.9950	0.9956	0.9963	0.9969
23	0.9975	0.9981	0.9987	0.9994
24	1.0000			

Source: Table 2-2, Volume 2, Procedures Stormwater Management Manual, Metropolitan Government of Nashville and Davidson County, 1998.

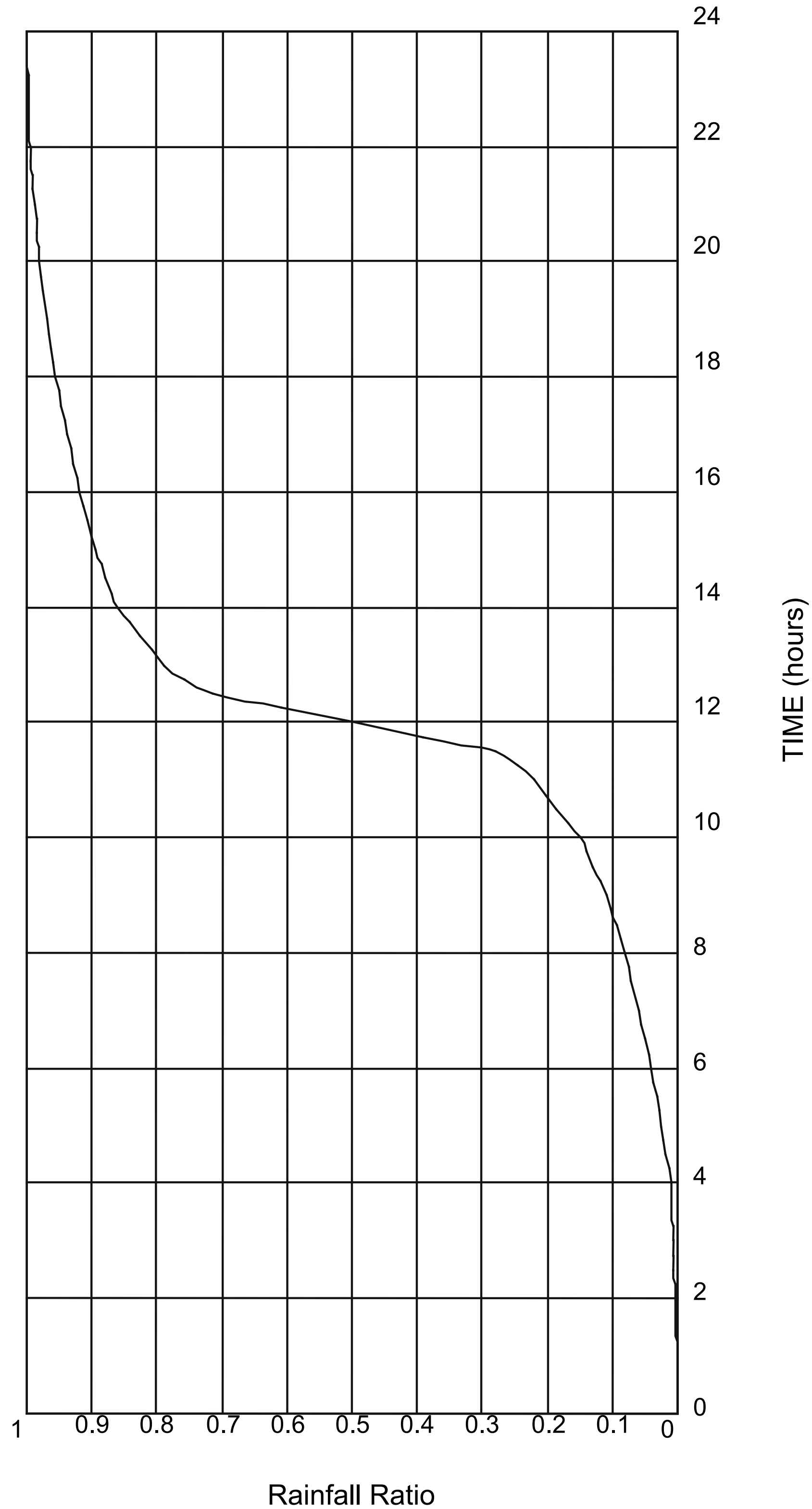


Figure 4-4 Balanced Storm Rainfall Distribution (P/P_{24} Ratio)

SECTION 4.05 – ACCEPTABLE SOFTWARE

The hydrology software listed in this section is acceptable for use on all TDOT projects. This software should be used unless special circumstances on the project or watershed require other software. The TDOT design manager should approve the use of any other software for these special circumstances. The acceptable software is listed in Table 4-11.

Under special circumstances, the designer will need to compute peak flow rates from mostly impervious areas or generate runoff hydrographs for the design of detention facilities, or determining peak flow rates from upstream reservoirs. When a runoff hydrograph is required, the designer should use either the Corps of Engineers HEC-HMS, or NRCS TR-20 hydrologic models. The Corps of Engineers HEC-1 model may be used only if there is an existing HEC-1 model.

Table 4-11. Acceptable Software

Approved Software	**Uses**
GeoPak	Rational Method NRCS Curve Number Method
HYDRAIN (HYDRO Module)	Rational Method
HYDRAIN (NFF Module)	USGS Rural Regression Equation USGS Urban Regression Equation USGS Memphis Regression Equation
HEC-HMS, HEC-1 *	Runoff Hydrographs using NRCS Curve Number and Unit Hydrograph Methods Channel Routings Reservoir Routings (existing and proposed) Diversions
TR-20	Runoff Hydrographs using NRCS Curve Number and Unit Hydrograph Methods Channel Routings Reservoir Routings (existing and proposed) Diversions

* HEC-1 may be used only if there is an existing HEC-1 model.

TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER IV
APPENDIX 4A

SECTION 4.06 - APPENDIX

4.06 APPENDIX

4.06.1 FIGURES AND TABLES

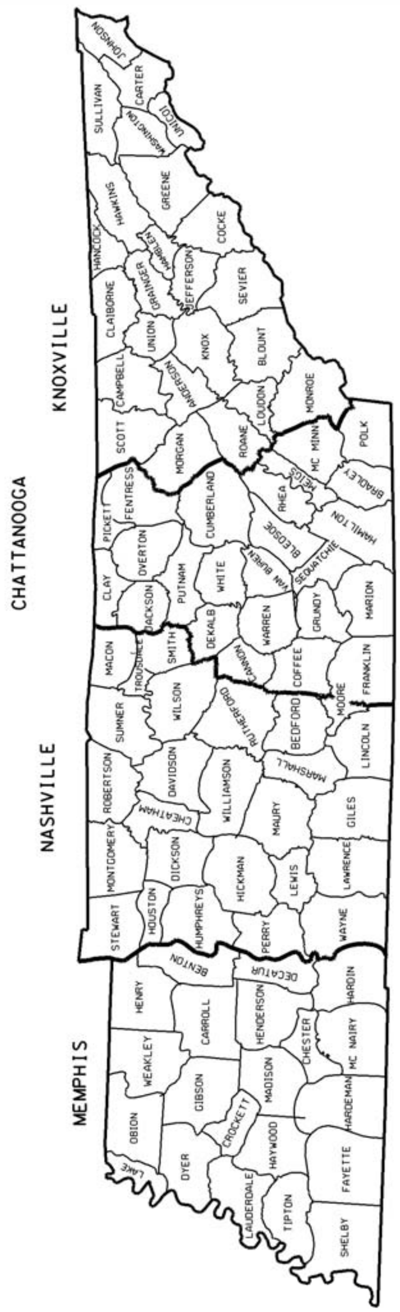
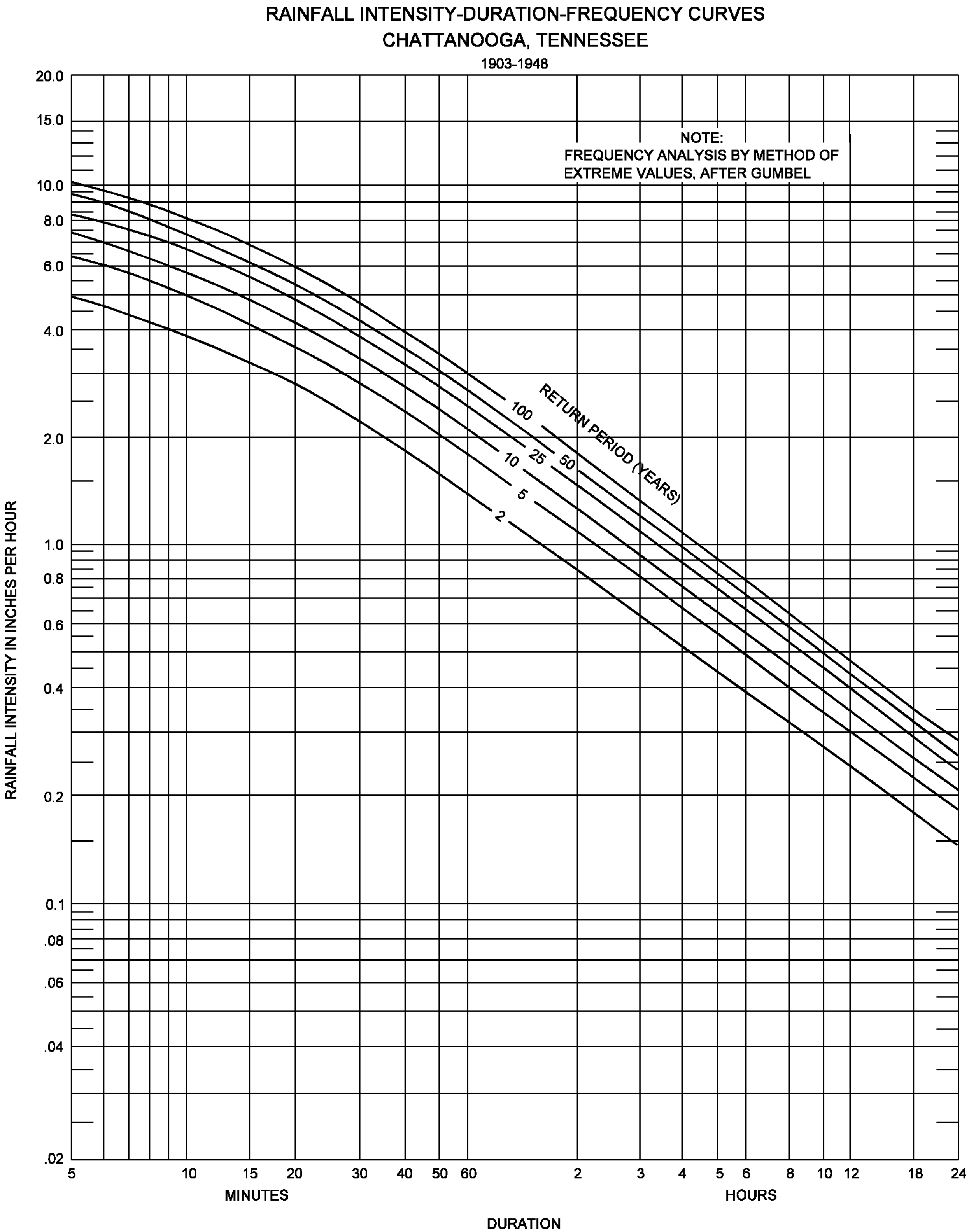


Figure 4A-1. IDF Zone Location Map



NOTE: Tc = 5 minutes is a minimum value to use in all cases
Figure 4A-2 Chattanooga IDF Curve

