3. Bridge Options

The Structure Concept Report (FIGG, 2001) identified three layout alternates with five associated structure types for further engineering study during the preliminary design phase. These bridge alternates were chosen for further study after evaluation of many options over a comprehensive list of project criteria. Preliminary engineering and cost analysis has been completed for each of these alternates and results presented in this report. The bridge alternates studied are listed below.

Bridge Alternate	Structure Type
Match Existing with Modified River Spans	Spliced Post-tensioned Bulb T Girders Spliced Post-tensioned U Girders
Moderate Span 2	Steel Plate Girders Steel Box Girders
Long Span 3	Cast-in-Place Concrete Box Girders Built from Above w/ Form Travelers

3.1 Alignment

Conceptual studies and subsequent comparison analysis recommended a new alignment for the bridge and roadway to the north of and parallel to the existing structure. Both north and south offset alignments were considered, but the north option was chosen for its more beneficial characteristics. Previous bridges were also situated to the north such that some CDOT right-of-way (ROW) exists in this area, which minimizes ROW acquisition requirements for this project. An alignment to the north allows for quick tie-ins to the existing roadway as well as improvements to the geometry including elimination of the double 'S' curve on the west end and an increase in the curve radius on the east end. Additional discussion on selection of the north alignment is included in the Structure Concept Report.

Preliminary Engineering has resulted in only slight modifications to the north alignment concept. The alignment continues to provide tangent tie-ins to 4th St. at both the east and west ends, near the Midtown Center mall entrance and West Corona Avenue, respectively. However, the curve radius on the east end has been increased to 950 feet to improve safety and to allow for a typical 2% crowned section over the entire length of the bridge and approaches. Bridge length has also increased due to additional span length provided at the East Abutment, as requested by the City of Pueblo, to accommodate future widening plans for the Loop Ramp roadway. A 4-lane build-out with 14-foot median and sidewalk has been included in the design span length.

In addition to the modifications detailed above, a split alignment has been chosen for the Long Span 3 bridge option, separating the westbound bridge from the eastbound bridge. Reasons for splitting the structures include:

- The existing cross-section can accommodate a future six-lane configuration without the need for additional deck between the structures. Thus, a closure strip between the structures is not necessary, and if placed would only serve to increase project costs.

- Separating the structures allows the Contractor maximum flexibility to construct as many bridge cantilevers simultaneously as desired. This results in maximum scheduling flexibility for the Contractor, reducing costs.

- Splitting the alignments allows the westbound structure to be built completely "off-line" without interrupting traffic on 4th St. and the existing bridge. Traffic phasing and maintenance of traffic (MOT) time and associated costs would be minimized.

- Separating the structures has aesthetic benefit in that it allows light to pass between the bridges and to the space below. This is an important consideration for not only the railroad yard, but also the planned Arkansas River restoration project, which intends on increasing pedestrian recreational use of this region.

Figure 3.1 illustrates the north alignment concept including the slight modifications discussed above.

3.2 Profile

The bridge and approach profile has been designed to current standards and accommodates all vertical clearance requirements. In the Pueblo Yard, the minimum clearance of 24'-0" from top of rail to bottom of structure will be provided as requested by the BNSF Railway Company. The UPRR requires 23'-0" of vertical clearance, which has also been accommodated. These railroad requirements control the vertical profile such that additional vertical clearance above the required 16'-6" (19'-11") is provided over the Loop Ramp roadway at the east end. The Pueblo Conservancy District owns and operates the Arkansas River Floodwall, and has indicated that no specific minimum clearance is required from the top of wall to the bottom of structure. The design profile provides a vertical clearance of approximately 9'-0" to the structure from the top of wall.

The overall profile has been designed to provide quick connection with the existing roadway without increasing the eastern grade above 4%. On the west end of the bridge, the centerline profile is approximately at existing grade at the abutment location, while at the east end, the profile closely follows the existing grade minimizing approach fill requirements. The alignment intersects the western bluff near the centerline construction

such that cut and fill will be required at the west end. Fill is also expected at the east end to extend the existing approach fill towards the Midtown Center parking lot.

3.3 Design Considerations

The proposed new 4th Street Bridge is approximately 1,137 feet long. In this relatively short distance, the bridge crosses a hike and bike trail, the Arkansas River, a floodwall, a Union Pacific Railroad yard (23 tracks including 2 mainline tracks), a Burlington Northern-Santa Fe Railroad yard (5 tracks including 1 mainline track), and a minor two-lane road. The railroad yards, river, and floodwall are challenging physical obstacles for this crossing. The selected bridge solution will minimize impacts to the physical, environmental, and recreational obstacles to the crossing, and at the same time strive to improve and enhance them.

Horizontal clearance between bridge piers and railroad tracks is a critical safety consideration. The AASHTO, American Railway Engineering and Maintenance-of-Way Association (AREMA), and BNSF/UPRR provisions require that the clear distance from the face of pier to the center of adjacent track be at least 18'-0" when pier protection is provided. This requirement increases to 25'-0" when pier protection is not provided. The selected bridge solution will address current railroad requirements through careful bridge layout and pier location choices. For alternates where piers are located in the yard between tracks and clearances cannot be satisfied given the existing conditions, yard modification would be required to provide the required safety clearances.

As important as the final configuration is consideration of the method of construction. Railroad yard constraints will add significant cost to the project if measures are not taken to minimize railroad impacts during construction of the bridge. This includes minimizing both substructure and superstructure activities, time, and cost through selection of the most appropriate method of construction. Erection of precast concrete or steel girders, for example, would progress using traditional ground-based techniques requiring movement and placement of large cranes in and on railroad tracks and facilities. Alternately, cast-in-place concrete box girders built from above using form travelers working from already constructed piers in a balanced cantilever fashion minimize disruption to railroad facilities since all work would be performed above the tracks. Costly interruptions, delays, and stoppages would be minimized. Figures 3.8 and 3.9 at the end of this section illustrate these different construction methods.

