Image 6.5: Extradosed/ Cable Stayed

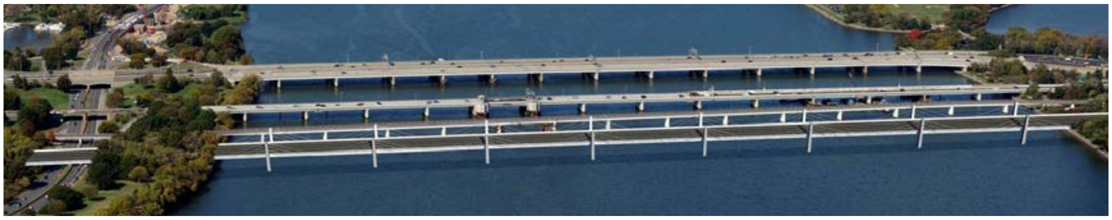
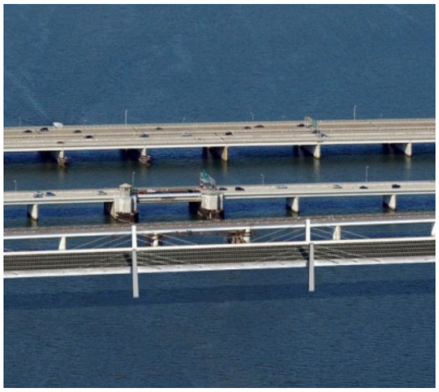


Image 6.6: Extradosed/ Cable Stayed Enlargement



Extradosed/Cable-Stayed

The extradosed/cable-stayed bridge uses a series of cable-supported spans to cross the river with equal span lengths of approximately 300 feet, as shown in Figure 6.7. The superstructure would be supported by cables above the deck anchored at one end to a central pylon and at the other end to the edge of the deck. The towers or pylons would extend 48 feet above the deck.

The deck elements could consist of either steel or concrete edge girders or concrete box girders. With a span length of 300 feet, it is anticipated that variable depth (haunched) girder elements would be practical and would provide optimal aesthetics, as shown in Figures 6.8 and 6.9. Figure 6.9 presents a full build concept that is designed to accommodate the widest cross section in the study, Alternative 8.

The towers would consist of concrete elements located on the outside of the deck at the ends of each span. A variety of options are available for the arrangement of the superstructure cables.

One advantage of extradosed or cable-stayed construction is that it is possible to perform the construction in a top-down fashion using balanced-cantilever erection. In this scenario, few if any temporary supports would be required in the Potomac River during construction. However, balanced cantilever construction results in significant unbalanced loads on the piers and foundations during construction, potentially resulting in larger and more expensive foundations. Also, by using 300-foot spans across the river, a significant number of piers that support this balanced-cantilever erection would be located in the river. Additionally, each pier would include a 48-foot tower, which would have to be cast in place on the river, adding cost and complexity.

The maintenance activities associated with this structure type are non-typical and include the need to inspect and maintain the stay cables that support the deck. Durability issues have been reported on cable-supported structures where the cables have not been properly grouted and subsequently exposed to salt-laden moisture or water. Therefore, great care must be taken in the grouting of the cables and the cables should be regularly inspected.

If steel edge girders were used for the superstructure, maintenance activities would be similar to a steel girder bridge. Specifically, periodic painting of the steel and maintenance or possible periodic replacement of bearings and expansion joints would be required. If a post-tensioned concrete superstructure was utilized, the superstructure could be designed to minimize cracking and enhance durability.

