



Bridge Design Manual

Chapter 2

Bridge Selection

January 2015 – v 2.0

(Revised August 2018)



Page intentionally left blank.

Chapter 2 Bridge Selection

2.1	General	2.1-1
2.1.1	General	2.1-1
2.1.2	Bridge Terms	2.1-1
<hr/>		
2.2	Guidelines for Bridge Site Visits	2.2-1
2.2.1	General	2.2-1
2.2.2	What to Bring on a Bridge Site Visit	2.2-2
<hr/>		
2.3	General Factors for Consideration	2.3-1
<hr/>		
2.4	Bridge Geometry	2.4-1
2.4.1	General	2.4-1
2.4.2	Highway Crossings	2.4-4
2.4.3	Railroad Crossings	2.4-7
2.4.4	Water Crossings	2.4-8
2.4.5	Bridge Widening	2.4-10
2.4.6	Detour Structures	2.4-10
2.4.7	Inspection and Maintenance Access	2.4-11
<hr/>		
2.5	Bridge Type	2.5-1
2.5.1	General	2.5-1
2.5.2	Handling and Shipping of Members	2.5-1
<hr/>		
2.6	Aesthetic Considerations	2.6-1
2.6.1	General Visual Impact	2.6-1
2.6.2	Substructure, Soundwalls, & Slope Protection	2.6-1
2.6.3	Intermediate Piers	2.6-2
2.6.4	Abutment, Pier and Wall Surface Treatments	2.6-2
2.6.5	Superstructure	2.6-3
<hr/>		
2.7	Bridge Hydraulic Study	2.7-1
2.7.1	General	2.7-1
2.7.2	Design Procedure	2.7-1
2.7.3	Data Collection	2.7-3
	A. Reconnaissance	2.7-3
	B. Studies by Other Agencies	2.7-3
	C. Environmental Impact	2.7-4
	D. Design Criteria	2.7-4
2.7.4	Project Scope of Work	2.7-4
	A. Level of Assessment	2.7-4
	B. Hydraulic Analysis Method	2.7-5
	C. Additional Survey Information	2.7-5
2.7.5	Hydrologic Analysis	2.7-6
	A. Design Frequency	2.7-6
	B. Tidal Conditions	2.7-8
	C. Temporary Bridges	2.7-9
	D. Deck Drainage	2.7-9
	E. Hydrologic Methods	2.7-9

	2.7.6 Hydraulic Analysis	2.7-14
	A. NHDOT Design Criteria	2.7-14
	B. Hydraulic Design Factors	2.7-16
	C. Select Hydraulic Method	2.7-17
	D. Single-Section Analysis	2.7-18
	E. Step-Backwater Analysis	2.7-18
	2.7.7 Stability Analysis and Countermeasures	2.7-22
	A. Conduct Scour Evaluation	2.7-21
	B. Scour Countermeasures	2.7-23
	C. Channel Protection	2.7-24
	2.7.8 Final Hydraulic Report & Contract Drawings	2.7-26
<hr/>		
2.8	Type, Size and Location (TS&L)	2.8-1
	2.8.1 General	2.8-1
	2.8.2 TS&L Outline	2.8-1
	2.8.3 TS&L for Bridge Rehabilitation Projects	2.8-2
<hr/>		
2.9	TS&L Estimate	2.9-1
	2.9.1 Cost Estimating Guidelines – Bridge Replacement	2.9-1
	2.9.2 Cost Estimating Guidelines – Roadway Construction	2.9-2
<hr/>		
2.10	Boring Request	2.10-1
	2.10.1 Boring Request	2.10-1
	2.10.2 Check of Boring Logs	2.10-2
<hr/>		
2.11	Survey Request	2.11-1
	2.11.1 Survey Request	2.11-1
<hr/>		
	References	2.R-1
<hr/>		
	Appendix A	
	Appendix 2.2-A1 Picture Check List	2.2-A1-1
	Appendix 2.2-A2 Bridge Site Visit Check List	2.2-A2-1
	Appendix 2.2-A3 Bridge Report	2.2-A3-1
	Appendix 2.4-A1 Design Exception Request	2.4-A1-1
	Appendix 2.4-A2 Railroad Clearance Guidelines	2.4-A2-1
	Appendix 2.4-A3 Bridge Inspection Snooper Truck Reach Limits	2.4-A3-1
	Appendix 2.4-A4 Statewide Corridor Maps	2.4-A4-1
	Appendix 2.5-A1 Bridge Selection Guide	2.5-A1-1
	Appendix 2.6-A1 NHDOT Aesthetic Bridge Details – Surface Treatment	2.6-A1-1
	Concrete Form Liner	2.6-A1-1
	Concrete Coloring Agent	2.6-A1-5
	Architectural Details	2.6-A1-6
	Stone Masonry Facing	2.6-A1-12
	Appendix 2.6-A2 NHDOT Aesthetic Bridge Details – Bridge Railing	2.6-A2-1
	T2 Steel Rail	2.6-A2-1
	T3 Steel Rail	2.6-A2-3
	Concrete Rail	2.6-A2-4

	Timber Rail	2.6-A2-9
	Pedestrian Rail	2.6-A2-11
Appendix 2.6-A3	NHDOT Aesthetic Bridge Details – Bridge Lighting	2.6-A3-1
Appendix 2.7-A1	FHWA Hydraulic Engineering Circulars	2.7-A1-1
Appendix 2.7-A2	Bridge Hydraulic Design Flow Chart	2.7-A2-1
Appendix 2.7-A3	Data Collection and Field Review Form	2.7-A3-1
Appendix 2.7-A4	Manning Roughness Coefficient	2.7-A4-1
Appendix 2.7-A5	Hydraulic Concept Definitions	2.7-A5-1
Appendix 2.7-A6	StreamStats for NH: Program Information	2.7-A6-1
Appendix 2.7-A7	Developing Models Compatible with FIS	2.7-A7-1
Appendix 2.7-A8	FHWA Technical Advisory T5140.23	2.7-A8-1
Appendix 2.7-A9	Final Hydraulic Design Report Checklist	2.7-A9-1
Appendix 2.7-A10	Sample Final Hydraulic Report Table of Contents	2.7-A10-1
Appendix 2.8-A1	Bridge Design TS&L Checklist	2.8-A1-1
Appendix 2.9-A1	Slope Intercept Method	2.9-A1-1
Appendix 2.9-A2	Slope-Intercept Bridge Costs per Square Foot	2.9-A2-1
Appendix 2.9-A3	Bridge Type Abbreviations	2.9-A3-1
Appendix 2.10-A1	Boring Request – Materials & Research	2.10-A1-1
Appendix 2.10-A2	Boring Request – Design Services	2.10-A2-1

Appendix B

Appendix 2.10-B1	Boring Request Sample Plan	2.10-B1-1
------------------	----------------------------	-----------

Page intentionally left blank.

Chapter 2**Bridge Selection**

2.1 General**2.1.1 General**

The Type, Span, and Location (TS&L) phase is the evaluation of bridge structure type which shall consider cost, constructability, historic issues, aesthetics, safety, hydraulics, right-of-way, and environmental impacts. Economic factors shall balance initial costs of the overall project as well as the cost of future maintenance. The structures evaluated shall consider all superstructure and substructure options that are relevant for the site. Superstructure cost increases may be offset by substructure cost decreases such as using shorter abutments, which are set back from the feature crossed, versus tall abutments. The choice of a structure type for a given site shall be the responsibility of the Senior Project Engineer and Design Chief with the approval of the Administrator.

The Project Engineer shall endeavor to select the most serviceable structure while optimizing sight distance, design speed and clearance criteria at the proposed structure site. It is the general practice of the Department to design structures of girder-deck type construction. During the TS&L (Type, Size, and Location) studies it is very important that the type of structure be approved before final profiles are set since the depth of the superstructure could greatly influence the roadway profile.

Many structures are now constructed in the same location as, or adjacent to, existing structures. Where substructures are in a suitable condition for re-use or can be rehabilitated to a serviceable condition, the merits and cost of re-using the existing substructure shall be considered. If the existing substructure is not deemed serviceable for support of a new superstructure, the merits of saving it as an earth retaining structure shall be considered.

When the bridge substructure is historic or is located in a historic area or in sensitive wetlands, the substructure may be retained without being incorporated into the new structure to minimize the impacts to these resources. The replacement bridge structure may be supported with piles driven behind and/or adjacent to the existing substructures.

2.1.2 Bridge Terms

AASHTO, Subcommittee on Transportation Communications has published a website that provides resources: <https://bridges.transportation.org/>

Bridge terms can be found at the following websites:
<http://sdrc.lib.uiowa.edu/eng/bridges/WaddellGlossary/GlossA.htm> .
<https://bridgemastersinc.com/breaking-down-essential-parts-of-a-bridges-structure/>

Page intentionally left blank.

2.2 Guidelines for Bridge Site Visits

2.2.1 General

The site visit provides an opportunity to visually examine and evaluate important aspects of the project. The following guidelines are to help all staff in determining what to look for and document when visiting a bridge site:

- Scope of Work
 - Evaluate bridge condition. Consider whether a structure is in need of widening, rehabilitation or replacement.
 - Safety issues that need correction.
 - Soil type in the area (bedrock visible?).
- Impacts
 - Evaluate for possible impacts to environmental or cultural resources and right-of-way.
- Traffic Control
 - If a detour around the project is required, it shall be driven to verify that it meets current traffic requirements. The detour shall be measured and accurately described with any concerns about width, road conditions, etc.
- Hydraulics
 - A visual inspection shall be conducted to determine the adequacy of the approach channel, waterway opening, stream alignment, flow velocities, dams or other structures, and flood relief.
 - Look for indications of the normal high water mark such as staining on abutments or piers or erosion along the channel embankments.
 - Look for possible scour issues.
- Survey Limits
 - Establish the survey limits, using easily identifiable landmarks.
- Utilities
 - Note if any utilities are on the bridge or in the area of the bridge.
- Pictures
 - All noteworthy physical features of the project shall be photographed and documented ([Appendix 2.2-A1](#)).
 - There shall be enough color photographs to provide the look and feel of the bridge site.
 - Upon return to the office, the pictures shall be downloaded to the V:\Towns\town name\Project number\Bridge Design directory. If the V:\ project file has not been created yet, one can be created at this time.

Bridge site visit guidelines are also documented on the Bridge Site Visit Check List ([Appendix 2.2-A2](#))

2.2.2 What to Bring on a Bridge Site Visit

Prior to a bridge site visit, the following information shall be collected and brought to the site:

- Project Folder (with the following):
 - Bridge Location Map
 - Latest Inspection Report
 - Bridge Report ([Appendix 2.2-A3](#))
 - Copy of Flat Card
 - Existing Plans
- Camera
- Vests, hard hat (PPE)
- Measuring Tape
- Gas Card
- Engineering Paper

2.3 General Factors for Consideration

Many factors must be considered in the bridge selection process. Some factors common of these are listed in general categories below. These factors will be discussed in appropriate detail in subsequent sections of this manual.

A. Site Requirements

- Topography alignment (tangent, curved, skewed)
- Vertical profile and superelevation
- Corridor tier and design speed
- Proposed or existing utilities

B. Safety

- Feasibility of falsework (impaired clearance and sight distance, depth requirements)
- Density and speed of traffic
- Detours or possible elimination of detours by construction staging
- Sight distance
- Horizontal clearance to piers
- Hazards to pedestrians, bicyclists

C. Economics

- Funding classification (federal and state funds, state funds only, municipal funds)
- Bridge preliminary cost estimate

D. Structural

- Limitation on structure depth
- Requirements for future widening
- Foundation and groundwater conditions
- Anticipated settlement
- Stage construction
- Falsework limitations (terrain, boulder filled stream)

E. Environmental

- Site conditions (wetlands, environmentally sensitive areas)
- Environmental Impact Statement (EIS) requirements
- Mitigation measures
- Construction access

F. Aesthetic

- General appearance
- Compatibility with surroundings and adjacent structures
- Visual exposure and experience for public

G. Construction

- Ease of construction
- Falsework clearances and requirements
- Erection problems
- Hauling difficulties and access to site
- Construction season
- Time limit for construction

H. Hydraulic

- Bridge deck drainage
- Stream flow conditions and drift
- Passage of flood debris
- Scour, effect of pier as an obstruction (shape, width, skew, number of columns)
- Bank and pier protection
- Consideration of a culvert as an alternate solution
- Permit requirements for navigation and stream work limitations

I. Maintenance

- Concrete vs. Steel
- Expansion joints
- Bearings
- Deck protective systems
- Inspection and Maintenance Access

J. Other

- Prior commitments made to other agency officials and individuals of the community
- Recommendations resulting from preliminary studies

In selecting the type, size and location of the structure, the following items shall be considered:

- Provide adequate clearance for the design flood.
- Determine if the structure will be under fill.
- Determine if a curved horizontal alignment will require curved girders.
- Consider possible future widening of the roadway under the bridge.
- Provide a structure requiring minimum future maintenance.
- Wherever possible, eliminate joints in the bridge deck.
- Minimize environmental impacts.
- Evaluate water control issues during construction.
- Eliminate elements in the substructure which are a hazard to traffic.
- Provide for maximum sight distance.
- Provide a type of structure that is both functional and aesthetic.
- Provide for placement of utilities in the superstructure as necessary.
- Consider adequate and safe access to both the bridge and its approaches for persons with disabilities when there is a sidewalk on the bridge. See the Americans with Disabilities Act Handbook.
- Provide the required horizontal and vertical clearances in accordance with the appropriate drawings in Chapter 3 of the Highway Design Manual and Chapter 2, Section [2.4.2](#) of the Bridge Manual.
- Use continuous span design whenever more than one span is required.

2.4 Bridge Geometry

2.4.1 General

A. Bridge Definition

In RSA 234:2, the State of New Hampshire defines “bridge” as follows:

A structure having a clear span of 10-feet or more measured along the center line of the roadway at the elevation of the bridge seats, spanning a watercourse or other opening or obstruction, on a public highway to carry the traffic across, including the substructure, superstructure and approaches to the bridge. For purposes of qualification of bridge aid under this subdivision, but not applicable to RSA 234:4 or RSA 234:13, the term bridge shall include a combination of culverts constructed to provide drainage for a public highway with:

- I. An overall combined span of 10-feet (3.05-m) or more; and
- II. A distance between culverts of $\frac{1}{2}$ the diameter or less of the smallest culvert.

The National Bridge Inspection Standards (used by FHWA) defines a bridge as a structure having a clear span of more than 20-ft. (6.1-m) measured along the center of the roadway. This definition includes multiple openings, where the clear distance between openings is less than half of the smaller contiguous opening.

B. Design Exception

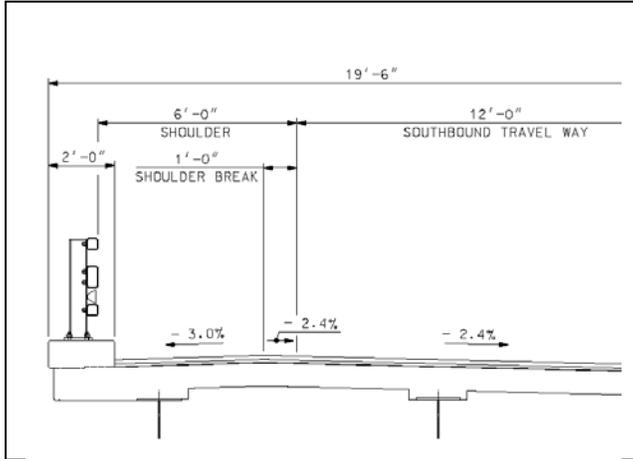
Design exceptions are required to waive established criteria contained in *AASHTO, A Policy on Geometric Design of Highways and Streets*. A design exception requires the Assistant Commissioner's approval and FHWA approval on Federal overview projects. Examples of details requiring design exceptions are design speed, lane and shoulder widths, bridge widths, horizontal and vertical alignments, grades, stopping sight distances, cross slopes, superelevations, and horizontal and vertical clearances. See [Appendix 2.4-A1](#) for a sample design exception letter.

C. Bridge Geometry Guidelines

Some bridge geometry guidelines for all bridge types include the following:

- 1) Bridge grades shall be 1.0% or more, when feasible, for rapid surface drainage and runoff of de-icing chemicals. In constrained areas (e.g. in urban locations, historical sites, or sites with environmental constraints such as wetlands, etc.) the minimum bridge grade shall be 0.5%. For a symmetrical crest vertical curve the K value shall be less than 105 for length of curve in feet (32-m) to insure a minimum grade of 0.5% about 50-ft. (15-m) from the crest.
- 2) Low points of sag vertical curves or superelevation crossovers shall be placed so these features occur outside the limits of the bridge decks and approach slabs because of the objectionable appearance of a sag camber in a beam and to allow for the installation of drainage structures at low points.
- 3) If a superelevation transition or runoff is located in the middle of a span, verify that this does not create a negative camber in a beam. If possible, begin or end transitions off the structure or begin or end the transition at the centerline of bearings of an abutment or pier.
- 4) For superelevated deck structures, the cross slope of the travel way shall continue to the curb if the shoulder width is 5-ft. (1.5-m) or less, rather than match any breaks in the approach superelevation. For shoulder widths wider than 5-ft. (1.5-m), the cross slope shall be broken on the high side (only) of a superelevated deck section, to match the cross slope on the

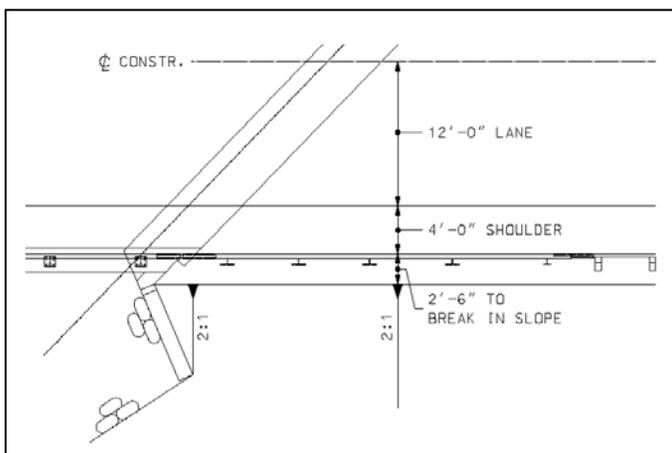
approaches. If the shoulder is 10-ft. (3-m) or greater, two breaks can be shown on the deck section to match approach cross-slopes. This prevents any water from traveling across the slope and potentially freezing. See Figure 2.4.1-1. The maximum algebraic difference between the travel way and shoulder grades is 7% (*AASHTO Geometric Design of Highways and Streets, Chapter 4*).



Example of a Superelevated Deck Section

Figure 2.4.1-1

- 5) For normal crown deck structures, the crown slope shall extend to the curb with no break in the shoulder, for all shoulder widths.
- 6) The deck overhang (distance from center of girder to edge of deck coping) shall be dimensioned between 2 to 3.5-ft. (0.6 to 1.1-m). If the overhang is greater than 3.5-ft. (1.1-m), the deck will need to be analyzed in accordance with *AASHTO A13.4, Deck Overhang Design*.
- 7) The deck coping width (face of curb to edge of coping) shall be set at 2-ft. (0.6-m).
- 8) The wingwall lengths shall be dimensioned to the nearest 6-in. (150-mm) so reinforcing can be placed at 6-in. (150-mm) intervals with 3-in. (75-mm) at the ends of the wingwall. This allows the footing J-bars to be tied to the vertical wingwall reinforcing.
- 9) The beginning of a flared wingwall is typically set from the intersection point of the abutment back-of-backwall (fixed ends and expansion joints located *in front* of the backwall) or back of abutment (expansion joints located *behind* the backwall) and the break-in-slope line which is 2'-6" (0.8-m) from the edge of shoulder/face of rail. See Figure 2.4.1-2 and Chapter 7, Appendix 7.4-B9.

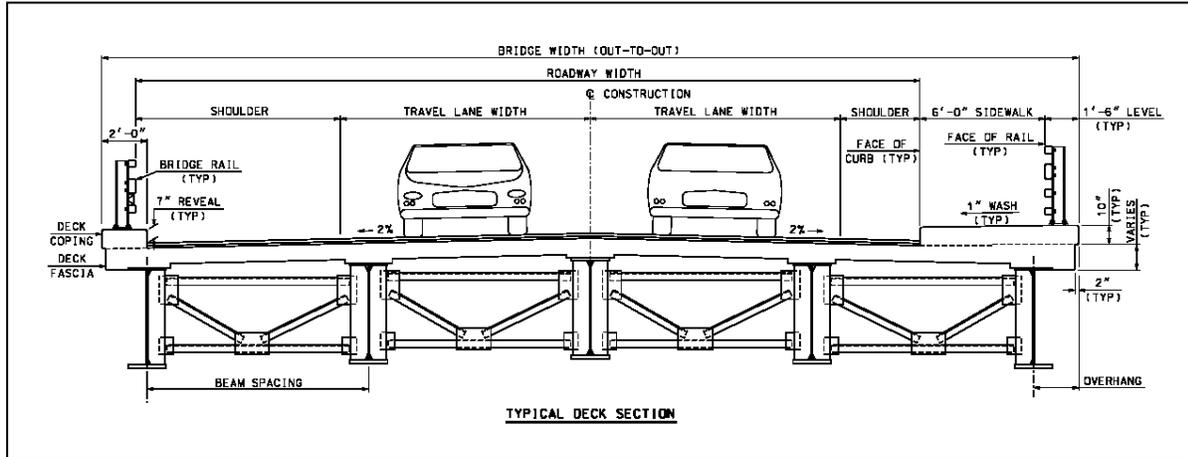


Determining the Beginning of a Flared Wingwall

Figure 2.4.1-2

- 10) The end of flared wingwalls shall be determined by the intersection of the proposed roadway slope lines and the proposed slopes lines for the channel or roadway crossing.
- 11) Flared wingwalls shall normally be the first option considered when laying out wingwall geometry. The flared wingwall gives the shortest length, lowest initial cost, and fewer conflicts with guardrail posts.
- 12) U-back wingwalls shall be considered in the following situations:
 - To avoid conflicts with cofferdams or substantially ease cofferdam construction.
 - To avoid impacts with existing bridge or approach roadway (maintenance of traffic).
 - To avoid having to construct the wingwalls(s) in an additional construction phase.
 - To avoid Right-of-Way impacts when necessary.
- 13) Principal layout lines shall be the CL of bearing or the face of frame leg, and the face of the wing lines. The intersections of these lines at each corner of the abutment or frame shall be designated as “working point” (WP). The intersection of the CL of construction and bearing or face of frame leg shall also be designated as “WP”. See Chapter 11, Appendix 11.2-B1 for a survey layout sample plan.
- 14) If a skew is required, each substructure element shall be skewed by the same angle relative to the centerline of construction.
- 15) A new bridge shall preferably have a minimum of five (5) beams to allow for any possible future phase construction.
- 16) Abutment and pier setback distances from roadways under the bridge shall be in accordance with *AASHTO Roadside Design Guide* and Chapter 6 of the *Bridge Design Manual*.
- 17) Show proposed sidewalks only where there are existing sidewalks on the approaches or on the bridge. There may be instances where a sidewalk may be added or removed as approved by the Design Chief.
- 18) Bridge sidewalks shall have a minimum width of 6'-0" (1.8-m) measured from the face of the curb to the face of the rail, unless approved otherwise by the Design Chief. The sidewalk cross-slope shall have a minimum of 1-in. (25-mm) wash for widths up to 6-ft. (1.8-m) and 1.5-in (38-mm) wash for widths 7-ft. to 12-ft. (2-m to 3.7-m) [1% min., 2% max. per ADA requirements].
- 19) The use of vehicular bridge railing separating the roadway and sidewalk shall be determined by the Design Chief.
- 20) The height of bridge railing on the fascia side of the sidewalk shall meet or exceed the minimum height requirement of 42-in. (1067-mm) from the top of the sidewalk for pedestrian railing. T2 steel bridge railing with protective screening can be used on the sidewalk for bridges over roadways. The protective screening shall continue the full length of the bridge since the protective screening is providing protection for the pedestrians.
- 21) On designated bike routes, the height of the bridge railing shall meet or exceed the minimum height requirement of 42-in. (1067-mm) from the top of the riding surface.
- 22) Catch basins should generally be located outside the bridge on all four (4) corners, or as directed by the Design Chief.
- 23) The clear width is the measurement between the faces of bridge railing (*AASHTO LRFD 3.6.1.1.1*). The bridge width (out-to-out) is measured between the outside deck copings (curbs). See Figure [2.4.1-3](#).

- 24) The bridge span length(s) measured center to center of bearings shall be in 1'-0" (0.3-m) increments for all new crossings.



Bridge Measurements

Figure 2.4.1-3

2.4.2 Highway Crossings

A. General

A highway crossing is defined as a grade separation between two intersecting roadways. Naming convention varies slightly between mainline highway crossings and ramp highway crossings, but typically, all bridges carry one highway, road, or street over the intersecting highway, road, or street.

1. Mainline highway crossings

Names for mainline highway crossings are defined by the route designation or name of state highway, town road, or city street being carried over another highway, road, or street.

2. Ramp highway crossings

Names for ramp highway crossings are defined by the state highway route numbers being connected, the directions of travel being connected, and the designation or name of the highway, road, or street being bridged.

B. Bridge Width

The bridge width shall not be less than that of the approach roadway section including shoulders or curbs, gutters, and sidewalks. For bridges on state highways, the preferred minimum width of 32-ft. (9.75-m) for total lanes and shoulders shall be used. For bridges on town roads, the minimum width (total of lanes and shoulders) shall be 24-ft. (7.3-m) unless there are conditions that make this width extremely impractical (e.g., covered bridges or severe impacts to adjacent buildings).

C. Horizontal Clearances

Safety dictates that fixed objects be placed as far from the edge of the roadway as is economically feasible. Criteria for minimum horizontal clearances to bridge piers and retaining walls are outlined in the *Highway Design Manual* and *AASHTO Roadside Design Guide*. These documents

outline clear zone and recovery area requirements for horizontal clearances in locations without guardrail or barrier.

Actual horizontal clearances shall be shown on the General Plan (to the nearest 0.1 foot [0.03 meter]). Minimum horizontal clearances to inclined columns or wall surfaces shall be provided according to *AASHTO Roadside Design Guide* and the *Highway Design Manual*.

Ideally, bridge piers and abutments shall be placed such that the minimum clearances can be satisfied. However, if for structural or economic reasons the best span arrangement requires a pier or abutment to be within the clear zone or recovery area, guardrail or barrier can be used to mitigate the hazard.

There are instances where it may not be possible to provide the minimum horizontal clearance even with guardrail or barrier. An example would be placement of a bridge pier in a narrow median. The required column size or column plus traffic barrier may be such that it would infringe on the shoulder of the roadway. In such cases, the safety shape barrier would be incorporated into the shape of the column. Barrier or guardrail would need to taper into the pier at a flare rate satisfying the criteria in the *Highway Design Manual* and *AASHTO Roadside Design Guide*.

D. Vertical Clearances

The required minimum vertical clearances are established by the functional classification of the highway and the construction classification of the project. As outlined in the *Highway Design Manual*, the clearances found in Table 2.4.2-2 shall be used for highway crossings (clearances include an allowance of 6-in. [152-mm] for future paving). See Appendix 2.4-A4 for the Statewide Corridor Maps or view the tiers on the “Tiers Viewer” located at: <http://www.nh.gov/dot/org/projectdevelopment/planning/gis-data-catalog/index.htm>.

NH Highway Tiers	
Tier 1:	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Interstates</p> </div> <div style="text-align: center;">  <p>Turnpikes and Divided Highways</p> </div> </div>
Tier 2:	<div style="text-align: center;">  <p>Other statewide corridors</p> </div> <p><i>Highways that provide statewide travel and carry high traffic volume at high speeds.</i></p>
Tier 3:	<div style="text-align: center;">  <p>Regional corridors</p> </div> <p><i>Highways that provide travel within regions, access statewide corridors, and support moderate traffic volumes at moderate speeds.</i></p>
Tier 4:	<div style="text-align: center;">  <p>Local connectors</p> </div> <p><i>Roadways that provide travel between and within communities, and support low traffic volumes at low speeds.</i></p>
Tier 5:	<div style="text-align: center;">  <p>Local roads</p> </div> <p><i>Community owned roadways that provide local access, and support varying volumes of traffic at varied speeds.</i></p>

NH Highway Tiers

Table 2.4.2-1

Vehicular Bridge Clearances	
Project Location	Vertical Clearance
Tier 1, 2 & 3: <ul style="list-style-type: none"> Under Tier 1, 2 or 3 Under Tier 4 or 5 	16'-6" (5.1 m)
Tier 4 & 5: <ul style="list-style-type: none"> Under Tier 1, 2 or 3 with interchange 	16'-6" (5.1 m)
Tier 4 & 5: <ul style="list-style-type: none"> Under Tier 1,2 or 3 without interchange Under Tier 4 or 5 	14'-6" (4.5 m)
Pedestrian Bridge Clearances	
All pedestrian bridges shall be 1'-0" (3.28-m) higher than the vehicular bridge clearance in accordance with <i>AASHTO LRFD 2.3.3.2</i>	

Minimum Vertical Clearances for Highway Crossings

Table 2.4.2-2

Minimum roadway vertical clearance is measured between overhead structures and the finished roadway surface. The designated minimum clearance must be provided over the entire usable roadway width including shoulders. Actual minimum vertical clearances shall be shown on all profiles (to the nearest 0.1 foot [0.03 meter]). For structures crossing divided highways, minimum vertical clearances for both directions are noted.

E. End Slopes

The type and rate of end slope used at bridge sites is dependent on several factors. Soil conditions and stability, right of way availability, fill height or depth of cut, roadway alignment and functional classification, and existing site conditions are important. The side slopes noted on the plan for the roadway shall indicate the type and rate of end slope. End slopes steeper than 2:1 need some type of erosion control, such as erosion control matting, slope paving or stone slope protection. Types of stone slope protection are discussed in Section 2.7.6, [Channel Protection](#).

F. Determination of Bridge Length

Establishing the location of the abutments for a highway crossing is a function of the profile grade of the overcrossing roadway, the superstructure depth, the minimum vertical and horizontal clearances required for the structure, the profile grade and channelization (including future widening) of the undercrossing roadway, and the type and rate of end slope used.

G. Pedestrian Only Crossings

Pedestrian crossings follow the same format as highway crossings. Geometric criteria for bicycle and pedestrian facilities are established in the *Highway Design Manual*. Width and clearances would be as established there and as confirmed by the Design Chief. Minimum vertical clearance over a roadway is noted above and in the *Highway Design Manual*. Unique items to be addressed with pedestrian facilities include ADA requirements, the railing to be used, handrail

requirements, overhead enclosure requirements, and profile grade requirements for ramps and stairs.

H. Bridge Redundancy

Design bridges to minimize the risk of catastrophic collapse by using redundant supporting elements (columns and girders).

2.4.3 Railroad Crossings

A. General

A railroad crossing is defined as a grade separation between an intersecting highway and a railroad. Names for railroad crossings are defined either as railroad over state highway or state highway over railroad.

Requirements for highway/railway grade separations may involve negotiations with the railroad company concerning clearances, geometrics, utilities, and maintenance roads. The railroad's review and approval will be based on the completed Preliminary Plan.

B. Bridge Width

For highway over railway grade separations the provisions of Chapter 2, Section [2.4.2](#) pertaining to bridge width of highway crossings shall apply. Details for railway over highway grade separations will depend on the specific project and the railroad involved.

C. Horizontal Clearances

For railway over highway grade separations, undercrossings, the provisions of Chapter 2, Section [2.4.2](#) pertaining to horizontal clearances for highway crossings shall apply. For railway under highway grade separations, the provisions of American Railway Engineering and Maintenance Association (AREMA) *Manual for Railroad Engineering* and requirements of the railroad company shall be followed. See Appendix 2.4-A2 for railroad clearance guidelines.

D. Crash Walls

Crash walls, when required, shall be designed to conform to the criteria of the *AREMA Manual*. To determine when crash walls are required, consult American Railway Engineering and Maintenance Association, *Guidelines for Design of Highway Separation Structures over Railroad (Overhead Grade Separation)*.

E. Vertical Clearances

The following is a guide of the minimum vertical clearances for railroad crossings:

- Tier 4 or 5 under railroads 14'-6" (4.5-m)
- Tier 1, 2 or 3 under railroads 16'-6" (5.1-m)
- Railroad under all roads 22'-6" (6.9-m)
- NH Title XXXIV – Public Utilities RSA 373:39 22'-0" (6.7-m)
(railroad under all roads)

All minimum clearances are from top of high rail to bottom of low edge of bridge. The provisions of American Railway Engineering and Maintenance Association (AREMA) *Manual for Railroad Engineering* and requirements of the railroad company shall be followed for the

minimum vertical clearance. Check with the Chief of Design Services, Bureau of Highway Design, to verify required clearances when railroads are involved.

If site conditions will not allow these clearances for the railroad crossing to be achieved without considerable impacts, clearance may be reduced to 21'-0" (6.4-m) with the Design Chief's approval. Lowering of the footing elevations shall be investigated to allow for future lowering of the tracks by 1'-6" (0.5-m) to achieve the 22'-6" (6.86-m) clearance. See [Appendix 2.4-A2](#) for railroad clearance guidelines.

F. Determination of Bridge Length

For railway over highway grade separations, the provisions of Chapter 2, Section [2.4.2](#) pertaining to the determination of bridge length shall apply. For highway over railway grade separations, the minimum bridge length shall satisfy the minimum horizontal clearance requirements.

G. Special Considerations

Any cofferdams, footings, excavation, etc., encroaching near the tracks requires the approval of the railroad. Falsework openings shall be checked to verify that enough space is available for falsework beams to span the required horizontal distances and still provide the minimum vertical falsework clearance. Minimum vertical openings of less than 22'-6" (6.9-m) shall be coordinated with the Chief of Design Services, Bureau of Highway Design.

Overhead bridge drainage shall be directed away from the railroad.

2.4.4 Water Crossings

A. Bridge Width

The provisions of Section [2.4.2](#) pertaining to bridge width for highway crossings apply here.

B. Horizontal Clearances

Water crossings over navigable waters requiring clearance for navigation channels shall satisfy the horizontal clearances required by the Coast Guard. For bridges over navigable waters, the centerline of the navigation channel and the horizontal clearances (to the nearest 0.1 foot [0.03 meter]) to the piers or the pier protection shall be shown on the Plan view.

C. Vertical Clearances

Vertical clearances for water crossings must satisfy floodway clearance and, where applicable, navigation clearance.

Bridges over navigable waters must satisfy the vertical clearances required by the Coast Guard. The actual minimum vertical clearance (to the nearest 0.1-ft. [0.03-m]) and location for the channel span shall be shown on the elevation and plan view. The clearance shall be shown to the water surface as required by the Coast Guard criteria.

Floodway vertical clearance shall be in accordance with Section 2.7, [Bridge Hydraulic Study](#). The roadway profile and the bridge superstructure depth must accommodate this. The actual minimum vertical clearance to the design flood and approximate location shall be shown (to the nearest 0.1-ft. [0.03-m]) on the elevation and plan view.

D. End Slopes

The type and rate of end slopes for water crossings is similar to that for highway crossings. Soil conditions and stability, fill height, location of toe of fill, existing channel conditions, flood and scour potential, and environmental concerns are all important. See Section 2.7.6, [Channel Protection](#) for guidelines on slopes for water crossings.

E. Determination of Bridge Length

Determining the overall length of a water crossing is not as simple and straightforward as for a highway crossing. Floodway requirements and environmental factors have a significant impact on where piers and fill can be placed.

Environmental studies will document any restrictions on fill placement, abutment and pier arrangement, and overall floodway clearance. The size, shape, and alignment of all bridge piers in the floodway and the subsequent effect they will have on the base flood elevation will need to be reviewed. The overall bridge length may need to be increased depending on the span arrangement selected and the change in the flood backwater, or justification will need to be documented. See NHDES Stream Crossing Guidelines located at [G:\BUR16\NH Stream Crossing Guidelines](#) for information on overall lengths over a waterway. See Section 2.7.7 C. [Channel Protection](#) for bench width requirement for inspection access.

F. Scour

A scour analysis shall be performed for each new bridge with a pier located in the waterway (see Section 2.7.7, [Stability Analysis and Countermeasures](#)). Pier shapes shall be developed to best streamline flow and reduce the scour forces. The scour analysis shall recommend measures to protect the piers from scour activity or accumulation of drift (use of deep foundations, minimum cover to top of footing, riprap, pier alignment to stream flow, closure walls between pier columns, etc.).

G. Pier Protection

For bridges over navigable channels, piers adjacent to the channel may require pier protection such as fenders or pile dolphins. The Coast Guard will determine whether pier protection is required. This determination is based on the horizontal clearance provided for the navigation channel and the type of navigation traffic using the channel.

H. Construction Access and Time Restrictions

Water crossings will typically have construction restrictions associated with them. These must be considered during TS&L stage.

The time period that the Contractor will be allowed to complete work within the waterway may be restricted by regulations administered by various agencies. Depending on the time limitations, a bridge with fewer piers or faster pier construction may be more advantageous even if more expensive.

Contractor access to the water may also be restricted. Shore areas supporting certain plant species are sometimes classified as wetlands. A work trestle may be necessary in order to work in or gain access through such areas. Work trestles may also be necessary for bridge removal as well as new bridge construction. Work trestle feasibility, location, staging, deck area and approximate number of piles, and estimated cost may need to be determined as part of the bridge preliminary plan.