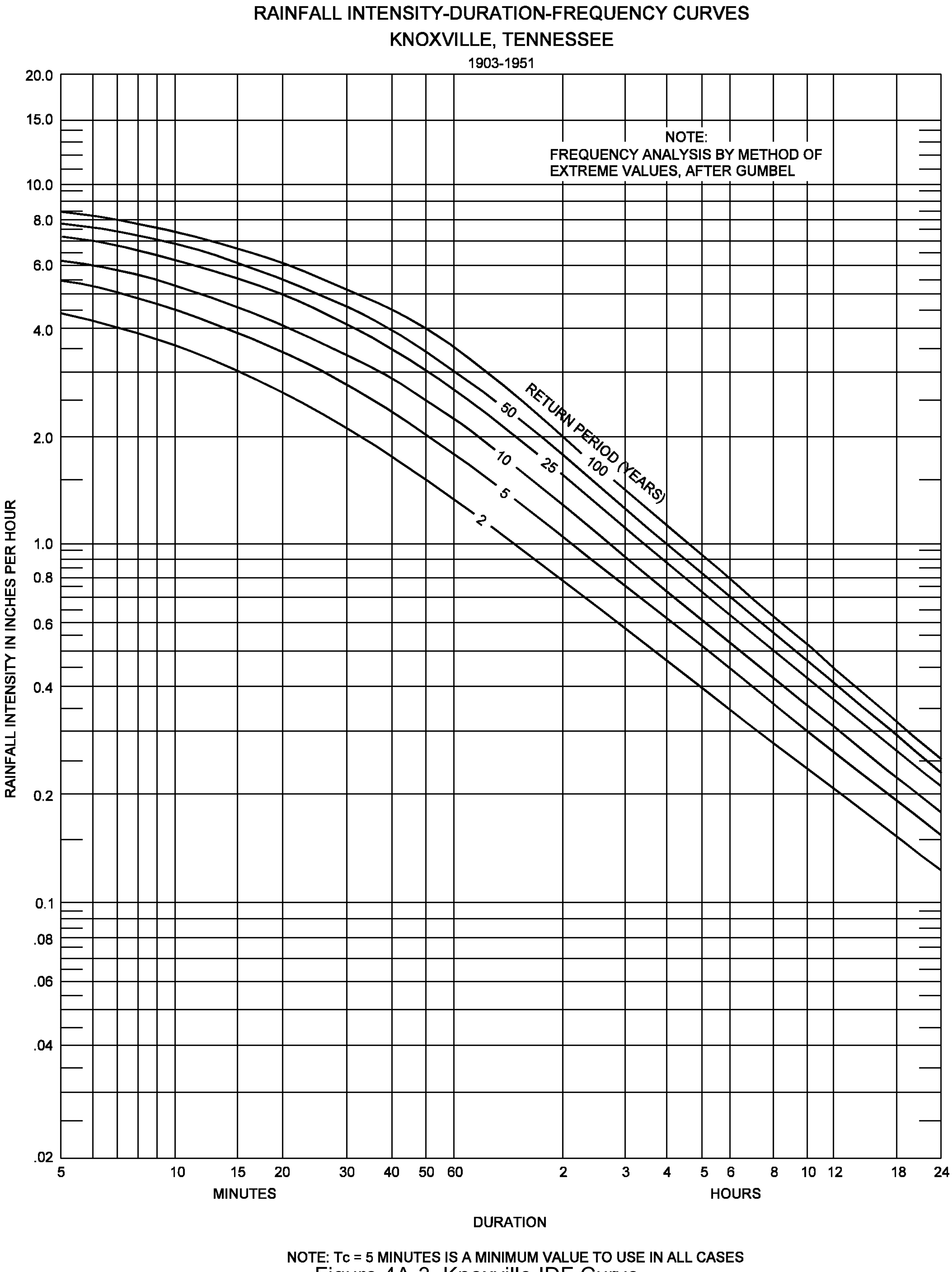


Figure 4A-3. Knoxville IDF Curve

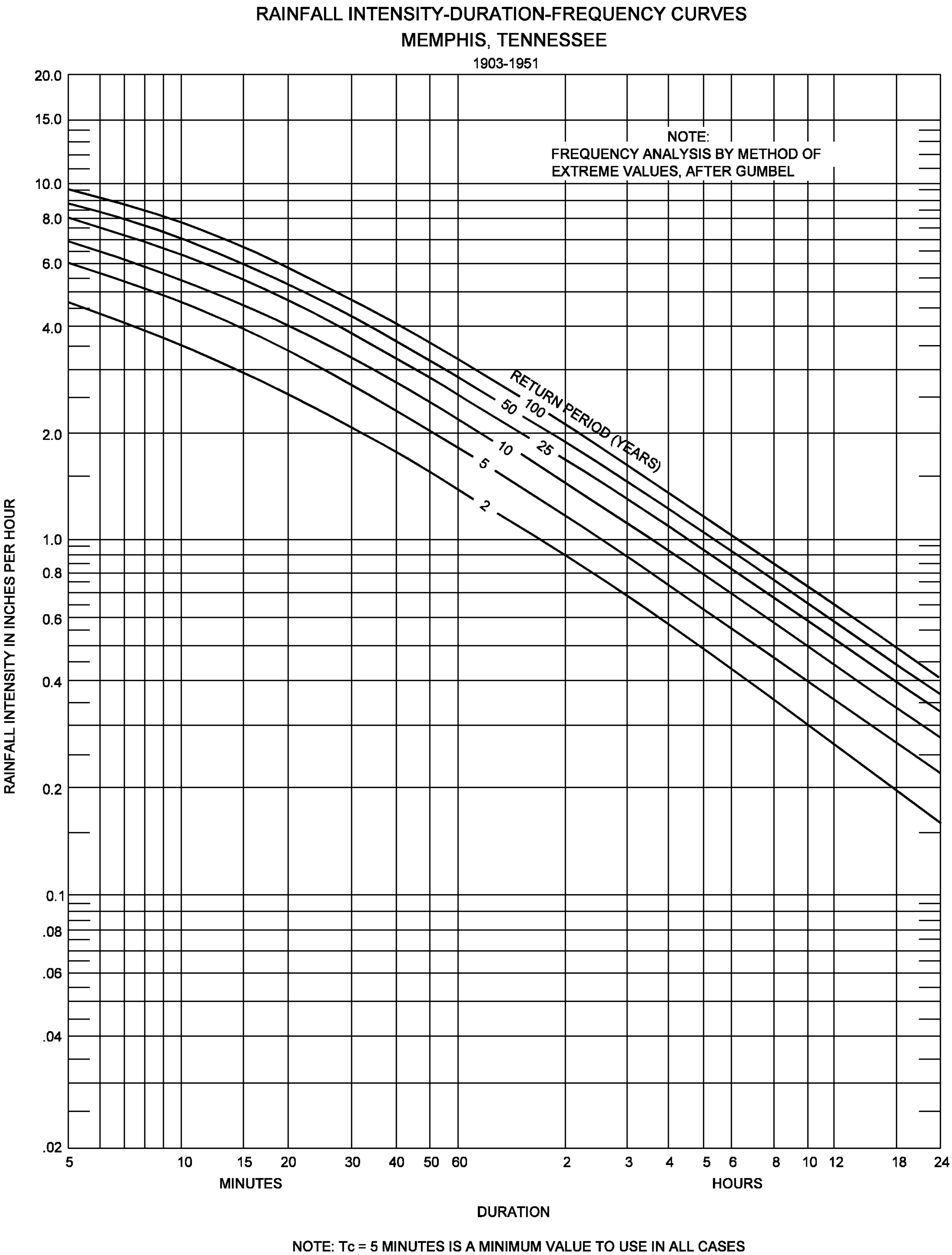


Figure 4A-4. Memphis IDF Curve

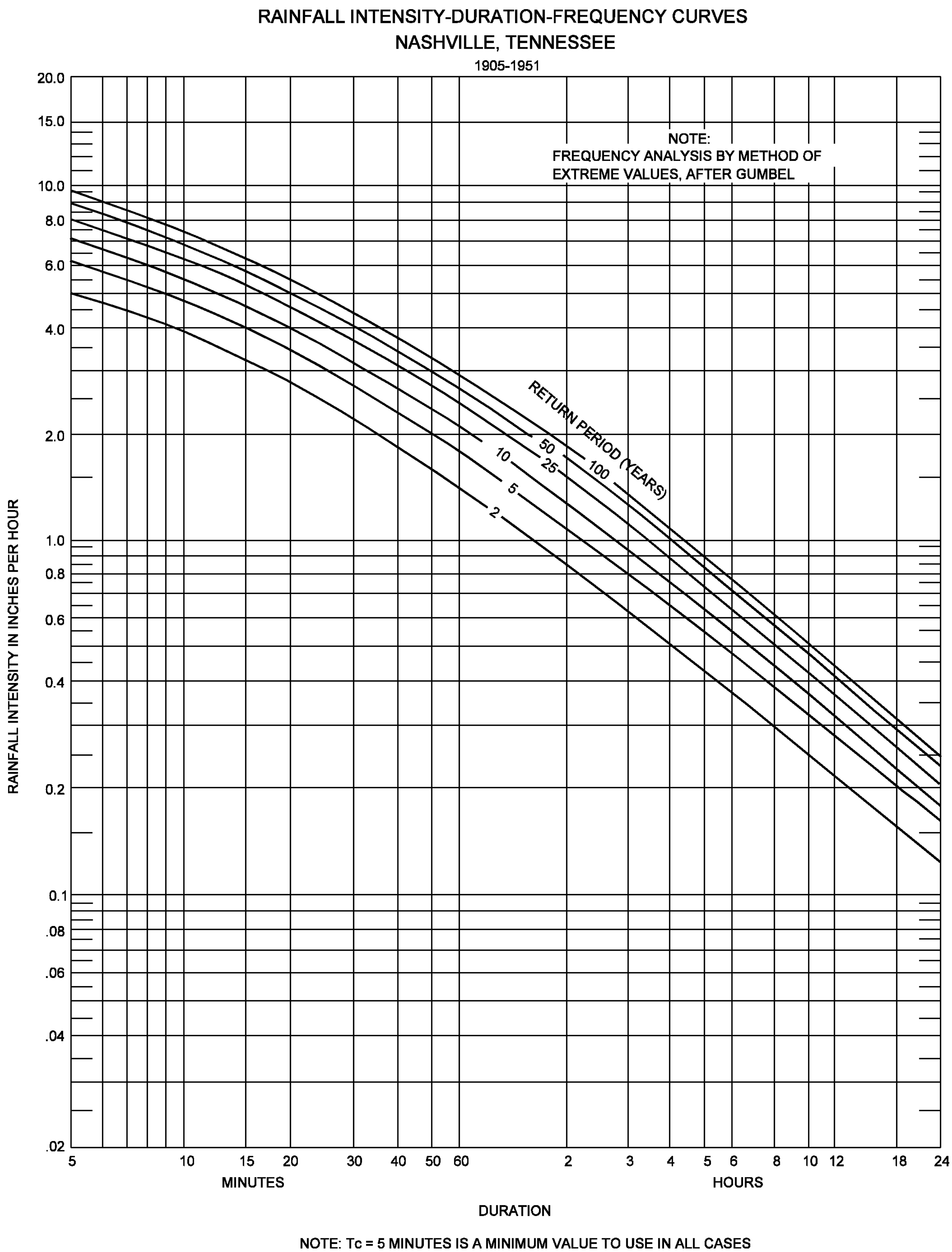


Figure 4A-5. Nashville IDF Curve

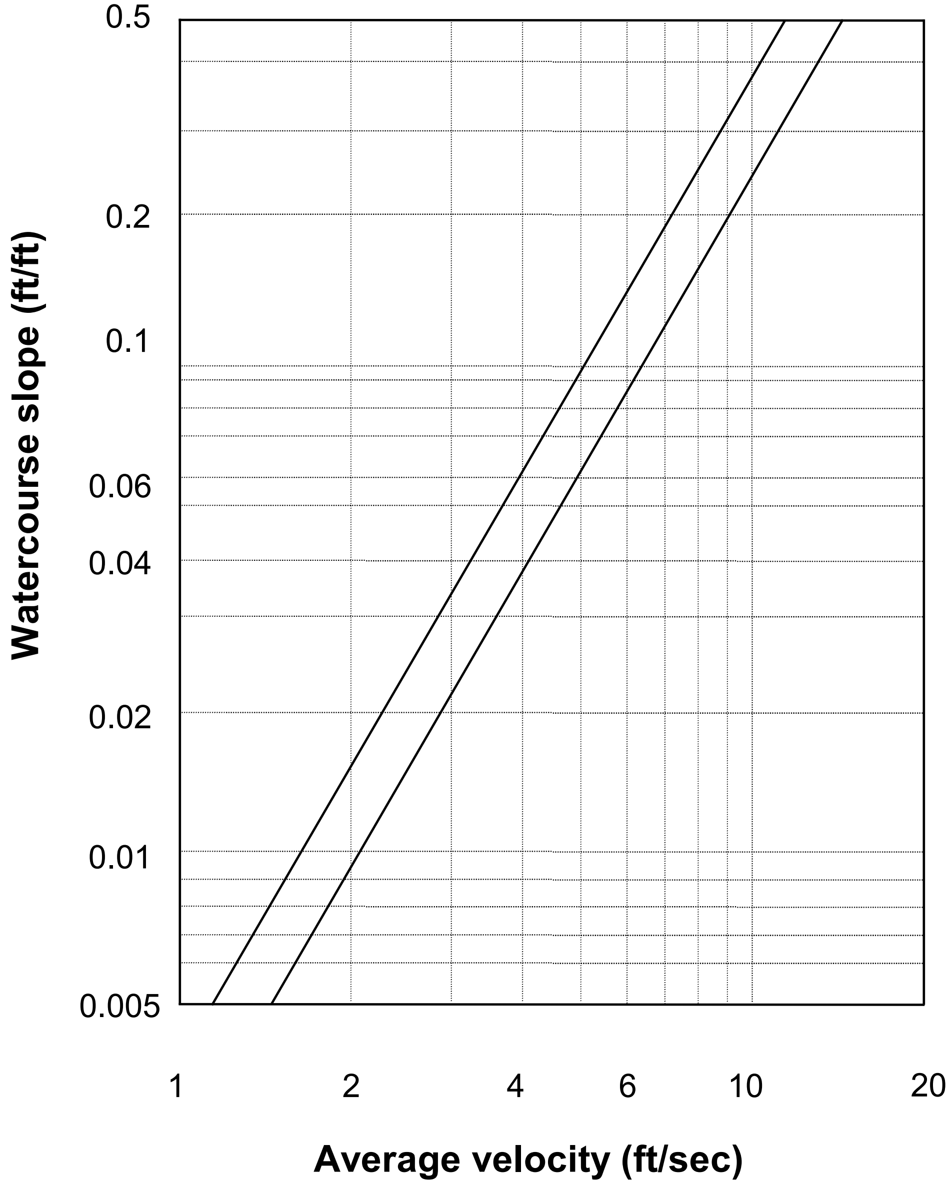


Figure 4A-6. Shallow Concentrated Flow Average Velocities

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

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

Sheet Flow (Applicable to T_c only)

Segment ID			
1. Surface description (Table 4-3)……………………….			
2. Manning's roughness coefficient, n, (Table 4-3)………..			
3. Flow length, L (maximum 300 ft)..………………… ft			
4. Two-year 24-hour rainfall, P_{2-24}…..…………………. in			
5. Land slope, s……………………………………… ft/ft			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_{2-24}^{0.5}\,s^{0.4}}$ Compute T_t………………. hr		+	=

Shallow Concentrated Flow

Segment ID			
7. Surface description (paved or unpaved))……………			
8. Flow length, L ………..……………………………. ft			
9. Watercourse slope, s …..………………………….. ft/ft			
10. Average velocity, V (Figure 4A-6) …………….. ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t……………..... hr		+	=

Channel Flow

Segment ID			
12. Cross sectional flow area, a ……………………. ft^2			
13. Wetted perimeter, p_w ……………………………... .ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute T_t…………. ft			
15. Channel slope, s ………………………………… ft/ft			
16. Manning's roughness coefficient, n ……………... in			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V…………... ft/s			
18. Flow length, L ………………………………………..			
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ………….. hr		+	=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ………………………………………….…			Hr

Figure 4A-7. NRCS Time of Concentration Worksheet

Table 4A-1. Runoff Curve Numbers For Urban Areas[a]

Cover Type and Hydrologic Condition	Average Percent Impervious Area[b]	Curve number for hydrologic soil group A	B	C	D
Fully developed urban areas (vegetation established):					
Open space (lawn, parks, golf courses, cemeteries, etc.)[c]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of -way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas:					
Newly graded areas (pervious areas only, no vegetation)[d]		77	86	91	94

(continued)

Table 4A-1. (continued)

Idle lands (CNs are determined using cover types similar to those in Table 4A-3)

---

[a]Average runoff condition, and I = 0.2S

[b]The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CNs for other combinations of conditions may be computed using methods described in TR 55.

[c]CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.

[d]Composite CNs to use for the design of temporary measures during grading and construction should be computed based on the degree of development (impervious area percentage) and the CNs for the newly graded pervious areas.

Sources:

American Association of State Highway and Transportation Officials. *Model Drainage Manual* [Metric Edition]. Washington, D.C. 1999.

Metropolitan Government of Nashville and Davidson County Department of Public Works Engineering Division. *Stormwater Management Manual* . Nashville, Tennessee. Sept. 1999.

United States Department of Agriculture. Soil Conservation Service. Engineering Division. *Urban Hydrology for Small Watersheds - Technical Release 55* . June 1986 (available for download at http://www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html).

Table 4A-2. Runoff Curve Numbers for Cultivated Agricultural Lands[a]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment[b]	Hydrologic condition[c]	A	B	C	D
Fallow	Bare soil	-----	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C +CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80

(continued)

Table 4A-2. (continued)

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment[b]	Hydrologic condition[c]	A	B	C	D
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[a]Average runoff condition, I = 0.2S.

[b]Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

[c]Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close seeded legumes, (d) percent of residue cover on the land surface (good $\geq$ 20%),and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Sources:

American Association of State Highway and Transportation Officials. *Model Drainage Manual* [Metric Edition]. Washington, D.C. 1999.

Metropolitan Government of Nashville and Davidson County Department of Public Works Engineering Division. *Stormwater Management Manual*. Nashville, Tennessee. Sept. 1999.

United States Department of Agriculture. Soil Conservation Service. Engineering Division. *Urban Hydrology for Small Watersheds - Technical Release 55*. June 1986 (available for download at http://www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html).

Table 4A-3. Runoff Curve Numbers For Rural Areas and Other Agricultural Lands[a]

Cover Description: Cover Type	Hydrologic Condition	Curve number for hydrologic soil group: A	B	C	D
Pasture, grassland, or range--continuous forage for grazing[b]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow--continuous grass, protected from grazing and generally mowed for hay	----	30	58	71	78
Brush--brush-weed-grass mixture with brush the major element[c]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[d]	48	65	73
Woods--grass combination (orchard or tree farm)[e]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[f]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[d]	55	70	77
Farmsteads--buildings, lanes, driveways, and surrounding lots	----	59	74	82	86

[a]Average runoff condition, and I = 0.2S.

[b]Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[c]Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.

(continued)

Table 4A-3. (continued)

[d]Actual curve number is less than 30; use CN = 30 for runoff computations.

[e]CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from CNs for woods and pastures.

[f]Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Sources:
American Association of State Highway and Transportation Officials. Model Drainage Manual [Metric Edition]. Washington, D.C. 1999.

Metropolitan Government of Nashville and Davidson County Department of Public Works Engineering Division. *Stormwater Management Manual* . Nashville, Tennessee. Sept. 1999.

United States Department of Agriculture. Soil Conservation Service. Engineering Division. *Urban Hydrology for Small Watersheds - Technical Release 55* . June 1986 (available for download at http://www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html).

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Runoff curve number

Soil name and hydrologic group (Table 4A-5)	Cover Description	CN [1] Table 4A-1	CN [1] Table 4A-2	CN [1] Table 4A-3	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
				Totals →		

[1] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ________ = ________ ; **Use CN →** ________

Figure 4A-8. Curve Number Worksheet

Source: TR-55 Second Edition, June 1986.

Table 4A-4. TENNESSEE HYDROLOGIC SOIL GROUPS

Soil	HSG	Soil	HSG	Soil	HSG
ADLER	C	BILTMORE	A	CHAGRIN	B
AGEE	D	BIRDS	B/D	CHENNEBY	C
ALCOA	B	BLAND	C	CHESTNUT	B
ALLEGHENY	B	BLEDSOE	C	CHEWACLA	C
ALLEN	B	BLOOMINGDALE	D	CHICKASAW	C
ALLIGATOR	D	BLUESTOCKING	C	CHISWELL	D
ALMAVILLE	D	BODINE	B	CHRISTIAN	C
ALMO	D	BOLTON	B	CITICO	B
ALTAVISTA	C	BONAIR	D	CLAIBORNE	B
ALTICREST	B	BONN	D	CLARKRANGE	C
AMAGON	D	BOSKET	B	CLARKSVILLE	B
APISON	B	BOSWELL	D	CLEVELAND	C
ARENTS	B	BOULDIN	B	CLOUDLAND (MONONGAHELA)	C
ARKABUTLA	C	BOWDRE	C	COBBLY ALLUVIUM	B
ARKAQUA	C	BRADDOCK	B	COBBLY ALLUVIUM (COBB)	B
ARMOUR	B	BRADYVILLE	C	COBBLY ALLUVIUM (WELCHLAND)	B
ARMUCHEE	C	BRANDON	B	COBSTONE	B
ARRINGTON	B	BRANTLEY	C	COGHILL	B
ASHE	B	BRASSTOWN	B	COILE	C
ASHE VARIANT	B	BRAXTON	C	COLBERT	D
ASHWOOD	C	BREVARD	B	COLLEGEDALE	C
ASKEW	C	BROOKSHIRE	C	COLLINS	C
ATKINS	D	BRUNO	A	COLVARD	B
AUGUSTA	C	BULADEAN	B	COMBS	B
BALSAM	B	BUNCOMBE	A	COMMERCE	C
BARBOURVILLE	B	BURTON	B	CONASAUGA	C
BARFIELD	D	BUSSELTOWN	C	CONGAREE	B
BARGER	C	BYLER	C	CONVENT	C
BAXTER	B	BLOOMINGDALE	D	COOKEVILLE(DEWEY)	B
BAYS	C	BUSSELTOWN	C	CORRYTON	B
BEASON	C	CALHOUN	D	COTACO	C
BEDFORD	C	CALLOWAY	C	CRAGGEY	D
BEECHY		CALVIN	C	CRAIGSVILLE	B
BEECHY (BIBB)	D	CANEYVILLE	C	CREVASSE	A
BEERSHEBA	B	CANNON	B	CRIDER	B
BELLAMY	C	CAPSHAW	C	CROSSVILLE	B
BETHESDA	C	CAPTINA	C	CULLASAJA	B
BEWLEYVILLE	B	CARBO	C	CULLEOKA	B
BIBB	D	CATASKA	C	CUMBERLAND	B
BIFFLE	B	CENTER	C	CURTISTOWN	B

(continued)

Table 4A-4. TENNESSEE HYDROLOGIC SOIL GROUPS (continued)

Soil	HSG	Soil	HSG	Soil	HSG
CUTHBERT	C	FALKNER	C	HOLSTON	B
CUTSHIN	B	FARRAGUT	C	HUMPHREYS	B
CYNTHIANA	D	FLETCHER	B	HUNTINGTON	B
DANDRIDGE	D	FORESTDALE	D	HYMON (COLLINS)	C
DEANBURG	B	FOUNTAIN	D	HYMON (IUKA)	C
DECATUR	B	FRANKSTOWN	B	IBERIA	D
DEKOVEN	D	FREELAND	C	INA (ARKABUTLA)	C
DELLROSE	B	FULLERTON	B	INA (MANTCHIE)	C
DEWEY	B	GILPIN	C	INMAN	C
DEXTER	B	GLADDICE	C	IRONCITY	B
DICKSON	C	GLADEVILLE	D	IUKA	C
DILLARD	C	GODWIN	D	JEFFERSON	B
DILTON	D	GREENDALE	B	JEFFREY	B
DITNEY	C	GREENLEE	B	JUNALUSKA	B
DONERAIL	B	GRENADA	C	KEENER	B
DOWELLTON	D	GRIMSLEY	B	KEYESPOINT	D
DUBBS	B	GROSECLOSE	C	KINSTON	B/D
DULAC	C	GUTHRIE	D	LANDISBURG (PADEN)	C
DUMPS	A	GUYTON	D	LANTON	D
DUNDEE	C	GUMDALE	C	LAWRENCE	C
DUNMORE	B	HAGERSTOWN	C	LAX	C
DUNNING	D	HAMBLEN	C	LEADVALE	C
EAGLEVILLE	D	HAMPSHIRE	C	LEE	D
EALY	B	HANCEVILLE	B	LEESBURG	B
EDNEYTOWN	B	HARMILLER	B	LEHEW	C
EDNEYVILLE	B	HARPETH	B	LEXINGTON	B
EGAM	C	HARTSELL	B	LEXINGTON MATERIALS	B
ELK	B	HARTSELLS	B	LILY	B
ELKINS	D	HATBORO	D	LINDELL	C
ELLISVILLE	B	HATCHIE	C	LINDSIDE	C
EMORY	B	HAWTHORNE	B	LINKER	B
ENDERS	C	HAYESVILLE	B	LITZ	C
ENNIS	B	HAYTER	B	LOBDELL	B
ENVILLE	C	HENDON	C	LOBELVILLE	C
ETOWAH	B	HENRY	D	LOMOND	B
EUSTIS	A	HERMITAGE	B	LONEWOOD	B
EVARD	B	HICKS	B	LONON	B
FAIRMOUNT	D	HILLWOOD	B	LORING	C
FALAYA	D	HOLLYWOOD	D	LOSTCOVE	B

(continued)

Table 4A-4. TENNESSEE HYDROLOGIC SOIL GROUPS (continued)

Soil	HSG	Soil	HSG	Soil	HSG
LUVERNE	C	NORENE	C	ROSEBLOOM	D
LYNNVILLE	C	NORTHCOVE	B	ROSMAN	B
MAGNOLIA (SMITHDALE)	B	OAKLIMETER	C	ROUTON	D
MANTACHIE	C	OCANA	B	RUSTON	B
MARSH	B	OCHLOCKONEE	B	SAFFELL	B
MASADA	C	OKTIBBEHA	D	SANDHILL	B
MAURY	B	OOLTEWAH	C	SANGO	C
MAYMEAD	B	OPENLAKE	D	SAUNOOK	B
MAYMEAD VARIANT	A	OPEQUON	C	SAVANNAH	C
MCCAMY	B	PACE (MINVALE)	B	SEES	C
MELVIN	D	PADEN	C	SENGTOWN	B
MEMPHIS	B	PAILO	B	SENSABAUGH	B
MERCER	C	PEMBROKE	B	SEQUATCHIE	B
MHOON	D	PETROS	D	SEQUOIA	C
MIMOSA	C	PETTYJON	B	SEWANEE	B
MINTER	D	PHILO	B	SHACK	B
MINVALE	B	PICKAWAY (BYLER)	C	SHADY	B
MONOGAHELA	C	PICKWICK	B	SHANNON (VICKSBURG)	B
MONONGAHELA	C	PIGEONROOST	C	SHARKEY	D
MONTEAGLE	B	PIKEVILLE	B	SHELOCTA	B
MONTEVALLO	D	PINEOLA	B	SHOUNS	B
MOREHEAD	C	PLOTT	B	SHUBUTA	C
MORGANFIELD	B	POPE	B	SILERTON	B
MOUNTVIEW	B	PORTERS	B	SKIDMORE	B
MULLINS	D	POTOMAC	A	SMITHDALE	B
MUSE	C	PRADER	D	SOCO	B
MUSKINGUM	C	PROVIDENCE	C	SPIVEY	B
NATCHEZ	B	PURDY	D	STASER	B
NEEDMORE	C	RAMSEY	D	STATE	B
NELLA	B	RANGER	C	STATLER	B
NELSE	B	RED HILLS	B	STEADMAN	C
NESBITT	B	REELFOOT	C	STECOAH	B
NEUBERT	B	RIVERBY	A	STEEKEE	C
NEWARK	C	ROANE	C	STEENS	C
NIXA	C	ROANOKE	D	STEMLEY	C
NOAH	B	ROBERTSVILLE	D	STIVERSVILLE	B
NOLICHUCKY	B	ROBINSONVILLE	B	SUCHES	B
NOLIN	B	ROCKDELL	B	SUGARGROVE	B
NONABURG	D	ROELLEN	D	SULLIVAN	B

(continued)

Table 4A-4. TENNESSEE HYDROLOGIC SOIL GROUPS (continued)

Soil	HSG	Soil	HSG	Soil	HSG
SULPHURA	B	TIGRETT (ELK)	B	VARILLA	B
SUMTER	C	TILSIT	C	VICKSBURG	B
SUNLIGHT	C	TIPPAH	C	WAKELAND	C
SUSQUEHANNA	D	TIPTONVILLE	B	WALLEN	B
SWAFFORD	C	TOCCOA	B	WAVERLY	B/D
SWAIM (TALBOTT)	C	TOOTERVILLE	D	WAYAH	B
SWAIM(MIMOSA)	C	TOWNLEY	C	WAYNESBORO	B
SWAMP (ROSEBLOOM)	D	TRACE	B	WEAVER	C
SWEATMAN	C	TRANSYLVANIA	B	WEHADKEE	D
SYKES	B	TSALI	C	WELCHLAND	B
SYLCO	C	TUNICA	D	WELLSTON	B
SYLVATUS	D	TUPELO	D	WHITESBURG	C
TAFT	C	TUSQUITEE	B	WHITWELL	C
TALBOTT	C	TYLER	C	WOLFTEVER	C
TARKLIN	C	UNA	D	WOODMONT	C
TASSO	B	UNAKA	B	WOOLPER	C
TATE	B	UNICOI	C	WORTHEN	B
TEAS	C	UNISON	B	ZENITH	B
TELLICO	B	UPSHUR VARIANT	C		
TICHNOR	D	VACHERIE	C		

Source: National Soils Information System (NASIS) Database, USDA-NRCS, searched June 8, 2001.