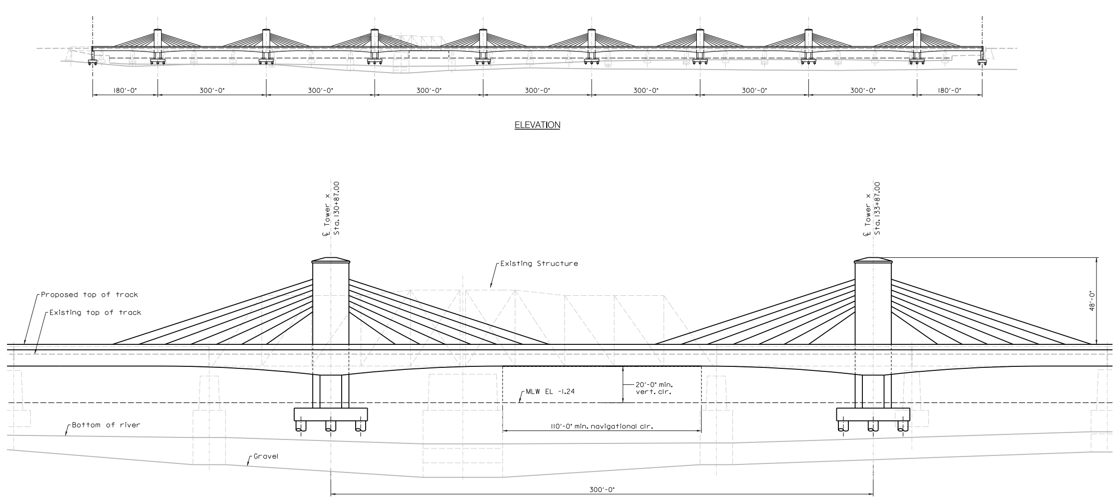
The extradosed/cable-stay option can be constructed to provide appropriate vertical clearance beneath the bridge without significant modification to the vertical profile on the structure. However, in order to do this, the superstructure depth would need to be kept to a minimum; this might require more cables supporting the superstructure, which could increase cost and complexity. The proposed 300-foot span would provide adequate horizontal clearance for Potomac River navigational traffic and a vertical clearance of 20 feet.

Like the arch concepts, this structure type would be difficult to construct while concurrently maintaining existing rail operations. This structure type cannot be built with phased construction; therefore, if rail service were kept on the existing structure during construction, the new structure would have to be built on a separate alignment next to the existing bridge.

This bridge type can accommodate a variety of bridge widths; however, like the other bridge concepts, a practical upper limit of approximately 120 to 140 feet in width should be considered. Typical cross sections provided in Chapter 4 identify the widest cross section at 137 feet for Alternative 8. It is envisioned that the engineering for an extradosed/cable-stay bridge would require additional structure width beyond the 137 feet presented in the typical cross section for Alternative 8. The widest engineering deck width for an extradosed/cable-stay option is 152 feet as determined for Alternative 8. Engineering bridge width assumptions are provided in the detailed cost summaries in Appendix E. Multiple extradosed/cable-stay structures would need to be considered for alternatives greater than 140 feet in width.

The extradosed bridge type is unique, as very few structures of this type have been built in the United States. This structure type would present an opportunity for an unusual bridge type near the heart of the nation's capital.

Figure 6.7: Extradosed/ Cable-Stayed Elevation



The above-deck cables of this bridge can be arranged in a number of different ways, including fan arrangement, parallel arrangement, or harp arrangement. The concrete towers also present opportunities for different treatments with the column shapes, sizes, colors, and textures. The cables also present a unique opportunity for architectural lighting.

The proposed span lengths are greater than the tied and deck arch concepts, creating a favorable view shed from the water and riverbanks. Navigation for smaller craft around the bridge would be enhanced and the openness would contribute positively to public perception of the entire structure.