3.4 Span Layout and Structure Type Options

3.4.1 Match Existing Railroad Spans with Modified River Spans

The Match Existing Railroad Spans with Modified River Spans option utilizes existing pier locations in the railroad yard and three spans over the Arkansas River rather than the two spans of the existing bridge. The bridge is divided into eight spans and five piers are required in the railroad yard. As per the existing configuration, a span of 184 feet is needed in the UPRR yard to cross thirteen (13) closely spaced tracks. The intent of this

layout is to reduce the long spans over the river and provide a bridge layout that accommodates precast pre-tensioned concrete beams, traditionally a lower cost structure type in Colorado. Figures 3.2 and 3.3 illustrate this bridge option.

Piers are placed in the railroad yard to match existing locations in an effort to provide the greatest amount of horizontal clearance given the existing track configuration. Track deviations under the new alignment required only slight modifications to these locations, and existing space was utilized as much as possible to minimize railroad impacts. In preliminary design, Pier 4 has been shifted into the floodwall toe of slope to eliminate an impact with the adjacent UPRR track, and the three easternmost spans have been modified and lengthened to accommodate future widening of the Loop Ramp roadway, as requested by the City of Pueblo. This revised span arrangement at the east end requires a radial alignment of Pier 7 such that span lengths do not exceed manageable limits for this structure type. Additional girder lines are required for these longer spans, and an expansion joint has been provided to accommodate the necessary change in cross-section. Pier 7 has also been adjusted to eliminate the BNSF mainline impact that was shown on the conceptual layout.

Two superstructure types were studied for this layout in preliminary design. As discussed in the Structure Concept Report (FIGG, 2001), these include spliced post-tensioned precast Bulb-T girders and spliced post-tensioned precast 'U' girders. The 184-foot span in the UPRR yard requires girder splicing with post-tensioning since the length is outside the range of acceptable pre-tensioning. Expansion joints were placed at each abutment and for the Bulb-T option, at Pier 7, as discussed above. The Bulb-T solution utilizes eleven (11) to fifteen (15) BT-84 girders with an 8-inch cast-in-place mildly reinforced concrete deck. Girder bottom flanges are thickened 2-feet in the haunched regions at piers 5 and 6. The 'U' Girder option utilizes six (6) precast girders that are 7-feet deep with a thickened bottom slab at piers 5 and 6 to accommodate the spliced post-tensioned unit. The bottom slab increases in thickness 1-foot to the inside of the girder, and as with the Bulb-T option, an 8-inch mildly reinforced concrete deck has been designed.

The substructure design includes two-column rigid frame bents with the bent cap supporting all girder lines. Each 4-foot by 8-foot column is supported on footings with two (2) 54" diameter drilled shafts penetrating into the bedrock layer. Abutments are supported on ten (10) 36" diameter shafts also penetrating the bedrock layer. Seven bents are required, five of which are in the railroad yard, the most of any option. The current track configuration in the yard will not allow for pier placement in this option without compromising safety clearance requirements. Therefore, significant yard modification would be required, adding significant cost to the project. Also of concern is the location of Pier 3 in the Arkansas River channel and near the floodwall toe of slope. Hydraulic studies have concluded that significant scour of the river channel and floodwall is likely due to the erodible nature of the underlying rock. In addition, the location of Pier 3 negatively impacts the riverine and recreational improvements planned under the Legacy Project, including possible river channel changes, re-introduction of aquatic life, and promotion of recreational use on the river such as boating and kayaking.

Construction of the bridge would involve typical ground based operations for foundation and substructure elements as well as ground-based erection of girders using large cranes positioned in the railroad yard and on existing tracks. Large impacts to railroad facilities and operations are expected requiring significant track delays, work stoppages, yard modifications, and the construction of many access crossings and platforms to complete the work. Large railroad impact costs would be incurred by the project, and a great deal of railroad coordination and scheduling would be necessary.

3.4.2 Moderate Span Layout 2

Moderate Span Layout 2 is a functional improvement over the existing bridge. The number of tracks without minimum horizontal clearance decreases from seven to two, and there are six spans, one less than the existing bridge. To reduce railroad impacts in the final configuration, the number of piers in the railroad yard is reduced to three, and adequate horizontal safety clearance is achieved for two of these: Pier 3 at the floodwall toe of slope, and Pier 5 on the west side of the east yard access road. Pier 4 is placed to match an existing pier where UPRR yard tracks 13 and 14 "bulge" apart; however, adequate horizontal clearance cannot be achieved for these two tracks without yard modification. Pier 6 is located at the BNSF east property line such that horizontal clearance to the nearest BNSF track is maintained. Reducing the number of piers in the UPRR yard results in a moderate 234-foot span. In addition, one pier has been removed from the BNSF yard resulting in a 217-foot span, such that the bridge completely spans the BNSF yard. Spans over the Arkansas River are similar to the existing bridge, except that Pier 2 has been moved slightly to the west placing it on the west riverbank. In preliminary design, the east end span was increased to allow for the future widening of the Loop Ramp roadway, as requested by the City of Pueblo. Figures 3.4 and 3.5 illustrate this option.

Two superstructure types were studied for this layout in preliminary design. As discussed in the Structure Concept Report (FIGG, 2001), these include steel plate girders and steel box girders. Expansion joints are located at each abutment such that the entire bridge is a continuous unit in the final configuration. The steel plate girder option utilizes ten (10) 8-foot deep girders, and the steel box girder option utilizes five (5) 8-foot deep girders. Pier and drop-in girder sections would be shop fabricated and field spliced to accomplish the required spans. Appropriate stiffening and changes in required girder section have been considered. Both options incorporate a 9-inch cast-in-place mildly reinforced concrete deck.

Similar to the Match Existing Railroad Spans with Modified River Spans option, the substructure design includes two-column rigid frame bents with the bent cap supporting all girder lines. Each 4-foot by 8-foot column is supported on footings with two (2) 54" diameter drilled shafts penetrating into the bedrock layer. Abutments are supported on ten (10) 36" diameter shafts also penetrating the bedrock layer. Five bents are required, three of which are in the railroad yard. The current track configuration in the yard will not allow placement of Pier 4 without compromising railroad horizontal safety clearance

requirements. Therefore, yard modification would be required for tracks adjacent to this pier, adding significant cost to the project. Also of concern is the location of Pier 2 on the western bank of the Arkansas River. Although not as severe as the previous bridge option, hydraulic studies have concluded that scour of the river channel is likely at this pier location due to the erodible nature of the underlying rock. In addition, the location of this pier is not ideal for the riverine and recreational improvements planned under the Legacy Project, including possible river channel changes, re-introduction of aquatic life, and promotion of recreational use on the river such as boating and kayaking.