2.4.5 Bridge Widening

A. Bridge Width

The provisions of Section [2.4.2](#) pertaining to bridge width for highway crossings shall apply. In most cases, the width to be provided by the widening will be what is called for by the design standards, unless a deviation is approved.

B. Traffic Restrictions

Bridge widenings involve traffic restrictions on the widened bridge and, if applicable, on the lanes below the bridge. The bridge plan shall contain information regarding temporary lane widths and phasing configurations. This information shall be checked to be certain that the existing bridge width and the bridge roadway width during the intermediate construction stages are sufficient for the lane widths, shy distances, temporary barriers, and staging area for the contractor. The temporary lane widths and shy distances on the roadway beneath the bridge being widened shall also be checked to ensure adequate clearance is available for any substructure construction.

C. Construction Sequence

A construction sequence shall be developed using the traffic restriction data. The construction sequence shall take into account the necessary steps for construction of the bridge widening including both the substructure and superstructure. Placement of equipment is critical because of limited access and working space limitations. Space is required for cranes to construct shafts and erect the girders. Consult the Bureau of Construction for crane information, such as: boom angle, capacities, working loads, working radius, and crane footprint. Construction work from and adjacent to the structure and the requirements of traffic flow on and below the structure shall be taken into account. Generally, cranes are not allowed to lift loads while supported from the existing structure. Checks shall be made to be certain that girder spacing, closure pours, and removal work are all compatible with the traffic arrangements.

Projects with several bridges being widened at the same time shall have sequencing that is compatible with the traffic plans during construction and that allow the Contractor room to work. It is important to meet with the District Construction Engineer to assure that the construction staging and channelization of traffic during construction is feasible and minimizes impact to the traveling public.

D. Existing Bridge Information

All new and rehabilitation work to bridges is printed on full-size plans and stored in the file tubs located in the Bureau of Bridge Design. Any maintenance or repair work to bridges is recorded by the Bureau of Bridge Maintenance and stored in their paper and electronic files. A request should be made to the Bureau of Maintenance to obtain a copy of the maintenance record of a bridge.

2.4.6 Detour Structures

A. Bridge Width

The lane widths and overall roadway widths for detour structures are determined by permit routes, winter maintenance and the provisions of Section [2.4.2](#). Review and approval of detour roadway widths is done by the Design Chief and District Construction Engineer.

B. Live Load

Unless otherwise specified on the Plans, the temporary bridge, including the rail system and substructures, shall meet the minimum strength requirements of an HL-93 design loading and pedestrian loading as required and specified in the *AASHTO LRFD Bridge Design Specifications*. The bridge, including superstructure, rail system, and substructures shall be designed by a Professional Engineer(s) licensed in the State of New Hampshire in accordance to Section 501 of *NHDOT Standard Specifications for Road and Bridge Construction* and as noted on the plans.

C. Dead Load Deflection

For longer spans, the Designer should be aware that the magnitude of the dead load deflection and pin-hole sag of modular prefabricated panel bridge systems (i.e., Acrow, Mabey) may become undesirable from a rideability stand point. For high speed and high volume roadways (Tier 1 and 2), the Designer shall decide whether the use of “camber panels” or “compression panels”, which compensate for the expected pin-hole sag and dead load deflection, shall be required. If panels are required, a note shall be placed on the Contract Plans.

2.4.7 Inspection and Maintenance Access**A. General**

NH State Statue, Bridges and Bridge Aid, RSA 234:22 and 234:23 as well as the National Bridge Inspection Standards (NBIS) mandate that bridges on class I, II, III, IV, and V highways and Municipally maintained bridges on class II highways, are to have a biennial inspection.

The Bridge Design inspectors are required to access bridge components to within 3-ft. (1-m) for visual inspection and to access bearings close enough to measure movement. Maintenance personnel need to access damaged members and locations that may collect debris. This is accomplished by using many methods. Safety cables, ladders, and inspection bucket trucks (Snoopers) ([Appendix 2.4-A3](#)) are just a few of the most common methods. Designers need to be aware of these requirements and prepare designs throughout the TS&L and Preliminary Plan planning phases that allow access for bridge inspectors and maintenance personnel.

As noted in [Appendix 2.4-A3](#), the inspection bucket truck (Snooper) can only lift the bucket 8-ft. (2.4-m) above the reference surface. If a security fence is placed on the bridge, the Snooper can place the bucket outside the bridge prior to driving onto the bridge and continue across the bridge to perform the inspection. However, if the bridge has light poles, the Snooper cannot continue across the bridge because the boom will hit the light pole. If the only way the bridge can be inspected is by the Snooper Bucket truck, then the designer needs to design/layout the bridge so truck can access the underside of the bridge.

Page intentionally left blank.

2.5 Bridge Type

2.5.1 General

See [Appendix 2.5-A1](#), Bridge Selection Guide for a bar graph comparing structure type, span range.

In selecting the bridge type, the following items shall be considered:

- Single span or multi-span steel or concrete beam bridges are common alternatives for the majority of structures. The choice shall be made on the basis of judgment, economy, appearance and serviceability.
- Redundant type (multiple load path) systems are required. Non-redundant (single load path; also called "Fracture Critical") systems shall be avoided.
- Steel structural plate pipes and pipe arches shall not be used for crossing hydraulic channels due to their tendency to corrode at the waterline. For pedestrian and recreational trails, steel structural plate may be used. Aluminum structural plate may be an appropriate alternative for either hydraulic or dry crossings. See Chapter 9, Section 9.2 for structural plate pipe-arch size.
- Concrete rigid frames or arches shall be considered in locations where the structure can be placed under fill, for spans up to 65-ft. (20-m) measured normal to the legs. Leg heights shall be 20% to 50% of the span length. This type of structure is also an excellent choice where aesthetics are a consideration.
- Voided slabs can be considered for spans less than 55-ft. (17-m) where vertical clearance is a significant design issue or where rapid or stage construction is required.
- Precast concrete box beams can be considered for spans between 46-ft. (14-m) and 80-ft. (24-m) where expedient construction is required.
- Integral abutments shall be considered for steel and concrete girder bridges. The maximum length for integral abutment steel bridges is 200-ft. (60-m). The maximum length for integral abutment concrete bridges is 325-ft. (100-m). Longer spans may be considered with approval of the Design Chief. See Chapter 6, Section 6.4 for additional information.

2.5.2 Handling and Shipping of Members

In all cases, bridges utilizing precast concrete or steel members need to have their access routes checked. The capacities of the bridge structures along the route must be reviewed to be certain that the members can be transported to the site. It must also be determined that they can be erected once they reach the site.

Both the size and the weight of the members must be checked. Likely routes to the site must be adequate to handle the truck and trailer hauling the members. Avoid narrow roads with sharp turns, steep grades, and/or load-rated bridges, which may prevent the beams from reaching the site. The weight and size limitations for shipping of a precast member are dependent upon the mode of transportation and locations of the precast plant and bridge site. A local precast/steel fabricator shall be contacted to confirm the beam can be transported to the site.

A list of local certified precast fabricators can be found at PCI Northeast's website located at: <http://www.pcine.org/content/members/index.cfm>. Also, the *PCI Bridge Design Manual, Vol. 1, Chapter 3, Section 3.5 Transportation*, provides further information on what a designer should consider when transporting a precast concrete member.

A list of certified structural steel fabricators can be found at the AISC website located at: <http://www.aisc.org/find/FindCertifiedCompany.aspx?id=5542>.

In addition, the project site shall be reviewed for adequate space for the contractor to mobilize the cranes and equipment necessary to hoist and place the girders. The reach and boom angle shall be checked and shall accommodate standard cranes.

2.6 Aesthetic Considerations

2.6.1 General Visual Impact

Bridges, retaining walls and sound walls have a strong visual impact in any landscape. Steps must be taken to assure that even the most basic structure will complement rather than detract from its surroundings. The Project Manager, Design Chief and Senior Project Engineer will review the aesthetic importance of the project site. For Context Sensitive Solutions projects, the early involvement with the community will include a process for input on aesthetics. The process for input on aesthetics can also come from Public Official/Public Informational Meetings, Regional Planning Committees, Natural and Cultural Resource Agencies and other agencies. Any use of aesthetics treatments on NHDOT bridge projects shall be approved by the Design Chief.

Aesthetics is a very subjective element that must be factored into the design process in the otherwise quantitative field of structural engineering. Generally, bridges that are well proportioned structurally use the least material possible are also aesthetically pleasing. However, details such as pier walls, columns, and crossbeams require special attention to ensure the structure will visually enhance its surroundings.

The following are additional resources for further information regarding bridge aesthetics:

- <https://www.dot.state.oh.us/policy/AestheticDesign/Documents/ODOTAesthetics.pdf>,
- http://www.wsdot.wa.gov/publications/fulltext/Bridge/Aesthetics_Sourcebook.pdf.
- <http://www.dot.state.mn.us/bridge/pdf/aestheticguidelinesforbridgedesign.pdf>
- Appendix 2.6-A1 through A3, NHDOT Bridge Aesthetic Details.

For large projects incorporating several bridges and retaining walls, an architectural theme is frequently developed to bring consistency in structure type, details, and architectural components. The Senior Project Engineer will notify the designer if an architectural theme is to be used.

2.6.2 Substructure, Soundwalls, & Slope Protection

A. Wingwalls

The size and exposure of the wingwall at the abutment shall balance, visually, with the depth and type of superstructure used.

It is less expensive for bridges greater than 40-ft. (12-m) in overall width to be designed with wingwalls (or curtain walls/retaining walls) than to use a longer superstructure.

B. Retaining Walls

For structures at sites where profile, right of way, and alignment restrictions dictate the use of high exposed wall-type abutments, retaining walls that flank the approach roadway can be used to retain the roadway fill and reduce the overall superstructure length. Stepped walls are often used to break up the height, and allow for landscape planting.

C. Slope Protection

The slope protection shall be compatible with the site and shall match what has been used at other bridges in the vicinity. The type selected shall be shown on the TS&L and Preliminary Plans.

D. Sound Walls

Approval by the Design Chief is required for a sound wall appearance, finish, materials or configuration that is different than the standard sound wall sheet.

2.6.3 Intermediate Piers

The size, shape, and spacing of the intermediate pier elements must satisfy two criteria: they must be correctly sized and detailed to efficiently handle the structural loads required by the design, and shaped to enhance the aesthetics of the structure.

The primary view of the pier must be considered. For structures that cross over another roadway, the primary view will be a section normal to the roadway. This may not always be the same view as shown on the Preliminary Plan as with a skewed structure, for example. This primary view shall be the focus of the aesthetic review.

Tapers and flares on columns shall be kept simple and structurally functional. Fabrication and constructability of the formwork of the pier must be kept in mind. Crossbeam ends shall be carefully reviewed. Skewed bridges, bridges with steep profile grades, or those in sharp vertical curves will require special attention to detail.

Column spacing shall not be so small as to create a cluttered look. Column spacing shall be proportioned to maintain a reasonable crossbeam span balance.

2.6.4 Abutment, Pier and Wall Surface Treatments

A. Plain Surface Finish

This finish will normally be used on structures that do not have a high degree of visibility or where existing conditions warrant. A bridge in a remote area or a bridge among several existing bridges all having a plain finish would be examples of this.

B. Concrete Form Liners

This finish is the most common and an easy way to add a decorative texture to a structure. Variations on this type of finish can be used for special cases. The specific areas to receive this finish shall be reviewed with the Design Chief and Senior Project Engineer.

If a cast-in place substructure is to match a MSE retaining wall, the note on the plans shall call for an SC Ashlar No. 1515 cut ashlar stone in random pattern form liner manufactured by Spec Formliners, Inc. or an approved equal that matches the MSE wall form liner. If there is no MSE wall to match, then the proposed concrete finish shall be reviewed with the Design Chief and Senior Project Engineer. It is preferred that the surface area that has a form liner, be shown on the plans with the form liner framed in with plain concrete 1.0-ft. [0.3-m] (min.) from the edges of the surface area or as needed to be aesthetically pleasing. Additional concrete cover is required due to the thickness of the form liner. See [Figure 2.6.4-1](#) and [Appendix 2.6-A1](#) for additional information regarding concrete form liners.

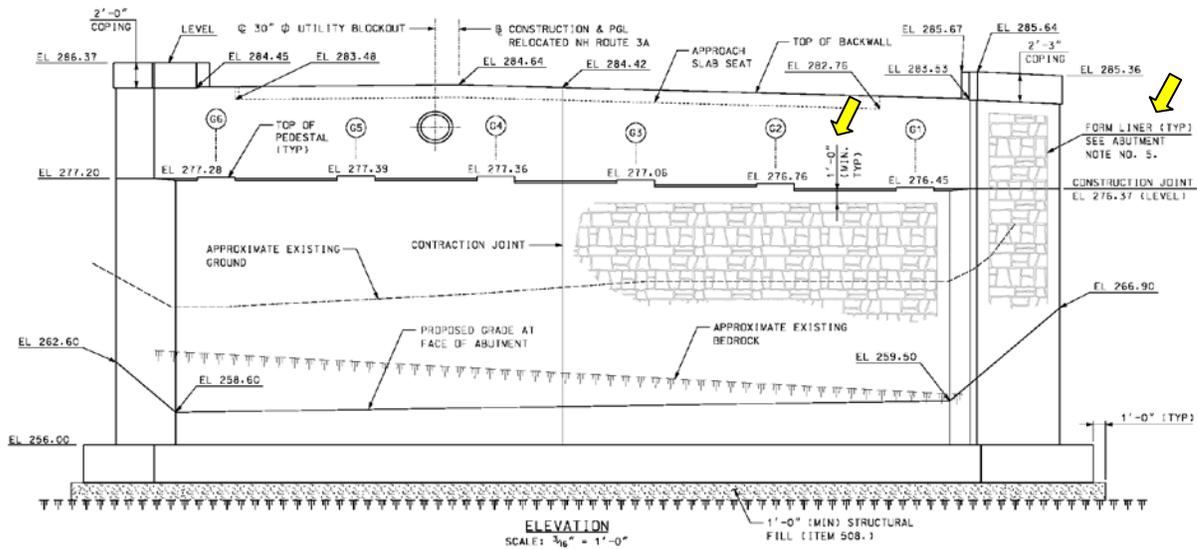
C. Pigmented Sealer

The use of a pigmented sealer can also be an aesthetic enhancement. The particular hue can be selected to blend with the surrounding terrain. NHDOT's typical colors are earth toned. Most commonly, this would be considered in urban areas. The selection shall be reviewed with the

Design Chief and Senior Project Engineer. The use of any type of concrete tinting requires the approval of the Design Chief. See [Appendix 2.6-A1](#) for additional information regarding pigmented sealer.

D. Architectural Details

Rustication grooves, relief panels, pilasters, and decorative finishes may visually improve appearance at transitions between different structure types such as cast-in-place abutments to structural earth retaining walls. The selection shall be reviewed with the Design Chief and Senior Project Engineer. Stone masonry facing may *only* be used on bridges over river crossings. Over time, the stone facing can separate from the concrete and fall off causing a danger to the public. See [Appendix 2.6-A1](#) for additional information regarding architectural details.



Example of Concrete Form Liner Shown on Abutment Elevation View

Figure 2.6.4-1

2.6.5 Superstructure

The horizontal elements of the bridge are perhaps the strongest features. The sizing of the structure depth based on the *AASHTO LRFD* span/depth ratios will generally produce a balanced relationship.

Haunches or rounding of girders at the piers can enhance the structure's appearance. The use of such features shall be kept within reason considering fabrication of materials and construction of formwork. The amount of haunch shall be carefully reviewed for overall balance from the primary viewing perspective. Haunches are not limited to cast-in-place structural steel superstructures, but may be used in special cases on precast, prestressed I girders. They require job-specific forms which increase cost, and standard design software is not directly applicable.

When using precast, prestressed girders, all spans shall be the same series, unless approved otherwise by the Design Chief.

When steel girders are to be painted, the color will be determined by the Design Chief. NHDOT's typical steel beam paint colors are brown or Dartmouth green.

All bridge railing shall meet the requirements as noted in Chapter 7, Section 7.6. See [Appendix 2.6-A2](#) for examples of aesthetic bridge railing.

2.7 Bridge Hydraulic Study

2.7.1 General

The NHDOT Bridge Design hydrology and hydraulics guidelines are prepared to supplement provisions of *AASHTO LRFD Bridge Design Specifications, Section 2, Article 2.6, Hydrology and Hydraulics*; *NHDOT Manual on Drainage Design for Highways*; the *AASHTO Highway Drainage Guidelines*; and the various *Hydraulic Engineering Circulars* and *Hydraulic Design Series* published by the Federal Highway Administration (See [Appendix 2.7-A1](#) for a list of the circulars). Unless otherwise specified, the design engineer should consult the most recent edition of these references for procedures and guidelines.

In addition to NHDOT policies and guidelines, the design of all bridges and culverts shall comply with all applicable Federal, State, local government and local flood control district statutes and regulations. The minimum requirements for a scour analysis are set by the FHWA Technical Advisory T5140.23, which requires that all bridges be designed to resist scour from a 100-year event and be checked against a 500-year event. A complete scour evaluation includes all piers and abutments in the channel migration zone. See Section 2.7.6, [Regulations](#) for the FHWA regulations and Section 2.7.7, [Stability Analysis and Countermeasures](#) for further information.

Bridge hydraulic studies are needed for the preparation of environmental documentation to evaluate the impacts of the proposed project on waterways and floodplains. Changes in water surface elevation, construction in channels, bridge construction methods, etc. commonly impact water resources. The identification of appropriate temporary and permanent stormwater quality best management practices may require input from the Environmental Manager.

Bridge hydraulic studies shall be completed as early as possible during the design phase of a project. Studies should be documented in accordance with the report format in [Appendix 2.7-A9 & A10](#). The degree of analysis and report documentation shall correspond with the complexity of the project; see [Section 2.7.2](#) for guidance. The hydrologic and hydraulic design shall be submitted to the Department (Consultant projects) or Design Chief (In-House projects) for approval prior to the Final Hydraulic Report submission.

2.7.2 Design Procedure

The design for a water crossing system requires a comprehensive engineering approach that includes formulation of alternatives, data collection, and selection of the most cost effective alternative. The following design steps outline is recommended for water crossings. See [Appendix 2.7-A2](#) for a flowchart of the design procedure.

- 1) Data Collection
 - A. Reconnaissance
 - B. Studies by Other Agencies
 - C. Environmental Impact
 - D. Design Criteria
- 2) Project Scope of Work
 - A. Level of Assessment
 - B. Hydraulic Analysis Method
 - C. Additional Survey Information

- 3) Hydrologic Analysis
 - A. Design Frequency
 - B. Tidal Conditions
 - C. Temporary Bridges
 - D. Deck Drainage
 - E. Hydrologic Methods
- 4) Hydraulic Analysis
 - A. Design Criteria
 - B. Hydraulic Design Factors
 - C. Design Procedures
- 5) Stability Analysis and Countermeasures
 - A. Scour Evaluation
 - B. Scour Countermeasures
 - C. Channel Protection
- 6) Documentation
 - A. Project records, calculations, etc.
 - B. Correspondence and Final Bridge Hydraulic Report

Required Documentation Levels:

The degree of analysis required for the hydrologic and hydraulic design will be determined by the Design Chief on a project-by-project basis and noted in the scope of work for Consultant projects. The following is a guide to determine the level of documentation that will be expected:

Level 1:

Projects that do not impact the substructure, lower the low chord elevation, or place material within the channel (temporarily or permanently), and have no history of flooding do not require any further hydrologic or hydraulic analysis. A brief summary to this effect along with existing hydraulic data shall be included in the Project File.

Level 2:

For projects with bridge spans less than 20-ft. (6-m) that involve enlarging the waterway opening and that are located on streams without FEMA base flood elevations, a single-section analysis as noted in [Section 2.7.6D](#) is sufficient unless there are other complicating factors (such as suspected backwater, complex geometry, or impoundments within the reach). A hydraulic design report documenting the change to the crossing shall be completed as noted in [Appendix 2.7-A9](#) and [A10](#).

Level 3:

For projects with bridge spans greater than 20-ft. that involve enlarging the waterway opening, crossing with a history of flooding, known or suspected backwater conditions, fill placed within the channel or FEMA floodway, or when there is a change in the type of conveyance, a full step-backwater hydraulic analysis (1-D model) such as HEC-RAS shall be performed. A hydraulic design report documenting the change to the crossing shall be completed as noted in [Appendix 2.7-A9](#) and [A10](#).

Level 4:

For projects that involve complex geometry (e.g., skews greater than 30 degrees, multiple embankment openings, multiple channels, multiple bridge openings), wide floodplains, large tidal

waterways, significant roadway overtopping, or upstream controls, a full step-backwater hydraulic analysis (2-D model) shall be performed per [Section 2.7.6E](#). A hydraulic design report documenting the change to the crossing shall be completed as noted in [Appendix 2.7-A9](#) and [A10](#).

2.7.3 Data Collection

The purpose of data collection is to gather all necessary site information. This shall include such information as topography and other physical features, land use and culture, flood data, basin characteristics, precipitation data, historic high-water marks, existing structures, channel characteristics, and environmental data. The effort necessary for data collection and compilation will be tailored to the specific project. Not all of the data noted in this chapter will be needed for every project. See [Appendix 2.7 – A3](#) for the Data Collection and Field Review Form.

A. Reconnaissance:

Data collection shall be as complete as possible during the initial field visit in order to avoid repeat visits. Thus, data needs must be identified and tailored to satisfy the requirements of the specific location and size of the project early in the project design phase.

Present and expected future land use should be defined and documented. Information on existing use and future trends may be obtained from:

- Aerial photographs
- Zoning maps and Master Plans
- USGS and other maps
- Municipal planning agencies
- Landsat (satellite) images
- District Office
- Highwater elevations, including the dates of occurrence.
- Rainfall and stream gage records
- Town residence
- Local Highway Department

A field inspection of the site and its contributing watershed should be undertaken as part of the hydraulic analysis and design.

Only after a thorough study of the area and a complete collection of all required information should the designer proceed with the design of the hydraulic facility. All pertinent data and facts gathered through the survey shall be documented.

B. Studies by Other Agencies:

The history of past floods and their effect on existing structures is of exceptional value in making flood hazard evaluation studies, as well as needed information for sizing structures. Information may be obtained from newspaper accounts, local residents, flood marks or other positive evidence of the height of historical floods. Changes in channel and watershed conditions since the occurrence of the flood shall be evaluated in relating historical floods to present conditions.

Recorded flood data is available from sources such as:

- Federal Emergency Management Agency (report shall be obtained if available)
- U.S. Army Corps of Engineers
- U.S. Geological Survey
- State libraries (Newspapers; Town, County, and State histories; historical accounts; etc.)

C. Environmental Impact:

The need for environmental data in the engineering analysis and design stems from the need to investigate and mitigate possible impacts due to specific design configurations. Wetlands are unique, and data needs can be identified through coordination with the Bureau of Environment, Cultural Resource and Natural Resource Agency, the U.S. Army Corps of Engineers, and U.S. Fish and Wildlife Service.

The Environmental Project Manager should be contacted to help define the environmental sensitivity of the facility's site relative to impacted surface waters or wetlands (e.g., water use, water quality and standards, aquatic and riparian wildlife biology, stream crossing guidelines, and wetlands information).

The need for and design of mitigation measures may be required—for example, fish characteristics (type, size, migratory habits), fish habitat (depth, cover, pool-riffle relationship), and water use and quality standards. Fish and fish habitat information is available from the Natural Resource Agency and the U.S. Fish and Wildlife Service.

D. Design Criteria:

A complete understanding of the physical nature of the natural channel or stream reach is of prime importance to a good hydraulic design—particularly at the site of interest. Any work being performed, proposed or completed, that changes the hydraulic efficiency of a stream reach, must be studied to determine its effect on the stream flow.

Geomorphological data is important in the analysis of channel stability and scour. Data needed includes:

- Scour history/evidence of scour. Scour potential is an important consideration relative to the stability of the structure over time. Scour potential will be determined by a combination of the stability of the natural materials at the facility site, tractive shear force exerted by the stream and sediment transport characteristics of the stream.
- Bed and bank material identification.
- Roughness coefficients, ordinarily in the form of Manning's "n" values, estimated for the entire flood limits of the stream. A tabulation of Manning's "n" values with descriptions of their applications can be found in [Appendix 2.7-A4](#).

2.7.4 Project Scope of Work**A. Level of Assessment:**

Scoping and reconnaissance are the investigative processes aimed at determining which issues are to be addressed by the project. Scoping initially identifies the major needs, issues, constraints, and feasibility of proposed improvements from which the more comprehensive, interdisciplinary preliminary engineering activities, surveys, investigations, environmental studies, and analysis can be effectively planned and budgeted. This includes the major elements of hydrologic and hydraulic work necessary to develop the project.

The scoping and reconnaissance effort should always include an appropriate assessment of the existing physical condition and the hydraulic performance of all drainage structures. The findings of the assessment will lead to recommendations as to whether existing structures should be replaced, rehabilitated, modified, abandoned, or left undisturbed.

B. Hydraulic Analysis Method:

The nature and scope of hydraulic analysis and design work varies depending on the type of project being undertaken and on the hydrologic/hydraulic (H&H) setting of the project. The degree of analysis and report documentation shall be commensurate with the complexity of the associated design. Prior to the hydraulic analysis, the Design Chief will direct the designer to what degree of analysis is required for the hydraulic design, on a project by project basis. See [Section 2.7.2](#), Required Documentation Levels.

C. Additional Survey Information:

Complete and accurate survey information is necessary to develop a design that will best serve the requirements of a site. The individual in charge of the survey needs to have a general knowledge of drainage design. The amount of survey data gathered shall be commensurate with the importance and cost of the proposed structure and the expected flood hazard.

The purpose of each survey is to obtain an accurate picture of the conditions within the zone of hydraulic influence of the facility. It is often much easier to interpret published sources of data (flood reports) after an on-site inspection.

The following data shall be obtained or verified:

- Contributing drainage area characteristics.
- Stream cross-section data that will represent typical conditions at the structure site as well as other locations where stage-discharge and related calculations will be necessary.
- Stream bed profile elevations for the site. This data should extend sufficiently upstream and downstream to determine the average slope and to encompass any proposed construction or aberrations. The required surveyed distance shall be coordinated with the Environmental Manager.
- Existing structures: The location, size, description, condition, observed flood stages, and channel section relative to existing structures on the stream reach and near the site shall be identified in order to determine their capacity and effect on the stream flow. Any structures, downstream or upstream, which may cause backwater or retard stream flow shall be investigated. Also, the manner in which existing structures have been functioning with regard to such things as scour, overtopping, debris and ice passage, fish passage, etc., shall be noted. For bridges, these data shall include span lengths, types of piers, and substructure orientation. The necessary culvert data includes other things such as size, inlet and outlet geometry, slope, end treatment, culvert material, and flow line profile. Photographs and highwater profiles or marks of flood events at the structure and past flood scour data can be valuable in assessing the hydraulic performance of the existing facility.
- Location and survey for development, existing structures, etc., that may affect the determination of allowable flood levels, capacity of proposed drainage facilities, or acceptable outlet velocities.
- Drift/debris characteristics. The quantity and size of debris and ice carried or available for transport by a stream during flood events shall be investigated and such data obtained for use in the design of structures. In addition, the times of occurrence of debris and ice in relation to the occurrence of flood peaks should be determined; and the effect of backwater from debris and ice jams on recorded flood heights should be considered in using stream flow records.
- General ecological information about the drainage area and adjacent lands.

2.7.5 Hydrologic Analysis

The first step in the design process is to determine the design discharge for the waterway. Hydrology is generally defined as a science dealing with the interrelationship between water on and under the earth and in the atmosphere. In the design of bridges, floods are usually considered in terms of peak runoff or discharge in cubic feet per second and hydrographs as discharge versus time. See [Appendix 2.7-A5](#) for hydrologic concept definitions.

Information required by the designer for analysis and design, includes not only the physical characteristics of the land and channel, but all the features that can affect the magnitude and frequency of the flood flow that will pass at the site under study. This data may include climatic characteristics, land runoff characteristics, stream gauging records, highwater marks, and the sizes and past performance of existing structures in the vicinity. The exact data required will depend on the methods used to estimate flood discharges, frequencies, and stages.

In the hydrologic analysis for a drainage structure, it must be recognized that there are many variable factors that affect floods. Some of the factors that need to be recognized and considered on a site-by-site basis include the following:

- Rainfall amount and storm distribution
- Drainage area size, shape and orientation
- Ground cover
- Type of soil
- Slopes of terrain and stream(s)
- Antecedent moisture condition
- Storage potential (overbank, ponds, wetlands, reservoirs, channel, etc.)
- Watershed development potential
- Type of precipitation (rain, snow, hail, or combinations thereof)
- Elevation

The type and source of information available for hydrologic analysis will vary from site to site, and it is the responsibility of the designer to determine what information is available and applicable to a particular analysis.

A. Design Frequency:

Because it is not economically feasible to design a structure for the maximum runoff a watershed is capable of producing, a design frequency must be established. The frequency with which a given flood can be expected to occur is the reciprocal of the probability or chance that the flood will be equaled or exceeded in a given year. If a flood has a 20 percent chance of being equaled or exceeded each year, over a long period of time, the flood will be equaled or exceeded on an average of once every five years. This is called the return period or recurrence interval (RI). Thus the exceedance probability equals $100/RI$.

The engineer must recognize that flood discharges for larger watercourses and rivers where the 100-year frequency must be used are the result of statistical analysis. When considering the 100 year flood discharges, for example, it is often misconstrued as a flood which happens once in a hundred years. In reality, it has a one percent chance of occurring in any one year. However, it can occur several times in any one year. The same reasoning applies to floods with other return periods.

Bridge structures are designed based on a particular flood frequency (peak flow rate). However, certain hydrologic procedures use rainfall and rainfall frequency as the basic input. Drainage systems involving detention storage, pumping stations, and large or complex storm sewer systems

require the development of a runoff hydrograph to estimate volume of runoff. Thus it is commonly assumed that the 10-year (10% exceedance probability) storm rainfall will produce the 10-year (10% exceedance probability) flood. This relationship may or may not hold true depending on antecedent soil moisture conditions and other hydrologic parameters.

Selection of the appropriate design flood frequency for structures is based on several factors, including class of highway, traffic volume, length of detour, and general importance of the bridge. When long highway routes have no practical detour, and are subject to independent flood events, it may be necessary to increase the design frequency at each site to avoid frequent route interruptions from floods. Consideration should be given to what frequency flood was used to design other structures along a highway corridor. While drainage structures are designed to operate for a given design frequency, performance should be checked for the review frequency (check flood). After sizing a drainage facility to pass a peak flood or the hydrograph corresponding to the design frequency, it may be necessary to review this proposed facility considering a larger discharge to insure that there are no unexpected flood hazards inherent in the proposed facility. Potential impacts to consider include possible flood damage due to high embankments where overtopping is not practical, backup due to the presence of noise walls, and flood damage where a storm drain might back up.

The purpose of the 500-year check flood (1% exceedance probability) for bridge structures is to ensure the safety of the structure and any downstream development by identifying any risk to life or property in the event of capacity exceedance. The intent is to investigate where the overflow travels, not to require the 500-year flood to pass through the structure. The investigation shall also include the assessment of tailwater. The effects of the 500-year check flood shall be documented in the Hydraulic Report. The report shall document all the effects and if the effects shall be remediated or why they cannot be remediated. Bridge importance as noted in Chapter 4, Section 4.2.2 Load Modifiers, shall also be considered if the 500-year check flood has impacts to the bridge and substructure. Discuss with the Bridge Design Chief if the 500-year flood impacts the structure with an importance modifier of 1.05.

Table [2.7.5-1](#) indicates the minimum design and check flood frequency for all new non-navigable waterway bridge structures. For design frequency of culverts (less than 10-ft. [3-m]), see NHDOT Manual on Drainage Design for Highways. See Table [2.4.2-1](#) for definition of the highway tiers and [Appendix 2.4-A4](#) the Statewide Corridor Maps.

DESIGN FREQUENCIES	
Project Location	Frequency
<p>Highway Tiers 1, 2, and 3:</p> <p>Bridges</p> <ul style="list-style-type: none"> • <i>Design</i> flood • <i>Check</i> flood for high flow damage, extreme limit state <p>Bridge Substructures:</p> <ul style="list-style-type: none"> • <i>Design</i> flood for scour • <i>Check</i> flood for scour, extreme limit state 	<p>100-year event 500-year event</p> <p>100-year event 500-year event</p>
<p>Highway Tiers 4 & 5:</p> <p>Bridges</p> <ul style="list-style-type: none"> • <i>Design</i> flood • <i>Check</i> flood for high flow damage, extreme limit state <p>Bridge Substructures:</p> <ul style="list-style-type: none"> • <i>Design</i> flood for scour • <i>Check</i> flood for scour, extreme limit state 	<p>50-year event 100-year event</p> <p>100-year event 500-year event</p>

Design Frequencies

Table 2.7.5-1

B. Tidal Conditions:

Unlike inland rivers where the design discharge is fixed by runoff and is virtually unaffected by the waterway provided, the size of the waterway opening of a tidal structure can modify the tidal regime and the associated tidal discharges.

Extreme events associated with riverine floods and tidal storm surges should be used to determine the hydraulic adequacy of a bridge. These events would have a return period based on the structure classifications. Difficulty arises in determining whether the storm surge, flood, or the combination of the storm surge and flood should be the controlling condition.

When inland flood discharges are small in relationship to the magnitude of the storm surge and are the result of the same event, then the flood discharge can be added to the discharge associated with the design tidal flow, or the volume of the runoff hydrograph can be added to the volume of the tidal prism. If the inland flood and the storm surge may result from different storm events, then a joint probability approach may be warranted to determine the magnitude of the design discharge.

In some cases there may be a lag time between the storm surge discharge and the stream flow discharge at the highway crossing. For this case, stream flow-routing methods such as the NRCS TR-20 and the USACOE HEC-HMS model can be used to estimate the timing of the flood hydrograph derived from runoff of the watershed(s) draining into the sound or estuary.

The selection of the method used to combine flood and tidal surge flows is a matter of judgment and must consider the characteristics of the site and the storm events.

The method and model used to analyze tidal conditions shall be approved by the Design Chief prior to the analysis.

C. Temporary Bridges:

The 10-year frequency flood event should generally be used as the design flood for temporary bridges/structures and fill that are in-place for less than or equal to 180 days. Temporary bridges/structures and fill that are in-place for greater than 180 days, shall be designed to not impact the 100-yr frequency flood event in accordance with FEMA Floodplain Regulations.

D. Deck Drainage:

Bridge decks should be watertight and all of the deck drainage should be carried to the ends of the bridge. Drains at bridge ends shall have sufficient capacity to carry all contributing runoff. Scuppers shall *not* be placed on a bridge unless a storm analysis performed using FHWA HEC-21, *Design of Bridge Deck Drainage* meets the criteria noted below. The design frequency of the deck drainage shall not be less than the storm frequency used for design of the pavement drainage system of the adjacent roadway (*AASHTO LRFD Section 2.6.6*). Any use of bridge scuppers requires the approval of the Design Chief.

Scuppers can only be placed on a bridge if the analysis indicates the following:

- Bridges with design speed < 45 mph (72 kph): The spread of deck drainage encroaches more than one-half the width of any designated traffic lane.
- Bridge with design speed \geq 45 mph (72 kph): The spread of deck drainage encroaches on any portion of the designated traffic lane.

E. Hydrologic Methods:

Estimating peak discharges of various recurrence intervals is one of the most common engineering challenges faced by drainage facility designers. The problem can be divided into two general categories: (1) Gage sites are at or near a gauging station with a streamflow record of sufficient length to provide estimates of peak discharge; (2) Ungaged sites are not near a gauging station and no streamflow record is available.

NHDOT Bridge Design practice is to use the discharge that best reflects local project conditions with the reasons documented. The applicability of each accepted methodology is outlined below. See Tables [2.7.5-2](#) & [2.7.5-3](#) for a summary of the methods.

1) Estimating Hydrologic Data:

The following methods are preferred by NHDOT Bridge Design for estimating hydrologic data (analysis):

Gaged Sites:

a) Stream Gage Data:

- The U.S. Geological Survey (USGS) maintains a network of stream gauging stations throughout New Hampshire. Peak flow rates for various return frequencies can be developed from long-term periods of observation and statistical analysis of the resultant data. *This data shall be used wherever possible in the design of hydraulic facilities.*
- A complete record is defined as one having at least 20-years of continuous or synthesized data for 100-yr. discharge or 15-yrs. of continuous data for 50-yr. discharge.

- USGS developed a program called, StreamStats for NH that shows the location of data-collection stations (gage stations). The program can be found at: http://water.usgs.gov/osw/streamstats/new_hampshire.html
- Additional information regarding StreamStats for NH and its limitations is noted in [Appendix 2.7-A6](#).

Ungaged Sites:

If streamflow measurements for determining a flood frequency relationship at a site are unavailable, it is accepted practice to estimate peak runoff rates and hydrographs using statistical or empirical methods. Currently, good engineering practice relies on formulas and models for estimating hydraulic flows based on statistical analyses of rainfall and runoff records, providing statistical estimates of flows with varying degrees of error.

