DESIGN PROCEDURES

FOR

HYDRAULIC STRUCTURES

TDOT

2004

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TENNESSEE HYDRAULICS MEMORANDA

DESIGN PROCEDURES FOR HYDRAULIC STRUCTURES

Tennessee Department of Transportation

1. Determine the drainage area of the site, in mi^2 (km^2).

2. Determine the hydraulic design responsibility. See below for details.

3. Check for previous hydraulic studies at or near the site:
   A. Corps of Engineers, TVA and F.E.M.A. Flood Insurance Study and Maps. See Tennessee Hydraulics Memorandum 04, "Index of Local Flood Studies by TVA, Corps of Engineers and F.E.M.A. Flood Insurance Studies".
   B. USGS flood studies.
   C. Previous TDOT projects.

4. Check for stream gage data at or near the site. Gage should be within 50 % of the site's drainage area.

5. All designs are to be in English units (except where metric is specifically called for).

6. Determine the flood frequencies for the site, in ft^3/s (m^3/s). Discharges are to be determined as shown below. Methods are shown in order of decreasing preference. Plot discharge vs. recurrence interval as shown in Figure 1. See Tennessee Hydraulic Memorandum – 2 for additional information.

7.
   - Method 1: Existing FEMA Flood Insurance Study (FIS).
   - Method 2: Analysis of gage data within the watershed.
   - Method 3: Regression equations from the following USGS publications.
     - For rural drainage basins: "Flood-Frequency Prediction Methods for Unregulated Streams of Tennessee, 2000" WRIR 03-4176
     - For urbanized drainage basins: "Synthesized Flood Frequency for Small Urban Streams in Tennessee" WRIR 84-4182.

8. Determine the average flood energy grade slope for a reach upstream and downstream of the site. This slope is usually approximately equal to the average streambed slope for that same reach. Using multiple methods such as quadrangle maps, site survey, and flood insurance studies to determine this slope is recommended.

9. The skew of the culvert or the skew of the bridge substructures should be in alignment with the direction of design flood flow downstream of the proposed structure.

10. Run a water surface profile model in HEC-RAS to determine the normal water surface profiles, the existing bridge water surface profiles and the proposed bridge water surface profiles for the 2, 10, 50, 100, and 500 year events. If the bridge location is within a FEMA designated floodway and an existing HEC-2 model available from FEMA, HEC-2 may be used but the preferred method is to import the HEC-2 model into HEC-RAS. Create a stage vs. discharge chart as shown in Figure 2. This chart should show all three water surface profiles at the upstream cross-section with highest proposed backwater.

11. See Tennessee Hydraulics Memorandum - 01 “Box and Slab Culverts and Bridges” for determination of the type of structure required at the design site.

12. For guidelines on selecting an acceptable structure size, refer to the following Tennessee Hydraulics Memorandums:
    A. “Design of Waterway Openings” - 03
    B. “Improved Inlets for Culverts and Box or Slab Bridges” -06
    C. “Scour and Fill at Bridge Waterways” - 08

13. Proper drainage of rainfall on the bridge deck shall be provided. See Tennessee Hydraulics Memorandum - 07 “Drainage of Bridge Decks”.

14. Where Rip-Rap is required for slope protection, refer to Tennessee Hydraulics Memorandum - 09 “Rip-Rap for Bridge Waterways, Open Channels and Grade Crossings”.

15. The proposed bridge plans may be subject to approval by various other agencies. See Tennessee Hydraulics Memorandum - 05 “Approval of Bridge Plans by Outside Agencies”.

16. An on site visual inspection should be made of the existing hydraulic conditions. See Tennessee Hydraulics Memorandum - 10 “On Site Inspection Report” for specific details of the inspection.

17. Compile the hydraulic design file. See below.

18. The roadway designer should submit roadway plans to the Environmental Planning and Permits Division in order to determine permit requirements and for permit application. See Roadway Design Guidelines and Tennessee Hydraulics Memorandum - 05 "Approval of Bridge Plans By Outside Agencies" for details.

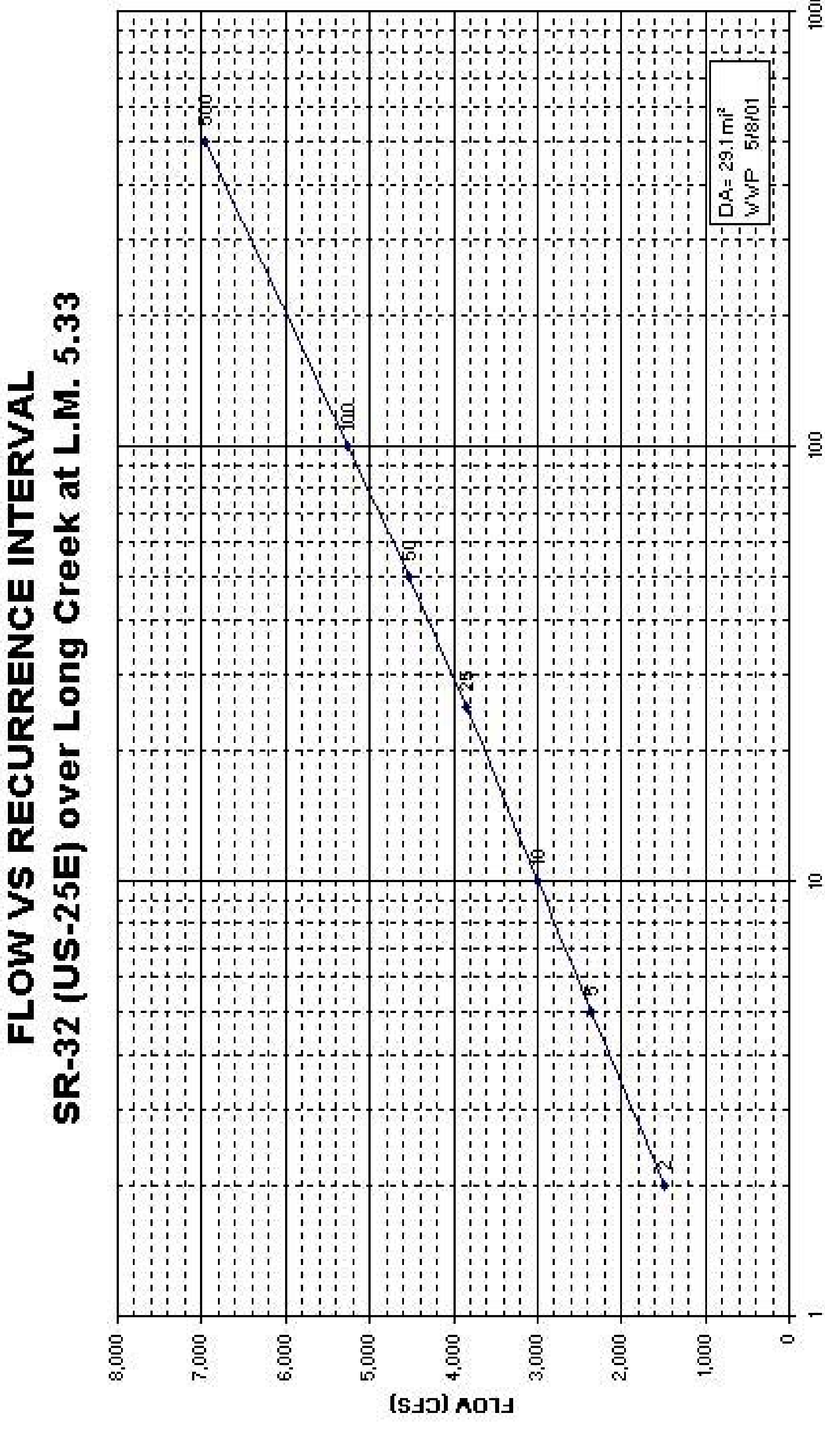


Figure 1: Example Flow versus Recurrence Interval

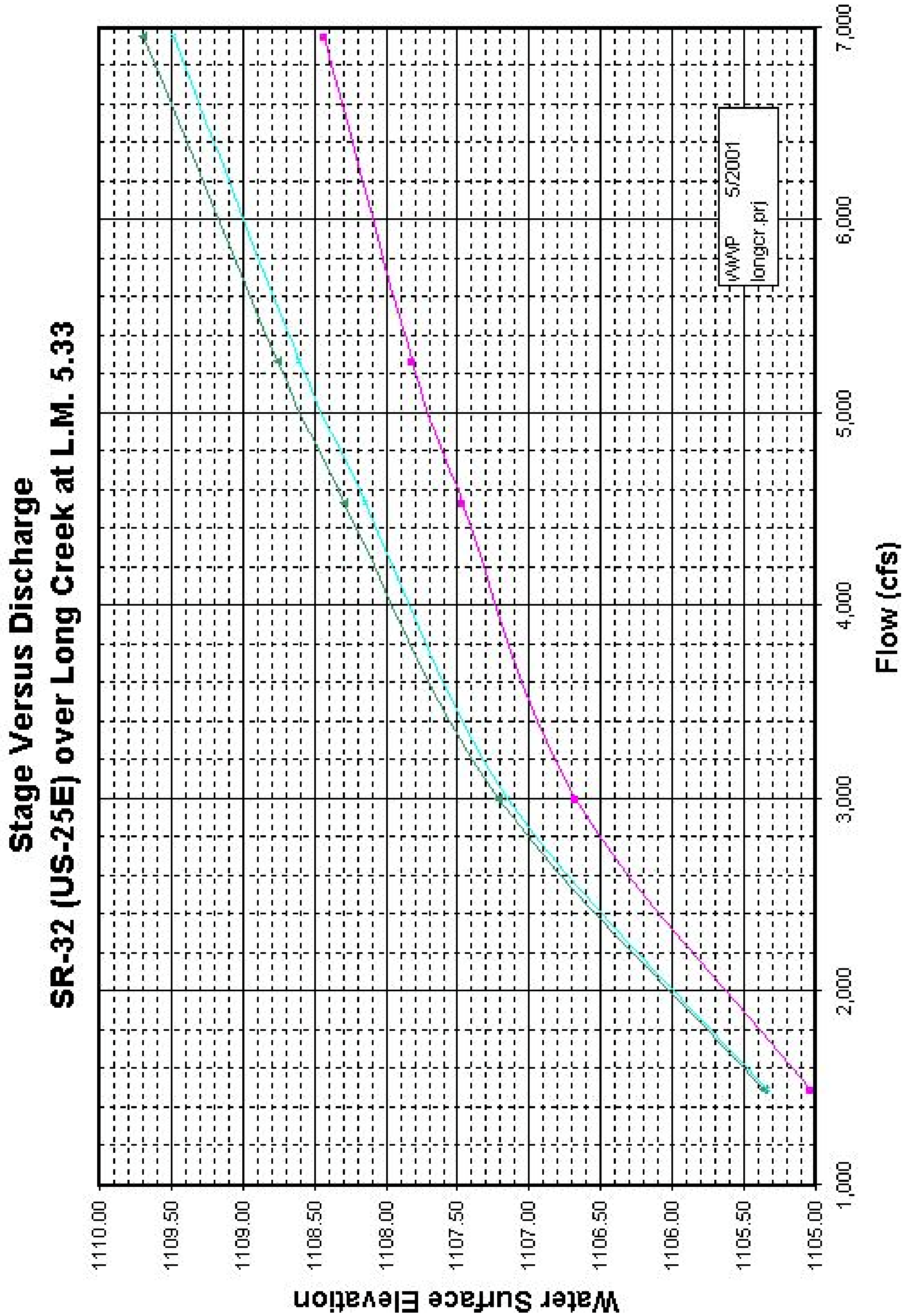


Figure 2: Example Stage versus Discharge

Hydraulic Design Responsibility

The Hydraulic Design and Permitting Section will be responsible for the hydraulic design of stream encroachments (bridges, culverts, channels, etc.) whose Q_{50} is greater than 500 ft^3/s (14 m^3/s) (by the USGS regression equations) at the downstream most portion of the encroachment. Additionally, replacement or rehabilitation of any existing structure 20 feet (6 m) long or longer will be reviewed by the Hydraulic Design and Permitting Section and a determination of hydraulic design responsibility will be made.

The roadway designer will submit to this office preliminary plans (typical sections, present and proposed layout, and profile, cross sections, etc.), location map, and survey information as indicated in the Drainage Surveys Section of the Survey Manual for all stream encroachments (bridges, culverts, channels, etc.) whose Q_{50} is greater than 500 ft^3/s (14 m^3s) (by the USGS regression equations) at the downstream most portion of the encroachment and for replacement or rehabilitation of any existing structure 20 feet (6 m) long or longer.

The Design Division will be notified by the scheduled grade approval date or within 5 weeks of receipt of a complete grade approval request (whichever is longer) of the finished grade requirements for the stream encroachment.

For the replacement or rehabilitation of any existing structure 20 feet (6 m) long or longer the Design Division will be notified whether the hydraulic design will be completed in this office or if they should proceed with replacement under their hydraulic design criteria.

Where removal of a portion of an existing structure is required for stage construction, the plans should be forwarded to the appropriate regional Manager 2 in the Structural Design Section of the Structures Division for review and a request for stage construction details that will affect roadway design should be made.

The final hydraulic data and any additional drawings required to complete plans for the stream encroachment will be forwarded to the Design Division no later than the scheduled bridge preliminary due date. At this time a Hydraulic Layout should be forwarded to the Director of Structures Division for structural design assignment.

Design File Requirements

Compilation of a hydraulic design file will be required for hydraulic structures under the responsibility of the Structures Division as discussed above.

The hydraulic design file should be bound (8.5" x 11") in the following approximate order and each section tabbed separately.