4.06.2 EXAMPLE PROBLEMS

4.06.2.1 RATIONAL METHOD EXAMPLE PROBLEMS

4.06.2.1.1 Simple Drainage Area Design Discharge Example

GIVEN: A ditch will collect runoff from the proposed roadway and an adjacent watershed. The tributary area has a fairly uniform cross section with 30 feet of bituminous concrete and shoulders, 15 feet of gravel lined ditch (1" stones), and 200 feet of meadow draining to the ditch. The ditch begins at a small summit and drains to a culvert for a length of 1,000 feet. The location of this proposed road is near Franklin, Tennessee.

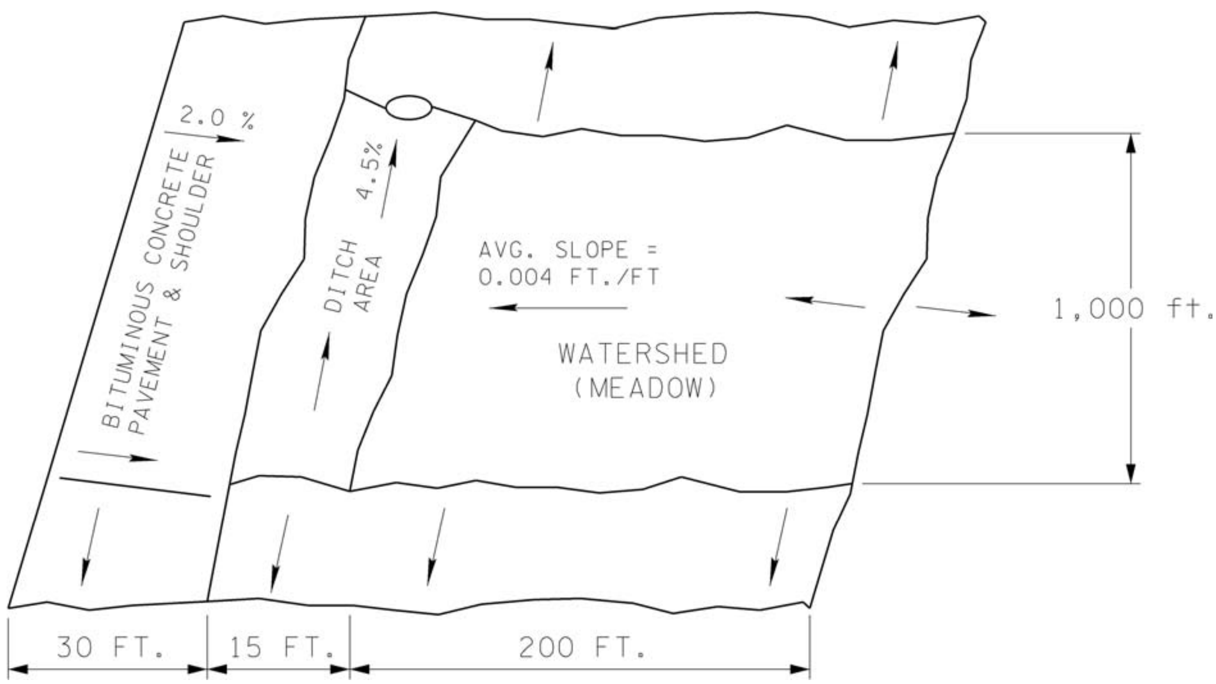


Figure 4A-9. Simple Drainage Example

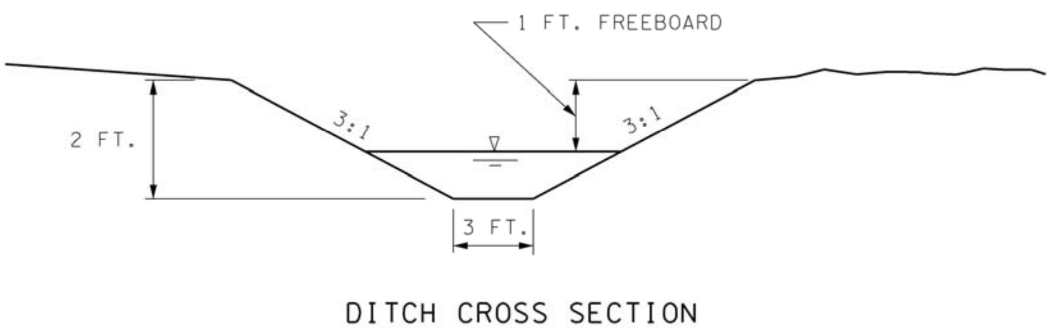


Figure 4A-10. Ditch Cross Section For Simple Drainage Area Example

SOLUTION:

STEP 1. Verify Rational Method is the Proper Method

SOLUTION:

DETERMINE DRAINAGE AREA

AREA = 1,000 ft. X (30 ft. + 15 ft. + 200 ft.)
= 245,000 square feet
= 5.62 acres

Since 5.62 acres is less than 100 acres and no other special conditions are identified, the Rational Method is selected (Q=CIA).

STEP 2. Determine Runoff Coefficient

SOLUTION:

Table 4A-5. Runoff Coefficient Calculation Example

Type of Surface	AREA		Runoff Coefficient (C) (Table 4-2)	C X A
	Square Feet	Acres (A)		
Roadway (Bituminous Concrete)	30,000	0.69	0.9	0.62
Ditch (Gravel)	15,000	0.34	0.6	0.20
Meadow	200,000	4.59	0.3	1.38
TOTAL	245,000	5.62		2.20

Weighted C = $\frac{2.20}{5.62} = 0.39$

STEP 3. Find Time of Concentration and Rainfall Intensity

SOLUTION:

Find the time of concentration. The time of concentration for this drainage area includes overland flow travel time and channel travel time. The overland flow component is obtained from the Kinematic Wave equation or the NRCS TR-55 method because the flow is assumed to be sheet flow. Sheet flow is assumed because areas of shallow concentrated flow are not identified and the distance to the ditch is 200 feet, which is less than the 300 feet requirement where shallow concentrated flow would need to be considered.

A. Sheet Flow Travel Time.
Known parameters for Kinematic Wave equation
L = 200 feet
n = 0.35 (Table 4-3 - assume "meadow" is similar to "pasture")
s = 0.004 ft./ft.
C = 0.938 (constant for Kinematic Wave equation)

Iteration 1.
Assume $t_{t(\text{sheet flow})}$ = 10 minutes
From IDF Curve (Figure 4A-5), I = 6.9 in./hr.

Use equation (4-5) : $t_t = C\frac{n^{0.6}L^{0.6}}{I^{0.4}s^{0.3}}$

$$10\,min. \rightarrow 0.938\frac{(0.35)^{0.6}(200)^{0.6}}{(6.9)^{0.4}(0.004)^{0.3}} = 29.0\,min.$$

Iteration 2.
Assume higher $t_{t(\text{sheet flow})}$ = 40 minutes
From IDF Curve (Figure 4A-5), I = 3.4 in./hr.

$$40\,min. \rightarrow 0.938\frac{(0.35)^{0.6}(200)^{0.6}}{(3.4)^{0.4}(0.004)^{0.3}} = 38.6\,min.$$

Iteration 3.
Assume lower $t_{t(\text{sheet flow})}$ = 38 minutes
From IDF Curve (Figure 4A-5), I = 3.5 in./hr.

$$38\,min. \rightarrow 0.938\frac{(0.35)^{0.6}(200)^{0.6}}{(3.5)^{0.4}(0.004)^{0.3}} = 38.1\,min.$$

Therefore $t_{t(sheet\ flow)}$ = 38 minutes.

B. Channel Travel Time
Find Channel Water Velocity

Use equation (4-9): $V = \frac{1.49}{n} * R_h^{0.67} * S_c^{0.5}$

where n = 0.04 (From table in Chapter 5)
R_h = A/P (assume 1 ft. of freeboard)
A = 6 ft.^{2} (area)
P = 9.3 ft. (wetted perimeter)
S_c = 0.045 ft./ft. (slope of channel)

$$V = \frac{1.49}{0.04} * (\frac{6}{9.3})^{0.67} * (0.045)^{0.5} = 5.9 \frac{ft.}{s.}$$

Find $t_{t(channel)}$

Use equation (4-3): $t_{t(channel)} = \frac{L}{60 * V} = \frac{1000}{60 * 5.9} = 2.8 \min.$

C. Time of Concentration

Use equation (4-2): $t_c = t_{t(sheet\ flow)} + t_{t(channel)}$ = 38 + 2.8 = 41 minutes

D. Rainfall Intensity

From Figure 4A-5 where t_c = 41 minutes, I = 3.4 in./hr.

STEP 4. Find Storm Runoff

Use equation (4-1): Q_{50} = CIA = (0.39) (3.4 in./hr.) (5.62 acres) = 7.5 cfs

STEP 5. Check to see if pavement provides higher discharge than meadow.

A. Determine Runoff Coefficient

SOLUTION:

Table 4A-6. Runoff Coefficient Calculation Example Check

Type of Surface	**AREA**		**Runoff Coefficient (C) (Table 4.2)**	**C X A**
	Square Feet	**Acres (A)**		
Roadway (Bituminous Concrete)	30,000	0.69	0.9	0.62
Ditch (Gravel)	15,000	0.34	0.6	0.20
TOTAL	45,000	1.03		0.82

Weighted C = $\frac{0.82}{1.03} = 0.80$

B. Find Time of Concentration and Rainfall Intensity

SOLUTION:

Find Time of Concentration. The time of concentration for this drainage area includes overland flow travel time and channel travel time. The overland flow component is obtained from the Kinematic Wave equation or the NRCS TR-55 method because the flow is assumed to be sheet flow for the pavement.

1. Sheet Flow Travel Time.

Known parameters for Kinematic Wave equation
L = 30 feet
n = 0.011 (Table 4-3)
s = 0.02 ft./ft.
C = 0.938 (constant for Kinematic Wave equation)

Iteration 1.
Assume $t_{t(\text{sheet flow})}$ = 5 minutes
From IDF Curve (Figure 4A-5), I = 9.0 in./hr.

Use equation (4-5): $t_t = C\frac{n^{0.6}L^{0.6}}{I^{0.4}s^{0.3}}$

$$5\,min. \rightarrow 0.938\frac{(0.011)^{0.6}(30)^{0.6}}{(9.0)^{0.4}(0.02)^{0.3}} = 0.6\,min.$$

This indicates that the sheet flow travel time to the ditch is much less than 5 minutes.

2. Channel Travel Time will be the same 2.8 minutes as calculated above.

3. The Time of Concentration calculates to 0.6 min + 2.8 minutes = 3.4 minutes. However, in Section 4.04.1.3 we are instructed to use a time of concentration no lower than 5 minutes. Use 5 minutes.

4. Rainfall Intensity

From Figure 4A-5 where t_c = 5 minutes, I = 9.0 in./hr.

C. Find Storm Runoff

Using equation (4-1): Q_{50} = CIA = (0.80) (9.0 in./hr.) (1.03 acres) = 7.4 cfs
This indicates that the pavement and ditch almost provide the same discharge as the entire drainage area.

STEP 6. Determine Design Discharge

The design discharge that should be used is 7.5 cfs because 7.5 cfs > 7.4 cfs.

4.06.2.1.2 Complex Drainage Area Design Discharge Example

GIVEN: A ditch will collect runoff from the proposed roadway and an adjacent watershed. The tributary area has a fairly uniform cross section with 30 feet of bituminous concrete and shoulders, 15 feet of grass lined ditch with some small shrubs and cattails, and 550 feet of forested land with light underbrush draining to the ditch. The ditch begins at a small summit and drains to a culvert for a length of 850 feet. The location of this proposed road is outside of Cleveland, Tennessee.

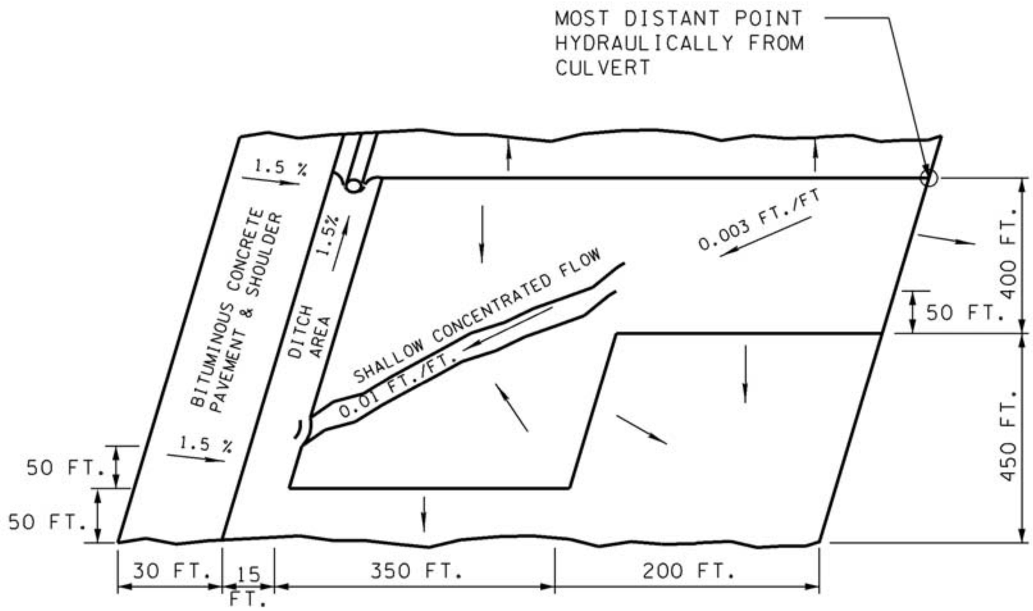


Figure 4A-11. Complex Drainage Area Example

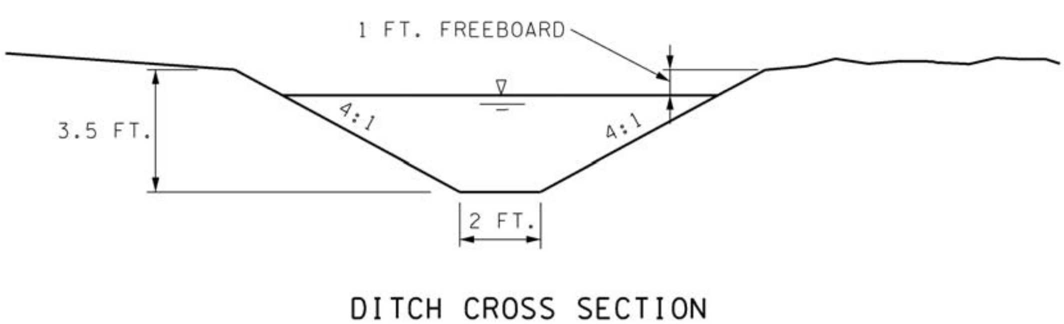


Figure 4A-12. Ditch Cross Section for Complex Drainage Area Example

FIND: Storm runoff to culvert for a 50-year storm.

SOLUTION:

STEP 1. Verify Rational Method is the Proper Method

SOLUTION:

DETERMINE DRAINAGE AREA

AREA = 30 ft.(850 ft.) + 15 ft.(850 ft.) + 350 ft.(850 ft.) + 200 ft.(400 ft.)
= 415,750 square feet
= 9.54 acres

Since 9.54 acres is less than 100 acres and no other special conditions are identified, the Rational Method is selected (Q=CIA).

STEP 2. Determine Runoff Coefficient

SOLUTION:

Table 4A-7. Runoff Coefficient Calculation – Complex Example

Type of Surface	**AREA**		**Runoff Coefficient (C) (Table 4-2)**	**C X A**
	Square Feet	**Acres (A)**		
Roadway (Bituminous Concrete)	25,500	0.59	0.9	0.53
Ditch (Grass & Vegetation)	12,750	0.29	0.4	0.12
Forested Land	377,500	8.67	0.2	1.73
TOTAL	415,750	9.55		2.38

Weighted C = $\frac{2.38}{9.55} = 0.25$

STEP 3. Find Time of Concentration and Rainfall Intensity

SOLUTION:

Find time of concentration. The time of concentration for this drainage area includes overland flow travel time and channel travel time. The overland flow is made of both sheet flow and shallow concentrated flow as described. The sheet flow component is obtained from the Kinematic Wave equation or the TR-55 method. The shallow concentrated flow travel time can be estimated by the equations or nomograph provided in this manual.

A. Sheet Flow Travel Time.

Known parameters for Kinematic Wave equation

L = $\sqrt{400^2 + 200^2}$ = 447 feet. However, 300 feet is the maximum allowed for sheet flow.

n = 0.400 (Table 4-3)

s = 0.003 ft./ft.

C = 0.938 (constant for Kinematic Wave equation)

Iteration 1.
Assume $t_{t(\text{sheet flow})}$ = 10 minutes
From IDF Curve (Figure 4A-2), I = 6.9 in./hr.

Use equation (4-5): $t_t = C\dfrac{n^{0.6}L^{0.6}}{I^{0.4}s^{0.3}}$

$$10\,min. \rightarrow 0.938\frac{(0.40)^{0.6}(300)^{0.6}}{(6.9)^{0.4}(0.003)^{0.3}} = 43.8\,min.$$

Iteration 2.
Assume higher $t_{t(\text{sheet flow})}$ = 45 minutes
From IDF Curve (Figure 4A-2), I = 3.3 in./hr.

$$45\,min. \rightarrow 0.938\frac{(0.40)^{0.6}(300)^{0.6}}{(3.3)^{0.4}(0.003)^{0.3}} = 58.8\,min.$$

Iteration 3.
Assume higher $t_{t(\text{sheet flow})}$ = 60 minutes
From IDF Curve (Figure 4A-2), I = 2.75 in./hr.

$$60\,min. \rightarrow 0.938\frac{(0.40)^{0.6}(300)^{0.6}}{(2.75)^{0.4}(0.003)^{0.3}} = 63.2\,min.$$

Iteration 4.
Assume higher $t_{t(\text{sheet flow})}$ = 64 minutes
From IDF Curve (Figure 4A-2), I = 2.7 in./hr.

$$64\,min. \rightarrow 0.938\frac{(0.40)^{0.6}(300)^{0.6}}{(2.70)^{0.4}(0.003)^{0.3}} = 63.7\,min.$$

Therefore $t_{t(\text{sheet flow})}$ = 64 minutes.

B. Shallow Concentrated Flow Travel Time
Find Velocity of Shallow Concentrated Flow

Use equation (4-7): $V_{unpaved} = 16.1345(s)^{0.5}$
where s = 0.01 ft/ft

$$V_{unpaved} = 16.1345(0.01)^{0.5} = 1.6\frac{ft.}{s.}$$

Use velocity to calculate travel time.

Use equation (4-3): $t_t = \frac{L}{60 * V}$

where L = $\sqrt{350^2 + 450^2}$ + (447 - 300) = 717 ft.
V = 1.6 ft./s.

$t_{t(\text{shallow concentrated flow})}$ = 7.5 min.