Many hydrologic methods are available. In general, the following shall be followed unless approved otherwise by the Design Chief:

- The use of only one method is not acceptable. Results shall be calculated using one of the preferred methods for analysis and two of the accepted methods for checking, as outlined below. The results shall be compared, not averaged.
 - If the hydrologic data from the check method is not within the percent error of the method used for the analysis, the designer shall submit the proposed method of hydrologic analysis along with explanations, to the Design Chief for approval.
 - If the site is located in a floodplain delineated by Federal Emergency Management Agency (FEMA), then the peak discharge computed by FEMA shall be used as one of the check methods.
 - If the project data falls outside the limitations of the methods listed below, the Design Chief shall be notified to determine what other options are available.
- a) USGS program, StreamStats for NH:
- The StreamStats outputs the uncertainty of the estimates for ungaged basins when basin characteristics for the selected site is within the range of basin characteristics for streamgages that were used to develop the regression equations. Errors for basins with basin characteristics that are beyond these bounds are unknown. The applicable range of each basin characteristic is provided in the outputs, and messages are provided when basin characteristics are outside the applicable range.
 - Additional information regarding StreamStats for NH and its limitations is noted in [Appendix 2.7-A6](#).
- b) Natural Resources Conservation Service (NRCS) (SCS) Unit Hydrograph Method:
- TR-20
 - 24-hr. rainfall distribution
 - The method computes a runoff hydrograph, which shows how runoff varies with time; from that, the peak flow, time of peak, and corresponding volume can be found.
 - Additional information can be found in the *NHDOT Manual on Drainage Design for Highways*.

2) Checking Hydrologic Data:

The following methods are accepted by NHDOT Bridge Design for checking the hydrologic data against one of the methods previously noted for estimating flows:

a) Flood Insurance and Floodplain Studies:

- Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS and maps).
 - NH GRANIT Flood Insurance Study. This site is considered NH's "official" DFIRM repository and allows users to view the original FEMA flood maps in pdf as well as access other flood information specific to NH. This site also contains the flood insurance studies themselves as well as other backup information. The flood insurance studies are available at: <http://www.granit.unh.edu/dfirms/index.html>
 - New Hampshire GRANITView II web mapping application is available at : <http://www.granit.unh.edu/data/onlinemapservices/mapservicesoverview.html> This is a web based GIS application which allows you to view FEMA's flood insurance rate maps and overlay other GIS data layers such as water resources, roads, conservation lands, aerial photography, topography, etc. all on the same map
 - FIS reports and maps for NH can be found on the FEMA web site at: <https://msc.fema.gov/portal>. Hit on "Search All Products" to download the FIS reports.
- USGS Flood Reports
 - Open file reports by the USGS have been developed, and in some cases, are available for download at: <http://water.usgs.gov/floods/reports/index.html>

b) Runoff Estimates for Small Rural Watersheds and Development of a Sound Method

- FHWA Report No. FHWA-RD-77-159, 1977.
- Additional information can be found in the *NHDOT Manual on Drainage Design for Highways*.

c) New England Hill and Lowlands (NEHL) and Adirondack White Mountains (AWM) Method

- Additional information can be found in the *NHDOT Manual on Drainage Design for Highways*.

d) Index Flood Method:

- See Table [2.7.5-3](#) for a summary of the method.

In addition to the procedures noted above, numerous proprietary software packages are available for hydrologic design. The hydraulic engineer should obtain approval from the Design Chief for the use of programs not specifically listed prior to their application in Department designs. The designer is referred to the Federal Highway Administration document entitled *Hydraulic Design Series No. 2, "Highway Hydrology," Second Edition (FHWA-NHI-02-001, October 2002)* for more detailed information on hydrologic methods. Note, the Rational Method shall only be used for small pipes or culverts (span < 10-ft. [3-m]). It shall not be used for design of bridges or culverts (span ≥ 10-ft. [3-m]).

METHODS FOR DETERMINING RUNOFF RATES/VOLUMES	
Preferred Methods for <i>Analysis</i>:	
Methods	Description/Limitations
USGS <i>StreamStats</i> for NH (gaged sites)	<ul style="list-style-type: none"> • Stream Gage Data • 20-years of continuous or synthesized data for 100-yr discharge • Peak discharges affected by dam failure, ice-jam breach, or a similar event are not included in the frequency analyses.
USGS <i>StreamStats</i> for NH (ungaged sites)	<ul style="list-style-type: none"> • Regression Equations • <i>StreamStats</i> takes flood characteristics from gaged to ungaged sites through use of watershed characteristics. • The regression equations are applicable only to sites on ungaged, unregulated streams in rural New Hampshire basins. • 0.7 sq. miles < Drainage Area ≤ 1290 sq. miles • 0% ≤ Wetlands ≤ 21.8% • 2.79 in. ≤ Basinwide mean of the average April precipitation ≤ 6.23 in. • 5.43 ft/mi ≤ Main Channel Slope ≤ 543 ft/mi
<i>Natural Resources Conservation Service (NRCS) (SCS) Unit Hydrograph Method</i>	<ul style="list-style-type: none"> • <i>TR-20</i> • <i>Intended for smaller watersheds</i> • <i>1 acre ≤ Total Drainage Area ≤ 300 sq. miles</i> • <i>1 acre ≤ sub-watershed area ≤ 20 sq. miles</i> • <i>Recommended when there is significant storage in the watershed</i> • <i>0.005 ≤ Manning “n” ≤ 1.00</i> • <i>100 ft. maximum length of sheet flow</i> • <i>30 ≤ Curve Number ≤ 100</i>

Methods for Determining Runoff Rates/Volumes

Table 2.7.5-2

METHODS FOR CHECKING RUNOFF RATES/VOLUMES	
Accepted Methods for <i>Check</i> :	
Methods	Description/Limitations
Flood Insurance Studies	<ul style="list-style-type: none"> • Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) <ul style="list-style-type: none"> ○ If the site is located in a floodplain delineated by FEMA, then the peak discharge computed by FEMA shall be used as one of the check methods. ○ These reports may have outdated datums and outdated information that was used to develop the study. • USGS Flood Reports
Runoff Estimates for Small Rural Watersheds and Development of a Sound Method	<ul style="list-style-type: none"> • FHWA Report No. FHWA-RD-77-159, 1977. • 5 and 7 Parameter Method (regression equations) • Intended for a drainage area < 50 sq.-mi. • Use for drainage area < 100 sq.-mi. • May contain outdated information that was used to develop the variables for the equations. • Used as a replacement for Potter's Method
New England Hill and Lowlands (NEHL) and Adirondack White Mountains (AWM) Method	<ul style="list-style-type: none"> • Use when the drainage area is between 1 sq.-mi. and 1,000 sq.-mi. • Uses figures dated 1960 (outdated information). • Storage can be estimated • Rainfall Index between 1.5 and 2 inches.
Index Flood Method	<ul style="list-style-type: none"> • Mean annual floods may vary throughout region • Homogeneity is established at the 10-yr level • Used as a check or where other methods are not applicable.

Methods for Checking Runoff Rates/Volumes

Table 2.7.5-3

2.7.6 Hydraulic Analysis

The next step in the design process involves selection of preliminary design alternatives that are judged to meet the site conditions and to accommodate the flood flows selected for analysis. The hydraulic analysis of a channel determines the depth and velocity at which a given discharge will flow in a channel of known geometry, roughness and slope. The depth and velocity of flow are necessary for the design or analysis of water crossings. The hydraulic analysis is performed utilizing appropriate formulas, physical models or computer programs for the purpose of defining, calibrating and checking the performance of the preliminary designs over a range of flows.

Bridge design for stream crossings requires analysis of the hydraulic characteristics for both the “existing conditions” and the “proposed conditions” of the project site. It is important at this stage of the design to develop water surface models with structures that are hydraulically adequate and models that consider the environmental permit requirements as related to fish passage, floodplain management and stream channel encroachment. A thorough hydraulic analysis is essential to providing a properly sized, safe, and economical bridge design and assessing the relative impact that the proposed bridge has on the floodplain.

Bridge hydraulic studies shall be completed as early as possible during the alternatives analysis of a project. The scour analysis shall be performed once boring and preliminary design information is available. The degree of analysis and report documentation shall correspond with the complexity of the associated design; see [Section 2.7.2](#) for guidance.

The hydrologic and hydraulic design shall be submitted to the Department (Consultant projects) or Design Chief (In-House projects) for approval, prior to the Final Hydraulic Report submission. All hydrologic and hydraulic studies shall be documented in accordance with the Final Hydraulic Design Report (see [Appendix 2.7-A9 & A10](#)).

A. NHDOT Design Criteria:

The following are the *AASHTO* general criteria related to the hydraulic analysis for the location and design of bridges as stated in the *Highway Drainage Guidelines* and NHDOT design criteria:

- Backwater will not significantly increase flood damage to property upstream of the crossing.
- Velocities through the structure(s) will neither damage the highway facility nor increase damages to adjacent property.
- Existing flow distribution maintained to the extent practicable.
- Pier spacing and orientation, and abutment designed to minimize flow disruption and potential scour.
- Foundation and/or scour countermeasures designed to avoid failure by scour.
- Freeboard at structure(s) designed to pass anticipated debris and ice.
- Acceptable risks of damage or viable measures to counter the vagaries of alluvial streams.
- Minimal disruption of ecosystems and values unique to the floodplain and stream.
- Level of traffic service compatible with that commonly expected for the class of highway and projected traffic volumes is provided.

1) Freeboard:

Freeboard is defined as the vertical distance between the low chord elevation of the bridge superstructure and the design flood elevation.

The design flood elevation shall be the *greater* of the following, projected onto the upstream face of the bridge (BU, Figure [2.7.6-1](#)):

- Water surface elevation measured at cross section 3. Normally located at the toe of the upstream road embankment. This cross section should **not** be placed immediately upstream of the bridge deck. See Figure [2.7.6-1](#) and *HEC-RAS Reference Manual* for additional information.
- Water surface elevation measured at cross section 4. Normally an upstream cross section where the flow lines are approximately parallel and the cross section is fully effective. The cross section shall be located a distance upstream of Section 3 equal to approximately one (1) [contraction ratio] times the length of the average embankment constriction. See Figure [2.7.6-1](#) and *HEC-RAS Reference Manual* for additional information.

The purpose of freeboard is to provide adequate clearance for passage of debris and ice during high flows and to reduce the potential of superstructure submergence. Debris and ice jams can create horizontal and buoyant forces on the bridge superstructure and can reduce the bridge waterway opening resulting in increased velocity, scour, and upstream flood levels.

The vertical distance between the low chord elevation and the governing water surface elevation (freeboard) shall be a minimum of 1-ft. (0.3-m), unless determined otherwise by the Design Chief, depending if the bridge has a history of debris and/or ice. If 1-ft. (0.3-m) freeboard cannot be met and there is no history of debris and/or ice, the Design Chief may revise the method of measuring the freeboard (e.g., hydraulic depth instead of water surface elevation) or decrease the freeboard measurement.

A girder superstructure may be susceptible to damage when ice and/or debris is a significant problem. Girder structures are susceptible to damage associated with buoyancy and lateral hydrostatic forces. In situations where the superstructure may be inundated during major flood events, it is recommended that the girders be anchored, tied, or blocked so they cannot be pushed or lifted off the substructure units by hydraulic forces. In addition, air vents near the top of the girder webs can allow entrapped air to escape and thus may reduce buoyancy forces.

2) Regulations:

A detailed hydraulic analysis is required for all bridge and culvert projects to ensure that the completed construction will satisfy the highway objectives and all flows which are naturally tributary to the site are considered in the design and are passed downstream by the structure. As it becomes necessary to replace existing structures, the design must consider legal increases in flow resulting from watershed development that has occurred since the existing structure was built.

In addition to NHDOT policies and guidelines, the design of all bridges and culverts shall comply with all applicable Federal, State, local government and local flood control districts statutes and regulations. See Chapter 3, Section 3.3 for information regarding permitting.

a) FHWA Compliance:

- Degradation or aggradation of the river should be estimated and contraction and local scour determined. The foundation shall be positioned below the total scour depth if practicable.
- The minimum requirements for a scour analysis are set by the *FHWA Technical Advisory T5140.23*, which requires that all bridges be designed to resist scour from a

100-year event and be checked against a 500-year event. A complete scour evaluation includes all piers and abutments in the channel migration zone.

- The FHWA document *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, located at <http://www.fhwa.dot.gov/bridge/nbi.cfm>, shall be used by the bridge designer to categorize the scour vulnerability of the bridge. For a proposed bridge, if any of the following NBIS items have a rating of 7 or lower, the designer will need to reanalyze the stream crossing until each of the items has a rating of 8 or 9. If the bridge is a rehabilitation project, coordinate with the Existing Bridge Section on what FHWA regulation shall be met.
 - Item 113: Rating Scour Critical Bridges
 - Item 71: Waterway Adequacy
 - Item 61: Channel and Channel Protection
- See Section [Conduct Scour Evaluation](#) for further information on scour evaluation.

b) FEMA Floodplain Compliance:

- The final design should not significantly alter the flow distribution in the floodplain.
- For FEMA Zones determined by Approximate Methods, it is allowable to increase the flood elevations up to 1.0-ft. provided that coordination with the community shows that the cumulative impact requirements have been addressed. If an increase in the 100-yr. flood level will cause adverse impact, then no increase shall be permitted.
- For FEMA Zones determined by Detailed Methods, it is not allowable to increase the 100-yr. flood elevation.
- If a “no rise” condition cannot be obtained when encroaching upon a regulatory floodway, the designer may need to apply to FEMA for revisions to the FIS by means of a Conditional Letter of Map Revision (CLOMR).
- FEMA current Flood Insurance Studies (FIS) can be found at: [Flood Insurance Studies](#)

B. Hydraulic Design Factors:

Several hydraulic factors dictate the design of both the bridge and the approach roadway within the floodplain limits of the project site. The critical hydraulic factors for design consideration are:

1) Bridge Skew:

When a roadway is at an angle (skew) to the stream or floodway, the bridge shall also be at a skew to the roadway with the abutments and piers parallel to the flow of the stream. The hydraulic section through the bridge shall be the section normal to the flow of the stream. Improper skew can greatly aggravate the magnitude of scour.

2) Backwater and High-water Elevation:

Roadways and bridges are generally restrictions to the normal flow of floodwaters and increase the flood profile in most situations. The increase in the flood profile is referred to as backwater and the resultant upstream water surface elevation is referred to as the High-Water (HW) Elevation.

The high-water elevation or backwater calculations at the bridge are directly related to the bridge size and roadway alignment. A significant design consideration when computing backwater is the potential for increasing flood damage for upstream property owners.

Backwater increases should conform to FEMA regulations for sites covered by the National Flood Insurance Program (NFIP).

Changes to existing road profile grades on bridge replacement projects also need careful consideration. The designer should ensure that raising profile grades in areas with a history of roadway overtopping does not negatively impact adjacent property owners.

One very subtle backwater criteria is the backwater produced for flood events less than the 100-year frequency flood. Design consideration should be given to the more frequent flood events when there is potential for increasing the extent and frequency of flood damage upstream.

3) Roadway Overflow:

The vertical alignment of the approach grade is a critical factor in the bridge design when roadway overflow is a design consideration. The two important design features of roadway overflow are overtopping velocity and overtopping frequency. See Section 2.7.6, [Roadway Overflow](#).

4) Velocity:

Velocity through the bridge opening is a major design factor. Velocity relates to the scour potential in the bridge opening and the development of scour areas adjacent to the bridge. Examination of the “existing conditions” model, existing site conditions, soil conditions, and flooding history will give good insight into acceptable design velocity.

While some bridge openings may have a relatively uniform velocity across the entire bridge opening, in most instances there are wide variations in the velocity profile. In some segments of the flow (e.g., near the center of the stream), the velocity may be considerably higher than the average velocity. In areas of shallow flow, the velocity may be quite low. The velocity profile may even include negative velocities (reverse flows).

5) Channel Protection:

Channel erosion is a natural process in which the stream adjusts to changing conditions within its channel and watershed. The main factors contributing to channel erosion are the velocity of water, angle of attack, soil type, lack of vegetation, and changes in land use. See Section 2.7.7, [Channel Protection](#) for further information,

6) Scour:

Bridge scour is erosion around a bridge pier or abutment caused by the river or stream. If this type of damage is not prevented or repaired, it could cause catastrophic failure of the bridge.

Reasonable and prudent hydraulic analysis of a bridge design requires that an assessment be made of the proposed bridge's vulnerability to undermining due to potential scour. Because of the extreme hazard and economic hardships posed by a rapid bridge collapse, special considerations must be given to selecting appropriate flood magnitudes for use in the analysis. The hydraulic engineer must endeavor to always be aware of and use the most current scour forecasting technology. See Section 2.7.6, [Regulations](#) and Section 2.7.7, [Conduct Scour Evaluation](#) for further information regarding scour analysis.

C. Select Hydraulic Method:

Two methods are commonly used in hydraulic analysis of open channels: (a) the single-section method is a simple application of Manning's equation to analyze situations in which uniform or nearly uniform flow conditions exist. Manning's equation can be used to estimate highwater elevations for bridges that do not constrict the flow; (b) the step-backwater method is used to

compute the complete water surface profile in a stream reach to evaluate the unrestricted water surface elevations for bridge hydraulic design, or to analyze other gradually-varied flow problems in streams.

D. Single-Section Analysis:

The single-section analysis method (slope-area method) is simply a solution of Manning's equation for the normal depth of flow given the discharge and cross section properties including geometry, slope and roughness. It implicitly assumes the existence of steady, uniform flow. There are several published sources on open channel hydraulics that contain tables for selecting appropriate “n” values. See [Appendix 2.7-A4](#) for tables of the Manning coefficient, “n”.

In stream channels the transverse variation of velocity in any cross section is a function of subsection geometry and roughness and may vary considerably from one stage and discharge to another. It is important to know this variation for purposes of designing erosion control measures and locating relief openings in highway fills, for example. The best method of establishing transverse velocity variations is by current meter measurements. If this is not possible, the single-section method can be used by dividing the cross section into subsections of relatively uniform roughness and geometry. It is assumed that the energy grade line slope is the same across the cross section so that the total conveyance K_t of the cross section is the sum of the subsection conveyances. The total discharge is then $K_t S^{1/2}$ and the discharge in each subsection is proportional to its conveyance. The velocity in each subsection is obtained from the continuity equation, $V = Q/A$.

Alluvial channels present a more difficult problem in establishing stage-discharge relations by the single-section method because the bed itself is deformable and may generate bed forms such as ripples and dunes in lower regime flows. These bed forms are highly variable with the addition of form resistance, and selection of a value of Manning's “n” is not straightforward. Instead, several methods outlined in (Vanoni, 1977) have been developed for this case (Einstein-Barbarossa; Kennedy-Alam-Lovera; and Engelund) and should be followed unless it is possible to obtain a measured stage-discharge relation.

There may be locations where a stage-discharge relationship has already been measured in a channel. These usually exist at gauging stations on streams monitored by the USGS. Measured stage-discharge curves will generally yield more accurate estimates of water surface elevation and should take precedence over the analytical methods described above.

E. Step-Backwater Analysis:

Step-backwater analysis is useful for determining unrestricted water surface profiles where a highway crossing is planned, and for analyzing how far upstream the water surface elevations are affected by a bridge. Because the calculations involved in this analysis are tedious and repetitive, it is recommended that a computer program be used.

There are several public and private computer software programs available for modeling open channel and bridge hydraulics using step-backwater analysis. The preferred program for NHDOT bridge design work is the public domain computer software program *HEC-RAS, River Analysis System* by the Army of Corps of Engineers (ACOE).

The *HEC-RAS* program is currently the most widely used methodology for floodplain and bridge hydraulic modeling. The Corps of Engineers Hydrologic Engineering Center (HEC) has developed the *HEC-RAS, River Analysis System* program package. It operates under *WINDOWS* and has full graphic support. The package includes all the features inherent to *HEC-2* and *WSPRO Plus* program selected friction slope methods, mixed flow regime capability, automatic “n” value calibration, ice cover, quasi 2-D velocity distribution, superelevation around bends,

bank erosion, riprap design, stable channel design, sediment transport calculations and scour at bridges. In addition to momentum balance, other methods are available in HEC-RAS for computing losses through bridges. These methods include the Energy Equation (standard step method), Yarnell equation, and FHWA WSPRO method. The HEC-RAS program and supporting documentation can be downloaded from the U.S. Army Corps of Engineers web site: <http://www.hec.usace.army.mil/software/hec-ras/>.

If there are site-specific criteria such as upstream storage, which is a limitation for the use of HEC-RAS, a different hydraulic program that addresses this situation should be used. The designer should read the HEC-RAS design manual to confirm that it is the right program for the site.

1) Develop HEC-RAS Hydraulic Model:

First, a hydraulic model shall be developed for the existing conditions at the bridge site. This shall become the basis for hydraulic design of proposed conditions for the project and allows for an assessment of the relative hydraulic changes associated with the proposed structure. Special attention should be given to historic high-water and flood history, evidence of scour (high velocity), roadway overtopping, existing high-water. For guidance on developing models compatible with existing Flood Insurance Study (FIS) profiles, see [Appendix 2.7-A7](#).

- Existing Design Condition Model:

Use the most recent survey and detailed bridge data to create or update any natural ground cross sections at the locations necessary to subsequently model any proposed construction. Any new model should extend sufficiently downstream and upstream of the crossing to adequately evaluate the conditions. This is typically at least 1000-ft. (305-m) in both directions. This model then becomes the basis for measurement of any changes that would take place as a result of the proposed construction.

- Proposed Design Condition Model:

Once the Existing Design Condition Model has been calibrated, the hydraulic model will be modified to include all proposed construction.

2) Determine HEC-RAS Hydraulic Stream Slope:

The primary method of determining the hydraulic slope of a stream is surveying the water surface elevation through a reach of stream distance upstream and downstream to the site. This distance will be as directed by the Environmental Project Manager or as required for design. Intermediate points through this reach should also be surveyed to detect any significant slope variation. The survey must take into account the presence of any existing control structures that may affect the hydraulic model. It is customary that cross-section stations decrease in the direction of flow. It is also important to note that unlike roadway stationing conventions, left and right within a channel cross-section are defined by looking in the direction of decreasing stations (downstream).

There are situations, particularly on flat stream profiles, where it is difficult to determine a realistic slope using survey data. This will occur at normal water surface elevation at the mouth of a stream, upstream of a dam, or other significant restrictions in the stream. In this case a USGS 7-1/2" quadrangle map and existing flood studies of the stream can be investigated to determine a reasonable stream slope.

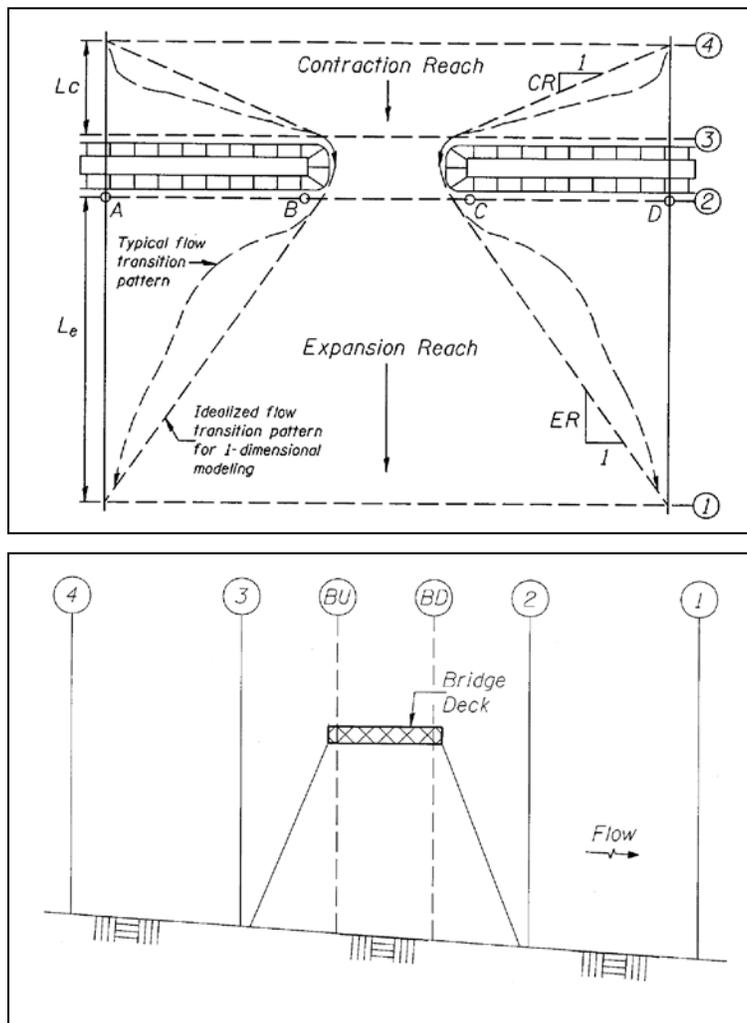
3) Select HEC-RAS Floodplain Cross-Sections:

Generally, a minimum of four (4) floodplain valley cross-sections are required to perform the hydraulic analysis of a bridge. The sections shall be normal to the stream flow at flood stage

and located as required per the hydraulic program. A detailed cross-section of one or both faces of the bridge will also be required. If the section is skewed to the flow, the horizontal stationing shall be adjusted using the cosine of the skew angle. See Figure 2.7.6-1 for a cross-section layout.

Additional cross-sections should be included on both the upstream and downstream side of the model. The most downstream cross-section in the model should be located far enough from the bridge to avoid user entered boundary conditions from effecting the hydraulic computations through the bridge.

Cross-sections taken from contour maps are acceptable when the information is supplemented with field survey sections and data. Additional sections may be required to develop a proper hydraulic model for the site. The hydraulic cross-sections should use ineffective flow areas to account for slack water portions of the flood plain or portions not contributing to the downstream movement of water.



**HEC-RAS
Cross-Section
Layout for Bridge
Modeling**

Figure 2.7.6-1

4) Assign Manning “n” Values to Sections:

Manning “n” values are assigned to the cross-section sub-areas. Generally, the main channel will have different “Manning n” values than the overbank areas. Values are chosen by on-site

inspection, pictures taken at the section, and use of aerial photos defining the extent of each “n” value. There are several published sources on open channel hydraulics that contain tables for selecting appropriate “n” values. See [Appendix 2.7-A4](#) for tables of the Manning coefficient, “n”.

5) Running HEC-RAS Hydraulic Model:

There are a number of important features of a steady state (constant flow) hydraulic model for a roadway stream crossing. They include the natural adjacent floodplain, subject structure, any supplemental structures, and the roadway. Accurate modeling and calculations are needed to account for all potential conveyance mechanisms. Generally, most modern step backwater methodologies can incorporate all of the above elements in the evaluation of hydraulic characteristics of the project site.

a) Bridge Hydraulics:

The losses associated with flow through bridges depend on the hydraulic conditions of low or high flow.

Low flow is a hydraulic condition in which the water surface throughout the approach, bridge, and exit cross sections provides freeboard (i.e., water surface does not impinge upon the superstructure). This condition should exist for the design of all new bridges.

Low flow is divided into the following Low Flow Classes:

- Type I: Subcritical flow (Froude No. < 1) throughout the approach, bridge, and exit cross sections. This is the most common condition encountered in practice.
- Type IIA and IIB: Subcritical approach flows that have been choked by the contraction resulting in the occurrence of critical depth in the bridge opening. In Type IIA the critical water surface elevation in the bridge opening is lower than the undisturbed normal water surface elevation. In the Type IIB it is higher than the normal water surface elevation and a weak hydraulic jump immediately downstream of the bridge contraction is possible.
- Type III: Supercritical (Froude No. > 1) approach flow that remains supercritical through the bridge contraction. Such a flow condition is not subject to backwater unless it chokes and forces the occurrence of a hydraulic jump upstream of the contraction.

High flow refers to three possible conditions in which the water surface impinges on the bridge superstructure:

- The tailwater does not submerge the lowchord of the bridge; the flow condition is comparable to a pressure flow sluice gate.
- The tailwater submerges the lowchord but does not exceed the elevation of critical depth over the road; the flow condition is comparable to orifice flow.
- The tailwater overtops the roadway; neither sluice gate flow nor orifice flow is reasonable, and the flow is either weir flow or open flow.

b) Roadway Overflow:

It is not allowable for the design flow to impinge on the bridge low chord or to inundate the roadway because it violates the definition of design frequency. However, flows exceeding the design flood may inundate the structure and roadway. Unless the route is an emergency escape route, it is often desirable to allow floods in excess of the design flood to overtop the road. This helps minimize both the backwater and the required length

of structure. This will also reduce the probability of submergence of the bridge and help to reduce the potential for scour at the bridge.

Hydraulically, the complete bridge profile includes any part of the structure that stream flow can strike or impact in its movement downstream. If the stream rises high enough to inundate the structure, then the bridge and all parts of the roadway become the complete bridge profile.

It is sometimes necessary to compute flow over highway embankments in combination with flow through structure openings. Most automated methodologies will incorporate the division of flow through a structure and over the road in determination of the solution. The WSPRO methodology will conduct the “combined flow” solution and internally determine and adjust the coefficient of discharge for both the structure and roadway weir section. Other methodologies rely on user defined coefficients for both the structure and roadway flow solutions.

2.7.7 Stability Analysis and Countermeasures

A. Conduct Scour Evaluation:

Since any bridge placed within a waterway can be vulnerable to scour, an analysis is required for all new and existing bridges, to determine the necessary protective measures. The minimum requirements for a scour analysis are set by the FHWA Technical Advisory T5140.23, which requires that all bridges be designed to resist scour from a 100-year event and be checked against a 500-year event. A complete scour evaluation includes all piers and abutments.

Every effort shall be made to minimize the effects of scour, such as, placing piers outside the waterway, aligning piers to the direction of flow, and using round piers or columns.

Observations based on historic information or current site conditions provide the most positive indication of erosion potential. Channel movement or bank instability may be identified using any of the following resources: aerial photographs, old maps, survey notes, bridge design files, river survey data, gauging station records, or interviews with long-time residents. Past aerial photos can be examined to determine an approximate rate of erosion. Historic USGS maps of New Hampshire can be found at: <http://docs.unh.edu/nhtopos/NewHampshire.htm>.

A scour analysis shall be performed in accordance with FHWA's Hydraulic Engineering Circular No. 18 (HEC-18), *Evaluating Scour At Bridges*; HEC-20, *Stream Stability at Highway Structures*; and HEC-23 *Bridge Scour and Steam Instability Countermeasures, Experience, Selection & Design*. The analysis shall be performed as stated in the FHWA Technical Advisory T5140.23, *Evaluating Scour at Bridges*: “Every bridge over a waterway, whether existing or under design, should be evaluated as to its vulnerability to scour in order to determine the prudent measures to be taken for its protection.” (See [Appendix 2.7-A8](#) for the full FHWA Technical Advisory T5140.23)

If the project is a rehabilitation of an existing bridge, the designer should check to see if a scour analysis has been performed by the Bureau of Bridge Design, Existing Bridge Section. If no analysis has been performed, then the designer needs to perform a scour analysis for the existing bridge.

There are three main components of total scour at a bridge site. They are Long-term Aggradation and Degradation, Contraction Scour, and Local Scour. In addition, lateral migration of the stream must be assessed when evaluating total scour at substructure units. Contraction and local scour

will be evaluated in the context of clear-water and live bed scour conditions. See Section 2.7.6, [Regulations](#) for information regarding compliance with FHWA.

Current equations and methods used to estimate the magnitude of abutment scour were developed in a laboratory under ideal conditions and lack adequate field verification. These equations may tend to overestimate the magnitude of scour. These equations should be incorporated with a great deal of discretion.

The scour analysis should include all calculations, computer runs, and information used to complete the analysis, as well as a conclusive summary. A copy of the scour analysis should be filed both in the project design folder and with the bridge rating.

The analysis shall include a summary table containing the following information:

- a. Recommended NBIS Item 113 Rating (Scour Critical Bridges)
- b. Recommended NBIS Item 71 Rating (Waterway Adequacy)
- c. Recommended NBIS Item 61 Rating (Channel and Channel Protection)
- d. Scour Risk Designation (Low Risk, Scour Susceptible or Scour Critical)
- e. Depth of Potential Scour (Provide the range of values computed for the various flood events analyzed)
- f. Foundation Type (Known/Unknown)
- g. Recommendation(s) (e.g., Monitor, Install Countermeasures or Design Foundation for Predicted Scour)

B. Scour Countermeasures:

A “countermeasure” is defined as a measure incorporated into a stream crossing to control, inhibit, change, delay, or minimize stream and bridge stability problems. Countermeasures may be installed at the time of highway construction or used as a retrofit to resolve stability problems at existing crossings.

The selection of an appropriate countermeasure for a specific bank erosion problem depends on factors such as the erosion mechanism, stream characteristics, construction and maintenance requirements, potential for vandalism, and costs. However, effectiveness in resolving the erosion or scour problem is perhaps the most important factor to consider.

The functions of countermeasures installed at or near a structure are to correct, prevent, or control the causes and resulting effects of scour or channel degradation. In many situations, more than one countermeasure may be suitable for use in dealing with a particular scour problem. The following items should be considered in determining what type of countermeasure to use:

1. The function the countermeasure is required to perform – corrective, preventive, or controlling.
2. Relative costs of different countermeasures.
3. Amount of damage a countermeasure is expected or able to sustain and still perform its intended function.
4. Any unwanted effects, such as inducing new or additional scour at another location which may occur as a result of installing the countermeasure.
5. The type and frequency of maintenance problems that are associated with a particular countermeasure.

New construction shall integrate features into the design to minimize the potential for scour. Possible scour problems listed below are best addressed by the following countermeasures:

1. Bank stabilization and meander migration: bank revetments, spurs, bendway weirs, longitudinal dikes, vane dikes, bulkheads, and channel relocations.
2. Channel braiding and anabranching: dikes, guide banks at bridge abutments, revetments on highway fill slopes, and spurs to constrict flow to one channel
3. Stream degradation: check dams, drop structures, cutoff walls, drop flumes, longitudinal rock toe-dikes to provide toe protection of steepening banks, and deeper bridge foundations.
4. Stream aggradation: channelization, debris basins, bridge modification, and maintenance through dredging of deposited material.
5. Contraction scour at bridges: longer bridges, relief bridges within the floodplain, superstructures at elevation above flood stage of extreme events, crest vertical profile on approach roadways for overtopping, elevation of bridge low beam, piers located outside of main channel, revetment on channel banks and slopewalls, and spurs and guide banks on upstream side.
6. Local scour at bridges: (1) Abutments: deep foundations, foundations in rock, revetments and riprap, and guide banks at abutments. (2) Piers: deep foundations, foundations in rock, pier shape and orientation to flow, webwalls to eliminate debris collection between columns, riprap, partially grouted riprap, geotextile sand containers, and sheet piling.

A Plan of Action (POA), which can include timely installation of scour countermeasures, should be developed for each scour critical bridge. The goal of the POA is to provide guidance for inspectors and engineers that can be implemented before, during, and after flood events to protect the traveling public. It documents what monitoring or countermeasure installation should be done and how frequently. If the bridge is to be monitored, the POA notes at what frequency or water surface elevation the monitoring should start, and identifies the critical elevation at each substructure. POAs are site-specific and are developed for each bridge considered scour critical.

Hydraulic Engineering Circular 18 (HEC-18), *Evaluating Scour at Bridges* and HEC-23 *Bridge Scour and Stream Instability Countermeasures* contain details of management strategies for developing a POA for a scour critical bridge, selecting countermeasures, countermeasure design concepts, scour monitoring techniques, and countermeasure performance case histories.

C. Channel Protection:

Riprap protection against scour damage shall be provided in the design of all bridge piers and abutments within the flood plain unless directed otherwise by the Design Chief. Embankment slopes adjacent to structures subject to erosion shall also be adequately protected.

Channel protection shall be designed in accordance with Hydraulic Engineering Circular HEC-23, *Bridge Scour and Stream Instability Countermeasures* (<http://www.fhwa.dot.gov/engineering/hydraulics/scourtech/counter.cfm>), and NCHRP Report 568 *Riprap Design Criteria* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_568.pdf).

Riprap consists of a layer of rock, placed in the channel and structure boundaries in a manner which produces a well-graded mass that will limit the effects of erosion. It is the most common type of countermeasure due to its general availability, ease of installation, and relatively low cost. Riprap is a very effective countermeasure when the riprapped area is of adequate size (length, width, and depth), it is of suitable gradation, and the correct installation procedures are followed. The designer may specify a minimum d_{50} (median stone diameter) for the rock comprising the riprap, which indicates the size for which 50% of the particles are smaller. See Figure [2.7.7-1](#) for a typical channel section.

The designer shall determine the required d_{50} and depth of riprap in accordance to FHWA HEC-23, Vol. 1 & 2 publication. The specific gravity (weighted average) of processed aggregates from quarries across the state is 2.69, which results in a density of 168 lb/cf (2.69 tonnes/m³).

NHDOT Standard Specifications provide the following riprap item:

- Item 583, Riprap
 - Riprap shall be quarry stone of approved quality, hard, durable, subangular to angular in shape, resistant to weathering and free from structural defects such as weak seams and cracks.
 - Riprap is required for erosion protection of bridge structures in waterways, for active waterway channel slopes and bottoms, and for intermittent waterway channels where the Engineer determines riprap protection is required to resist expected high water flow velocities or volumes.
 - The designer shall specify a minimum d_{50} (median stone diameter) for the rock comprising the riprap to correspond with standard classes as noted in the Table 1 of the Specification 583 and FHWA HEC-23 publication.