1. Correspondence in chronological order
2. Maps- located on a portion of the county map or city map and 7.5 minute USGS quadrangle (preferably color).
3. Hydraulic report summary form as shown below.
4. Photographs - See THM-10 for minimum requirements. Aerial photographs should be included if available.
5. Analysis
   a) Discharge calculations.
   b) Frequency discharge relationship as shown in Figure 1 above.
   c) Stage discharge relationship as shown in Figure 2 above.
   d) Supporting hydraulic information (previous flood studies, gage data, etc..).
   e) Existing structure analysis, with cross sections plotted (if applicable).
   f) Proposed structure analysis, with cross sections plotted.
   g) Scour analysis, if applicable.
   h) Deck drainage analysis.
   i) On site inspection report.
   j) Other information.

Where multiple structures occur on a single project, the correspondence section should not be repeated. The cover of the design file should include the project description as indicated in Department schedules. Also each stream crossings station, stream name and associated bridge location number (if available) should be indicated on the cover. Survey data should be included in the file for future reference.

The hydraulic design file will be filed in the Hydraulic Design and Permitting Section's files.

STATE OF TENNESSEE

DEPARTMENT OF TRANSPORTATION - DIVISION OF STRUCTURES
HYDRAULIC REPORT
Date: ____________ Designer:_____________________

A. SITE DATA

1. LOCATION

a. Name of Stream:	________________________	Channel Mile:	________________________
b. Route Name:	________________________	P.E. No.:	________________________
c. Route No.:	________________________	Project No.:	________________________
d. County:	________________________	USGS Quad #:	________________________
e. City:	________________________	Name:	________________________

2. VICINITY

a. See attached location map or bridge survey.
b. Nature of Stream Bed: ________________________________
c. Bank subject to Erosion: _____ Severe = 10 Stable = 0
d. Should Drift be a consideration: _____ Extreme = 10 No = 0

3. EXISTING BRIDGE DATA

a. Bridge Location No.:	______________________________	______________________________
b. Bridge Selection No.:	______________________________	______________________________
b. Drawing No.:	______________________________	______________________________
c. Bridge Length:	________ ft.	________ ft.
d. Bridge Width:	________ ft.	________ ft.
e. Bridge Type:	______________________________	______________________________
f. Bridge Skew:	___ °	___°
g. Drainage Area:	________ mi^2.	________ mi^2.
h. Design Discharge:	________ ft^3/s	________ ft^3/s
i. Design Frequency:	________ Year	________ Year
j. Design Water Area:	________ $ft.^2$	________ $ft.^2$
k. Design Elevation:	________ ft.	________ ft.
l. Design Backwater:	________ ft.	________ ft.
m. Design Velocity:	________ ft/s	________ ft/s
n. Overtopping El.:	________ ft.	________ ft.

4. EXISTING WATER STAGES AT PROPOSED BRIDGE SITE

a. Maximum High Water El.: __________ Date: ___/___/___
Frequency: __________ year Source: ________________________
b. ________ Year High Water Elevation: _____________ ft.
c. Datum Elevation: ________ ft. Ordinary High Water Elevation: _________ ft.
d. In Reservoir (Y/N): _________ Reservoir Name: ____________________________
Normal Pool Elevation: ________ ft. Minimum Pool Elevation: _____________ ft.
e. Backwater Elevation: ________ ft. From: ______________________________

B. HYDROLOGICAL ANALYSIS

1. FLOOD RECORDS

a. Floods in Tennessee - Magnitude and Frequency - 1992 [ ] U.S.G.S. [ ]
Corps of Engineers [ ] TVA [ ] Other [ ] ____

b. Stream Gage No.: ____________________ At Site [ ] In Vicinity [ ]

c. None Available [ ]

2. DRAINAGE AREA

a. ____________ sq. mi. Calculated: ______ Published: ____

3. DISCHARGE

a. Magnitude: ________ ________ ________ ______ ________ ________ _______
Frequency: 2 yr 5 yr 10 yr 25 yr 50 yr 100 yr 500 yr

b. Proposed Overtopping: _____ Frequency_______ year & Discharge _______ cfs

c. Source: _________ Floods in Tennessee - Magnitude and Frequency – 1993
_________ Corps of Engineers
_________ TVA
_________ Federal Insurance Study __________ County or City
_________ Other ____

4. STREAM SLOPE

a. From U.S.G.S. Quad Map: ________________________ ft./ft.

b. From Site Survey Data: ________________________ ft./ft.

c. From Flood Flow Profiles: ____

C. HYDRAULIC ANALYSIS OF PROPOSED BRIDGE

1. PROPOSED STRUCTURE ____

a. Station: ____________________ Drainage Area: ____________________ mi.^{2}.
Design Frequency: _________________ year Design Discharge: __________________ ft3/s
Design Velocity: __________________ ft/s Design Bridge Backwater: ___________ ft.
Design Bridge Backwater El: ________ ft. Roadway Overtopping Elevation: ______ ft.
Design Waterway Area: _____________ ft.^{2} below elev. ________ ft.

b. Is Bridge Backwater a consideration? (Y/N) : ____
_____ Year Bridge Backwater: _________ ft.
_____ Year Bridge Backwater Elevation: __________ ft.
Describe Control: ____

c. Are Spur Dikes Needed (Y/N) : _______
Describe Reason: ____

d. Is Channel Transitioning Involved (Y/N) : ____ See attached detail.

e. Is Channel Change Involved (Y/N) : ____ See attached detail.

f. Is Bank Protection Needed (Y/N) : ____ See attached detail.

g. Final Layout: See Drawing No. ________________

D. SCOUR ANALYSIS OF PROPOSED BRIDGE

1. CHANNEL CHARACTERISTICS

a. USGS/TDOT "observed" scour ranking at existing bridge is ____________, or at nearest bridge upstream [] /downstream [ ] is ___________ (Br. No. ________________).
b. USGS/TDOT "potential" scour ranking at existing bridge is _____________, or at nearest bridge upstream []/downstream [ ] is ____________ (Br. No. ________________).
c. Current stage of channel evolution : Stable [ ] Degrading [ ] Widening [ ] Aggrading [ ]
d. Streambed material type: silt/sand [ ]; coarse gravely sand [ ]; gravel/cobbles [ ]; gravel and cobbles on rock [ ]; slab rock [ ]

2. COMPUTED SCOUR DEPTH

a. Design discharge (_____ yr.) = ____________ cfs
b. Design velocity (_____ yr.) = _____________ fps
c. Estimated degradation [ ] /aggradation [ ] = __________ ft.
d. Estimated contraction scour = __________ ft.
e. Estimated pier scour = __________ ft.
f. Estimated total scour depth = __________ ft.
g. Preliminary ftg. and/or pile tip elev. (based on soils report? Y/N): _____________________
h. Comments : ____
____

E. OTHER AGENCY REVIEW and/or APPROVAL

YES	NO	
_____	_____	Corps of Engineers – Individual
_____	_____	Corps of Engineers - Nationwide
_____	_____	Tennessee Valley Authority
_____	_____	U. S. Coast Guard
_____	_____	Tennessee Wildlife Resource Agency
_____	_____	State Water Quality Control
_____	_____	Federal Highway Administration
_____	_____	Federal Emergency Management Agency
_____	_____	Local Government, if participating in FEMA Program
_____	_____	Individual ARAP required
_____	_____	General ARAP required
_____	_____	National Pollutant Discharge Elimination System (NPDES)

Is the location governed by the National Flood Insurance Program Regulations? (Y/N): _____

Has the TDOT policy on selection of Design Flood Frequency been satisfied? (Y/N): _____

F. REMARKS

____
____
____

TENNESSEE HYDRAULICS MEMORANDUM - 01
Box and Slab Culverts and Bridges

PDD

Distribution: Office, Consultants

Definitions For Cast-In-Place & Precast Concrete and Corrugated Metal Structures

Box Culvert - A box type structure consisting of a single box or multiple boxes with a bottom slab, having a length measured along the centerline of the roadway of **less** than 20 feet (6.1 m) between the extreme ends of the openings.

Slab Culvert - A structure consisting of a single box or multiple boxes without a bottom slab, having a length measured along the centerline of the roadway of **less** than 20 feet (6.1 m) between the extreme ends of the openings.

Box Bridge - A box culvert type structure consisting of a single box or multiple boxes with a bottom slab, having a length measured along the centerline of the roadway of **more** than 20 feet (6.1 m) between the extreme ends of the openings.

Slab Bridge - A structure consisting of a single box or multiple boxes without a bottom slab, having a length measured along the centerline of the roadway of **more** than 20 feet (6.1 m) between the extreme ends of the openings.

Bridge - A structure erected over a stream, watercourse, highway, railroad or opening, for carrying traffic, having a length measured along the centerline of the roadway of more than 20 feet (6.1 m) between the faces of the end supports or the extreme ends of the openings for box bridges.

The distinction between Culverts, Box Bridges and Bridges is important in that separate bid items for concrete and reinforcing are provided for each. See SMO13-04 and Tennessee Standard Specifications Articles 101.07, 101.08 and 604.32.

The distinction between slabs and boxes is important in that it establishes whether or not the structure has a bottom slab. When the foundation for the structure is capable of providing sufficient bearing resistance and is a non-erodible material the bottom slab is replaced by a small footing to support the walls of the structure. When the foundation material is erodible the bottom slab serves as the structure footing and is the bottom floor of the channel.

Available Standards

Box and Slab Culverts and Bridges are primarily used to provide roadway crossings for small streams. They are also used as cattle and machinery passes. Openings are sized to suit their intended use. Stream crossings are sized based on the hydraulic design as described in THM-03. A large selection of Standard Box and Slab Culverts and Bridges have been developed and are on file in the Division of Structures. An index of all available Box and Slab Standard drawings is maintained by the Division of Structures.

Standards are available for a wide variety of barrel heights and widths, number of barrels, skews and fill heights. Barrel widths of 6 feet to 18 feet increasing in 2 feet intervals are available in single, double and triple barrels. The barrel heights vary from 4 feet up to a height equal to a single barrel width increasing in increments of 1 foot. These combinations provide a size range from a single 6' x 4' to a three at 18' x 18' with corresponding openings ranging from 18 square feet to 324 square feet respectively. The hydraulic characteristics for a culvert may be improved with special inlet details. See THM-06 for details on improved culvert inlets.

Culvert end skews are available for 45°, 60°, 75° and 90°. Although the field engineer will construct the box to the exact skew (the angle between the centerline of the culvert and the centerline of the road) of the crossings the design and details of the closest available culvert end skew may be used.

Standard details also vary depending on the amount of fill to be placed on the box. Fill height shown on the standard drawings is measured from the bottom of the top slab to the top of the fill. When the fill height is less than one foot the "No Fill" section shown on the standard drawings may be used. Details are available for fill heights of 3 feet, 5 feet, and 10 feet to 60 feet (increasing in increments of 10 feet).

The proper way to designate a box is to list, in order, the number of barrels, barrel width, height, skew and fill height. For instance, a 3 @ 10' x 8' @ 45° and 30 feet of fill would be three barrels each 10 feet wide and 8 feet high skewed 45° and designed for a 30 feet high fill.

Other standards will be developed as necessary to provide skews, openings or fill heights not available on the current list of standards.

Quantities and Cost Estimates

The quantities shown on the standards are given per foot of box length for each combination of culvert height and fill section. Quantities for wings, cut-off walls, debris deflection walls, and edge beams are shown on separate drawings.

See Structures Memorandum 013 for instructions regarding cost estimates for boxes and slabs.

Contract Drawings and Specifications

Roadway plans in the contract drawings show the location, skew, elevation, size, fill height and Standard Drawings applicable for the construction of each box or slab. The location is shown on the roadway plan and profile. The length, elevations and fill height are shown in a roadway cross section. The project engineer has some flexibility in adjusting the location to fit field conditions unless otherwise noted on the plans.

All hydraulic data for Bridges and Culverts shall be shown on the roadway plan profile sheet as follows:

Station 5+12.50, 3 @ 12' (m) x 4' (m) 75° skew box, skewed
80° to centerline survey.
Drainage Area = 5.2 mi^2 (km^2)
Design Discharge (100 year) = 38.7 cfs (m^3/s)
100 yr. Bridge Backwater = 0.76 ft (m) at El. 122.63
100 yr. Velocity = 3.02 fps (m/s)
500 yr. Discharge = 56.2 cfs (m^3/s) at El. 122.87
Inlet Invert El. = 119.2
Outlet Invert El. = 118.9
Roadway Overtopping El. = 124.2
Std. Dwg. No. = STD-15-??

Excavation and backfill for boxes and slabs shall be in accordance with the Standard Specifications and Standard Drawing STD-10-1.

Bridge Deck Forms

Precast, prestressed concrete panels are frequently being used by contractors to form the top slabs or decks of many structures. When reviewing shop drawings for precast deck panels the reviewer should be very familiar with Bridge Deck Panel Standard Drawings STDM-4-1 through 3, Structural Memorandum 054. The check list on SM054-08 will be of special benefit to the reviewer.

Deck panels for design spans greater than 20 feet (6.1 m) should be reviewed as precast prestressed box beams. Elastomeric bearing pads may be required as indicated by the design chart for deck panel bearing material on STD-4-1 (STDM-4-1).

Bridge Deck Reinforcing

Box and slab structures are in many cases designed requiring only minimum fill (0 to 10 ft (m)) over the top slab. In order to protect the reinforcing and extend the life of the box, epoxy coating is to be specified for the top mat steel of the top slab. The bridge designer will specify which projects to call for epoxy coated steel and notify the roadway designer accordingly.

The following notes will be included on all metric standard culvert drawings. If these notes are not on the culvert drawings being used, then they should be added to the roadway plans.

