CHAPTER 2
PRELIMINARY ENGINEERING GUIDELINES

2.1 GENERAL

2.1.1 Purpose of Preliminary Engineering

The purpose of Preliminary Engineering is to obtain sufficient information about the project parameters, through site investigations, material testing, limited structural analysis, and hydraulic and geotechnical studies, to make an informed decision regarding the scope of the project and/or type of structure to be pursued in subsequent phases of the design process.

2.1.2 Goal of a Bridge Project

2.1.2.1 The goal of any bridge project undertaken in accordance with this Bridge Manual shall be as follows:

- NEW BRIDGE OR BRIDGE REPLACEMENT: to provide a bridge structure that has been designed in accordance with the latest applicable AASHTO and MassDOT Bridge Manual requirements for design and load carrying capacity and which can reasonably be expected to achieve a minimum service life of 75 years.

- BRIDGE REHABILITATION: to provide a bridge structure where all existing structural deficiencies have been repaired, which has been brought up to the latest applicable AASHTO and MassDOT Bridge Manual requirements for design and load carrying capacity and which can reasonably be expected to have its service life extended for a minimum of 75 years after the conclusion of construction.

A "deficiency" is defined as a defect requiring corrective action. Under some circumstances, the goal for a rehabilitated bridge may not be fully achieved due to significant project constraints, such as historic considerations. In these situations, MassDOT will work with the Designer to arrive at more realistic project specific goals.

2.1.2.2 SUPERSTRUCTURE REPLACEMENT: this type of project is a cross between a Bridge Replacement and a Bridge Rehabilitation, since the superstructure is replaced in its entirety while most or all the substructure units are retained and rehabilitated. As a result, the new components should meet the goals of a Bridge Replacement project while the retained and rehabilitated components should meet the goals of a Bridge Rehabilitation project.

2.1.2.3 Other Bridge Projects. Deck Replacement, Bridge Preservation and Bridge Repair Projects are primarily maintenance projects and are not required to bring the entire bridge up to the latest applicable AASHTO and MassDOT Bridge Manual requirements for design and load carrying capacity. However, a Deck Replacement Project, because the entire deck is being replaced, affords the Designer the ability to potentially improve the load carrying capacity of the bridge (if needed) and to upgrade the railing/barrier to current standards.

2.1.3 Preliminary Engineering Decision Making Methodology

2.1.3.1 In the Preliminary Engineering phase, the Designer must first identify all of the parameters and constraints that either affects the bridge project or that may be affected by the type of project and/or type of structure selected. The Designer must also ascertain how absolute a project constraint is: is there room for compromise or not. Next, the Designer must determine how important each parameter is overall. Finally, the Designer must develop a project solution that optimizes as many of the parameters as possible without violating the constraints. When identifying the parameters and constraints, the Designer must be realistic and practical and should consider actual, real-world problems and situations. The Designer should refrain from giving inordinate consideration to hypothetical, "what if" problems that have little or no possibility of occurring within the life span of the structure.

2.1.3.2 NEW BRIDGE AND BRIDGE REPLACEMENT PROJECTS: Preliminary Engineering is used to select the structure type to be pursued in subsequent phases of the design process that best addresses the project constraints and parameters and best fits the site conditions. This is important because the selected structure type will be easier to design, easier to construct and will be more durable since it will work with the site, not against it. However, the Designer should not select a structure type before starting preliminary engineering and carry it through design, ignoring its incompatibility with the site parameters and constraints. Rather, the Designer should use the Preliminary Engineering process to determine the most appropriate structure type for the given site.

2.1.3.3 BRIDGE REHABILITATION PROJECTS: Preliminary Engineering shall establish all of the deficiencies that need to be addressed by the rehabilitation project, including structural, physical and code/load carrying deficiencies, and will develop strategies of addressing these deficiencies to be pursued in subsequent phases of the design process.

2.1.3.4 SUPERSTRUCTURE REPLACEMENT PROJECTS: These types of projects are most viable if the existing substructure units are in good condition and can be rehabilitated to meet current AASHTO and MassDOT requirements at reasonable cost. These projects are also essential where a bridge superstructure needs to be replaced using rapid construction techniques. For these projects, Preliminary Engineering shall establish all of the deficiencies in the substructure units that need to be addressed as part of the overall project, including structural, physical and code/load carrying deficiencies, and will develop strategies of addressing these deficiencies to be pursued in subsequent phases of the design process. Preliminary Engineering shall also select the most appropriate superstructure type of to be used.

2.1.4 Use of Accelerated Bridge Construction (ABC) Methods

2.1.4.1 The use of Accelerated Bridge Construction (ABC) methods is becoming more commonplace. ABC allows a bridge to be replaced more rapidly, reducing the amount of time that the public is inconvenienced. It also makes full closures for construction more viable, thereby reducing the time and additional costs needed for staged construction. However, ABC should be used only in cases where the benefits of accelerated construction have a positive effect on the construction costs and the overall benefits to the community. Some of the factors to consider when choosing between cast-in-place and ABC methods of construction are maintenance of traffic, including temporary roadways and bridges, reduction in environmental impacts, user costs, construction site access for heavy lift equipment, etc.

2.1.4.2 Use of Prefabricated Bridge Elements and Systems (PBES). PBES, as detailed in Part III of this Bridge Manual, may be used for new bridge construction, for bridge rehabilitation projects, as well as superstructure replacement projects. PBES are comprised of prefabricated and separately shipped pieces, which are assembled in the field to form the complete bridge. These pieces include abutments (cantilever, semi-integral, or integral), pier bents, cantilever walls, footings, bridge superstructure unit, etc. There are numerous benefits to the use of PBES. Prefabrication improves the quality of bridge elements and systems since they are constructed in a controlled environment, and thus extends the service life of a bridge. When compared to conventional construction practices, prefabrication reduces on-site construction time, resulting in less traffic disruption, improved safety, reduced environmental limitations, and reduced dependence on the weather.

2.1.4.3 In order to guide the Designer to a decision as to what construction method to use for a particular bridge project, the Decision Flowchart has been developed and shall be used at the stage of the preliminary engineering decision making. There are certain factors that need to be evaluated and the Preliminary Decision Value shall be computed, before the referenced chart can be used. The following procedure shall be used to calculate the Preliminary Decision Value:

Highway Evaluation Value

ADT Value	
ADT (I-29)	**Value**
<1000	1
1000-4999	2
5000-9999	3
10000-19999	4
≥20000	5

Detour Value	
Detour (I-19)	**Value**
0-1 KM	1
2-3 KM	2
4-5 KM	3
6-9 KM	4
10+ KM	5

Classification Value	
Class (I-26)	**Value**
09, 19	1
08	2
07, 17	3
06, 16	4
01, 02, 11, 12, 14	5

Note: Items 29, 19 and 26 shall be taken from the SIA.

Highway Evaluation Value = (ADT value + Detour value + Classification value) / 3.0

Highway Evaluation Value (A) = ______

Other Factors Value

a). Is it an Emergency Replacement? (2 Points if YES; 0 Points if NO) ______

a). Is the Bridge over an active and busy RR or Navigation Channel? (2 Points if YES; 0 Points if NO) ______

c). Is the Bridge on Evacuation Route? (1 Point if YES; 0 Points if NO) ______

Other Factors Value = (a + b + c)

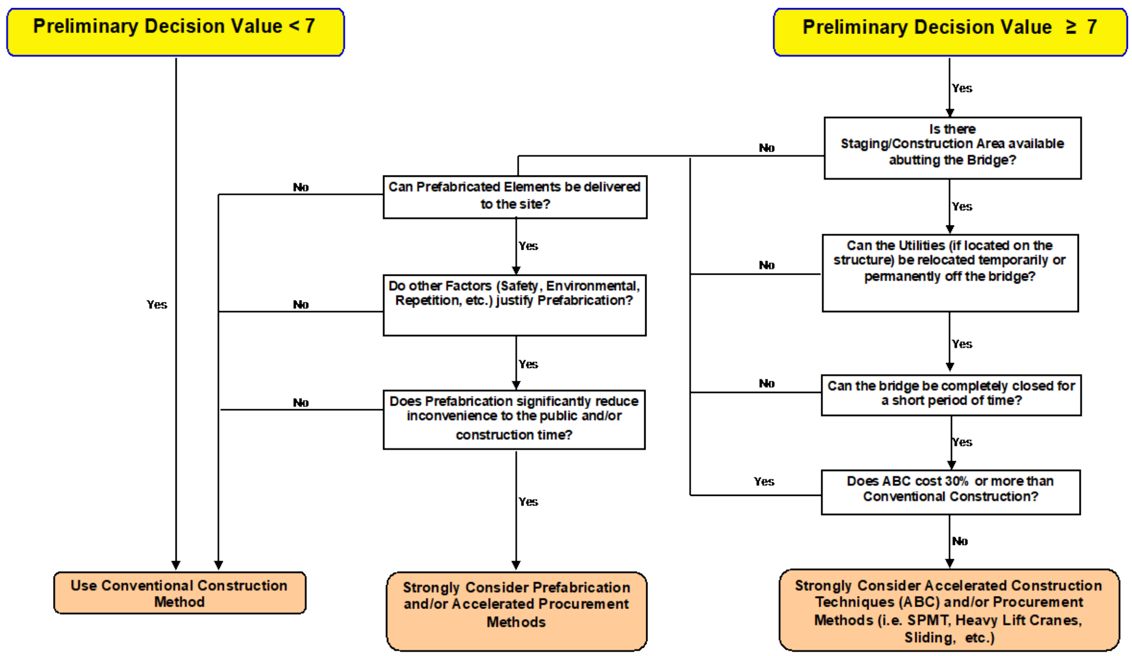
Other Factors Value (B) = ______

PRELIMINARY DECISION VALUE = 2 x [0.6(A) + 0.4(B)]

PRELIMINARY DECISION VALUE = ______

After the Preliminary Decision Value has been computed based on the above procedure the Designer can utilize the Preliminary Decision Making Flowchart shown below to make his/her decision on the method of construction (Conventional vs. Prefabricated) for a bridge project under consideration.

Preliminary Decision Making Flowchart



2.1.5 Preliminary Engineering Phase Deliverables

At the conclusion of the Preliminary Engineering Phase, the Designer will provide the following deliverable reports and plans:

- BRIDGE TYPE SELECTION WORKSHEET (for all New Bridge and Bridge Replacement projects), including a completed PBES Preliminary Decision Value form and Preliminary Decision Making Flowchart
- PRELIMINARY STRUCTURE REPORT (For all Bridge Rehabilitation and Superstructure Replacement projects. Will require an abbreviated Bridge Type Selection Worksheet if re-using the existing substructures, and may also require a Bridge Type Selection Worksheet, if choosing between Replacement and Rehabilitation)
- HYDRAULIC REPORT (if the bridge is over water)
- GEOTECHNICAL REPORT
- SKETCH PLANS

Please refer to the applicable Subsection of this Chapter for the specific information that is required for each of these deliverables.

2.2 CONTEXT SENSITIVITY AND AESTHETICS

2.2.1 General Objectives

Bridges are highly visible elements of the transportation infrastructure in the surrounding landscape. Often, they traverse environmentally and ecologically sensitive sites, culturally or visually significant areas or are visually prominent features in communities and other developed settings. Although bridges can have negative impacts on these environments, they can also be designed in such a way that they are pleasing or welcome additions to the landscape or community.

Achieving this requires that the Designer pay careful attention to the details starting from an understanding of the setting within which the structure will be built to the design and detailing of the bridge structure itself. Bridges can be designed to blend into the surrounding natural or built environment, if that is what is desired, or they can serve as signature elements of the community by standing out from their surroundings.

In either case, the Designer must remember that a bridge can last many decades. The Designer has the power to make the bridge structure be a source of pride and admiration or be a lasting monument to a Designer's insensitivity and brutalism.

2.2.2 Understanding the Context

The first task that the Designer must perform is to understand the context of the site within which the bridge is to be built. If it is in a natural area, the Designer should map out the topography and natural features of the site. A bridge should be designed to fit into its setting rather than have the setting altered to fit a bridge structure selected without regard for its context.

In a developed or urban setting, the bridge is typically part of a grade separation. This change in elevation can result in either embankments or walls that create visual and functional barriers between different parts of a community. In some cases, the barrier effect from a grade separation can intensify the barrier effect of the roadways themselves. On the other hand, longer grade separations, such as an elevated or depressed high speed, high volume roadway through a developed area can improve community connectivity if the crossings of the facility are well designed and at appropriate locations.

When rehabilitating existing bridges, or when re-using existing substructure elements as part of a new bridge structure, the Designer should attempt to preserve the architectural elements as much as possible. If existing features must be cut back to allow for the construction of new elements of the structure, such as when the pylons of the existing substructure are cut back to construct a new superstructure, the Designer should reconstruct the cut off portion of that feature so that it still looks complete and in keeping with its original architectural detailing.

Similarly, if new elements must be added to an existing structure that has prominent architectural features, the Designer should attempt to incorporate those architectural features into the new element so that the structure maintains a consistent architectural look overall, rather than being a mismatched jumble of incompatible architectural styles.

2.2.3 Bridge Aesthetics

The true aesthetics of a bridge start with the design of the bridge structure itself. Those bridges that are considered to be today's best examples of an aesthetic bridge are the ones whose primary structural systems follow and physically manifest the basic structural mechanics of how the structure carries all applied loads down to the foundations. Therefore, a well-designed and aesthetically pleasing bridge is not one that is based on some abstract physical form, but rather one that expresses natural, physical principles that people intuitively relate to.

However, this alone is not enough to make a bridge structure aesthetically successful. In order for a bridge to be truly aesthetically satisfying, the Designer must remember that there are three levels on which the public experiences a bridge. These are:

1. The overall view of a bridge and how it relates to its setting.
2. The personal experience of someone driving over or under a bridge.
3. The human level experience of a pedestrian walking over, under or beside a bridge.

Each of these requires a level of detail that a person can relate to and be visually engaged by. Failure to adequately address the aesthetic expectations at any one of these levels will result in a bridge that people will find fault with, no matter how aesthetically successful the bridge may be on the other levels.

Aesthetics on all levels are achieved by attention to detail and consideration of how each element of the bridge relates to the others, since the design of the bridge structure must present a coherent overall vision of what each component part should represent and all architectural surface treatments should be consistent with this vision. A bridge's aesthetics are vastly improved when all of the component parts, the piers, abutments and superstructure, are designed to work together and complement each other visually. Therefore, the decisions that the Designer makes regarding structure type and substructure configuration and location will determine the aesthetics of a bridge, and not the application of superficial decoration after the basic bridge has been designed.

MassDOT has used this philosophy in developing the standard details of Parts II and III of this Bridge Manual. The piers and abutments are the bridge's supports, thus they must contain and emphasize vertical elements, while the superstructure represents the horizontal spanning element and, thus, should have details that accentuate the horizontal. The lines of the bridge sidewalk or coping are carried over the wingwalls, thereby creating a sense of flow from one touch down point to the other. Thus, it is visually clear what each element represents, and it is easier to unite their separate functions into one structure without creating visual conflict.

2.3 NEW BRIDGE AND BRIDGE REPLACEMENT PROJECTS

2.3.1 General Objectives

In selecting a structure type for a bridge project, the Designer shall endeavor to provide the most serviceable structure, in terms of constructability, safety, minimized long term maintenance, historic issues, right of way and environmental impacts while optimizing sight distance, design speed and clearances at the proposed structure site. It is MassDOT and Federal Highway Administration (FHWA) policy to design structures of multiple stringer/deck type construction wherever possible due to their structural redundancy and ease of construction, inspection and maintenance.