Item 583.1 Riprap, Class I

Item 583.3 Riprap, Class III

Item 583.5 Riprap, Class V

Item 583.5 Riprap, Class VII

Item 583.9 Riprap, Class IX

Item 585.X, Stone Fill, Class X shall only be used for highway work such as roadway slope protection and at drainage outlets. *This item is no longer used for channel protection.*

For new or replacement bridges, the pier shall be designed with the foundations and piling designed for expected scour depths. Riprap shall be installed around the pier to provide a secondary scour countermeasure for new or replacement bridges and a scour countermeasure for rehabilitation bridges. Installation of the riprap shall not be heaped in a pile but be placed with the top at or below the elevation of the streambed to minimize maintenance and the need to replace stones washed downstream.

Use the flow velocity just upstream of the pier but outside the influence of the pier, including the constriction caused by the bridge, for pier riprap design. If the channel average velocity is used, then it should be increased to account for velocity variation within the channel. Often the maximum velocity in the channel is used for design purposes to account for channel shifting. Apply a velocity adjustment of 1.7 for square piers and 1.5 for circular piers to account for flow acceleration and added turbulence around the pier, as well as the horseshoe vortex that forms at the base of the pier.

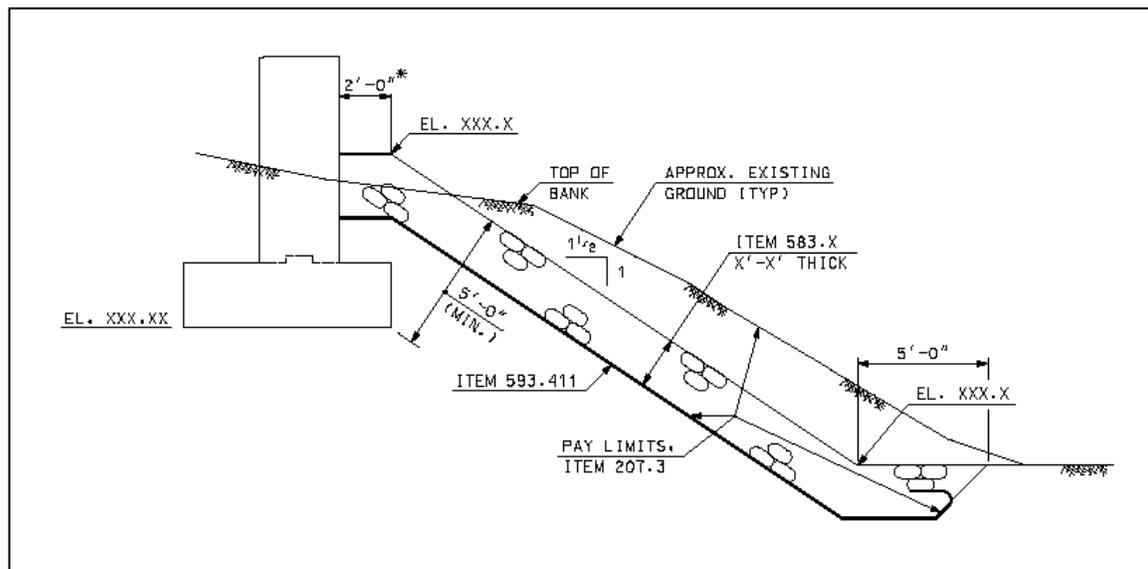
Although there is not a specific adjustment factor for the velocity used for abutment riprap sizing, obtaining an accurate estimate of the flow velocity is not a trivial matter. The set-back ratio (SBR) method for estimating flow velocity at the abutment accounts for flow conditions upstream of the bridge and the proximity of the abutment to the channel bank. The SBR method is well suited for estimating velocity at an abutment if the estimated velocity does not exceed the maximum velocity in the channel.

Ice and debris can create additional stresses on riprap by impact and flow concentration. In addition, ice attachment to riprap particles can cause displacement. A study by USACE's Cold Regions Research Engineering Laboratory (CRREL) (Sodhi et al., 1996) suggests that the predominant mode of ice damage to riprap on slopes takes place during pileup events. As the incoming ice sheet is forced against the slope, it is driven between the riprap and the previously

piled up ice. In doing so, the ice sheet forces rocks from the bottom to the surface of the ice pile. The CRREL recommends that the d_{100} of the riprap be at least twice the ice thickness for mild slopes (shallower than 3H:1V) and about three times the ice thickness for steeper slopes to counteract this effect.

Bank protection for abutments shall be provided up to the elevation of the design flow condition. Provide a 2-ft. minimum (0.6-m) wide top shelf on the slopes in front of the abutments. If directed by the Design Chief and feasible, a 5-ft. (1.5-m) wide shelf at the top of the slopes shall be provided in front of the abutments for future inspection access.

The bridge plans shall include details showing the stone riprap layout, the shelf location and width, proposed top and toe of slope elevations and cross-sections along the channel. The slopes are typically 2H:1V but shall not exceed 1.5H:1V. Geotextile shall be placed under all riprap as directed by the Geotechnical Engineer. See Figure 2.7.7-1 for a typical channel section.



Typical NHDOT Channel Protection Section

Figure 2.7.7-1

* Use 2-ft. (0.6-m) minimum top shelf width unless directed otherwise by the Design Chief, to provide provisions for inspection access.

2.7.8 Final Hydraulic Report & Contract Drawings

Once the hydrologic and hydraulic design, has been approved by the Department (Consultant projects) or the Design Chief (In-House projects), a Final Hydraulic Report stamped by a P.E., shall be completed for water crossings. This report shall be a finalization of the hydrologic and hydraulic study, including the scour countermeasures and channel protection designs. It should contain all calculations and computer runs, including design flow (Q), flood elevations, waterway opening, span length, channel protection, angle of crossing, and all other data required to complete the Preliminary Plan. See Appendix 2.7-A9 & A10 for information that should be included in the submission. Once completed, the Final Hydraulic Report should be filed in the project design folder.

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 so that recurring damage can be avoided.

The hydraulic report is intended to serve as a complete documented record containing the engineering justification for all drainage modifications that occur as a result of the project. The primary use of a hydraulic report is to facilitate review of the design and to assist in the preparation of the PS&E documents. The writer should approach the hydraulic report from the position of its defense in a court of law. It should be clearly written and show conditions before and after construction. The documentation should include all material used in selecting the design, including notes and observations made from the site inspection. The documentation should also include the results of studies of alternatives and reasons for rejecting alternatives. For smaller watershed areas, the degree of report documentation shall be commensurate with the complexity of the associated hydraulic design.

As a minimum the following hydraulic information shall be provided on the bridge General and Elevation plan in the contract drawings, as applicable (see Appendix 3.3-B1 for a sample plan):

- Drainage area
- Design storm
- Design flow discharge
- Waterway opening and clearance (vertical and horizontal)
- Water surface elevations (design flood and ordinary high water [OHW])
- Design tidal elevations (mean high tide, mean high water, mean low water, mean low low water)
- Design velocities
- Anticipated depth of maximum scour due to the 100-year and 500-year storm events

See Tables [2.7.8-1](#) & [2.7.8-2](#) for the hydraulic data table that should be placed on the bridge General Plan.

HYDRAULIC DATA	
Drainage Area:	xx sq. mi.
Design Flood Discharge (xx yr):	xx cfs
Design Flood Elevation (xx yr):	xx feet
Design Flood Velocity (xx yr):	xx fps
Scour Check Discharge (500 yr):	xx cfs
Anticipated Depth of Scour (100 yr):	<i>Indicate location and depth xx feet</i>
Anticipated Depth of Scour (500 yr):	<i>Indicate location and depth xx feet</i>
Bridge Full Waterway Opening \perp to River:	xx sq. ft.

**Hydraulic Data Table for Bridge General Plan
(Freshwater Structures)**

Figure 2.7.8-1

HYDRAULIC DATA	
Mean Low Water (MLW):	xx feet
Mean High Water (MHW):	xx feet
High Tide Line (1-yr. Tide)	xx feet
10-yr. Tide	xx feet
100-yr. Tide	xx feet
Design Frequency/Event*	Tidal: xx yr/event*
Design Discharge:	xx cfs
Design Water Surface Elevation (Ebb Direction):	xx feet
Design Water Surface Elevation (Flood Direction):	xx feet
Anticipated Depth of Scour (xx yr/event*):	<i>Indicate location and depth xx feet</i>
Scour Discharge (xx yr/event*):	xx cfs
Bridge Full Waterway Opening \perp to River:	xx sq. ft.

* Event means other occurrence such as average daily flow, mean high water, mean low water, etc.

**Hydraulic Data Table for Bridge General Plan
(Tidal Structures)**

Figure 2.7.8-2

2.8 Type Size and Location (TS&L)

2.8.1 General

To determine the preferred structural alternative, the designer shall:

- 1) Develop a list of all feasible alternatives. At this stage, the range of alternatives shall be kept wide open. Brainstorming with supervisors and other engineers can provide new and innovative solutions.
- 2) Eliminate the least desirable alternatives by applying the constraints of the project. Question and document the assumptions of any restrictions and constraints. There shall be no more than four alternatives at the end of this step.
- 3) Perform preliminary design calculations for unusual or unique structural problems to verify that the remaining alternatives are feasible.
- 4) Compare the advantages, disadvantages, and costs of the remaining alternatives to determine the preferred alternative(s).

2.8.2 TS&L Outline

The TS&L report shall describe the project and the proposed structure, and give reasons why the bridge type, size, and location were selected. For a TS&L checklist, see [Appendix 2.8-A1](#).

- 1) Cover, Title Sheet, and Index/Table of Contents

These shall identify the project, owner, location, and the contents of the TS&L.

- 2) Photographs

There shall be enough color photographs to provide the look and feel of the bridge site. The prints shall be labeled.

- 3) Introduction

The introduction describes the report, references, and other reports used to prepare the TS&L study. The following reports shall be listed, if used:

- Design Reports and Supplements
- Environmental Reports
- Architectural Visual Assessment or Corridor Theme Reports
- Hydraulic Report
- Geotechnical Reports

- 4) Project Description

The TS&L report clearly defines the project. A vicinity map shall be shown. Care shall be taken to describe the project adequately but briefly. The project description summarizes the preferred alternative for the project design.

- 5) Design Criteria

The design criteria should identify the *AASHTO LRFD Bridge Design Specifications* and *AASHTO Guide Specifications* that will be used for the bridge design. Sometimes other design criteria or special loadings are used. These criteria shall be listed in the TS&L. Some examples in this category might be the temperature loading used for segmental bridges or areas defined as wetlands.

6) Structural Studies

The structural studies section documents how the proposed structure Type, Size, and Location were determined. The following considerations shall be addressed.

- Aesthetics
- Cost Estimates
- Geometric constraints
- Project staging and Stage Construction Requirements
- Foundations
- Hydraulics
- Feasibility of construction
- Structural constraints
- Maintenance
- Roadway Issues
- Environment Constraints
- Utilities
- Right-of-Way

This section shall describe how each of these factors leads to the preferred alternative. Show how each constraint eliminated or supported the preferred alternatives. Here are some examples. “Prestressed concrete girders could not be used because environmental restrictions required that no permanent piers could be placed in the river. This requires a 200-ft. (61 m) clear span.” “Restrictions on falsework placement forced the use of self-supporting precast concrete or steel girders.”

7) Executive Summary

The executive summary shall be able to “stand alone” as a separate document. The project and structure descriptions shall be given. Show the recommended alternative(s) with costs and include a summary of considerations used to select preferred alternatives or to eliminate other alternatives.

8) Drawings

TS&L plan of the recommended alternative are included in an appendix. The drawings show the plan, profile, and typical section. For projects where alternative designs are specified as recommended alternatives, TS&L drawings for each of the different structure types shall be included. Supplemental drawings showing special features, such as complex piers, are often included to clearly define the project.

2.8.3 TS&L for Bridge Rehabilitation Projects

The designer shall review the as-built plans, load ratings, and existing inspection reports, and schedule a site visit. Special inspection of certain portions of the structure may be included in the site visit or scheduled later with the Bridge Inspectors. The purpose of the inspections is to obtain more detailed information about the bridge’s condition; the designer will use this information to obtain dimensions and take photographs of details needed for the project scope.

Following the site visit, the following items shall be considered:

- What is the load capacity of the existing bridge?
- What type of rehabilitation work is needed and what time frame is required to accomplish the work?

- Are there any special construction staging requirements? Can the bridge be totally shut down for the rehabilitation period? How many lanes will need to be open? Can the work be accomplished during night closures or weekend closures?

Develop various alternatives and cost estimates for comparison, ranging from “do nothing” to “complete replacement”.

- Determine what the remaining life expectancies are for the various rehabilitation alternatives.
- Determine the cost of a new replacement bridge.

Page intentionally left blank.

2.9 TS&L Estimate

2.9.1 Cost Estimating Guidelines – Bridge Replacement

An estimated cost of the proposed bridge can be determined using the Slope-Intercept Method noted below. See [Appendix 2.9-A1](#) for an explanation of slope-intercept dimensions; [Appendix 2.9-A2](#) for Slope-Intercept Costs per Square Foot of projects grouped by bridge type and project type, and [Appendix 2.9-A3](#) for Bridge Type Abbreviations.

The Slope-Intercept Method is a conceptual method used for estimating costs at the TS&L stage only. Other estimating methods may be required if the project is unique, complicated or alternative bridge types are presented.

Slope-Intercept Method Formula:

Bridge Cost = [(Bridge Length for Estimating) x (Bridge width) x (Estimated Square Foot or square meter) Cost] + (Additive Costs).

- Bridge Length for Estimating (see [Appendix 2.9-A1](#)):

For Overpasses:

$$L = \text{SPAN} + \left[\frac{(2 \times \text{slope}) \times \overbrace{(\text{finished grade overpass to finished grade underpass})}^{\text{Slope Intercept Height, H}}}{\text{cosine}(\text{skew})} \right]$$

For Stream Crossings:

$$L = \text{SPAN} + \left[\frac{(2 \times \text{slope}) \times \overbrace{(\text{finished grade overpass to top of stone elev. at face of abut.})}^{\text{Slope Intercept Height, H}}}{\text{cosine}(\text{skew})} \right]$$

Slope value examples = 1.5 for 1.5:1 slope, 2 for 2:1 slope

SPAN = c. to c. of bearings measured along centerline of construction.

skew angle = angle formed between a line perpendicular to the centerline of roadway and the centerline of abutment.

- Bridge Width for Estimating:
 - Face to face of rail plus any pedestrian requirements for one or two sidewalks. (Sidewalks normally 6'-0" [1.8 m] wide.)
- Slope-Intercept Cost per Square Foot:
 - [Appendix 2.9-A2](#) shows a list of NHDOT projects' costs per square foot calculated by using the total of bridge items bid costs as the "Bridge Cost" (*excluding* the items unique to the project [see Chapter 1, Section 1.4] and the items listed below as "additive costs") and backing the number into the slope-intercept method formula noted above.

- The slope-intercept costs per square foot listed in [Appendix 2.9-A2](#) are a *starting point* and include many variables such as date of bid, type of project, difficulty of project, etc. It is *not* a total bridge cost.
- Below are some *additional costs* for a TS&L estimate that must be *considered* since they are *excluded* from the slope-intercept cost/sf. The estimator shall also be aware, and make note in the field, of unusual costs that might occur during construction and add these costs to the slope-intercept cost. This might be items due to such things as unusual channel work requirements, a historic bridge, a historic site, archeological considerations, bridge removal, cofferdams, a temporary bridge, bridge painting, or other items unique to the project. Adjustments in square foot (square meter) cost shall also be made for other complications such as skew, difficult access, rapid construction, etc. For stage construction add 20-25% to slope-intercept cost.
 - Additive Costs for Estimating:
 - Bridge Removal: Shall be based on past experience from similar projects. (adjust cost to suit actual field conditions).
 - Cofferdam: Shall be based on past experience from similar projects.
 - Temporary Bridge: Based on past experience of similar projects.
 - Preliminary Engineering: Determine total bridge and roadway costs. Contact the Design Chief for estimate costs.
 - Construction Engineering: Determine total bridge and roadway costs. Contact the Design Chief for estimate costs.
 - Inspection and Incentives: See Chapter 1, Section 1.4.4, “Develop PS&E Estimate” for guidelines; for estimating inspection services for structural steel, precast concrete, and painting, as well as incentives for QC/QA concrete. Contact the Design Chief for estimate costs.
 - Right of Way: Estimate \$25,000 minimum (unless it is a rehabilitation with no involvement by right-of-way) and add estimated property acquisitions and easements. The Bureau that initiates the project determines these estimated costs.

2.9.2 Cost Estimating Guidelines – Roadway Construction

When Bridge Design is responsible for the minimal roadway construction (approach) work to a bridge project, the estimated costs for work shall be based on past experience of similar projects.

2.10 Boring Request

2.10.1 Boring Request

After approval of the bridge TS&L by the Bridge Design Administrator, Commissioner's Office, and Hearing (if applicable), a boring request shall be prepared and submitted to both the Bureau of Materials and Research and the Design Services Section in the Bureau of Highway Design.

1) Boring Request Submittal to *Materials and Research* shall include the following:

- Plan of proposed boring request location for bridge/structure. Also include proposed boring request location for any detour bridge if required. The proposed boring request location plan shall be placed on the 11x17 NHDOT border and include the following (see Appendix 2.10-B1 for a sample plan):
 - Title box with town name, bridge number, bridge location, drafter, and date.
 - Site plan showing the existing contours at the proposed structure location, outline of existing and proposed substructure, and existing detail.
 - Requested boring locations (identified by number [numbers shall increase from left to right as the observer faces the structure up-station, except for Abutment A]).
 - A minimum of three (3) borings per abutment are recommended with one boring on centerline of bearing and one at the end of each wing.
 - Maximum recommended spacing of abutment borings is 50-ft. (15 m).
 - Two (2) borings per pier are recommended.
 - A chart showing the coordinates of the proposed boring locations (station and offsets are required for contract plans).
 - North arrow
 - Proposed CL alignment and any proposed detour alignment if required.
 - Labels on all roads and water crossings.
 - Plan drawn at a scale of 1"=20' (1:250)
 - Benchmark description and elevation if known.
- Additional plan (11x17) of proposed boring locations *without* the boring locations plotted, for the use of the Bureau of Materials and Research.
- Profile at proposed structure/detour locations and any available cross sections.
- Any available existing bridge or roadway plans or information (previous test boring information).
- Hydraulic data for water crossings.
- Location map of project
- Transmittal letter ([S:\Bridge-Design\FORMS\PROJECT\BoringRequest1.doc](#)) (Appendix 2.10-A1)

2) Boring Request Submittal to *Design Services* shall include the following:

- Email *Survey Supervisor, Survey Section, Bureau of Highway Design* and CC: *Senior Supervisor, Design Services, Bureau of Highway Design*. The email shall include the following:

- Table of the boring locations including coordinates (same as shown on the boring request location plan), name and number of the project, and a note that the paper copy request has been sent to the Chief of Design Services.
- Plan of boring layout that was sent to Materials and Research.
- Location map of project.
- Survey request slip form. (<S:\Bridge-Design\Forms\Project\survey-request-slip.doc>)

The survey request slip requests the Survey Section to stake the boring locations. No completion date needs to be filled out on the slip. Note on the slip that the Survey Section shall contact Materials and Research prior to staking the borings.
- Transmittal letter to *Chief of Design Services, Bureau of Highway Design* (<S:\Bridge-Design\FORMS\PROJECT\BoringReq2.doc>) ([Appendix 2.10-A2](#)). The letter shall include the following:
 - Plan of boring layout that was sent to Materials and Research
 - Location map of project.
 - Survey request slip form. (<S:\Bridge-Design\Forms\Project\survey-request-slip.doc>)

The survey request slip requests the Survey Section to stake the boring locations. No completion date needs to be filled out on the slip. Note on the slip that the Survey Section shall contact Materials and Research prior to staking the borings.

2.10.2 Check of Boring Logs

Upon receipt of the boring logs, a check shall be made between the ground elevations shown on the borings and the survey plan. The ground elevations shall be verified from the survey notes located in the survey book (the survey book shall be routed to Bridge Design once the survey is completed).

2.11 Survey Request

2.11.1 Survey Request

Survey will be requested for the project by the lead Bureau (Highway Design or Bridge Design) from the Survey Office of the Design Services Section of the Bureau of Highway Design. The request needs to show the limits of survey for the project.

For bridges crossing hydraulic channels, the request shall include a river grid for as much of the channel as will be necessary to perform the hydraulic design (generally 200-ft. [61 m] upstream and 200-ft. [61 m] downstream from the bridge). If backwater and scour calculations are anticipated, the request should include adequate distance up and down the waterway to obtain sufficient data. The Environmental Coordinator shall be contacted to ensure the survey request includes all information needed for the environmental documentation and Wetland Permit.

The topographical datum changed in 1988. The survey supervisor shall be contacted to determine whether the survey will use the 1929 or 1988 datum. If existing bridge plans dated prior to 1988 are used, then a request shall be made to obtain common benchmark elevations to confirm the differences in the change of datums. Also, there may be plans *after* 1988 that may still use the 1929 datum. Therefore, a request shall be made to obtain common bench mark elevations. The datum shall be noted on the plans.

- Send an email or two (2) paper copies of the following to:
Survey Supervisor, Survey Section, Bureau of Highway Design (See survey supervisor map for which supervisor has that location.)
S:\Bridge-Design\FORMS\PROJECT\survey_supervisor_areas.pdf
 - Plan showing the limit of survey
 - Request for topographical and existing detail and river grid (river sections) if the project involves a water crossing, with the limits of each noted (existing detail will give details of the bridge, topographical data will provide contours from changes in the terrain.)
 - Location map
 - Survey request slip
<S:\Bridge-Design\FORMS\Project\survey-request-slip.doc>
- CC: *Survey Engineer Technician, Bureau of Highway Design*
 - The Engineer Technician keeps track of all survey work.
- CC: *Chief of Design Services, Bureau of Highway Design*
 - The Chief of Design Services will request a list of property owners in the project area from the Bureau of Right-of-Way; the Survey Section will notify the owners prior to beginning their work.
- CC: *Plan Prep Supervisor, Bureau of Highway Design*
 - Plan prep will process the survey into CADD.
- Put one (1) paper copy of plan and survey request slip in the Project Folder.

Page intentionally left blank.

References

1. American Association of State Highway and Transportation Officials (AASHTO), *AASHTO LRFD Bridge Design Specifications, 7th Ed., 2014*, Washington, D.C.
2. American Association of State Highway and Transportation Officials (AASHTO), *Standard Specifications for Highway Bridges, 17th Ed., 2002*, Washington, D.C.
3. American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide, 4th Ed., 2011*, Washington, D.C.
4. American Railway Engineering and Maintenance Association (AREMA) *Manual for Railroad Engineering*. Note: This manual is used as the basic design and geometric criteria by all railroads. Use these criteria unless superseded by FHWA or NHDOT criteria.
5. Arizona Department of Transportation, *Bridge Hydraulics*. Retrieved from <http://www.azdot.gov/business/engineering-and-construction/bridge/guidelines>
6. Chow, V. T., ed. 1959, *Open Channel Hydraulics*, New York, McGraw Hill.
7. Connecticut Department of Transportation, *2000 Drainage Manual*. Retrieved from <http://www.ct.gov/dot/cwp/view.asp?a=3200&q=260116&dotPNavCtr=#40139>
8. Cowan, W.L., 1956, *Estimating Hydraulic Roughness Coefficients: Agricultural Engineering*
9. Federal Emergency Management Agency (FEMA), *Current Flood Insurance Studies (FIS)*. Retrieved from <https://msc.fema.gov/portal>
10. Federal Highway Administration (FHWA), USDOT, *National Bridge Inspection Standards (NBIS)*. Retrieved from <http://www.fhwa.dot.gov/bridge/nbis.htm>
11. Federal Highway Administration (FHWA), USDOT, *Hydraulics Engineering*. Retrieved from <http://www.fhwa.dot.gov/engineering/hydraulics/>
12. Federal Highway Administration (FHWA), USDOT, *Hydraulics Engineering-Current Publications*. Retrieved from http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm
13. Federal Highway Administration (FHWA), USDOT, *Hydraulic Design Series No. 4, Introduction to Highway Hydraulics, Pub. No. FHWA-NHI-08-090*, June 2008. Retrieved from http://www.fhwa.dot.gov/engineering/hydraulics/pubs/08090/HDS4_608.pdf
14. Federal Highway Administration (FHWA), *Recording and Coding Guide for the Structure Inventory and Appraisal for the Nation's Bridges*, Report No. FHWA-PD-96-001, December 1995. Retrieved from <http://www.fhwa.dot.gov/bridge/nbi.cfm>
15. Illinois Department of Transportation, *IDOT Drainage Manual*. Retrieved from <http://www.dot.state.il.us/bridges/brmanuals.html>
16. Iowa Department of Transportation, *LRFD Design Manual*. Retrieved from <http://www.iowadot.gov/bridge/manuallrfd.htm>

17. Maine Department of Transportation, *Bridge Design Guide*. Retrieved from <http://www.maine.gov/mdot/technicalpubs/bdg.htm>
18. Minnesota Department of Transportation, *Aesthetic Guidelines for Bridge Design*. Retrieved from <http://www.dot.state.mn.us/bridge/pdf/aestheticguidelinesforbridgedesign.pdf>
19. Minnesota Department of Transportation, *LRFD Bridge Design Manual*. Retrieved from <http://www.dot.state.mn.us/bridge/lrfd.html>
20. Minnesota Department of Transportation *Drainage Manual*. Retrieved from <http://www.dot.state.mn.us/bridge/hydraulics/drainagemanual.html>
21. New Hampshire Department of Transportation Bureau of Bridge Design, *Bridge Design Manual, October 1, 2000*, Concord, NH
22. New Hampshire Department of Transportation Bureau of Highway Design, *Highway Design Manual, 2007, Vol. 1*, Concord, NH. Retrieved from <http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/designmanual/index.htm>
23. New Hampshire Department of Transportation, *NHDOT Standard Specifications for Road and Bridge Construction 2010*, Concord, NH. Retrieved from <http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/specifications/index.htm>
24. New Hampshire Department of Transportation Bureau of Highway Design, *NHDOT Manual on Drainage Design*. Retrieved from <http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents.htm>
25. New Hampshire GRANIT, *NH Statewide GIS Clearinghouse*. Retrieved from <http://www.granit.unh.edu/data/onlinemapservices/mapservicesoverview.html>
26. Ohio Department of Transportation, *Aesthetic Design*. Retrieved from <https://www.dot.state.oh.us/policy/AestheticDesign/Documents/ODOTAesthetics.pdf>
27. Precast/Prestressed Concrete Institute, *PCI Bridge Design Manual*, Chicago, IL.
28. Rhode Island Department of Transportation, *LRFD Bridge Design Manual*. Retrieved from <http://www.tmc.dot.ri.gov/business/contractorsandconsultants.php>
29. South Dakota Department of Transportation, *Drainage Manual*. Retrieved from <http://sddot.com/business/design/forms/drainage/Default.aspx>
30. State of New Hampshire, *New Hampshire Revised Statutes Annotated (RSAs)*. Retrieved from <http://www.gencourt.state.nh.us/rsa/html/indexes/default.html#DISCLAIMER>
31. Tennessee Department of Transportation, *Design Procedures for Hydraulic Structures*. Retrieved from http://www.tdot.state.tn.us/chief_engineer/assistant_engineer_design/structures/hydraulic.htm

32. Texas Department of Transportation, *Hydraulic Design Manual*.
Retrieved from <http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm>
33. Transportation Research Board, *NCHRP Report 568, Riprap Design Criteria, Recommended Specifications, and Quality Control*, 2006, Washington, D.C., retrieved from
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_568.pdf
34. Vermont Agency of Transportation, *Structures Design Manual*.
Retrieved from <http://vtransengineering.vermont.gov/sections/structures>
35. Vermont Agency of Transportation, *Hydraulics Manual*.
Retrieved from <http://vtransengineering.vermont.gov/sections/environmental/hydraulics>
36. Washington State Department of Transportation, *Aesthetics Sourcebook*. Retrieved from
http://www.wsdot.wa.gov/publications/fulltext/Bridge/Aesthetics_Sourcebook.pdf
37. Washington State Department of Transportation, *Bridge Design Manual (BFM) M 23-50*.
Retrieved from <http://www.wsdot.wa.gov/Publications/Manuals/M23-50.htm>
38. Washington State Department of Transportation, *Hydraulics Manual*. Retrieved from
<http://www.wsdot.wa.gov/Publications/Manuals/M23-03.htm>
39. Wisconsin State Department of Transportation, *LRFD Bridge Manual*.
Retrieved from
http://on.dot.wi.gov/dtid_bos/extranet/structures/LRFD/LRFDManualIndex.htm

Page intentionally left blank.



Bridge Design Manual

Chapter 2- Appendix A

January 2015 – v 2.0

(Revised August 2018)



Page intentionally left blank.

		<h3>Picture Check List for Bridge Site Visit</h3>	
Project Name		Br. No.	
Project Number		Made By & Date	
Project Location			
		Notes	Picture Number(s)
<input type="checkbox"/>	Both Roadway Approaches		
<input type="checkbox"/>	Upstream and Downstream		
<input type="checkbox"/>	Both Roadway Appr. for Road Crossing		
<input type="checkbox"/>	Drainage/Drainage Problem Areas		
<input type="checkbox"/>	High Water Marks		
<input type="checkbox"/>	Possible Temp. Bridge/Detour Location		
<input type="checkbox"/>	Features of the Bridge		
<input type="checkbox"/>	Problem Areas		
<input type="checkbox"/>	All Four Corners of Bridge		
<input type="checkbox"/>	Safety Issues		
<input type="checkbox"/>	Possible Impacts		
<input type="checkbox"/>	Posted Speed Limit		
<input type="checkbox"/>	Bridge and Approach Rail		
<input type="checkbox"/>	Curbing		
<input type="checkbox"/>	Utilities/Utility Pole Number		
<input type="checkbox"/>	Signals		
<input type="checkbox"/>	Lighting		
<input type="checkbox"/>	Sidewalks		

<input type="checkbox"/>	Hydraulics		
<input type="checkbox"/>	Channel Approach		
<input type="checkbox"/>	Waterway Opening		
<input type="checkbox"/>	Flow Velocities		
<input type="checkbox"/>	Channel Erosion		
<input type="checkbox"/>	Scour Issues		
<input type="checkbox"/>	Flood Relief		
<input type="checkbox"/>	Description of Riverbed/Channel		
<input type="checkbox"/>	Slope of Riverbed		

		<h3>Check List for Bridge Site Visit</h3>	
Project Name		Br. No.	
Project Number		Made By & Date	
Project Location			
		Notes	
<input type="checkbox"/>	Existing Roadway Alignment		
<input type="checkbox"/>	Existing Pavement Condition		
<input type="checkbox"/>	Existing Roadway Typical		
<input type="checkbox"/>	Drainage/Drainage Problem Areas		
<input type="checkbox"/>	Right-of-Way Impacts		
<input type="checkbox"/>	Possible Temp. Bridge/Detour Location		
<input type="checkbox"/>	Drive Detour		
<input type="checkbox"/>	Features of the Bridge		
<input type="checkbox"/>	Expansion Joint		
<input type="checkbox"/>	Bridge and Approach Rail		
<input type="checkbox"/>	Deck Condition		
<input type="checkbox"/>	Substructure		
<input type="checkbox"/>	Superstructure		
<input type="checkbox"/>	Problem Areas		
<input type="checkbox"/>	Historical Importance		
<input type="checkbox"/>	Safety Issues		
<input type="checkbox"/>	Traffic Control		
<input type="checkbox"/>	Survey Limits		
<input type="checkbox"/>	Utilities		

<input type="checkbox"/>	Existing Signals	
<input type="checkbox"/>	Lighting	
<input type="checkbox"/>	Sidewalks	
<input type="checkbox"/>	Hydraulics	
<input type="checkbox"/>	Channel Approach	
<input type="checkbox"/>	Waterway Opening	
<input type="checkbox"/>	Flow Velocities	
<input type="checkbox"/>	Flood Relief	
<input type="checkbox"/>	Channel Erosion	
<input type="checkbox"/>	Scour Issues	

**STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION**

BRIDGE REPORT

Project: **Project No.**
Bridge No. **Roadway:**
Description:

1. Questions to be asked of Division Engineer or Patrolman:

- a. Extent of trouble caused by ice or drifting:
- b. Does all high water pass through existing structure?
- c. Do all existing approaches supply relief for high water?
- d. Additional information by Division Engineer or Patrolman:

2. Additional information by local residents

3. High water information at proposed site:

- a. Elevation of highest water: **Date:**
- b. Elevation of average high water:
- c. Location:

4. Additional remarks:

5. Location of nearest existing structure over same waterway:

- a. Type of Structure:
- b. Clear Span:
- c. Clear Height:
- d. Is waterway adequate?
- e. Additional remarks:

Page intentionally left blank.

**STATE OF NEW HAMPSHIRE
INTER-DEPARTMENT COMMUNICATION**

From: Consultant Design Chief

Date: May 13, 1998

**Subject: PIERMONT
12260
STATE WIDE CONTRACT No. 12318
(NH Route 10 over Bean Brook)**

At(Office): Department of Transportation
Bureau of Bridge Design

To: Assistant Commissioner and Chief Engineer

Thru: _____	_____	_____
Administrator Bridge Design	Assistant Director of Project Development	Director of Project Development

MEMORANDUM

It is requested that a design exception be approved for this project to allow 4 foot shoulder construction.

Background:

- 1) Project includes:
 - Replacement and realignment of the NH Route 10 bridge over the Bean Brook.
- 2) NH Route 10 is a rural minor arterial highway.
- 3) Posted Speed - 50 mph.
- 4) The traffic for NH Route 10:
 - 1997 DHV - 180
 - 2017 DHV - 270
 - 1997 AADT - 1510
 - 2017 AADT - 2260
 - 2.4 % truck DHV
 - 7.6 % truck ADT

- 5) The existing paved roadway width for NH Route 10 varies from 24 feet north of the bridge to 26 feet south of the bridge. Paved shoulder widths vary 1 to 2 feet and gravel shoulder widths vary from 1 to 6 feet. Travel lane widths vary from 11 to 12 feet.
- 6) The existing bridge width is approximately 24 feet curb to curb.
- 7) In the AASHTO, Policy on Geometric Design of Highways and Streets (1990) publication, information in table VII-2 on page 499 indicates the recommended shoulder width for roadways with an ADT over 400 or DHV of 100 – 200 is 6 feet. An 8 foot paved shoulder is recommended for roadways with a DHV over 200, (the DHV for this roadway is expected to exceed 200 vph by the year 2003).

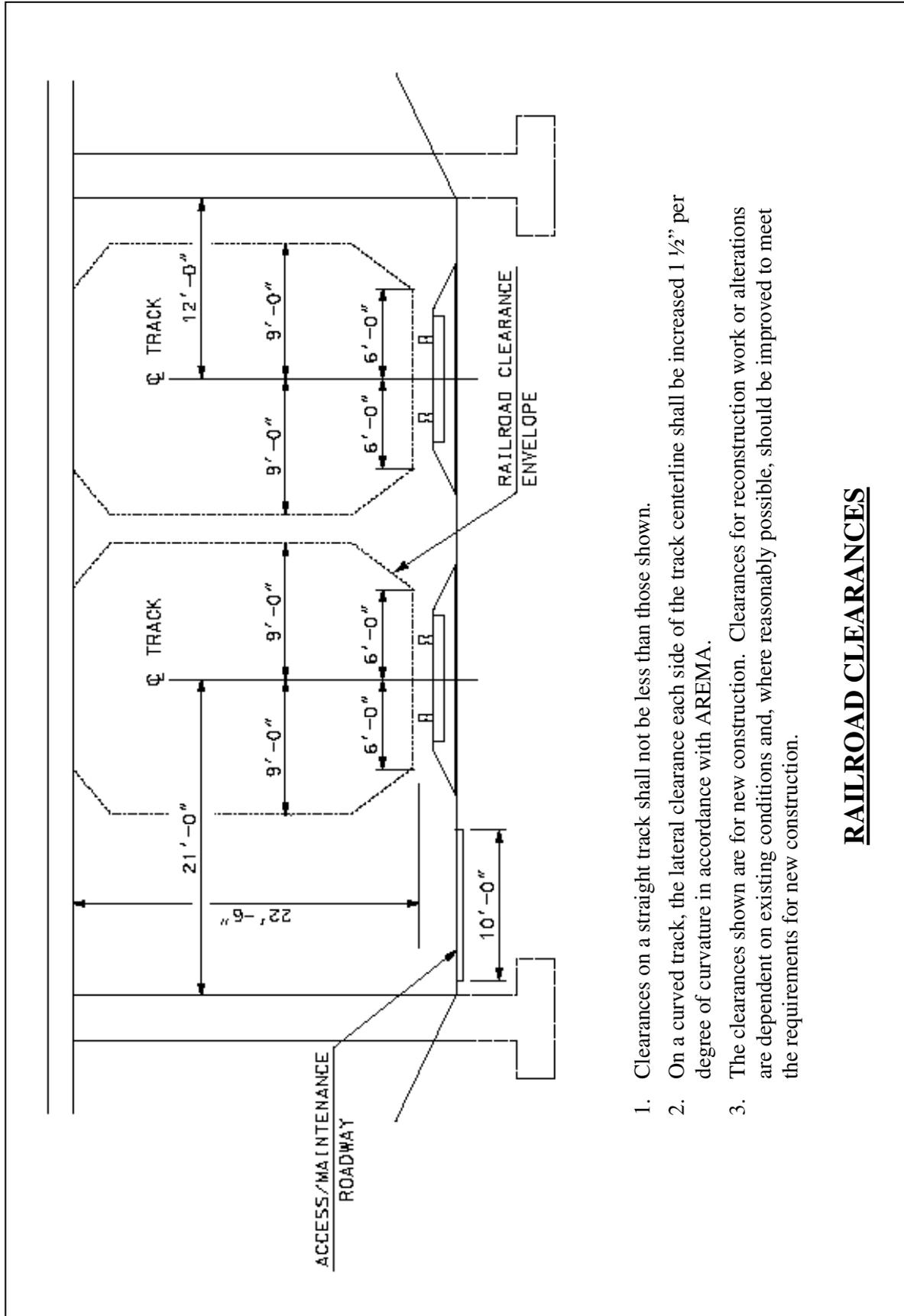
Reason for Exception:

- 1) NH Route 10 is generally a rural, low volume highway. The proposed travel lane widths are 12 feet. This segment of the road is located in a rural setting where the homes and buildings at the beginning and end of the project are located close to the roadway. A 4 foot shoulder will reduce the impact on the properties located along both sides of NH Route 10.
- 2) The project will be paid for with 100% State funding. A reduced shoulder width will provide a cost savings to this funding. The construction cost savings for a total 8 foot width (4 feet each side) over the 2906 foot (0.55 mile) length of the project is estimated to be approximately \$235,000, which includes the roadway and bridge work. There would also be a savings in right-of-way costs for easements.