C. Channel Travel Time

Find Channel Water Velocity

Use equation (4-9): $V = \frac{1.49}{n} * R_h^{0.67} * S_c^{0.5}$

where n = 0.20 (From table in Chapter 5)
R_h = A/P (Assume 1 ft. of freeboard)
A = 30 ft.^{2} (area)
P = 22.6 ft. (wetted perimeter)
S_c = 0.015 ft./ft. (slope of channel)

$$V = \frac{1.49}{0.20} * (\frac{30}{22.6})^{0.67} * (0.015)^{0.5} = 1.1 \frac{\text{ft.}}{\text{s.}}$$

Find $t_{t(\text{channel})}$

Use equation (4-3): $t_{t(channel)} = \frac{L}{60 * V} = \frac{800}{60 * 1.1} = 12.1 \min.$

D. Time of Concentration

Use equation (4-2):
$t_c = t_{t(\text{sheet flow})} + t_{t(\text{shallow concentrated flow})} + t_{t(\text{channel})}$ = 64 + 7.5 + 12.1 = 84 minutes

E. Rainfall Intensity

From Figure 4A-2 where t_c = 84 minutes, I = 2.2 in./hr.

STEP 4. Find Storm Runoff

Use equation (4-1): Q_{50} = CIA = (0.25) (2.2 in./hr.) (9.55 acres) = 5.3 cfs

STEP 5. Check to see if pavement provides higher discharge than forested area.

A. Determine Runoff Coefficient

SOLUTION:

Table 4A-8. Runoff Coefficient Calculation – Complex Example Check

Type of Surface	**AREA**		**Runoff Coefficient (C) (Table 4-2)**	**C X A**
	Square Feet	**Acres (A)**		
Roadway (Bituminous Concrete)	25,500	0.59	0.9	0.53
Ditch (Gravel)	12,750	0.29	0.4	0.12
TOTAL	38,250	0.88		0.65

Weighted C = $\frac{0.65}{0.88} = 0.73$

B. Find Time of Concentration and Rainfall Intensity

SOLUTION:

Find Time of Concentration. The time of concentration for this drainage area includes overland flow travel time and channel travel time. The overland flow component is obtained from the Kinematic Wave equation or the TR-55 method because the flow is assumed to be sheet flow for the pavement.

Sheet Flow Travel Time.

Known parameters for Kinematic Wave equation.
L = 30 feet
n = 0.011 (Table 4-3)
s = 0.015 ft./ft.
C = 0.938 (constant for Kinematic Wave equation)

Iteration 1.
Assume $t_{t(\text{sheet flow})}$ = 5 minutes
From IDF Curve (Figure 4A-2), I = 9.0 in./hr.

Use equation (4-5): $t_t = C\frac{n^{0.6}L^{0.6}}{I^{0.4}s^{0.3}}$

$$5\,min. \rightarrow 0.938\frac{(0.011)^{0.6}(30)^{0.6}}{(9.0)^{0.4}(0.015)^{0.3}} = 0.7\,min.$$

This indicates that the sheet flow travel time to the ditch is much less than 5 minutes.

Channel Travel Time will be the same 12.1 minutes as calculated above.

The Time of Concentration calculates to 0.7 min + 12.1 minutes = 13 minutes.

Rainfall Intensity

From Figure 4A-2 where t_c = 13 minutes, I = 6.4 in./hr.

C. Find Storm Runoff

Using Equation (4-1): Q_{50} = CIA = (0.73) (6.4 in./hr.) (0.88 acres) = 4.1 cfs
This indicates that the pavement and ditch provide less discharge than the entire drainage area.

STEP 6. Determine Design Discharge

The design discharge that should be used is 5.3 cfs because 5.3 cfs > 4.1 cfs.

4.06.2.1.3 Computer Application

Using the software program HYDRAIN and the hydrology module, HYDRO, two choices are available for the designer to calculate the design flow. HYDRO permits the designer to calculate the design runoff by having the software reference internal intensity duration frequency curves and then calculate a time of concentration by a choice of methods. HYDRO also permits the designer to input the time of concentration and the intensity directly. With the Rainfall Intensity Duration Frequency curves scheduled for update, the designer should not have HYDRO reference the software's internal curves and should instead input this information directly. The time of concentration methodology within HYDRO does not always correspond to the procedures outlined in this manual. The differences become more apparent as the drainage area becomes more complex, the designer should select an appropriate method of calculating the time of concentration and then examine the results closely. HYDRO may combine various combinations of travel times into one calculation which may result in a different value than when each type of travel time is individually considered. It is preferred that the time of concentration be calculated by hand and input into HYDRO. Similarly, since the IDF curves used by TDOT are anticipated to be changed shortly, calculating the intensity should be done with the curves provided in this manual and the value manually input into HYDRO. HYDRAIN also appears to round the discharge flow to the closest cubic foot per second (cfs). When flow is less than 10 cfs, it is recommended to show the flow to the nearest tenth of a cfs. The designer should be aware of HYDRO's limitations.

The two rational method examples provided previously for simple and complex drainage areas have also been input into HYDRO. The inputs and results are included in Figures 4A-13 through 4A-20. Each example was input into HYDRO with the time of concentration and intensity input directly.

```
JOBRATIONAL METHOD EXAMPLE
FLW1
RPD50
TCU0.68
UIT3.4
RTL0.3 * * * * 0.6 *
BAS4.59 0 0 0 0 0.34 0.69
END
```

Figure 4A-13. HYDRO Input File (Simple Example) T_c & I Input

```
               *************** HYDRO - Version 6.1 ***************
                *  HEC19 / Design Event vs Return Period Program  *
                *              Date of Run: 06-22-2001            *

        Page No  1
                      RATIONAL METHOD
        EXAMPLE
 --- Input File: C:\USER\JMORGAN\RAT1A.HDO
  FLW 1
  === FLOW ANALYSIS (Rational Method Suboption) Selected ...
  RPD 50
       --- The Selected Return Period is   50 years.
        TCU 0.68
       --- The User-Supplied Time of Concentration is    .680 h.
        UIT 3.4
       --- The User-Supplied Rainfall Intensity is   3.400 in/h.
        RTL 0.3 * * * * 0.6 *
        BAS 4.59 0 0 0 0 0.34 0.69
       --- The Basin Area is      5.62 ac
        +++ End of HYDRO Command File
               Subarea Acreages & Runoff Coefficients
                 Meadow ..........    4.59 C =  .300
                 Woods ...........     .00 C =  .200*
                 Pasture .........     .00 C =  .300*
                 Crops ...........     .00 C =  .300*
                 Residential .....     .00 C =  .400*
               Urban/Highway ...     .34 C =  .600
          Pavement ........     .69 C =  .900*
          - TOTAL Basin Area     5.62 ac -
          Weighted runoff coefficient is .392
          +++ NOTICE: * indicates that a default
                    runoff coefficient used.
     *************************************************
     *  Time of Concentration equals     .68 h       *
     *        Intensity equals       3.40 in/h       *
     *************************************************
          **********************************
          * The Peak Flow is        7. cfs *
          **********************************
                   +++ NORMAL END OF HYDRO
      ***** HYDRO ***** (Version 6.1) *****         Date 06-22-2001
                                                         Page No  2
        SIMPLE DRAINAGE AREA RATIONAL METHOD EXAMPLE
     *************************************************
     *  Time of Concentration equals     .67 h       *
     *        Intensity equals       3.42 in/h       *
     *************************************************
          **********************************
          * The Peak Flow is        8. cfs *
          **********************************
              +++ NORMAL END OF HYDRO
```

Figure 4A-14. HYDRO Output File (Simple Example) T_c & I Input

```
JOBCOMPLEX RATIONAL METHOD EXAMPLE
FLW1
RPD50
TCU1.40
UIT2.2
RTL* * * * * 0.4 *
BAS0 8.67 0 0 0 0.29 0.59
END
```

Figure 4A-15. HYDRO Input File (Complex Example) T_c & I Input

```
   *************** HYDRO - Version 6.1 ***************
*  HEC19 / Design Event vs Return Period Program  *
*              Date of Run: 06-26-2001            *
                                                     Page No  1
         COMPLEX RATIONAL METHOD EXAMPLE
--- Input File: C:\USER\JMORGAN\RAT2A.HDO
 FLW 1
 === FLOW ANALYSIS (Rational Method Suboption) Selected ...
 RPD 50
--- The Selected Return Period is   50 years.
 TCU 1.40
--- The User-Supplied Time of Concentration is   1.400 h.
 UIT 2.2
--- The User-Supplied Rainfall Intensity is   2.200 in/h.
 RTL * * * * * 0.4 *
 BAS 0 8.67 0 0 0 0.29 0.59
--- The Basin Area is      9.55 ac
 +++ End of HYDRO Command File
     Subarea Acreages & Runoff Coefficients
      Meadow .........     .00 C =  .200*
      Woods ..........    8.67 C =  .200*
      Pasture ........     .00 C =  .300*
      Crops ..........     .00 C =  .300*
      Residential .....    .00 C =  .400*
      Urban/Highway ...    .29 C =  .400
      Pavement ........    .59 C =  .900*
      - TOTAL Basin Area     9.55 ac -
      Weighted runoff coefficient is .249
      +++ NOTICE: * indicates that a default
                            runoff coefficient used.
                  *************************************************
                   *  Time of Concentration equals    1.40 h
   *
                   *        Intensity equals       2.20 in/h
   *
                  *************************************************
                        **********************************
                        * The Peak Flow is        5. cfs *
          **********************************
    +++ NORMAL END OF HYDRO
```

Figure 4A-16. HYDRO Output File (Complex Example) Tc & I Input

4.06.2.2 REGRESSION EQUATION EXAMPLES

4.06.2.2.1 Rural Regression Example

GIVEN: A drainage culvert located under US 43 over a tributary to Bluewater Creek near Leoma, TN, Lawrence County. There was a USGS stream gaging station near this site from 1955 to 1983. The drainage area at the gage was 0.49 square miles (314 acres).

FIND: The design flow for a culvert under an arterial route.

SOLUTION:

1. Delineate and measure drainage area on USGS topographic quadrangles. (See Figure 4A-17)

   Drainage Area is 302 acres.

2. Determine in which Hydrologic Area the drainage basin is located in using Figure 4-3.

   Drainage area is located in Hydrologic Area 2.

3. Determine the design frequency and which regression equation to use.

   The design frequency in Table 4-1 for a culvert is the 50-yr storm. The equation to use for a 50-year design storm in Hydrologic Area 2 with a drainage area greater the 300 acres is in Table 4-4.

4. Compute 50-year recurrence interval design flow using the USGS Rural Regression Equation for Hydrologic Area 2.

   $Q_{50} = 800 * (A / 640)^{0.694}$

   Where: A=302 acres

   $Q_{50} = 800 * (302 / 640)^{0.694} = 475$ cfs (Equation from Table 4-4).

   See Figures 4A-18 and 4A-19 for the HYDRAIN National Flood Frequency Module (NFF) output listings.

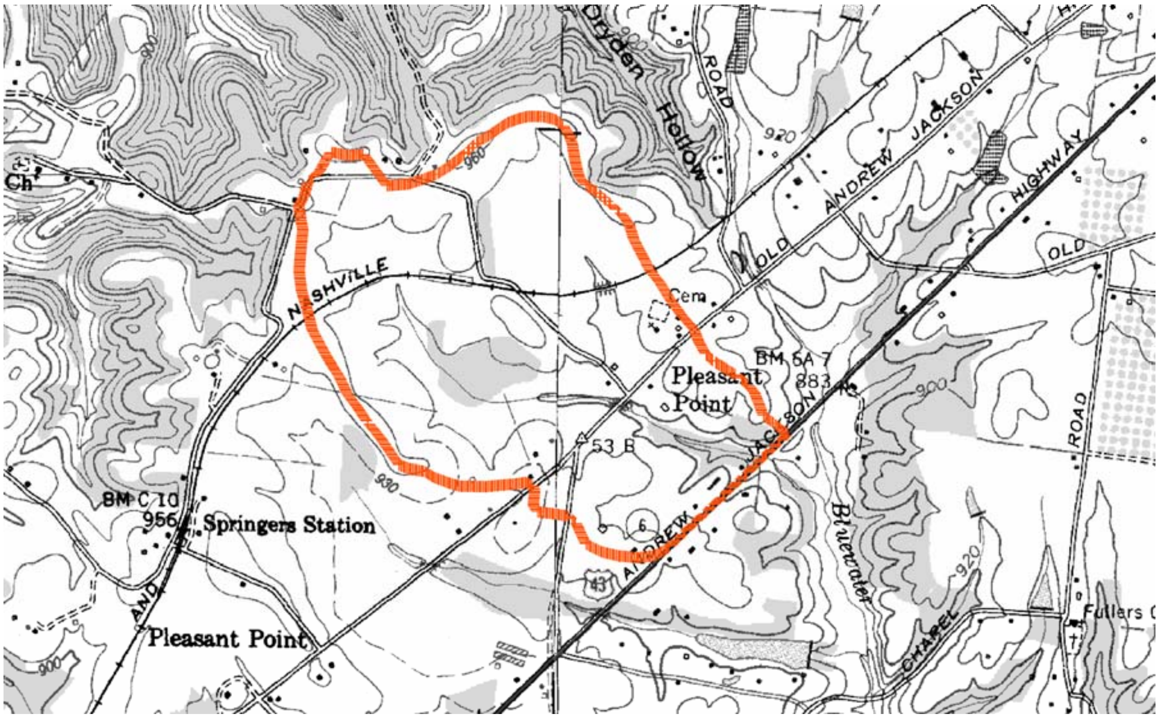
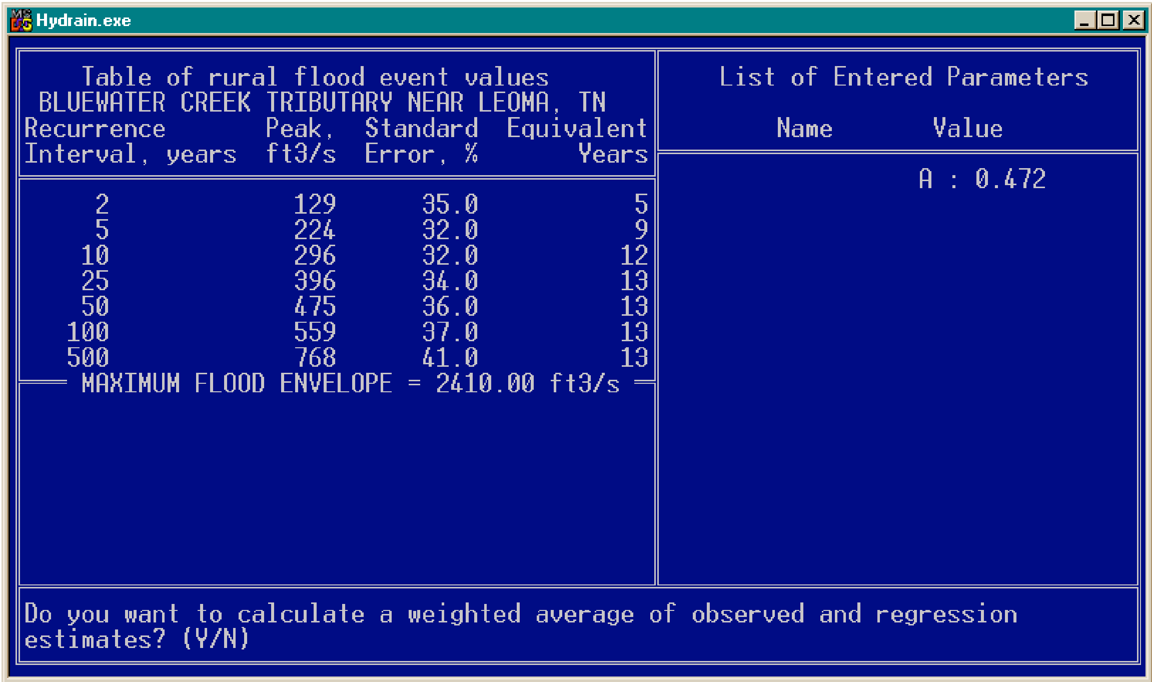


Figure 4A-17. Bluewater Creek Tributary Drainage Area at US 43



Source: HYDRAIN Version 6.1.

Figure 4A-18. HYDRAIN NFF Output Screen for Rural Regression Example

```
         --------------------- National Flood Frequency Log Session --------------------
NFF Log session started 06/13/2001 09:36
Enter state ID code : TN
Enter name of basin under study: BLUEWATER CREEK TRIBUTARY NEAR LEOMA, TN
List of Hydrologic Regions
in Tennessee
Region #      Region Name
==============================
   1   Area 1
   2   Area 2
   3   Area 3
   4   Area 4
Is basin contained in more than one
hydrologic region? (Y/N) N
Hydrologic region? (1-4) : 2
Area 2 parameters:
Drainage Area (sq mi), A (0.47-707.00) : .4719
Enter the maximum flood region for the basin (see page 16, USGS WRIR 94-4002).
Enter 0 if not applicable (e.g. outside of conterminous United States) : 7
|Table of rural flood event values
|BLUEWATER CREEK TRIBUTARY NEAR LEOMA, TN
|Recurrence       Peak,  Standard  Equivalent
|Interval, years  ft3/s  Error, %       Years
|============================================
| RQ2              129      35.0           5
| RQ5              224      32.0           9
| RQ10             296      32.0          12
| RQ25             396      34.0          13
| RQ50             475      36.0          13
| RQ100            559      37.0          13
| RQ500            768      41.0          13
 ============================================
   MAXIMUM FLOOD ENVELOPE = 2410.00 ft3/s
  List of Entered Parameters
      Name       Value
==============================
              A : 0.472
Do you want to calculate a weighted average of observed and regression
estimates? (Y/N) N
Do you want to perform urban calculations? (Y/N) N
Enter a name for the flood frequency data file: E:\P61103\EXAMPLE\BLUEWATR.Q
Do you want to compute a hydrograph for the rural peak calculated? (Y/N) N
Do you want to do more flood frequency calculations in Tennessee? (Y/N) N
Do you want to do flood frequency calculations in another state? (Y/N) N
Program terminated.
NFF Log session ended 06/13/2001 10:10
```

Figure 4A-19. HYDRAIN NFF Output Log File

4.06.2.2.2 Statewide Urban Regression Example

GIVEN: A drainage culvert on Bybee Branch in McMinnville, TN, in Warren County.

FIND: The culvert design flow for a collector route.

SOLUTION:

1. Delineate and measure drainage area on USGS topographic quadrangle. (See Figure 4A-20)
   The drainage area is 199 acres.

2. Determine the 2-year, 24-hour rainfall amount using Figure 4A-26.
   The 2-year, 24-hour rainfall is 3.56 inches.

3. Estimate the amount of impervious area in the watershed.
   The impervious area is 30 acres or 15% of the watershed.

4. The design frequency for a collector route is the 50-year according to Table 4-1. The project site is in an urban area. Equation 4-15 should be used.

5. Compute the 50-year recurrence interval design flow rate.

   $Q_{50} = 44.9 * (A/640)^{0.75} * I_{IMP}^{0.40} * P_{2\text{-}24}^{1.42}$

   where A = 199 acres
   IA = 15 percent
   $P_{2\text{-}24}$ = 3.56 inches

   $Q_{50} = 44.9 * (199/640)^{0.75} * (15)^{0.40} * (3.56)^{1.42} = 334$ cfs

   See Figures 4A-21 and 4A-22 for the HYDRAIN NFF output listings.