As with the match existing option, construction of the bridge would involve typical ground based operations for foundation and substructure elements as well as ground-based erection of girders using large cranes positioned in the railroad yard and on existing tracks. Large impacts to railroad facilities and operations are expected requiring significant track delays, work stoppages, yard modifications, and the construction of many access crossings and platforms to complete the work. Large railroad impact costs would be incurred by the project, and a great deal of railroad coordination and scheduling would be necessary.

3.4.3 Long Span Layout 3

The intent of the Long Span Layout 3 bridge solution is to provide a structure that completely spans both the UPRR and BNSF railroad yards such that required horizontal railroad clearances are satisfied at all pier locations under existing yard conditions. As a result, no yard modifications are required and associated railroad costs eliminated. The previous two bridge options have a pier between UPRR yard tracks 13 and 14, requiring yard modification to achieve required clearances at this pier. To remedy this situation and completely eliminate yard impacts in the final configuration, this pier is removed and the UPRR span increased to 378-feet. Piers supporting this span are located at the floodwall toe of slope, and on the western edge of the east yard access road. The western side span is 238-feet resulting in a pier located between the Arkansas River and the toe of the western bluff. The eastern side span is 237-feet resulting in a pier placed between the BNSF eastern boundary fence and the Loop Ramp roadway, completely outside of BNSF property. The eastern yard access road is owned by the UPRR meaning that with this option, no piers are located within the BNSF property limits. Figures 3.6 and 3.7 illustrate this option.

As discussed in the Structure Concept Report (FIGG, 2001), a cast-in-place concrete box girder built from above with form travelers is the best choice of structure types for this layout. Building from above over the yard minimizes railroad impacts during construction by eliminating the need for the movement and placement of heavy cranes and other construction equipment on and over active railroad tracks. Additionally, superstructure construction can continue above active railroad tracks without interruption to railroad operations. Only two piers are required to be built in the railroad yard, minimizing substructure operations and construction time in this area. Once foundations and piers are built, a “pier table” is constructed atop each pier to serve as a platform for the balanced cantilever superstructure erection. At this point, the Contractor is done with

operations in the yard, and activity occurs only above the tracks. With Long Span Layout 3, yard modification costs are eliminated and railroad impact costs during construction are minimized.

The superstructure cross-section is comprised of two side-by-side box girders on a split alignment, as discussed in Section 3.1. The single cell box girders are separated by 6-feet, and haunched at piers 3 and 4 to accommodate the 378-foot main span. Girder depth is typically 8'-0" at mid-span and in constant depth regions, with the depth increasing to a maximum of 18'-0" at piers 3 and 4. The deck is cast integrally with the superstructure eliminating the need for a secondary deck placement operation. Longitudinal and transverse post-tensioning required for the structure has the benefit of providing an integral deck pre-compressed in two directions. An asphalt and waterproofing membrane overlay provides the final riding surface.

The substructure for this option involves a single column under each box girder at each pier location. The box girder cross-section allows for minimization of column dimensions and thus the substructure and foundation footprint required in the railroad yard. Columns for main span piers 3 and 4 are 7'-0" by 17'-0" and are supported on a footing and two (2) 96" diameter drilled shafts. Columns for piers 2 and 5 are 3'-6" by 17'-0" and are supported on a footing and two (2) 60" diameter drilled shafts. Abutments are supported on ten (10) 36" diameter shafts similar to the other bridge options. All drilled shafts penetrate the bedrock layer as required.

Long Span Layout 3 is the most functional of all layouts studied and is the only layout that satisfies railroad clearance requirements given existing yard conditions. Minimum horizontal clearances provided from face of pier to centerline of adjacent track are as follows:

Pier	Adjacent RR Track	Horizontal Clearance Provided
3	UPRR Yard Track 21	20'-4"
4	UPRR West Mainline	18'-3"
4	BNSF Mainline	34'-7"

These clearances require pier protection since they are less than 25'-0". However, the column size, based on structural capacity, exceeds AREMA "crash wall" requirements (30 sq. ft. minimum) such that supplemental pier protection is not required. Pier 4 is located on the west side of the east yard access road similar to the other options studied. Due to the size and location of the Pier 4 columns, some slight re-routing of the east access road is likely. The piers extend approximately 7'-0" into the 20-foot wide road. If the roadway width must be maintained, adequate space exists to shift the road to the east around Pier 4, while still maintaining adequate distance to the BNSF mainline.

Pier 2 is located midway between the Arkansas River and the trail at the toe of bluff. This is the ideal location for this pier considering the riverine and recreational

improvements planned under the Legacy Project. The pier location allows for river channel changes, re-introduction of aquatic life, and promotion of recreational use on the river such as boating and kayaking without obstruction.

3.5 Foundation Type

All of the structure options studied are founded on drilled shafts penetrating into rock. As discussed in the Structure Concept Report (FIGG, 2001), drilled shafts are the most practical foundation solution for this site. Shafts are excavated with a drilling rig and auger requiring little space and causing minimal vibration to the adjacent bridge and surrounding railroad facilities. The number of drilled shafts required is much less than the number of piles that would be necessary for a pile foundation, greatly reducing the required footing size. The smaller footprint of the drilled shaft foundation option also requires less excavation and minimizes disturbance to railroad tracks, facilities, and operations.

3.6 Summary of Bridge Options

Preliminary engineering has been completed for the three span layouts and five associated structure types recommended for further study in the Structure Concept Report completed in the Conceptual Design phase of the project. These include the Match Existing Railroad Spans with Modified River Spans Layout, Moderate Span Layout 2, and Long Span Layout 3. Spliced post-tensioned Bulb-T and U girders were considered for the match existing layout, steel plate and box girders for the moderate span layout, and cast-in-place concrete box girders built from above with form travelers for the long span layout. In the next section, quantity-based cost estimates for each option are presented, and all options are evaluated against the project criteria to provide a recommended structure selection for the project.