DESIGN APPROVED _____

NOT APPROVED _____

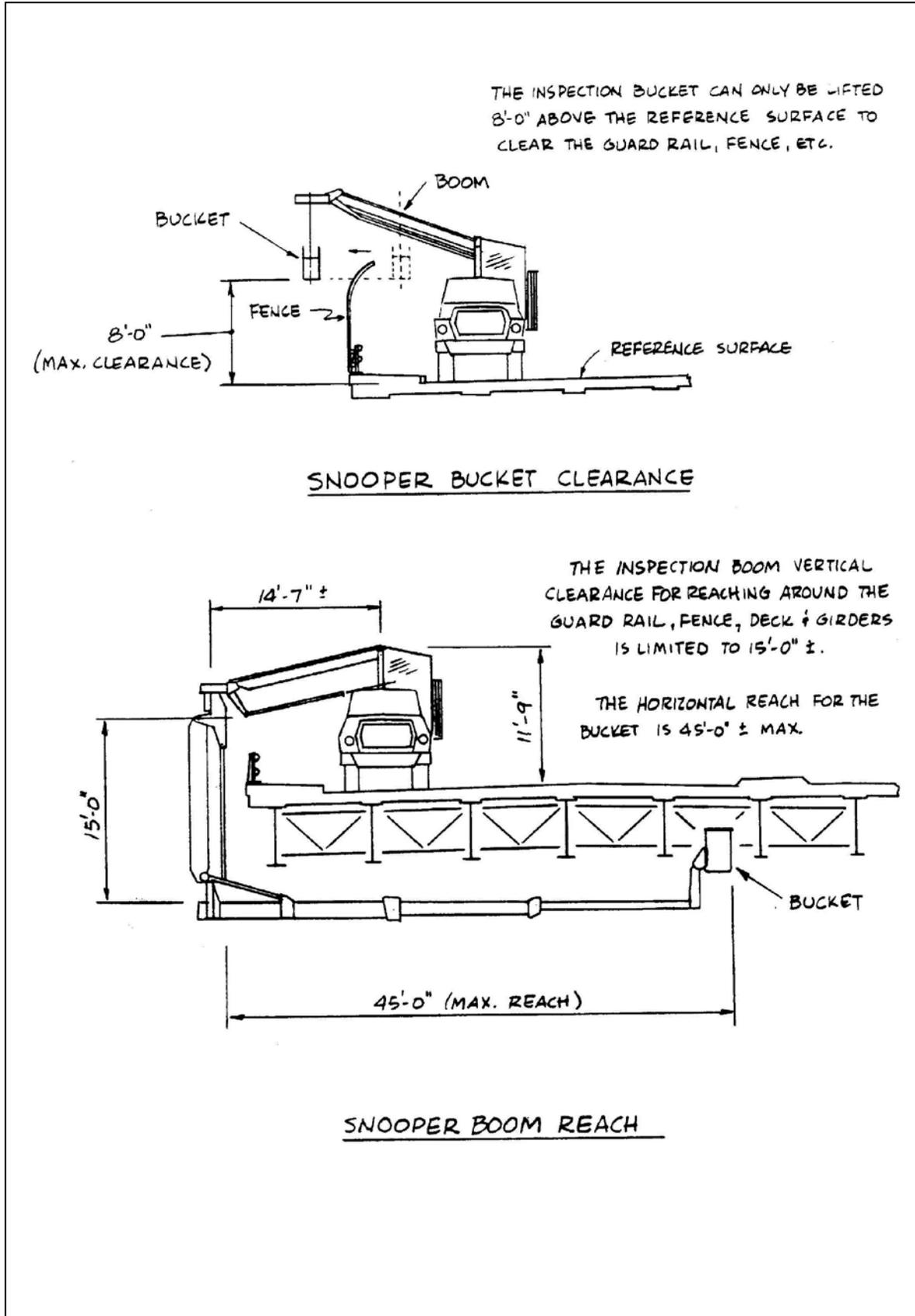
Assistant Commissioner and Chief Engineer



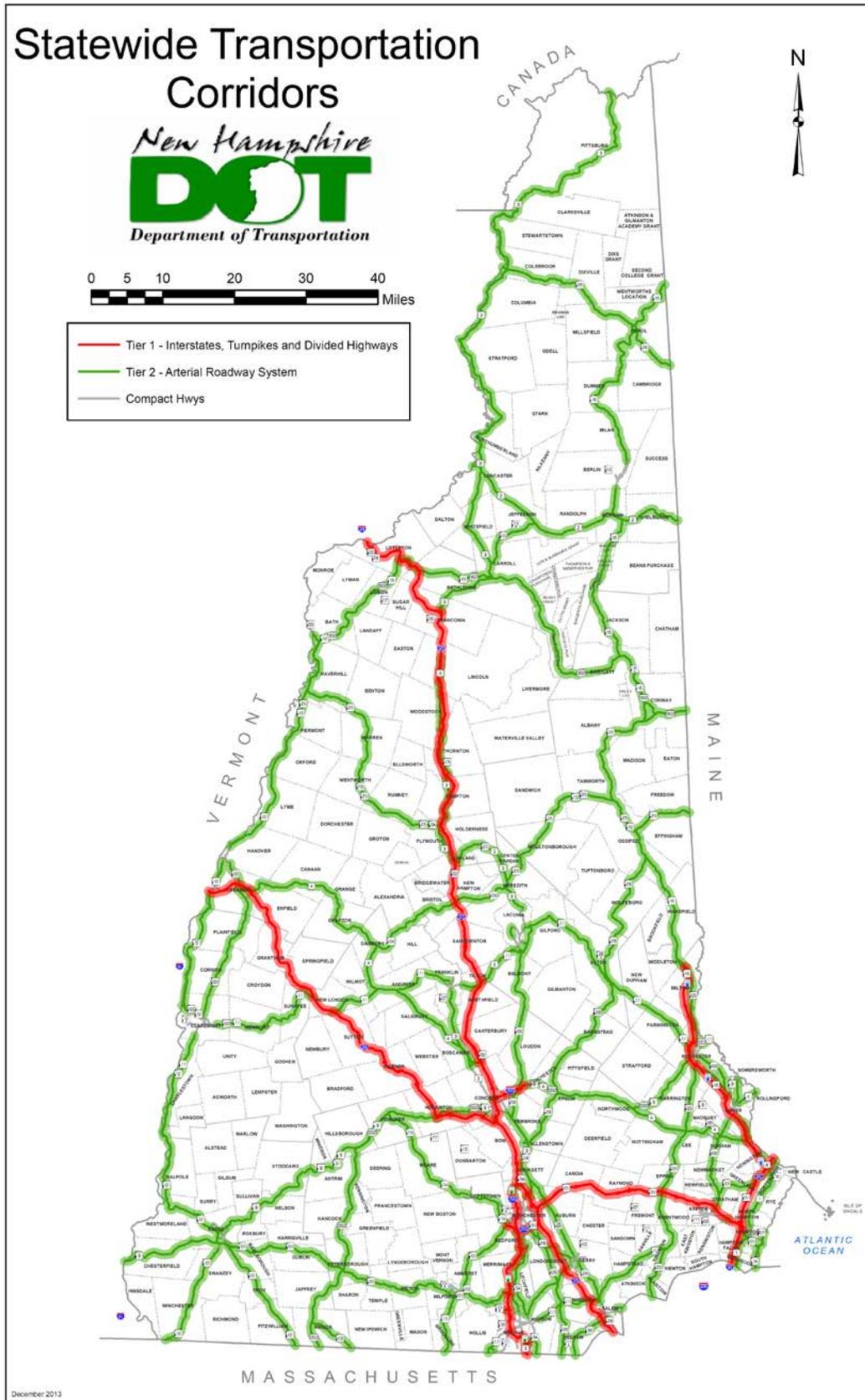
1. Clearances on a straight track shall not be less than those shown.
2. On a curved track, the lateral clearance each side of the track centerline shall be increased 1 1/2" per degree of curvature in accordance with AREMA.
3. The clearances shown are for new construction. Clearances for reconstruction work or alterations are dependent on existing conditions and, where reasonably possible, should be improved to meet the requirements for new construction.

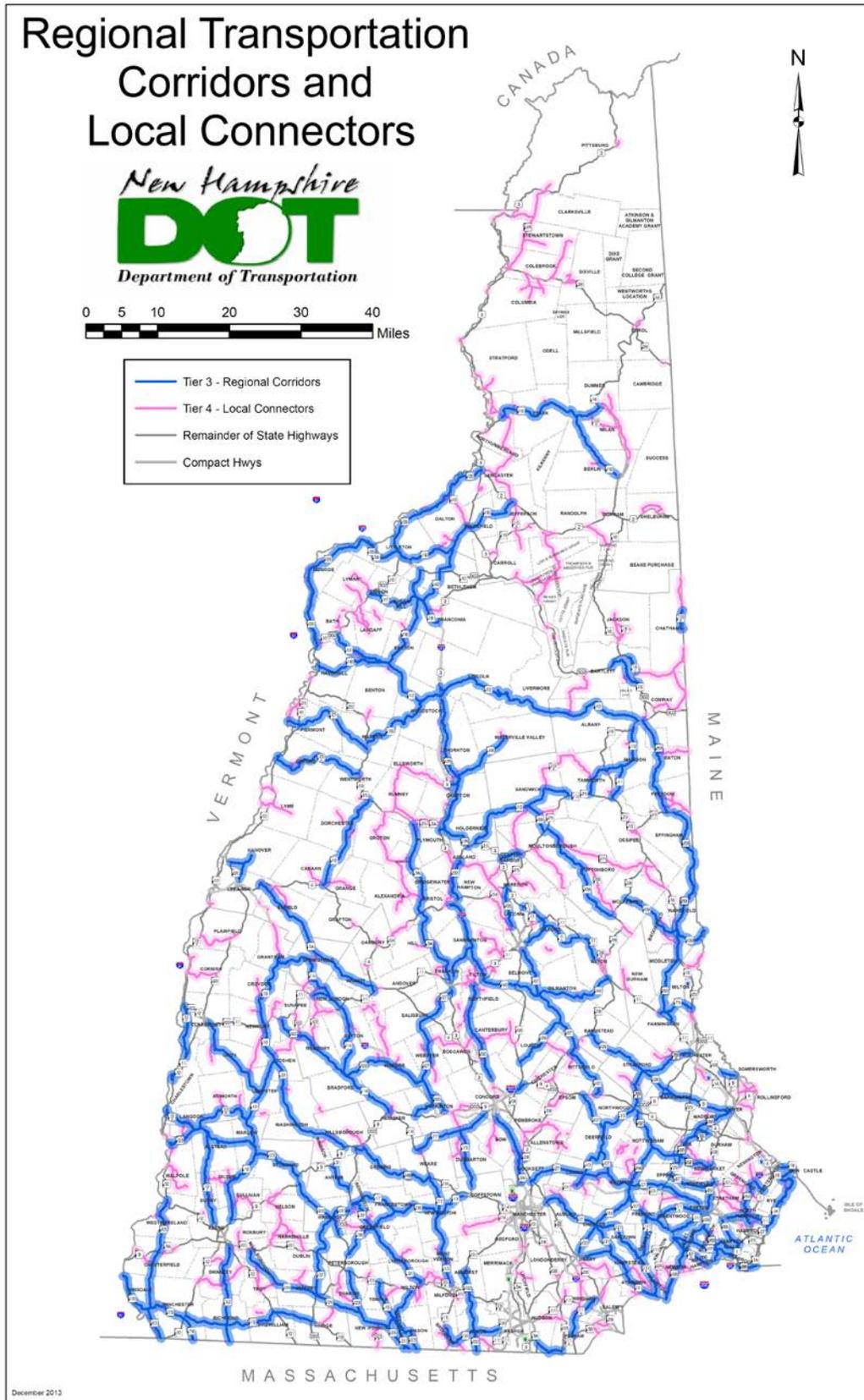
RAILROAD CLEARANCES

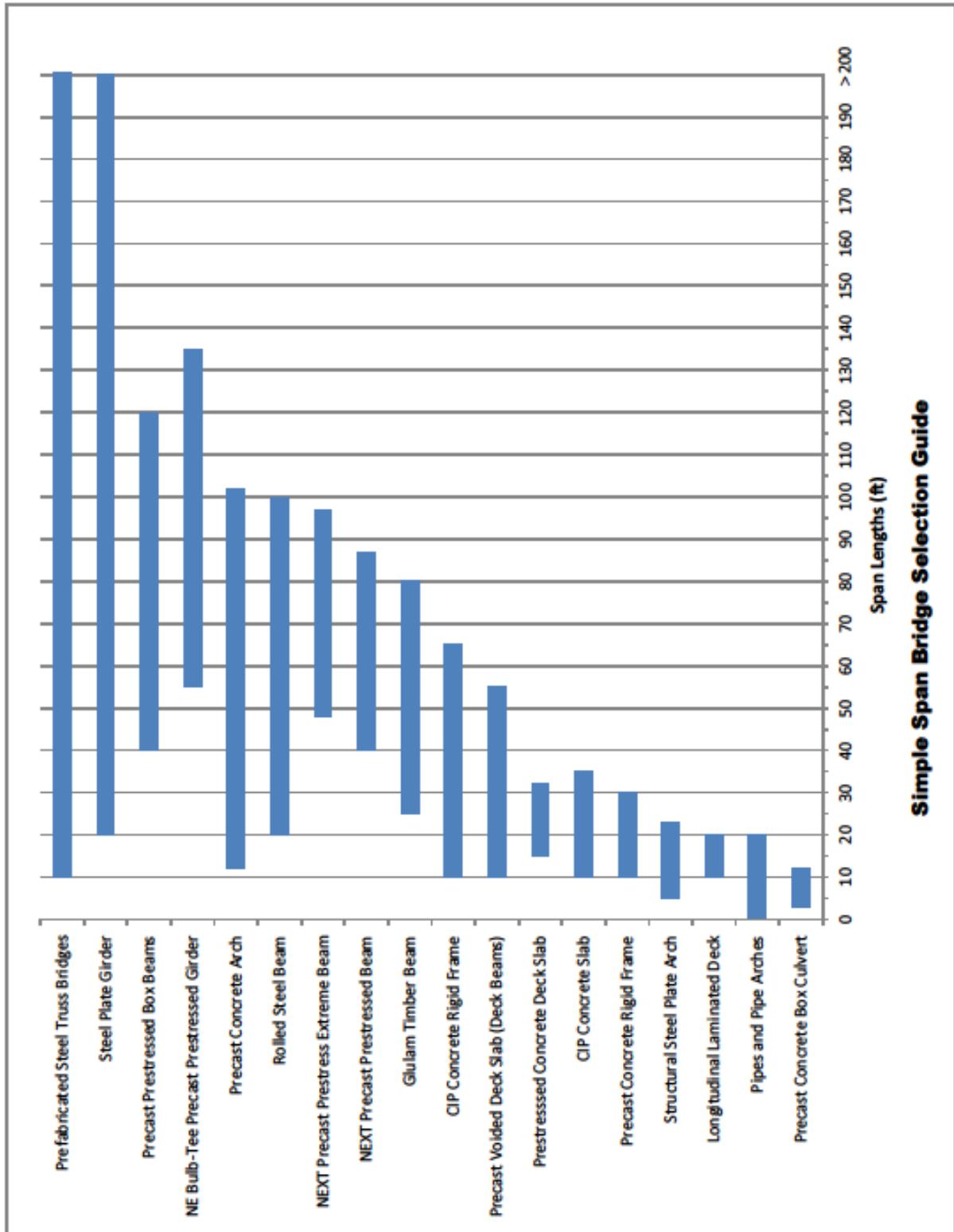
Page intentionally left blank.



Page intentionally left blank.





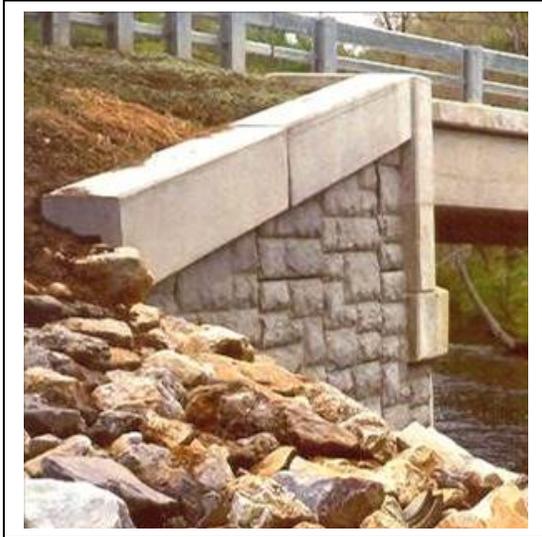


Page intentionally left blank.

CONCRETE FORM LINER

LOUDON 13207

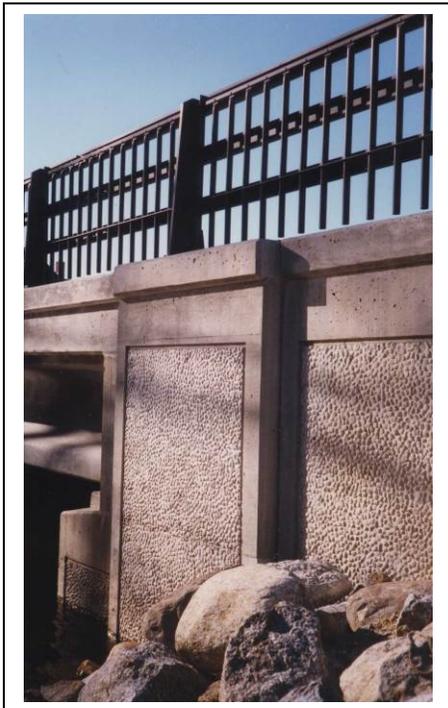
(Staniels Rd over Soucook River)



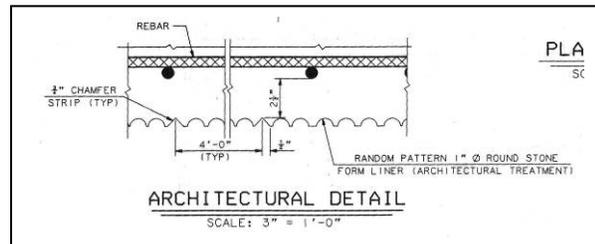
Rustication:
MSE panels with Form
Liners, Ashlar Stone Pattern

BRISTOL P-4380

(US Rte 3A over Newfound River)



Rustication:
Symons ABS Form Liners, Pattern
P/C 30251-7,
1" Diameter Round Stone Finish



CONCRETE FORM LINER

SALEM-MANCHESTER 14633E

(I-93 NB over NH 111A)



Rustication:
MSE panels with Symons Form
Liners Ashlar Stone
Pattern P/C 30664

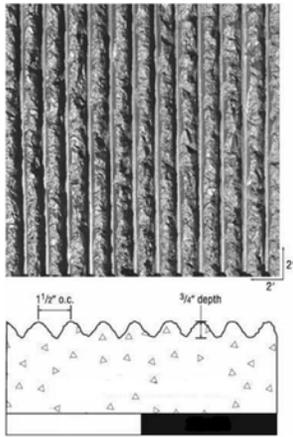
ENFIELD 10652

(Shaker Hill Rd over Recreation Trail)

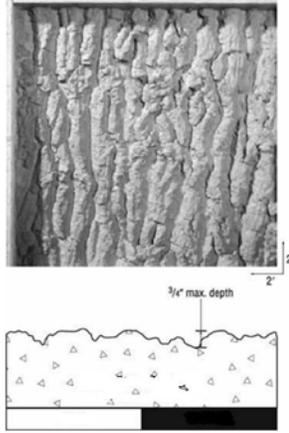


Rustication:
Symons Form Liners 1520 Batavia
Random Fieldstone Texture

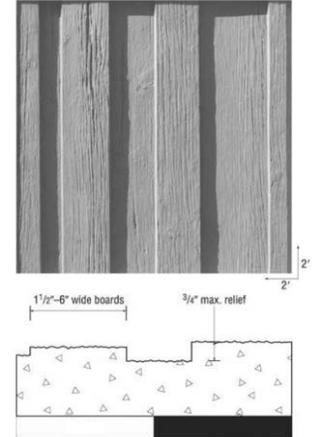
CONCRETE FORM LINER



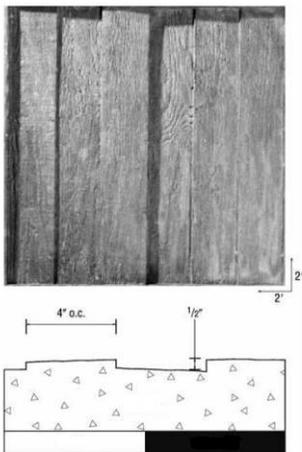
Fractured Fin



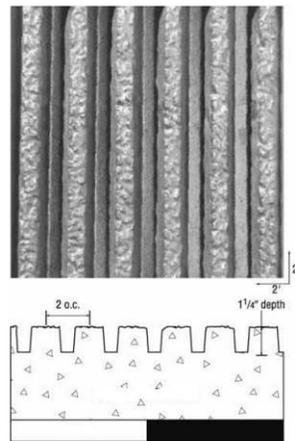
Fractured Granite
(surface treatment resembles bark or fractured granite)



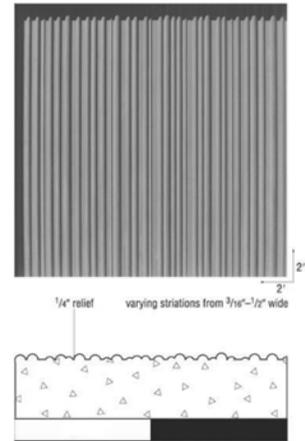
Random Board Finish (3/4")
(natural looking, rough-cut wood textures)



Random Board Finish (Variable Depth)

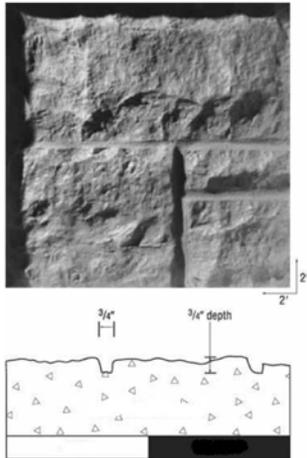


Ribbed Finish

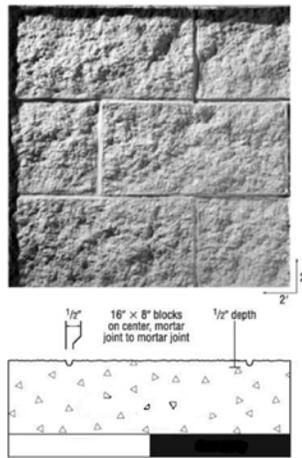


Striated Finish

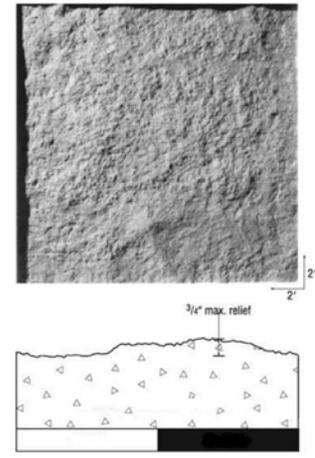
CONCRETE FORM LINER



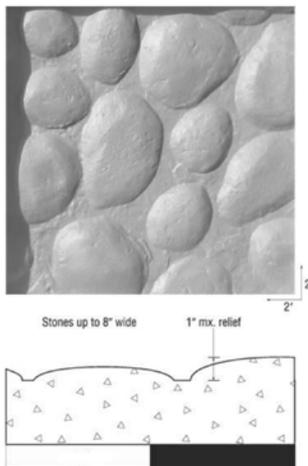
Ashlar Stone Finish
(random cut stone texture)



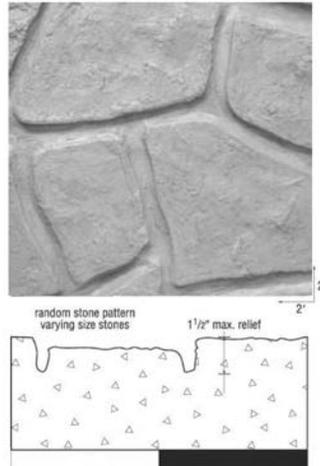
Block Finish
(blends with modular block structural earth walls)



Split Face Finish
(appearance of split stone)



River Rock Finish



Cascadian Stone Finish
(surface crease a random rubble stone appearance)

CONCRETE COLORING AGENT

ENFIELD 10652

(Shaker Hill Rd over Mascoma River)



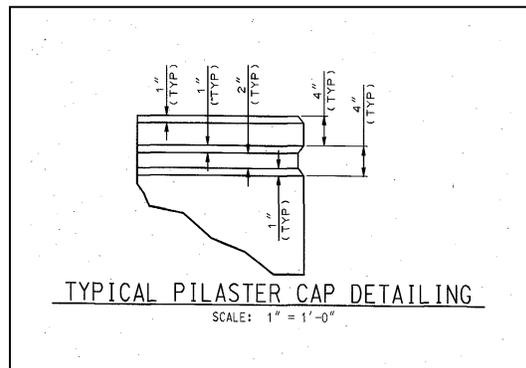
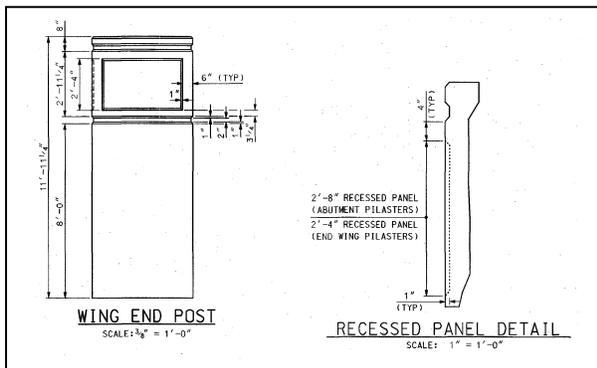
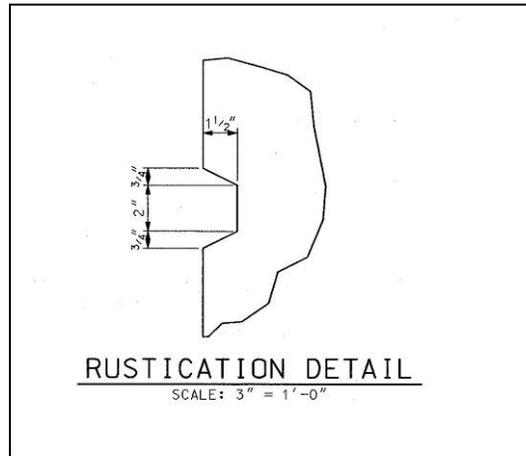
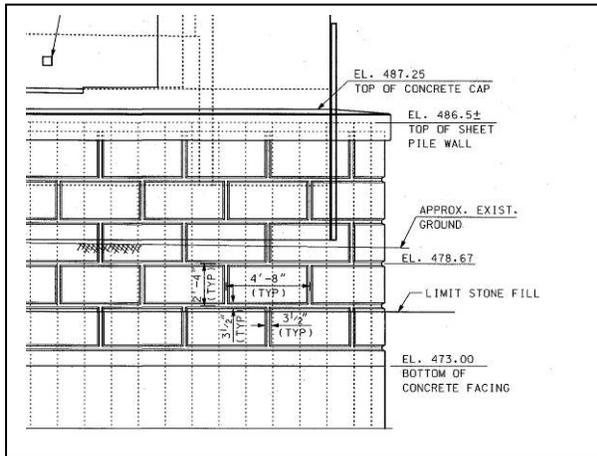
Concrete Coloring Agent:
L.M. Scofield Co., Chromix
Admix., ASTM C 979,
Color: Quarry Red;
Texture Mat: L.M. Scofield Co.,
Brick Pattern:
Herringbone
(Special Provision Item 520.04
Concrete Class AA, Textured
Reinforced Concrete Sidewalk)



ARCHITECTURAL DETAILS

HOLDERNESS-PLYMOUTH 11849

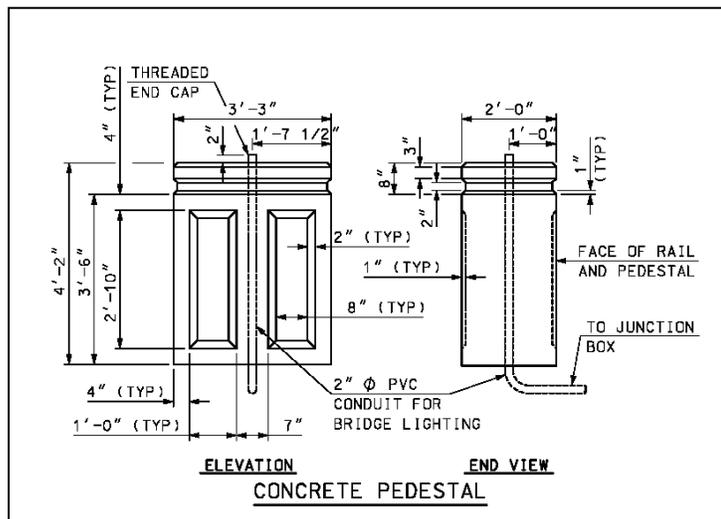
(Rte 175A over Pemigewasset River)



ARCHITECTURAL DETAILS

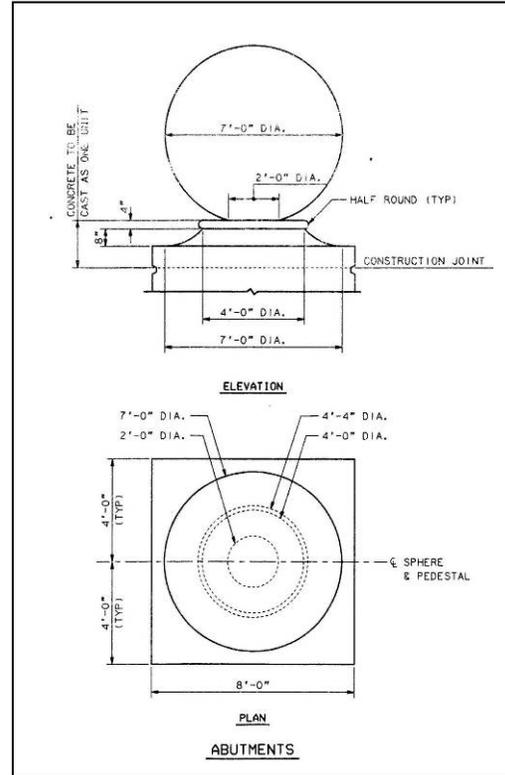
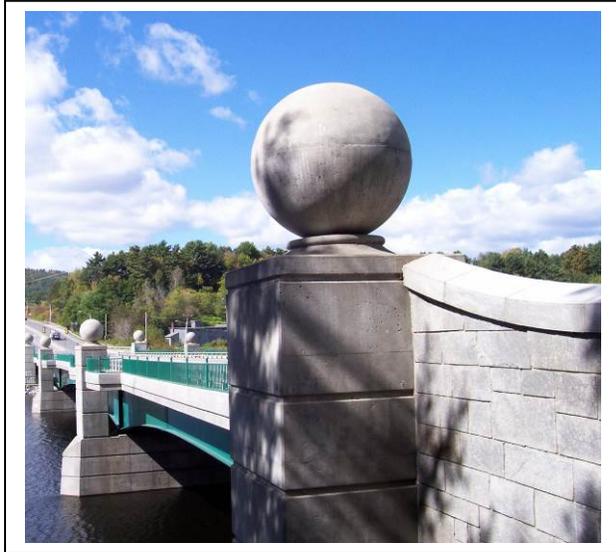
PEMBROKE – ALLENSTOWN 12978

(Main St. over Suncook River)



ARCHITECTURAL DETAILS

HANOVER, NH – NORWICH, VT 10029-A
(Rte 10A over Connecticut River)

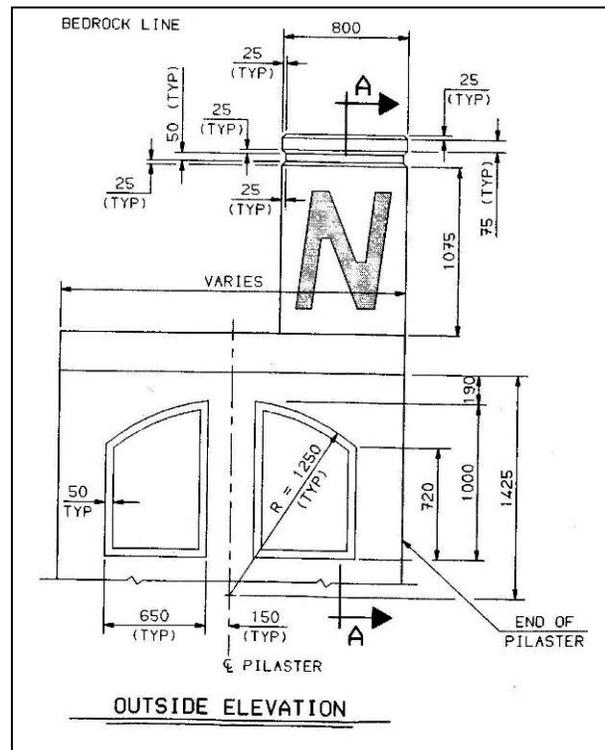
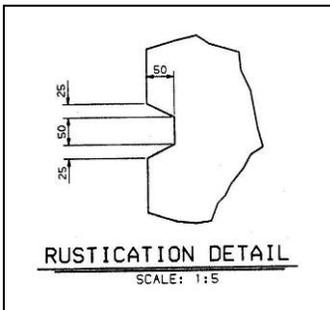
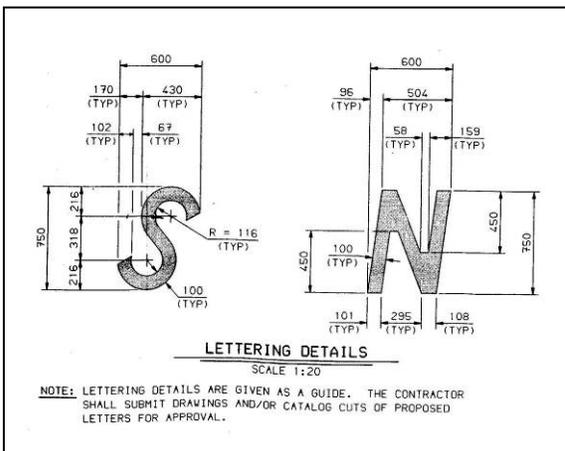


Concrete pavers
23 1/2" x 23 1/2" x 2"

ARCHITECTURAL DETAILS

NEWFIELDS-STRATHAM P-4386

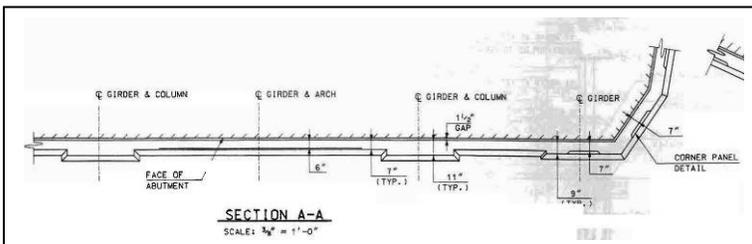
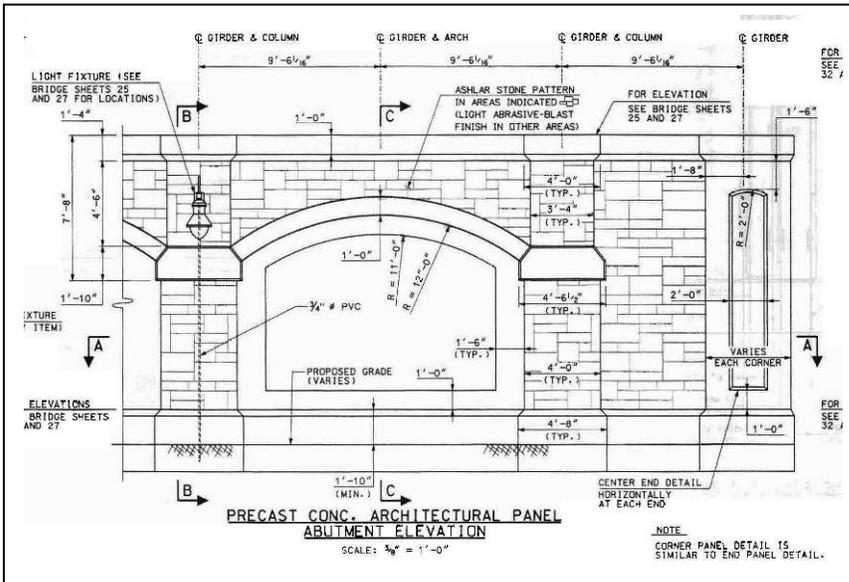
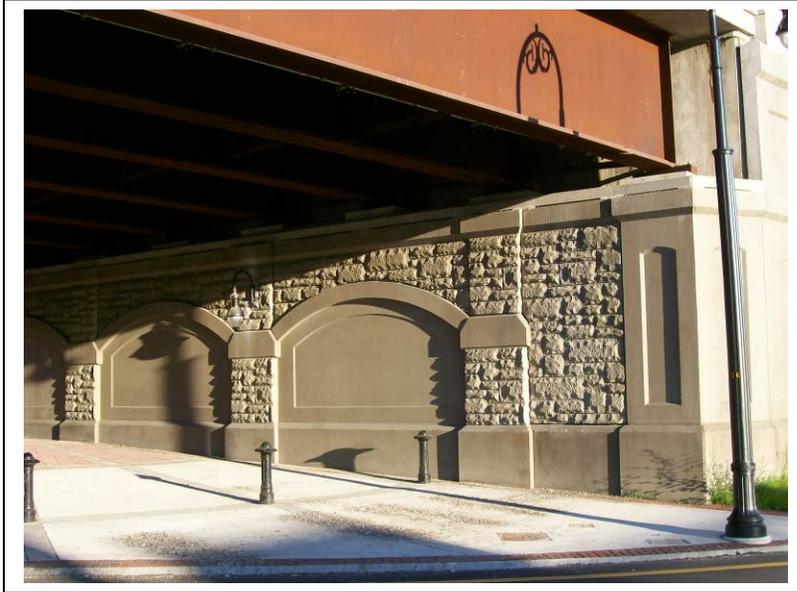
(NH 108 over Squamscott River)



ARCHITECTURAL DETAILS

MANCHESTER 10622-C

(I-293 NB & SB over Granite St)



STONE MASONRY FACING

(Note: Can only be used on bridges over river crossings.)