Figure 6.8: Extradosed/ Cable-Stayed Cross Section – Rail

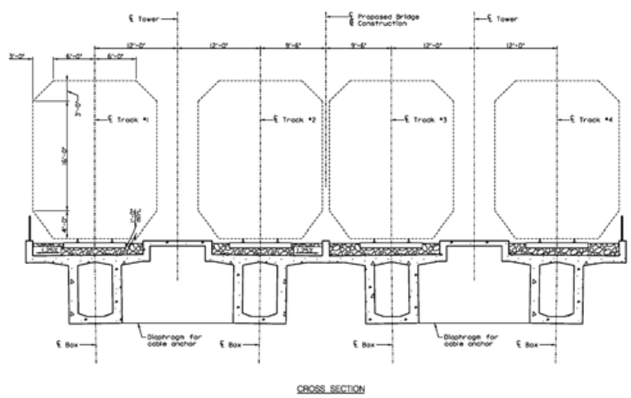


Figure 6.9: Extradosed /Cable-Stayed Cross Section – Full Build

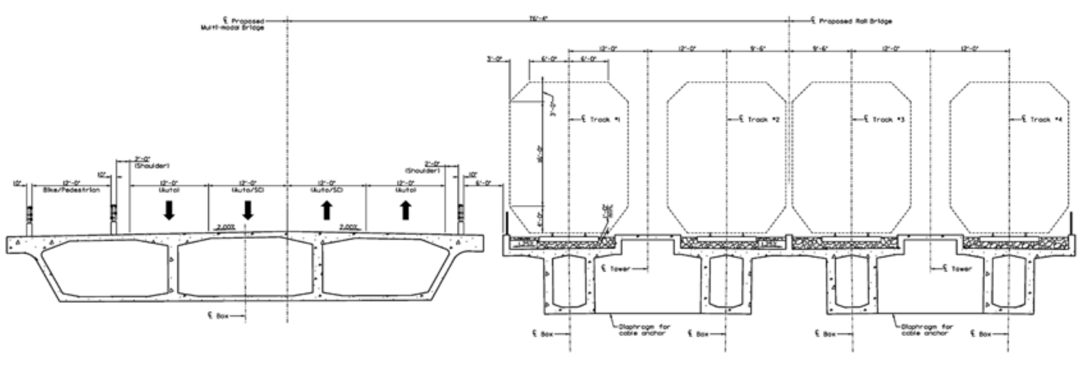


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Image 6.7: Deck Arch

Image 6.8: Deck Arch Enlargement - Closed Spandrel

Image 6.9: Deck Arch Enlargement - Open Spandrel

Deck Arch

The deck arch bridge would employ a series of deck arch spans across the Potomac River, each with a span of approximately 170 feet as shown in Figure 6.10. The arches for this concept would support the superstructure from below the deck, as opposed to the other three arch type concepts. Several variations are available for this option that could include:

• An open spandrel deck arch, where the area between the arches and the deck is open;

• A closed spandrel deck arch, where the area between the arches and the deck is closed; and,

• An option that consists of steel or concrete I-girders for the majority of the cross section, with precast concrete arch façade elements on each fascia. This structure type would be a multi-girder structure, with the precast façade elements emulating a closed spandrel deck arch.

There are many considerations that factor into an evaluation of constructability of a deck arch bridge. If a standard girder superstructure with façade elements were chosen, this would be the easiest and most straightforward construction with the shortest anticipated construction schedule of all the bridge types under consideration. If a post-tensioned arch construction were used, the arch sections would need to be precast elements, since cast-in-place concrete is not practical on a river. Delivery and erection of large curved precast concrete elements in an urban environment would need to be evaluated. Depending upon the locations available where precast concrete elements can be constructed, it would be more practical to use segments to comprise the arch and post-tension the segments together. If precast arch ribs were used, a significant amount of temporary shoring could be needed to erect the arch ribs. The erection of temporary shoring towers in the river could be difficult and expensive.

The future maintenance requirements of a deck arch bridge are influenced by numerous factors. If post-tensioning were used in the precast arch ribs, the tendons and tendon ducts would need to be protected from water intrusion. Proper grouting of the tendon ducts would be critical to the long-term durability of the structure. If conventional girder construction was used for the majority of the cross-section, periodic inspection would be straightforward and inexpensive. Because the structural elements are below the deck, inspections for this bridge type could typically occur with little impact to traffic and ongoing operations on the bridge. If girder construction was used with steel girders, the steel girders would need to be repainted periodically. If concrete girders were used, there would be no need for future painting of the structure.

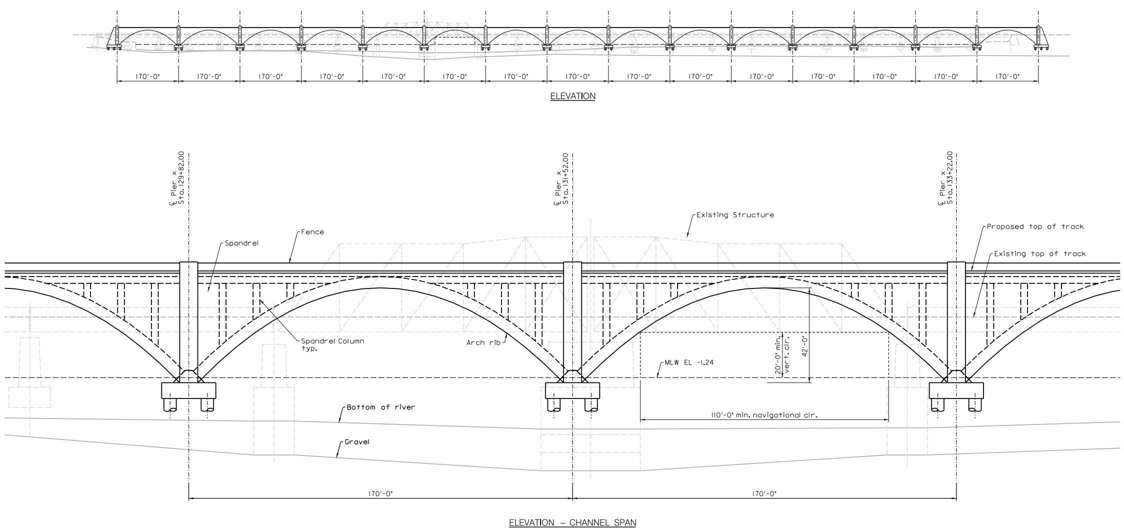
The most significant potential shortcoming of this bridge type is that it provides the least horizontal clearance for navigation below the bridge at 110 feet. The arch ribs dictate the height of the water vessel such that the 110-foot horizontal clearance could only accommodate a 20-foot vertical clearance. Narrower vessels would be able to take advantage to the highest point in the vertical clearance at 42 feet.