> *Epoxy coated steel shall be provided for all reinforcing bars in the top mat of the top slab and curbs, including tie bars for curbs and corner bars for exterior walls. All other steel is to be black bars.*

Additionally, a footnote is to be shown on the box or slab bridge quantity tabulations for the reinforcing steel bid item:

> *The unit cost for bid item 604M02.02 is to include any additional cost for epoxy coated steel as noted on the plans details.*

Standard Slab Bridges

Reinforced slab bridges can provide economical and attractive solutions to short span bridge needs. In recent years slab bridge designs have been overlooked due to the desire to reduce the quantities of concrete and steel required. In the past decade, with the rise of labor rates, slab bridges have become economical due to the simplicity of design and ease of construction.

Slab bridges also allow much shallower superstructure depths requiring less approach fill. Slab bridges are economically competitive for spans up to 40 feet (12 m).

TENNESSEE HYDRAULICS MEMORANDUM - 02
Hydrology

WWP

Distribution: Office, Consultants

General

Before hydraulic design can begin the designer must have a thorough understanding of the hydrology of the project site. A hydrologic study must be undertaken to determine flood flows at a particular project location. If significant watershed urbanization is expected within the next 20 years, then future conditions should be taken into account when analyzing hydrology and proposed flows should reflect the expected watershed changes.

Sources of Hydrologic Information

The following methods of determining hydrology are acceptable, in order of decreasing preference. Proper documentation of the method used should be provided in all cases, as well as a graph of the resulting flow versus recurrence interval.

- Method 1: Existing FEMA Flood Insurance Study. If the project site is located within a city or county which participates in the National Flood Insurance Program (NFIP), then flood flows have likely been previously calculated by a detailed engineering study. The appropriate Flood Insurance Study (FIS) should be consulted. In order to provide continuity with the NFIP, flows obtained from a FIS are highly preferable.

- Method 2: Data available from stream gages located in the watershed. The U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (Corps) own and operate numerous stream gage stations throughout the state. If one of these is present within a reasonable distance from the project, the appropriate agency should be consulted to obtain flow versus recurrence interval data. If the gage is located at the project site, then this data may be used for project hydrology. If gage data is not available on site, data from nearby gages should be used to evaluate results from Methods 1 and 3.

- Method 3: Regression. The USGS has performed studies to determine the flow characteristics of ungaged watersheds. Rural basins should use the methods discussed in "Flood-Frequency Prediction Methods for Unregulated Streams of Tennessee" *WRIR 03-4176.* Flood flows for urban basins should be calculated using the methods discussed in "Synthesized Flood Frequency for Small Urban Streams in Tennessee" *WRIR 84-4182*. Further discussion of the rural methods is included below.

All methods should not be blindly accepted and should be evaluated for validity prior to using and all verification efforts should be documented in the design file. The Hydraulic Design Section reserves the right to require a more detailed study at high risk project locations, or when deemed necessary due to unusual circumstances such as karst topography or storage within the watershed.

Rural Regression Methods

As mentioned previously, flood flows for rural ungaged basins may be obtained using methods discussed in WRIR 03-4176. This publication provides three methods for determining flood flows, the single regression equations (SRE), the multiple regression equations (MRE), and the region of influence method (ROI). The SRE and MRE methods may be done manually, however the ROI method may only be done using a computer program provided by the authors of WRIR 03-4176. The publication and supporting computer application may be obtained from the website http://water.usgs.gov/pubs/wri/wri034176/.

The program provided with WRIR 03-4276 computes flows for a given site using the SRE, MRE, and ROI methods. The three methods should be compared and the method with the lowest calculated error should be used to determine flood flows for the structure. In certain cases, the program calculates outlier flows which it then corrects using a linear interpolation method (see WRIR 03-4276 for further detail). We do not recommend using this method for design. In certain high risk situations where conservative design is warranted the method resulting in the highest flows may be used rather than the method resulting in the lowest errors.

TENNESSEE HYDRAULICS MEMORANDUM - 03
Design of Waterway Openings

PDD

Distribution: Office, Consultants

General

Bridges and culverts should provide waterway openings which will not produce excessive backwater or scouring velocities. The minimum structure length should be that which will bridge the natural or man-made stream channel. The structure should be designed so that the accumulation of debris on the structure is avoided.

Design Frequency Criteria

The minimum "design flood" magnitude for stream crossings on State Routes is the 10 year frequency runoff and for Interstates and other 4 or more lane routes it is the 100 year frequency runoff based on land development expected 20 years hence. An analysis using the design condition is made of the flood risk to the highway, and the effect of the proposed crossing on the possible damages to surrounding property, the stream stability and the environment. Drainage facilities for Off-System and/or low traffic volume systems may be based on lesser floods if the conditions of the site warrant lower standards. The selection of the "design flood" includes consideration of construction cost analysis, probable property damage, the cost of traffic delays, the availability of alternate routes, emergency supply and evacuation routes, the potential loss of life and budgetary constraints.

When hydraulic structures are required on existing routes, the existing roadway grade may not be suited to being raised to desired design frequency. In this case a design exception would be required. See ADDENDUM page 7 of THM-03.

The hydraulic design for bridge crossings and/or encroachments shall be consistent with standards established by the Federal Emergency Management Agency and local governments for the administration of the National Flood Insurance Program.

Peak discharges should be reduced when floodwater retarding structures and/or reservoir systems are "existing" upstream from the bridge crossing, or can be expected to be in service upon completion of the highway construction. The appropriate Flood Control Agency should be contacted for computation of the reduced discharge.

Bridge Openings

Waterway openings should be designed to keep scour in the main channel and the overbanks within reasonable limits for which the bridge may be designed to withstand. It should be able to pass the 500 year flood without causing structural failure.

Backwater computations must be made to determine backwater caused by the bridge constriction. Generally, for the design flood event, the bridge opening should not create more than a one foot (0.3 m) differential in water levels between the normal water surface elevation, with no roadway fill or structure present, and the proposed water surface elevation, with the proposed roadway fill and structure present. Land development at the site or other topography may fix the allowable headwater elevations. Surrounding bridges will also influence the structure location and waterway area selected and in some cases analysis of these surrounding bridges may be required in addition to the project bridge.

Roadway grades shall provide a minimum clearance of 1 feet (0.3 m) between the design flood and low girder elevations, except in cases where cost constraints or vertical geometry controls dictate a lower profile.

In addition to the above flood design criteria, structure clearances must satisfy any requirements set by the U. S. Coast Guard, the Corps of Engineers, or the Tennessee Valley Authority where the site falls within the jurisdiction of any of these agencies. The Tennessee Valley Authority and the Corps of Engineers will exercise their reviewing authority in some locations where flood control measures have been taken, or, are in the planning stage.

Culvert Openings

The selection of opening size for box bridges and culverts is normally based on the following guidelines:

1. The culvert shall not create more than one foot (0.3 m) differential in water levels between the normal water surface elevation, with no roadway fill or structure present, and the proposed water surface elevation, with the proposed roadway fill and structure present, unless flood damage due to the increased water level is insignificant.

2. If outlet velocities exceed what the natural streambed can withstand, then a larger culvert opening may be required. If increased culvert size is not feasible, then streambed protection shall be provided. Energy dissipaters may be required in extreme conditions.

Hydraulic Data Requirements

Hydraulic data will be required to be shown for every hydraulic structure. This hydraulic data is to be located on the roadway profile sheet for culverts and on the bridge layout sheet for bridges. The Hydraulic Data is as follows:

1. Culverts: (See THM-01)

2. Bridges:
   A. Single Bridge Crossing:

      Drainage Area = 7.8 mi^2 (km^2)
      Design Discharge (100 year) = 56.8 cfs (m^3/s)
      Water Area Provided Below El. 125.28 = 43.4 ft^2 (m^2)
      100 Year Velocity = 1.31 fps (m/s)
      100 Year Bridge Backwater = 0.14 ft (m) @ El. 125.47
      500 Year Discharge = 76.9 cfs (m^3/s) @ El. 125.80
      Roadway Overtopping El. = 127.3

   B. Multi Bridge Crossing:

      Drainage Area = 7.8 mi^2 (km^2)
      Design Discharge (100 year)
      Total = 113.4 cfs (m^3/s)
      Thru this Bridge = 56.8 cfs (m^3/s
      Water Area Provided Below El. 125.28 = 43.4 ft^2 (m^2)
      100 Year Velocity = 1.31 fps (m/s)
      100 Year Bridge Backwater = 0.14 ft (m) @ El. 125.47
      500 Year Discharge (Total) = 76.9 cfs (m^3/s) @ El. 125.80
      Roadway Overtopping El. = 127.3

Temporaray Run-Arounds

Temporary run-arounds should be designed to pass a 2 to 5 year flood without substantial flood damage or without overtopping the run-around. Site conditions may merit a higher frequency design. A cost analysis should be made to justify a higher design.

References

For more specific information regarding other hydraulic design and details refer to Tennessee Hydraulics Memorandums - 04, 05, 06, 07, 08 and 09.

See also Federal Highway Manuals - Hydraulic Engineering Circular No. 17, HDS5, HEC18, HEC20 and Hydraulics of Bridge Waterways.

Attachment

Flood Design Policies for Roads & Bridges, TDOT, March 1983, with addendum and risk assessment form, THM-03 pages 4-8.

FLOOD DESIGN POLICIES FOR ROADS AND BRIDGES
TENNESSEE DEPARTMENT OF TRANSPORTATION
March 1983

In accordance with the requirements of FHWA's HEC-17 (1981), the design of all flood plain encroachments "shall be supported by the analyses of design alternatives with consideration given to capital costs and risks, and other economic, engineering, social and environmental concerns". The analyses of capital cost and risk shall consist of a risk assessment or risk analysis, as appropriate. The risk analysis is based on the least total expected cost (LTEC) design procedure described in the FHWA Hydraulic Engineering Circular No. 17.

This statement sets the policy to be followed by the Tennessee Department of Transportation for determining when to use a risk assessment or risk analysis in the design of flood plain encroachments.

The *design elements which are subject to this economic anal*ysis include but not limited to the following:

A. For transverse encroachments:
   1. Finished grade elevation
   2. Type, size and location of drainage structure
   3. Span length
   4. Orientation of bridge substructures to flood flow
   5. Channel Changes

B. For longitudinal encroachments:
   1. Extent of the encroachment on the flood plain
   2. Channel changes

There are *constraints which may control* the design features noted above which would eliminate that design from the economic analysis requirements.

1. Backwater produced by an encroachment may be limited to one foot (0.3 m) for the flood which has the probability of 1% of occurrence in any one year (100 year flood).

2. No backwater may be produced by an encroachment on the designated floodway over and above that already existing when the floodway was established by the local government. (Note: If this requirement is impractical, the Department may acquire flood easements for the property affected by the backwater or make appropriate improvements in conveyance in the floodway or appeal to FEMA through the local community to redesignate the limits of the floodway.

3. See THM-03 page 1 for the design frequency criteria.

4. Limitations imposed by roadway geometrics such as maximum or minimum grade lines, site distance or vertical curvature.

5. Grades may be controlled by intersection with, or clearance over or under, other highways or railroads.

6. Navigational clearance requirements or channel improvement controls.

7. Structures adjacent to the roadway such as dams, levees, buildings and etc. which may control grades, structure size, location or structure type.

8. Allowable stream velocities which are controlled by potential channel instability and/or bank degradation depending on soil types present.

9. Provision for debris passage which will affect grades and span lengths.

10. Geological or geomorphic considerations, including sub-surface conditions, which may affect location and type of substructure for bridges.

11. Structural requirements.

12. Economical, social and environmental considerations including the importance of the facility as an emergency evacuation route.

Levels of Analysis Required Relative to Type Improvement

1. For structural replacement on the same alignment with no appreciable grade change and/or waterway opening - A risk assessment

2. For structural replacement on the same alignment with a grade change:

    a) Grade change due to increased superstructure depth - A risk assessment
    b) Grade change due to roadway geometry or increased level of design flood frequency - A risk assessment or risk analysis

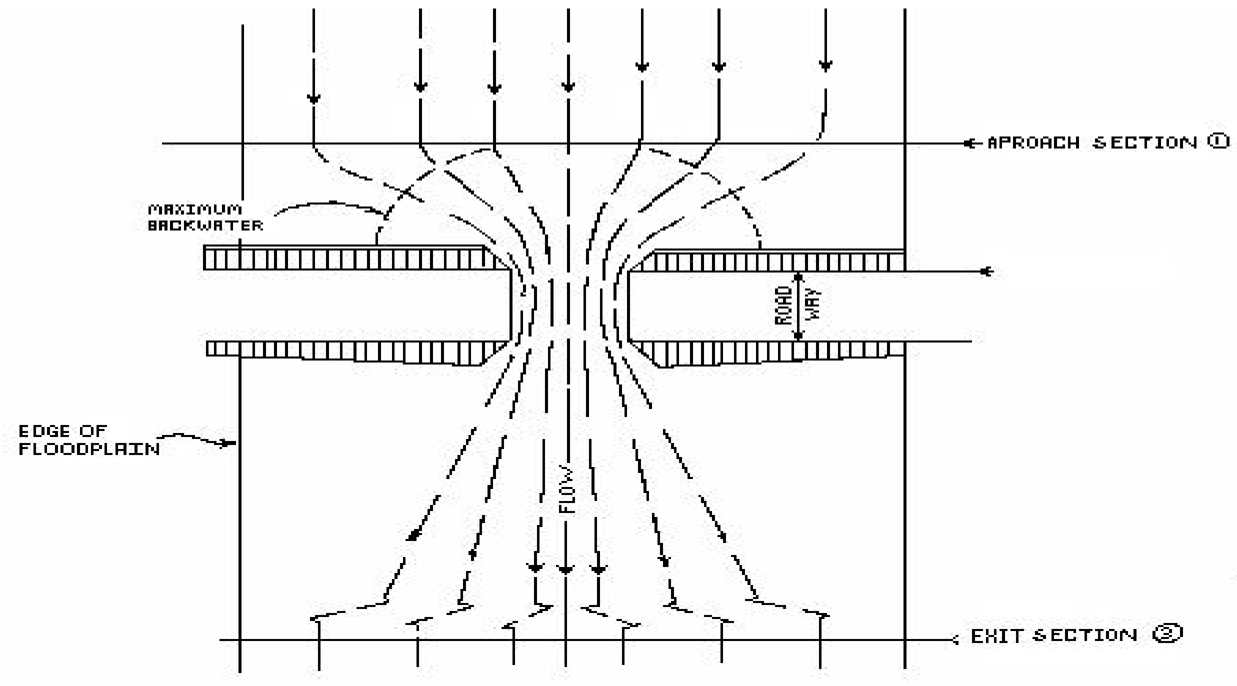
3. For a relocation - A risk assessment or risk analysis