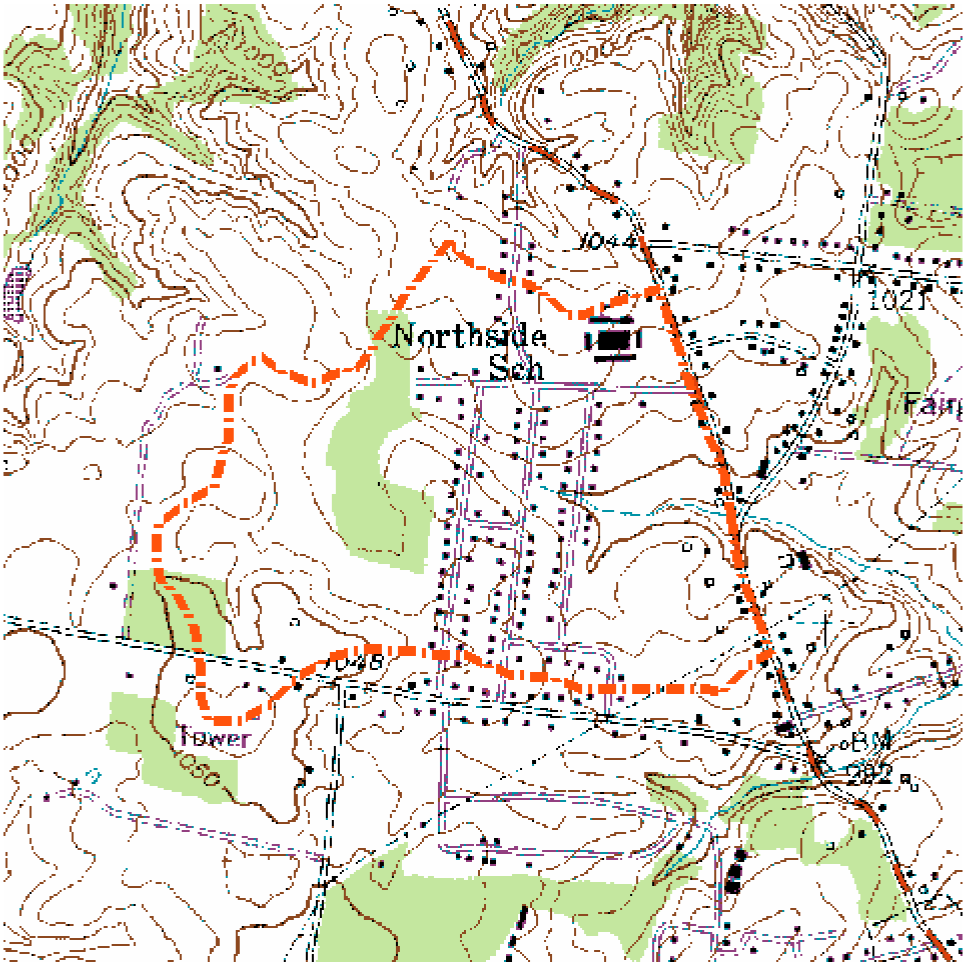
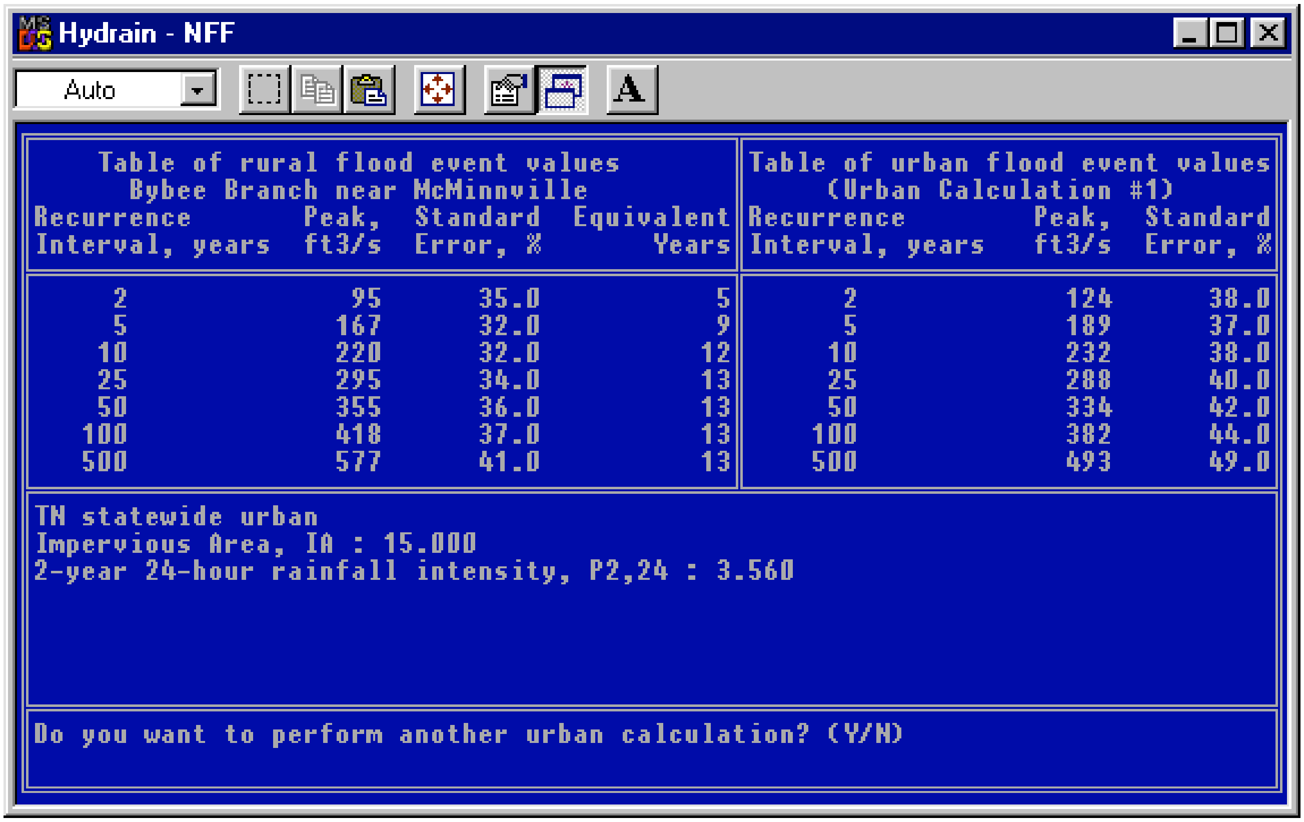


Figure 4A-20. Bybee Branch Drainage Area



Source: HYDRAIN Version 6.1.

Figure 4A-21. HYDRAIN NFF Output Screen

Figure 4A-22. HYDRAIN NFF Output Screen

--------------------- National Flood Frequency Log Session --------------------

```
NFF Log session started 07/11/2001 14:22
Enter state ID code : TN
Enter name of basin under study: Bybee Branch near McMinnville, TN
List of Hydrologic Regions
in Tennessee
Region #      Region Name
==============================
   1   Area 1
   2   Area 2
   3   Area 3
   4   Area 4
Is basin contained in more than one
hydrologic region? (Y/N) n
Hydrologic region? (1-4) : 2
Area 2 parameters:
Drainage Area (sq mi), A (0.47-707.00) : 0.31
WARNING ->>> Value of A is outside of (0.47-707.00) allowed range
Reenter value? (Y/N) n
Enter the maximum flood region for the basin (see page 16, USGS WRIR 94-4002).
Enter 0 if not applicable (e.g. outside of conterminous United States) : 5
|Table of rural flood event values
|Bybee Branch near McMinnville, TN
|Recurrence       Peak,  Standard  Equivalent
|Interval, years  ft3/s  Error, %       Years
|============================================
| RQ2               95      35.0           5
| RQ5              167      32.0           9
| RQ10             220      32.0          12
| RQ25             295      34.0          13
| RQ50             355      36.0          13
| RQ100            418      37.0          13
| RQ500            577      41.0          13
 ============================================
   MAXIMUM FLOOD ENVELOPE = 4450.00 ft3/s
  List of Entered Parameters
      Name       Value
==============================
              A : 0.310
Do you want to calculate a weighted average of observed and regression
estimates? (Y/N) n
Do you want to perform urban calculations? (Y/N) y
(1) National Urban Equations
(2) Memphis Shelby Co urban
(3) TN statewide urban
Perform 1st set of urban calculations using which equations above? : 3
Impervious Area (%), IA (4.7-74.0) : 15
2-year 24-hour rainfall intensity (in), P2,24 (3.0-4.0) : 3.56
|Table of urban flood event values
|     (Urban Calculation #1)
|Recurrence        Peak,  Standard
|Interval, years   ft3/s  Error, %
|=================================
| UQ2               124      38.0
| UQ5               189      37.0
| UQ10              232      38.0
| UQ25              288      40.0
| UQ50              334      42.0
| UQ100             382      44.0
| UQ500             493      49.0
 =================================
Do you want to perform another urban calculation? (Y/N)
Do you want to perform another urban calculation? (Y/N) n
Enter a name for the flood frequency data file: bybee.q
Do you want to compute a hydrograph for the rural or urban peaks calculated? (Y/N) n
Do you want to do more flood frequency calculations in Tennessee? (Y/N) n
Do you want to do flood frequency calculations in another state? (Y/N) n
Program terminated.
NFF Log session ended 07/11/2001 14:26
```

4.06.2.2.3 Memphis Urban Regression Example

GIVEN: A drainage culvert under U.S. 70/79 over a tributary to Fletcher Creek near Bartlett in Shelby County, TN.

FIND: The culvert design flow for an arterial route in Shelby County.

SOLUTION:

1. Delineate and measure drainage area on USGS topographic quadrangles. (See Figure 4-4)

   Drainage area is 169 acres.

2. Determine the channel lining factor at the 25, 50, 75, and 100 percent drainage area locations.

   See Figure 4-4 for the 25, 50, 75, and 100 percent drainage area locations.

3. Determine the channel lining factor (P) at the 25, 50, 75, and 100 percent of the total drainage area locations.

   This channel is a natural channel that has not been lined upstream of U.S.70/79. The channel lining factor is 1 at all four locations.

4. Compute the average channel lining factor for the watershed.

   The average of the four locations is 1.0.

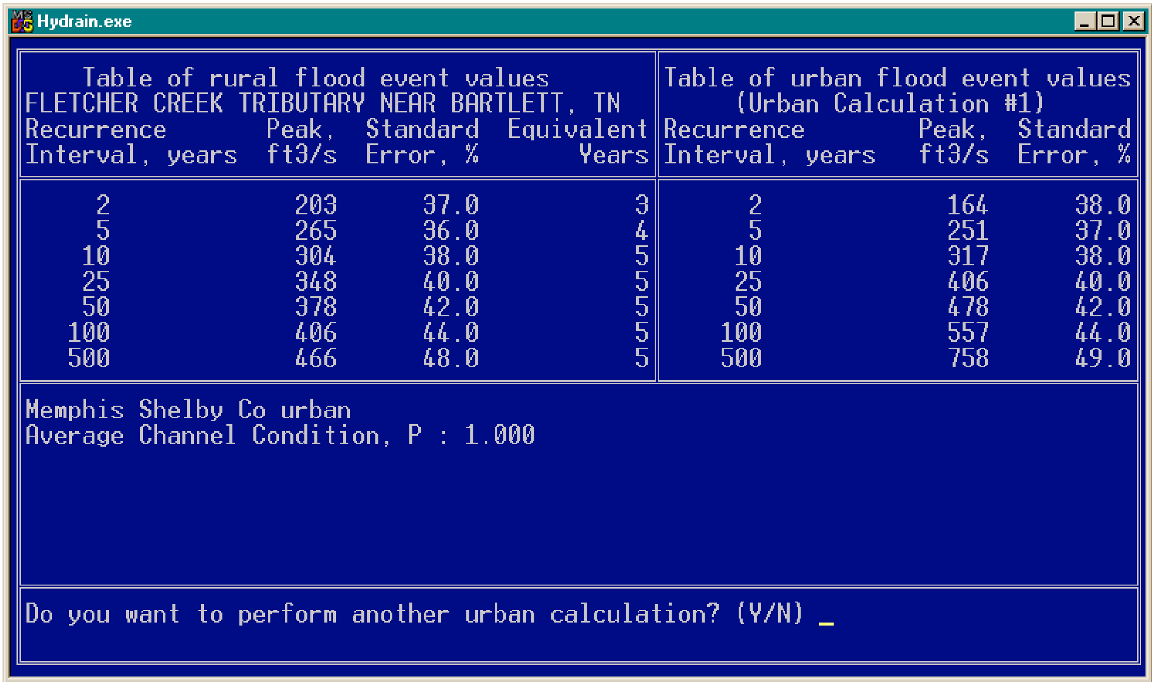
5. Compute the 50-year recurrence interval design flow using the Memphis Urban Regression Equation 4-21.

   $Q_{50} = 1{,}350 * (A/640)^{0.77} * P^{1.05}$

   where A = 169 acres
   P = 1.0

   $Q_{50} = 1{,}350 * (169/640)^{0.77} * (1.0)^{1.05} = 478$ cfs

   See Figures 4A-23 and 4A-24 for the HYDRAIN NFF output.



Hydrain.exe

Table of rural flood event values
FLETCHER CREEK TRIBUTARY NEAR BARTLETT, TN

Recurrence Interval, years	Peak, ft3/s	Standard Error, %	Equivalent Years
2	203	37.0	3
5	265	36.0	4
10	304	38.0	5
25	348	40.0	5
50	378	42.0	5
100	406	44.0	5
500	466	48.0	5

Table of urban flood event values
(Urban Calculation #1)

Recurrence Interval, years	Peak, ft3/s	Standard Error, %
2	164	38.0
5	251	37.0
10	317	38.0
25	406	40.0
50	478	42.0
100	557	44.0
500	758	49.0

Memphis Shelby Co urban
Average Channel Condition, P : 1.000

Do you want to perform another urban calculation? (Y/N) _

Source: HYDRAIN Version 6.1

Figure 4A-23. HYDRAIN NFF Output Screen

```
         --------------------- National Flood Frequency Log Session --------------------
NFF Log session started 06/13/2001 11:05
Enter state ID code : TN
Enter name of basin under study: FLETCHER CREEK TRIBUTARY NEAR BARTLETT, TN
List of Hydrologic Regions
in Tennessee
Region #      Region Name
==============================
   1   Area 1
   2   Area 2
   3   Area 3
   4   Area 4
Is basin contained in more than one
hydrologic region? (Y/N) N
Hydrologic region? (1-4) : 4
Area 4 parameters:
Drainage Area (sq mi), A (0.76-2308.00) : 0.26
WARNING ->>> Value of A is outside of (0.76-2308.00) allowed range
Reenter value? (Y/N) N
Enter the maximum flood region for the basin (see page 16, USGS WRIR 94-4002).
Enter 0 if not applicable (e.g. outside of conterminous United States) : 3
|Table of rural flood event values
|FLETCHER CREEK TRIBUTARY NEAR BARTLETT, TN
|Recurrence       Peak,  Standard  Equivalent
|Interval, years  ft3/s  Error, %       Years
|============================================
| RQ2               203      37.0           3
| RQ5               265      36.0           4
| RQ10              304      38.0           5
| RQ25              348      40.0           5
| RQ50              378      42.0           5
| RQ100             406      44.0           5
| RQ500             466      48.0           5
 ============================================
   MAXIMUM FLOOD ENVELOPE = 1500.00 ft3/s
  List of Entered Parameters
      Name       Value
==============================
              A : 0.260
Do you want to calculate a weighted average of observed and regression
estimates? (Y/N) N
Do you want to perform urban calculations? (Y/N) Y
(1) National Urban Equations
(2) Memphis Shelby Co urban
(3) TN statewide urban
Perform 1st set of urban calculations using which equations above? :
2
Average Channel Condition (), P (1.0-2.0) : 1
|Table of urban flood event values
|     (Urban Calculation #1)
|Recurrence        Peak,  Standard
|Interval, years   ft3/s  Error, %
|=================================
| UQ2                164      38.0
| UQ5                251      37.0
| UQ10               317      38.0
| UQ25               406      40.0
| UQ50               478      42.0
| UQ100              557      44.0
| UQ500              758      49.0
 =================================
Do you want to perform another urban calculation? (Y/N) n
Enter a name for the flood frequency data file: e:\p61103\example\memphis.q
Do you want to compute a hydrograph for the rural or urban peaks calculated? (Y/N) n
Do you want to do more flood frequency calculations in Tennessee? (Y/N) n
Do you want to do flood frequency calculations in another state? (Y/N) n
Program terminated.
NFF Log session ended 06/13/2001 11:08
```