The structures evaluated shall consider only those superstructure and substructure options that are most appropriate for the site. Cost considerations shall balance initial cost as well as future maintenance costs, however, cost alone should not drive the decision-making process but rather it should be used only to select between equal, appropriate alternatives.

For bridge replacement projects, if the condition of some or all of the existing substructure units is such that they can potentially be rehabilitated to have their service life for at least another 75 years, the merits and cost of rehabilitating them should be considered. This evaluation must include all investigation, testing and analysis required for a Preliminary Structure Report, since technically the project will be a Superstructure Replacement Project. If the existing substructure is not deemed to be serviceable for reuse as part of a new bridge structure, the merits of re-using the existing abutments and wingwalls as an earth retaining structure or scour protection independent of the new bridge structure should be considered.

The Designer shall consider the following items when selecting the structure type:

- Open the bridge to maximum extent for sight distance.
- Consider possible future widening of the roadway under the bridge.
- Provide a structure requiring minimum future maintenance.
- Eliminate roadway joints in the bridge deck where possible.
- Eliminate roadway joints at abutments by using integral abutments.
- Provide a structure that allows for adequate hands on inspection access.
- Minimize environmental impacts.
- Minimize water control during construction.
- Eliminate elements in the substructure that are a hazard to traffic.
- Provide a type of structure that is both functional and architecturally aesthetic and contextually sensitive to the location that it will be constructed in.
- Provide for placement of utilities in the superstructure.
- For bridges with sidewalks, consideration will be given for adequate and safe access for persons with disabilities on both the bridge and its approaches.
- Provide the required horizontal and vertical clearances in accordance with the Project Development & Design Guide and Part II of the Bridge Manual.

2.3.2 Bridge Type Selection Process

2.3.2.1 General Considerations. After identifying all project parameters and constraints, the first step in selecting a bridge structure type is to develop a preliminary bridge layout which includes possible span arrangements (single versus multiple span) and preliminary span lengths. The bridge geometrics and clearance standards given in Chapter 2 of Part II of this Bridge Manual must be considered in combination with the site data, profiles and cross sections of the feature being crossed as well as the roadway on the bridge to establish the span arrangement and lengths.

2.3.2.2 Substructure Layout Considerations. The Designer must establish the locations and the type of the substructure units. This effort must consider the foundation type, support of excavation and its impact on surrounding features, environment and property. See Subsection 2.3.4 for more guidance on locating the substructure units. Since span lengths, skew, clearances, structure depth and profile impacts are interrelated, this exercise should consider all these factors in developing the preliminary bridge layout. It is also important that the structure type be selected and approved before the final profiles are set, since the depth of the superstructure could greatly influence the profile.

2.3.2.3 Skews. Designers should not avoid bridges with skews. Placing the substructure units parallel with the feature crossed helps maintain consistent sight lines for bridges over highways and helps avoid the creation of eddies and turbulence for bridges over water, which can result in scour related issues. This also allows for the shortest span length over the feature, as opposed to locating the substructure units perpendicular to the roadway on the bridge but far enough back so that the feature can run on a skew under this longer span. This is important in those situations where the depth of structure must be kept small. However, Designers are cautioned that large skews can create structural problems that need to be considered. See Paragraph 2.3.4.1 for more guidance on the structural implications of skews and see Paragraph 2.3.5.8 for more guidelines on locating substructure units on skews.

2.3.2.4 Finally, the Designer must select the most appropriate superstructure type for the span arrangement and length, taking into account the effect of structure type and depth on the clearances, roadway profile, utility requirements, and environmental impacts. Superstructure type also has an impact on the ability to construct a replacement bridge structure in stages. This process may require several iterations, as the possible superstructure types may require reconsideration of the substructure location and arrangement.

2.3.3 Requirements for Bridge Inspection Access

2.3.3.1 The main purpose of a bridge inspection is to assure the safety of a bridge for the travelling public by uncovering deficiencies that can affect its structural integrity. The results of a bridge inspection are used to initiate maintenance activities and/or a load rating. In order to comply with these requirements, all structural components of a bridge must be accessible for a hands-on inspection. Therefore, it is vital that the Designer properly provides for safe inspection access and accommodation of inspection access equipment as part of the design process. The best time for accomplishing this is when inspection access is taken into consideration during the preliminary design phase of the project. This will ensure that the bridge can be thoroughly inspected in the future. Otherwise, bridge inspectors may be faced with an impossible task of trying to properly inspect an inaccessible structure.

The standard MassDOT bridge, as detailed in Parts II and III of this Bridge Manual, allows inspectors to access all structural members through the use of ladders, bucket trucks or the Under Bridge Inspection Unit (UBIU). However, this equipment does have limitations, outlined below, that may prevent full access in some locations. Also, non-standard bridges may require special considerations for inspection access and maintenance. In these cases, inspection access must be secured through the use of rigging, platforms, walkways, scaffolding, barges, and in some cases, special travelling gantries.

2.3.3.2 Ladders. Typically, the maximum safe reach for a ladder is about 25 feet. In addition, ladders must be set on firm and level ground. If the topography of the ground under a bridge is sloping, unstable, too rough or if the bridge is directly over water, ladders probably cannot be used.

2.3.3.3 Bucket trucks. Bucket trucks can be used to access the underside of a bridge from below. The maximum safe vertical reach for a bucket truck is about 25 feet. In order to use a bucket truck, there must be a road directly under the bridge. If there is no road, a bucket truck cannot be used. Bucket trucks also cannot be used on sloping ground.

2.3.3.4 Under Bridge Inspection Unit (UBIU). The UBIU is a versatile inspection truck that allows access to the underside of a bridge from the bridge deck. The vehicle has a maneuverable boom with a bucket that can reach over the side of the bridge and move around underneath. The UBIU that are available for use have various capabilities and limitations. At a minimum, the following limitations should be considered:

- The maximum width of sidewalk that the UBIU can reach over from the curb is 12 feet.
- The UBIU cannot be operated with one set of wheels on the sidewalk and the other on the roadway.
- If the sidewalk can support the truck's weight, the minimum width of sidewalk that the UBIU requires for driving on is 10 feet and there must be a ramp type access to the sidewalk.
- The UBIU bucket can be deployed over a railing or fence with a maximum height of 10 feet.
- The minimum safe vertical underclearance for operating the bucket is 10 feet.
- The maximum roadway cross slope that the UBIU can operate on is 7%.
- The bucket and boom must stay a minimum of 10 feet away from power lines.
- Underneath, the maximum reach of the UBIU under favorable conditions is 75 feet, which is reduced if the UBIU is required to navigate between tall girders.
- The UBIU cannot be used to access a bridge from below.

2.3.3.5 Bridges with confined spaces in which inspectors must work require special considerations in order to ensure that they will be safe for inspection personnel. OSHA's definition of a confined space is a space large enough and so configured that an employee can bodily enter and perform assigned work but has limited or restricted means for entry or exit and is not designed for continuous employee occupancy. Examples of such confined spaces on a bridge include the inside of steel box girders, hollow abutments, etc. The Designer is obligated to insure that there is sufficient room inside the confined space for a reasonably sized individual to move and turn around, that there is sufficient means of egress in an emergency or access by emergency personnel to rescue a stricken or incapacitated inspector.

2.3.3.6 When locating access hatches for steel box beams, the Designer, to the greatest extent possible, shall locate them above paved shoulders, slope-paving or other areas that are typically not located above live traffic so that the hatches can be accessed without the need for lane closures. Likewise, hatches should not be located near overhead electrical wires or other overhead utilities that would interfere with access to the hatches.

2.3.3.7 In all cases of non-standard bridges or bridges with difficult access, the Designer shall consult the MassDOT Bridge Inspection Unit for recommendations for providing adequate and safe access for bridge inspection.

2.3.4 Appropriate Bridge Structure Types by Span Range

2.3.4.1 General. The following guidelines for appropriate bridge structure types are based on the standard bridge details found in Parts II and III of this Bridge Manual, unless otherwise noted. Except where specific skew limitations are given, all of these details can generally be used as is for skews up to and including 40°. For skews greater than 40°, these details may still be used, however the Designer may need to modify the details to accommodate these larger skews to mitigate potential construction and fabrication issues. However, Designers are cautioned that large skews, typically over 50°, can create structural problems with acute corners, horizontal twisting movement of the superstructure under thermal effects, and fatigue problems with diaphragms and their connections to the beams. Therefore, special attention should be paid to mitigating these effects when designing structures with such skews. Also, for these large skews, Designers should consider alternate types of beam layouts, such as placing beams perpendicular to the feature being crossed and running the roadway diagonally over the bridge structure.

2.3.4.2 SINGLE SPAN - LENGTHS LESS THAN 40'.

1. Structural Plate Pipes (Not in this Bridge Manual): (aluminum and steel), generally under 20' in span. These are available as pre-engineered structures in various shapes and sizes and can be used for fills as shallow as 2'. They can be used for pedestrian, bike and animal underpasses; vehicular tunnels; and overflow relief structures. They have also been used as structural liners for masonry and concrete arches and other pipes. These structures should generally not be used for water crossings since they have reduced life span due to deterioration of the metal at the water line. For this same reason, they should not be used on Interstate or other limited access highways in such applications. Environmental and size constraints normally dictate whether to use steel or aluminum. For details on this type of structure see the latest manufacturer's catalogs. Manufacturers may have skew limitations for these structures.
2. Concrete Four-Sided Box Culverts: (precast or cast-in-place). They can be used for pedestrian, bike and animal underpasses; overflow relief structures; and are preferred for water crossings, especially where a low structure profile is desired. Shipping considerations usually limit precast boxes to spans of less than 15'. Larger overall openings are made possible by using multiple boxes set side by side, however multi cell culverts are more prone to trapping debris. The concrete inverts may raise objections in sensitive fishing areas, where a natural stream bed is preferred. Various programs can be used to design these boxes.
3. Precast Concrete Three Sided Culverts (Not in this Bridge Manual): These units include flat top frames and arched top shapes that have a maximum span of approximately 40'. These units are supported on strip footings founded on gravel, rock, or piles. However, due to their fixed span to depth ratios, it may be difficult to ship the larger size units to the construction site. Both of these units can be used in low fill areas. In areas of high fill (>16') there may be design problems with flat top units with long spans. Skewed arrangements must be considered in design as not all manufacturers produce units with skewed end walls. The design should be coordinated with the appropriate manufacturers.
4. Slabs or Composite Deck/Stringer Designs: Prestressed adjacent deck beams on abutments are applicable for this entire span range. Steel stringers or spread prestressed deck beams with composite concrete decks are also applicable, especially for spans greater than 25'. Conventional reinforced concrete slabs on abutments are inefficient for spans greater than 25' due to their excessive depth and heavy reinforcement.

2.3.4.3 SINGLE SPAN - LENGTHS BETWEEN 40' AND 110'.

1. Adjacent prestressed concrete deck beams can be used up to a maximum span of about 63'. Adjacent prestressed concrete box beams can be used for the remainder of the span range. Both can be used with conventional abutments only.
2. Spread prestressed concrete box beams with a composite concrete deck can be used with span ranges of up to about 80'. Can be used with both conventional abutments and integral abutments. Spread prestressed concrete deck beams can also be used in place of box beams on the shorter end of this span range.

3. NEXT Beams with a composite concrete deck (NEXT F Beams) or with a full-thickness top flange (NEXT D Beams) can be used for span ranges up to about 85'. Can be used with both conventional abutments and integral abutments.
4. Steel stringer and prestressed concrete NEBT girders with a composite concrete deck or NEBT girders with a full-thickness top flange (NEDBT Beams) can be used for the entire span range. Rolled beam sections can be used up to about 90' and welded plate girders for the remainder of the range. Steel box beams with a composite concrete deck may also be used starting at about a 90' span. Can be used with both conventional abutments and integral abutments.

All beams listed above can potentially be shipped in one piece to the construction site.

2.3.4.4 SINGLE SPAN - LENGTHS BETWEEN 110' AND 150'.

1. Steel plate girders and steel box girders with a composite concrete deck can be used for this entire span range, however, the girders must be shipped in pieces and spliced together in the field. Can be used with both conventional abutments and integral abutments.
2. Prestressed concrete NEBT girders with a composite concrete deck can span up to about 139'. Can be used with both conventional abutments and integral abutments.
3. Adjacent prestressed concrete box beams can span up to about 135'. Can be used with conventional abutments only.

2.3.4.5 SINGLE SPAN - LENGTHS GREATER THAN 150'. Single spans greater than 150' are rarely built in Massachusetts. If a bridge needs to span that distance from abutment to abutment, consideration should be given for evaluating a multi-span structure. If a single span in this range is still required, then a special study will need to be made to determine the most appropriate structure which will balance superstructure and substructure costs to achieve an optimum design, as well as balancing aesthetics and constructability.

2.3.4.6 MULTIPLE SPAN ARRANGEMENTS. For multi-span bridges, a continuous design shall be used wherever foundation conditions warrant and the span ratios are satisfactory to eliminate deck joints. However, unbalanced span ratios in a continuous beam can result in uplift and should be avoided. Steel beam bridges can be designed to take full advantage of moment distribution resulting from continuity and thus can reduce the depth of the beam. Prestressed concrete bridges are typically erected as simple spans for self-dead load and then made continuous for superimposed dead loads and live loads by closure pours and additional reinforcement at the piers. If the NEBT girders are to be spliced together to form a continuous multi-span girder, then the single clear opening of this girder can span up to about 150'. Can be used with both conventional abutments and integral abutments.

The preceding guidelines for single span structures can still be used to select the appropriate multi-span structure type with the following modifications for steel beams. Based on the number of spans, the span ratio and the table below, the longest span of a continuous steel beam can be equated to a shorter, equivalent simple span, which is then used to select the structure. These ratios are only to be used as a guide for preliminary design and are not intended to exclude other span ratios necessitated by site conditions as long as uplift is avoided.

Number of Spans	Ratio of Spans	Equivalent Simple Span
2	1.0 : 1.0	0.90 x 1.0 span
3	0.75 : 1.0 : 0.75	0.85 x 1.0 span
4	0.80 : 1.0 : 1.0 : 0.80	0.75 x 1.0 span
5	0.60 : 0.80 : 1.0 : 0.80 : 0.60	0.60 x 1.0 span

2.3.4.7 CURVED SINGLE AND MULTI-SPAN BRIDGES.

1. Steel plate I-girders and steel box beams can be curved to follow the horizontal curvature of the road, which allows the deck to be built to a constant width and can be designed to be continuous for multi-span bridges. The deck overhangs are constant and can be set as specified by the Bridge Manual, which improves the overall aesthetics of the structure. Steel box beams are torsionally stiff and, because of this, are preferred for horizontally curved bridges, especially for long, multi-span bridges. Because of the additional expense of fabricating the curved beams, curved steel plate I-girders and steel box beams may not be cost competitive for short spans and/or large radius curves. In such cases, straight beams set on chords with a curved deck overhang should be considered, unless aesthetic considerations of providing curved beams outweigh the cost considerations, such as locations where there is pedestrian access and activity below the bridge. In any case, mixing straight interior beams and curved fascia beams should be avoided due to the increased complexity of laying out and fabricating the diaphragms and the poor aesthetics of the resulting structure.
2. Adjacent prestressed deck and box beam systems must be set on chords while the curb lines are set to follow the curve of the roadway. As a result, the overall width of the sidewalk and/or safety curb varies. The disadvantage is that the out to out width of the adjacent beam system must be set wide enough so that the minimum sidewalk and/or safety curb dimensions are met. Because of this, adjacent beam systems are not recommended for curved roadway applications except for large radius curves or short spans, so that the width of the sidewalk and/or curb behind the railing or barrier is not excessive, or where there is a need for a shallow superstructure. NEXT Beams, while they too must be set on chords, have the advantage that their flanges can be formed on a radius, so that the Designer can maintain a constant out to out width of the bridge structure.
3. Prestressed concrete spread deck and box beams, as well as NEBT girders can only be set on chords, while the composite concrete deck is set to a constant cross section to follow the curvature of the roadway. Similarly, steel rolled beams, plate I-girders or box beams can be set on chords in situations where fully curved beams are not needed. All these superstructures have variable width deck overhangs, which makes the Designer responsible for making sure that the maximum overhang dimensions as specified by the Bridge Manual are not exceeded. Also, the variable width overhangs create curved shadows on the fascia beams, which may be aesthetically objectionable. As a result, these types of superstructures are more applicable for shorter spans or large radius curves or where aesthetics are not that important.