4. For a new facility - A risk assessment or risk analysis

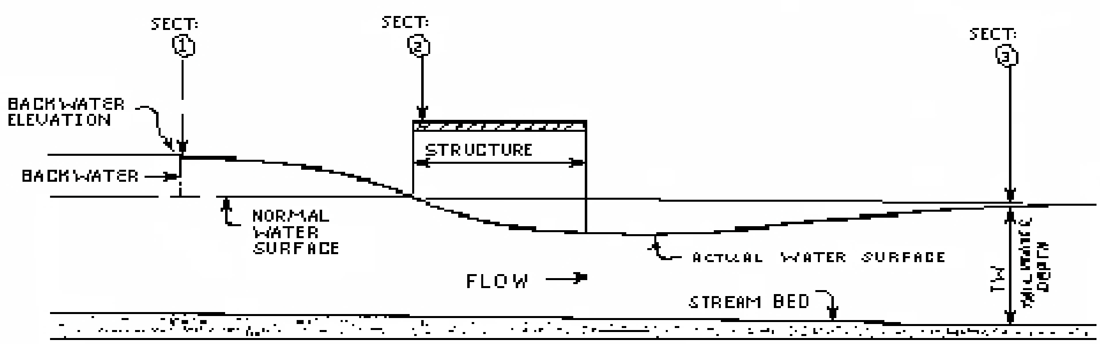
5. For locations where there is a high risk of damage to property due to backwater or to increased concentration of flow - A risk analysis.

(See THM-03 page 8 for Risk Assessment)

Hydraulic Definition Sketches



PLAN VIEW OF FLOOD FLOW



PROFILE ON STREAM ℄

ADDENDUM
Flood Design Policies for Roads & Bridges
Tennessee Department of Transportation

The following conditions may be considered as exceptions to State Route Design Frequency as identified on page 1 of THM-03.

1. A bridge and approach project located in a wide flood plain (e.g. West Tennessee) at which the present road profile is subject to frequent overtopping. Raising the present grade would drastically increase the length of the project.

2. A bridge replacement design involving a frequently flooded (more often than 10-year intervals) route and land developments located at the site in a flood-prone area. Raising the road level to suit a 10-year highwater frequency would increase potential damage to the property owner.

3. The proposed project intersects another route in which both are frequently flooded by less than a 10-year occurrence. Land developments in a flood-prone area are impacted.

4. The present road is frequently flooded at the bridge to be replaced as well as various other locations along the route. No betterment for the route is anticipated in the foreseeable future. Higher type road service at one location only would not improve the road operation.

5. A project to widen or rehabilitate an existing structure at a location where the waterway opening and/or overtopping elevation is not suitable to provide for a 10-year flood frequency.

General Guidelines:

Exceptions to the minimum design for the 10-year flood is only justified under unusual site conditions which are defined above and in which careful consideration has been given to traffic volume, available detour in case of highwater, cost increase above replacement-in-kind, expected maintenance and the increased hazard to the driver at the location.

Tennessee Department of Transportation
Risk Assessment for Hydraulic Design
1985

Prepared by ____________________
Date ____________________

Project ___________________________________ County _____________

Instructions: If the answer to any of statements 3 thru 10 is yes analyze the encroachment using the LTEC design process or justify why it is not required.

Design Feature Checklist

1. Bridge Widening or Culvert Extension	Yes___ No___
2. Bridge replacement with no less than equal hydraulic capacity	Yes___ No___
3. Bridge replacement with less than equal hydraulic capacity	Yes___ No___
4. New alignment	Yes___ No___
5. Significant channel change involved	Yes___ No___

Flood Level Conditions

6. Backwater produced is greater than 0.3 meters for the 100-year flood	Yes___ No___
7. Backwater produced is greater than existing in a designated floodway	Yes___ No___
8. Design Discharge for	
A. Storm drains less than a 10-year flood	Yes___ No___
B. Primary road (SR and/or ADT > 750) less than a 10-year flood	Yes___ No___
C. Interstate route less than a 50-year flood	Yes___ No___
9. Significant grade change due to roadway geometry or increased level of design flood frequency	Yes___ No___
10. Location with a high risk of damage to property improvements due to backwater or to increased concentration or redirection of flow	Yes___ No___

COMMENTS:

TENNESSEE HYDRAULICS MEMORANDUM - 04
Index of Local Flood Studies by TVA, Corps of Engineers and FEMA Flood Insurance Studies

PDD:JKZ:WWP

Distribution: Office, Consultants

The attached index of flood reports lists those reports that are now available in our hydraulic library and are available to the public through the appropriate agency. Additional studies will be added to the list as they become available.

NOTE: The Division files are for the use of Department personnel only. The Division is not to be considered a library. The following lists are for general information purposes. Data from these reports should be requested through the respective agency.

Federal Emergency Management Agency (FEMA)
Flood Hazard Studies

County	City/Vicinity	Flood Hazard Boundary Map (FHBM)	Flood Insurance Rate Map (FIS)	Flood Insurance Study (FIS)
Anderson	Unincorporated	Combined	9/84 (1/6/94)	1/6/94
	Clinton	Combined	7/18/77	
	Lake City	11/27/76		
	Oak Ridge	5/15/85	7/6/98	7/6/98
	Olivar Springs	5/15/80		12/79
	Norris	Combined	1/6/94	1/6/94
Bedford	Unincorporated	12/23/77		
	Bell Buckle	Combined	9/4/85	
	Normandy	6/20/80		
	Shelbyville	Combined	1/17/97	1/17/97
	Wartrace	Combined	9/1/87	
Benton	Unincorporated	Combined	7/2/91	7/2/91
	Big Sandy	9/24/76		
	Camden	Combined	7/17/86	
Bledose	Unincorporated	2/16/79		
	Pikeville	Combined	5/17/88	5/17/88
Blount	Unincorporated	Combined	6/3/91	6/3/91
	Alcoa	4/15/77		
	Friendsvile	6/11/76		
	Maryville	6/29/79	6/29/79	
	Rockford	9/24/76		
	Townsend	6/18/76		
Bradley	Unincorporated	Combined	9/4/94	9/4/91
	Charleston		3/18/80	9/79
	Cleveland	Combined	8/89 (4/2/93)	4/2/93
Campbell	Unincorporated	Combined	8/5/86	
	Caryville	9/3/76		
	Jacksboro	5/28/76		
	Jellico	Combined	9/30/92	9/30/92
	Lafollette	9/5/84	9/5/84	3/5/84
Cannon	Unincorporated	Converted	7/1/91	
	Auburntown	Combined	5/15/86	
	Woodbury	9/1/77		
Carroll	Unincorporated		9/1/90	
	Bruceton	2/11/90		
	Hollow Rock	6/25/76		
	McKenzie	Combined	9/4/85	6/3/88
	Huntington	Combined	6/3/88	
	Trezevant	2/5/77		
County	City/Vicinity	Flood Hazard	Flood Insurance Rate	Flood Insurance

		Boundary Map (FHBM)	Map (FIS)	Study (FIS)
Carter	And Incorporated	Combined	4/16/03	4/16/03
Cheatham	And Incorporated	Combined	12/6/99	12/6/99
Chester	Unincorporated	11/7/78		
	Enville	10/29/76		
	Henderson	Combined	3/16/86	
Claiborne	Unincorporated	Combined	5/4/88	5/4/88
	Cumberland Gap	5/28/76		
	New Tazwell	Combined	8/5/86	
	Tazwell	7/23/76		
Clay	Unincorporated	3/30/79		
	Celina	Combined	4/30/86	
Cocke	And Incorporated	Combined	4/6/98	4/6/98
Coffee	Manchester	Combined	3/4/88	3/4/88
	Tullahoma	6/5/89	6/5/89	6/5/89
Crockett	None			
Cumberland	Crab Orchard	Combined	6/3/86	
	Crossville	Combined	7/3/86	
Davidson	And Incorporated	Combined	11/21/02	11/21/02
Decatur	Unincorporated	Combined	1/7/00	1/7/00
	Decaturville	9/24/76		
	Parsons	6/11/76		
	Scotts Hill	Combined	7/17/86	
Dekalb	Unincorporated	Combined	9/27/91	9/27/91
	Alexandria	Combined	6/17/86	
	Dowelltown	Combined	8/19/86	
	Liberty	Combined	9/4/86	
	Smithville	Combined	7/17/86	
Dickson	Unincorporated	6/15/84	6/15/84	12/15/88
	Dickson	11/17/82	11/17/82	5/17/82
Dyer	Unincorporated	3/1/84	7/19/00	7/19/00
	Dyersburg	2/3/93	2/3/93	2/3/93
	Newburn		7/19/00	
	Trimble		7/19/00	
Fayette	Unincorporated	7/5/83	7/5/83	1/5/83
	Gallaway	7/5/82	7/5/82	1/5/82
	Moscow	6/1/81	6/1/81	12/1/80
	Rossville	6/1/81	6/1/81	12/1/80
	Somerville	7/5/82	7/5/82	1/5/82
County	City/Vicinity	Flood Hazard Boundary Map	Flood Insurance Rate Map	Flood Insurance Study (FIS)

		(FHBM)	(FIS)	
Fentress	None			
Franklin	Unincorporated	Combined	9/30/95	9/30/95
	Cowan	3/4/80		9/79
	Decherd	3/4/80	9/30/95)	9/30/95
	Estill Springs	Combined	5/15/86	
	Huntland		11/1/98	
	Winchester	7/2/80	9/30/95	9/30/95
Gibson	Unincorporated	10/18/83	10/18/83	4/18/83
	Bradford	2/16/83	2/16/83	8/16/82
	Humboldt	9/15/83	9/15/83	3/15/83
	Kenton	2/16/83	2/16/83	8/16/82
	Milan	2/83	2/83	8/82
	Rutherford	9/30/83	9/30/83	3/30/83
	Trenton	2/16/83	2/16/83	8/16/82
Giles	Ardmore	6/6/80		
	Elkton	6/27/80		
	Minor Hill	8/1/80		
	Pulaski	Combined	1/16/87	1/16/87
	Unincorporated	Combined	1/2/92	1/2/92
Grainger	Unincorporated	Combined	5/3/90	5/3/90
	Blaine	Combined	12/5/90	12/5/90
Greene	Unincorporated	Combined	3/18/91	3/18/91
	Greeneville		8/23/00	
Grundy	Unincorporated		3/1/95	
	Tusculum	7/27/76		
Hamblen	Unincorporated	Combined	3/18/91	3/18/91
	Morristown	Combined	2/11/83	12/77
Hamilton	And Incorporated		11/7/02	11/7/02
Hancock	Sneedville	Combined	6/17/86	
	Unincorporated	7/14/78		
Hardeman	Unincorporated	Combined	4/2/91	4/2/91
	Bolivar	Combined	8/19/87	
Hardin	Unincorporated	Combined	4/2/91	
	Savannah	Combined	7/86 (6/1/94)	
	Crump	Combined	7/5/93	7/5/93
	Saltillo		6/1/94	
Hawkins	Unincorporated	Combined	3/18/91	3/18/91
	Bulls Gap	Combined	7/3/86	
	Rogersville	Combined	6/86 (7/19/93)	7/19/93
	Surgoinsville	Combined	7/17/86	
	Church Hill		6/1/94	
County	City/Vicinity	Flood Hazard Boundary Map (FHBM)	Flood Insurance Rate Map (FIS)	Flood Insurance Study (FIS)

County	City/Vicinity	Flood Hazard Boundary Map (FHBM)	Flood Insurance Rate Map (FIS)	Flood Insurance Study (FIS)
Haywood	Unincorporated	Combined	9/1/86	
	Brownsville	Combined	3/4/88	3/4/88
Henderson	Incorporated	Combined	9/2/88	9/2/88
	Lexington		9/2/88	
Henry	And Incorporated	Combined	6/6/01	6/6/01
Hickman	Unincorporated		9/1/86	
	Centerville	Combined	1/16/87	1/16/87
Houston	Erin	Combined	7/86 (9/15/93)	9/15/93
Humphreys	New Johnsonville	Combined	5/4/87	
	Waverly	3/4/86	3/4/86	3/4/86
	McEwen	Combined	7/76 (6/2/94)	
Jackson	Unincorporated	Combined		
	Gainsboro	Combined		
Jefferson	Unincorporated	11/2/90	11/2/90	11/2/90
	Dandridge	Combined	6/17/89	
	Jefferson City	Combined	5/22/81	
	New Market	Combined	9/30/87	
	White Pine	Combined	9/3/92	9/3/92
Johnson	Unincorporated	Combined	7/17/86	
	Mountain City	Combined	8/5/86	
Knox	Unincorporated	5/16/83	5/16/83	11/16/82
	Farragut	2/15/85	2/15/85	8/15/84
	Knoxville	Combined	1/17/91	1/17/91
Lake	Unincorporated	Combined	3/16/81	9/16/80
	Tiptonville	3/16/81		9/16/80
Lauderdale	Unincorporated	Combined	9/87 (12/5/95)	12/5/95
	Gates	Combined	7/2/87	7/2/87
	Halls	Combined	3/18/87	3/18/87
	Henning	Combined	3/4/88	3/4/88
	Ripley	Combined	5/87 (4/17/95)	4/17/95
Lawrence	Incorporated	Combined	12/16/88	12/16/88
Lewis	Unincorporated	2/9/79		
	Hohenwald	Combined	7/2/87	
Lincoln	And Incorporated	Combined	12/20/99	12/20/99
Loudon	Unincorporated	8/3/92	8/3/92	8/3/92