ORANGE 10927

(Tuttle Hill Rd. over Orange Brook)



Item 570.4, Mortar Rubble Masonry
Item 570.2, Mortar Squared
Masonry (fascia of concrete arch)

LITCHFIELD 10946

(NH Rte 3A over Nesenkeag Brook)



Item 570.4, Mortar Rubble Masonry
Item 570.2, Mortar Squared
Masonry (fascia of concrete arch)

STONE MASONRY FACING

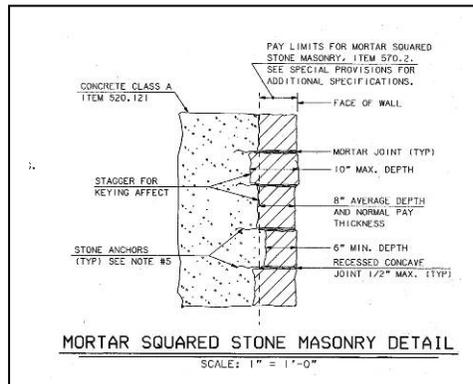
(Note: Can only be used on bridges over river crossings.)

WOODSTOCK 10052

(Rte 112 over Wild Ammonoosuc River)



Item 570.2, Mortar Squared Stone Masonry, 8"± thick



STONE MASONRY FACING

(Note: Can only be used on bridges over river crossings.)

LOW & BURBANKS 12188

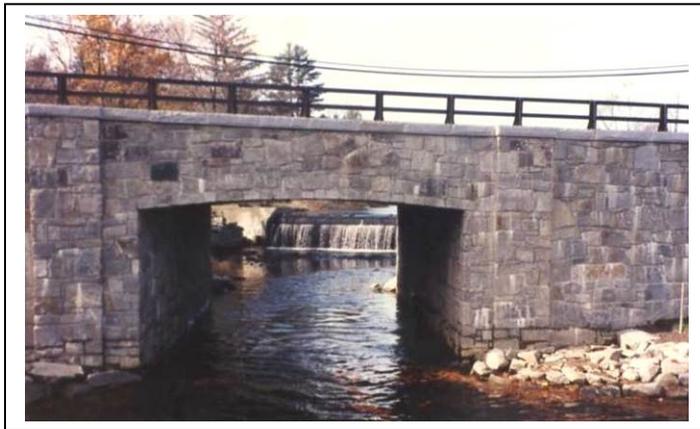
(Jefferson Notch Rd. over North Branch Israel River)



Item 570.4, Mortar Rubble
Masonry

DURHAM P-3816

(NH Rte 108 over Oyster River)



Item 570.2, Mortar Squared Stone
Masonry, 8"± thick



4. STONE MASONRY NOTE:
THE CONTRACTOR SHALL CONSTRUCT AND ADEQUATELY SUPPORT THE FRAME, WING AND PILASTER STONE FACING BEFORE PLACING THE CONCRETE BEHIND THE STONE. TIE STONE MASONRY TO CONCRETE WITH 1"x½"x8" LONG CORRUGATED GALVANIZED ANCHORS. SPACE ANCHORS AT 1'-0" C-C EACH DIRECTION, BUT DO NOT USE LESS THAN ONE ANCHOR PER STONE.
ALL STONES SHALL HAVE A ROUGH TEXTURE FINISH AND SHALL BE A UNIFORM GREY COLOR. SAMPLES SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL. BOTH THE EXISTING ABUTMENT MASONRY AND THE STONE PATTERN SHOWN ON THE ELEVATION VIEW OF BRIDGE SHEET 1 OF 23 SHALL BE USED AS GUIDES IN ACHIEVING AN ARCHITECTURAL FINISH WHICH HAS THE SAME CHARACTERISTICS AS THE EXISTING STONE SUBSTRUCTURE. SEE STANDARD SPECIFICATIONS AND SPECIAL PROVISIONS FOR ADDITIONAL INFORMATION.
5. STONE COPINGS SHALL BE SQUARED WITH A ROUGH FINISH EXCEPT THE TOP SURFACE OF THE STONE SHALL HAVE A SAWN SMOOTH FINISH. STONE SIZE FOR COPINGS SHALL BE A UNIFORM THICKNESS OF 10"± AND 36"-60" IN LENGTH. COPING JOINTS SHALL BE A UNIFORM 1/2" MAX. THICKNESS.

STONE MASONRY FACING

(Note: Can only be used on bridges over river crossings.)

FRANCONIA P-2371-N

(NH Rte 18 over I-93 Parkway)



Item 570.71, Quarry Rubble Stone Masonry

Can you find the Old Man of the Mountain?

MANCHESTER P-1050-L

(I-93 SB over Bridge Street)

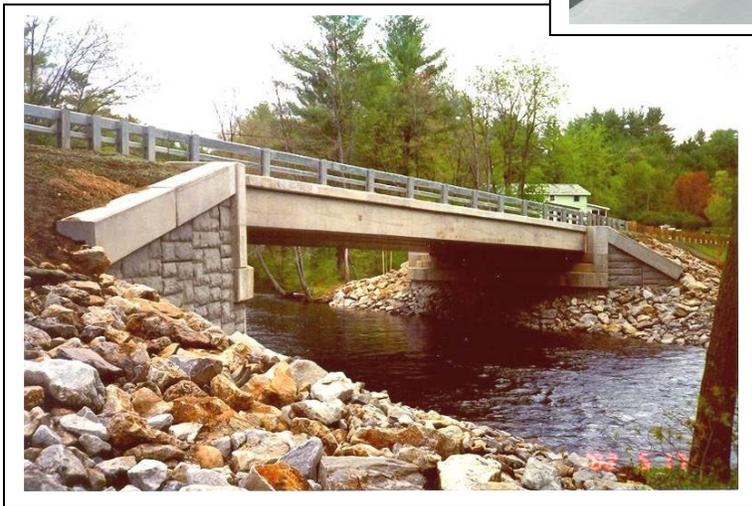


Item 570.2, Mortar Squared Stone Masonry, 8"± thick

Page intentionally left blank.

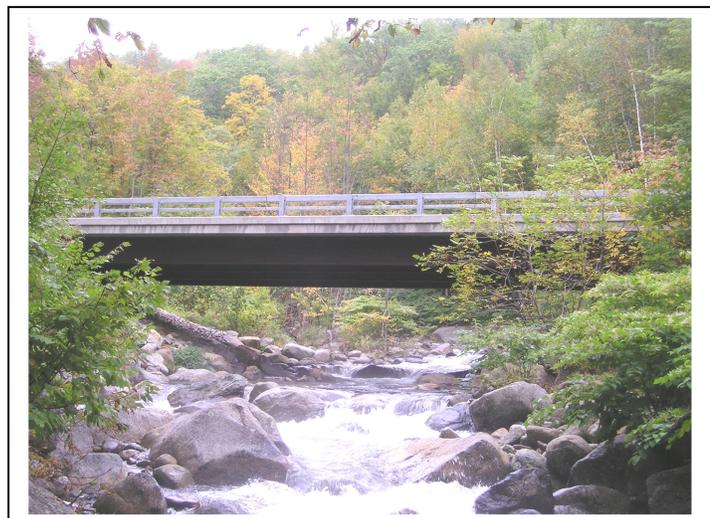
TRAFFIC BRIDGE RAIL

T2 STEEL RAIL:



LOUDON
(Staniels Rd over
Soucook River)

RUMNEY
(Stinson Lake Rd over
Stinson Brook)

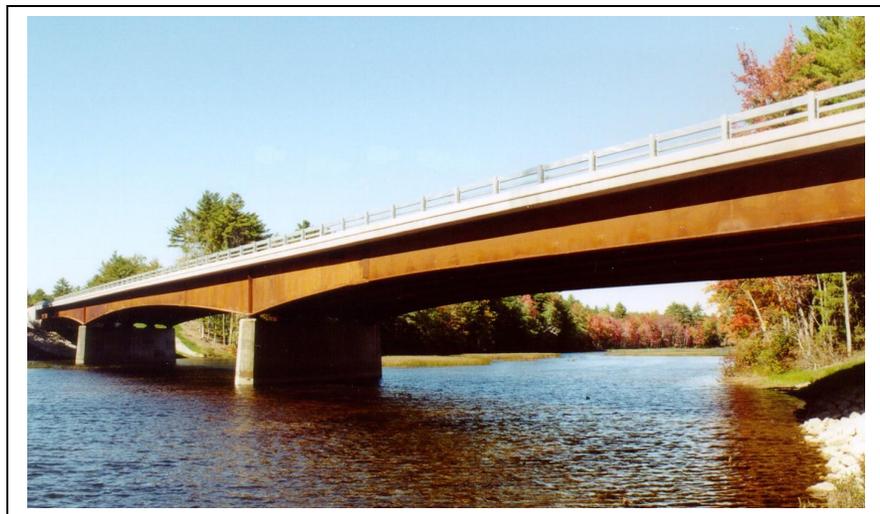


TRAFFIC BRIDGE RAIL

T2 STEEL RAIL:



FRANCONIA
(I-93 Parkway Ramp
over US 3)
(Bridge railing anodized
brown)



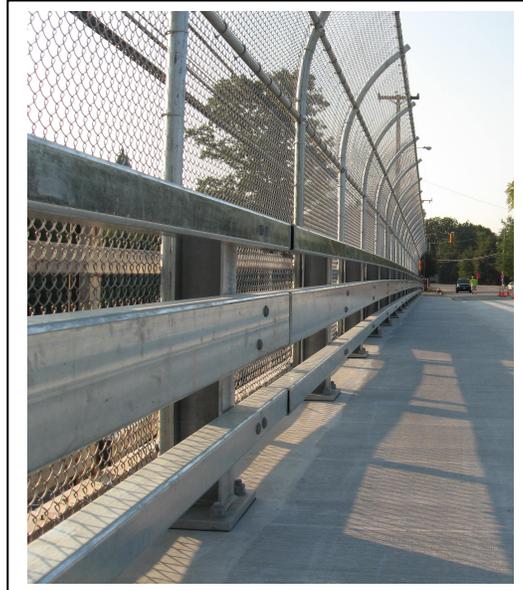
EFFINGHAM
(NH Rte. 25 over
Ossipee R.)



CONCORD
(I-93 over Manchester St.)
(2-bar bridge railing with
snow fence)

TRAFFIC BRIDGE RAIL

T3 STEEL RAIL:



ALTON
(NH Rte. 28 over
Merrymeeting R.)

TRAFFIC BRIDGE RAIL

T4 STEEL RAIL:



New Ipswich
(NH Rte 123 & 124 over
Souhegan River) (Hot-dipped
galvanized and shop-applied
brown paint, Federal Color
#20062)



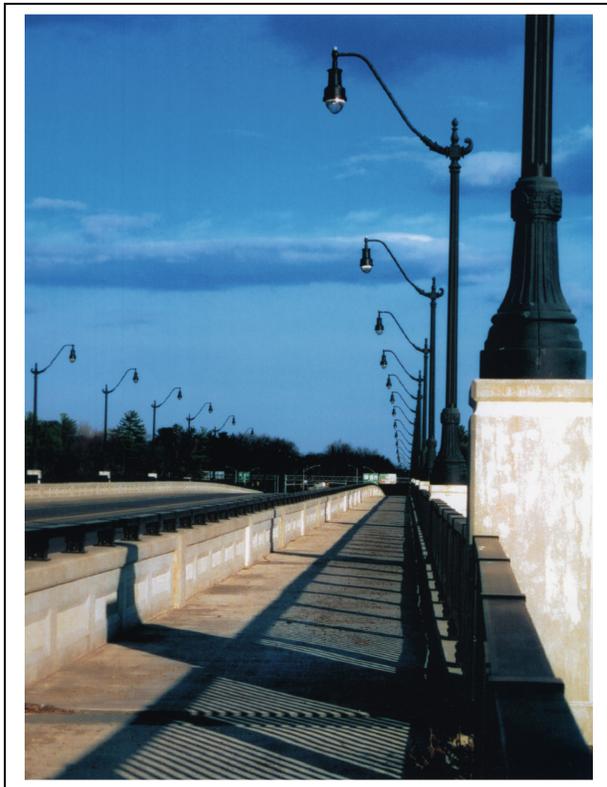
Ossipee
(NH Rte. 25 over
Bearcamp River) (Hot-
dipped galvanized and
shop-applied brown paint,
Federal Color #20059)

TRAFFIC BRIDGE RAIL

CONCRETE RAIL:

DOVER

(US Rte. 4 over Bellamy R.)



DOVER

(US Rte. 4 over Bellamy R.)
*(concrete bridge rail with
top steel rail)*

TRAFFIC BRIDGE RAIL

CONCRETE RAIL:

**HOLDERNESS-
PLYMOUTH**

(Rte. 175A over
Pemigewasset R.)



**HOLDERNESS-
PLYMOUTH**

(Rte. 175A over
Pemigewasset R.)

ROLLINSFORD

(Rollins Rd. over
Main St., BM RR)



TRAFFIC BRIDGE RAIL

CONCRETE RAIL:



Texas C411 Concrete Bridge Rail



Texas F411 Concrete Bridge Rail

TRAFFIC BRIDGE RAIL

CONCRETE RAIL:



CA Type 80 (SBC12d) Concrete Bridge Rail

TRAFFIC BRIDGE RAIL

CONCRETE RAIL:



**MNDOT Concrete Bridge Rail
Edgerton Street Bridge
(I-35E/I-694)**



**WISDOT Concrete Bridge Rail
(I-94 North-South Freeway Project)**

TRAFFIC BRIDGE RAIL

TIMBER RAIL:



RYE
(NH 1A over
Seavey Creek)



LEBANON
(Payne Rd. over
Rec Trail)

TRAFFIC BRIDGE RAIL

TIMBER RAIL:



**T1-4 Glulam Timber
Bridge Rail
(FHWA SBD01d)**

PEDESTRAIN BRIDGE RAIL



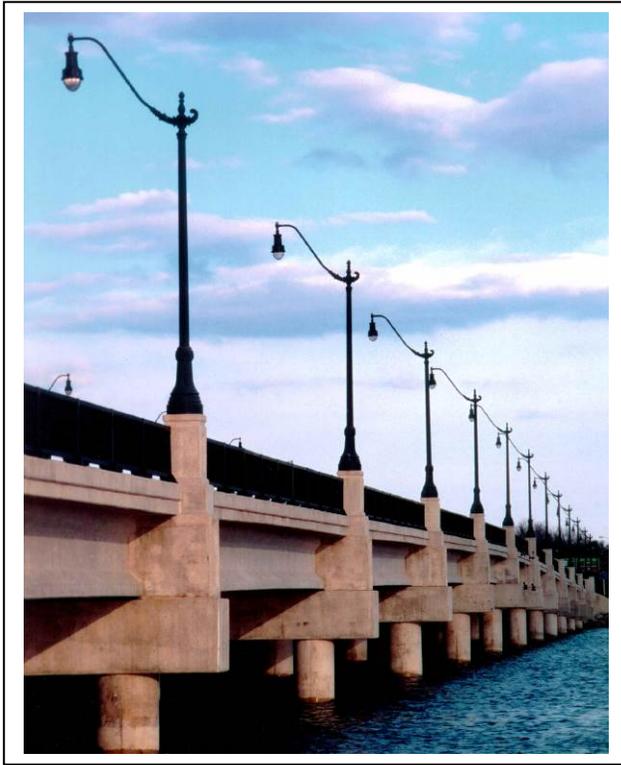
NEWINGTON-DOVER
(Pedestrian Access over Hilton Park)

HANOVER, NH – NORWICH, VT
(Rte 10A over Connecticut R.)



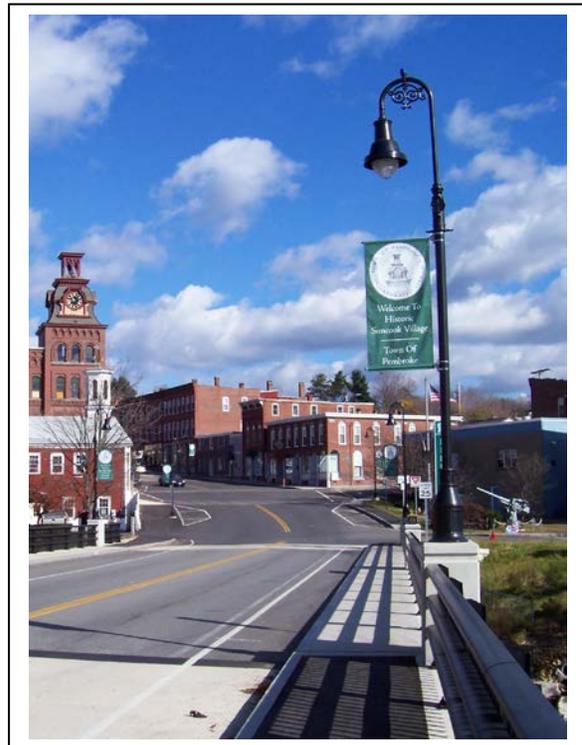
HOLDERNESS-PLYMOUTH
(Rte. 175A over Pemigewasset R.)

BRIDGE LIGHTING

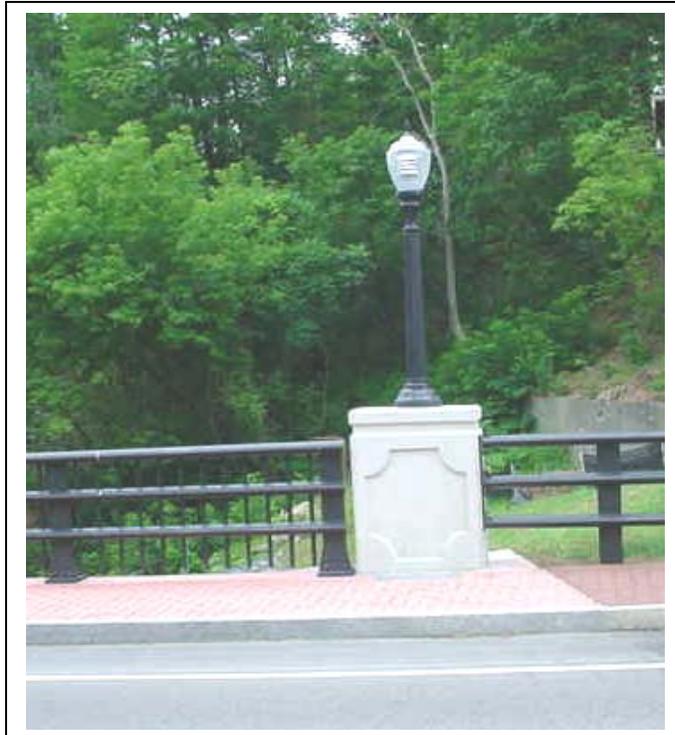


DOVER 11657
(US Rte. 4 over Bellamy River)

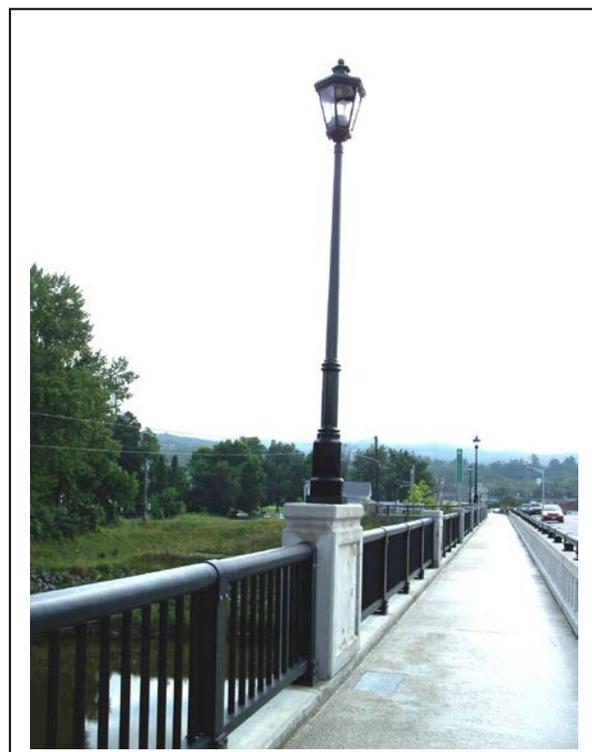
PEMBROKE-ALLENSTOWN 12978
(Main Street over Suncook River)



BRIDGE LIGHTING



ENFIELD 10652
(Main Street over Mascoma River)

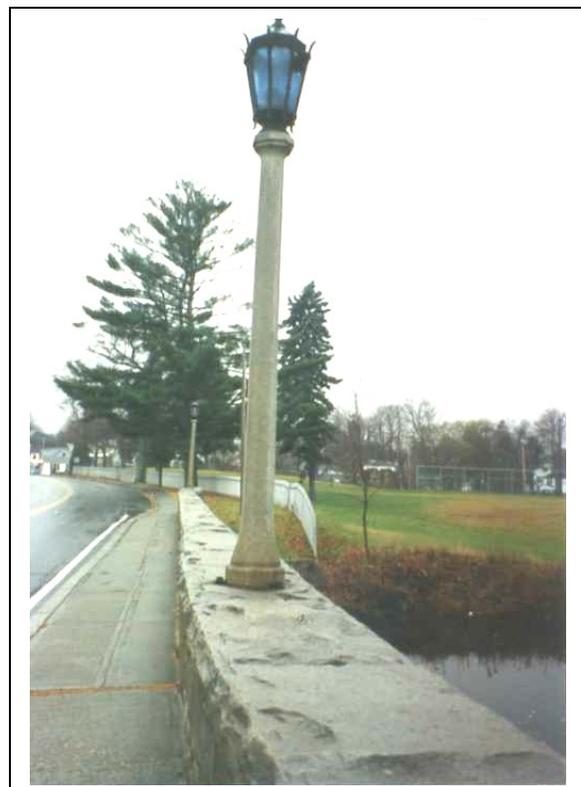


HOLDERNESS-PLYMOUTH 11849
(NH Rte 175A over Pemigewasset River)

BRIDGE LIGHTING



HAVERHILL
(US 302 over Connecticut R.)



PITTSFIELD
(Rte. 107 over Suncook River)

Page intentionally left blank.

FHWA HYDRAULIC ENGINEERING CIRCULARS

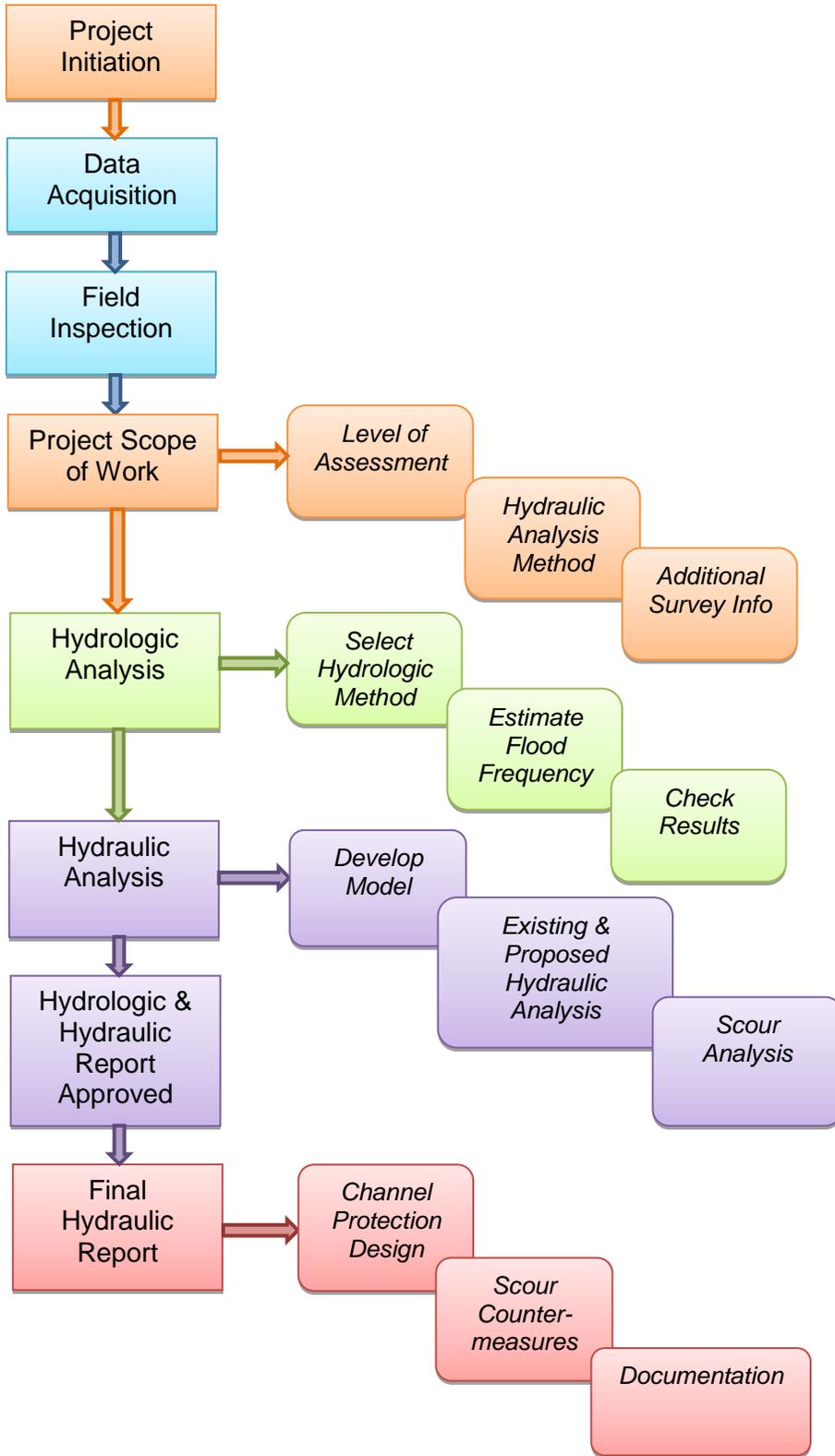
The following reference manuals supplement the *Bridge Design Manual* and the *Manual on Drainage Design for Highways in New Hampshire* by providing technical guidance. It is intended to use the latest edition of the referenced document. The current and archived circulars are located at:

http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm

HDS 2	Highway Hydrology
HDS 3	Design Charts for Open-Channel Flow
HDS 4	Introduction to Highway Hydraulics
HDS 5	Hydraulic Design of Highway Culverts
HDS 6	River Engineering for Highway Encroachments
HDS 7	Hydraulic Design of Safe Bridges
HEC 9	Debris Control Structures Evaluation & Countermeasures
HEC 14	Hydraulic Design of Energy Dissipators for Culverts & Channels
HEC 15	Design of Roadside Channels with Flexible Linings
HEC 17	The Design of Encroachments on Flood Plains Using Risk Analysis;
HEC 18	Evaluating Scour at Bridges
HEC 20	Stream Stability at Highway Structures
HEC 21	Design of Bridge Deck Drainage
HEC 22	Urban Drainage Design Manual
HEC 23	Bridge Scour and Stream Instability Countermeasures Experience, Selection, & Design Guidance
HEC 24	Highway Stormwater Pump Station Design
HEC 25	Highways in the Coastal Environment
HEC 26	Culvert Design for Aquatic Organism Passage

Page intentionally left blank.

BRIDGE HYDRAULIC DESIGN FLOWCHART



Page intentionally left blank.

DATA COLLECTION AND FIELD REVIEW



I. GENERAL PROJECT DATA

Bridge No.: _____
 Town: _____
 Feature carried: _____

Project No: _____
 Feature crossed: _____

Functional class: Tier 1, 2 or 3
 Tier 4 or 5

Year built: _____
 Overall NBIS structure rating: _____
 USGS total scour index: _____

Year Rebuilt: _____
 NBIS Item 113: _____
 Sufficiency rating: _____

Plans available? yes no

II. SUPERSTRUCTURE INFORMATION

Bridge width: _____ (ft)
 Number of spans: _____

Bridge length: _____ (ft)
 Bridge skew: _____ (degrees)

III. HYDROLOGIC AND HYDRAULIC INFORMATION

Watershed area: _____ (sq. mi.) (if available from existing plans or report)

Is it tidally influenced? yes no

What information is available?
 floodway analysis report hydraulic report scour report
 FEMA F.I.S. SCEL analysis comparative report
 Other: _____

Existing Bridge Hydraulic Information (if available):

	Source	2 Yr. Event	10 Yr. Event	50 Yr. Event	100 Yr. Event	500 Yr. Event
Flow rates (cfs)						
Precipitation (in)						
Tidal elevations (ft)						

Elevations (ft.)							
At Structure			Water Surface at Approach Cross Section				
Streambed	Low Chord	Roadway	2 Yr. Event	10 Yr. Event	50 Yr. Event	100 Yr. Event	500 Yr. Event

Pressure flow at design storm? yes underclearance_____(ft.)

Comments: _____

IV. SITE DATA

A. Existing structure(s) – Provide sketch of culvert/structure with dimensions and brief description.

Comments: Include structure or culvert type and condition. Note particularly any scour adjacent to abutments or at culvert outlet and the presence of debris or sediment. Also note the location of any utilities in the area of the crossing.

- B. High water marks – Describe the nature and location of any apparent high water marks and relate to a date of occurrence, if possible.

- C. Maximum allowable headwater – Describe the nature of the apparent controlling feature and note its location.

- D. Fish passage requirements – Comment on the apparent need for fish passage or impediments to same; such as dams or restrictive crossings in the area.

V. PERIPHERAL SITE DATA

- A. Hydraulic control – Note location and description.

- B. Upstream and downstream structures – Provide sketches and brief descriptions of existing bridges/culverts. Include dimensions.

Comments: _____

C. Watershed area – Check watershed boundaries for accuracy. Note current land uses within watershed.

D. Flow control structures within watershed – Note the location and type of all significant flow control structures (dams, etc.) within the watershed. Provide sketches with dimensions as required.

VI. STREAM CHANNEL AND RELATED ASPECTS

A. Stream characterization (completed with Environmental Project Manager)

Twenty Groupings of Stream Characteristics (check box)

	Identifier	Drainage Area	Streambed Slope	Streambed Soils	Land Use
<input type="checkbox"/>	A	Large	Low	SD	S/F
<input type="checkbox"/>	B	Large	Low	SD	Urban
<input type="checkbox"/>	C	Large	Moderate	SD	Forested
<input type="checkbox"/>	D	Medium	Moderate	SD	Urban
<input type="checkbox"/>	E	Medium	Moderate	SD	S/F
<input type="checkbox"/>	F	Medium	Moderate	CLAY	S/F
<input type="checkbox"/>	G	Medium	Moderate	TILL	S/F
<input type="checkbox"/>	H	Medium	Moderate	SD	Forested
<input type="checkbox"/>	I	Medium	Moderate	TILL	Forested
<input type="checkbox"/>	J	Small	Low	SD	Urban
<input type="checkbox"/>	K	Small	Moderate	TILL	Urban
<input type="checkbox"/>	L	Small	Low	SD	S/F
<input type="checkbox"/>	M	Small	Moderate	SD	S/F
<input type="checkbox"/>	N	Small	Moderate	SD	Forested
<input type="checkbox"/>	O	Small	Low	CLAY	S/F
<input type="checkbox"/>	P	Small	Steep	TILL	S/F
<input type="checkbox"/>	Q	Small	Moderate	TILL	S/F
<input type="checkbox"/>	R	Small	Low	TILL	S/F
<input type="checkbox"/>	S	Small	Moderate	TILL	Forested
<input type="checkbox"/>	T	Small	Steep	TILL	Forested

Drainage area Small ≤ 25 mi²
 Medium > 25 mi² and ≤ 100 mi²
 Large > 100 mi²

Streambed slope Low ≤ 25 ft/mi
 Moderate > 25 ft/mi and ≤ 100 ft./mi
 Steep > 100 ft/mi)

Streambed soils SD = Stratified Drift
 Land Use S/F = Suburban or Farming

B. Channel stability

Previous NBIS Item 61 rating: _____

Lateral stability: stable Unstable

Bank erosion:

none light fluvial erosion heavy fluvial erosion mass wasting

Streambed: stable aggradating degrading

Armoring potential: none low moderate high

Geomorphic factors that affect stream stability (circle factors that apply)

STREAM SIZE	Small (< 30 m wide)	Medium (30-150 m)	Wide (> 150 m)		
FLOW HABIT	Ephemeral	(Intermittent)	Perennial but flashy	Perennial	
BED MATERIAL	Silt-clay	Silt	Sand	Gravel	Cobble or boulder
VALLEY SETTING	 No valley; alluvial fan	 Low relief valley (< 30 m deep)	 Moderate relief (30-300 m)	 High relief (> 300 m)	
FLOOD PLAINS	 Little or none (< 2X channel width)	 Narrow (2-10 channel width)	 Wide (> 10X channel width)		
NATURAL LEVEES	 Little or None	 Mainly on Concave	 Well Developed on Both Banks		
APPARENT INCISION	 Not Incised	 Probably Incised			
CHANNEL BOUNDARIES	 Alluvial	 Semi-alluvial	 Non-alluvial		
TREE COVER ON BANKS	<50 percent of bankline	50-90 percent	> 90 percent		
SINUOSITY	 Straight Sinuosity 1-1.05	 Sinuous (1.06-1.25)	 Meandering (1.25-2.0)	 Highly meandering (> 2)	
BRAIDED STREAMS	 Not braided (< 5 percent)	 Locally braided (5-35 percent)	 Generally braided (> 35 percent)		
ANABRANCHED STREAMS	 Not anabranching (< 5 percent)	 Locally anabranching (5-35 percent)	 Generally anabranching (> 35 percent)		
VARIABILITY OF WIDTH AND DEVELOPMENT OF BARS	 Narrow point bars	 Wide point bars	 Irregular point and lateral bars		
	 Equiwidth	 Wider at bends	 Random variation		

Source: Adapted From Brice and Blodgett, 1978

(See also FHWA HEC-20, "Stream Stability at Highway Structures" for discussion of the above factors)

Bank protection

Type	<input type="checkbox"/> none	<input type="checkbox"/> modified	<input type="checkbox"/> intermediate	<input type="checkbox"/> standard
	<input type="checkbox"/> concrete	<input type="checkbox"/> slope paving	<input type="checkbox"/> absent	
	<input type="checkbox"/> other			
Condition	<input type="checkbox"/> n/a	<input type="checkbox"/> good	<input type="checkbox"/> weathered	<input type="checkbox"/> slumped
	<input type="checkbox"/> poor	<input type="checkbox"/> missing	<input type="checkbox"/> fair	

Comment on the need (if any) for training walls, cutoff walls or special slope or channel protection.