2.3.4.8 RAILROAD BRIDGES OVER HIGHWAYS. On some occasions, MassDOT may need to build a bridge for an operating railroad for the purposes of a grade separation or to construct a new segment of roadway. In such cases, the standards of the operating railroad company will be used.

However, all railroad bridge structures over highways will be of the ballast deck type to prevent ballast, water and/or icicles from falling onto the roadway traffic below.

2.3.5 Substructure Location Guidelines

2.3.5.1 General Considerations. The locations of the abutments and piers are dependent on balancing the required clearances as specified in Chapter 2 of Part II of this Bridge Manual, the foundation type, which is dependent on the subsurface exploration and assessment, constructability, which may be complicated by stage construction considerations, and span length, which impacts superstructure depth and can raise the approach roadway profile thereby creating undesirable impacts on the approaches.

Integral abutment bridges have a demonstrated history of initial cost savings due to economy of material usage and lifecycle cost savings through reduced maintenance. They should be considered wherever possible provided that the soil conditions will permit the piles to be driven below the theoretical point of fixity. Integral abutments are also ideal for bridge sites where there is limited room for excavation or there is a need to minimize the impacts of abutment construction on existing surrounding structures and/or the environment.

Where the existing bridge structure to be replaced is historic, found in a historic area, or is in sensitive wetlands, the abutments may be retained without being incorporated into the new structure to minimize the impacts to these resources. As evaluated in the geotechnical report, the replacement bridge structure may be supported on integral abutments or on piles or drilled shafts placed behind and/or adjacent to the existing substructures or on micropiles or small diameter drilled shafts drilled through the existing substructure. In such cases, adequate inspection access, as specified in Chapter 2 of Part II of this Bridge Manual must be provided.

For bridge replacement projects utilizing accelerated construction methods and/or attempting to minimize the impact on traffic, and where the existing substructures are not to be reused, the Designer should consider locating the proposed substructure elements in different locations than the existing ones. This would allow the construction of the foundation or even a substantial portion of the substructures without major impacts to traffic, so that once the existing is closed for construction, the duration of this construction would be minimized.

2.3.5.2 Abutments shall be located where a logical transition from bridge structure to the approach topography can occur. This first requires a good understanding and mapping of the topography within the bridge project area, not just at the bridge site itself. Full height abutments are expensive to construct, require longer wingwalls and extensive excavation and backfill to construct. They should be used primarily where the topography does not permit a stub abutment or integral abutment and where there is ample room to provide for the excavation. Stub, mid-height, or integral abutments are preferred due to the reduced expense of their construction and impacts on topography and because they do not require long wingwalls. Stub abutments founded directly on MSE wall supported backfill or MSE walls providing a full height facing for integral abutments or for abutments founded on drilled shafts or piles may also be considered in place of full height abutments.

2.3.5.3 Wingwalls can be either splayed or U-shaped. Splayed wingwalls are more economical to construct, however, because they angle away from the abutment, they need a wider right of way so that all of the structure, including the wingwall footings are within it. U-wingwalls are appropriate for restricted right of way situations, since they follow the roadway, and they can be used to retain the approach embankment fill from spilling into environmentally sensitive areas. However, they are more expensive to construct because of their height and they require additional length of bridge railing or barrier to be provided to the end of the U-wingwall. Also, the Designer must make sure that the U-wingwall footing is fully within the right of way layout. For both types of wingwalls, the taller the abutment, the longer the wingwalls and the greater the impacts described above. MSE walls should be considered as alternatives to long cast in place wingwalls, however they may not be practical for bridge approaches that have buried utilities that would interfere with the MSE wall soil reinforcing or which would require future excavations for maintenance or replacement.

2.3.5.4 When developing a span arrangement, generally the fewer the piers the better, since this opens up the underside of the bridge to sight distances, eliminates roadway hazards for bridges over roadways, eliminates visual clutter, and reduces the potential for scour, aggradation of the channel, and prevents the trapping of floating debris for bridges over water. However, fewer piers result in longer spans, which result in deeper superstructures. This can raise a profile and move the toe of slope out, thereby encroaching on environmentally sensitive areas such as wetlands, or require additional right of way takings or require a retaining wall. Therefore, span length and structure depth must be carefully balanced to arrive at an optimal structure.

For multi-span curved girder structures, it is preferred that the piers and pier caps be oriented radially to minimize the skew effects. If the piers cannot be oriented radially, then the effects of the skew combined with the effects of curvature must be taken into account in the design of all main structural components using appropriate curved girder software that can fully model the bridge superstructure in 3-D.

2.3.5.5 The type of foundation has a major impact on the location and number of substructure units.

1. Spread footings are the most economical where soil conditions permit; however, they may require large, extensive and costly support of excavations to construct.
2. Deep foundations using piles, either concrete filled steel pipe piles, steel H-piles or prestressed concrete piles require less complex equipment than that required for drilled shafts or micropiles to install, however, they may be difficult to design for a combination of loadings, including seismic and scour. Pile foundations may also require larger excavations similar to spread footings to provide for the pile cap. Piles shorter than 10’ should be avoided.
3. Micropiles are a good compromise as a deep foundation between driven piles and drilled shafts where these foundation types have been evaluated and cannot be efficiently used due to site constraints, existing structures, or utilities. Micropiles can be used when the deep foundations need to be drilled through existing footings, in low overhead or otherwise restrictive (tight) site constraints, and where very dense, very hard or subsurface soil conditions with boulders or other obstructions are anticipated.
4. Drilled shafts require less area for their excavation and so can be installed in constrained construction sites. They also produce less excavation material, which is advantageous if the site contains hazardous waste whose disposal must be mitigated. Drilled shafts are also better for situations where the effect of scour on the stability of the abutment or pier is of a concern. Drilled shafts can be used as a foundation for either abutments, where they are used with a pile cap, or with piers, where the pier column is a continuation of the drilled shaft. However, drilled shaft construction quality is highly dependent on contractor experience, means and methods, and subsurface conditions. Therefore, the Designer must make sure that the drilled shaft equipment can access the construction site so that the shafts can be readily constructed.

5. A spread footing must be founded on the same material throughout its bearing area. If the top of rock is comparatively level and is located at a shallow depth from the proposed bottom of footing, then, for economy, consideration shall be given to place the footing so that it will be situated entirely on rock. Depending on the slope of the bedrock and its condition, the Designer should evaluate subsurface conditions, cost and constructability to determine the optimal solution to either over excavate and backfill with GRAVEL BORROW FOR BRIDGE FOUNDATION or place concrete up to the bottom of proposed footing. If there is a competent rock outcrop that can be retained, consideration should be given to a stub or mid-height abutment founded directly on the outcrop.
6. For bridge replacement projects, stage construction considerations must take into account interference between the existing and proposed features, (e.g., substructures, beams, pier caps, pile driving - especially battered piles, etc.) as well as utilities that must remain in service. Accurate survey data on existing features is essential for stage construction projects.

2.3.5.6 Support of Excavation. The Designer must be mindful of the support of excavation that the foundation type will require for construction and whether the site can accommodate it. For example, support of excavation for staging and substructure construction may consist of cantilever sheet piles, tied-back sheet piles and whalers, or pile and lagging. For in-water construction, support of excavation may take the form of a cofferdam with a tremie seal. Stage construction may require support of excavation to retain the existing roadway while the new structure is being constructed. In these cases, the Designer must consider the depth of the excavation that the new structure's foundation will require and the live load surcharge that must be retained. In extreme situations, the required support of excavation may be so massive that it cannot be physically constructed within the site constraints. In such cases, an alternate substructure type or bridge configuration must be utilized that will minimize the support of excavation.

2.3.5.7 Utility Conflicts. The Designer must locate the substructure units to avoid utilities that would require costly relocations. Also, some construction activities, such as pile driving and sheet pile placement, bridge demolition or beam erection may be limited by overhead or underground interference.

2.3.5.8 Skews. The substructure units shall be placed parallel with the feature crossed, which will determine the skew of the bridge. This helps maintain consistent sight lines for bridges over highways, and helps avoid the creation of eddies and turbulence, which can result in scour for bridges over water as described in Paragraph 2.3.5.9 below. However, larger skews can create structural design, detailing and construction issues. See Paragraph 2.3.4.1 for more guidance on these considerations. Bridges can be built on smaller skews than the intersection of the road with the feature crossed, however this will produce longer spans. For horizontally curved bridges, a radial orientation of the substructure units is preferred.

2.3.5.9 Water Crossings. The first parameter to be established for a water crossing is the navigational requirements for marine traffic. The United States Coast Guard is responsible for all rules and regulations for bridges over navigable waterways, such as establishing channel width, horizontal clearances from fender to fender, vertical clearances for fixed span bridges and/or the need for a movable bridge. Constructing a fixed span bridge at a higher elevation should be considered in place of a movable bridge, where possible. If an existing movable bridge has been closed to marine traffic for years, consideration should be given to obtaining Coast Guard approval to permit the construction of a fixed span bridge, if this approval has not been officially obtained previously. In addition, Chapter

91 of the Massachusetts General Laws, Sections 14 and 23, requires an Act by the General Court for the construction of a bridge without a draw span over a tidal river, cove, or inlet, except when a fixed bridge, dam, or other structure is in existence downstream of the proposed bridge.

Every effort should be made to place and orient the substructure units for water crossings, including abutments, shore line piers and in-water piers, parallel to the flow of the stream in order to minimize flow disruption and potential scour, as discussed in Subsection 1.3.2, *Hydraulic Design Criteria*, Bullet 5, of Part I of this Bridge Manual. If this is not possible and the substructure units must be placed at a skew to the flow, the Hydraulic Report shall be prepared to reflect their actual orientation.

In locating substructure units, and where clearance conditions warrant, long spans should be used to open up the waterway from obstructions, reduce the potential for scour and trapping debris and to keep the substructure construction in the dry, where possible. For multi-span bridges, two piers close to each shoreline may be more hydraulically efficient and economical to build than one deep water pier. Piers in the water should typically be solid; however, a column bent on top of a solid stem should be used if the top of the pier is 22' above the design storm elevation. The use of a short column bent can result in shrinkage cracks in the columns. Shore line piers can be column bents with a drilled shaft foundation, with the column being a continuation of the shaft. This reduces the size of the excavation and the amount of dewatering required to construct the pier.

Where the wingwalls of an abutment are at or near the water's edge, the wingwalls on the upstream side should be splayed to improve the hydraulic entrance condition and should be aligned to direct the flow through the bridge opening. If possible, the elevation of the end of the wingwall should be higher than design storm elevation or, at a minimum, the ordinary high water. In such cases, the downstream wingwalls should also be made splayed for ease of design and construction.

2.3.5.10 Bridges over Railroads. Typically, a three-span structure is more economical to construct than a simple span with full height abutments. Where site conditions restrict the construction of a multi-span bridge, mid-height abutments should be considered if geotechnical conditions are favorable, otherwise full height abutments should be considered.

For new bridges, Massachusetts General Laws, Chapter 160, Section 134A specifies a clearance of 22'–6" above top of rail. For those bridges that were acquired by MassDOT from the railroad companies and municipalities under Chapter 634 of the Acts of 1971, this Chapter authorizes MassDOT to replace these bridges at the existing horizontal and vertical clearances. Generally, railroad companies desire more vertical clearance and may be willing to reduce the horizontal clearance for a gain in the vertical.

Typically, MassDOT attempts to improve the vertical clearance where right of way, approach roadway geometry, and site conditions allow. On certain railroad lines that have been identified as potential double stack routes, MassDOT attempts to provide a minimum vertical clearance of 21' from top of rail. If the clearance cannot be improved to this height, the foundations of the abutments and/or piers should be set so that the railroad company can undercut the tracks to achieve this clearance without impacting the stability or performance of the bridge structure.

Wherever possible, the construction of the bridge should avoid impacting the railroad roadbed. Chapter 2 of Part II of this Bridge Manual provides the influence slope requirements for all major railroads operating within Massachusetts. Abutments and/or piers should be located so that their foundation excavations stay outside this slope line. Drilled shafts should be considered in constricted site conditions, since they do not require a wide excavation to construct a spread footing or pile cap, and so the pier can be located closer to the track. However, if the railroad face of any pier is located within a distance of 25’ from the centerline of the track, AREMA requires that the pier be protected by an integral crash wall.

2.3.6 Superstructure Selection Guidelines

2.3.6.1 The final step in the Bridge Type Selection Process is to select the superstructure type that will fit the project parameters, roadway geometry, site accessibility, constructability and the arrangement, spacing and span of the substructure units. The following guidelines are to be used in determining the superstructure type that best meets all these requirements. If two or more superstructure types equally meet the project requirements, then total cost should be used to make the final selection. In determining this total cost, the Designer must add to the cost of the superstructure all consequential costs, including the cost of any adjustments to the approach roadway profile, substructure and foundations necessitated by the given superstructure type.

2.3.6.2 Adjacent prestressed concrete deck and box beams provide the shallowest depth structure for a given span, provide for more rapid construction since the beams act as a form for the structural slab which also minimizes work over the feature intersected, and provide a better, smoother roof for the hydraulic opening. These systems typically have lower life cycle costs because they require little routine maintenance and, because they are made from concrete in a controlled environment, they are not subject to corrosion or deterioration. This makes them an ideal choice for bridges over water with high constant humidity and for areas where it is difficult to access the superstructure for maintenance work. However, if a single beam within the systems is damaged, it is difficult to replace it.

These systems have limited room for utilities, which requires that large or numerous utilities must be attached to the outside of the superstructure. Since prestressed concrete beams are essentially straight, they cannot follow the vertical roadway profile, which results in additional midspan dead load for large vertical curve middle ordinates. Skews and profile effects require special design and construction procedures for the bridge seats. Adjacent prestressed concrete beam systems are not recommended for skew angles over 45°, due to the warping behavior of the beams at the bearings from beam deflections, and the staggered beam cambers make it difficult to thread the transverse post tensioning strands through and create misalignment in the keyway details. This superstructure system may not be feasible when an existing substructure is being reused due to the greater weight of this system. A stringer type bridge with a composite deck slab would be preferred at these sites.