	Greenback	Combined	9/30/88	9/30/88
	Loudon	5/7/82	5/7/82	5/1/82
	Philadelphia	Combined	6/3/86	
	Lenoir City	Combined	8/18/92	8/18/92
Macon	Unincorporated	Combined	9/4/85	
	Red Boiling Spr.	Combined	4/15/88	4/15/88
Madison	And Incorporated	7/5/83	1/21/98	1/21/98
Marion	Unincorporated	5/15/80		11/79
	Jaspar	6/10/77	6/10/77	
	Kimball	Combined	5/19/87	5/19/87
	New Hope	Combined	9/27/85	
	South Pittsburg	2/18/77	2/77 (10/16/92)	10/16/92
Marshall	And Incorporated	Combined	2/17/88	2/17/88
Maury	Unincorporated	Combined	11/3/89	11/3/89
	Columbia	Combined	8/1/84	8/1/84
	Mount Pleasant	8/1/84	2/17/88	2/17/88
	Spring Hill	Combined	5/4/87	5/4/87
McMinn	Unincorporated	Combined	9/4/91	9/4/91
	Athens	12/4/86	12/4/86	12/4/86
	Calhoun	Combined	7/3/86	
	Englewood	Combined	8/19/86	
	Etowah	Combined	5/15/86	
McNairy	Unincorporated	Combined	4/2/91	4/2/91
	Adamsville	Combined	2/15/02	2/15/02
	Michie	8/29/90		
	Selmer	Combined	4/15/02	
Meigs	Unincorporated	Combined	11/16/90	11/16/90
	Decatur	Combined	6/3/86	
Monroe	Unincorporated	Combined	9/4/91	9/4/91
	Sweetwater	Combined	3/18/86	
	Tellico Plains			1/4/04
Montgomery	Unincorporated	6/15/84	6/15/84	12/15/83
	Clarksville	6/15/84	6/15/84	12/15/83
Moore	Lynchburg	Combined	9/86 (5/16/95)	5/16/95
Morgan	Unincorporated		3/1/87	
	Oakdale	Combined	9/29/86	9/29/86

County	City/Vicinity	Flood Hazard Boundary Map (FHBM)	Flood Insurance Rate Map (FIS)	Flood Insurance Study (FIS)
Obion	Unincorporated	Combined	6/17/91	6/17/91
	Kenton	2/16/83	2/16/83	8/16/82

	Obion	3/16/81	3/16/81	9/16/80
	South Fulton	Combined	6/19/81	
	Troy	Combined	7/3/86	
	Union City	5/5/81	5/5/81	11/5/80
Overton	Unincorporated	1/13/78		
	Livingston	Combined	6/3/86	
Perry	Unincorporated	12/22/78		
	Lobelville	1/13/78		
	Linden	Combined	8/5/86	
Pickett	Byrdstown	Combined	7/3/86	
Polk	Benton	Combined	7/3/86	
	Copperhill	Combined	2/3/93	2/3/93
	Unincorporated	Combined		6/16/95
Putnam	Unincorporated		11/1/98	
	Cookeville	Combined	8/19/86	
Rhea	Unincorporated	Combined	9/4/91	9/4/91
	Dayton	Combined	7/4/89	7/4/89
	Graysville	Combined	12/2/88	12/2/88
	Spring City	Combined	2/5/92	2/5/95
Roane	Unincorporated	7/5/84	7/5/84	3/80
	Harriman	9/5/84	9/5/84	3/5/84
	Rockwood		8/4/03	
Robertson	Unincorporated	6/15/84	6/15/84	12/15/83
	Springfield	9/30/83	9/30/83	3/30/83
Rutherford	And Incorporated	Combined	12/20/02	12/20/02
Scott	Oneida	Combined	6/17/86	
Sequatchie	Unincorporated	10/21/77		
	Dunlap	Combined	3/4/88	3/4/88
Sevier	Unincorporated	6/15/84	6/15/84	12/15/83
	Gatlinburg	2/15/84	2/15/84	8/15/83
	Pigeon Forge	9/18/87	9/18/87	9/18/87
	Pittman Center		12/23/77	
	Sevierville		1/17/97	1/17/97
Shelby	And Incorporated		12/2/94	12/2/94

County	City/Vicinity	Flood Hazard Boundary Map (FHBM)	Flood Insurance Rate Map (FIS)	Flood Insurance Study (FIS)
Smith	Unincorporated	4/15/81	7/7/99	7/7/99
	Carthage	9/30/80		3/80
	Gordonsville		7/7/99	7/7/99

	South Carthage	11/5/80	11/5/80	5/80
Stewart	Unincorporated	2/24/78		
	Dover	12/9/77		
Sullivan	Unincorporated	10/16/90	10/90 (6/16/93)	6/19/93
	Bristol	7/19/82	2/4/04	2/4/04
	Kingsport	Combined	6/4/90	6/4/90
Sumner	And Incorporated		11/21/02	11/21/02
Tipton	Incorporated	4/2/91	4/2/91	4/2/91
Trousdale	Unincorporated	8/16/82	8/16/82	2/16/82
	Hartsville	8/16/82	8/16/82	2/16/82
Unicoi	Unincorporated	Combined	7/16/90	7/16/90
	Erwin	9/5/84	9/5/84	3/5/84
Union	Unincorporated	Combined	7/16/90	7/16/90
	Luttrell	Combined	9/1/89	
	Maynardsville	6/3/86		
VanBuren	Unincorporated		12/1/78	
Warren	Incorporated	Combined	3/16/88	3/16/88
Washington	Unincorporated	Combined	10/16/96	10/16/96
	Johnson City	6/1/83	6/1/83	4/80
	Jonesboro	9/30/82	9/30/2	3/30/82
Wayne	Unincorporated	3/16/79		
	Clifton	Combined	3/4/88	3/4/88
	Waynesboro	Combined	1/16/87	1/16/87
Weakley	Unincorporated	Combined	7/2/91	7/2/91
	Dresden	Combined	2/1/90	
	Martin	Combined	9/15/89	9/15/89
White	Sparta	Combined	8/27/82	
Williamson	And Incorporated		1/16/03	1/16/03
Wilson	Unincorporated	6/15/84	5/16/94	5/16/94
	Lebanon	1/6/83	2/3/93	2/3/93
	Mt. Juliet	5/17/82	5/16/94	5/16/94
	Watertown	Combined	1/1/87	

Flood Studies by Various Agencies
Region 1

Stream Name	County	Vicinity	Date	Agency
Brush Creek	Washington	Johnson City	1959	TVA
Doe River & Tributary Creeks	Carter	Roane Mountain	1961	TVA
French Broad & Pigeon River	Cocke	Newport	1958	TVA
Little Limestone Creek	Washington	Jonesboro	1970	TVA
Little Pigeon River & Dudley Creek	Sevier	Gatlinburg	1974	TVA
Nolichucky River and North and South Indian Creeks	Unicoi	Erwin	1967	TVA
Streams	Carter	Near Elizabethton	1967	TVA
Sweetwater Creek	Monroe	Sweetwater	1958	TVA
Tellico River & Hunt Branch	Monroe	Tellico Plains	1966	TVA
Town, Goose, and Furnace Creeks	Johnson	Mountain City	1967	TVA
Watauga and Doe Rivers	Carter	Elizabethton	1957	TVA
Large Springs	--	Valley & Ridge Province	1990	USGS
Streams	Unicoi	Erwin	1966	TVA
French Broad, Little, & Hiawassee Rivers	--	Upper River Basins	1965	TVA
Love Creek Drainage	Knox	Knoxville	1983	UTK
West Prong Little Pigeon River, Roaring, Baskins, and Leconte Creeks	Sevier	Gatlinburg	1982	TVA
Ten Mile & Sinking Creeks	Knox	Knox County	1973	TVA
First Creek	Knox	Knoxville	1967	COE
Beaver Creek	Sullivan	Bristol, VA - TN	1956 1959	TVA TVA

Big Creek	Campbell	LaFollette	1958	TVA
Bull Run & Hinds Creek	Anderson	Anderson County	1965	TVA
Clinch River	Anderson	Clinton	1955	TVA
			1956	TVA
Clinch River	Anderson	Oak Ridge	1957	TVA
Clinch River & Blackwater Creek	Hancock	Sneedville	1969	TVA
Clinch River & East Fork	Anderson	Oak Ridge	1959	TVA
Popular Creek			1968	TVA
Coal Creek	Anderson	Briceville & Lake City	1962	COE
Coal Creek & Tributaries	Anderson	Lake City	1968	TVA
Dog Creek	Campbell	Jacksboro	1971	TVA
Holston River, Big Creek, and Caney Creek	Hawkins	Rogersville	1961	TVA
Holston River	Hawkins	Surgoinsville & Church Hill	1961	TVA
Little Pigeon & West Fork Little Pigeon Rivers	Sevier	Sevierville	1958	TVA
Mossey Creek	Jefferson	Jefferson City	1965	TVA
North Fork Bull Run Creek	Union	Maynardville	1966	TVA
Reedy Creek	Sullivan	Kingsport	1955	TVA
			1956	TVA
			1957	TVA
			1960	TVA
Russell Creek	Claiborne	Tazwell- New Tazwell	1968	TVA
South Fork Holston River @ Long Island	Sullivan	Kingsport	1955	TVA
			1956	TVA
			1960	TVA
Streams	Hamblen	Near Morristown	1957	TVA
Streams	Cocke	Near Newport	1968	TVA

TN River, First, Second, Third, and Fourth Creeks	Knox	Knoxville	1958	TVA
TN River, French Broad, & Holston Rivers, Bull Run & Beaver Creeks	Knox	Knox County	1965	TVA
Turkey Creek	Knox	Knox County	1974	TVA
West Fork Little Pigeon River	Sevier	Pigeon Forge	1962	TVA
West Fork Little Pigeon River	Sevier	Gatlinburg	1958	TVA
Black Creek and Middle Fork Black Creek	Roane	Rockwood	1967	TVA
Emory & Obed Rivers, Clear & Daddy Creeks	--	Nemo Project	1960	TVA
Emory River	Roane	Harriman	1958	TVA
Little River	Blount	Townsend & Kinzel Springs	1960	TVA
Pistol Creek, Brown Creek & Duncan Branch	Blount	Maryville & Alcoa	1959 1964 1966	TVA TVA TVA
Poplar Creek	Anderson	Frost Bottom and Laurel Grove	1968	TVA
Poplar and Indian Creeks	Anderson	Oliver Springs	1960	TVA
Stoney Fork	?	Clinchmore	1965	TVA
Streams	Roane	Near Kingston	1957	TVA
TN River & Little River	Blount	Blount County	1965	TVA
TN River & Little River, Town & Muddy Creeks	Loudon	Lenoir City	1964	TVA
TN River, Steeke & Sweetwater Creeks	Loudon	Loudon & Philadelphia	1963	TVA

Clear Fork & Elk Creek	Campbell	Jellico	1972	COE
Sinkholes	Knox	Knox County	1973	COE

Region 2

Stream Name	County	Vicinity	Date	Agency
Conasauga & Cane Creeks	McMinn	Etowah	1962	TVA
Hiwassee & Ocoee Rivers	McMinn, Brad.	Charleston & Calhoun	1961	TVA
Oostanaula Creek	McMinn	Athens	1956 1957	TVA TVA
South Mouse Creek	Bradley	Cleveland	1969	TVA
Toccoa-Ocoee River & Fightingtown Creek	Polk	McCaysville, GA & Copperhill, TN	1958	TVA
Chestuee, Little Chestuee & Middle Creeks	McMinn	Englewood	1969	TVA
South Mouse & Candies Creeks	Bradley	Bradley County	1976	TVA
Sale, Roaring, & Mcgill Creeks & Hickman Branch	Rhea	Graysville	1975	TVA
North Chickamauga, Mountain, and Lookout Creeks	Hamilton	Chattanooga	1961	TVA
Piney River	Rhea	Spring City	1961 1962	TVA TVA
Richland and Little Richland Creeks	Rhea	Dayton	1957	TVA
Soddy, Little Soddy, Possum, Sale, & Rock Creeks	Hamilton	North Hamilton County	1972	TVA
South & West Chickamauga & Spring Creeks	Hamilton	Chattanooga	1958	TVA

TN River & Battle Creek	Marion	South Pittsburg & Richard City	1960	TVA
TN River, Chattanooga & Dry Creeks, Stringers Branch	Hamilton	Chattanooga	1955 1959	TVA TVA
TN River, Sequatchie River & Tributaries	Marion	Marion County	1962	TVA
Wolftever and Chesnutt Creeks	Hamilton	Hamilton County	1972	TVA
Floods	Coffee	Manchester	1966	TVA
Duck River & Little Duck Ri ver, Grindstone Hollow, Hunt, Hickory, Flat, and Wolf Creeks	Coffee	Manchester	1984	TVA
Calfkiller River	White	Sparta	1971	COE
Collins & Barren Fork Rivers, Hockory & Charles Creeks	Warren	McMinnville	1973	COE
Cumberland & Caney Fork Rivers	Smith	Carthage	1967	COE
Cumberland & Roaring Rivers & Doe Creek	Jackson	Gainsboro	1968	COE
Cumberland & Obey River	Clay	Celina	1968	COE
West and North Fork, Rock Creek	Coffee	Tullahoma	1960	TVA
East Fork Stones River	Cannon	Woodbury	1970	COE