C. Channel and overbank roughness coefficients

Basic channel description:

<input type="checkbox"/> channel in earth	<input type="checkbox"/> channel cut into rock
<input type="checkbox"/> channel fine gravel	<input type="checkbox"/> channel coarse gravel

Surface irregularity of channel:

- smooth – best obtainable section for materials involved
- minor – slightly eroded or scoured side slopes
- moderate – moderately sloughed or eroded side slopes.
- severe – badly sloughed banks of natural channels or badly eroded sides of man-made channels - jagged and irregular sides or bottom sections of channels in rock.

Variations in shape and size of cross sections

- changes in size or shape occurring gradually
- large and small sections alternating occasionally or shape changes causing occasional shifting of main flow from side to side.
- large and small sections alternating frequently or shape changes causing frequent shifting of main flow from side to side.

Channel obstructions – Judge the relative effect of obstructions – consider the degree of reduction in the average cross sectional area, the character of obstructions, and the location and spacing of obstructions.

NOTE: Smooth or rounded objects create less turbulence than sharp, angular objects.

The effect of obstructions is:

- negligible
- minor
- appreciable
- severe

Degree of vegetation - note amount and character of foliage.

The effect of vegetative growth upon flow conditions is:

- LOW** - Dense growths of flexible turf grasses where average depth of flow is 2 to 3 times the height of vegetation. Sparse seedling tree switches where the average depth of flow is 3 to 4 times the height of the vegetation.
- MEDIUM** - Turf grasses where the average depth of flow is 1 to 2 times the height of vegetation. Stemmy grasses, weeds, or tree seedlings, (moderate cover), with average depth of flow 2 to 3 times the height of vegetation. Bushy growths (moderately dense) along channel side slopes with no significant vegetation along channel bottom.
- HIGH** - Turf grasses where average height is about equal to the average depth of flow. Willow or Cottonwood trees 8 to 10 years old with some weeds or brush. Bushy growths about 1 year old. No significant vegetation along channel bottom.
- VERY HIGH** - Turf grasses where the average depth of flow is less than one half the height of vegetation. Bushy growths about 1 year old intergrown with weeds. Dense growth of cattails along channel bottom. Trees intergrown with weeds and brush (thick growth).

Additional comments:

VII. HYDRAULIC VULNERABILITY

- | | | | |
|-------------------------------|--|---|--|
| Is there confluence present? | <input type="checkbox"/> yes | <input type="checkbox"/> no | |
| Angle of attack (flood flow): | <input type="checkbox"/> yes | <input type="checkbox"/> no | |
| Bends in channel: | <input type="checkbox"/> upstream of bridge
<input type="checkbox"/> straight channel reach | <input type="checkbox"/> downstream of bridge
<input type="checkbox"/> at bridge | |
| Trapping potential: | <input type="checkbox"/> low | <input type="checkbox"/> medium | <input type="checkbox"/> high |
| Debris potential: | <input type="checkbox"/> low | <input type="checkbox"/> moderate | <input type="checkbox"/> high |
| Overtopping relief: | <input type="checkbox"/> none
<input type="checkbox"/> on bridge | <input type="checkbox"/> left approach
<input type="checkbox"/> relief bridge | <input type="checkbox"/> right approach
<input type="checkbox"/> cannot be determined |

Primary bed material: sand gravel boulders manmade
 silt/clay cobble bedrock

Comments: _____

VIII. VISUAL SCOUR EVIDENCE

USGS observed scour index: _____

History of scour problem: yes no

Comments: _____

Note: Comment should address any evidence of scour at ALL substructure units.

CONTRACTION SCOUR SUSCEPTIBILITY

Channel width upstream: _____ (ft.)
Channel width under bridge: _____ (ft.)
Channel width ratio (channel width upstream / channel width under the bridge): _____

Overbank flow: yes no

Percent of flow in main channel of the approach section:
 >90% 75%-90% 50%-75% 25%-50% <25%

Average bed material size (D50):
@ approach section _____ (in) sample taken for sieve analysis
@ bridge _____ (in) sample taken for sieve analysis

Contraction scour susceptibility rating: low medium high

Comments: _____

ABUTMENT SUSCEPTIBILITY (EXISTING BRIDGE) (if applicable):

Which abutment is worse?: left right

Observed scour depth: _____ (ft) Remaining embedment in river bed: _____ (ft)

Abutment protection:

Type: _____

Condition: good weathered slumped missing
 fair poor N/A

Abutment exposure due to scour:

none no exposure footing exposed piles
 undermining settlement failed

Comments: _____

PIER SUSCEPTIBILITY (EXISTING BRIDGE) (if applicable):

Worst pier number: _____

Observed scour depth: _____ (ft.) Remaining embedment in river bed: _____ (ft)

Pier exposure due to scour: none no exposure footing exposed
 piles exposed undermining settlement

Pier protection:

Type: modified intermediate standard slope paving
 concrete other absent none

Condition: good weathered slumped missing
 fair poor N/A

Comments: _____

MANNING ROUGHNESS COEFFICIENT

Cowan (USGS 1956) published the following relationship for estimating the Manning resistance coefficient: $n=(n_0+n_1+n_2+n_3+n_4)m_5$

Where n_0 is a base n value for a straight, uniform, smooth channel, n_1 is the degree of surface irregularities of the channel, n_2 is the variation of the channel cross section, n_3 is the relative effect of obstructions, n_4 is due to the effect of vegetation and flow conditions, and m_5 relates to the degree of meandering. Table Appendix 2.7-A4-1 is a reproduction of Cowan's summary table taken from Chow (1959). Chow also presented an excellent table listing typical n values for a range of conditions. The minimum, normal, and maximum values of n are shown in Table 2.7-A4-2. A more complete discussion can be found in Chow (1959, pp. 108-113). Table 2.7-A4-1 shows a portion of the table for Natural Streams taken from Chow's *Open-Channel Hydraulics* book.

Manning's roughness coefficient can also be calculated using *USGS Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* located at:

<http://www.fhwa.dot.gov/bridge/wsp2339.pdf>

Values for Computation of Manning Roughness Coefficient (Chow 1959)			
Channel Conditions		Values	
Material involved	Earth	n_0	0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse Gravel		0.028
Degree of irregularity	Smooth	n_1	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Variation of channel cross section	Gradual	n_2	0.000
	Alternating occasionally		0.005
	Alternating frequently		0.010-0.015
Relative effect of obstructions	Negligible	n_3	0.000
	Minor		0.010-0.015
	Appreciable		0.020-0.030
	Severe		0.040-0.060
Vegetation	Low	n_4	0.005-0.010
	Medium		0.010-0.025
	High		0.025-0.050
	Very High		0.050-0.100
Degree of meandering	Minor	m_5	1.000
	Appreciable		1.150
	Severe		1.300

Manning Roughness Coefficient Using Chow Equation

Table 2.7-A4-1

Values of the Manning Roughness Coefficient for Natural Channels.			
Type of channel and description	Minimum	Normal	Maximum
D. Natural Streams			
D-1 Minor stream (top width at flood stage < 100 ft)			
a. Stream on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as above, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.03	0.04	0.05
2. Bottom: cobbles with large boulders	0.04	0.05	0.07
D-2 Flood Plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.05	0.07
2. Light brush and trees, in winter	0.035	0.05	0.06
3. Light brush and trees, in summer	0.040	0.06	0.08
4. Medium to dense brush, in winter	0.045	0.07	0.11
5. Medium to dense brush, in summer	0.070	0.10	0.16
d. Trees			
1. Dense willows, summer, straight	0.11	0.15	0.20
2. Cleared land with tree stumps, no sprouts	0.03	0.04	0.05
3. Same as above, but with heavy growth of sprouts	0.05	0.06	0.08
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.08	0.10	0.12
5. Same as above, but with flood stage reaching branches	0.10	0.12	0.16
D-3 Major streams (top width at flood stage > 100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	up to	0.06
b. Irregular and rough section	0.035	up to	0.10

**Manning Roughness Coefficient
Chow (1959)**

Table 2.7-A4-2

Hydrologic Concept Definitions	
Antecedent Moisture Conditions	Antecedent moisture conditions are the soil moisture conditions of the watershed at the beginning of a storm. These conditions affect the volume of runoff generated by a particular storm event. Antecedent moisture has a rapidly decreasing influence on runoff as the flood recurrence interval becomes longer.
Depression Storage	Depression storage is the volume of the natural depressions within a watershed which store runoff. Generally after the depression storage is filled runoff will commence.
Drainage Area (A)	The area draining into a stream at a given point along the stream.
Frequency	Frequency is the number of times a flood of a given magnitude or greater can be expected to occur on average over a long period of time. Frequency analysis is the estimation of peak discharges for various recurrence intervals. Another way to express frequency is with probability. Probability analysis seeks to define the flood flow with a probability of being equaled or exceeded in any year.
Hydraulic Roughness	Hydraulic roughness is a composite of the physical characteristics which influence the flow of water across the earth's surface, whether natural or channelized. It affects both the time response of a watershed and drainage channel as well as the channel storage characteristics
Hydrograph	The hydrograph is a graph of the time distribution of runoff from a watershed.
Hydrologic Soil Group	A group of soils having the same runoff potential under similar storm and cover conditions.
Hyetographs	The hyetograph is a graph of the time distribution of rainfall over a watershed.
Infiltration	Infiltration is a complex process of runoff penetrating the ground surface and flowing through the upper soil surface. The infiltration curve is a graph of the time distribution at which this occurs.
Interception	Storage of rainfall on foliage and other intercepting surfaces during a rainfall event is called interception storage.
Lag Time	The lag time is defined as the time from the centroid of the rainfall excess to the peak of the hydrograph.

Hydrologic Concept Definitions	
Peak Discharge	The peak discharge, sometimes called peak flow, is the maximum rate of flow of water passing a given point during or after a rainfall or snowmelt event.
Rainfall Excess	The rainfall excess is the water available to runoff after interception, depression storage and infiltration have been satisfied.
Rainfall Intensity (I)	Amount of rainfall occurring in a unit of time, measured in inches per hour.
Recurrence Interval	The average number of years between occurrences of a discharge or rainfall that equals or exceeds the given magnitude.
Runoff (Q)	The part of the precipitation which runs off the surface of a drainage area after all abstractions are accounted for.
Runoff Coefficient	A factor representing the portion of runoff resulting from a unit rainfall, principally dependent on terrain, topography, slope, land use, and soil type.
Time of Concentration	The time of concentration is the time it takes a drop of water falling on the hydraulically most remote point in the watershed to travel through the watershed to the point under investigation.
Ungaged Stream Sites	Locations at which no systematic records are available regarding actual stream flows.
Unit Hydrograph	A unit hydrograph is the direct runoff hydrograph resulting from a rainfall event which has a specific temporal and spatial distribution and which lasts for a unit duration of time. The ordinates of the unit hydrograph are such that the volume of direct runoff represented by the area under the hydrograph is equal to one inch of runoff from the drainage area.

STREAMSTATS FOR NH: PROGRAM INFORMATION

StreamStats is a cooperative effort of the USGS and ESRI, Inc. It is an integrated GIS application that uses ArcIMS , ArcSDE , ArcGIS , and the ArcHydro Tools. It incorporates a map-based user interface for site selection; a Microsoft Access database that contains information for data-collection stations; a GIS program that delineates drainage-basin boundaries and measures physical and climatic characteristics of the drainage basins; and a GIS database that contains land elevation models, historic weather data, and other data needed for measuring drainage-basin characteristics and for locating sites of interest in the user interface.

Streamstats for NH is located at: http://water.usgs.gov/osw/streamstats/new_hampshire.html

Below is a short *summary* of the program. Designers shall read *all* the StreamStats description, user guide, and limitations noted on the program site to confirm its use.

- The reports below present the equations used to estimate the flow statistics, describe the errors associated with the estimates, and describe the methods used to develop the equations and to measure the basin characteristics used in the equations. Users should familiarize themselves with the reports before using StreamStats to obtain estimates of streamflow statistics for ungaged sites.
 - 1) [Olson, S.A., 2009, Estimation of flood discharges at selected recurrence intervals for streams in New Hampshire, U.S. Geological Survey Scientific Investigations Report 2008-5206, 57 p.](#)
 - 2) [Flynn, Robert H., 2003, Development of regression equations to estimate flow durations and low-flow-frequency statistics in New Hampshire streams, U.S. Geological Survey Water-Resources Investigations Report 02-4298, 66 p.](#)
- Flood-frequency and drainage-basin characteristics from 117 streamgages were used in developing the equations (2008). The selection criteria required the streamgage to have a minimum of 10 years of annual peak-discharge data that were free of trends and unaffected by regulation or urbanization. Peak-discharge data from sites that had greater than 4.5 million cubic feet of usable storage per square mile of drainage area were not used. None of the streamgages included in this investigation have drainage basins considered to be urbanized.
- However, a review of the sites reveals that the hundreds of small drainage basins in New Hampshire with drainage areas of less than 15 mi² are poorly represented. Only 12 small drainage basins in New Hampshire had sufficient discharge data for the study, and currently (2008) only one of the streamgages is active. Therefore, streamgages of small drainage basins in States adjacent to New Hampshire were included to compensate for this shortage.
- The U.S. Geological Survey (USGS) and other agencies have been measuring and recording discharge at numerous streamgage sites throughout New Hampshire for the past 100 years.
- In 2008, there were 48 continuously operating streamgages in New Hampshire.
- The primary products delivered by StreamStats:
 - a. Streamflow statistics: Examples include the 100 yr. flood, the mean annual flow, and the 7-day, 10-day low flow.
 - b. Basin characteristics: Examples of basin characteristics include the drainage area, stream slope, mean annual precipitation and percentage of forested area. Basin characteristics are the physical factors that control delivery of water to a point on a stream.

c. Data-collection stations: Station name, identification number, latitude, longitude, and station type.

1) Gaged Streams:

- Data collected at the continuous streamgaging stations and partial-record stations are used to calculate the streamflow statistics for the station.
- “Regulated” indicates if the streamflow at the station is affected by flow regulations or diversions. Possible values are yes, not or undefined.
- The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood discharges for the 117 streamgages (table 1 in back of report) were computed using the guidelines in Bulletin 17B.
- Bulletin 17B recommends fitting the systematic annual peak-discharge data to a log-Pearson Type III probability distribution for estimating flood-discharge magnitude and frequency and provides procedures for weighting station skews, historical peaks, and the detection and treatment of outliers. Software developed by the USGS to analyze flood-discharge frequency, PEAKFQ, was used for these computations.
- Peak discharges affected by dam failure, ice-jam breach, or a similar event are not included in the frequency analyses.

2) Ungaged Streams:

- StreamStats takes flood characteristics from gaged to ungaged sites through use of watershed characteristics.
- A process known as regionalization is used to develop equations that can be used to estimate stream flow statistics for ungaged sites.
- Regionalization involves use of regression analysis to relate streamflow statistics computed for a group of selected streamgaging stations and basin characteristics measure for the stations.
- After StreamStats measures the drainage-basin characteristics, the values are input to a separate program named the USGS [National Flood Frequency Program \(NFF\)](#), which is a Microsoft Windows program that contains all of the USGS-developed equations for estimating flood-frequency statistics in the Nation.
- The regression equations are applicable only to sites on ungaged, unregulated streams in rural New Hampshire basins.
- StreamStats outputs report the uncertainty of the estimates for ungaged basins when basin characteristics for selected sites are within the ranges of the basin characteristics for streamgages that were used to develop the regression equations. Errors for basins with basin characteristics that are beyond these bounds are unknown. The applicable ranges of the basin characteristics are provided in the outputs and messages are provided when basin characteristics are outside of the applicable ranges.

3) Limitations:

- Users are advised to carefully check all results for accuracy and to exercise their own professional judgment in evaluating the appropriateness of the results for their application. *Basin delineations*, in particular, frequently have been found to be erroneous. StreamStats provides tools and base maps useful for verifying the accuracy of the basin delineations and for correcting them, if necessary.

- Estimates obtained by use of the Generate Flow Statistics tool assume natural flow conditions at the ungaged site. If human activities such as *dam regulation* and *water withdrawals* substantially affect the timing, magnitude, or duration of flows at a selected site, the estimates provided by StreamStats should be adjusted by the user to account for those activities.
- Extrapolation occurs when one or more of the basin characteristics needed to solve the applicable regression equations for an ungaged *site are outside the ranges of basin characteristics* for the sites used to develop the regression equations. When extrapolation occurs, StreamStats provides a warning in the output to indicate that the basin characteristics are out of range. StreamStats will provide extrapolated estimates for ungaged sites, as those estimates still are often the best estimates that can be obtained for the site; however, the errors associated with extrapolated estimates are unknown. As a result, StreamStats does not provide indicators of the errors for the estimates.
- Users should carefully evaluate their sites of interest to determine if the available regression equations for that location are suitable for their intended purpose, and if extrapolation is occurring because of a basin characteristic that does not appear in the applicable regression equations for the location. In particular, numerous reports that contain regression equations provide limits to the applicability of the equations based on the percentage of the basin that is either *urbanized* or *regulated*.
- Streamstats Regression Equation
 - Unregulated streams in rural locations
 - $0.7 \text{ square miles} \leq \text{Drainage Area} \leq 1290 \text{ square miles}$
 - $2.79 \text{ inches} \leq \text{Basinwide mean of the average April precipitation} \leq 6.23 \text{ inches}$
 - $0\% \leq \% \text{ wetlands} \leq 21.8\%$
 - $5.43 \text{ ft/mi} \leq \text{Main channel slope} \leq 543 \text{ ft/mi}$
- Streamstats Drainage-Area-Only Regression Equation
 - Unregulated streams in rural locations
 - $0.7 \text{ square miles} \leq \text{Drainage Area} \leq 1290 \text{ square miles}$
 - Less accurate than full regression equations, but can be used with sites that fall outside the limits of one of the other watershed characteristics.

Page intentionally left blank.

Method for Developing Models Compatible with FIS

Models for site covered by officially delineated floodplain (FIS):

When current information and/or estimates of site conditions or flows differ significantly from adopted regulatory information (FIS), it may be necessary to compute the “*duplicate effective model (DEM)*” and the “*corrective effective model*” as noted below:

1) Effective (Regulatory) Existing Conditions Model:

- In the event a FEMA floodplain (or other officially delineated floodplain) is involved, it will be necessary to obtain any available flood profiles, maps, and hydraulic model data. The designer is required to obtain from the Floodplain Administrator (FPA) or FEMA the effective hydraulic model or study data to use for the analysis.
- Sometimes the *effective* hydraulic computer model is not available, or the data are unreadable and therefore unusable. The designer then must obtain any available information from the HEC-2 printout.
- The first step will be to mathematically reproduce the hydraulic model if practicable using the same stepbackwater computer model on which the original floodplain was based to a new HEC-RAS model. The entire length of the model usually does not need to be used; the designer should select the appropriate reach for the analysis. However, the selected reach shall fit seamlessly into the entire model; that is, water surface elevations and velocities must match exactly at both the downstream and upstream ends of the selected reach.
- Older studies that were modeled in HEC-2, WSPRO, or another program should be converted to HEC-RAS. Corrections to the model must be made because of differences in modeling practices, such as the tendency of piers to be modeled as ground points in HEC-2. Differences in programmed algorithms within the software will cause differences in the water surface elevations. The reasons for the differences are explained in detail in a memorandum from FEMA dated April 30, 2001, titled "[Policy of Use for HEC-RAS in the NFIP](#)". FEMA requires that the revised and unrevised Base Flood Elevations (BFE) match within 0.5-ft. at the bounding cross sections between the output of the older model and HEC-RAS.
- Once the new HEC-RAS model meets the allowable differences, the model should be labeled “*Duplicate Effective Model (DEM)*”.

2) Updating Duplicate Effective (DEM) Existing Condition Model:

- The designer should examine the *duplicate effective (DEM)* hydraulic model for errors such as unrealistic or incorrect flows (Q), inaccurate survey data, missing bridges, and bridges where hydraulically inefficient rails were excluded in the model.
- The next step would be to adjust the *duplicate effective* existing conditions model with the most recent survey and detailed bridge data to create or update any natural ground cross sections at locations necessary to subsequently model any proposed construction. Any new model should extend sufficiently downstream and upstream of the crossing to adequately evaluate the conditions. This is typically at least 1000-ft. (305-m) in both directions. It should

be emphasized that any changes made in the *duplicate effective* model should be for the purpose of updating the survey and correcting any observed errors in modeling methodology within the area of the project. This model then becomes the basis for measurement of any changes that would take place as a result of the proposed construction.

- Once the new *duplicate effective* model is updated, the model should be labeled “*Corrected Effective Model (Existing Conditions)*”.

3) Proposed Condition Model:

- The designer should then utilize the *corrected effective* hydraulic model as the base for the proposed conditions model. The model will be modified to include all proposed construction, including the new structure and roadway configuration.
- FEMA allows for encroachment into the fringe floodplain provided that the increase in floodway elevation does not exceed the permissible value provided in the FIS. This allowable increase can be up to 1.0-ft. (0.3m).
- If a “no rise” condition cannot be obtained when encroaching upon a regulatory floodway, the designer may need to apply to FEMA for revisions to the FIS by means of a Conditional Letter of Map Revision (CLOMR).
- Additionally, Municipalities that are mapped by the National Flood Insurance Program (NFSIP) are required to have a floodplain development ordinance. The designer shall check for any Municipality ordinances and confirm the Proposed Conditions Model meets the Municipality regulations.
- See [Chapter 2, Section 2.7.6](#), Hydraulic Analysis for further information on regulations.

FEMA Flood Insurance Studies can be found at: [Flood Insurance Studies](#).

Flood Insurance Studies (FIS) Data Request Form can be found at: <http://www.fema.gov/media-library/assets/documents/7320>



Technical Advisory Evaluating Scour at Bridges

October 28, 1991
T5140.23

PURPOSE To provide guidance on developing and implementing a scour evaluation program for:

1. designing new bridges to resist damage resulting from scour;
2. evaluating existing bridges for vulnerability to scour;
3. using scour countermeasures; and
4. improving the state-of-practice of estimating scour at bridges.

CANCELLATION Technical Advisory T 5140.20, Scour at Bridges, dated September 16, 1988, is cancelled.

BACKGROUND

1. The need to minimize future flood damage to the Nation's bridges requires that additional attention be devoted to developing and implementing improved procedures for designing, protecting and inspecting bridges for scour. (See National Bridge Inspection Standards, 23 CFR 650 Subpart C.) Current information on this subject has been assembled in the Federal Highway Administration (FHWA) design publication Hydraulic Engineering Circular (HEC) 18, "Evaluating Scour at Bridges," FHWA-IP-90-017.
2. Paragraph 4 contains the FHWA recommendations for developing and implementing a scour evaluation program. The recommendations have been developed based on the review and evaluation of the existing policies and guidance pertaining to bridge scour set forth in paragraph 5. The procedures in HEC 18 provide approaches for implementing these recommendations.

RECOMMENDATIONS FOR DEVELOPING AND IMPLEMENTING A SCOUR EVALUATION PROGRAM. Every bridge over a waterway, whether existing or under design, should be evaluated as to its vulnerability to scour in order to determine the prudent measures to be taken for its protection. Most waterways can be expected to experience scour over a bridge's service life (which could approach 100 years). Exceptions might include waterways in massive, competent rock formations where scour and erosion occur on a scale that is measured in centuries. (See HEC 18, Chapter 2.) The added cost of making a bridge less vulnerable to scour is small when compared to the total cost of a failure which can easily be two or three times the original cost of the bridge. Moreover, the need to ensure public safety and to minimize the adverse effects stemming from bridge closures requires the best effort to improve the state-of-practice of designing and maintaining bridge foundations to resist the effects of scour. The recommendations listed below summarize the essential elements which should be addressed in developing a program for evaluating bridges and providing countermeasures for scour. Detailed

guidance regarding approaches for implementing the recommendations is included in HEC 18.

- a. **Interdisciplinary Team.** Scour evaluations of new and existing bridges should be conducted by an interdisciplinary team comprised of hydraulic, geotechnical and structural engineers. (See HEC 18, Chapters 3 and 5.)
- b. **New Bridges.** Bridges over tidal and non-tidal waterways with scourable beds should withstand the effects of scour from a superflood (a flood exceeding the 100-year flood) without failing; i.e., experiencing foundation movement of a magnitude that requires corrective action.

- (1) Hydraulic studies should be prepared for bridges over waterways in accordance with Article 1.3.2 of the Standard Specifications for Highway Bridges of the American Association of State Highway and Transportation Officials (AASHTO) and the floodplain regulation of the FHWA as set forth in 23 CFR 650, Subpart A.

- (2) Hydraulic studies should include estimates of scour at bridge piers and evaluation of abutment stability. Bridge foundations should be designed to withstand the effects of scour without failing for the worst conditions resulting from floods equal to or less than the 100-year flood. (See HEC 18, Chapters 3 and 4.) Bridge foundations should be checked to ensure that they will not fail due to scour resulting from the occurrence of a superflood on the order of magnitude of a 500-year flood. (See HEC 18, Chapter 3.)

- (3) The geotechnical analysis of bridge foundations should be performed on the basis that all stream bed material in the scour prism above the total scour line for the design flood (for scour) has been removed and is not available for bearing or lateral support. In addition, the ratio of ultimate to applied loads should be greater than 1.0 for conditions of scour for the superflood. (See HEC 18, Chapter 3.)

- (4) Data on scour at bridge piers and abutments should be collected and analyzed in order to improve existing procedures for estimating scour. (See HEC 18, Chapter 1.)

- c. **Existing Bridges.** All existing bridges over tidal and non-tidal waterways should be evaluated for the risk of failure from scour during the occurrence of a superflood on the order of magnitude of a 500-year flood. (See HEC 18, Chapter 5.)

- (1) An initial screening process should identify bridges susceptible to scour and establish a priority list for evaluation. (See HEC 18, Chapter 5.)

- (2) Bridge scour evaluations should be conducted for each bridge to determine whether it is scour critical. A scour critical bridge is one with abutment or pier foundations which are rated as unstable due to:

- (a) observed scour at the bridge site or

(b) a scour potential as determined from a scour evaluation study. (See HEC 18, Chapter 5.)

(3) The procedures in Chapter 5 of HEC 18 should be followed in conducting and documenting the results of scour evaluation studies

d. Scour Critical Existing Bridges. A plan of action should be developed for each existing bridge determined to be scour critical. (See HEC 18, Chapter 5.)

(1) The plan of action should include instructions regarding the type and frequency of inspections to be made at the bridge, particularly in regard to monitoring the performance and closing of the bridge, if necessary, during and after flood events. (See HEC 18, Chapter 7.)

(2) The plan of action should include a schedule for the timely design and construction of scour countermeasures determined to be needed for the protection of the bridge. (See HEC 18, Chapter 7.)

e. Bridge Inspectors. Bridge inspectors should receive appropriate training and instruction in inspecting bridges for scour. (See HEC 18, Chapter 6.)

(1) The bridge inspector should accurately record the present condition of the bridge and the stream. At least one cross section at each bridge should be documented and compared with previously recorded cross section(s) at the site. Pier locations and footing elevations should be included.

(2) The bridge inspector should identify conditions that are indicative of potential problems with scour and stream stability.

(3) Effective notification procedures should be available to permit the inspector to promptly communicate findings of actual or potential scour problems to others for further review and evaluation.

(4) Special attention should be focused on the routine inspection of scour critical bridges and on the monitoring and closing as necessary of scour critical and other bridges during and after floods.

f. EXISTING POLICY AND GUIDANCE. The following existing policy and guidance serve as the basis for the recommendations set forth in paragraph 4.

a. AASHTO Standard Specifications for Highway Bridges. The FHWA has accepted these specifications for the design of highway bridges. The 1991 Interim Specifications contain requirements for designing bridges to resist scour. Particular attention is directed to Article 1.3.2, Hydraulic Studies, which advises that, "Hydraulic studies . . . should include applicable parts of the following outline:" Included in this outline is item 1.3.2.3 (b), Estimated scour depth at piers and abutments of proposed structures.

- b. AASHTO Manual for Bridge Maintenance. The FHWA endorses the guidance contained in this 1987 Manual for Bridge Maintenance. Particular attention is directed to the following two statements which support the recommendations contained in this Technical Advisory:

(1) "The primary function of the bridge maintenance program is to maintain the bridges in a condition that will provide for safe and uninterrupted traffic flows. The protection of the investment in the structure facility through well programmed repairs is second only to the safety of traffic and to the structure itself." (p. 25.)

(2) "Determining an effective solution to a stream bed or river problem is difficult. Settlement of foundations, local scour, bank erosion, and channel degradation are complex problems and cannot be solved by one or two prescribed methods. Hydraulic, geotechnical, and structural engineers are all needed for consultation prior to undertaking the solution of a serious maintenance problem. In some cases, certain remedial work could actually be detrimental to the structure." (p. 155.)

- c. AASHTO Manual for Maintenance Inspection of Bridges. The FHWA endorses the guidance provided in the current version of this manual which serves as a standard and provides uniformity in the procedures and policies in determining the physical condition and maintenance needs of bridges. The manual emphasizes the importance of documenting and comparing cross sections taken upstream of bridges over time to discern potential scour problems.
- d. Code of Federal Regulations, 23 CFR 650, Subpart C. The 1989 revision of this FHWA regulation on the National Bridge Inspection Standards requires that bridge owners maintain a bridge inspection program that includes procedures for underwater inspection. This Technical Advisory and HEC 18 provide guidance on the development and implementation of procedures for evaluating bridge scour to meet the requirements of the regulation.
- e. Memorandum From the Director, Office of Engineering, to Regional Federal Highway Administrators and Direct Federal Program Administrator Dated April 17, 1987. This memorandum stated in part, "Each State should evaluate the risk of its bridges being subjected to scour damage during floods on the order of a 100 to 500 year return period or more."
- f. FY 1991 High Priority Research Program of the FHWA. The FHWA recognizes the subject of scour at bridges as a long range high priority national program area for research and recommends that appropriate studies be carried out to improve the state-of-practice of designing new bridges and evaluating existing bridges for scour.

/S/ Original signed by
Thomas O. Willett, Director
Office of Engineering

FINAL HYDRAULIC DESIGN REPORT CHECKLIST

The hydraulic report is intended to serve as a complete documented record containing the engineering justification for all drainage modifications that occur as a result of the project. The primary use of a hydraulic report is to facilitate review of the design and to assist in the preparation of the PS&E. The writer should approach the hydraulic report from the position of its defense in a court of law. It should be clearly written and show conditions before and after construction. The documentation should include all material used in selecting the design, including notes and observations made from the site inspection. The documentation should also include the results of studies of alternatives and reasons for rejecting alternatives. For smaller watershed areas, the degree of report documentation shall be commensurate with the complexity of the associated hydraulic design.

The documentation of a hydrologic & hydraulic analysis is the compilation and preservation of all pertinent information on which the hydrologic & hydraulic decision was based. This might include drainage areas and other maps, field-survey information, source references, photographs, hydrologic calculations, flood frequency analyses, stage-discharge data and flood history, including narratives from highway maintenance personnel and local residents who witnessed or had knowledge of an unusual event. Additionally, the designer should include in the documentation file items which are useful in understanding the analyses, design, findings, and final recommendations.

The following is a checklist of items to be included in the Final Hydraulic Design Report:

- Title Page
 - Reports prepared by a Consultant: the stamp of the professional engineer who prepared or supervised the preparation of the report. The report shall also identify the engineers responsible for preparing and checking the work.
- Table of Contents
- Introduction
 - Project description, including bridge/culvert number, stream name and location of study site
 - Location Map
- Design Criteria
 - Design and check frequencies
 - Freeboard requirements
 - Any other project requirements
- Hydrology Analysis
 - Watershed description, including area, shape, storage, topography, and cover.
 - Stream description
 - Past flooding history, including any information regarding the flood of record with associated high water marks, if available. Describe any unique circumstances which caused or contributed to the flood of record, such as an upstream dam break, high tailwater condition downstream, or debris blockage at the site.

- Hydrologic design methodology.
- Summary of discharges and comparison with FEMA FIS, if available.
- Hydraulic Analysis
 - Discussion on the modeling approach and development, including information about downstream controls.
 - Duplicate Effective Model description (if applicable).
 - Corrected Effective Model description (if applicable).
 - Proposed Conditions Model description, including discussion for each alternative.
 - Comparison of Pre- and Post- construction headwater elevations, velocities, freeboard, and waterway opening.
- Stability and Scour Assessment
 - Channel description
 - Scour analysis discussion (existing and proposed condition)
 - Channel protection discussion
- Conclusion and Recommendations
 - Brief narrative summary of study results.
- References
- Appendices
 - Photographs of the bridge, roadway, and river.
 - Data Collection Form from site visit.
 - Watershed area map.
 - The scale and overall size of this map shall be as required for the watershed under study; the map may accompany the report as a separate item.
 - Watershed map or plan shall include:
 - Watershed boundaries
 - Subarea delineation and areas, if using TR-20 method
 - Existing contours
 - Natural storage areas
 - FEMA FIS information (if available). Include FIS map, profiles, and floodway data.
 - Reports from other agencies (if available).
 - Hydrologic Discharge Calculations.
 - Plan (aerial photo, survey or topo map) showing the location of the Hydraulic Model cross-sections.
 - Duplicate Effective, Corrected Duplicate Effective (if applicable) and Proposed Conditions Model Results. Computer printouts for each model should be in a separate section and should include the following information for, at a minimum, the Ordinary High Water, Design flood and Check flood profiles:

- Channel profile.
 - Cross-section plots (one per sheet) including the bridge section.
 - Computer model report printout showing input data, including the plan data, flow data, geometric data, Manning's n values, reach lengths, contraction and expansion coefficients; and the resulting output, including detailed cross-section table, detailed bridge tables, other detailed output as applicable, and summary tables including Standard Table 1, Six XS Bridge, and others as applicable to the model.
- Bankfull width supporting documents.
 - Scour Analysis.
 - Channel Protection Calculations, with a plan that shows the location of any protection measures.
 - CD of Hydraulic Report and working files for hydrologic and hydraulic analysis.

Page intentionally left blank.

SAMPLE FINAL HYDRAULIC REPORT TABLE OF CONTENTS

TABLE OF CONTENTS	
1.	Introduction.....1.1
1.1	Background.....1.1
1.2	Site Location1.1
2.	Design Criteria.....2.1
2.1	Design Frequency and Freeboard.....2.1
2.2	FEMA Regulatory Compliance2.1
2.3	Designing the Bridge to Resist Scour.....2.1
2.4	Minimizing Impacts on Channel Stability.....2.1
3.	Hydrology3.1
3.1	Drainage Basin Description.....3.1
3.2	River Channel and Floodplain3.1
3.3	Flood History3.2
3.4	Hydrologic Study Approach.....3.2
3.4.1	FEMA FIS Hydrology.....3.4
3.4.2	Hydrologic Method Comparison.....3.4
3.4.3	Selection of Design Flow Rates.....3.5
4.	River Hydraulic Analysis4.1
4.1	General Hydraulic Model Approach4.1
4.2	Existing Bridge4.1
4.2.1	Flow Patterns4.2
4.2.2	Hydraulic Modeling Approach.....4.2
4.2.3	Hydraulic Performance of Existing Bridge4.4
4.3	Proposed Bridge.....4.4
4.3.1	Alternative Selection.....4.4
4.3.2	Proposed Bridge Geometry4.5
4.3.3	Hydraulic Modeling Approach.....4.5
4.3.4	Hydraulic Performance of Proposed Conditions4.6
4.3.5	Comparison of Water Surface Profiles for FEMA Compliance4.6
5.	Stability and Scour Assessment.....5.1
5.1	Channel Description.....5.1
5.2	Scour Assessment5.1
5.2.1	Degradation Potential.....5.1
5.2.2	Lateral Migration Potential.....5.1
5.2.3	Contraction Scour5.2

TABLE OF CONTENTS (continued)

5.2.4	Abutment Scour	5.2
5.2.5	Pier Scour	5.2
5.2.6	Total Potential Scour	5.3
5.2.7	Scour Resistance of the Underlying Bedrock.....	5.3
5.3	Foundation and Countermeasure Recommendations.....	5.4
5.3.1	Scour Countermeasures.....	5.5
5.3.2	Channel Protection	5.6
6.	References	6.1
APPENDIX A	– Photographs	--
APPENDIX B	– Data Collection Form	--
APPENDIX C	– Watershed Area Map	--
APPENDIX D	– FEMA FIS	--
APPENDIX E	– Hydrology Documentation.....	--
APPENDIX F	– Plan of Hydraulic Model.....	--
APPENDIX G	– HEC-RAS Input and Output.....	--
APPENDIX H	– Bankfull Width Supporting Documents.....	--
APPENDIX I	– Detailed Scour Calculations	--
APPENDIX J	– Countermeasure Design	--
APPENDIX K	– Channel Protection Calculations.....	--

TS&L Tasks - Cont.	Y	N	N/A	Designer Checker Reviewer	DATE
TS&L Narrative Report Cont.					
o Type of superstructure				Comments:	
o Type of bents & location					
o Alternate structure types considered and estimated costs					
o Phase construction & detour requirements.					
• <i>Design Concepts (decision/assumptions):</i>					
o Building a new bridge vs. widening existing one					
o Use a bridge vs. culvert					
o Foundation support assumptions					
o Assumed foundation bearing capacity loads					
o Seismic load assumptions					
• <i>Environmental Assessment</i>					
Considerations (applies to many bridge replacements):					
o Project timing and chronology					
o In-Water Work Period					
o Environmental concerns					
o Invasive species					
o Alignment and size of the new bridge in relation to the existing (e.g., no. of spans, length)					
o Type of new deck and construction methods					
o Proposed treatment of the runoff					
o Number & sizes of bents/footings added for new bridge w/in OHWM and the wetted channel. Discuss construction of new footings, bents & piles.					
o Type of water diversion methods used during construction (e.g., cofferdam)					
o If a detour bridge is required, how many bents & types of temporary supports that may be within the OHWM and wetted channel. Discuss the construction & removal methods that might be used.					
o Extent and duration of in-water work (e.g., heavy machinery in wetted channel)					
o Amount or extent of fill or rip-rap					

Page intentionally left blank.