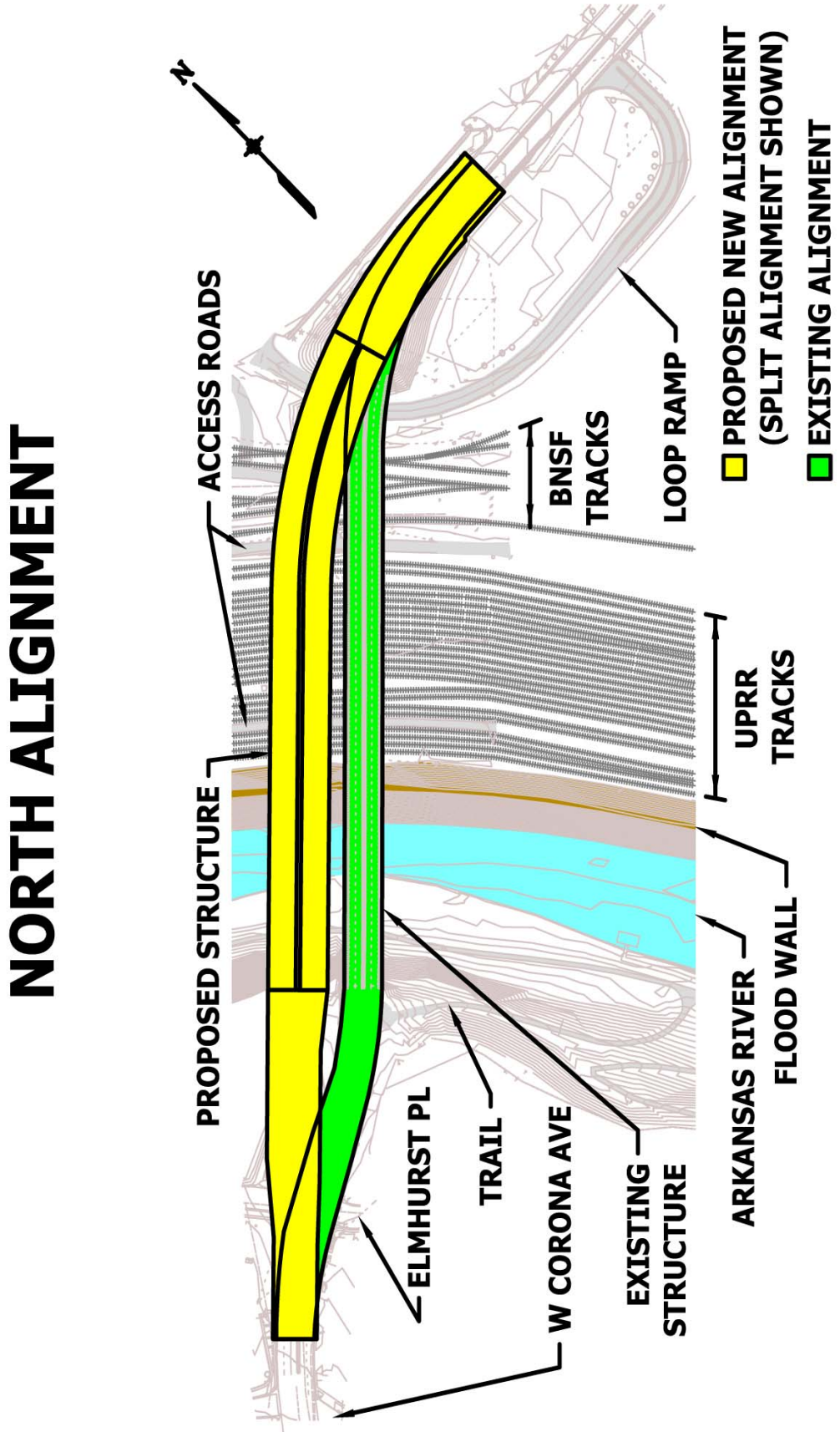


Figure 3.1 North Alignment

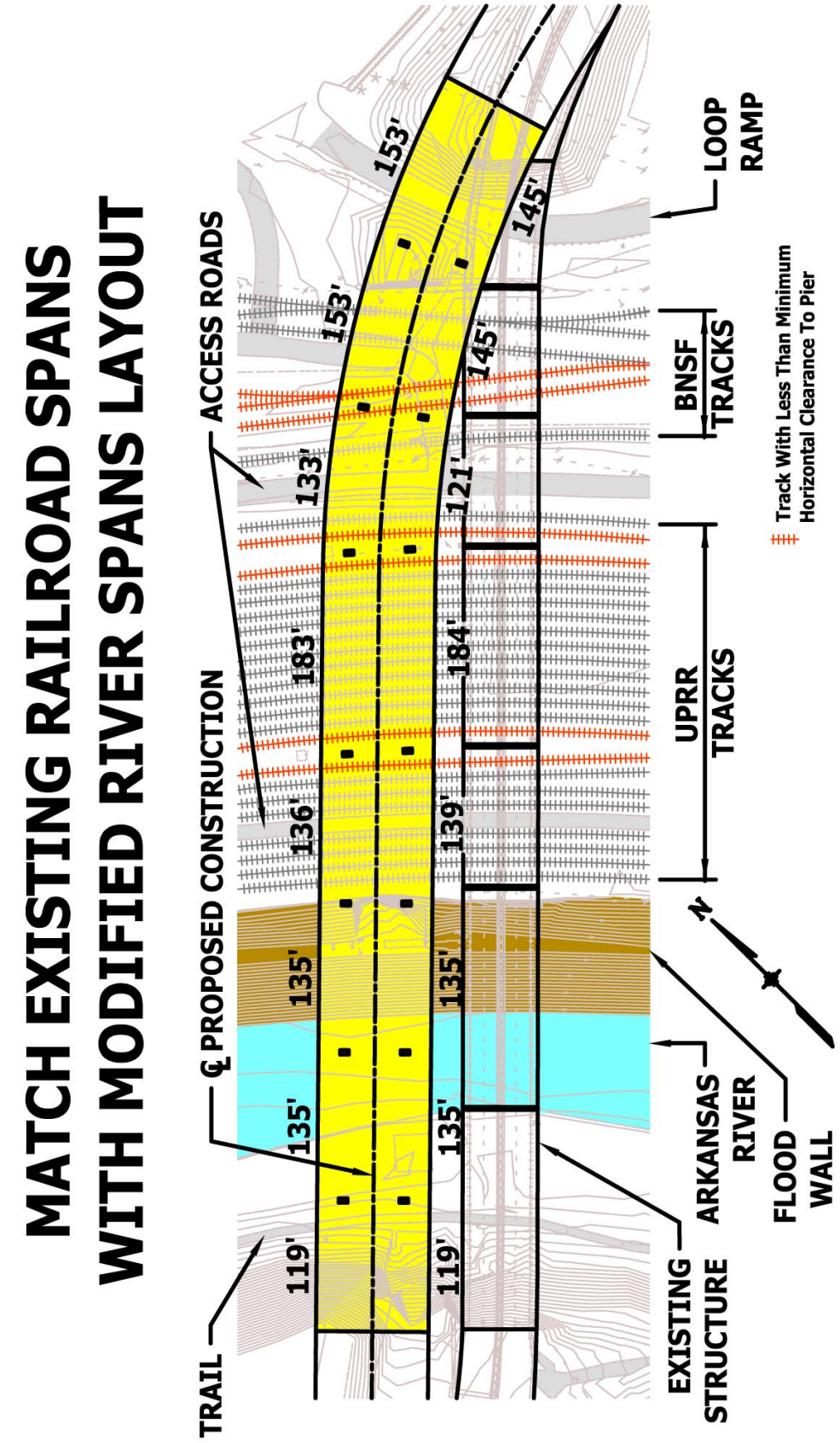


Figure 3.2 Match Existing RR Spans w/ Modified River Spans - Plan