Region 3

Stream Name	County	Vicinity	Date	Agency
Big Rock Creek	Marshall	Lewisburg	1954	TVA
			1955	TVA
Cane Creek	Marshall	Petersburg	1964	TVA
Duck River	Hickman	Centerville	1954	TVA
			1984	TVA
Duck River	Maury	Columbia	1954	TVA
Duck River	Bedford	Shelbyville	1954	TVA
			1955	TVA
Elk River	Lincoln	Fayetteville	1954	TVA
			1961	TVA
Elk River & East Fork Mulberry Creek	Moore	Moore County	1968	TVA
Elk River & Norris Creek	Lincoln	Fayetteville	1960	TVA
Green River & Hurricane Creek	Wayne	Waynesboro	1962	TVA
Little Bigby Creek	Maury	Columbia	1956	TVA
Richland Creek	Giles	Pulaski	1954	TVA
			1955	TVA
			1957	TVA
Richland Creek & Pigeon Roost Creek	Giles	Pulaski	1956	TVA
Shoal & Little Shoal Creeks	Lawrence	Lawrenceburg	1959	TVA
Sugar Fork & Sugar Creek	Maury	Mount Pleasant	1962	TVA
TN River & Trace Creek	Humphreys	New Johnsonville	1958	TVA
Trace Creek	Humphreys	Waverly	1957	TVA

Trace Creek & Tributaries	Humphreys	Waverly	1975 1981 1981	TVA TVA TVA
Big Rock, Collins, & Snake Creeks, Capps, Loyd, & Snell Branches	Marshall	Lewisburg	1985	TVA
McCutcheon Creek & Tributaries	Maury	Spring Hill	1975	TVA
Shoal, Little Shoal, Beeler, Fork Shoal, & Crowson Creeks, Tripp, Town, & Dry Branches	Lawrence	Lawrenceburg	1985	TVA
Hurricane Creek & Finch Branch	Rutherford	Lavergne	1976	COE
Green River, Hurricane & Chalk Creeks, Rocky Mill Branch	Wayne	Waynesboro	1984	TVA
Duck River, Flat, Big Spring, Bomar, & Little Hurricane Creeks, Pettus & Holland Branches & Tribs	Bedford	Shelbyville	1985	TVA
Bartons & Sinking Creeks	Wilson	Lebanon	1971	COE
Cypress Creek	AL	Florence, AL	1956	TVA
Cypress Creek & Cox Creek	AL	Florence, AL	1961	TVA
Selected Streams	Davidson	Nashville	1975	USGS
Cumberland & Red Rivers	Montgomery	Clarksville	1964	COE
Cumberland River	Cheatham	Ashland City	1970	COE
Drakes Creek	Sumner	Hendersonville	1971	COE
East Camp & Town Creeks	Sumner	Gallatin	1976	COE
Harpeth River	Williamson	Franklin	1968	COE

Harpeth River	Williamson	Mouth to Franklin	1975	COE
Little Goose Creek	Trousdale	Hartsville	1975	COE
Little Harpeth River	Williamson	Williamson County	1968	COE
Mill & Seven Mile Creeks	Davidson	Nashville	1973	COE
Sulpher Fork	Robertson	Springfield	1972	COE
Wells Creek & Tribs	Houston	Erin	1973	COE
West Fork Stones River, Lytle & Sinking Creeks	Rutherford	Murfreesboro	1966	COE
East Fork Mulberry Creek & Price Branch	Moore	Near Lynchburg	1986	TVA
Stewerts Creek, & Harts Branch	Rutherford	Smyrna	1976	COE

Region 4

Stream Name	County	Vicinity	Date	Agency
Beech River, Wolf & Owl Creeks, Brazil, Onemile Branches & a Branch	Henderson	Lexington	1985	TVA
Bailey Fork, Town & Jones Bend Creeks, Mcgowan Branch	Henry	Paris	1969	TVA
Beaver Creek & Tribs	Carroll	Huntingdon	1971	COE
Big Creek	Shelby	Millington	1974 1981	COE COE
Cypress, Cane, Charlie, and Burnside Creeks	Benton	Camden	1961	TVA
Forked Deer Rivers & Lewis Creek	Dyer	Dyersburg	1968	COE
Hatchie River, Pleasant Run & Spring Creeks	Hardeman	Bolivar	1970	COE

Loosahatchie River	Shelby	Shelby County	1970	COE
Middle Fork Forked Deer River & Tribs	Gibson	Humboldt	1970	COE
Nonconnah Creek	Shelby	Shelby County	1974	COE
Nonconnah Creek	Shelby	Shelby County	1987 1990	COE-GDM COE-GDM
North Fork Forked Deer River & Cane Creek	Gibson	Trenton	1962	COE
North Fork Obion River, Hoosier & Grove Creeks	Obion	Union City	1968	COE
South Fork Forked Deer River & Sugar Creek	Chester	Henderson	1968	COE
South Fork Forked Deer River, North Fork Drainage Canal, Bond Creek	Madison	Jackson	1967	COE
Sugar Creek & Little Nixon Creek	Haywood	Brownsville	1973	COE
Harrington Creek	Madison	Bartlett	1975	COE
Grays & Marys Creeks	Shelby	Shelby County	1970	COE
Rutherford Fork Obion River	Gibson	Milan	1974	COE
Cane Creek & Tribs	Lauderdale	Ripley	1977	COE
Mud Creek & Laterals A, B, C, & D	Weakley	Dresden	1976	COE
Wolf & Loosahatchie Rivers	Shelby	Shelby County	1971	COE
Harris Fork Creek & South Fulton Branch	Obion	South Fulton	1971	COE
Harris Fork Creek	Obion	South Fulton	1983	COE-GDM

TENNESSEE HYDRAULICS MEMORANDUM - 05

Approval of Bridge Plans by Outside Agencies

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Preliminary and/or final bridge plans must be submitted to various agencies for review. The degree of review varies with each agency, depending on their project involvement and legal responsibilities. Some reviews are only for the purpose of coordinating plans, while others are based on the legal authority of the agency to review and dictate design considerations.

The various agencies involved in Tennessee D.O.T. work are listed below with a brief description of their review responsibility. Submittal to these agencies for work prepared by consultants shall be through the Tennessee D.O.T. Division of Structures, unless instructed differently.

1 - Design Division

Prior to submitting preliminary plans to the FHWA (see 4 below) or commencing final design on other work, a preliminary layout shall be submitted to the appropriate Engineering Manager - Roadway Design Section, to insure agreement with the design criteria established for the roadway. For information regarding preparation of preliminary layout, see Structures Memorandum 010.

2 - Utilities

All bridges may be used to accommodate utility lines provided they are not injurious to the structure, do not restrict hydraulic capacity or are not visible to the normal view of the public. Proposals regarding utilities are submitted through the Manager - Utilities Section. See Structures Memorandum 036.

3 - Environmental Planning and Permits Division

The Environmental Planning and Permits Division is responsible for obtaining approval for construction of TDOT projects from all environmental regulatory agencies including the Tennessee Valley Authority, Tennessee Department of Environment and Conservation, and the U.S. Army Corps of Engineers. The Division should be provided with roadway plans and bridge preliminary layouts when available.

4 - Railroads

Four (4) sets of prints of the preliminary layout and related roadway plans for all structures involving railroads must be submitted through the Manager - Utilities Section to the railroad for approval. The preliminary layout shall be prepared in accordance with Structures Memorandum 010.

5 - FHWA

Preliminary plans for the following structures shall be submitted to FHWA for approval:

a) Bridges that are a part of an Interstate Highway Project.
b) Bridges in Non-Interstate Highway Projects that cross the Interstate Highway System (for clearance approval only).

The Division office of FHWA has requested to have the opportunity to review bridges on and over National Highway System (NHS) routes and any bridges receiving Federal Funds, with an estimated cost of $10,000,000 or more. (The $10,000,000 cost applies to Single structures or dual bridge crossings).

The submittal should consist of one print of bridge preliminaries and one print of roadway plans with: Title Sheet, Typical Cross Sections, pertinent R.O.W. and Plan & Profile Sheets showing bridge sites involved.

6 - Tennessee Valley Authority

Navigational clearance requirements shall be coordinated with TVA and the Hydraulic Design Section. In some cases approval of plans will be necessary under the authority of Section 26a of the TVA Act of 1933. Permit submittal requirements will be provided by the Environmental Planning and Permits Division. Projects requiring placement of fill in TVA reservoirs shall be coordinated with the Hydraulic Design Section and the Environmental Planning and Permits Division.

7 - U. S. Coast Guard

Applications must be made to the Eighth Coast Guard District for Permits for bridge construction over navigable waterways of the United States as identified in "Applications For Coast Guard Bridge Permits" published by the Eighth Coast Guard District, St. Louis, MO. This publication also identifies locations not actually navigated other than by logs, log rafts, row boats, canoes and small motor boats where "Advance Approval" will be given.

8 - Corps of Engineers

Construction on waterways deemed navigable by the Corps of Engineers requires a Section 10 permit and shall be coordinated with the Hydraulic Design Section. Construction in any waters of the United States requires approval of the Corps of Engineers under the authority of the Clean Water Act, Section 404. Section 404 requirements will be supplied by the Environmental Planning and Permits Division.

9 - U. S. Natural Resource Conservation Service

These agencies will be contacted, where stream crossings are involved, for information purposes and/or co-ordination of design. The Division of Structures will maintain liaison with the NRCS according to instructions given in Structures Memorandum 024.

TENNESSEE HYDRAULICS MEMORANDUM - 06
Improved Inlets for Culverts and Box or Slab Bridges

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Culvert capacity is based on either culvert entrance conditions (inlet control) or barrel resistance (outlet control). For inlet control, the culvert's capacity is based only on entrance configuration and headwater depth, in which case the culvert barrel could handle more flow than the inlet. Therefore, for culverts operating in inlet control the use of improved inlets would maximize the barrel capacity.

Culverts in inlet control usually lie on steep slopes and flow only partly full. Entrance improvements can result in a reduction in barrel size and a proportional reduction in project cost. The amount of reduction depends on site conditions and engineering judgment regarding the dependability of flood estimates and limiting headwater elevations to avoid damages.

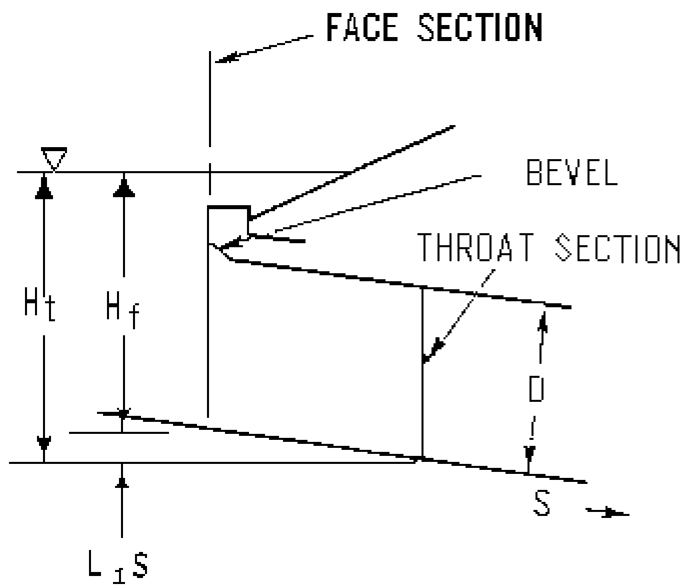
Improved inlets may be constructed on existing culverts with inadequate capacity. This may avoid the replacement of the entire structure or the addition of a new parallel culvert.

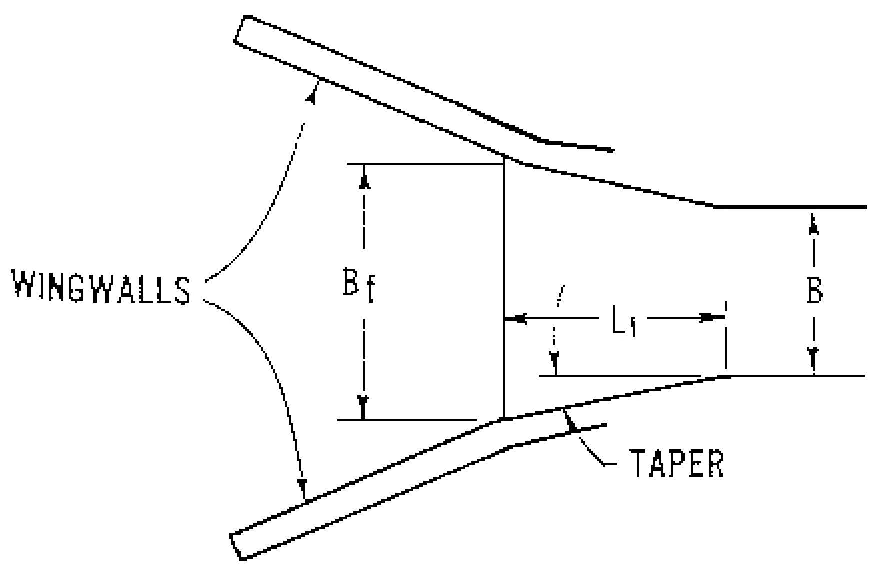
Three types of inlet improvements should be considered. These are bevel-edged, side-tapered and slope-tapered inlets. Bevel-edged inlets are utilized on all Tennessee Department of Transportation standard culvert drawings.

Side-tapered inlets have an enlarged face area with tapering sidewalls to transition to the culvert barrel (see Figure 1). They can provide as much as 40 percent increase in flow capacity over that of conventional inlets. Slope-tapered inlets provide a depression or fall in conjunction with a taper at the inlet (see Figure 2). In some cases they can provide over 100 percent greater capacity than a conventional inlet. Cost of excavation and sediment potential are prime considerations for these designs.