Because the supporting structural elements for this bridge type are all below the deck, this structure type would only be able to provide sufficient vertical clearance if the profile were raised, making the piers higher and increasing cost. Cross sections for the deck arch bridge are shown in Figures 6.11 and 6.12. Figure 6.12 presents a full build concept that is designed to accommodate the widest cross section in the study, Alternative 8. This could also have aesthetic implications if the profile of this bridge was significantly higher than neighboring bridges. Raising the profile could also have impacts at the ends of the bridge and increase the overall structure length, subsequently influencing cost.

In contrast to these factors, this bridge type does present a major advantage over the other bridge types by potentially allowing for phased construction. If an option were pursued that consisted of standard girder construction with precast façade elements to create the arch aesthetic, the bridge could be built in stages, which would create an opportunity to maintain existing rail traffic throughout construction.

Many of the prominent bridges in the Washington, DC region consist of concrete arch members, including the recently constructed Woodrow Wilson Memorial Bridge. Thus, the deck arch bridge type would be very compatible with the existing bridges in the

Figure 6.10: Deck Arch Elevation



area. Additionally, the use of concrete for the structure type fits in well with the local architecture of nearby buildings and facilities.

The existing bridge and four bridge concept elevations are provided in Figure 6.13 for side-by-side comparison. A variation on the full extradosed/cable-stayed option is also provided with the extradosed concept only at the main span.