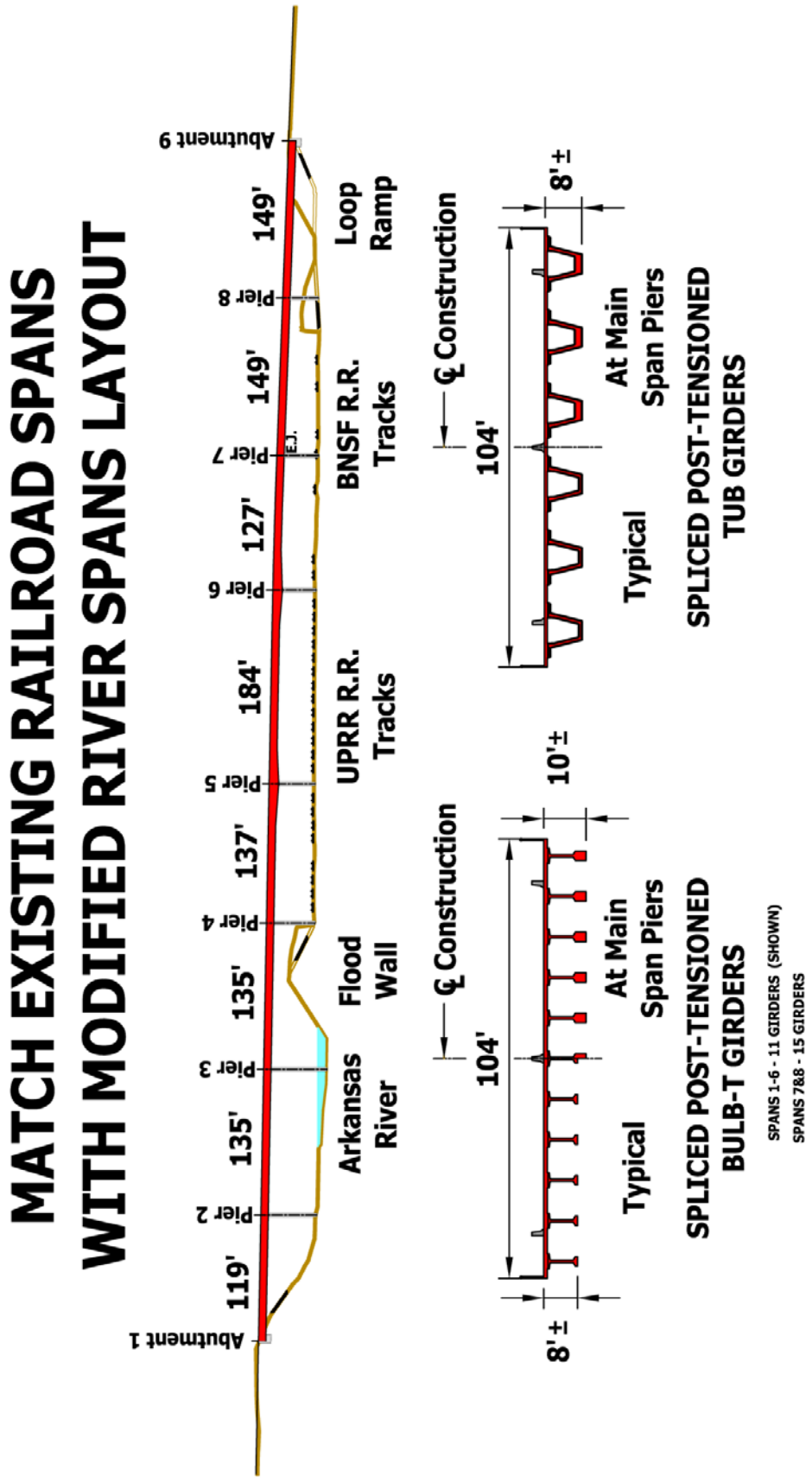


Figure 3.3 Match Existing RR Spans w/ Modified River Spans - Elevation

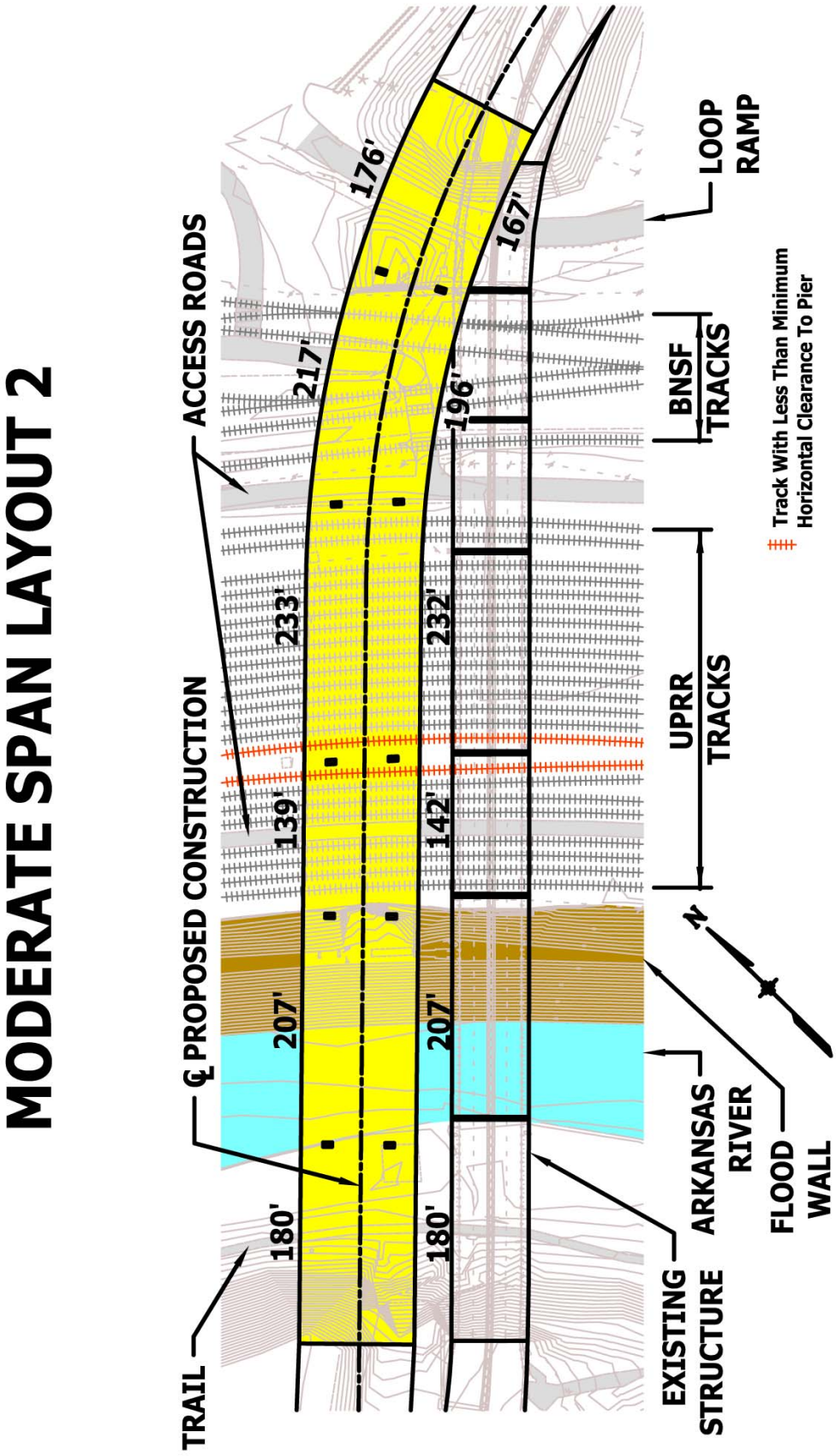


Figure 3.4 Moderate Span Layout 2 - Plan