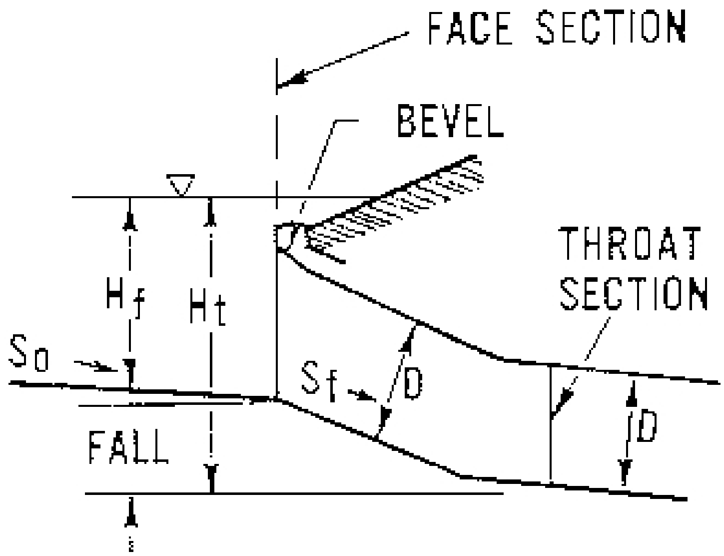
Culvert and inlet designs should be based on procedures outlined in F.H.W.A. publications "Hydraulic Design of Highway Culverts (HDS-5)" and "Hydraulic Design of Improved Inlets for Culverts (HEC-13)."

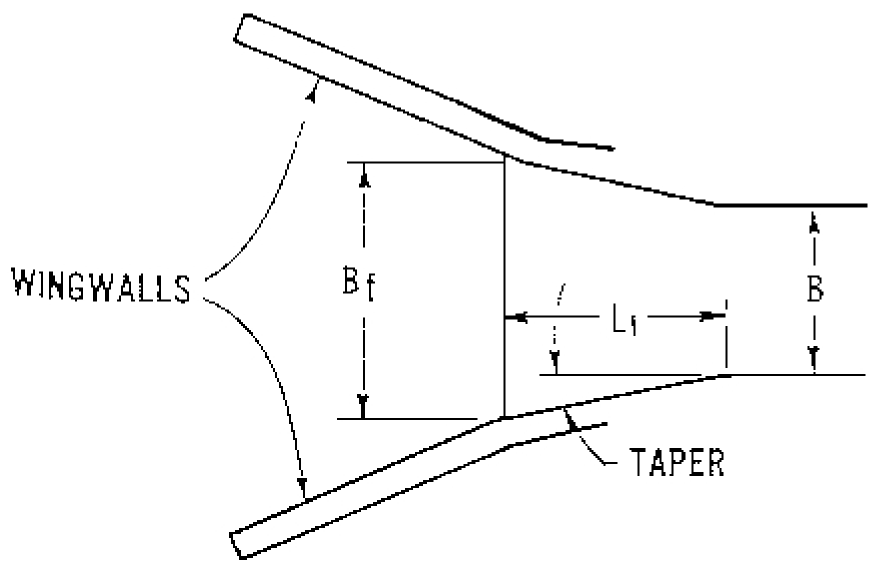
Side Tapered Inlet





Slope Tapered Inlet





TENNESSEE HYDRAULICS MEMORANDUM - 07
Drainage of Bridge Decks

PDD

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General Drainage Requirements

Bridge Deck Drains and End of Bridge Drains shall not be used unless necessary to prevent flooding of the traveled way or to prevent erosion around abutment wingwalls.

The Rational Method shall be used for computing runoff with rainfall intensity for the site selected from the Weather Bureau Rainfall - Frequency Atlas for the site using 5 minute duration (minimum).

The Design Storm will be a 10-year frequency storm, except that a 50-year frequency storm shall be used for bridges in which the low point of a sag vertical curve would occur on the bridge or approach pavements.

The methods described in Hydraulic Engineering Circular No. 21 (HEC 21), Design of Bridge Deck Drainage, published by the Federal Highway Administration shall be utilized in the analysis and design of bridge deck drainage.

A modified Manning's equation will be used in the analysis of the triangular flow along the gutter line. Bridges constructed on 0.00 % grades are undesirable and should be avoided. However, cases do arise where a 0.00% grade is required. In these cases the methods described in HEC 21 should be used.

Bridge Deck Drains and End of Bridge Drains shall be spaced so that no more than the shoulder area would be flooded during the design storm.

At locations with a Design Speed of 40 mile/h (65 km/h) or less and minimum shoulder widths of 2 to 4 feet (0.6 to 1.2 meters), it may be acceptable to allow limited spread into the lane adjacent to the shoulder. In no case will the usable roadway width in the inundated lane be reduced to less than 6 feet (1.8 m) Additionally, an open bridge rail (STD-7-1) is desirable in these locations and may negate the need for drainage appurtenances.

Bridge Rail Selection Criteria

Girder bridges on all systems are to be fitted with the appropriate concrete rail. Three standard designs for bridge rails are available.

- STD-1-1: This is the standard reinforced concrete closed parapet rail. (Item # 620-03.10)
- STD-7-1: This is an open concrete post and rail which allows drainage to flow unimpeded off of the bridge deck. The open rail may not be used on Interstates or primary State Routes. It may be used on local roads or secondary State Routes with a design speed less than 45 miles per hour (70 km per hour). It is best used in situations where flood flow frequently overtops the road, where sight distance considerations prohibit the use of STD-1-1, or when roadway geometry prohibits draining the bridge deck with standard deck drains. (Item # 620-06)
- STD-11-1: This is a straight faced concrete parapet with structural tubing. This rail is used on all bridges with a sidewalk. (Item # 620-05)

Use of the STD-7-1 open rail should be carefully considered even at sites that meet the above criteria if there are unusual mitigating factors such as high traffic volume, unusual roadway geometry, or a long drop to natural ground. The use of any rail other than the three standard rails must be approved by the Director of the Structures Division.

The criteria for the use of Bridge Deck Drains are as follows:

At locations where a sag occurs on a bridge, flanking inlets will be required in addition to a drain at the sag location. Additionally, where end of bridge drains are required, deck drains may be required so that the end of bridge drains can intercept the required bridge deck drainage (See End of Bridge Drain Requirements).

Special consideration will be given to drain spacing on structures with reverse horizontal curves occurring on the bridge. Sufficient drain openings will be provided to minimize "cross flow" onto traffic lanes at superelevation transition areas.

In the event deck drains are used, **drainage should not be allowed to fall onto bridge piers and girders, railroad beds, roadways or other sensitive features**. Additionally, it is undesirable to allow drainage to fall onto abutment berms and roadway shoulders. An underdeck collection and discharge system may be required in certain cases. The design of underdeck collection and discharge systems shall conform to the methods described in HEC 21.

See STD-1-2 for standard parapet openings and standard grate type openings. Parapet openings are the drain of choice due to cost considerations and should be utilized where possible. In cases where grate type openings may be required (e.g., curb & gutter sections, adjacent to median barriers, superelevation cross over sites, special conditions, etc...), the grate opening inlet on STD-1-2 should be used. The grate inlet is considerably more efficient in most cases and may solve excessive spread problems. However the grate type inlet is generally more expensive.

Deck Drain downspouts should not be used where the downspout will exit the bridge deck outside exterior beam lines of a bridge (i.e. under an overhang). Where grate type deck drains are required outside beam lines, STD-1-2 Grate Inlet Type 1 should be utilized. Where a grate type drain with a downspout is required, the downspout shall terminate 3 inches (0.08 m) below the bottom face of adjacent beam lines. All clearance requirements both horizontal and vertical shall remain in effect.

Every attempt possible shall be made to avoid the use of deck drains on structures utilizing Weathering Steel beams. Where deck drains are required, a drain utilizing a downspout shall be required subject to approval by the Director of the Structures Division.

Conditions do arise where deck drains detailed in STD-1-2 do not conform to site conditions. In these cases a site specific drain will be developed subject to review by the Director of the Structures Division.

<u>The criteria for the use of End of Bridge Drains are as follows:</u>

End of Bridge Drains will be required in all cases with the following exceptions;

1.)	When using an open type bridgerail (STD-7-1, etc...).
2.)	When Rip-Rap is brought up to the edge of shoulder and the discharge around the wing is not excessive.
3.)	In curb and gutter sections where flow cannot exit the roadway and erode fill slopes, End of Bridge Drains may not be required. If spread requirements can be met, roadway drains should be used instead of End of Bridge Drains. The location of roadway drains should be coordinated with the roadway designer in order to determine if spread requirements can be met.

When End of Bridge Drains are required, the following drawings are to be utilized.

For Bridges with Pavement at Bridge Ends.	
Drain Size	Standard Drawings
2 ft X 8 ft 7in (610 mm X 2620 mm)	STD-1-6, 7, 8 (STDM-1-6, 7, 8)
4 ft X 8 ft 7in (1220 mm X 2620 mm)	STD-1-6, 7, 9 (STDM-1-6, 7, 9)

For Bridges without Pavement at Bridge Ends.	
Drain Size	Standard Drawings
2 ft X 8 ft 7 in (610 mm X 2620 mm)	STD-1-10,11,12 (STDM-1-10,11,12)
4 ft X 8 ft 7in (1220 mm X 2620 mm)	STD-1-10,11,13 (STDM-1-10,11,13)

The width of drain to be used shall be two feet unless more width is required based on hydraulic calculations of inlet efficiency and shoulder width. In **no case** shall the drain grate protrude into the traffic lane.

TENNESSEE HYDRAULICS MEMORANDUM - 08
Scour and Fill at Bridge Waterways

PDD

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General

All structures should be evaluated for possible scour potential. The Federal Highway Administration's Hydraulic Engineering Circular Number 18 (HEC-18) entitled "Evaluating Scour at Bridges" should be used to determine design scour elevations for substructures. See below for sketch on how to show scour on the bridge layout sheets.

Channel migration in meandering streams, bank failure studies and effects of aggradation or degradation on side slopes are other key factors to be determined using USGS techniques provided in reference 4, 5 and 6.

Procedures/Guidelines

Geologic survey assistance may be necessary for evaluation of channel conditions and predictions of bed elevations over time. Bank stability analysis will be included in Tennessee Department of Transportation soils and foundation reports. Scour values calculated during the preliminary layout design, prior to receipt of soil borings, are considered tentative and must be confirmed using Tennessee Department of Transportation reports.

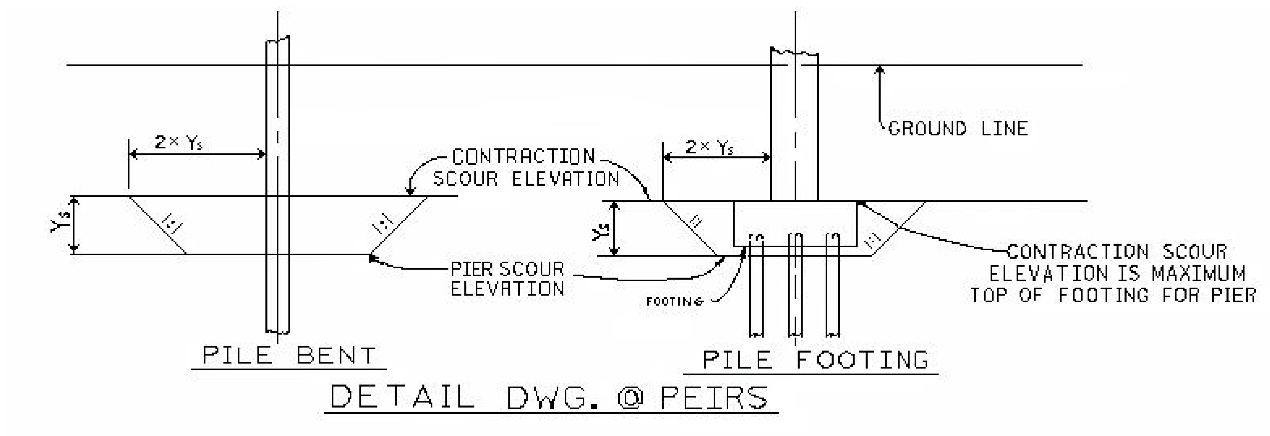
Top of footings will be placed a minimum of 6 feet (1.8 m) below the stable stream bed, considering degradation, if applicable. Footings for side piers adjacent to channel banks will be set at elevations below other land piers to account for possible bank slope failure and for lateral migration of the channel. Where stream channels are prone to meander, such as the Hatchie and Wolf Rivers, side pier footings are to be treated as if located in the channel bed.

Pile penetration of at least 10 feet (3 m) is to be provided below the computed elevations for the combination of all components of scour for the flood, which produces the greatest amount of scour up to a 500 year flood. Spread footings on soil or erodible rock shall be placed below the computed scour line. Sufficient subsurface investigations will be made for shallow foundations to identify weathering and rock discontinuities in establishing footing elevations.

All countermeasures to protect the structure against effects of scour are to be developed during the hydraulic study phase for each project. Typical designs and remedies include rip-rap and gabion slope protection, retaining walls and cut-off walls, deep foundations, flood relief flow over approaches, overflow bridges, excavation under bridges and guide banks.

The USGS has completed a study to identify scour potential for streams in Tennessee and scour critical bridge locations. This report should be reviewed for the site under study. The report is on file in the Hydraulic Section of the TDOT Structures Division.

Typical Scour Detail



List of References

1) "Evaluating Scour at Bridges", FHWA Hydraulic Engineering Circular No. 18.

2) "Stream Stability at Highway Structures", FHWA Hydraulic Engineering Circular No. 20.