SLOPE-INTERCEPT METHOD

Slope-Intercept Method Formula:

Bridge Cost = [(Bridge Length for Estimating) x (Bridge width) x (Estimated Square Foot (square meter) Cost)] + (Additive Costs).

Bridge Length for Estimating:

1) For Overpasses:

$$L = \text{SPAN} + \left(\frac{(2 \times \text{slope}) \times (\text{finished grade overpass to finished grade underpass})}{\cos(\text{skew})} \right)$$

Slope Intercept Height, H

2) For Stream Crossings:

$$L = \text{SPAN} + \left(\frac{(2 \times \text{slope}) \times (\text{finished grade overpass to top of stone elev. at face of abut.})}{\cos(\text{skew})} \right)$$

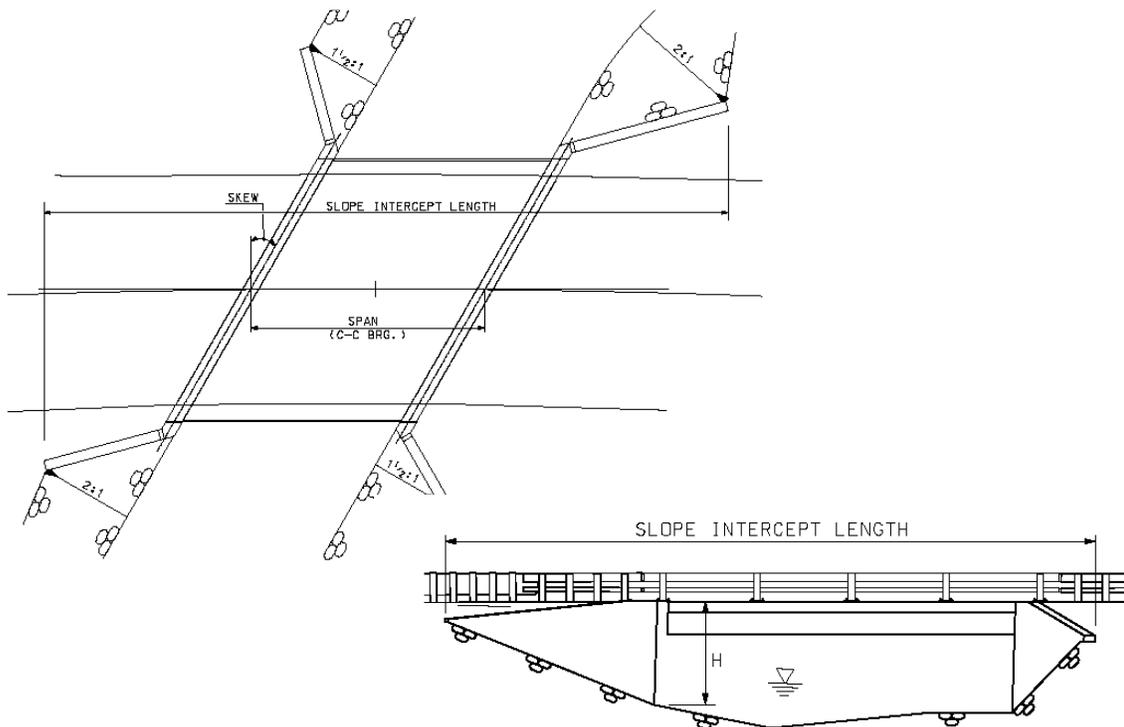
Slope Intercept Height, H

slope value examples: 1.5 for 1.5:1 slope, 2 for 2:1 slope

SPAN = c. to c. of bearings measured along centerline of construction.

skew angle = angle formed between a line perpendicular to the centerline of roadway and the centerline of abutment.

Note: See Chapter 1, Section 1.4 for which items to include and exclude in the slope-intercept cost.



Page intentionally left blank.

Town	Project No.	Road	Feature Crossed	Bridge No.	Ad. Year	Slope Intercept Cost (\$/sf)	Slope Intercept Area (sf)	Span (ft)	Bridge Type	Project Type
Dublin-Peterborough	22092	NH101	GOLD MINE ROAD	196/065	2012	\$50.00	2082	43.875	CA	Rehabilitation
Ossipee	23820	NH16	PINE RIVER	238/112	2013	\$50.00	1144	22	CACUL	Rehabilitation
BEDFORD - MANCHESTER - LOND	11512J	MAAR RAMPS H & J	SOMERVILLE DRIVE	206/086	2009	\$90.89	8390	36	CACUL	New Bridge
SALEM TO MANCHESTER	14633H	I-93 NB	Cohas Brook (culvert)	200/143	2016	\$37.00	17942	30.8	CB	Rehabilitation
SALEM TO MANCHESTER	14633H	I-93 SB	Cohas Brook (culvert)	179/126	2016	\$10.00	51090	40.7	CB	Rehabilitation
SALEM TO MANCHESTER	14633H	I-93/I-293 EB	Cohas Brook (culvert)	179/125	2016	\$10.00	12568	43.8	CB	Rehabilitation
SALEM TO MANCHESTER	14633H	I-93 NB/I-293 WB	Cohas Brook (culvert)	179/128	2016	\$10.00	30673	40.5	CB	Rehabilitation
SALEM TO MANCHESTER	14633B	I-93 NB & SB	Recreation Trail	102/145	2015	\$55.00	11088	12	CB	New Bridge
Epsom-Northwood	28356	US 4, US202, NH 9	Pedestrian Underpass	086/090	2014	\$110.00	1130	69	CB	Rehabilitation
ALSTEAD	14540M	NH 123	Warren Brook	120/123	2011	\$85.00	4498	14	CB	New Bridge
SALEM TO MANCHESTER	13933D	I-93 SB	Porcupine Brook	071/070	2010	\$25.00	7110	12	CB	Rehabilitation
SALEM TO MANCHESTER	13933D	I-93 NB	Porcupine Brook	076/065	2010	\$25.00	6952	14	CB	Rehabilitation
ROCHESTER	10620H	SP. TPK. RECONSTRUCTION	AXE HANDLE BROOK	147/099	2009	\$25.00	23098	26	CB	New Bridge
BELMONT-LACONIA	40423	NH 106	US 3 and NH 11	132/027	2016	\$49.00	3680	57.0	CRF	Preservation
WESTMORELAND	15867	NH 12	WHITE BRIDGE BROOK	167/122	2013	\$75.00	796	24	CRF	Rehabilitation
Ossipee	23820	NH 16	PINE RIVER	232/121	2013	\$80.00	1100	25	CRF	Rehabilitation
NEWINGTON - DOVER	11238M	Spaulding Turnpike NB & SB	Shattuck Way	103/124	2012	\$86.49	8282	42	CRF	Rehabilitation
ROCHESTER	10620H	SP. TPK. RECONSTRUCTION	WALNUT STREET (NH 202A)	128/089	2009	\$60.00	22497	58.667	CRF	Replacement
WESTMORELAND	15867	NH 12	MILL BROOK	163/124	2013	\$95.00	700	22	CS	Rehabilitation

Friday, August 24, 2018

<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost (\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>
WESTMORELAND	15867	NH 12	MILL BROOK	145/131	2013	\$80.00	1240	37.71	CS	Rehabilitation
ALSTEAD	14540M	NH 123	Warren Brook	107/130	2011	\$165.00	1953	27.7	CS	Replacement
EPSOM	15266	NH 107	GRIFFIN BROOK	160/111	2010	\$290.00	1495	18.9	CS	Replacement
ANDOVER-DANBURY	41298	US 4	BLACKWATER RIVER	120/092	2017	\$50.00	1695	60.0	CTB	Preservation
BELMONT-LACONIA	40423	NH 106	TIOGA RIVER	113/080	2016	\$34.00	1892	41.3	CTB	Preservation
WENTWORTH	15908	NH 25 & 118	Baker River	146/120	2012	\$65.00	7139	94.5	DPG	Rehabilitation
KEENE - SWANZEY	10309P	MULTI-USE TRAIL	NH RTES 12 & 101	128/061	2015	\$410.00	3670	340	HT	New Bridge
CHARLESTOWN, NH - SPRINGFIELD	29801	NH 11	CONNECTICUT RIVER	135/052	2015	\$50.00	10702	500	HT	Rehabilitation
CONWAY	15864	US 302	Conway Lake Outlet	158/137	2018	\$208.00	8046	120.0	IB-C	Replacement
ANDOVER-DANBURY	41298	NH 11	PLEASANT STREAM	044/088	2017	\$50.00	4160	100.0	IB-C	Preservation
EAST KINGSTON	26942	NH 107A	BMRR, ROAD	061/064	2017	\$308.00	3842	119.4	IB-C	Rehabilitation
PORTSMOUTH	13455D	Woodbury Ave	US 1 Bypass	205/116	2017	\$150.00	11751	110.0	IB-C	Replacement
PORTSMOUTH	13455D	Stark Street	US 1 Bypass	211/114	2017	\$185.00	6900	110.0	IB-C	Replacement
BELMONT-LACONIA	40423	US and NH 11	NH 107	136/027	2016	\$35.00	6970	132.0	IB-C	Preservation
SALEM TO MANCHESTER	14633H	I-93 NB	Bodwell Road	185/132	2016	\$33.00	23429	141.5	IB-C	Rehabilitation
SALEM TO MANCHESTER	14633H	I-93 SB	Bodwell Road	185/131	2016	\$25.00	36693	155.4	IB-C	Rehabilitation
SALEM TO MANCHESTER	14633D	I-93 NB	Kendall Pond Road	054/067	2016	\$51.00	13843	105.8	IB-C	Rehabilitation
SALEM TO MANCHESTER	14633D	I-93 SB	Kendall Pond Road	054/066	2016	\$52.00	13568	104.3	IB-C	Rehabilitation
SALEM TO MANCHESTER	14633H	I-93 NB	Cochas Brook	187/134	2016	\$37.00	22631	146.0	IB-C	Rehabilitation

Friday, August 24, 2018

<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost (\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>
NORTHFIELD - TILTON	16147	I-93 NB	Winnepesaukee River	118/158	2016	\$131.00	13568	328.3	IB-C	Rehabilitation
NORTHFIELD - TILTON	16147	I-93 SB	Winnepesaukee River	117/157	2016	\$123.00	16474	336.2	IB-C	Rehabilitation
STEWARTSTOWN	16312	NH145	BISHOP BROOK	122/115	2016	\$287.00	3165	50.0	IB-C	Replacement
SALEM TO MANCHESTER	14633D	NH102	I-93 NB & SB	149/106	2016	\$155.00	62039	350	IB-C	Replacement
SALEM TO MANCHESTER	14633D	Ash Street	I-93 NB & SB	140/119	2016	\$233.00	17264	308	IB-C	Replacement
SALEM TO MANCHESTER	14633B	I-93 SB	Fordway Extension	065/059	2015	\$39.00	18261	115.59	IB-C	Rehabilitation
SALEM TO MANCHESTER	14633B	I-93 NB	Fordway Extension	065/060	2015	\$40.00	18839	122.583	IB-C	Rehabilitation
CANAAN	28335	US 4	MASCOMA RIVER	103/049	2015	\$155.00	3568	112	IB-C	Rehabilitation
KEENE	16152	NH 9 & NH 10	Elm Street	129/099	2015	\$65.00	11463	71.25	IB-C	Rehabilitation
JEFFERSON	16153	US 2	Israel River	046/178	2015	\$63.00	16523	160	IB-C	Rehabilitation
HOOKSETT	29494	Access Rd over Ramp "C"		072/136	2015	\$265.00	1753	63.5	IB-C	Rehabilitation
MILTON	40422	APPLEBEE ROAD	BRANCH RIVER	102/120	2015	\$45.00	5960	125	IB-C	Rehabilitation
NEW IPSWICH	14465	NH 123 & 124	SOUHEGAN RIVER	157/093	2014	\$252.00	6503	160	IB-C	New Bridge
NEWINGTON - DOVER	11238O	Spaulding Tumpke NB	Little Bay	201/025	2014	\$120.06	116892	1588	IB-C	Rehabilitation
GILFORD	15903	US 3, NH 11 BYPASS	NH 11A	160/053	2014	\$450.00	3496	76	IB-C	Rehabilitation
NORTHUMBERLAND, NH - GUILDH/28454		GUILDHALL ROAD	CONNECTICUT RIVER	141/059	2014	\$60.00	10850	310	IB-C	Rehabilitation
HOOKSETT	28435	MAIN STREET	ROAD, BMRR, MERRIMACK RIVER	060/148	2014	\$65.00	22950	675	IB-C	Rehabilitation
Wilton	16128	NH 31	Souhegan River	129/126	2014	\$75.00	10223	76.74	IB-C	Rehabilitation
LEBANON, NH - HARTFORD, VT	14957	US 4	Connecticut River	056/128	2013	\$210.00	25463	444	IB-C	New Bridge

Friday, August 24, 2018

Town	Project No.	Road	Feature Crossed	Bridge No.	Ad. Year	Slope Intercept Cost (\$/sf)	Slope Intercept Area (sf)	Span (ft)	Bridge Type	Project Type
WINCHESTER - SWANZEY	12906	NH 10	ASHUELOT RIVER	151/181	2013	\$225.00	9147	225	IB-C	New Bridge
Milton-Wakefield	23817	NH 16	BRANCH RIVER	285/063	2013	\$75.00	2959	66	IB-C	Rehabilitation
KEENE	22272	NH 9, NH 10, NH 12	WEST STREET	120/076	2013	\$155.00	3810	84.67	IB-C	Rehabilitation
KEENE	22272	NH 9, NH 10	ASHUELOT RIVER	121/093	2013	\$45.00	14760	240	IB-C	Rehabilitation
KEENE	22272	NH 9, NH 10	NH 12	115/089	2013	\$40.00	9690	152	IB-C	Rehabilitation
MANCHESTER	14966	I-293 FEET SPUR	SO. BRANCH PISCATAQUOG R.	146/065	2013	\$105.00	8206	211	IB-C	Rehabilitation
NORTH HAMPTON	15848	NH 111	I-95	081/093	2013	\$59.00	20111	291.5	IB-C	Rehabilitation
MANCHESTER	14966	I-293 FEET	SO. BRANCH PISCATAQUOG R.	145/065	2013	\$105.00	41552	193	IB-C	Replacement
MANCHESTER	14966	I-293 FEET	NO. BRANCH PISCATAQUOG R.	143/066	2013	\$90.00	35301	128	IB-C	Replacement
MANCHESTER	14966	I-293 RAMP	I-293 FEET	152/062	2013	\$180.00	9989	240	IB-C	Replacement
PORTSMOUTH	13455B	Middle Road (NH 33)	US 1 Bypass	183/087	2013	\$120.00	8125	134	IB-C	Replacement
PORTSMOUTH	13455B	Islington Street	US 1 Bypass	188/097	2013	\$120.00	7996	134	IB-C	Replacement
PORTSMOUTH	13455C	Maplewood Ave	US 1 Bypass	227/112	2013	\$145.00	13038	130	IB-C	Replacement
NEWINGTON - DOVER	11238M	Woodbury Avenue	Spaulding Turnpike NB & SB	114/107	2012	\$160.88	28269	259	IB-C	New Bridge
Keene	22293	NH 12/NH101	ASHUELOT RIVER	132/060	2012	\$85.00	5280	120	IB-C	Rehabilitation
ANDOVER	15901	NH 11	Blackwater River	050/093	2012	\$130.00	10920	120	IB-C	Rehabilitation
GREENLAND	16267	OCEAN ROAD	I-95	141/109	2012	\$100.00	14484	267	IB-C	Rehabilitation
TILTON	16187	NH140	WINNIPESAUKEE RIVER	109/062	2012	\$113.83	5312	128	IB-C	Rehabilitation
WENTWORTH	15908	NH 25 & 118	Baker River	146/090	2012	\$130.00	13280	200	IB-C	Rehabilitation

Friday, August 24, 2018

<u>Slope Intercept Bridge Costs by: Bridge Type, Ad. Year, & Project Type</u>												
<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost (\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>		
WENTWORTH	15908	NH 25 & 118	Baker River (North Branch)	166/059	2012	\$20.00	20196	218	IB-C	Rehabilitation		
SEABROOK	15769	NH 107	I-95	096/120	2012	\$100.00	23714	218	IB-C	Rehabilitation		
PORTSMOUTH	13455A	US 1 SB	US 1 Bypass	173/071	2012	\$9.00	7553	177	IB-C	Removal		
SALEM TO MANCHESTER	13933E	I-93 NB	Pelham Road (NH 97)	071/080	2012	\$121.57	18014	150	IB-C	Replacement		
SALEM TO MANCHESTER	13933E	I-93 SB	Pelham Road (NH 97)	067/077	2012	\$119.63	18014	150	IB-C	Replacement		
ROLLINSFORD, NH - SOUTH BERM	14241	NH 4	SALMON FALLS RIVER	116/086	2011	\$67.00	13629	160	IB-C	Rehabilitation		
SALEM TO MANCHESTER	13933N	I-93 SB	NH 111-A	136/090	2011	\$130.00	20754	125	IB-C	Replacement		
SALEM TO MANCHESTER	13933N	I-93 SB	NH 111	137/102	2011	\$155.00	48493	400	IB-C	Replacement		
NEWINGTON - DOVER	11238L	Spaulding Turnpike SB	Little Bay	201/024	2010	\$240.46	120384	1639	IB-C	New Bridge		
NEWINGTON - DOVER	11238L	Pedestrian Access to GSB	Hilton Park	196/024	2010	\$365.00	3597	125	IB-C	New Bridge		
MANCHESTER - HOOKSETT	14604	I-93 NB	NH RTE 3A	076/079	2010	\$60.00	9625	134	IB-C	Rehabilitation		
MANCHESTER - HOOKSETT	14604	I-93 NB	MERRIMACK RIVER	059/067	2010	\$160.00	54310	821	IB-C	Rehabilitation		
THORNTON	15906	Cross Road	Pemigewasset River	175/076	2010	\$110.00	18005	412	IB-C	Rehabilitation		
MILTON	15905	NH 125	NH Northcoast RR	212/128	2010	\$190.00	4601	146	IB-C	Rehabilitation		
WINCHESTER	15881	NH 119	ASHUELOT RIVER	113/077	2010	\$90.00	7654	189	IB-C	Rehabilitation		
ROCHESTER	10620J	SP, TPK, RECONSTRUCTION	CHESTNUT HILL CONNECTOR	095/097	2010	\$76.00	32828	103	IB-C	Replacement		
ROCHESTER	10620L	SPAULDING TURNPIKE	TEN ROD RD	117/086	2010	\$75.00	37285	112	IB-C	Replacement		
SALEM TO MANCHESTER	13933D	I-93 SB	Lowell Road (NH 38)	076/063	2010	\$108.00	15768	126	IB-C	Replacement		
SALEM TO MANCHESTER	14633F	I-93 SB	NH 28	098/161	2010	\$114.02	20622	170.5	IB-C	Replacement		

Friday, August 24, 2018

<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost./(\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>
SALEM TO MANCHESTER	14633F	I-93 NB	NH 28	099/161	2010	\$118.07	19767	170.5	IB-C	Replacement
ENFIELD	12967	MAIN ST	MASCOMA LAKE	078/139	2010	\$200.00	15822	340	IB-C	Replacement
SALEM TO MANCHESTER	13933D	I-93 NB	Lowell Road (NH 38)	079/063	2010	\$109.00	16094	126	IB-C	Replacement
SALEM TO MANCHESTER	13933F	Brookdale Road	I-93 NB & SB	060/088	2010	\$161.00	10926	310	IB-C	Replacement
ROCHESTER	10620I	EXIT 15 SB OFF-RAMP (RAMP W)	COCHECO RIVER BACKWATER	107/090	2009	\$252.00	8253	224	IB-C	New Bridge
BEDFORD - MANCHESTER - LOND 11512F		AIRPORT ACCESS ROAD	US3	203/083	2009	\$87.74	30398	139.333	IB-C	New Bridge
ROCHESTER	10620I	SPAULDING TURNPIKE	B & M RAILROAD	103/094	2009	\$86.00	16267	40	IB-C	Replacement
ROCHESTER	10620I	NH 11	SPAULDING TURNPIKE	109/090	2009	\$103.00	37497	189	IB-C	Replacement
ROCHESTER	10620H	SP. TPK. RECONSTRUCTION	US 202	139/094	2009	\$110.00	40836	147	IB-C	Replacement
ROCHESTER	10620I	SPAULDING TURNPIKE	CHESTNUT HILL RD	102/096	2009	\$95.00	16867	67	IB-C	Replacement
ROCHESTER	10620I	SPAULDING TURNPIKE	COCHECO RIVER (NORTH)	106/092	2009	\$210.00	18500	140.5	IB-C	Replacement
DOVER	13042	NH 9	B&M RAILROAD	109/106	2009	\$155.00	8492.725	122.672	IB-C	Replacement
HANCOCK	13778	NH 137	MOOSE BROOK	138/110	2008	\$178.00	1960	68	IB-C	Rehabilitation
LISBON	14464	US 302	AMMONOOSUC RIVER	094/114	2008	\$80.00	12876		IB-C	Rehabilitation
MERRIMACK	12105	FEET NB & SB	SOUHEGAN RIVER	111/115	2008	\$80.00	48058	224	IB-C	Rehabilitation
SALEM TO MANCHESTER	13933K	I-93 NB	NH 111-A	137/092	2008	\$60.00	44304	132	IB-C	Replacement
SALEM TO MANCHESTER	14633I	I-93 SB	Stonehenge Road	113/143	2016	\$115.00	11584	67.0	NEBT	Rehabilitation
SALEM TO MANCHESTER	14633I	I-93 NB	Stonehenge Road	114/144	2016	\$119.00	12858	69.0	NEBT	Rehabilitation
NEWINGTON - DOVER	11239Q	US 4	Spaulding Turnpike NB & SB	182/038	2016	\$167.00	26668	191.2	NEBT	Replacement

Friday, August 24, 2018

<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost (\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>
SALEM TO MANCHESTER	14633B	I-93 NB	North Lowell Road	105/142	2015	\$85.00	24327	90.5833	NEBT	Rehabilitation
SALEM TO MANCHESTER	14633B	I-93 SB	North Lowell Road	104/142	2015	\$85.00	22667	90.5	NEBT	Rehabilitation
SALEM TO MANCHESTER	14633F	I-93 SB	Recreation Trail	095/164	2010	\$115.00	18842	91.0833	NEBT	Replacement
SALEM TO MANCHESTER	14633F	I-93 NB	Recreation Trail	096/164	2010	\$120.00	19542	91.0833	NEBT	Replacement
SALEM TO MANCHESTER	14633E	I-93 SB off-ramp	Railroad Corridor	094/164	2008	\$200.00	6793	99.3333	NEBT	New Bridge
SALEM TO MANCHESTER	14633E	I-93 NB on-ramp	Railroad Corridor	098/164	2008	\$216.00	7270	99.33	NEBT	Replacement
TAMWORTH	16239	NH 113	Bearcamp River	150/106	2017	\$350.00	5164	133.0	PBB	Replacement
ALSTEAD	14541K	NH 123	COLD RIVER	059/160	2008	\$186.00	5027	90	PBB	Replacement
HAMPTON FALLS - HAMPTON	13408B	I-95 SB	TAYLOR RIVER	120/103	2015	\$360.00	5590	74	PSC	Replacement
HAMPTON FALLS - HAMPTON	13408B	I-95 NB	TAYLOR RIVER	121/103	2015	\$340.00	6584	74	PSC	Replacement
SALEM TO MANCHESTER	14633D	I-93 NB	Beaver Brook	051/071	2016	\$155.00	12969	75	PTB	Replacement
SALEM TO MANCHESTER	14633D	I-93 SB	Beaver Brook	159/099	2016	\$158.00	10789	75	PTB	Replacement
LEBANON	25784	I-89 NB	Hardy Hill Road	156/117	2015	\$34.00	13918	40	PTB	Rehabilitation
ASHLAND	16237	US 3 & NH 25	Owl Brook	107/094	2015	\$192.00	4881	60	PTB	Rehabilitation
LEBANON	25784	I-89 SB	Hardy Hill Road	155/117	2015	\$34.00	13918	40	PTB	Rehabilitation
MANCHESTER	14966	I-293/FEET	SPUR D	149/062	2013	\$115.00	22798	63	PTB	Replacement
ACWORTH	16301	NH Route 123A	Bowers Brook	113/064	2017	\$336.00	1872	36.0	PVS	Replacement
RYE	13269	NH 1A	SEAVEY'S CREEK	252/156	2008	\$185.00	7335	160	TB	Replacement
ANDOVER-DANBURY	41298	US 4	NHRR(ABD)	178/091	2017	\$50.00	2995	100.0	TPG	Preservation

Friday, August 24, 2018

Town	Project No.	Road	Feature Crossed	Bridge No.	Ad. Year	Slope Intercept Cost (\$/sf)	Slope Intercept Area (sf)	Span (ft)	Bridge Type	Project Type
CLARKSVILLE	16183	US Route 3	Connecticut River	030/066	2011	\$85.00	5136	214	TPG	Rehabilitation
THORNTON-WOODSTOCK	40404	I-93 NB	Mirror Lake Rd	202/034	2016	\$4.75				Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202W	PORTSMOUTH STREET	153/149	2016	\$56.45	4708	121.5		Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202E	PORTSMOUTH STREET	154/150	2016	\$56.38	4708	121.5		Preservation
CONCORD-PEMBROKE	40405	I-393 WB RAMP	NH 9	045/084	2016	\$33.00	4266	150.0		Preservation
THORNTON-WOODSTOCK	40404	I-93 NB	US 3 & B&M RR	203/064	2016	\$37.25				Preservation
THORNTON-WOODSTOCK	40404	I-93 SB	Merrill Rd	173/064	2016	\$34.50				Preservation
THORNTON-WOODSTOCK	40404	I-93 NB	Merrill Rd	173/066	2016	\$34.50				Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202W	HORSE CORNER ROAD	050/081	2016	\$43.00	3024	66.0		Preservation
THORNTON-WOODSTOCK	40404	I-93 SB	US 3 & B&M RR	202/064	2016	\$27.78				Preservation
WALPOLE, NH - WESTMINSTER, V	40070	NH123	CONNECTICUT RIVER	132/062	2016	\$24.00	22001			Preservation
THORNTON-WOODSTOCK	40404	I-93 SB	US 3	243/076	2016	\$22.25				Preservation
THORNTON-WOODSTOCK	40404	I-93 NB	US 3	243/077	2016	\$22.00				Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202E	HORSE CORNER ROAD	051/081	2016	\$43.50	2556	65.8		Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202E	SOU COOK RIVER	162/184	2016	\$21.00	17346	405.0		Preservation
CONCORD-PEMBROKE	40405	I-393,US 4,US202W	SOU COOK RIVER	161/184	2016	\$17.65	16318	390.0		Preservation
THORNTON-WOODSTOCK	40404	I-93 SB	Mirror Lake Rd	201/034	2016	\$4.75				Preservation
Raymond	40458	PRESCOTT RD	NH 101	161/105	2015	\$27.00	8382	234		Rehabilitation
LISBON	29774	US302,NH 10	NHRR(ABD)	094/112	2015	\$115.00	2772	57		Rehabilitation

Friday, August 24, 2018

<u>Slope Intercept Bridge Costs by: Bridge Type, Ad. Year, & Project Type</u>										
<u>Town</u>	<u>Project No.</u>	<u>Road</u>	<u>Feature Crossed</u>	<u>Bridge No.</u>	<u>Ad. Year</u>	<u>Slope Intercept Cost (\$/sf)</u>	<u>Slope Intercept Area (sf)</u>	<u>Span (ft)</u>	<u>Bridge Type</u>	<u>Project Type</u>
CANDIA-RAYMOND	28903	GREEN STREET	NH101	076/096	2014	\$30.00	9572	268		Rehabilitation
CANDIA-RAYMOND	28903	OLD MANCHESTER RD	NH101	112/099	2014	\$35.00	17746	228		Rehabilitation
CANDIA-RAYMOND	28903	DEPOT ROAD	NH101	172/064	2014	\$25.00	8382	234		Rehabilitation
LINCOLN	15755	I-93 SB	Hanson Brook	171/092	2013	\$21.00	4277	86		Rehabilitation
LINCOLN	15755	I-93 SB	Ramp 3S-F	140/102	2013	\$30.00	3800	94		Rehabilitation
MILAN	16182	Bridge Street	Androscoggin River	201/097	2011	\$65.00	6480	270		Rehabilitation

Friday, August 24, 2018

Page intentionally left blank.

		BRIDGE TYPE ABBREVIATIONS	
BAIB	Bailey or similar bridge	Jack	Jack Arch Concrete on I-Beams
BAS	Bascule Span	LIFT	Vertical Lift
BGB	Beam Girder Bridge	LT	Low Truss
CA	Concrete Arch	MA	Masonry Arch
CACUL	Concrete Arch Culvert	MA-CA	Masonry and Conc. Arch
CAR	Concrete Arch Rib	MP	Metal Pipe
CB	Concrete Box	MP-A	Metal Plate Arch
CG	Concrete Girder	MP-B	Metal Plate Box Culvert
CP	Concrete Pipe	MS	Masonry Slab
CPP	Corrugated Polymer Pipe	NEBT	Prestressed Bulb Tee
CRF	Concrete Rigid Frame	PBB	Prestressed Butted Boxes
CRF-P	Concrete Rigid Frame-Precast	PIB	Prestressed I-Beams
CS	Concrete Slab	PSB	Prestressed Spread Boxes
CTB	Concrete Tee Beam	PSC	Prestressed Concrete
CTC	Concrete Timber Composite	PTB	Prestressed Tee Beams
DPG	Deck Plate Girder	PVS	Prestressed Voided Slabs
DT	Deck Truss	SA	Steel Arch
HT	High Truss	SRF	Steel Rigid Frame
IB	I Beams without deck	SWING	Swing Bridge
IB-BP	I Beams w/ Bridge Plank	TB	Timber Bridge
IB-C	I Beams w/ Concrete Deck	TB-C	Covered Bridge
IB-G	I Beams w/ Steel Grid	TB-CS	Timber Bridge Conc. Slab
IB-S	I Beams w/ Steel Plate	TPG	Thru Plate Girder
IB-W	I Beams w/ Wood Deck	TS	Timber Slab
INVER	Inverset I-Beam/Concrete	TS-P	Prestressed Timber Slab

Page intentionally left blank.

STATE OF NEW HAMPSHIRE
INTER-DEPARTMENT COMMUNICATION

FROM William Saffian
Project Engineer

DATE November 12, 2008
AT (Office) Bridge Design

SUBJECT **EPSOM 15266**
NH ROUTE 107 over GRIFFIN BROOK
Boring/Rock Core and Geotechnical Report Request

TO Chuck Dusseault, P.E.
Geotechnical Chief
Bureau of Materials and Research

SAMPLE

Transmitted herewith are the following for the subject bridge:

1. General Plan with Bridge Boring Locations and without Boring Locations
2. Preliminary Hearing Plan
3. Existing Plans (roadway and bridge)
4. Bridge Borings Coordinates
5. Location Map
6. Utility List
7. ROW Property Owners Names and Addresses
8. Engineering Report
9. Mainline Cross-Sections
10. Detour Alignment Cross-Sections
11. Initial Site Assessment (ISA) Checklist
12. Hydraulic Information

One copy of the Boring Location Plan has been forwarded to Highway Design Bureau-Survey Section for field survey staking.

Please furnish us with the necessary Geotechnical Report and structures borings for this project. Please take roadway borings as appropriate.

Please note that the Ad Date for this project is scheduled for October 13, 2009.

DDT
Enclosures

cc: A. Vogt

Page intentionally left blank.

STATE OF NEW HAMPSHIRE
INTER-DEPARTMENT COMMUNICATION

FROM William Saffian
Project Engineer

DATE November 12, 2008
AT (Office) Bureau of Bridge Design

SUBJECT **EPSOM 15266**
NH ROUTE 107 over GRIFFIN BROOK
Boring Request

TO Melodie Esterberg, P.E.
Chief of Design Services
Bureau of Highway Design

SAMPLE

Transmitted herewith is one copy of the following for field survey staking for the above referenced project:

- Structure Boring Layout Plan
- Location Map
- Survey Request Slip

Materials and Research should be contacted prior to field staking to discuss the proposed boring locations.

DDT
Enclosure

Page intentionally left blank.



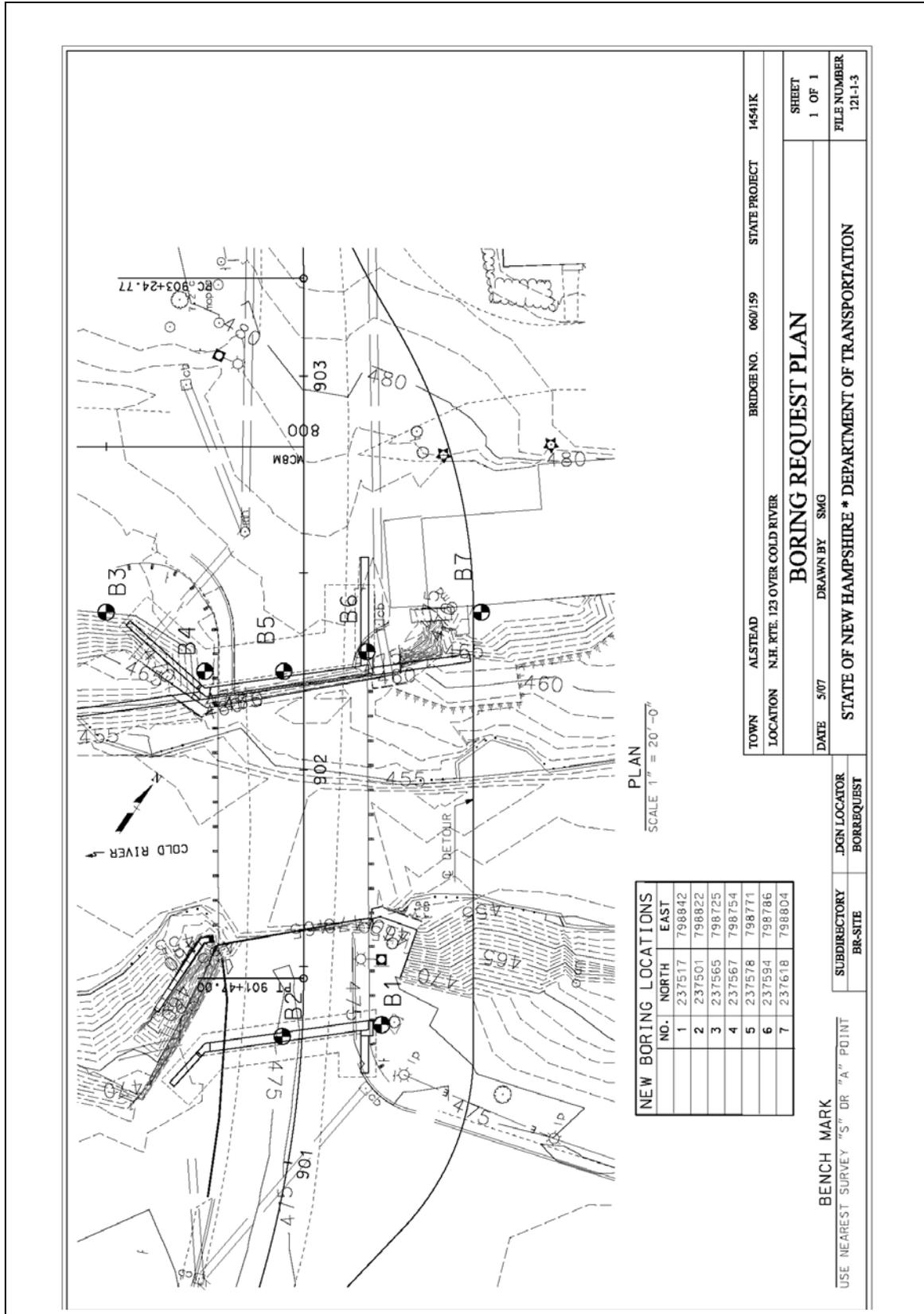
Bridge Design Manual

Chapter 2- Appendix B

January 2015 – v 2.0



Page intentionally left blank.



Page intentionally left blank.