2.3.6.3 The NEXT Beams (both NEXT F and NEXT D series) provide an excellent alternative to adjacent precast concrete deck and box beams for most short-to-moderate span bridges and, in some cases, to typical stringer beam bridges. Some of the advantages of the NEXT beams are ease of fabrication and its reduced cost (straight strands only, no draping); ample room for under-bridge utilities; the use of the beam top flange as a deck form and subsequently reduced construction time (NEXT F Beams); a full thickness top flange that acts as the structural slab for the bridge (NEXT D Beams); there is no installation or stripping of formwork required in the field; no intermediate diaphragm required, which eliminates a time-consuming construction process.

The most important advantage of the NEXT beams over adjacent precast concrete deck and box beams is that these beams can be used in construction of integral abutment bridges due to the fact that they have a full-depth cast-in-place deck and consequently, due to their ability to provide for a significant connection between the beams and the abutment to resist positive and negative bending moments.

2.3.6.4 Prestressed concrete spread deck, spread box beam, NEBT girder bridges with a composite concrete deck and NEDBT girders have the lowest life cycle costs because they require minimal routine maintenance and, because they are made from concrete in a controlled environment, they are not as subject to corrosion or deterioration. This makes them an ideal choice for harsh environments, such as over roadways where there is high salt usage or over water with high constant humidity and for areas where it is difficult to access the superstructure for maintenance work. These beam types, especially the NEBT girders, also have more room for utilities than adjacent beam systems.

However, these beams generally result in deeper superstructures than steel beams for a comparable span. They are heavier, especially for longer spans and, as a result, may be difficult to ship and will require bigger cranes to erect. These beams must be shipped in one piece, because it is difficult to splice them in the field. Because these beams are essentially straight, they cannot easily follow a vertical curve. Deep haunches must be used to allow the concrete deck slab to follow the profile. The top flanges are very wide, which can also create deep haunches, especially as the cross slope increases. Both of these situations separately and in combination, will result in significant dead load. These beams are also not recommended for skew angles over 45°, due to the warping behavior of the beams at the bearings from beam deflections and because of the construction problems created by the wide beam flanges. Although superstructures using these beams may weigh less than an adjacent prestressed concrete beam system for the same span, they weigh more than steel superstructures of the same span, which may be a consideration when existing substructures are being reused.

2.3.6.5 Steel rolled beam, steel plate I-girder and steel box girder bridges with a composite concrete deck provide a shallower superstructure than the spread prestressed concrete deck and box beams and NEBT girder bridges, they can be cambered to better follow the profile of the road, which may provide additional vertical clearance under the bridge. All steel beams can be designed and fabricated to take full advantage of continuity, which can further reduce the depth of the superstructure for a given span. Plate girders can also be fabricated to any size, which allows steel to fit unique site conditions. Steel beam superstructures provide the most room for utilities than any of the other superstructure types. Steel beam superstructures have a low weight, which may make them the only feasible alternative when reusing an existing substructure. All steel beam types can be easily field spliced, so the beam can be divided into shorter segments for easier shipment and erection. Steel rolled beams and plate girders can more easily accommodate skew angles over 45°, however, fatigue of diaphragms and their connections becomes more of a problem as well as more pronounced deck cracking as the skews become greater.

All steel beams have higher life cycle costs because they are subject to more deterioration from corrosion and require more routine maintenance to preserve them. Although weathering steel does not require painting, the protective effect of its patina is compromised by contamination from road salt and the patina fails to form in continuously moist environments. These same factors affect coated beams as well, so steel should be used cautiously over highways with high salt usage and over water, especially in shaded locations with high constant humidity. In these locations, steel beam superstructures should be used primarily when they provide significant advantages over the other superstructure types. If steel is to be used in high humidity locations, all of the superstructure steel, including the diaphragms, should be coated.

2.3.6.6 Reinforced concrete slab superstructures are typically not economical over 25' since a form must be built to support the weight of the plastic concrete until it cures. Since in most cases building falsework to support the forms from below is not feasible, either because the bridge is over water or over traffic, some type of overhead support system must be used, which limits the span of the slab bridge structure. Reinforced concrete slab bridges, however, are to be used exclusively where the new bridge structure will be entirely hidden from view and inspection, such as a bridge that is to be built within the walls of a historic arch or stone clapper bridge that is to be retained in its entirety in order to maintain the existing visual appearance.

2.3.7 Prefabricated Bridge Elements and Systems (PBES) and Prefabricated Bridge Units (PBU's)

2.3.7.1 As discussed in Subsection 2.1.4, Prefabricated Bridge Elements and Systems (PBES), as detailed in Part III of this Bridge Manual, are comprised of prefabricated and separately shipped pieces that are assembled in the field to form a complete bridge. Since PBES use emulative design, whereby the final bridge component is designed as a conventional cast in place component that is then divided up into discrete elements for fabrication and erection, Designers can follow the selection guidelines given above in arriving at the bridge structure type and configuration.

2.3.7.2 Prefabricated Bridge Units (PBU's) typically consist of two steel beams that support a factory cast deck section, although precast concrete beams, such as the NEXT D and NEDBT beams, can also be considered a type of PBU. These PBU's are placed on abutments and piers and are then assembled into the final bridge superstructure by cast-in-place longitudinal closure pours and possibly closure pours at the abutments. Multi span bridges made up of PBU's are typically designed and erected as simple span bridges where the deck is made continuous with a link slab closure pour, although full beam continuity for live load can be achieved by connecting the beam ends either through a bolted connection that will transmit moment or through a full height diaphragm that encases and connects the beam ends.

Since steel beam PBU's are an emulative design of a typical steel stringer bridge, theoretically PBU's can have the same span lengths as conventional steel bridges. However, in reality, shipping considerations of width, height and length, erection considerations of pick weight and crane size, and the constraints of site to accommodate the crane and the swing radius limit the practical size of the PBU.

2.3.8 Instructions for Completing the Bridge Type Selection Worksheet

2.3.8.1 Introduction. The Bridge Type Selection Worksheet (BTSW) is set up to guide the Designer step-by-step through the bridge type selection process that was described in Subsection 2.3.2 above and applying the Preliminary Engineering Decision Making Methodology described in Subsection 2.1.3 above. The idea of the BTSW is to streamline the type selection by narrowing down the range of possible bridge structure types to only those that best address the site and project parameters and constraints and discounting those that do not. The ultimate goal is to arrive at a structure type that best fits the site and all project parameters and constraints.

The instructions that follow are intended to assist the Designer in filling out the headings of the BTSW, and in interpreting and evaluating this information in order to arrive at the recommended structure type.

2.3.8.2 Project Cost Considerations. In the past, bridge structure types were selected based on lowest estimated first initial construction cost. However, a bridge with the lowest first cost is not necessarily the one that best fits the site or addresses the project parameters and constraints nor does it guarantee the best performance and lowest maintenance cost over the life of the structure. For this reason, cost must not be used as one of the primary factors in selecting the proposed bridge structure type for the project. Selection should be based on how well the bridge structure will fit the site and address all project parameters and constraints. If two or more bridge structure types are equally well suited for the project, then first initial cost can be used but only as a tiebreaker.

If a Designer feels compelled to use cost as a primary factor in the decision making, then they will be required to perform a full life-cycle cost analysis for each bridge structure type being evaluated and use that cost for the decision making. This life cycle cost analysis must include not only the full, structure type specific construction cost estimate (e.g. any variation in the profile between structure types would result in different construction costs between them due to the different backfill gravel needs), but also the present value of all maintenance work that can be anticipated for each structure type over its 75 year life. Since MassDOT does not have a life cycle cost methodology other than to use a 4% annual inflation rate, the Designer will be on their own in developing this methodology and identifying all maintenance actions, their costs and their frequency.

2.3.8.3 PROJECT LOCATION. This BTSW Heading is basically self-explanatory. Provide the information that identifies the location of the project site.

2.3.8.4 DESCRIPTION OF EXISTING SITE CONDITIONS. The information in this BTSW Heading is intended to help familiarize the Designer with the existing conditions found at the project site. These existing conditions may affect or limit the selection of the bridge structure type or will require special accommodation in design or in construction.

2.3.8.5 DESCRIPTION OF PROJECT PARAMETERS AND CONSTRAINTS. The information in this BTSW Heading is intended to help the Designer identify all of the project parameters from the geometrics of the roadway on the bridge, the feature the bridge crosses as well as constraints that each of the existing site conditions impose on the selecting the structure type for this site. The Designer must also prioritize the parameters and constraints as discussed in Paragraph 2.1.3.1. It is important that the Designer has a clear understanding of the project parameters and constraints before beginning to select the structure type. For bridges over water, when several structure types are being considered, a Preliminary Hydraulic Analysis will be prepared in lieu of a full Hydraulic Report for the Type Selection phase that gives the relevant hydraulic information for each alternative. A full Hydraulic Report will be prepared once a final alternative is selected for the Sketch Plan phase.

2.3.8.6 APPROPRIATE BRIDGE STRUCTURE TYPES. In this BTSW Heading, the Designer identifies the structure types, both superstructure and substructure, that are most suited for this site based on the existing site conditions and project parameters that were identified in the BTSW Headings 1 and 2. Structure types that are not suited for this site because they cannot address the existing site conditions and/or project parameters and constraints need not be considered any further. The Designer should refer to Subsection 2.3.4 above for guidance in identifying the appropriate bridge structure type.

2.3.8.7 PROPOSED SUBSTRUCTURE ARRANGEMENT, SPAN AND FOUNDATION TYPE. Once the suitable bridge structure types have been identified, the Designer can do a preliminary layout of the substructures (e.g. single span versus multi-span, integral abutments versus stub versus full height, etc.) and make a preliminary determination of the bridge span lengths. This layout of the substructure should take into account the site conditions, project parameters and constraints that will affect the location of the substructure units, including constructability considerations including location of cranes, water control, delivery of the beams and other bridge components, etc. The Designer should refer to Subsection 2.3.5 above for guidance in laying out the substructure units.

2.3.8.8 PROPOSED SUPERSTRUCTURE TYPE. After the substructure arrangement has been laid out and the span lengths established, the Designer must evaluate all appropriate superstructure types that were identified under BTSW Heading 4 in order to determine the bridge structure type to recommend. This evaluation should be based on the pros and cons of each structure type based on the following evaluation factors:

- How each structure type fits the most important site conditions identified in Heading 2.
- How each structure type addresses and accommodates the most important project parameters and constraints as identified under Heading 3.
- Constructability
- Anticipated future maintenance requirements
- If this is a candidate for accelerated construction methods, the anticipated construction time

Additional evaluation factors can be used as needed if they reflect important project requirements. The Designer should refrain from using generic pros and cons that have no relation to the site conditions or project parameters and. The Designer should provide a realistic evaluation of the superstructure type and not should use assumptions that lack a factual basis or make vague and unquantifiable comparisons, such as making a statement “will take longer to construct”, without quantifying how much longer. In order to get a fair comparison, the same evaluation factors should be used for all superstructure types being evaluated. The superstructure type that maximizes the pros and minimizes the cons should be superstructure type recommended.

First initial construction cost must not be used as a primary evaluation factor. If two or more superstructure types are equally well suited for the project, then the first initial construction cost can be used, but only as a tiebreaker. The Designer should refer to Subsection 2.3.6 above for guidance in evaluating superstructure types.

2.3.8.9 PRELIMINARY PROJECT COST ESTIMATE. This should be the total anticipated cost estimate for the recommended bridge structure type and would be the sum of: cost estimate of the bridge structure itself, any required approach roadwork, and the cost of any traffic management costs. If there are several equally viable bridge structure types, then the a total project cost shall be estimated for each viable bridge structure type alternative and the one that has the lowest project cost will be selected.

2.3.8.10 RECOMMENDATION OF PROPOSED BRIDGE STRUCTURE TYPE. In this BTSW Heading, the Designer recommends the proposed bridge structure type for this project along with the reasons why the Designer considers it to be the most appropriate bridge structure type for this project site. This can be based on the evaluation of the pros and cons of this structure type.

NOTE: If the Designer recommends a structure type:

- That has fracture critical members

- That has unique or special features whose condition cannot be fully assessed through a standard visual inspection, or which requires additional attention during an inspection to insure the safety of such bridges
- That requires special periodic maintenance to insure satisfactory and safe operation

and MassDOT approves this recommendation for final design, then the Designer shall also be required to submit the following design deliverables, as applicable:

- A Fracture Critical Inspection Procedure (see Subsection 3.13.2)
- A Special Inspection Procedure (see Paragraph 3.13.3.1)
- A Special Maintenance Procedure Manual (see Paragraph 3.13.3.2)

2.3.8.11 APPENDICES. The information that is to be included in the appendices is described in the Bridge Type Selection Worksheet Format outline as presented in Paragraph 2.3.8.12 below.

2.3.8.12 Bridge Type Selection Worksheet Format. The standard outline to be followed in filling out the BTSW is presented below. It is organized by main headings, which are numbered sequentially and are in bold and all caps, and subheadings, which are numbered sequentially within the heading and are underlined. The italicized text next to each subheading is intended to provide guidance to the Designer as to what information is to be presented under each subheading and is not intended to be a complete and exhaustive summary. The Designer should provide all of the information as thoroughly and as concisely as possible, ideally in bullet form, as it applies to this specific bridge structure and site. Extensive text writing should be avoided unless it is necessary to adequately describe the decision making process. If a subheading does not apply to the specific bridge project, a notation of "Not Applicable" should be provided.

The worksheet shall not be protected by copyright and shall be signed by the Engineer preparing it. All required drawings and diagrams should be presented in an 8½" x 11" format with an 11" x 17" format foldout used only when necessary. These illustrations should be specific to the bridge structure type being discussed and any extraneous details appropriate to highway layout, utility plans, etc. should not be submitted, unless they are required to identify a project constraint and its relationship to the bridge structure.

In addition to submitting the BTSW in an Adobe Acrobat format (PDF)), the number of hardcopies of the BTSW to be submitted shall be as requested by the Project Manager.