3) "Scourability of Rock Formations", FHWA Memo, July 19, 1991.

4) "Man-Induced Channel Adjustments in Tennessee Streams, 1983" USGS.

5) "Gradation Processes and Channel Evolution in Modified Streams, 1985" USGS.

6) "Effects of Channel Adjustment in West Tennessee, 1988", U.S. Geological Survey.

7) "Highways in the River Environment, 1975" FHWA.

8) "Evaluation of Scour Critical Bridges in Tennessee, 1990" USGS.

9) AASHTO Manual for Condition Evaluation of Bridges, 1994.

10) Transportation Research Record No. 1201 pp. 46-53, 1988.

TENNESSEE HYDRAULICS MEMORANDUM - 09
Rip-Rap For Bridge Waterways, Open Channels And Grade Crossings

PDD

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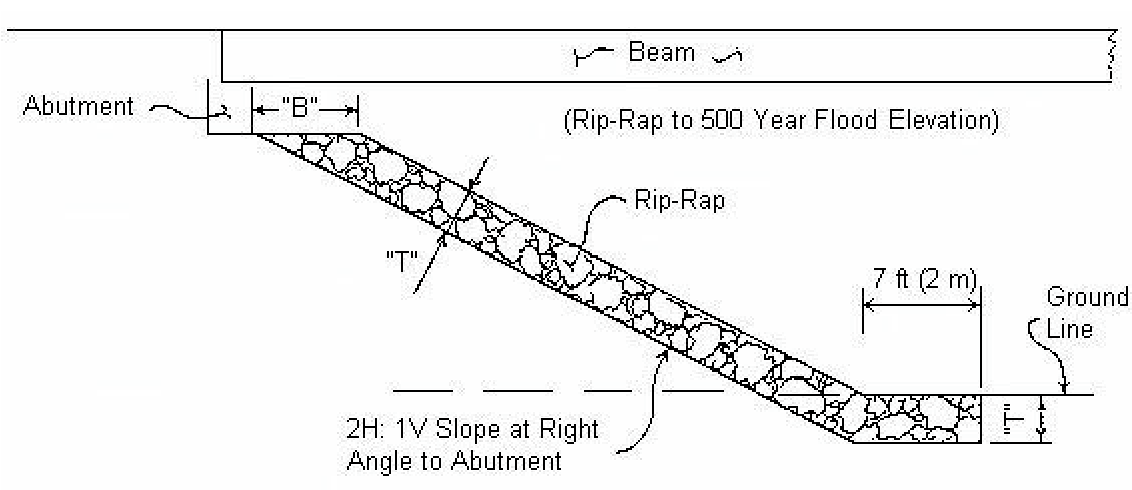
PART I - Rip-Rap for Bridge Waterways and Open Channels

General Guidelines

Slope stabilization should be used at all structures over streams where earth fill material is placed below the 500 year flood stage or on channels where the vegetation has been removed such as occurs at a channel widening or relocation. This also applies to box bridge locations in select cases.

See the sketch below for slope protection at bridge abutments. The rip-rap should be carried along the roadway embankment beyond the abutment wingwalls for 25 feet (7 m). This Rip-Rap sketch is also valid for bank protection.

Figure 1: Rip Rap Sketch For Bridge And Bank Slopes



Class of Rip-Rap	"B" at right angle to abut.	"T" Rip-Rap thickness
A	4 ft (1.2 m)	1.5 ft (0.45 m)
B	6 ft(1.8 m)	2.5 ft (0.75 m)
C	8 ft (2.4 m)	3.5 ft (1.10 m)

Rip-rap protection may be needed to protect undisturbed earth if velocities through a structure are increased enough to require bank or channel protection more substantial than could be resisted by the natural conditions.

Formulas for calculating rip-rap stone size, thickness requirements, need for filter blanket and safety factor can be found in Chapter VI of "Highways in the River Environment", Reference 1.

Most accepted methods for calculating rip-rap stone size give formulas for the D_{50} stone size. The term D_{50} is defined as the sieve diameter of the rock for which 50 percent of the material by weight is finer. The maximum stone size for a specific design has a diameter twice that of the D_{50}. The minimum layer thickness is equal to the maximum stone size diameter. If the rip-rap is expected to be subjected to strong wave action, the minimum thickness should be increased by 50 percent.

Design Alternatives

Rip-rap for bridge waterway openings and open channels shall be designed and selected on a project by project basis. The rip-rap specified shall be either Machined Rip-Rap (Class A-1), Machined Rip-Rap (Class A-2 with hand placed rubble stone alternate), Machined Rip-Rap (Class B), Machined Rip-Rap (Class C) or Rubble Stone Rip-Rap (plain). All machined rip-rap and rubble stone rip-rap shall be in accordance with Section 709 of the Standard Specifications except as modified by Special Provision 709.

Rubble Stone Rip-Rap

When Rubble Stone Rip-Rap is called for specifically on the plans (i.e., it is not an alternate to Machined Rip-Rap, Class A-2), specify the thickness if the thickness is other than 12 inches (0.3 m) and eliminate any reference to Special Provision 709.

Filter Blanket

A filter blanket may be required to prevent the fines from the embankment from being drawn out through the voids in the rip-rap stone, as occurs with fill material having a high sand content. The filter blanket may be either crushed stone, gravel or an approved manufactured filter cloth, or gravel with filter cloth, if embankment material is extremely fine grained. If a filter cloth is used, construction procedures shall be utilized which ill insure that the cloth is not damaged during placement of the rip-rap stone. If a crushed stone filter blanket is used, the thickness of the layer of stone shall be 4 to 6 inches (0.10 to 0.15 m) and the size shall be specified on the plans. The filter blanket will be included in the rip-rap bid item with the rip-rap quantity increased by the thickness of the filter blanket.

Measurement and Payment

If rip-rap is required specifically for protection of bridge substructures or fills, the rip-rap quantities shall be included under bridge pay items. If rip-rap is required to protect roadway slopes or channel improvement, it will be bid and paid for under roadway items. Measurement and payment shall be in accordance with Section 709 of the Standard Specifications except as modified by Special Provision 709.

Notes For Plans

Machined Rip-Rap shall be Class _____ *in accordance with Special Provision 709 of the standard specifications and shall be paid for as a roadway item.*

Rubble Stone Rip-Rap shall be hand placed in accordance with Subsection 709.06 of the Standard Specifications and shall be paid for as a roadway item.

PART II - Rip-Rap for Grade Crossings

A - Machined Rip-Rap

Rip-Rap shall be used in lieu of slope paving for bridges over roadways, railroads and streams where the abutment berm elevation is higher than the 500 year flood, unless otherwise directed on the Construction P.S. & E., and shall be included in the bridge quantities. The bridge designer shall specify machined Rip-Rap, 3 to 6 inch (0.08 to 0.15 m), Item No. 709-05.04 and refer to the details and notes on Standard Drawing RD-SA-1. Drawing RD-SA-1 shall be included in the list of Standard Drawings. Base quantities on 8 inch (0.20 m) thickness.

Machined Rip-Rap for slope protection shall be 3" to 6" (0.08 to 0.15 m) in size, uniformly graded and meet the quality requirement of subsection 918-10 and paid for as a roadway item.

See Standard Drawing No. RD-SA-1.

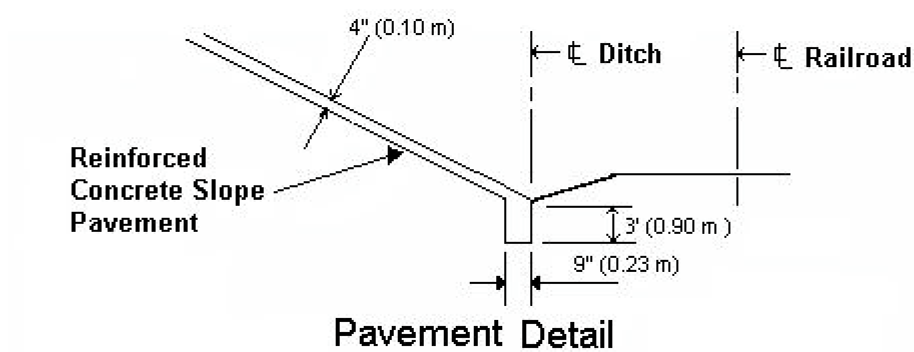
B - Reinforced Concrete Slope Paving

In special cases when reinforced concrete slope paving is required, it shall be included in the bridge items as Item 709-04, Reinforced Concrete Slope Pavement, ft^3 (m3), with the following notes shown on the bridge layout sheet.

Pave exposed earth slopes under bridges with 4" (0.10 m) thick cement concrete slab reinforced with No. 4 gage wire fabric @ 6" (0.15 m) centers and 58 lb. (26 kg) per100 ft^2 (9.3 m^2). The wire fabric reinforcement shall be placed at one-half the depth of the slab and extend to within 3" (0.08 m) of its edge with a 12" (0.3 m) lap required on all sheets. The cost of the wire fabric reinforcement to be included in the unit price bid for item 709-04, Reinforced Concrete Slope Pavement. One-half inch (1.3 cm) premolded expansion joints without load transfers shall be formed about all structures and features projecting through, in or against the slab. The slab shall be grooved parallel with and at right angles to the under roadway centerline at 6 ft (1.8 m) centers. Depth of groove to be not less than 1 inch (2.5 cm). (See Standard Drawing RDM-SA-1 for limits of slope protection)

Note to Detailer - Use slope dimensions when computing rip-rap or reinforced concrete pavement quantities.

Figure 2: Pavement Detail at Railroad Ditch



List of References

1. "Highways in the River Environment" Hydraulic and Environmental Design Considerations U.S.D.O.T., FHWA 1975.
2. HEC-16, Addendum to "Highways in the River Environment", U.S.D.O.T., FHWA 1980.
3. HEC-15, Design of Stable Channels with Flexible Linings, U.S.D.O.T., FHWA 1975.
4. Tentative Design Procedure for Rip-Rap Lined Channels, Highway Research Board 1970.
5. Highway Drainage Guidelines, AASHTO 1979.
6. HEC-11, use of Rip-Rap for Bank Protection U.S.D.O.T., FHWA 1967.
7. Countermeasures for Hydraulic Problems at Bridges FHWA, September 1978 Final Report.
8. HEC-18, "Evaluating Scour at Bridges".
9. HEC-20, "Stream Stability at Highway Structures".

TENNESSEE HYDRAULICS MEMORANDUM - 10
On Site Inspection Report

PDD

Distribution: Office, Consultants

A visual inspection should be made of the proposed structure site. The form below, which serves as an inspection guide, should be filled out and included in the hydraulic design notes.

Photographs should be taken of the structure site. The following is the minimum photograph requirement:

1. An elevation view of the existing structure opening and/or the proposed structure location.
2. A view of the upstream channel.
3. A view of the downstream channel.
4. Views of the upstream left and right floodplain.
5. Views of the downstream left and right floodplain.
6. A view looking forward on centerline survey.
7. A view looking back on centerline survey.
8. Any other pictures that would be helpful in the hydraulic analysis.

ON SITE INSPECTION REPORT

FOR STREAM CROSSINGS

C. INSPECTION MADE BY: ________________ **BRIDGE NO.:** ____________________ **COUNTY:** ______________

DATE: ________ **ROUTE NAME:** _____________________________ **STREAM NAME:** _______________________________

CHANNEL

Approx. depth and width of channel: Hor. _______ Vert. _______
Depth of normal flow: ___________ In Reservoir: [ ] Yes [ ] No
Depth of Ordinary H.W.: _________
Type of material in stream bed: _______________________________
Type of vegetation on banks: ________________________________
" N " factor of the channel: _______________
Are channel banks stable: _______________
If the streambed is gravel: D_{50} = __________ D_{85} = _________
Skew of the channel with the roadway: _____________

Channel Shape Sketch

FLOOD PLAIN

Is the skew same as the channel ? _________________
Is it symmetrical about the channel ? _______________
Type of vegetation in the floodplain and "N" factors
Left U.S.: __________________ Right U.S.: ____________________
Left D.S.: __________________ Right D.S.: ____________________
Are roadway approaches lower than the structure ? _________________
Are there any buildings in the floodplain ? ________________________
Approx. floor elevations: ______________________________________
Flood information from local residents:
(elevations & dates) ____

Floodplain Sketch

EXISTING STRUCTURE

Length: _____ No. of spans: _____ Structure type: ______________________________ No. of lanes: ____ Skew: ______
Width (out to out): ________ Width (curb to curb): _______________ Approach: [ ] paved [ ] graveled
Sidewalks (left, right): ____________ Bridgerail type: _________________________ Bridgerail height = _________
Superstructure depth: Finished Grade to low girder = _____________ Girder depth = ______________
Are any substructures in the channel ? _______________________________________ Area of opening = __________
Indications of overtopping: ____
High water marks: ____
Local scour: __________________________________ ________________________________
Any signs of stream [ ] aggradation or [ ] degradation ? ____________________________
Any drift or drift potential ?____
Any obstructions (pipes, stock fences, etc.) ? ____

PROPOSED STRUCTURE

[ ] Replacement [ ] Rehabilitate [ ] Widening [ ] New location
Bridge length: ________ Bridge type: __________________________ Span arrangement: ______________ Skew: ______
Bridge width: __________ Sidewalks: ________________ Design speed: _________ ADT ( ) = _______
Proposed grade:__________________________ Proposed alignment: ________________________
Method of maintaining traffic: [ ] Stage construction [ ] On site detour [ ] Close road [ ] Shift centerline _____ m
Cost of proposed structure: _______ per m^2 _______ length/width , Cost = _______
Cost of bridge removal: _________ per m^2 ______________ length/width , Cost = _____________
Detour structure: Type and size = ________________ , Cost = _____________
Total Structure Cost = _____