Figure 6.11: Deck Arch Cross Section – Rail

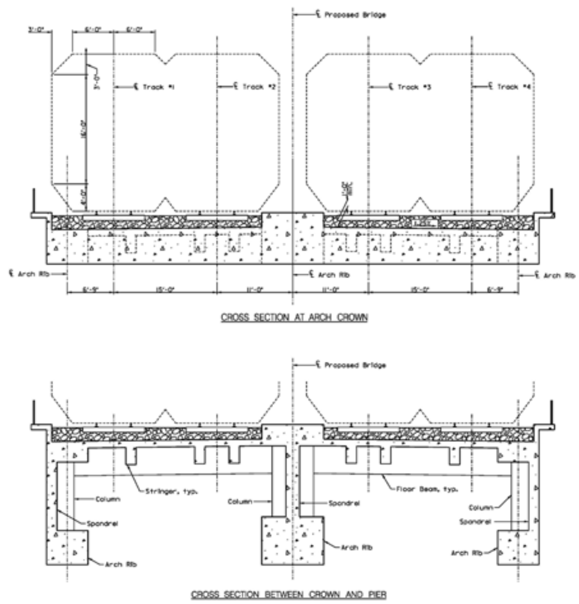


Figure 6.12: Deck Arch Cross Section – Full Build

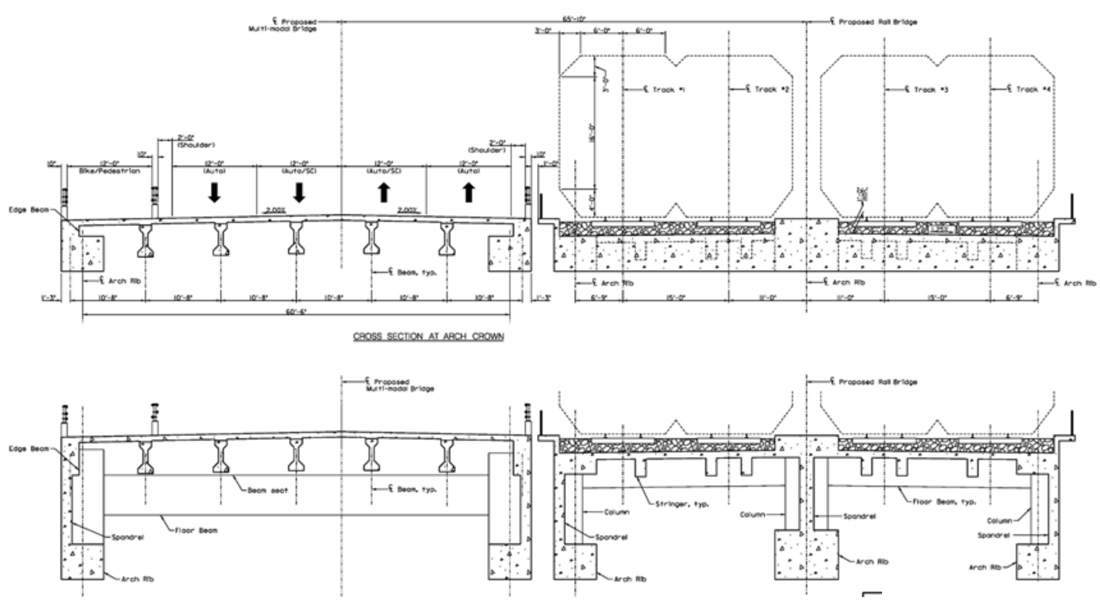
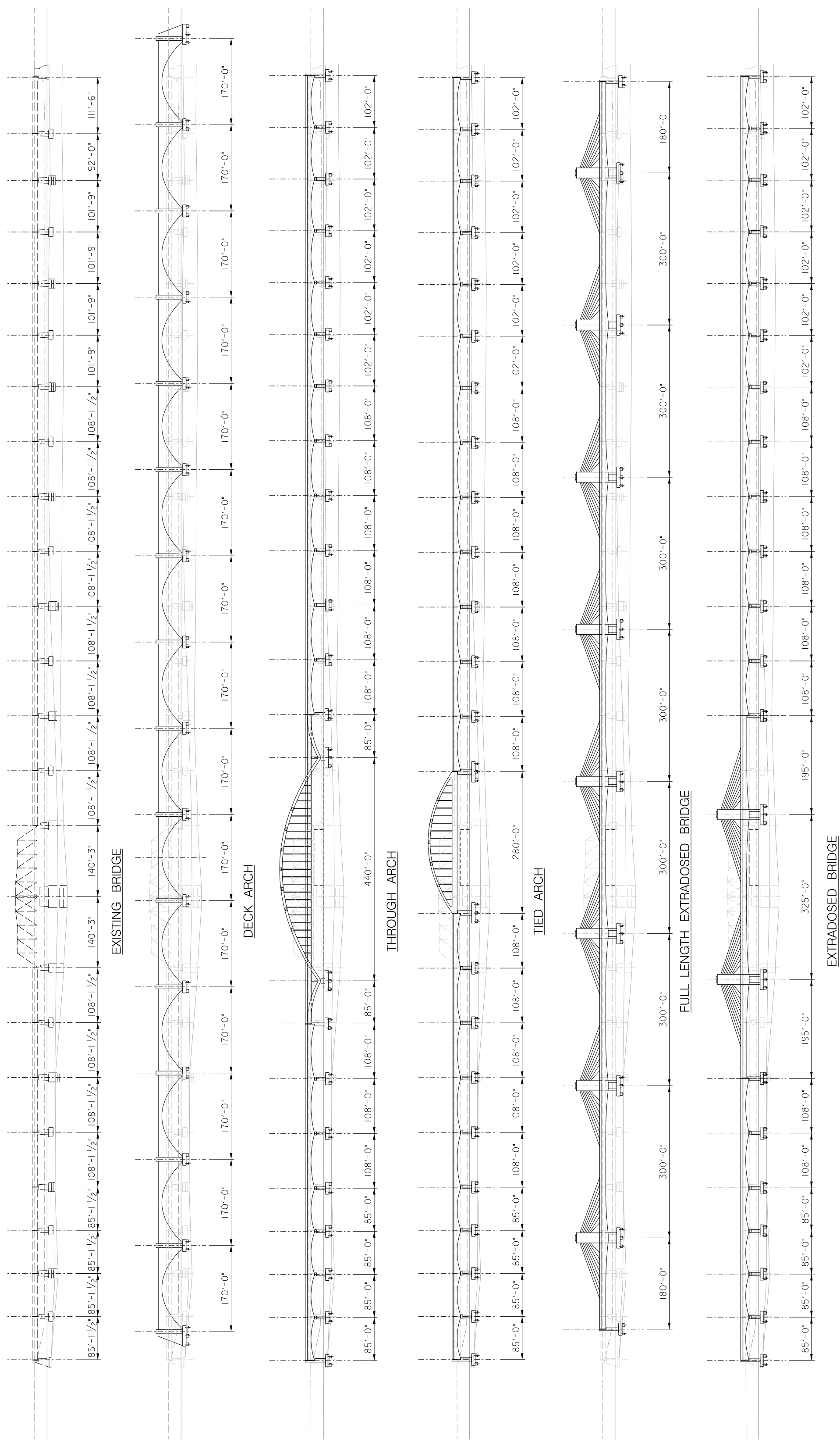