BRIDGE TYPE SELECTION WORKSHEET

1. PROJECT LOCATION

1.1 City or Town:
1.2 District:
1.3 Bridge Number:
1.4 BIN:
1.5 Structure Number:
1.6 Roadway on Bridge:
1.7 Feature Intersected:

2. DESCRIPTION OF EXISTING SITE CONDITIONS

2.1 Description of Existing Bridge Structure: *(Provide cross section information including dimensions, number of lanes, shoulders, sidewalks, skew, span arrangement and length(s), description of superstructure, substructure and foundation type, underclearances (horizontal and vertical), historical significance or relationship to a historic district and any other factors that are peculiar to the existing bridge structure.)*

2.2 Description of Approach Roadway: *(Provide cross section information including dimensions, number of lanes, shoulders, sidewalks, roadway system, design speed, present ADT and Percentage Truck Traffic, vertical and horizontal alignment through the bridge site, roadway system including if NHS or not, and any other factors that are peculiar to the existing approach roadway that may affect the bridge structure.)*

2.3 Description of Feature Under the Bridge Structure: *(Provide a description of the feature that the bridge structure crosses. For other highways, provide all information as specified above for the approach roadway. For railroads, provide cross section information including number of tracks, spacing between tracks, width of service roads, clearances from centerline of track to the adjacent substructure unit, vertical clearances over each track, locations of drainage swales or drainage structures within the bridge site, track alignment and location of any railroad structures for 1000' on either side of the bridge site, if bridge comes under Chapter 634 regulations, and any other factors peculiar to the railroad that may affect the bridge structure. For water crossings, provide width and depth of channel, description of channel alignment both upstream and downstream of bridge structure, condition of the banks, condition of the channel, observation of debris, beaver activity, marine traffic and navigational features, State and/or Federal Wild, Scenic or Recreational River designation and any other factors peculiar to the river that may affect the bridge structure. For other types of features, provide as complete a description as possible of all relevant characteristics of the feature to be crossed as they may affect the proposed construction.)*

2.4 Description of Existing Hydraulics at the Bridge Site: (*Provide the hydraulic information for the existing bridge hydraulic opening, identify the potential for scour or actual scour that exists or the structure is being monitored for, tidal flushing action through the existing opening, and any other hydraulic factors that may need to be addressed by the proposed construction.)*

2.5 Description of All Utilities Within the Bridge Site: *(Identify and describe all utilities, including location, type and size. This description should include all utilities that are presently on the bridge, utilities that may be buried in the vicinity of the bridge structure that could be affected by the proposed construction, including all utilities that share a railroad's right of way, and any overhead utilities.)*

2.6 Description of Environmentally Sensitive or Cultural Resource Areas Affecting the Bridge Site: *(Identify and describe all environmentally sensitive areas, such as but not limited to wetlands, vegetation and animal habitats that are adjacent or within the bridge site and that may be affected by the proposed construction; identify and describe all cultural resource sites including historic districts, archeological sites, historic structures and markers or any other cultural resources that may be affected by the proposed construction.)*

2.7 Hazardous Materials: *(Identify and describe all potential hazardous materials or contaminants on the existing bridge structure, on the approach roadway and in the ground within the bridge site that may be disturbed or would require disposal as a result of the proposed construction.)*

3. DESCRIPTION OF PROJECT PARAMETERS AND CONSTRAINTS

3.1 Description of Proposed Roadway Cross Section: *(Provide proposed cross section information including dimensions, number of lanes, shoulders, sidewalks, roadway system, design speed, design ADT and Percentage Truck Traffic, vertical and horizontal alignment through the bridge site, roadway system including if NHS or not, and any other factors that are peculiar to the existing approach roadway that may affect the bridge structure type selection.)*

3.2 Proposed Traffic Management: *(Provide description of how traffic is to be maintained during construction: for total shut down provide a description of the detour; for stage construction provide number of stages, number of lanes to be maintained; for temporary bridges within the bridge site, provide number of lanes to be maintained, location of temporary bridge, temporary roadway alignment; and any other factors to manage traffic that may affect the type of structure to be selected.)*

3.3 Proposed Clearances: *(Identify the required underclearances, both horizontal and vertical and the location of these clearances.)*

3.4 Hydraulic Data*:* *(If a Preliminary Hydraulic Analysis was prepared, provide the following hydraulic data: Design Flood frequency in years and Design Flood Elevation (NAVD 88); Base Flood Elevation (NAVD 88, 100-year storm); Free Board in feet; Abutment Design Scour storm frequency in years and Depth in feet; Abutment Check Scour storm frequency in years and Depth in feet; Pier Design Scour storm frequency in years and Depth in feet; Pier Check Scour storm frequency in years and Depth in feet. If a full Hydraulic Report was prepared, in addition to the above provide: drainage area in square miles; Design Flood discharge in cubic feet/second; Design Flood velocity in feet/second; Base Flood (100 year) discharge in cubic feet/second; Base Flood (100 year) water surface elevation (NAVD); Flood of record frequency in years; Flood of record discharge in cubic feet/second; Evidence of scour and erosion; History of ice floes)*

3.5 Preliminary Geotechnical Data: *(Identify any preliminary geotechnical information that may affect the selection of the bridge structure type. If no borings have been taken, this information may be obtained from the borings of the existing structure or through site examination if prominent geotechnical features, such as the existence of rock outcrops are readily visible.)*

3.6 Constraints Imposed by Approach Roadway Features: *(Identify any features that would limit the approach roadway alignment or profile, such as driveways, buildings, abutting private property.)*

3.7 Constraints Imposed by Feature Crossed: *(Provide a description of any constraints that the feature crossed imposes that would affect the construction of the bridge structure. For bridges over highways this would include traffic management during all phases of construction and any restrictions on foundation excavation. For bridges over railroad this includes the limitations on the excavation of foundations, driving sheet piling, windows of operation for the contractor, or any other factors that the railroad imposes that would affect* *the bridge structure type to be selected. For bridges over water includes considerations of marine traffic, including restrictions on contractor operations, partial or total shutdowns to marine traffic, seasonal marine traffic considerations and any other marine traffic factors that would affect the bridge structure type selected. Environmental issues affecting the construction of bridges over water should not be covered here, but rather in the* Constraints Imposed by Environmentally Sensitive Areas *subheading.)*

3.8 Constraints Imposed by Utilities: *(Identify how all utilities whether on the bridge, under the bridge, over the bridge or within the bridge site must be accommodated, including either total shut down for the duration of construction, temporary relocation, utilities that cannot be shut down or relocated and so must be remain in their current location and any utilities that share a railroad right of way.)*

3.9 Constraints Imposed by Environmentally Sensitive Areas: *(Identify all restrictions imposed by regulations for environmentally sensitive areas that may be affected by the construction of the bridge structure and its foundations or by any approach roadway work.)*

3.10 Constraints Imposed by Cultural Resource Areas: *(Identify all restrictions imposed by cultural resource protection regulations that would affect the selection of the bridge structure type or that would be affected by the construction of the bridged structure and its foundations.)*

3.11 Hazardous Material Disposition: *(Identify the disposition requirements or mitigation strategies for all hazardous material that would be affected by the construction of the bridge structure.)*

3.12 Other Project Constraints: *(Identify any other constraints that would affect the selection of or the construction of the bridge structure. For superstructure replacement projects, this constraint would be the material and structural evaluation of the existing substructure units from the Preliminary Structures Report)*

4. APPROPRIATE BRIDGE STRUCTURE TYPES

4.1 *(Identify all bridge structure types that are potentially viable for this particular project site and indicate how well they address or do not address the project parameters and constraints. For additional guidance, see Paragraph 2.3.7.6 above.)*

5. PROPOSED SUBSTRUCTURE ARRANGEMENT, SPAN AND FOUNDATION TYPE

5.1 *(Identify those substructure arrangements, span lengths and preliminary foundation types that are viable for this project site and indicate how well they address or do not address the project parameters and constraints. For additional guidance, see Paragraph 2.3.7.7 above.)*

6. PROPOSED SUPERSTRUCTURE TYPE

6.1 *(Identify that superstructure type (or types) that is viable for this project site and indicate how well it addresses or does not address the project parameters and constraints. For additional guidance, see Paragraph 2.3.7.8 above.)*

7. PRELIMINARY PROJECT COST ESTIMATE

7.1 *(Provide a preliminary cost estimate of the total project cost. This would consist of an estimate of the cost of the bridge structure itself, any required approach roadwork, and the cost of any traffic management costs. If there are several equally viable bridge structure types, then a total project cost shall be estimated for each bridge structure type alternative and the one that has the lowest project cost will be selected. For additional guidance, see Paragraph 2.3.7.9 above.)*

8. RECOMMENDATION OF PROPOSED BRIDGE STRUCTURE TYPE

8.1 *(Recommendation of the proposed bridge structure type and a statement of why it is the most appropriate bridge structure type for this project site. For additional guidance, see Paragraph 2.3.7.10 above.)*

9. APPENDICES

9.1 Completed Preliminary Decision Value form and Preliminary Decision Making Flowchart

9.2 Plan, Profile, Elevation and Cross Section of the proposed bridge structure *(if there are several equally viable bridge structure types, provide this for each alternative)*

9.3 Typical Approach Roadway Cross Section

9.4 Clearance Diagram for Feature Crossed

9.5 Plan, Profile and Cross Section of the feature crossed *(if it is a highway or railroad)*, Channel Cross Section (*if the feature crossed is water)*

9.6 Stage Construction Diagrams *(if stage construction is proposed)*

9.7 Traffic Detour Diagram *(if a total roadway shut down is proposed for construction)*

9.8 Backup Calculations *(for the preliminary project cost estimate)*

2.4 BRIDGE REHABILITATION AND SUPERSTRUCTURE REPLACEMENT PROJECTS

2.4.1 General Guidelines

2.4.1.1 A bridge rehabilitation project may be a viable option and should be considered for those bridges that:

- do not have significant highway geometry deficiencies;
- have only a limited number of deteriorated bridge structure members and the rest are in satisfactory condition;
- have substructure units and foundations in satisfactory condition, have not been undermined by scour, and do not have significant seismic deficiencies;
- have structural systems that are redundant and which can be brought up to current code and load carrying requirements without extensive and expensive structural work.

Bridge rehabilitation may be the only feasible choice for historic bridges that must be retained in a highway capacity.

2.4.1.2 A bridge rehabilitation may not be feasible for those bridges that:

- have substandard horizontal and vertical underclearances;
- have a poor roadway alignment both on the bridge and on the approaches;

- have extensive deterioration of the substructure, including active scour undermining, pronounced seismic vulnerability, and/or questionable foundations;
- have numerous deficiencies throughout the superstructure and/or substructure;
- have structural systems that are non-redundant or incorporate poor details that require increased maintenance and inspection effort.

In such cases, a bridge replacement will better address the goals as stated in Subsection 2.1.2 and will pose fewer uncertainties during construction.

2.4.1.3 Superstructure Replacement. A superstructure replacement project is a cross between a bridge rehabilitation and a bridge replacement project since the existing substructure is retained and rehabilitated while the superstructure is replaced in its entirety. Superstructure replacement projects are addressed in this Subsection because they require the same assessment of the re-use potential of the substructure units as do bridge rehabilitation projects and this assessment shall follow the same guidelines as outlined below except that the superstructure shall not be included. Superstructure replacement projects may be a viable option and should be considered for those bridges where the existing substructure units:

- and their foundations are in satisfactory condition
- do not have significant load carrying, scour or seismic deficiencies and have not been undermined by scour
- do not pose significant highway geometric deficiencies for the roadway below or poor roadway alignment on the approaches
- can be rehabilitated to meet current standards as well as improvements to the vertical clearances if needed.

Superstructure replacement projects should also be strongly considered for those locations where the use of prefabricated bridge units is needed for rapid construction to address traffic management issues.

If a superstructure replacement project is feasible, an abbreviated Bridge Type Selection Worksheet is still required, where Headings 4 and 5 are eliminated and the existing substructure units and their evaluations in the Preliminary Structures Report become one of the project parameters and constraints in Heading 3.

2.4.1.4 Accident History. The rehabilitation versus replacement decision must consider the accident history and the potential for accidents. An examination of accident reports can determine the accident history and can establish trends in accident patterns that would point to the bridge as being the cause of contributing element to them. A review of the roadway geometrics at the bridge, including sight distance, bridge width, horizontal clearances, alignments, etc., can identify the potential for accidents and those geometric elements that need upgrading.

2.4.1.5 Traffic Management. There may be several feasible alternatives to maintaining the traffic flow around the project site. They may include closing the structure and detouring traffic around the site, maintaining traffic on a temporary bridge, maintaining traffic on the existing structure while a new structure is constructed on a new alignment, or maintaining traffic on a portion of the existing structure by stage construction. These alternatives must be carefully considered as to their practicality, overall cost, delay of the traffic, and impact to the surrounding community. In some cases, the type of project will be driven by the fact that there is only one practical solution to managing the traffic.

2.4.1.6 Feature Crossed. The feature crossed can have a significant effect on the type of project selected and its cost. Environmental or Coast Guard concerns may push the decision in the direction of the rehabilitation while hydraulic inadequacies, poor stream alignment and scour susceptibility as identified in the Hydraulic Report may push the decision toward replacement.

2.4.1.7 If, based on the above considerations, a bridge structure appears to be viable for a rehabilitation project, then the next step is to perform an assessment of the existing structure that will include:

- a field survey of the structure in order to establish all of the deficiencies that need to be addressed during the rehabilitation;
- material testing in order to establish any potential problems that would reduce the service life of the rehabilitated structure and to establish material properties to be used as part of the rehabilitation design;
- a preliminary structural analysis in order to determine the potential load carrying capacity of the rehabilitated structure;
- a preliminary estimate of the cost of the rehabilitation project in order to compare it to a cost estimate of a comparable replacement project.

All these investigations shall be prepared as part of the *Preliminary Structure Report*.

2.4.2 Preliminary Structure Report

2.4.2.1 All of the findings outlined below, including the results of all material testing and preliminary structural analysis, preliminary seismic analysis and preliminary cost estimate, but excluding the Geotechnical and Hydraulic Reports, shall be presented in a report called the *Preliminary Structure Report* (PSR).

2.4.2.2 Preliminary Structure Report Format. Since the scope of work, and therefore, the amount of investigation and material testing can vary from project to project, there is no set format to the report. However, the main body of the report shall consist of a summary of the results of all investigations performed accompanied by the Designer's evaluation of these results as they pertain to the reuse of the bridge components. It should be organized by each investigation category, as defined in Paragraphs 2.4.2.3 through 2.4.2.11 below. The main body of the report should conclude with a final discussion that ties the results of all investigations and evaluations together into one comprehensive recommendation regarding the re-use or replacement of all or part of the bridge structure. The actual back up from the investigations, such as material testing reports, inspection reports, etc., should be included as appendices following the main body of the report. However, the full set of preliminary calculations including computer output should not be included in the PSR.

All required drawings and diagrams should be presented in an 81/2" x 11" format with an 11" x 17" format foldout used only when necessary. These illustrations should be specific to the bridge structure type, features and locations of deterioration being discussed. Any extraneous details appropriate to highway layout, utility plans, etc. should not be submitted unless they are required to identify a project constraint and its relationship to the bridge structure.

In addition to submitting the PSR in an Adobe Acrobat format (PDF), the number of hardcopies of the PSR to be submitted shall be as requested by the Project Manager.

2.4.2.3 FIELD SURVEY OF THE EXISTING STRUCTURE: The Designer shall perform a complete field survey of the existing structure in order to establish its structural deficiencies with the intent of developing Construction Drawings and a reasonable estimate for the work. At a minimum, this field survey shall document the following:

1. Map all patches, spalls, delaminations, and any other concrete deficiencies on all concrete bridge members, including areas of deficiency in the concrete deck.

2. For prestressed concrete beams, a visual evaluation of the extent of deterioration of the beams and a visual evaluation of the condition of the bearings.

3. For structural steel, location and extent of all corrosion and measurement of loss of section, identification of fatigue prone details, location and condition of cover plate cutoffs, condition of connection details and fasteners, and presence of lead paint,

4. A visual survey of all abutments, wingwalls, pier caps and columns, in order to determine the location, extent and depth of the deterioration that would require removal and replacement in order to return the substructure to a usable condition. If a substructure replacement appears necessary, evaluate locations and feasibility of providing temporary superstructure supports.