Figure 4A-24. HYDRANT NFF Output File

4.06.3 FIGURES AND TABLES (RAINFALL INTENSITY)

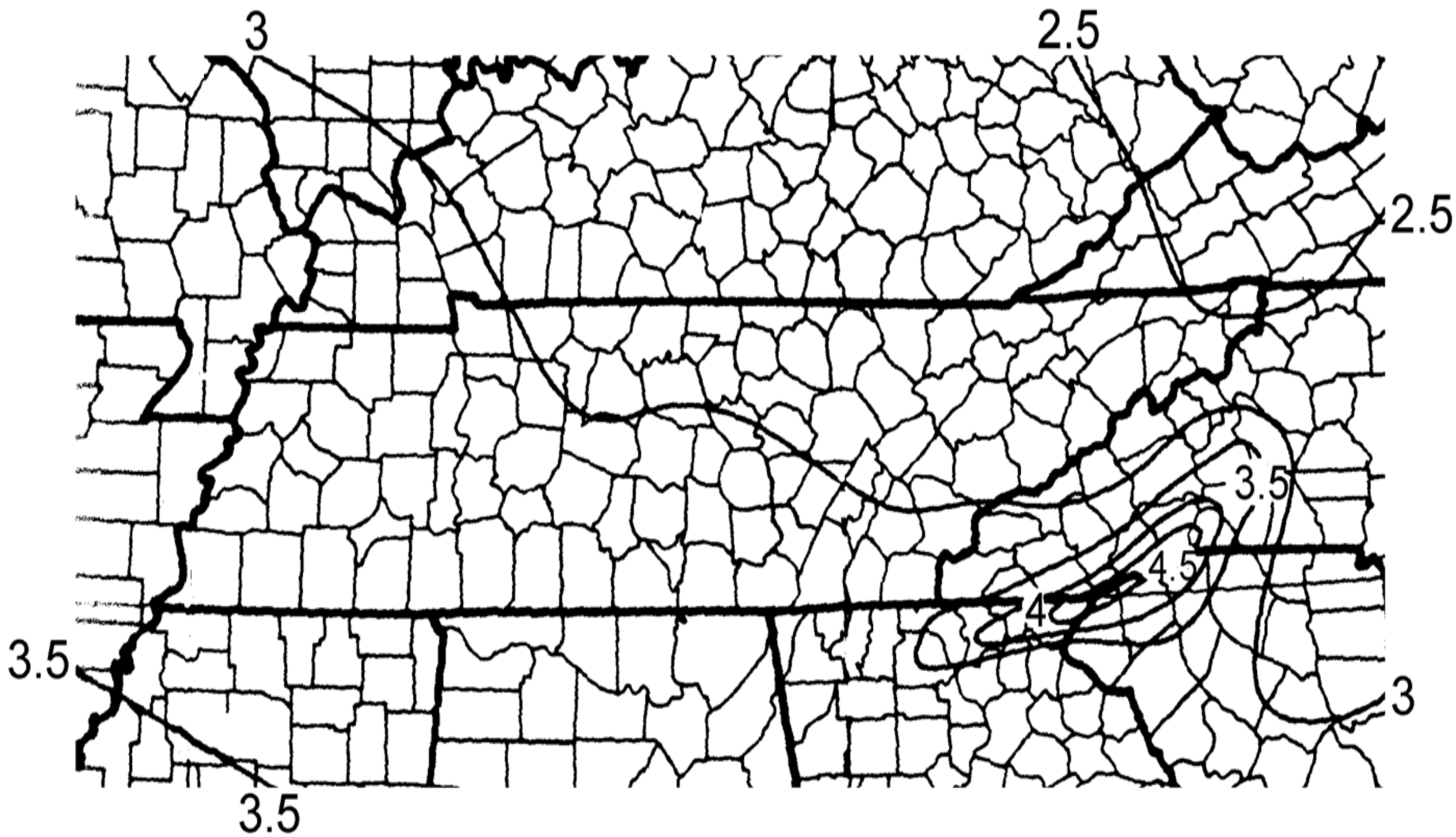


Figure 4A-25. 1 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

** Note: 2.5 inches is to be used for the northern portions of Sullivan, Carter, and Johnson Counties.

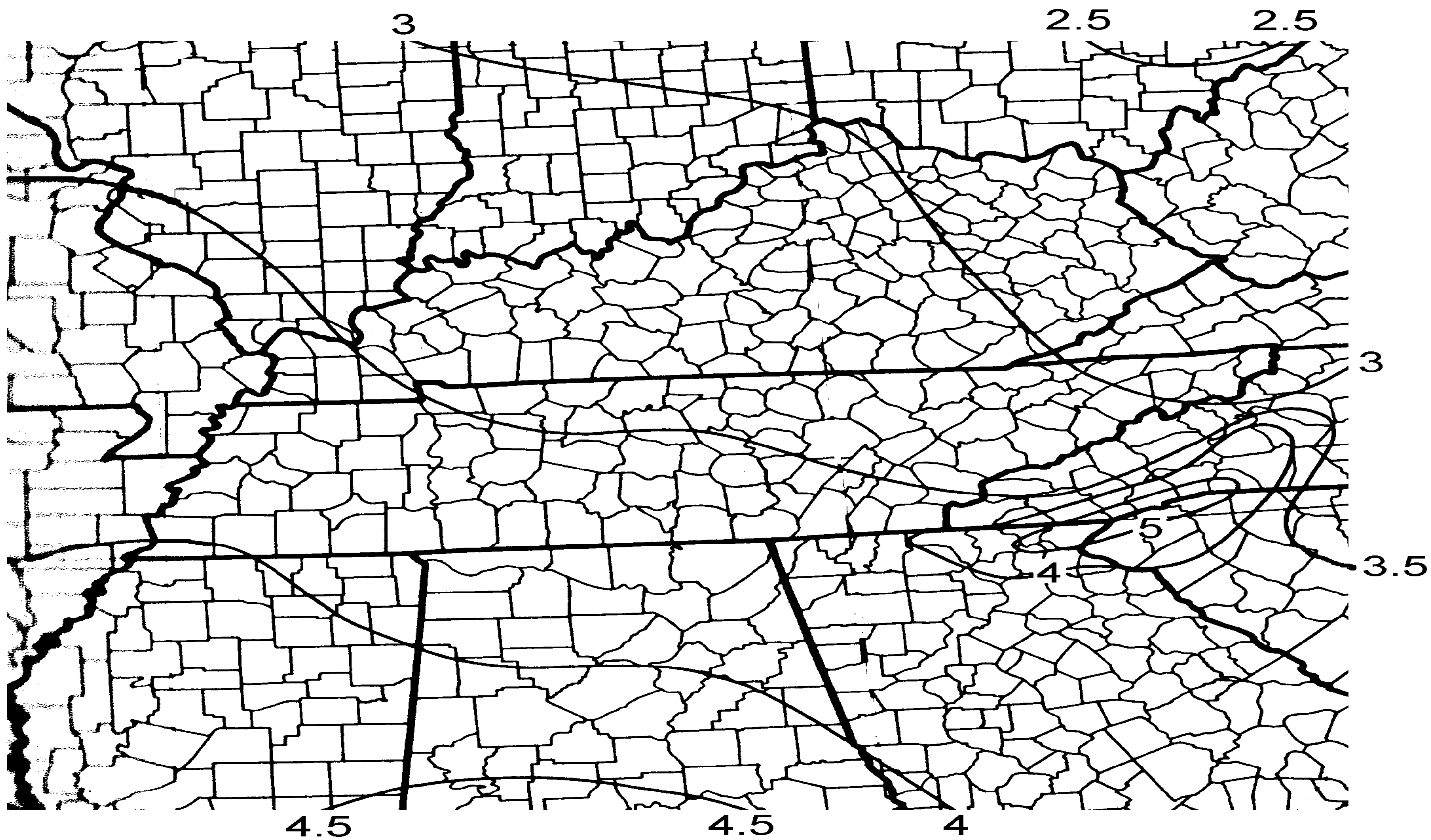


Figure 4A-26. 2 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

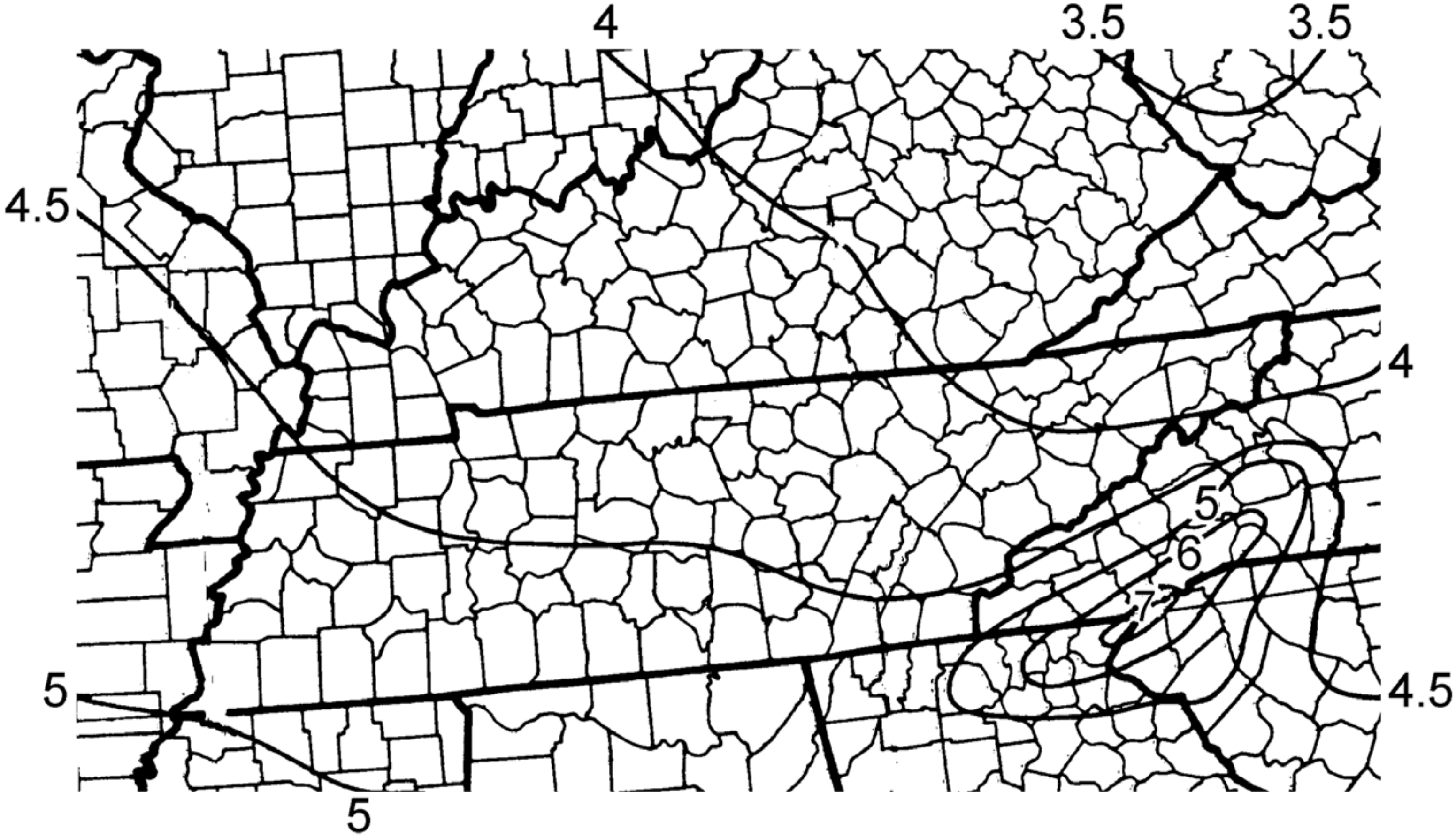


Figure 4A-27. 5 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

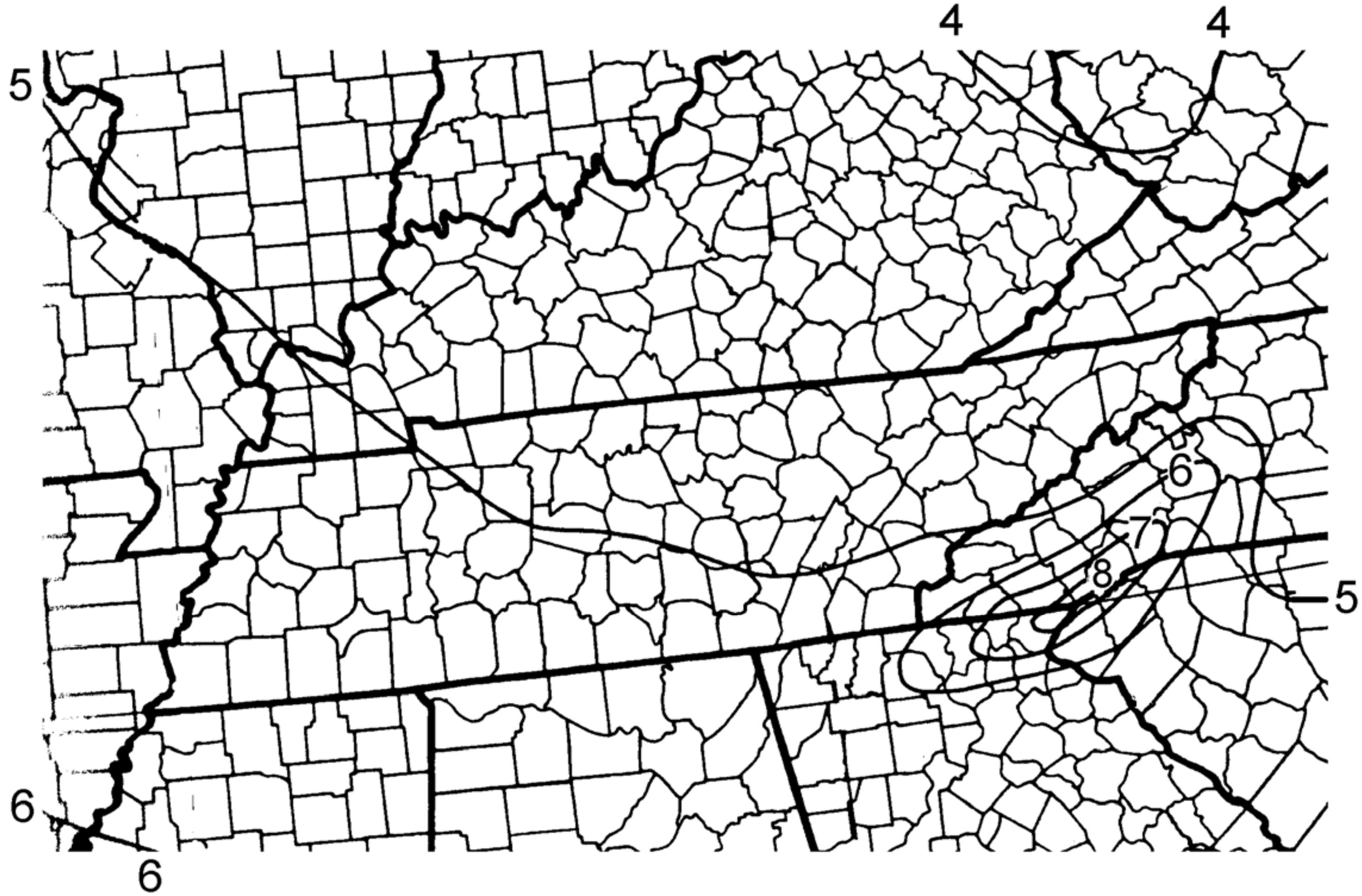


Figure 4A-28. 10 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

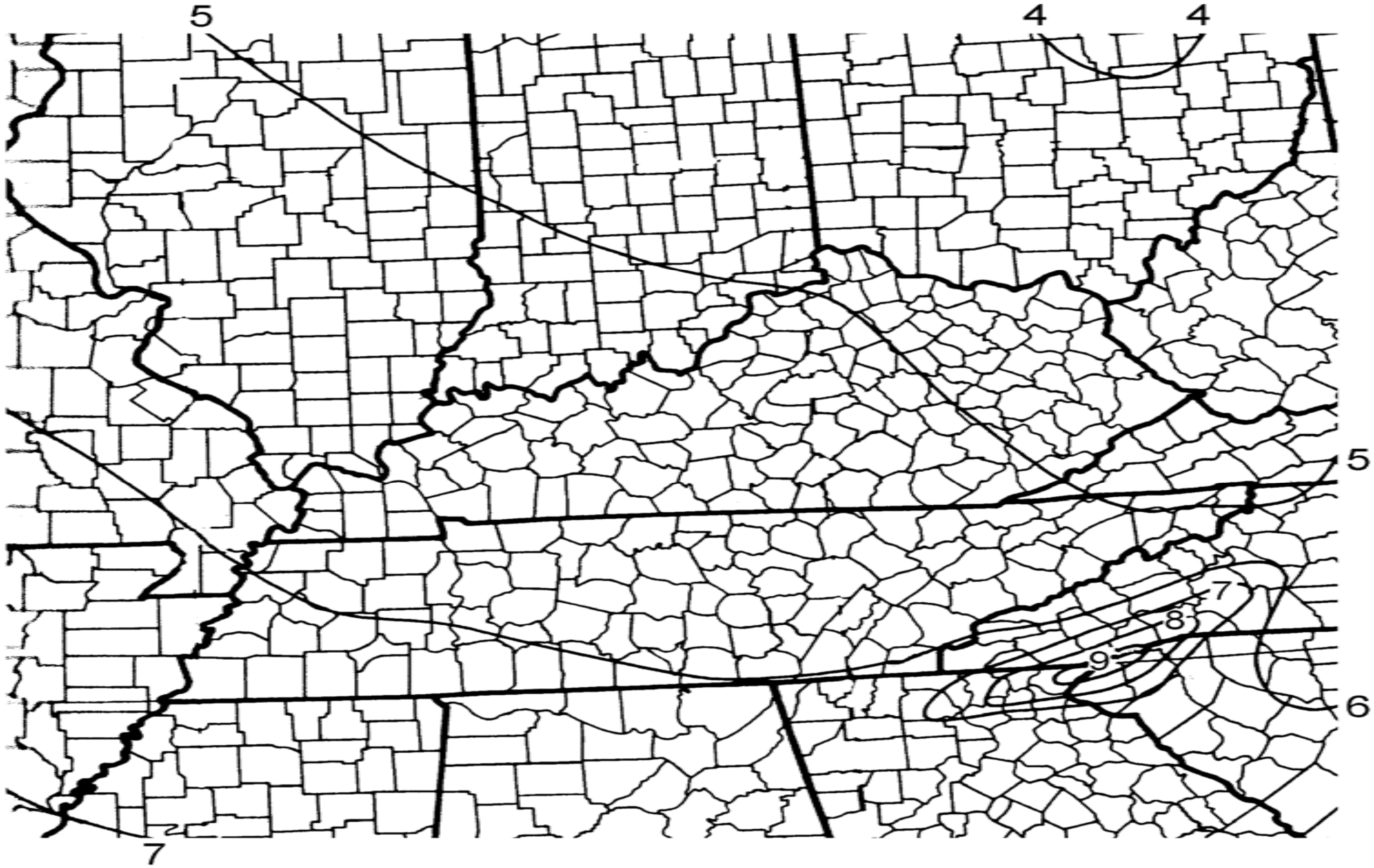


Figure 4A-29. 25 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

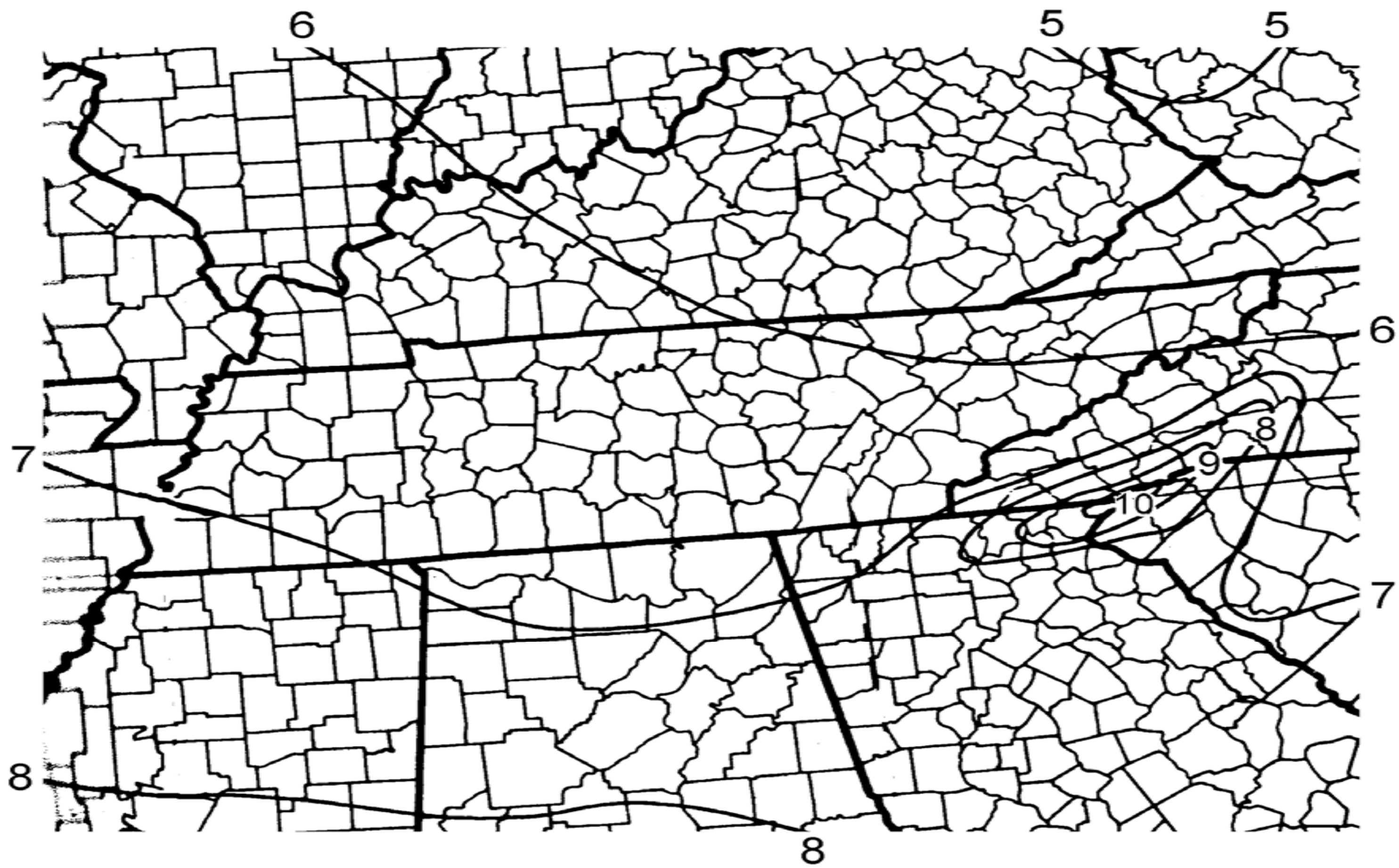


Figure 4A-30. 50 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

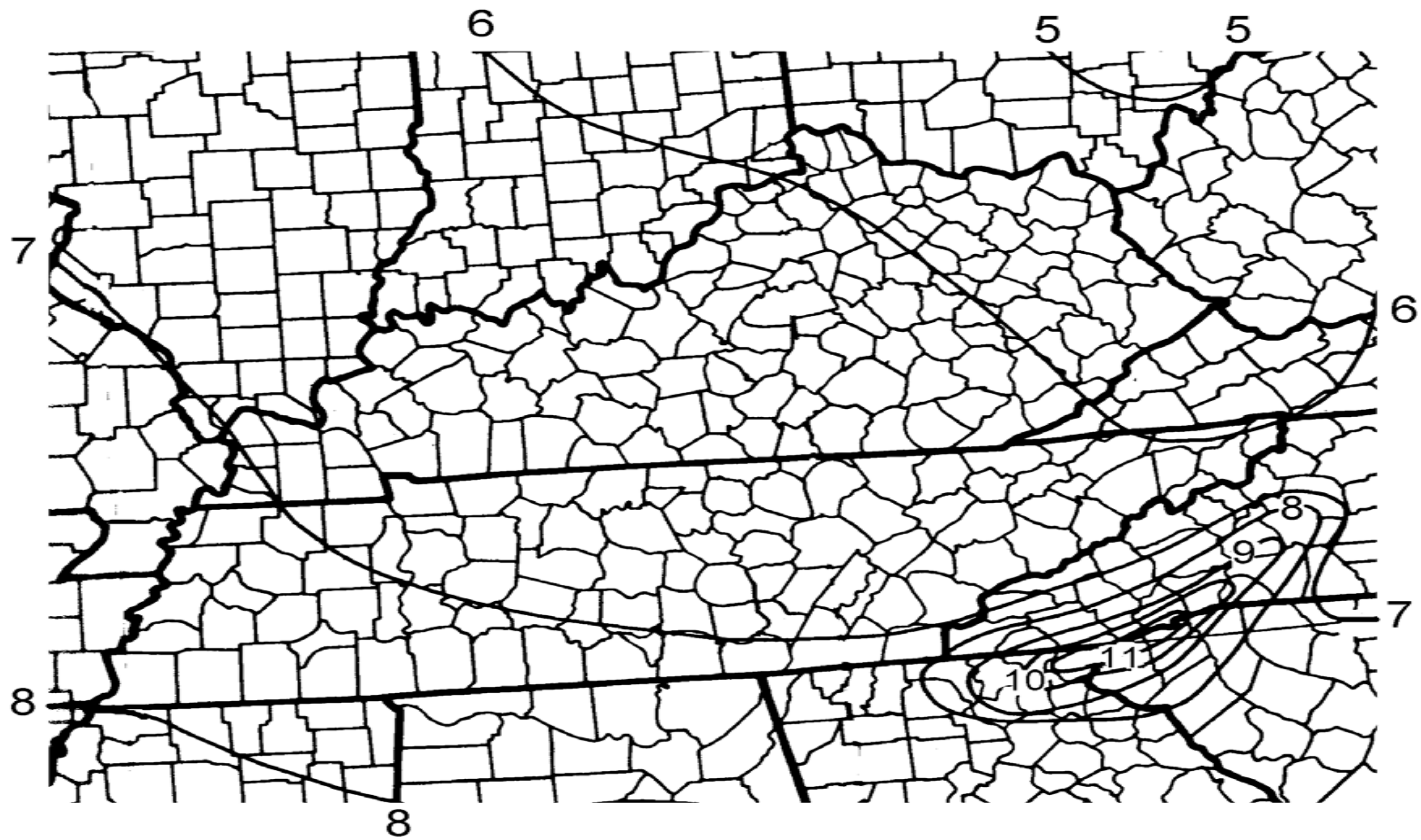


Figure 4A-31. 100 year 24 hour rainfall (inches)