Figure 6.13: Elevations – 5 Bridge Concepts



Tunnel

Tunnel options for this study consisted of several types of tunnel designs, including jacked segmental, submersed segmental, or twin bore. These designs are considered different means and methods for constructing tunnels and all require utility relocation and replacement in the areas of the assembly and retrieval shafts and tunnel approaches of several thousand feet.

A number of constraints and specifications were required to develop the passenger and freight rail tunnel profiles. Requirements for the size of the tunnel and the critical measurement of top-of-rail to prepare the profiles were taken from the American Railway Engineering and Maintenance-of-Way Association (AREMA) Design Manual and recommended clearance envelopes from the Association of American Railroads (AAR). AREMA and AAR provide industry standards and define the required railway widths for passenger and freight rail as well as height required for single- and double-stack trains and associated guide wire and catenary requirements for electrified passenger rail. Table 6.2 provides specifications for the different elements that were considered in tunnel design.

Underground obstructions and existing infrastructure to be avoided when considering a tunnel alignment include existing Metro tunnels, roadway foundations, utilities, and building foundations. Tunnel concepts assumed that all tracks could be electrified in concept, with the catenary and guide wire above the maximum height requirement for double-stacked freight trains. The availability of electrification also necessitates the availability of switching (interlocking) between all tracks. Figure 6.14 shows the cross section used for assessing tunnel alignments and the location of tunnel portals.

Plans and profiles for the freight and passenger tunnels require controlling criteria to determine the length of each tunnel and the portal locations where a tunnel would reach the surface at its earliest point. The channel in the Potomac River is the control point at 80 feet to the bottom of the tunnel below the river mud line with the top-of-rail at 12 feet 2 inches above that, which started the profile at 67 feet 10 inches below the river mud line. Separate plans and profiles were developed for the freight and passenger tunnel concepts. The difference in maximum grade limits results in varying tunnel lengths and the location of portals and connections back into existing tracks. Appendix E provides the plans and profiles for the freight and passenger tunnel alignments. An important consideration for constructability is to hold the grade of the passenger tunnel to 1 percent through the L'Enfant area in the Southwest waterfront. This is critical for considering passenger stations and the location of interlockings to allow for switching between tracks. An underground passenger station was also considered for the Southwest waterfront area. This would provide passenger egress to the area and would also consider an underground connection to the Metrorail L'Enfant station. The estimated length of the freight tunnel is approximately 25,950 linear feet with 2,000-foot portal egress in both Virginia and the District. The estimated tunnel length of the passenger tunnel is 14,225 linear feet. A 1,000-foot egress portal is assumed in Virginia. There is no passenger tunnel portal in the District as the tunnel continues and connects to the existing underground tunnel to Union Station.

Assessment of the vertical alignment and anticipated profile of a tunnel with the stipulated depth requirements to avoid existing underground structures makes it unlikely that a jacked or submersed tunnel will be constructed. A jacked or submersed tunnel is practical only for a relatively short distance. The grade restrictions for a freight tunnel and the tunnel length require long approach tunnels to the Potomac River crossing. This leaves the bore tunnel as the practical solution for the estimated linear feet required for a tunnel.