2.4.2.4 MATERIAL SAMPLING AND TESTING - CONCRETE: For concrete, this will entail the taking of concrete samples to determine the quality of the concrete and the extent of any chloride contamination, as well as to determine if there any material deficiencies that will reduce the service life of the retained concrete members. The common material deficiencies found in concrete are:

1. High chloride concentrations that indicate that there is a higher potential for rebar corrosion, especially if there is evidence of active rebar corrosion, such as horizontal or vertical cracks on a regular pattern that lines up with where the rebars are located, rust staining emanating from cracks, or exposed rebar which are indicative of rust expanding and spalling the concrete cover.
2. Alkali-Silica Reactivity (ASR) is a reaction that occurs between the silica in the aggregates and the alkali in the cement paste. This reaction produces an expansive gel that causes the concrete to expand volumetrically from the inside. Externally, the ASR results in a network of cracks in the area where ASR is going on. See Figure 2.4.2-1 for examples of ASR induced cracking. ASR can be detected through a petrographic analysis of the concrete cores. In some cases, a petrographic analysis can show that ASR had begun, but it consumed all of the available silica years ago and has produced very little expansive gel. In these cases, ASR does not pose a long-term threat and the substructure can be re-used, especially if there is no visible cracking. On the other hand, if the reaction is still on-going or if the amount of expansive gel that has been created is large and pervasive throughout the concrete matrix and has already resulted in the cracking shown in Figure 2.4.2-1, there is little that can be done to halt it and restore the concrete. Complete replacement is the only cost-effective long-term action. Sometimes, the cracks formed by ASR provide a pathway for water to enter the concrete matrix and initiate Freeze-Thaw damage. As a result, ASR can be confused with Freeze-Thaw and vice versa.

(a) Moderate ASR Cracking **(b) Moderate ASR Cracking**

(c) Severe ASR Cracking **(d) Severe ASR Cracking**

Figure 2.4.2-1 a through c: Examples of ASR Cracking of Bridge Substructures
(From FHWA Alkali-Silica Reactivity Field Identification Handbook)

3. Freeze-Thaw damage is the most common form of concrete deficiency. It occurs through repeated cycles of water infiltrating the concrete matrix, freezing in the cold weather, melting when it warms and then freezing again when it gets cold. Since ice is expansive, the frozen water acts like a wedge in creating micro cracks that break up the concrete matrix. Externally, freeze-thaw damage appears as linear cracks accompanied by efflorescence. With time, the concrete spalls off, exposing the concrete substrate that has the appearance of gravel. In extreme cases, the concrete is so deteriorated that it can even be excavated with bare hands. As this loosened concrete sloughs off, bridge components such as bearings are undermined. See Figure 2.4.2-2 for examples of freeze-thaw damage to bridge elements. If the concrete is found to have significant amounts of freeze-thaw damage, full replacement is the only cost-effective remedy. In the 1960's it was discovered that concrete's susceptibility to freeze-thaw damage could be reduced or eliminated by entraining air in the concrete matrix. From that time, commercial air entraining admixtures were developed that allowed the entrainment of air to be more consistent and reliable. The amount of air entrainment in existing concrete can be determined through a petrographic

analysis of the concrete cores. However, there are instances where older, pre-1960 concrete structures, although lacking air entrainment, exhibit little to no freeze-thaw damage even after decades of use. This may be due to the impervious nature of the concrete matrix or they are protected from the freeze-thaw cycles. In these cases, lack of air entrainment must be considered in relation to the actual condition and performance of the concrete.

(a) Early Stage **(b) More Advanced Stage**

(c) Extreme Stage of Damage **(d) Extreme Stage of Damage**

Figure 2.4.2-2 a through d: Examples of Freeze-Thaw Damage to Bridge Elements

When coring or drilling the concrete to take samples, steel reinforcing must be avoided. This will require the use of equipment capable of locating existing reinforcement prior to concrete sampling. At a minimum, the samples to be taken shall include:

1. Drilled concrete dust samples in order to determine salt content at various levels of all existing cast-in-place concrete members. They shall be taken on the deck, superstructure and substructure at representative locations, unless the deficiencies are so obvious and complete that re-use or rehabilitation can be dismissed.
2. Core samples in order to determine the presence of alkali-silica reactivity, the concrete's susceptibility to freeze-thaw deterioration, and the concrete's integrity and strength. These cores are to be taken on the deck, superstructure and substructure at representative

locations, unless the deficiencies are so obvious and complete that any re-use or rehabilitation can be dismissed.

The method of sampling and testing shall be submitted to MassDOT for approval.

2.4.2.5 MATERIAL SAMPLING AND TESTING - STEEL: For steel, this will entail taking coupons of the structural steel members if the grade and/or chemical properties of the steel is not known and if knowledge of these properties will reduce or eliminate the need for extensive retrofitting of the existing steel members. The number and location of the coupons to be taken shall not reduce the capacity of the member and, at the same time, shall give a statistically reliable representation of the structural steel in the bridge structure. At a minimum, the samples to be taken shall include steel coupons to identify the steel grade and actual yield stress, as well as its chemistry, which is needed to determine the weldability of the steel if the rehabilitation will require welded steel attachments, such as shear studs to make the steel members composite with the concrete deck.

For reinforcing bars, this will entail the taking of rebar samples to identify the yield strength of the existing reinforcement. The chemical composition of the reinforcing bars may need to be investigated as well, if there is a possibility that the rehabilitation will require welding of the reinforcement. Samples should be taken at locations of minimum stress in the reinforcement. To avoid excessive reduction in member strength and to provide better representation of the strength of the reinforcement, no two samples should be taken from the same cross-section of a structural member.

The method of sampling and testing shall be submitted to MassDOT for approval.

2.4.2.6 PRELIMINARY STEEL SUPERSTRUCTURE EVALUATION. A structural analysis shall be performed to establish the actual present capacity of the stringers, splices, cover plates, and connection details of the members to be retained and to identify retrofitting strategies required to upgrade the structure to current load carrying requirements as specified in Chapter 3 of this Bridge Manual. These results will be used to determine the cost effectiveness, service life and resulting constructability of retaining existing steel members. The condition of any existing roadway joints shall be noted and the feasibility of retrofitting the structure to make it continuous for live load should be considered.

2.4.2.7 PRELIMINARY CONCRETE SUPERSTRUCTURE EVALUATION. A structural analysis shall be performed to establish the actual present capacity of the concrete superstructure members and to determine the need for and identify strategies of upgrading them to current load carrying requirements as specified in Chapter 3 of this Bridge Manual. This analysis should also determine the feasibility of retrofitting these members to make the structure continuous for live load.

2.4.2.8 PRELIMINARY SUBSTRUCTURE EVALUATION. A structural analysis shall be performed to determine the capacity of the substructure units for current load carrying requirements as specified in Chapter 3 of this Bridge Manual, including their capacity to withstand seismic demands. The results of these analyses shall be presented to the Bridge Section for consideration and final determination as to the course of action. The State Bridge Engineer shall determine what code requirements can be waived or not waived in deciding the re-use of the existing substructure units. This analysis will be performed as follows:

I. Load Carrying Capacity. Check the existing substructure units for HL-93 live load and the proposed superstructure dead loads using the LRFD Strength I Limit State and all

applicable load and resistance factors. If the existing substructure units do not meet the Strength I Limit State for HL-93 loading, check capacity of the existing substructure units for HS25 loading and the new superstructure dead loads using the *AASHTO Standard Specifications for Highway Bridges* using the Load Factor method. If the existing substructure units do not meet the HS25 loading using the Load Factor Method, then determine if or how the substructure can be upgraded to meet HL-93 requirements along with a cost estimate for this upgrade.
Substructures of historic structures that are being rehabilitated need only be checked to meet the anticipated truck loading that will be used for the design of the superstructure as specified in Subsection 3.1.3 of Part I of this Bridge Manual.

II. Code Compliance. The existing substructure units may not meet all detailing requirements of the *AASHTO LRFD Bridge Design Specifications*.

Code provision requirements may be waived with the approval by the State Bridge Engineer, provided the substructure unit being analyzed meets the following criteria:

1. The factored nominal resistance exceeds the factored applied force effect for all limit states
2. The pier cap or substructure unit being analyzed has been inspected and does not exhibit visible signs of distress. In the event that the substructure unit cannot be inspected (i.e. rear face of an abutment), it can be assumed to be in acceptable condition if the abutment stem appears to be vertical and not compromised.

Examples of such code provisions include *AASHTO LRFD Bridge Design Specifications*, Articles 5.7.3.3 (Limits for Reinforcement) and 5.10.8 (Shrinkage and Temperature Reinforcement).

If the above criteria are not met, a check should be made to determine which of the LRFD code requirements they meet and which they do not. This analysis shall also include a study of the feasibility and cost of upgrading them to these code requirements.

If such an upgrade is not practical or cost effective, then check the existing substructure units to see if they meet the *AASHTO Standard Specifications for Highway Bridges* Load Factor requirements for detailing. If they do not meet the Load Factor requirements for detailing, a study shall be performed to determine the feasibility and cost of upgrading them to the Load Factor requirements.

III. Seismic Evaluation. The existing substructure units shall be analyzed for their capacity to resist seismic demands. This evaluation shall be performed using the seismic analysis and design procedures outlined in Section 3.4 of Part I of this Bridge Manual. The return period used shall be based on whether the bridge under consideration is Critical/Essential or not. The analysis and evaluation shall be performed as if this it were a new bridge. The detailing requirements need not be greater than what is required for the SDC classification of the bridge, i.e. SDC A detailing for bridges classified as SDC A, SDC B detailing for bridges classified as SDC B, etc.

If the bridge does not have the capacity to meet the seismic demand, check if a seismic isolation Earthquake Resisting System using elastomeric or PTFE bearings will help the structure meet the seismic demand. If the substructure units still do not have the capacity to meet the seismic demand, determine the feasibility and cost of upgrading them to meet that demand.

For certain structures where the re-use of the existing substructure units is essential, the expense of performing a multimode spectral analysis, alone or in combination with a site specific hazard analysis, can be justified since it may lower the seismic demand to a level that the existing substructure units can meet, or can be cost effectively upgraded to meet the demand.

2.4.2.9 GEOTECHNICAL EVALUATION. A subsurface exploratory program, in accordance with the guidelines of Chapter 1, shall be performed, which may include probes, borings and in-situ testing, to evaluate the subsurface conditions and to establish the adequacy of the foundations and of the supporting soils for the loads to be imposed by the rehabilitated structure.

2.4.2.10 HYDRAULIC EVALUATION. For bridges over water, a hydraulic study shall be performed in accordance with Section 1.3 in order to determine the adequacy of the hydraulic opening as well as the susceptibility of the structure to scour. The existing substructure units shall be evaluated for their ability to withstand both a design flood and check flood for scour events in accordance with the analysis procedures outlined in Subsection 3.2.9. Critical/Essential bridges shall meet the requirement to be scour stable and available for limited use immediately after the check scour event. If the substructure units do not meet the requirements of Subsection 3.2.9, consideration shall be given to either retrofitting the existing substructure units to be scour stable or providing scour countermeasures as an upgrade strategy or a combination of the two. Bridge foundation scour countermeasures that are acceptable to MassDOT for use in retrofit applications are based on the countermeasure matrix presented in Table 2.1 of the HEC-23, Volume 1 Design Guidance Document.

Note: FHWA has prepared generic contract special provisions for all the listed HEC-23 Design Guidelines.

2.4.2.11 PRELIMINARY PROJECT COST ESTIMATE. A preliminary cost estimate of the rehabilitation project shall be prepared that will include all costs of addressing structural deficiencies, for upgrading the structure to current load carrying and code requirements and for retrofitting the bridge structure to address seismic resistance and scour, roadway improvements, traffic management and utility management.

2.4.3 Selecting between Bridge Rehabilitation and Bridge Replacement

2.4.3.1 Almost any structure can be rehabilitated, but the question is at what cost and whether this money will be spent wisely or would it be more economical to replace the existing structure. To make this determination the Designer must first determine which project type will best achieve the goal as stated in Subsection 2.1.2 above. If both are equally viable, the Designer must then consider constructability of each project type, accident history, utilities, the constraints imposed by the feature crossed and the constraints of traffic management. If both project types are still equal, then the Designer shall use the estimated construction cost as the deciding factor.

2.4.3.2 Establishing a bridge rehabilitation cost. It is more difficult to estimate the cost of bridge rehabilitation than the cost of a new bridge. The rehabilitation estimate must account for many uncertainties, such as the actual condition of members that were fully or partially hidden from view during the initial field survey. The Designer should also keep in mind that the bridge rehabilitation project may be under construction several years after the field survey was originally performed. Consequently, the estimate of quantities should incorporate reasonable projections to account for continued deterioration. The unit prices used in the estimate should take into consideration the cost of the Contractor's access to the members to be rehabilitated as well as the inefficiency of working in close or constricted quarters.

2.4.3.3 Establishing a bridge replacement cost. In order to avoid excessive and needless study, the Item 94 cost from the bridge's SI&A can be used to approximate the replacement cost for the bridge structure alone. Item 94 is calculated using the area of the bridge times the per-square-foot bridge cost that is reported to FHWA. This per square foot cost is derived from actual bid prices from the preceding year and is updated annually. The Item 94 cost only covers the cost of the bridge structure: substructure, superstructure and deck. The cost for any roadway improvements, traffic management, including any temporary bridges, and demolition of the existing structure should also be estimated and added to the Item 94 cost to arrive at an estimated replacement project cost.

2.5 GEOTECHNICAL REPORT

2.5.1 General

The Geotechnical Report is a basic document used to present the subsurface site conditions and make design and construction recommendations for all foundation and earthwork aspects of a bridge project.

The Geotechnical Report shall not be protected by copyright and shall be signed by the Engineer preparing it. In addition to submitting the Geotechnical Report in an Adobe Acrobat format (PDF)), the number of hardcopies of the Geotechnical Report to be submitted shall be as requested by the Project Manager.

All geotechnical design properties, engineering values, calculations, data, and equations shall be presented using appropriate units consistent with the following guidelines:

Parameter or Property	Preferred Units
Deformation, Settlement	inches
Force	kips
Pressure, Stress, Strength	kips/ft^2
Modulus	kips/ft^2
Subgrade Reaction Modulus	kips/in^3
Density, ρ	lb/ft^3
Unit Weight, γ	lb/ft^3
Particle Diameter, d	inches
Coefficient of Permeability, k	in/s
Coefficient of Consolidation, c_v	ft^2/s

The text of the report shall be concise and as definitive as possible and shall be based upon careful analysis of subsurface data and sound engineering judgment. Extraneous data or discussions should not be included. All recommendations, calculations and analyses shall be consistent with the requirements of the *AASHTO LRFD Bridge Design Specifications*. All laboratory or in-situ tests conducted on rock, soil or water shall be conducted in accordance with the applicable standards of ASTM.

2.5.2 Report Outline

The report content shall include the following geotechnical elements applicable to the particular project:

1. **EXECUTIVE SUMMARY**

2. **INTRODUCTION**
   - 2.1 Scope of report.
   - 2.2 Subject background, proposed construction, history.
   - 2.3 Site reconnaissance and overall description.

3. **SUBSURFACE CONDITIONS**
   - 3.1 Local geology: rock, surficial and miscellaneous.
   - 3.2 Subsurface exploration program.
     - a. Available subsurface information.
     - b. Borings/Soil and Rock samples review.
     - c. Probes/Test pits/Observation Wells.
     - d. Geophysical investigations.
     - e. Soils testing, Laboratory and/or In-situ.
   - 3.3. Verification of sample descriptions on boring logs.
     - a. Statement that all soil and rock samples were visually and manually examined by the Engineer preparing the geotechnical report.
     - b. Location and date of sample examination.
     - c. Discrepancies or concurrence with boring logs.
   - 3.4. Subsurface profile.
     - a. Written description, characteristics and classification of all soils and rock.
     - b. Graphic presentation showing all strata and water conditions as in Appendix 6.1.c.
     - c. Applicable design parameters for soil and rock: unit weight, gradation, strength, compressibility, moduli, rockmass rating, and jointing.
   - 3.5. Seismic Design Category Evaluation.
     - a. Site Class Definition (A through F, based on the type of soil and its profile)
     - b. Seismic Design Category (SDC) assigned to each bridge based on the Design Spectral Acceleration Coefficient at 1.0-sec period (S_{D1}).
   - 3.6. Liquefaction potential.