Source: U.S. Department of Commerce (1961)

4.06.4 REFERENCES

4.06.4.1 PUBLICATIONS

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4.06.4.2 ABBREVIATIONS

AASHTO - American Association of State Highway Transportation Officials
BLM - Bureau of Land Management
CFR - Code of Federal Regulations
CFS - Cubic feet per second
COE - U.S. Army Corps of Engineers
EOC - Emergency Operation Center
EPA - U.S. Environment Protection Agency
FBFM - Flood Boundary and Floodway Map
FEMA - Federal Emergency Management Agency
FHBM - Flood Hazard Boundary Map
FHWA - Federal Highway Administration
FIRM - Flood Insurance Rate Map
FIS – Flood Insurance Studies
FWS - United States Fish and Wildlife Service
HDS-4 – Introduction to Highway Hydraulics Hydraulic Design Series Number 4
HEC-1 - Hydrologic Engineering Center Flood Hydrograph Package
HEC-HMS – Hydrologic Engineering Center Hydrologic Modeling System
HSG – Hydrologic Soil Group
IDF – Intensity Duration Frequency
ISTEA - 1991 Intermodal Surface Transportation Efficiency Act
NFF – National Flood Frequency
NFIP - National Flood Insurance Program
NOAA - National Oceanic and Atmospheric Administration
NRCS - Natural Resources Conservation Service (formerly Soil Conservation Service)
NWS - National Weather Service
P – Channel Condition
SCS - Soil conservation Service
TR-20 – *The Natural Resources Conservation Service Technical Release 20*
TR-55 – *Urban Hydrology for Small Watersheds- Technical Release 55*
USFS - U.S. Forest Service
USGS - United States Department of the Interior, Geological Survey
USWB - United States Department of Commerce, Weather Bureau
WS – Water Surface

TDOT DESIGN DIVISION

DRAINAGE MANUAL

GLOSSARY

GLOSSARY

AASHTO. Acronym for American Association of State Highway Transportation Officials.

Allowable High Water. The maximum water levels that can occur through a reach and at a culvert, bridge-type opening, or other drainage facility without contravention of the adopted design criteria. May also be the usual term used to describe the estimated water surface elevation or profile in the stream (or other surface waters) at the project site for the selected design discharge.

Backwater. The increase in water surface elevation induced upstream from such things as a bridge, culvert, dike, dam, another stream at a higher stage, or other similar structures or conditions that obstruct or constrict a channel relative to the elevation occurring under natural channel and floodplain conditions. Stated another way, water backed up or retarded in its course as compared with its normal or natural conditions of flow. Also applies to the water surface profile in a channel or conduit.

Base Flood. See Flood, Base

Base Floodplain. Surface area flooded by the base flood.

BLM. Acronym for the Bureau of Land Management.

Box Bridge. A culvert (see definition of culvert) which is a square or rectangular concrete conduit twenty feet or greater in width based on inside dimension(s).

Box Culvert. A culvert (see definition of culvert) which is a square or rectangular concrete conduit less than twenty feet in width based on inside dimension(s).

Capacity. A measure of the ability of a channel or conduit to convey water. Compare with Conveyance.

Catch Basin. A structure for inletting drainage from such places as a gutter or median and discharging the water through a conduit. The structure may have a sump for intercepting debris that settles from the water. In common usage it is a grated inlet, curb opening, or combination inlet with or without a sump. According to the AASHTO Model Drainage Manual, "Note that sumps in catch basins may cause environmental hazards by further polluting “first flush” runoff and subsequent runoff passing through the catch basin."

CFR. Acronym for Code of Federal Regulations.

CFS. Acronym for cubic feet per second. See Cubic Feet per Second.

Channel. The term “channel” has been defined numerous ways: 1. the bed and banks that confine the flow of surface water in a natural stream or artificial channel; also see River and Stream; 2. The course where a stream of water runs or the closed course or conduit through which water runs, such as a pipe; 3. An open conduit either naturally or artificially created which periodically or continuously contains moving water or which forms a connecting link between two bodies of water. River, creek, run, branch, anabranch, arroyo, draw, wash, and tributary are some of the terms used to describe natural channels. Natural channels may be single or braided. Canal, lateral, and floodway are some of the terms used to describe artificial channels.

A Channel has also been defined as an elongated, open depression in which water may, or does, flow. An elongated depression, either naturally or artificially created and of appreciable size, which periodically or continuously contains moving water or which forms a connecting link between two bodies of water. The channel must have a definite bed and bank, which serve to confine the water up to some bankfull discharge amount. Local convention may use river, stream, arroyo, or branch. With constructed canals, the term ditch or lateral may be used.

Channel Condition. The average channel condition between points along the main channel. If the channel is paved with concrete, the value is 2. If the channel is unpaved, the value is 1. For partially paved channels, the value should be estimated between 1 and 2. This term is used in the USGS regression equations for Memphis and Shelby County.

Channel Diversion. The taking of water from a stream or other body of water into a canal, pipe, or other conduit. The removal of all or a portion of the flow from a natural or artificial (canal, ditch, field ditch, or lateral) channel.

Channel Modification. The alteration of a channel by changing the physical dimensions or materials of its bed or banks.

Channel, Natural. A surface or underground watercourse created by natural agents and conditions. The principal stream channel or channels and, if the stream is braided, its natural and customary overflow channels.

Channel, Open. A channel having a water surface exposed at all points to atmospheric pressure. Any conveyance in which water flows with a free surface.

Civil Action. Action presenting an issue to be resolved under civil law, as distinguished from criminal law, and/or brought to establish or recover private and civil rights or redress for damage; tort action.

Civil Law. The system of jurisprudence established by a nation, state, or commonwealth peculiarly for itself; the division of law regulating ordinary private matters, as distinct from laws regulating criminal, political or military matters. The civil laws regarding the management of naturally occurring waters established the rights or easements, both favorable and restrictive, of the riparian owners individually and with respect to others, and are directed toward equitable use and the preservation and continuation of natural drainage conditions.

Civil Law Doctrine or Rule. A rule of law pertaining to the disposal of drainage waters, under which the owner of higher land has the right or easement to dispose of the surplus or excess waters from his lands to lower lands, unobstructed by the owners thereof.

Coast Guard. United States Coast Guard (USCG) is a naval force employed in guarding a coast or responsible for the safety, order, and operation of maritime traffic in neighboring waters. The USCG has regulatory authority to approve plans and issue permits for construction activities in or over navigable rivers.

Code of Federal Regulations (CFR). Codifies and publishes at least annually Federal regulations currently in force. The CFR is kept up to date by individual issues of the Federal Register. The two publications must be used together to determine the latest version of any given rule.

COE. Acronym for the U.S. Army Corps of Engineers.

Common Enemy Doctrine or Rule. A common law rule recognized by some states, pertaining to the disposal of surplus or excess surface waters, which holds that such waters are a “common enemy,” and, therefore, the land owner has the right to protect his lands from such waters coming from higher lands. Under this rule, surface waters are regarded as a common enemy which each landowner may fight as he deems best and without regard to the harm that may be caused to others.

Common Law. As distinguished from “Roman” or “Civil” law, the body of unwritten law, especially of England, based on long-standing usages and customs and the court decisions and decrees recognizing, affirming and enforcing such usages and customs.

Common Law, Federal. A body of decisional law developed by the Federal courts, unencumbered by state court decisions.

Common Law Rules. Principles or maxims established under the common law doctrine or rule.

Complex Drainage Area. Drainage areas that have multiple types of flow (i.e., sheet, shallow concentrated, and channelized).

Conveyance. A measure of the ability of a stream, channel, or conduit to convey water. A comparative measure of the water-carrying capacity of a channel; that portion of the Manning discharge formula which accounts for the physical elements of the channel. Conveyance is expressed as: (1/n)AR2/3 where n is Manning's n, A is the cross section area of flow, and R is the hydraulic radius. See Manning's Equation. A measure of the water transporting capacity of such things as a channel, floodplain, drainage facility, storm drain, and/or other natural or artificial watercourse feature traversed by flows such as runoff or irrigation water. With the review flood or storm, conveyance may include that associated with overtopping flows and inundation of a traveled way at cross-drainages.

Corps of Engineers. The United States Army Corps of Engineers (Corps, COE, or USACE) is made up of civilian and military men and women serving the Army and the United States in water resources development, environment, infrastructure, disasters, and warfighting. One key service the Corps provides is the issuance of permits including the Section 404 permit and evaluation of related activities. They have regulatory authority over construction of dams, dikes, or other obstructions which are not considered bridges or causeways yet cause excavation or deposition of fill material in waterways.

Criteria. See Design Criteria.

Criteria, Design. See Design Criteria.

Cross Culvert. A culvert (see definition of culvert) that crosses the roadway conveying storm water from the upstream side of the roadway to the downstream side of the roadway.

Cross Drainage. The runoff from contributing drainage areas both inside and outside the highway right of way and the transmission thereof from the upstream side of the highway facility to the downstream side.

Cubic Feet Per Second (cfs or ft3/s). A unit of measurement of water flow. The rate of discharge representing a volume of one cubic foot passing a given point during one second and equivalent to 7.48 gallons per second or 448.8 gallons per minute.

Culvert. A structure which is usually a closed conduit or waterway that is designed hydraulically to take advantage of submergence to increase hydraulic capacity. A structure used to convey surface runoff through such things as a highway or railroad embankment. Although there are borderline cases, a culvert is a structure, as distinguished from bridges, which is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on spread footings with the channel bed serving as the bottom of the culvert. A culvert commonly has a regular, uniform shape, where a bridge opening may not—in other words, a culvert is a relatively large pipe or conduit. A culvert usually has a large ratio of length to width.

Dam. A barrier to confine or raise water for storage or diversion, or to create a hydraulic head.

Design Criteria. Criteria, coupled with prudent judgmental factors, that are used to design a drainage facility.

Design Flood. The maximum rate of flow (or discharge) for which a drainage facility is designed and thus expected to accommodate without exceeding the adopted design constraints. Maximum flow a bridge, culvert, or other drainage facility is expected to accommodate without contravention of the adopted design criteria. The peak discharge or volume and its associated probability of exceedance selected for the design of a road culvert or bridge over a channel, or floodplain.

Design Flow. The flow rate for a selected flood frequency used in designing the drainage system component.

Designer. A licensed engineer, a technician or unlicensed engineer working under the supervision and direction of a licensed engineer.

Detention Basin. A basin or reservoir incorporated into the watershed whereby runoff is temporarily stored, thus attenuating the peak of the runoff hydrograph. A stormwater management facility that impounds runoff and temporarily impounds runoff and discharges it through a hydraulic outlet structure to a downstream conveyance structure.

Discharge. Volume of water passing a point during a given time. The rate a volume of flow passes a point per unit of time, usually expressed in cubic feet per second (ft3/s or cfs). Four somewhat differently stated definitions are: 1. the quantity of water, silt, or other mobile substances passing along a conduit per unit of time; 2. rate of flow such as cubic feet per second (ft3/s), gallons per second, millions of gallons per day; 3. the act involved in water or other liquid passing through an opening or along a conduit or channel; 4. the water or other liquid which emerges from an opening or passes along a conduit or channel.

In its simplest concept, discharge means outflow; therefore, the use of this term is not restricted as to course or location, and it can be applied to describe the flow of water from a pipe or from a drainage basin. If the discharge occurs in some course or channel, it is correct to speak of the discharge of a canal, channel, or of a river. It is also correct to speak of the discharge of a canal, channel, or stream into a lake or stream. The volume of water (or more broadly, volume of fluid plus suspended sediment) that passes a given point within a given period of time.

The data in the reports of USGS on surface water represent the total discharge, and streamflow and runoff represent water with the solids dissolved in it and the sediment mixed with it. Of these terms, discharge is the most comprehensive. The discharge of drainage basins is distinguished as follows:

Yield - Total water runoff or crop; includes runoff plus underflow.

Runoff - That part of water yield that appears in streams.

Streamflow - The actual flow in streams, whether or not subject to regulation, or underflow.

Each of these terms can be reported in total volumes (such as cubic feet per second or acre-feet per year).

Districts. A subset of a larger organization or geography. Some organizations may call these subsets regions or divisions. The boundary limits are designated by the principal organization.

Divert. To take water from a stream or other body of water into a canal, pipe, or other conduit. The removal of all or a portion of the flow from a natural or artificial (canal, ditch, field ditch, or lateral) channel.

Diversion. The method used to divert water.

Doctrine. A rule, principle, theory, or tenet of the law.

Drainage. Two definitions are provided: 1. the process of removing surplus groundwater or surface waters by artificial means and 2. the manner in which the waters of an area are removed.

Drainage Area. The catchment area (i.e., the term implies all physical characteristics, including the contributing area) for rainfall and other forms of precipitation which is delineated as the drainage area producing runoff or contributing drainage area. The area is delineated by a continuous ridge or drainage divide within which all runoff is expected to join into a single flow stream and which extends to the point of junction of this flow stream (downstream) with the ridge. Natural boundaries, constructed boundaries, or minimum size of pipe are criteria which can be used to define the catchment. The area may be of different sizes for surface runoff, subsurface flow, and base flow, but generally the surface runoff area is used as the drainage area. The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide. Over the years, use of the term to signify drainage basin or catchment area has come to predominate, although drainage basin is preferred. Used alone, the term "watershed" is ambiguous and should not be used unless the intended meaning is made clear.

Drainage Notebook. See Notebook.

Easement. An interest in land owned by another that entitles the holder of the easement to a specific use. A drainage easement may be needed for conveyance of water.

Economic Analysis. A probabilistically based analysis that compares the estimated construction costs with those expected average flood-related operational costs and risks that can be quantified for the anticipated service life of a project to identify an optimum design flood frequency.

Effect. Something produced by an agent or cause, a result. It is what occurs to surface waters as a direct or indirect result of a highway action.

Eminent Domain. In law, the right of a government to take, or to authorize the taking of private property for public use, just compensation being given to the owner.

Encroachments. A highway action within the limits of a base (100-year) floodplain. With a design or review storm system, encroachment is sometimes used when referring to the width gutter flow spreads onto a traveled way as measured perpendicular from either the edge of the traveled way or from the face of the curb.

End Treatment. The type of headwall, endwall, or other structural component used at the end of a culvert.

Engineer. A title or designation of an held for those meeting specific requirements: 1. Graduation from an accredited engineering program with a degree in engineering. 2. Registration as a professional engineer or engineer-in-training under a state engineering registration law. 3. An official ruling designating an individual or a group in an engineering capacity as meeting the definition of "Professional Engineer" under the Taft-Hartley Act, or the Fair Labor Standards Act. Only persons in one of these categories should be designated by an appropriate title "engineer" or "professional engineer". This policy shall not be construed to prohibit using the word "engineering" as a modifier in titles such as "engineering assistant", "engineering aide" and "engineering technologist" where the title clearly implies that the duties of the position are not those of professional engineer. The title "engineer" should be applied only to people qualified professionally by accepted standards of law and/or engineering practice.

Engineering Judgment. The process of forming an opinion or evaluation by discerning and comparing based on education in the field of engineering and engineering project experience.

Environmental Effects. Pertaining to the effects of highway engineering works on their surroundings and on nature.

EOC. Acronym for Emergency Operation Center.

EPA. Acronym for the U.S. Environment Protection Agency.

Erosion. Displacement of soil particles on the land surface due to such things as water or wind action. The wearing away or eroding of material on the land surface or along channel banks by flowing water or wave action on shores.

Event. As used in data collection, event represents a point at which a gage reaches a preset value and records the occurrence or transmits it to a receiver.

Exceedance Frequency. The percentage of values that exceed a specified magnitude.

Exceedance Probability. The percentage of values that exceed a specified magnitude.

Executive Order. Executive orders are official documents, numbered consecutively, through which the President of the United States manages the operations of the Federal Government. The text of Executive Orders appears in the daily Federal Register as each Executive Order is signed by the President and received by the Office of the Federal Register. The text of Executive orders beginning with Executive Order 7316 of March 13, 1936, also appears in the sequential editions of Title 3 of the Code of Federal Regulations.

Federal Common Law. Case law developed in the Federal Courts. Federal common law is used when Federal statutory law does not completely address an issue or problem.

Federal Register. A daily publication of the Federal Government making federal regulations, legal notices, Presidential Proclamations, Executive Orders, etc., known to the public as they are proposed and subsequently issued..

FBFM. Acronym for Flood Boundary and Floodway Map.

FEMA. Acronym for Federal Emergency Management Agency.

FHBM. Acronym for Flood Hazard Boundary Map.

FHWA. Acronym for Federal Highway Administration.

Field Data. All stormwater data collected in the field regardless of whether or not it was analyzed in the field.

Field Reconnaissance. A site visit where the designer or design team becomes familiar with the project topography, features, and verifies collected survey data.

FIRM. Acronym for Flood Insurance Rate Map.

Fill. Material placed in a specific location.

Flood. In common usage, an event that overflows the normal flow banks or runoff that has escaped from a channel or other surface waters. The flow may cause or threaten damage. It may also be described as a relatively high flow measured by either gage height or discharge quantity. In a frequency analysis it can also mean an annual flood that may not overflow the normal flow banks. In technical usage, it refers to a given discharge based, typically, on a statistical analysis of an annual series of events.

Flood, Base. A flood (or storm) or reservoir pool elevation having a 1 percent chance of being exceeded in a one year period; commonly termed a 100-year event.

Flood Event. A flow of water in a stream constituting a distinct progressive rise, culminating in a crest, together with the recession that follows the crest.

Flood Exceedance Probability. Probability that a random flood event will exceed a specified magnitude in a given time period, usually one year unless otherwise indicated.

Flood Frequency. The average time interval between occurrences of a hydrological event of a given or greater magnitude, usually expressed in years. May also be called recurrence interval.

The average time interval, in years, in which a given storm or amount of water in a stream will be exceeded. Also, referred to as exceedence interval, recurrence interval, or return period. May be stated as: 1. the average time interval between actual occurrences of a hydrological event of a given or greater magnitude; 2. the percent chance of occurrence in any one year period, e.g., a 2 percent chance of flood. The chances that a specific flood magnitude (discharge) will be exceeded each year expressed as a percent; i.e., a 100-year flood has a flood probability of 1 percent of being exceeded each year. In the analysis of hydrologic data the flood frequency is simply called frequency and has years as a unit of measure. Note that flood frequency is not hyphenated when referring to a specific flood's frequency, but is when referring to such things as a "flood-frequency" curve.

Flood, Overtopping. Incipient discharge escaping via such things as over a highway, at a watershed divide, or through emergency relief facilities. Stated another way, the flood which, if exceeded, results in flow over a highway, bridge or culvert, over a watershed divide or dike, or through structures provided for emergency relief. The worse case scour condition may occur with the overtopping flood. The total flood magnitude cannot exceed the probable maximum flood and its frequency accuracy is limited by the state of the art capability to estimate a recurrence interval.