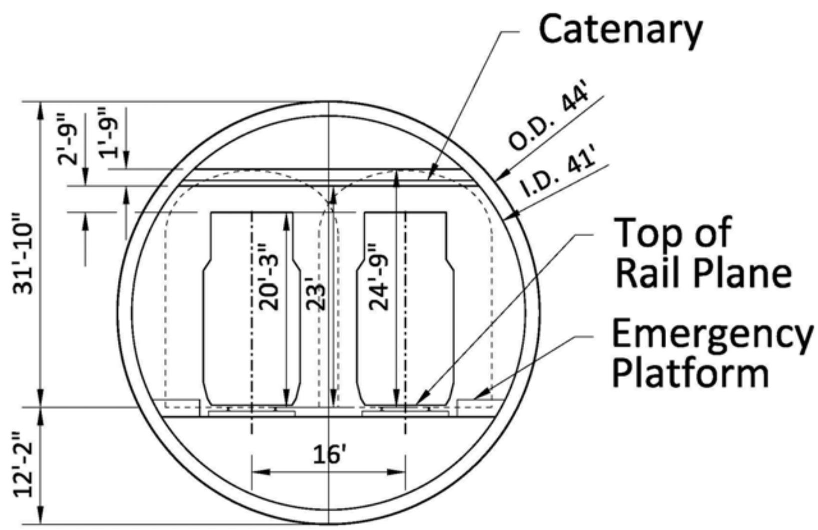
Other considerations for tunnel construction include fire/life safety elements for passenger rail tunnels and stations, including ventilation, emergency walkways, emergency exits, fire suppression, alarms, lighting, and emergency communications. These elements have not been evaluated in detail for the Long Bridge tunnel concepts and are not depicted in the plans, profiles, and typical sections. Because the tunnel concepts provide the ability for passenger and freight trains to use all tracks, all tunnels are assumed to have the same level of fire/life safety protection. Ventilation for diesel exhaust is less robust than that needed for emergency smoke management and therefore can be handled with the smoke management ventilation equipment assumed for the ventilation for this study.

Tunnel construction requires large aboveground staging areas in close proximity to the construction location. The location of tunnel portals and temporary construction shafts would need to be considered due to the length of the bore tunnels and possible impacts to existing aboveground structures.

Table 6.2: Criteria for Tunnel Design

Tunnel Element	Specification
Height for double-stack freight train	20’-3” maximum
Spacing from top of train to catenary guide wire	1’ – 6”
Outside diameter of tunnel	44’
Distance between track centers	16’
Spacing between tunnels or other underground infrastructure	10’ to 20’
Maximum grade for freight train operations	1%
Maximum grade for passenger train operations	3%
Length of vertical curve minimum operations speed	40 mph (V)
Maximum vertical acceleration	0.10 feet/sec (freight)
Minimum length of vertical curve	3 x V
Passenger platforms	800’ minimum
Spiral transition at each end of platform	100’ to 150’
Rail interlockings	1,200’ to 2,500’

Figure 6.14: Typical Tunnel Cross Section



Aesthetic implications of tunnel options are confined to where the tunnel emerges from underground (portals) and the tunnel ventilation system along the tunnel alignment. Typically these portals are simple in appearance, showing the basic outline of the tunnel in concrete or a more decorative façade covered in stone or sculptured concrete. These openings would not be visible from the existing bridges or from the banks of the Potomac River.

In an urban environment, tunnel venting systems can be unsightly above ground. Two methods of ventilation are considered for the construction of a tunnel: the installation of vent shafts with fans along the length of the tunnel; and the separate ventilation requirement at underground passenger stations, which would require some type of aboveground ventilation plant. Aboveground venting structures are often blended into the surroundings and signing structures and other vertical structures are often used as vent shafts.

By virtue of being underground, the tunnel option presents no impacts to the existing Long Bridge structure, the federal parklands at the bridge approaches, or the Southwest waterfront. The aboveground treatment of the tunnel portal opening, where the tunnel connects back into the existing rail system, will need to be considered. The portal for the freight tunnel in the District would be close to the Anacostia River, east of 11th Street, SE, and the portal in Virginia would be just south of the Ronald Reagan Washington National Airport access road. The portal for the passenger tunnel in Virginia would be at the west end of Long Bridge Park. There is no portal in the District, as the passenger tunnel would tie directly into the current passenger tunnel portal at New Jersey Avenue and the entire length at this end could remain underground to Union Station.

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