4. **RECOMMENDED FOUNDATION SYSTEM**
   - 4.1. Retain or modify existing foundation.
     - a. Existing foundations/substructure depth, configuration, integrity and bearing material. The Designer shall design and conduct the appropriate method of investigation.
     - b. Applicable design study (see 4.2, 4.3 or 4.4.)

4.2. Embankment considerations (primarily for weak subsoils).
   a. Stability - excavation/replacement, stage construction, berms, flattened slopes, lightweight fill, subsoil soil modification, fill reinforcement, erosion control.
   b. Settlement - magnitude, primary, secondary, subsoil modification, waiting periods, surcharges, lateral movements, down-drag on piles.

4.3. Shallow foundation design.
   a. Rational supporting shallow foundation selection (qualifying reasons, site and cost factors).
   b. Bottom of footing elevation selection.
   c. Factored and Nominal soil bearing resistances and appropriate resistance factor.
   d. Estimate of total settlement, differential settlement and lateral movements.
   e. Parameters for internal and external stability and design of abutments, walls and earth support systems.
   f. Global stability (substructure-slope-subsoil system).
   g. Subsoil preparation, fill material and compaction, soil/rock removal, treatment or stabilization.
   h. Scour protection.
   i. Special considerations.

4.4. Deep foundation design.
   a. Rational supporting deep foundation system.
   b. Recommended type (qualifying reasons, site and cost factors).
   c. Factored and Nominal axial resistances - static analysis, appropriate resistance factor selection, stress wave analysis (piles), actual driving resistance vs. design resistance (scour), load tests.
   d. Lateral load analysis.
   e. Estimated lengths, depths and tip elevations.
   f. Group design - group size, capacity, configuration, settlement.
   g. Drilled shaft design - diameter, socket length, settlement.
   h. Construction considerations - likely method of construction, pile driving criteria and procedures, negative skin friction, vibrations, pre-drilling, obstructions.
   i. Special considerations - corrosion, coatings.
   j. Other methods - pressure injected footings, ground improvement (jet grouting, etc.).

5. CONSTRUCTION CONSIDERATIONS

5.1. Water table - fluctuations, artesian conditions, effects of drawdown, pumping.

5.2. Recommended method for water control and preliminary design thereof.

5.3. Excavations - methods, earth support requirements, rock removal, OSHA requirements.

5.4. Obstructions - nature of, method of removal, break-through and payment.

5.5. Protection of adjacent structures and utilities - excavations, construction loads, settlement, vibrations, pumping.

5.6. Sequence of construction activities - stage construction, surcharging, pile installation.

5.7. Special geotechnical monitoring and instrumentation.

6. APPENDICES

6.1. Graphic Presentations.

a. Project locus map.
b. Site Plan showing as drilled boring locations, proposed and existing structures.
c. Interpreted soil profile with foundation elements.
d. Design charts and graphs.
e. In-situ and lab test results.

6.2. Tables and Text.

a. Tabulated soil design parameters.
b. Tabulated in-situ and lab test results.
c. Table of foundation design alternates, criteria and costs.
d. All calculations performed by hand, spreadsheet or computer program including date performed, initials and references used.
e. Design charts or tables.
f. Final approved boring logs.
g. Applicable special provisions or specifications.
h. All special notes for plans.
i. Specific limitations.

2.6 HYDRAULIC REPORT

2.6.1 General

The Hydraulic Report shall be based on results of the hydraulic study and analysis that are specified in Section 1.3 and shall include a narrative explaining the analytical methods used and summarizing the results and recommendations. Pertinent information collected, computations, plans, and other data should be included in the report's appendices.

The report shall not be protected by copyright and shall be signed by the Engineer preparing it. In addition to submitting the Hydraulic Report in an Adobe Acrobat format (PDF)), the number of hardcopies of the Hydraulic Report to be submitted shall be as requested by the Project Manager.

For bridges over water, when several structure types are being considered, a Preliminary Hydraulic Analysis will be prepared in lieu of a full Hydraulic Report for the Type Selection phase. This will be a one page summary formatted as shown in Figure 2.6.1-1 that will give the relevant hydraulic information for each alternative for use during the Type Selection Phase.

Preliminary Hydraulic Analysis

mm/dd/yyyy
Town/City
Bridge No. x-xx-xxx (xxx)
Project File No. xxxxxx
Road/Stream

Alternative	Description	Design Flood Elevation (ft) (xx-yr)	Free Board (ft)	Base Flood Elevation (ft) (100-yr)	NO-RISE Required (Y/N)	LOMR Required (Y/N)	Abutment Design Scour Depth (ft) (xx-yr)	Abutment Check Scour Depth (ft) (xx-yr)	Pier Design Scour Depth (ft) (xx-yr)	Pier Check Scour Depth (ft) (xx-yr)	Notes & Recommendations
Existing											
Alt-1											
Alt-2											
Alt-3											
Alt-4											

Note: All elevations shall be in NAVD 88 datum

cc: , Project Manger

Figure 2.6.1-1: Preliminary Hydraulic Analysis Form

2.6.2 Report Outline

An outline of the standard text plus information to be included in each section is as follows:

TABLE OF CONTENTS

- List of topics by page number
- List of figures by page number
- List of tables by page number

1. EXECUTIVE SUMMARY

This section is intended to briefly summarize the scope and significant results of the study. Its content should identify the existing structure and its general location, the crossed waterway and its watershed affiliation, the preferred project alternative, and any special regulatory, transportation, scour safety, or flood conveyance considerations associated with the crossing site.

2. PROJECT DESCRIPTION

This section is intended to define the context of existing structure within the local and regional built and natural environment and should consist of the following separate subsections, as described below.

2.1 Existing Structure – include highway route number and/or local name of the road, water body crossed, functional classification, and average daily traffic, date of construction, type of existing structure, geometric configuration including - deck width, clear span and depth of the superstructure, type of foundation, description of Item 113-scour critical bridges in the NBIS coding data, and the reason for replacement/rehabilitation (if applicable).

2.1.1 Crossed Waterway at the Bridge Location – Including watershed size, land cover, topography and degree of urbanization, approach channel slope, sinuosity, bed stability

2.1.2 Highway Conveyed – Including highway number or local name, functional classification, and average daily traffic

2.1.3 Land Use in the Vicinity of the Bridge – Type of land use pattern in the vicinity of the bridge

2.1.4 Special Site Considerations – Including pertinent regulatory, transportation, National Flood Insurance Program (NFIP), or scour safety issues associated with the crossing site and how they may affect project design, construction, and maintenance.

2.2 Proposed Action – include type, geometric configuration including deck width, clear span, depth of the superstructure, type of foundation of the proposed structure.

3. DATA COLLECTION

This section shall briefly summarize the results of the hydraulic study's data collection phase such as survey, sediment sampling results, any prior hydrologic and hydraulic studies etc.

4. ENGINEERING METHODS

This section is intended to identify analytical methods used in the hydraulic study, and to present a concise summary of the results of those analyses and shall consist of three separate subsections, as indicated below. Each sub-section shall incorporate a brief description of the analytical methods employed, the associated primary data sources, and a concise tabulation of pertinent computational results.

4.1 Hydrologic Analyses – For projects studied in the NFIP, describe the FIS data and discharges used. FIS discharges shall be compared with discharges calculated using other hydrologic methods. If FIS discharges are not used for design, fully explain why. FIS base flow shall be used for No-Rise analysis.

For drainage basins that are not studied in the NFIP, describe in detail the hydrologic method used and state the basis for selecting the design flow and frequency. This section shall include the following:

- Description of watershed characteristics
- Any available stream gage information
- Computer model used
- Hydrologic parameters used in the model
- Discharges from previous studies (if available) etc.

Table* 4-1: Summary of Peak Flood Discharges

River Name	Drainage Area (mi^2)	10% Annual Chance [10-yr] (CFS)	4% Annual Chance [25-yr] (CFS)	2% Annual Chance [50-yr] (CFS)	1% Annual Chance [100-yr] (CFS)	0.5% Annual Chance [200-yr] (CFS)	0.2% Annual Chance [500-yr] (CFS)
Bridge Location							

**All tables presented here are examples. The Designer shall include the return frequencies that are applicable to the bridge.*

4.2 Hydraulic Analyses – This section shall describe the methods used to perform the hydraulic analysis including the computer model used, hydraulic parameters including manning coefficients, boundary conditions, etc. NAVD 88 vertical datum should be used for the analysis.

4.2.1 No-Rise Hydraulic Analysis – if the bridge falls under the National Flood Insurance Program (NFIP), Special Flood Hazard Area (SFHA) zone

AE, a "no-rise" analysis is required and shall be performed as described in Subection 1.3.5 of this Bridge Manual.

4.2.2 Duplicate Effective Model – include a "No-Rise" Summary Table (if applicable) with all cross sections used in the analysis from the most upstream section to the most downstream section. Discuss any necessity for a corrected model. If a "no-rise" analysis could not be performed fully explain why not.

Table 4-2: Summary of Duplicate Effective Model Results

River Station	FIS Cross-Section	[1] Published Data (FEET, NAVD)	[2] Duplicate Effective Model (FEET, NAVD)	[2] – [1]
	Bridge			

4.2.3 Existing Conditions Model – briefly describe the hydraulic model development for the existing conditions. Include any changes to the model parameters such as geometry, manning coefficients, boundary conditions, etc.

4.2.4 Proposed Condition Model – briefly describe the hydraulic model development for the proposed conditions. Include any changes to the model parameters such as geometry, manning coefficients, boundary conditions, etc. Describe the freeboard based on design flood.

Table 4-3: Comparison of Hydraulic Performance for the Base Flood Elevation (BFE)

Model Cross Sections	FIS Cross-Section	[1] Existing Condition Model (FEET)	[2] Proposed Condition Model (FEET)	[2] – [1] No – Rise Evaluation

Note: This table shall be based on FIS Base flow

Table 4-4: Summary of Hydraulic Performance

AEP [%]	Peak Flow (CFS)	Existing		Proposed	
		WSEL (FT)	Velocity* (FT/S)	WSEL (FT)	Velocity* (FT/S)
10%					
4%					
2%					
1%					
0.2%					

Note: This table shall be based on the design flow used
**The velocity shall be the maximum velocity near the bridge*

4.3 <u>Scour Safety/Stability Analyses</u> – Scour and stability analysis shall be performed in accordance with the guidance provided in Section 1.3.3.4 and Section 3.2.9 of this Bridge Manual. Provide a brief description of the analysis and pertinent data sources with a summary table as shown below.

Table 4-5: Summary of Calculated Scour for Bridges

Alternative	Return Frequency (year)	[1] Contraction Scour (Feet)	[2] Maximum Local Pier Scour (Feet)	[3] Long Term Degradation (Feet)	[4] Abutment Scour (Feet)	[3] + [4] Design Total Abutment Scour* (Feet)	[1] + [2] + [3] Design Total Pier Scour (Feet)
Existing Condition	Design						
	Check						
Proposed Condition	Design						
	Check						

** Bend scour depth shall be calculated and added to the design total abutment scour if the bridge crossing is located near the bend*

Table 4-6: Summary of Calculated Scour for Culverts

Alternative	Return Frequency (year)	Scour Depth (h_s) (Feet)	Scour Width (W_s) (Feet)	Scour Length (L_s) (Feet)	Scour Volume (V_s) (Feet^3)	Location of Maximum Scour (L_m) (Feet)
Existing Condition	Design					
	Check					
Proposed Condition	Design					
	Check					

4.4 Scour Countermeasure Design – This section should include the scour countermeasure design and the recommendations for the countermeasure type, size, layout, dimensions, etc. See the template for countermeasure design shown in Table 4-7 for sizing of rock riprap at Bridge Abutments. Additional countermeasure design tables should be included for piers, stream stability etc. where applicable.

Table 4-7: Summary of Scour Countermeasure Design at Bridge Abutments

Alternative	Riprap Size D_{50} (Inches)	Riprap Size D_{100} (Inches)	Riprap Thickness (Feet)	Riprap Apron Extend from toe (Feet)	Riprap Extend along u/s and d/s face of the Embankment (Feet)	Vertical Extend up Abutment Slope (Feet)
Existing						
Proposed						

5. CONCLUSIONS AND RECOMMENDATIONS

This section shall consist of the following separate subsections, as described below.

5.1 Conclusions – incorporating a concise summary of the Designers' conclusions and observations regarding the computed results of the study, how the proposed structure will meet the design requirements.

5.2 Recommendations – incorporating the Designer's hydraulic design recommendations regarding the preferred alternatives waterway geometric configuration, installation of structural or non-structural scour countermeasures, and approaches to resolving any flood related construction, environmental permitting/regulatory, or right-of way issues affiliated with the project.

The information in Table 5-1 below should be presented within the Hydraulic Data Tables in the General Notes of the Bridge Sketch Plans and Construction Drawings.

Table 5-1: Hydraulic Design Data

Hydraulic Design Data	
Drainage Area:	Square miles
Design Flood Discharge:	Cubic Feet Per Second
Design Flood Annual Chance (Return Frequency):	% (Years)
Design Flood Velocity:	Feet Per Second
Design Flood Elevation:	Feet, NAVD
Base (100- YEAR) Flood Data	
Base Flood Discharge:	Cubic Feet per Second
Base Flood Elevation:	Feet, NAVD
Design and Check Scour Data	
Scour Design Flood Annual Chance (Return Frequency):	% (Years)
Design Flood Abutment Scour Depth:	Feet
Design Flood Pier Scour Depth:	Feet
Scour Check Flood Annual Chance (Return Frequency):	% (Years)
Check Flood Abutment Scour Depth:	Feet
Check Flood Pier Scour Depth:	Feet
Flood of Record	
Discharge:	
Frequency (If Known):	
Maximum Elevation:	
Date:	
History of Ice Floes:	
Evidence of Scour and Erosion:	

6. REFERENCES

6.1 Data Sources – incorporating a list of primary references and data sources

6.2 Data Application – incorporating a list of data application packages/sources employed to support the study's analytical processes.

7. APPENDICES

The following sections shall include all supporting data used for hydrologic and hydraulic modeling and scour calculations for existing and proposed conditions where applicable.

7.1 FEMA Documents

7.2 Hydrologic Analyses

7.3 Hydraulic Analyses
7.4 Scour and Countermeasure Calculations

2.7 TEMPORARY WATER CONTROL MEASURES MEMORANDUM

2.7.1 GENERAL

The Temporary Water Control Measures Memorandum shall provide the hydraulic design criteria and the estimated flood elevation based on the results of the hydrologic and hydraulic analyses performed from the information that provided to MassDOT Hydraulic Section as described in Paragraph 1.3.3.1 F. This Memorandum shall be provided to the Designer to be used in accordance with Paragraph 3.2.4.5. This information shall also be provided on the Construction Drawings for the Contractor to design the cofferdam in accordance with Paragraph 3.2.4.6.

2.7.2 MEMORANDUM OUTLINE

The outline of the memorandum shall be as follows:

1.0 EXECUTIVE SUMMARY
This section describes the temporary water control measure that will be used and its orientation for all the design stages.