Flood Waters. Waters which escape from a natural watercourse in great volume and flow over adjoining lands in no regular channel. The fact that such errant waters make for themselves a temporary channel or follow some natural channel, gully, or depression, does not affect their character as "floodwaters" or give to the course which they follow the character of a natural "watercourse."

Floodplain. Any plain which borders a stream and is covered by its waters in time of flood. Topographic area adjoining a channel that is covered by flood flows as well as those areas where the path of the next flood flow is unpredictable, such as a debris cone, alluvial fan or braided channel. A nearly flat, alluvial lowland bordering a stream and commonly formed by stream processes, that is subject to inundation by floods.

Freeboard. Vertical clearance between the lowest structural member of the bridge superstructure, the top culvert invert, or the point of escape in a canal or channel to the water surface elevation of a flood. Freeboard may also be the vertical distance above a design stage that is allowed for waves, surges, drift and other contingencies. The vertical distance between the level of the water surface, usually corresponding to the design discharge (or wave runup) selected for freeboard considerations and a point of interest such as a low chord of a bridge beam, specific location on the roadway grade, or top of a channel bank. The distance between such things as the normal operating level and the top of the sides of an open conduit or channel, or the crest of a dam that is left to allow for wave action, floating debris, or any other condition or emergency, without overtopping the structure. For irrigation flows intercepting runoff, freeboard is based on the expected water surface elevation determined for the sum of the water right, flood right and design discharge.

The marginal height provided above the design discharge lines, stage on levees and in certain channels, to insure, as fully as practicable, against overtopping due to uncertainties in such things as the state of project maintenance or flood flow characteristics. In appropriate circumstances, special increments of levee freeboard may be provided to achieve design objectives (e.g., to control, in such an extremity, the location where initial overtopping of a levee would take place; to reduce wave overtopping; to extend the interval between major maintenance efforts for removal of tree growth, sediment deposition, etc. from the channel the levee bounds). Added height to earth levees is sometimes provided to allow freeboard for settlement. In project evaluation, one-half of the inundation reduction benefits creditable to the levee freeboard zone may be included.

Frequency. See Flood-Frequency.

FWS. Acronym for United States Fish and Wildlife Service.

Groundwater. Subsurface water occupying the saturation zone, from which wells and springs are fed. A source of base flow in streams. In a strict sense the term applies only to water below the water table. Water at and below, the water table; basal or bottom water; phraetic water. Used also in a broad sense to mean all water below the ground surface.

HEC-1. U.S. Army Corps of Engineers Hydrologic Engineering Center Flood Hydrograph Package

HEC-HMS. U.S. Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System.

Hydraulics. The Applied science concerned with the behavior and flow of liquids, especially in pipes, channels, structures, and the ground. In highway drainage, the science addressing the characteristics of fluid mechanics involved with the flow of water in or through drainage facilities.

Hydraulic Radius. The cross sectional area of a stream of water (normal to flow) divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter.

Hydrograph. A graph showing the variance over time of discharge, stage, velocity, or other property of water.

Hydrology. The science and study concerned with the occurrence, circulation, distribution and properties of the waters of the earth and its atmosphere, including precipitation, runoff, and groundwater. The science dealing with the waters of the earth in their various forms: precipitation, evaporation, runoff and groundwater. In highway drainage, the science dealing with the runoff and flood-producing process.

HYDRO. The module of the software program HYDRAIN that computes drainage runoff volumes.

HYDRO-35. Technical Memorandum 35, Five to 60 Minutes Precipitation Frequency for the Eastern and Central United States.

Impact. The striking together of two masses. When particles or streams of water suffer impact, energy losses result. Impact can also refer to the short- and long-range changes and their significance to surface waters and related social and environmental relationships resulting from an effect(s) brought about by a highway drainage facility.

Impervious Surface. Any hard-surfaced, man made area that does not readily absorb or retain water, including but not limited to roofs, streets, parking lots, driveways, sidewalks, and paved recreation area.

Impounded. Water collected and confined; storage. Water may be in a reservoir or detained in depressions, channels, basins, etc.

Improvements. Changes made to natural conditions. Improvements can consist of many possibilities including: placement of pavement, plantings, and grading.

Inlet. Consider four definitions: 1. a surface connection to a closed drain; 2. a structure at the diversion end of a conduit; 3. the upstream end of any structure through which water may flow; 4. an inlet structure for capturing concentrated surface flow. Inlets may be located in such places as along the roadway, a gutter, the highway median, or a field.

Instructional Bulletin. A memorandum that is released by the TDOT informing users of the Drainage Manual of updates or changes.

ISTEA. Acronym for 1991 Intermodal Surface Transportation Efficiency Act.

Iteration. The action or a process of iterating or repeating: as a procedure in which repetition of a sequence of operations yields results successively closer to a desired result.

Kinematic Wave Method. A flow routing method which neglects the local acceleration, convective acceleration, and pressure terms in the momentum equation. The method assumes that the water surface slope and bed slope are equal.

Lake. An area of open, relatively deep water sufficiently large to produce somewhere on its periphery a barren, wave-swept shore.

Levee. An embankment, generally landward of a top bank, that confines flow during highwater periods, thus preventing overflow into lowlands. A linear embankment outside a channel for containment of flow. Longer than a dike.

Liable. Subject to civil action against, or for redress from infringement of private rights.

Litigation. To carry on a legal contest by judicial process.

Local Government. The government of a specific local area constituting a subdivision of a major political unit (as a nation or state); also the body of persons constituting such a government.

Manning's Equation. An empirical formula devised by Manning, based upon original work by Ganguillet and Kutter, for computing flow in open channels and pipes. In its present form it has been modified to: v = (1/n)R2/3S1/2 where v = velocity, n = Manning's roughness coefficient, R = hydraulic radius or A/Wp where A = cross section area and Wp = wetted perimeter and S = Hydraulic Gradient. See Manning's Roughness Coefficient.

Manning's Roughness Coefficient. A coefficient representing the resistance to flow in a given channel. The factors used in estimating the resistance to flow are the surface roughness of the channel, vegetation, channel irregularity, channel alignment, obstructions to flow, size and shape of channel, and depth of flow.

Municipality. Primarily an urban political unit having corporate status and usually powers of self-government and also defined as the actual governing body of a municipality.

Navigable Waters. Primarily a regulatory term as it applies to highway drainage planning, design and construction in jurisdictional surface waters. The term "navigable waters" refers to jurisdictional surface waters as used in Public Law 92-500 and defined in Section 502(7) as "waters of the United States including the territorial seas." The territorial seas; coastal and inland waters, lakes, rivers and streams that are navigable waters of the United States, including adjacent wetlands; tributaries to navigable waters of the United States, including adjacent wetlands; inter-state waters and their tributaries, including adjacent wetlands; and all other waters not identified above, the degradation or destruction of which could affect interstate commerce (33 CFR 323.3, 42 FR 37144, 1977); also see 80 Stat. 941, Volume 80 of the U.S. Statutes at Large, page 941; 49 USC. 1651 et seq.: Title 49, United States Code, Section 1651 and that which follows (or "and following"); PL 92-500: Public Law number 500 enacted by the 92nd Congress; 40 FR 55810: Volume 40 of the Federal Register, page 55810; 40 CFR 126: Title 40 of the Code of Federal Regulations, part 126. Those waters of the United States that are subject to the ebb and flow of the tide and/or those waters of the United States that are presently used, or have been used in the past, or may be susceptible to use in the future to transport interstate or foreign commerce. (33 CFR 322.2, 42 FR 37139, 1977).

Further, navigable waters are considered to be territorial seas of the United States and internal waters of the United States that are subject to tidal influence and internal waters of the United States not subject to tidal influence that: 1. are or have been used, or are or have been susceptible for use by themselves or in connection with other waters, as highways for substantial interstate or foreign commerce, not withstanding natural or man-made obstructions that require portage, or 2. a governmental or non-governmental body, having expertise in waterway improvement, determines to be capable of improvement at a reasonable cost (a favorable balance between cost and need) to provide, by themselves or in connection with other waters, highways for substantial interstate or foreign commerce (40 FR 49327; 33 CFR 2.05-25).

NFIP. Acronym for the National Flood Insurance Program. In 1968, Congress created the NFIP in response to the rising cost of taxpayer funded disaster relief for flood victims and the increasing amount of damage caused by floods. The NFIP makes Federally-backed flood insurance available in communities that agree to adopt and enforce floodplain management ordinances to reduce future flood damage. The NFIP is managed by the Federal Emergency Management Agency's Federal Insurance Administration and Mitigation Directorate.

NOAA. Acronym for National Oceanic and Atmospheric Administration is a unit of the United States Department of Commerce.

Notebook. A notebook assembled by the drainage designer and stamped by a licensed engineer which contains the TDOT required drainage correspondence, reports, design computations, maps, and other pertinent information.

NRCS. Acronym for Natural Resources Conservation Service (formerly Soil Conservation Service) is a unit of the United States Department of Agriculture.

NRCS Curve Number Runoff Method. A procedure used to compute the runoff hydrograph of a drainage area. The NRCS Curve Number Runoff Method is dependent on the hydrologic soil group, ground cover type, treatment, hydrologic condition, antecedent runoff condition, and how the flow enters the drainage system.

NWS (NOAA). Acronym for the National Weather Service. More specifically, the United States Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service; formerly the U.S. Weather Bureau.

Obstruction. A blockage in a drainage system.

Others. A generic term sometimes used for such things as another governmental agency or quasi governmental agency (such as a flood control district, or irrigation district), as well as party(ies) or individual(s) from the private (non-governmental) sector of society.

Overland Flow. The flow of rainwater or snowmelt over the land before it becomes channelized.

Overland Flow Travel Time. The time required for runoff to flow over the ground surface to a channel, gutter, inlet, or pipe.

Overtopping Flood. See Flood, Overtopping.

Pipe Culvert. A culvert (see definition of culvert) which is a round or oval prefabricated conduit.

Policy. A definite course of action or method of action, selected to guide and determine present and future decisions whereas criteria are the standards by which a policy is carried out or placed in action.

Precipitation. The process by which water in liquid or solid state falls from the atmosphere. The total measurable supply of water received directly from clouds, as rain, snow and hail; usually expressed as depth over a specified time period and designated as daily, monthly, or annual precipitation. (Not synonymous with Rainfall.) As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. It is the common process by which atmospheric water becomes surface or subsurface water. The term “precipitation” is also commonly used to designate the quantity of water that is precipitated. Precipitation includes rainfall, snow, hail and sleet and is therefore a more general term than rainfall.

Preconstruction Documentation. Contains information gathered during the advance planning stage of a roadway project and design. Numerous types of data are included including aerial photography, contour mapping, watershed maps, survey data, flood insurance studies and maps, soil maps, field reconnaissance reports, and reports from other sources.

Probability. The science that deals with the measure of chance or likelihood based on the sampled data. It is the ratio of observed or expected events to all possible events; it is expressed as a decimal less than or equal to one.

Probability of Exceedance. See Exceedance Probability.

Promulgate. To make known by open declaration or to proclaim. It is also to make known a public term or law and can also mean to put the law or action into force.

Rainfall Intensity. Amount of rainfall occurring in a unit of time, converted to its equivalent in inches per hour at the same rate.

Rainfall Intensity Duration Frequency Curves. Curves representing the amount of rainfall occurring in a unit of time for given locations.

Rational Method. A method of estimating the peak runoff rate which will occur from a drainage basin. The method is based on the area in acres, percentage of precipitation that will become runoff, and the maximum rainfall intensity in inches per hour that will probably occur during the time of concentration for the drainage basin.

Regime. The condition of a stream and its channel as regards to their stability. A river or canal is “in regime” if its channel has reached a stable form as a result of its flow characteristics. General pattern of variation around a mean condition, as in such things as flow regime, tidal regime, channel regime and sediment regime; used also to mean a set of physical characteristics of a river. The system or order characteristic of a stream; its behavior with respect to such things as velocity and volume, form of and changes in channel, capacity to transport sediment and amount of material supplied for transportation.

Regime Change. A change in channel characteristics resulting from such things as changes in imposed flows, sediment loads or slope.

Regression. A functional relationship between two or more correlated variables that is often empirically determined from data and is used especially to predict values of one variable when given values of the others

Regulations. Formal instructions or rules governing the application and administration of specified legislative acts, which have the force and effect of law. As used in the Code of Federal Regulations, rule and regulation have the same meaning.

Right-of-way. A general term denoting land, property, or interest acquired for, or devoted to highway purposes.

Riparian. Pertaining to the banks of a stream. Of, on, or pertaining to the bank of a channel or the shore of a pond or a lake. Pertaining to anything connected with or adjacent to the banks of a channel or other body of water; a riparian owner is one who owns the banks.

Riparian Doctrine or Rule. A doctrine that holds that the property owner adjacent to a surface water body has first right to withdraw and use the water. This doctrine may be set aside by a state's statutory law that holds that all surface waters are the property of the state.

Riparian Owner. A riparian proprietor who owns land on the bank of a river, lake, channel or other body of water. An owner of land, in part bounded generally by a stream or river of water and having a qualified property in the soil to the thalweg thread of the channel with the privileges annexed thereto by law.

Riparian Rights. The rights of the owners of lands along a watercourse, relating to such things as water, its use, ownership of soil under the stream or river and accretions. The legal right of a riparian owner to use the water on his riparian land originated in the common law, which permitted him to require that the waters of a stream or river reach his land undiminished in quantity and unaffected in quality except for minor domestic uses.

Riparian Water. Water which is below the highest line of normal flow of a river or stream, as distinguished from floodwaters.

River. Natural stream of water of considerable volume. Depending on local usage, a larger form of a stream.

Riverine. Relating to, formed by, or resembling a river. Situated on or inhabiting the banks of a river. Operating on or equipped to operate on rivers.

Road. A general term denoting a public way for purposes primarily of vehicular travel and includes the entire area within the right of way; generally with emergency parking areas adjacent to the traveled ways (shoulders), but without curb and gutters. The portion of a road within the limits of construction.

Runoff. That part of the precipitation which runs off the surface of a drainage area after accounting for all abstractions. The portion of precipitation that appears as flow in streams; total volume of flow of a stream during a specified time. Runoff may be classified as to: speed of appearance after rainfall or snow melting; direct runoff and base runoff, and source; surface runoff, storm seepage, and groundwater runoff.

Runoff Coefficient. A factor representing that portion of runoff which results from a unit of rainfall. The coefficient is dependent on land cover, and topography.

Sag. The low point in a vertical curve where flanking inlets are used to collect water.

Sediment. Fragmental material that originates from weathering of rocks and is transported by, suspended in, or deposited by water or air or is accumulated in beds by other natural agencies.

Sewer. A conduit for conveying sanitary waste flows.

Shallow Concentrated Flow. The collection of sheet flow with a depth greater than 0.1 feet (1.2 inches).

Sheet Flow. Sheet flow is normally considered when water flows at a depth of 0.1 feet (1.2 inches) or less and has not collected in a swale, ditch or other drainage structure.

Sheet Flow Travel Time. The time taken for sheet flow to travel to a drainage structure or an area where the flow collects.

Shoulder. The portion of the roadway contiguous with the traveled way for accommodating stopped vehicles, for emergency use, and for lateral support of the road's base and surface courses.

Soil Conservation Service. see NRCS

Spillway. A passage for spilling surplus water.

Standard Drawing. A standard detail drawing contained in the Standard Roadway Drawings published by the State of Tennessee Department of Transportation, Bureau of Planning and Development, Design Division or the Standard Structure Drawings published by the Tennessee Department of Transportation, Bureau of Planning and Development, Division of Structures.

Statute. See Statutory Law.

Statutory Laws. Law established by a legislative body and set forth in a formal document. In its specific application, law implies prescription and enforcement by a ruling authority.

Stochastic Hydrology. Stochastic Processes are the laws of chance and the sequence of various variables that describe the random phenomena of such things as precipitation, evaporation, runoff, groundwater levels, sediment transport, lake levels, snow and ice accumulation and melt, water quality properties and properties of porous environments, river basin geomorphic forms, etc.

Storm Drain. A conduit for carrying off stormwaters.

Storm Sewer. Principally a drain for conveying stormwater, may also be a drain which also conveys raw sewage is termed a storm sewer.

Storm flow. See Runoff

Stream. A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally as in the term "stream gaging," it is applied to the water flowing in any channel, natural or artificial. To flow in or as if in a stream. Depending on local or regional usage, a lesser form of a river. A body of water that may range in size from a large river to a small rill flowing in a channel. By extension, the term is sometimes applied to a natural channel or drainage course formed by flowing water whether it is occupied by water or not. A body of flowing water, whether in an open or closed conduit, a jet of water as from a nozzle.

Streams in natural channels may be classified as follows:

relation of a stream (or river) to time:

- perennial - one which flows continuously
- ephemeral - one that flows only in direct response to precipitation and whose channel is at all times above the water table; relation of a stream (or river) to space
- continuous - one that does not have interruptions in space
- interrupted - one which contains alternating reaches, that are either perennial, intermittent, or ephemeral; and relation of a stream (or river) to groundwater
- gaining - a reach that receives water from the zone of saturation
- losing - a reach that contributes water to the zone of saturation
- insulated - a reach that neither contributes water to the zone of saturation nor receives water from it; it is separated from the zones of saturation by an impermeable bed
- perched - a reach that is either a losing or insulated and is separated from the underlying groundwater by a zone of aeration

Street. A general term denoting a public way for purposes of vehicular travel, usually including curb and gutters, to include the entire area within the right-of-way.

Surface Area. That area of a body of water outlined on the latest U.S. Geological Survey topographic map as the boundary of the water and measured by a planimeter in acres. In localities not covered by topographic maps, the areas are computed from the best maps available at the time planimetered. All areas shown are those for the stage when the planimetered map was created.

Surface Waters. Water on the surface of the earth. Any stream, river, lake, pond, or reservoir. Some include wetlands in surface waters.

Template Ditch. A ditch that is designed based solely on the typical roadway cross sections for areas in cut.

Thalweg. The line or path (such as a rill) connection the lowest flow points along the bed of a channel. The line does not include local depressions. The path very low flows would follow in proceeding down a stream, river, swale, or channel. The line extending along a channel profile that follows the lowest elevation of the bed.

Time of Concentration (tc). The time (tc) it takes water from the most distant point (hydraulically) to reach a watershed outlet.

Tort. A private or civil wrong committed upon the person or property independent of contract. The elements of every tort action are: 1. existence of legal duty from defendant to plaintiff; 2. breach of duty; and 3. damage as proximate result.

TP40. Technical Paper No. 40, Rainfall Frequency Atlas of the United States for Durations from 30 minutes to 24 hours and Return Periods from 1 to 100 years.

TR-20. The Natural Resources Conservation Service Technical Release 20, Computer Program for Project Formulation – Hydrology.

TR-55. The Natural Resources Conservation Service Technical Release 55, Urban Hydrology for Small Watersheds.

Travel Time (tt). The average time for water to flow from one point to another.

USFS. Acronym for U.S. Forest Service.

USGS. Acronym for United States Department of the Interior, Geological Survey.

USWB. Acronym for United States Department of Commerce, Weather Bureau. Weather Bureau changed to National Oceanic and Atmospheric Administration, National Weather Service (NWS NOAA).

Water Law. Includes doctrines, rules, riparian doctrine or rule, water right, flood right, common law, civil law, common enemy doctrine or rule, civil law doctrine or rule, natural drainage doctrine or rule, reasonable use doctrine or rule, rule of law, and water drainage rights.

Watershed. See Drainage Area.

Waterway. Any stream, river, lake, pond, or ocean that can be traversed for purposes of commerce or recreation. May also refer to a channel.

Wetlands. Those lands having: wetland hydrology; hydric soils; and hydrophyte type vegetation as delineated by current editions of the Federal Manual for Identifying and Delineating Jurisdictional Wetlands. These include wetlands subject to Federal law regardless of whether they involve Federal, State, or private lands. More generally, an area that is inundated or saturated by surface waters or groundwater at a frequency and duration sufficient to support and under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. Mudflats, sand flats, rocky shores, gravel beaches and sand bars, although they often do not support vegetation, can also be considered wetlands. Wetlands typically have hydric soils, phreatic vegetation and wetland hydrology.

Some regulatory agencies may prefer land that has a predominance of hydric soils that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support "and that under normal circumstances does support," a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions.

TDOT DESIGN DIVISION

DRAINAGE MANUAL

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