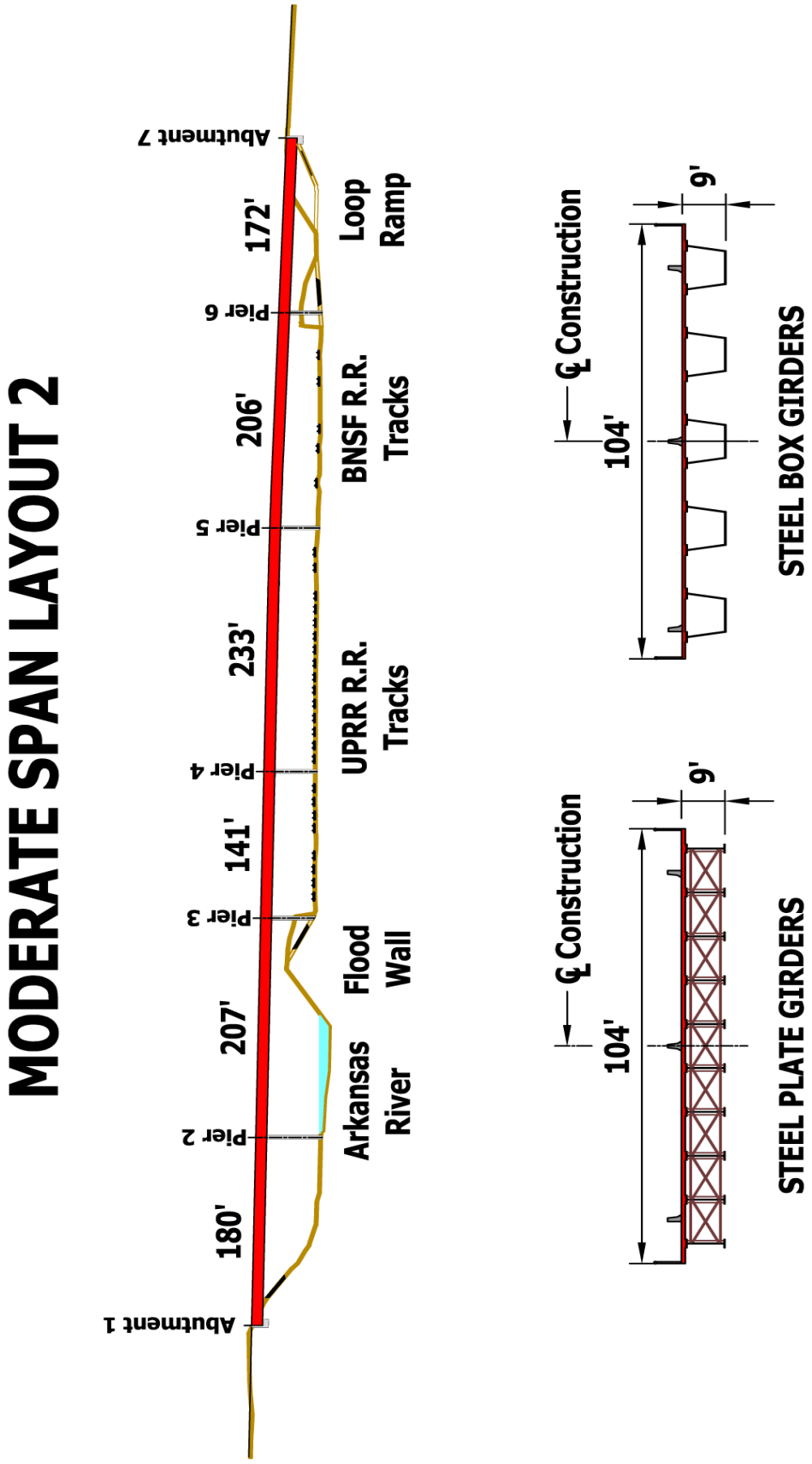


Figure 3.5 Moderate Span Layout 2 - Elevation

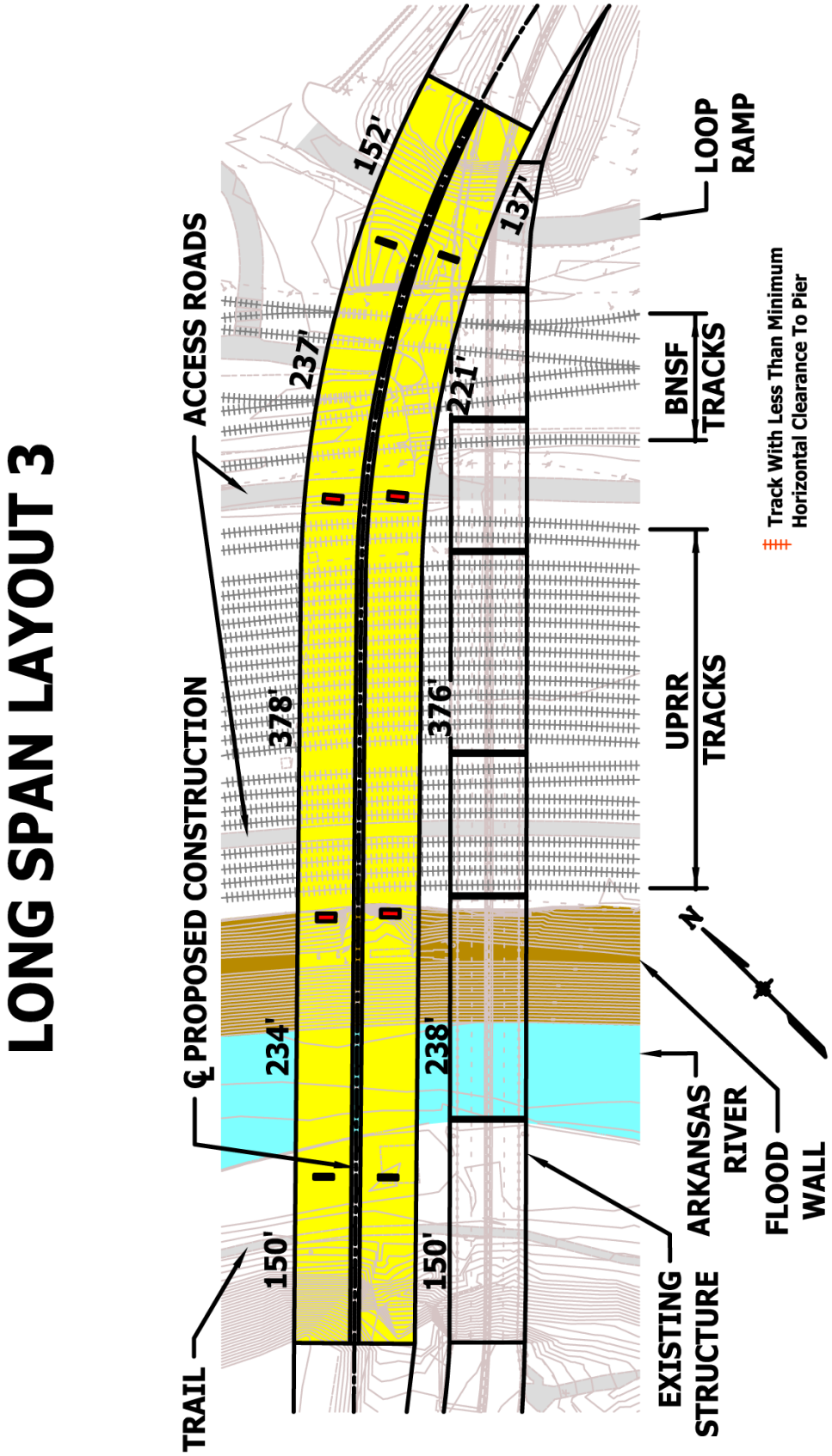


Figure 3.6 Long Span Layout 3 - Plan