2.0 HYDROLOGIC ANALYSIS
This section describes the peak flow calculations based on the design criteria that explained below:

- For temporary water control that will be in place for one year or less, the 50% Annual Chance (2-Year) flood discharge should be used.
- For temporary water control that will be in place for not more than two years, the 20% Annual Chance (5-Year) flood discharge should be used.
- For temporary water control that will in place for more than two years, the 10% Annual Chance (10-Year) flood discharge should be used.

3.0 HYDRAULIC ANALYSIS
This section describes the hydraulic modeling results, as shown in Table 1:

Table 1: Temporary Water Control Design Data

Flood Frequency[1]	Peak Flow (cfs)	WSE (ft)	Velocity (fps)	Free Board (ft)	Recommended Elevation for the Coffer Dam[2] (ft)
50% (2-yr)					
20% (5-yr)					
10% (10-yr)					

Note:
1. *The Designer shall include the return frequencies that are applicable to the bridge.*
2. *The top elevation of the temporary water control measure shall be the design flood elevation plus 1 foot of freeboard.*

2.8 SKETCH PLANS

2.8.1 Introduction

2.8.1.1 The Bridge Sketch Plans are a preliminary presentation of the overall concept of the proposed structure or proposed rehabilitation. It allows the Designer and MassDOT to agree on the principal components of the structure type or the rehabilitation scheme to be pursued in the final design phase since the Sketch Plans show all major features to be incorporated into the Construction Drawings. However, the approval of the Sketch Plan shall not be considered approval of non-standard details, which must be approved individually before they are used in the final design. The Designer shall proceed with the preparation of Sketch Plans only after receiving approval of the structure type or rehabilitation scheme from MassDOT.

2.8.1.2 The Designer shall not proceed with the preparation of Construction Drawings until approved Sketch Plans have been received from the MassDOT. In addition to MassDOT approval, the Sketch Plans may require approval by FHWA.

2.8.1.3 Sketch Plans must be provided for all structures that require design. Sketch Plans are not required for structures taken from MassDOT Construction Standards. Exceptions to the above will be made only with the approval of the State Bridge Engineer. Before the Sketch Plans are submitted, the Designer must obtain the Bridge Number and/or BIN (Bridge Identification Number) for each structure from the State Bridge Engineer. This request must be made in writing as soon as the recommended bridge structure type has been approved.

In general, a new BIN is required for functional replacements of existing bridges where no portion of the existing structure provides direct support for the new structure. For bridge rehabilitation projects or where the existing structure remains to provide direct support for the new structure, the BIN of the existing structure is retained. For new bridges, both a new Bridge Number and new BIN are required.

2.8.2 Data Required for the Preparation of Sketch Plans

1. Borings
2. Hydraulic Data (if applicable)
3. Traffic Data
4. Highway Geometrics
5. Clearances
6. Bridge Type (approved by MassDOT)
7. Soils Report
8. Design Loading
9. Requirements of Utility Companies
10. Plot Plan (or other documentation used to determine length of walls)

2.8.3 Preparation of Sketch Plans

2.8.3.1 Sketch Plans submitted for signature shall be drafted on mylar (plastic drafting film). The Sketch Plans shall be organized as follows:

1. First Sheet
2. Boring Sheets
3. Structure Detail Sheets

Please note that if all required information needed to be provided on the First Sheet, as specified in Paragraph 2.7.3.2 below, cannot be fit in, an additional drawing following the First Sheet may be generated and used exclusively for the purpose of providing additional required information. No other information shall appear on this drawing.

2.8.3.2 First Sheet. (*See Dwg. No. 1.2.1 of Part II of this Bridge Manual for the organization of the first sheet)*. The first sheet of the Sketch Plans shall contain the following information (also see Paragraph 2.7.3.1 above):

Standard Title Block. *(See Dwg. No. 1.2.2 or Dwg. 1.2.3 of Part II of this Bridge Manual)*. The project description shall be the same as the description to be used on the Construction Drawings. See Paragraph 4.2.2.2 for the standard project descriptions and their definitions.

The names of Facility Carried / Feature Intersected must be exactly the same as those given on the SI&A. The generic Feature and/or Facility Codes (i.e. WATER, HWY, RR, etc.) should be omitted, but the Interstate (I-), US Route (US) and State Route (ST) code along with the route number, followed by the local street names (if any) in parentheses, shall be provided. The local street names shall be fully spelled out (e.g. N WSHNGTN ST on the SI&A shall be spelled out as North Washington Street). If the same stretch of road has several numbered routes associated with it, then all of the routes shall be provided separated by a slash (/) starting with the Interstate then the US Route then the State Route and followed by the local street name (if any) in parenthesis. The following are examples of the proper identification of the bridge with some common Facility Carried/Feature Intersected:

- *ST 19 (WALES ROAD) OVER MILL BROOK*
- *ST 20A (PLAINFIELD STREET) OVER I-91*

- *US 202 (GRANBY ROAD) OVER ST 116 (NEWTON STREET)*
- *I-95/US 1/ST 3 OVER WEST STREET*
- *ST 31 (RESERVOIR STREET) OVER PROVIDENCE & WORCESTER RR*
- *WOLOMOLOPOAG STREET OVER AMTRAK/MBTA*

Project Information Block. (*Provide table as shown on Dwg. No. 1.2.4 of Part II of this Bridge Manual)*

Traffic Data Block. (*Provide table as shown on Dwg. No. 1.1.6 of Part II of this Bridge Manual)*

Seismic Data Block. (*Provide table as shown on Dwg. No. 1.1.7 of Part II of this Bridge Manual)*

Hydraulic Data Block. *(Provide table as shown on Dwg. No. 1.1.8 of Part II of this Bridge Manual for any structure over a stream. If only a Preliminary Hydraulic Analysis is available, put N/A in those fields for which data is not provided)*

Locus. A small-scale plan which serves as a map to locate the structure. Approximate scale is 1" = 2000'.

Key Plan. A plan of the proposed structure, typically drawn to a scale of 1" = 40', showing baselines, center lines of construction, curve data, roadway widths, angles of intersection to establish geometry of the structure, equation of stations of intersecting baselines, existing and relocated utilities, configuration of proposed and existing structures and their footings, topographical features, and layout lines if available. Where a waterway is involved, show the old location and the proposed location of the stream. Show riprap treatment and any channel paving. The locations of all borings, test pits and/or other subsurface investigations shall be shown on the key plan.

Profiles. A profile of each road, railroad or stream bed shall be shown with proposed and existing ground grades, outline of proposed and existing structures and limits of any pre-loaded earth embankments. Observed, design and base (100-year) water surface elevations shall be shown on the profile where applicable. For most structures, the vertical scale is ⅛" = 1'- 0" and the horizontal scale is 1" = 40'.

Design Specification. The following note should appear on the first sheet:

DESIGN
IN ACCORDANCE WITH THE 20-- AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS WITH INTERIM SPECIFICATIONS THROUGH 20-- FOR HL-93 LOADING. *(Use this note for bridges carrying roadways. If the design loading is different from HL-93, specify the actual design loading)*

Any design criteria that varies from *AASHTO LRFD Bridge Design Specifications* or the MassDOT LRFD Bridge Manual shall be so noted on the Sketch Plans.

DESIGN
IN ACCORDANCE WITH THE 20-- AREMA SPECIFICATIONS FOR RAIL BRIDGES, WITH INTERIM SPECIFICATIONS THROUGH 20--. *(Use this note for bridges carrying railroads)*

Notes. The following notes shall appear on the first sheet:

NOTES:

1. APPROVAL DOES NOT INCLUDE STRUCTURAL ANALYSIS. *(Approval of the Sketch Plans does not relieve the Designer of the responsibility for proposing an economical and constructible structure).*

2. DIMENSIONS OF STRUCTURAL MEMBERS ARE APPROXIMATE, AND WILL BE FINALIZED DURING THE FINAL DESIGN PHASE.

3. SEE GEOTECHNICAL REPORT, DATED *(provide date)*.

4. SEE HYDRAULIC REPORT, DATED *(provide date. If only a Preliminary Hydraulic Analysis is available instead of a full Hydraulic Report, change this note to read: See PRELIMINARY HYDRAULIC ANALYSIS, DATED, and provide date)*.

5. NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988 IS USED THROUGHOUT.

2.8.3.3 Boring Sheets. The following information shall appear on the boring sheets:

Boring Data.
Boring Logs: Boring logs shall be plotted in groups as they relate to substructure units. All boring logs shall be plotted to the same base elevation.

Water Levels: Water level at each boring should be plotted to scale and date of observation should be shown.

Footing Elevations: The elevations at the bottom of each proposed substructure unit should be plotted to scale. The approximate elevation of the pile tips or drilled shaft bottom shall be plotted where appropriate. In the case of a substructure unit founded on rock, the elevation at the top of the footing shall be plotted.

Boring Notes. The following notes shall appear on the First Sheet of the Boring Data sheets of all Sketch Plans:

BORING NOTES:

1. LOCATION OF BORINGS SHOWN ON THE PLAN THUS: *(boring symbols shall be as per the MassDOT Highway Division CAD Standards Manual)*.

2. BORINGS ARE TAKEN FOR PURPOSE OF DESIGN AND SHOW CONDITIONS AT BORING POINTS ONLY, BUT DO NOT NECESSARILY SHOW THE NATURE OF THE MATERIALS TO BE ENCOUNTERED DURING CONSTRUCTION.

3. WATER LEVELS SHOWN ON THE BORING LOGS WERE OBSERVED AT THE TIME OF TAKING BORINGS AND DO NOT NECESSARILY SHOW THE TRUE GROUND WATER LEVEL.

4. FIGURES IN COLUMNS INDICATE NUMBER OF BLOWS REQUIRED TO DRIVE A 1 3/8" I.D. SPLIT SPOON SAMPLER 6" USING A 140 POUND WEIGHT FALLING 30".

5. BORING SAMPLES ARE STORED AT A STORAGE FACILITY LOCATED ON ROUTE 114 (219 WINTHROP AVE.) IN LAWRENCE, MA. THE CONTRACTOR MAY EXAMINE THE SOIL AND ROCK SAMPLES BY CONTACTING THE MASSDOT GEOTECHNICAL SECTION AT 10 PARK PLAZA, BOSTON, MA.

6. ALL BORINGS WERE MADE IN *(give month(s) and year(s))*.

7. BORINGS WERE MADE BY *(give name and address of boring contractor)*.

8. THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988 IS USED THROUGHOUT.

Ground Water. If ground water observation wellpoints have been installed, the observed water levels will be tabulated on the Sketch Plans along with the following notation:

GROUND WATER

THE WATER LEVELS RECORDED IN THE TABLE ARE THOSE MEASURED ON THE DATES GIVEN AND DO NOT NECESSARILY REPRESENT GROUND WATER LEVEL AT TIME OF CONSTRUCTION.

2.8.3.4 Structure Detail Sheets. At a minimum, the following information shall be put on the structure detail sheets:

Longitudinal Section. The scale is normally ⅛" = 1'- 0", but it will vary depending upon the length of structure. This is a section taken parallel to the centerline of the structure showing its relationship to the highway, railroad, or stream under the structure. Shown on this view are the following items:

1. All square and skew horizontal dimensions and vertical clearances (if the proposed structure modifies or replaces an existing structure, show existing and proposed clearances).
2. All inspection access clearances. If the proposed superstructure employs steel box beams, show the proposed location of the inspection access hatches.
3. Elevation at bottom of footings (top of footings if on rock) or approximate pile tip of bottom of shaft elevation.

4. Location of bearings (indicate fixed and expansion bearings if not using the floating bridge concept).
5. Factored soil bearing pressures and capacities, or factored pile or shaft loads and capacities for Group X loading (define critical group number).
6. Type of pile (if any).
7. Gravel borrow for bridge foundations or crushed stone for bridge foundations (if any).
8. Existing ground.
9. Proposed cross-section of road, railroad, or stream under the structure (give all pertinent dimensions such as sidewalk and roadway widths, track to track centerlines as well as their distances from the proposed or retained substructure elements).
10. Individual span lengths and overall span length, both square and skew (center line to center line of bearings).
11. Tremie seal and sheeting (if applicable, see Subsection 3.2.4 for guidelines).
12. Observed (if known), Design (__Year), and Base (100-Year) water surface elevations.
13. Calculated Design and Check Scour elevations.

Elevation of Pier. A scale view, along the length of the pier, showing critical dimensions to be used in its design.

Transverse Section of Superstructure. A cross-section of the superstructure showing:

1. All critical dimensions
2. Roadway cross-slopes
3. Type of railing or barrier
4. Utility locations
5. Spacing, depth, and type of beam
6. Slab thickness and type
7. Type of wearing surface

If stage construction is involved, show the limits of both the existing and proposed structures for all stages of construction. These sections should also show all details and dimensions necessary to determine the adequacy of the proposed staging from both a structural and traffic safety standpoint.

Channel Approach Section. A cross-section of the waterway approaches to the bridge showing:

1. Existing and proposed channel dimensions
2. Riprap Toe Details
3. Observed water elevation (if known, date)
4. Design (__Year) water surface elevation
5. Base (100 Year) water surface elevation

Approach Section. A cross-section of the approach to the superstructure showing controlling dimensions and details.

2.8.4 Submittals and Approvals

2.8.4.1 General. All Bridge Sketch Plans Submittals shall conform to the requirements of the current MassDOT Highway Division CAD Standards Manual and the provisions as specified below. The number of sets of Sketch Plans required for each submittal shall be as requested by the Project Manager.

2.8.4.2 First Submittal of Sketch Plans (SP1). Fully prepared as per Subsection 2.7.3 above and thoroughly checked (QC/QA'd) sets of Sketch Plans along with the completed and signed Sketch Plans Checklist shall be submitted to the Bridge Section for review.

The Bridge Section will review the submitted Sketch Plans and will return marked-up documents with formal written comments to the Designer for their reconciliation.

2.8.4.3 Second Submittal of Sketch Plans (SP2). After all Bridge Section's comments to the First Submittal of Sketch Plans have been addressed and reconciled, the Designer shall resubmit updated Sketch Plans to the Bridge Section for a back-check review.

If an additional submittal of Sketch Plans is required it shall be given the number in sequence in relation to the previous submittal, such as SP3, SP4, etc. ***Please note that the Designer shall keep the number of submittals to the absolute minimum, which is SP1, SP2, and SPF. The number of submittals in the excess of the referenced above may affect the Designer's performance evaluation.***

2.8.4.4 Final Submittal of Sketch Plans (SPF). After the Bridge Section's review of the Second Submittal of Sketch Plans confirms that the plans are acceptable, the Designer shall submit the approved Sketch Plans to the Bridge Section. The number of the required sets to be submitted shall be as per Paragraph 2.7.4.1 above.

2.8.4.5 Submittal of Mylars. When the Bridge Section receives FHWA approval, the Designer shall submit Sketch Plans mylars to the Bridge Section for approval signatures. The mylars become the property of MassDOT. After the mylars are signed, two (2) sets of prints of approved Sketch Plans will be sent back to the Designer and shall be used as the basis for design.

2.8.4.6 Related Approvals. License plans for permits, if applicable, are to be prepared as outlined in the Federal Register. Federal legislation of 1975 requires the filing of applications with both the U.S. Coast Guard and the U.S. Corps of Engineers.

Permit plans, with letters of application, environmental requirements, water pollution control requirements, and other related material as required, will be processed through MassDOT.