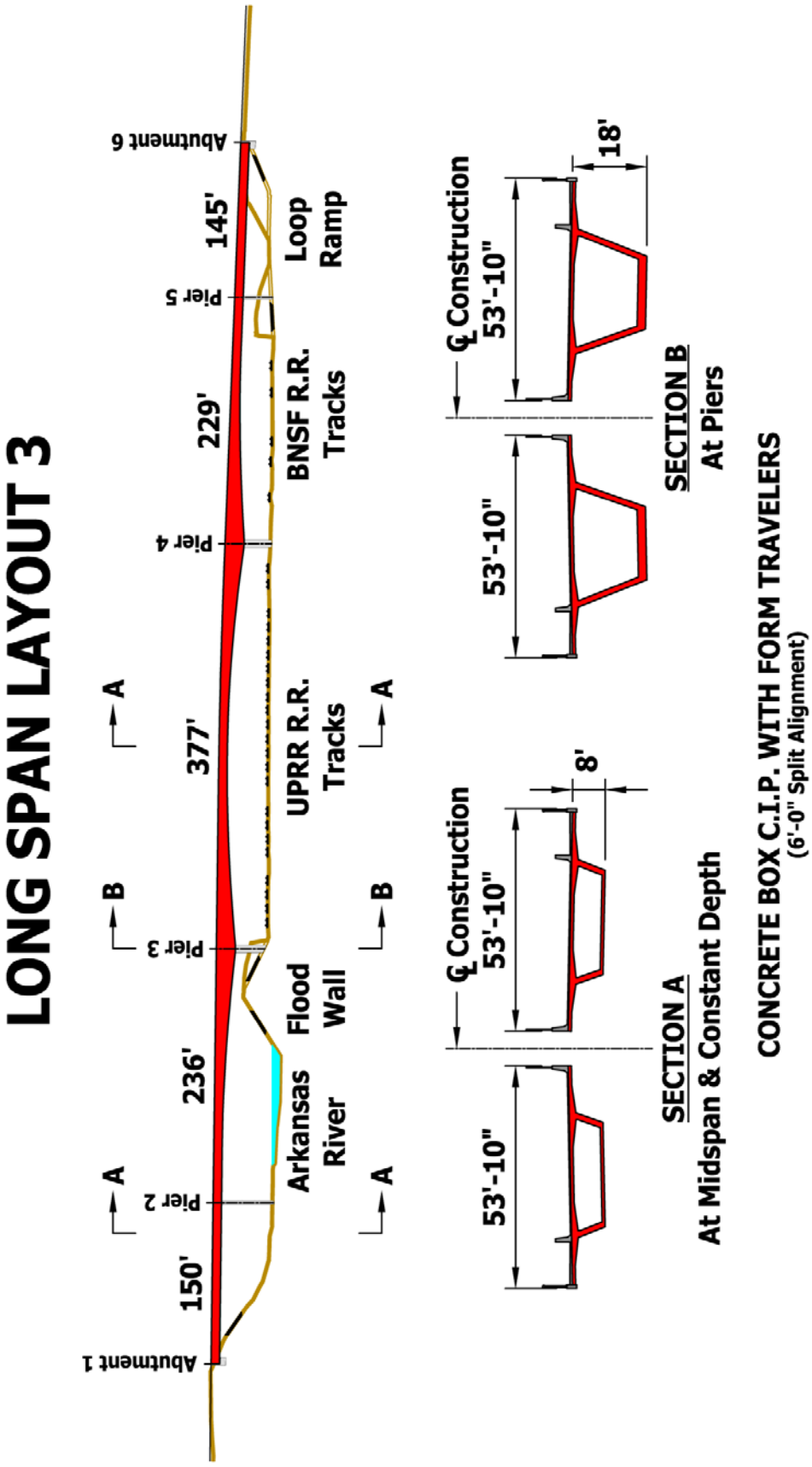
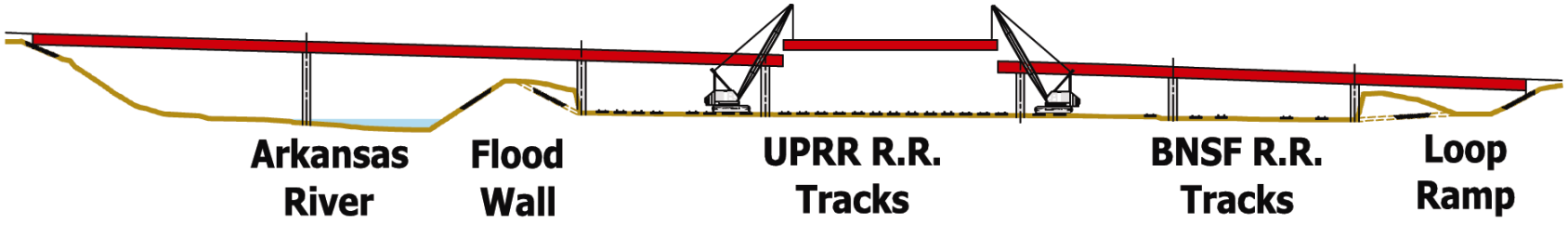
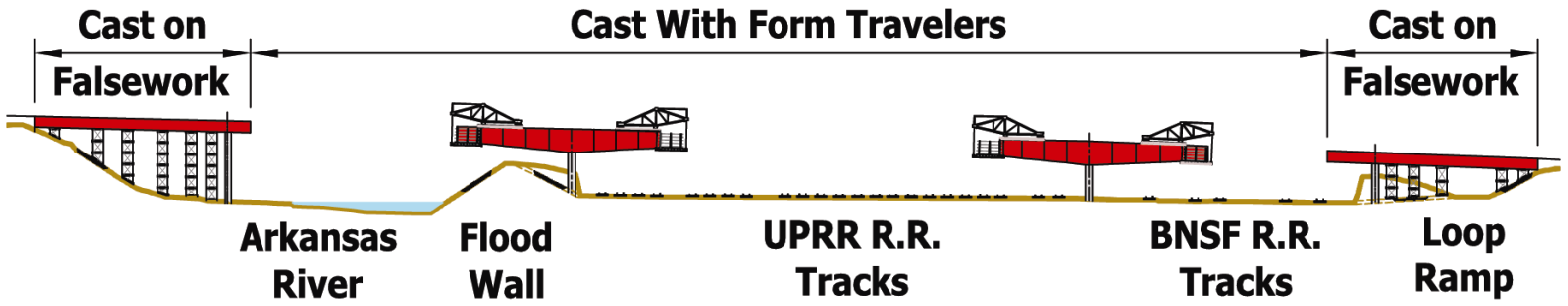


Figure 3.7 Long Span Layout 3 - Elevation



ERECTION SCHEMATIC FOR GIRDERS

Figure 3.8 Girder Erection with Ground Based Cranes



ERECTION SCHEMATIC FOR CIP

Figure 3.9 Cast-In-Place Balanced Cantilever Erection with Form Travelers