4. Structure Options

This section presents an investigation into the span layout and structure type alternatives for construction of a new bridge at this complex site. Also included is a discussion of suggested foundation types and possible construction methods.

4.1 Layout Considerations

The 4th Street Bridge is approximately 1100 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 UPRR and BNSF railroad yards are challenging physical obstacles for this crossing. Consideration of the Arkansas River and floodwall is also important. The preferred solution will minimize impacts to the physical, environmental, and recreational obstacles and at the same time have the potential to enhance them.

Horizontal clearance between bridge piers and railroad tracks is an important consideration. Current American Railway Engineering and Maintenance-of-Way Association (AREMA) provisions require that the clear distance from the face of pier to the center of track be at least 18'-0" when pier protection is provided and 25'-0" when pier protection is not provided. Current clearances do not satisfy railroad requirements. The minimum as-built clearance is 8'-3" at UPRR Yard Track 21 adjacent to the floodwall. Existing horizontal clearances for all piers are listed in Table 2.1. The lack of horizontal clearance is the primary reason that the existing bridge has a sufficiency rating of 44.5 and is specified as "functionally obsolete." The preferred solution should address current railroad clearance requirements through the careful selection of pier locations. If piers are located in the yard between tracks where clearances are not satisfied, negotiation with the railroads will be necessary to either remove tracks, or use a reduced clearance agreed to by all parties.

Constructibility is an important consideration for structure layout. There are a variety of practical structure types and construction methods that are available for this site. Possible structure types include: precast concrete bulb-T girders, precast concrete U girders, steel plate girders, steel box girders, and cast-in-place or precast concrete box girders. Construction with precast concrete or steel girders could progress using traditional ground-based techniques, while cast-in-place concrete box girders can be built either on falsework or from above using form travelers in a balanced cantilever fashion from the piers. Traditional cast-in-place on falsework is not practical in the railroad yard and river because of the disruption that would result; however, this is practical outside of these areas near the ends of the bridge. Figures 4.17 and 4.18 at the end of this section illustrate these construction methods.

Given the complexity of the site, ground-based construction will be difficult and should be minimized. Access to the site for drill rigs, pile drivers, and other heavy equipment

required for foundation and substructure construction will be limited due to the extensive and frequently used railroad facilities. Gaining access to pier locations within the railroad yard will require the construction of temporary track crossings at the expense of the project.

Construction of a cast-in-place concrete box girder from above using form travelers would minimize operations and impacts to the space below the bridge. Impacts to the railroads and river would be limited to foundation and substructure construction activities. Concrete delivery could be accomplished from the existing bridge. To construct the bridge, form travelers are assembled atop the completed substructure, and construction of the superstructure is completed from above in balanced cantilever from the piers.

4.2 Layout Options

Span layout studies identified eight possible layouts with a variety of span lengths and associated structure types. The span layouts that have been studied include:

- **Match Existing Span Layout**
- **Match Existing Span Layout over the Railroad Yard with Modified River Spans**
- **Moderate Span Layout 1**
- **Moderate Span Layout 2**
- **Moderate Span Layout 3**
- **Long Span Layout 1**
- **Long Span Layout 2**
- **Long Span Layout 3**

These layouts are discussed in detail in the following sections. Two vertical profiles are being considered in conjunction with these layouts. The lower profile is similar to the existing bridge and applicable for the Match Existing and Moderate Span options. The higher profile is slightly raised on the east end to provide vertical clearance over the railroad tracks where longer span variable depth structures are considered. Effects on the approaches are minimal with both profile options. A lower profile allows for a gentler downgrade to intersections on the east end and reduces the amount of earthwork required near the east abutment. In both instances, a minimum vertical railroad clearance of 23’-0” is maintained.

4.3 Span Layout and Structure Type Options

4.3.1 Match Existing Span Layout

One option for the new bridge is to duplicate the span layout of the existing structure. This layout option is illustrated in Figures 4.1 and 4.2. Slight modifications to the pier

locations of the new structure were made to account for deviations of the railroad tracks to the north of the existing bridge. This layout has a total of seven spans and five pier locations in the railroad yard. Spans of 197 feet and 198 feet at the west end of the bridge provide crossing of the Arkansas River. A span of 184 feet in the yard crosses 13 UPRR tracks. The remaining spans are shorter with lengths of 134 feet or less.

The functionality of a new bridge matching the existing pier layout in the railroad yard would be essentially the same as the existing structure. The number of tracks with less than the minimum required horizontal clearance does not change; however, the critical clearance at Pier 2 located at the western edge of the railroad yard could be improved by moving the pier west into the foot of the floodwall. The proposed layout improves this clearance by approximately 3 feet to match other minimum existing clearances at other piers. Pier 1 would be located on the west bank of the Arkansas River to match the current pier location.

Possible structure types for this layout are spliced post-tensioned concrete bulb-T girders, spliced post-tensioned concrete U girders, steel plate girders, and steel box girders. Steel plate girders or steel box girders are best suited for this layout. Bulb-T and U girders require splicing for the longer spans since girders of this length cannot be transported and are outside the range of pre-tensioning. This option utilizes typical ground-based construction as shown in Figure 4.17. Numerous piers and ground-based construction techniques adversely affect the railroads.

4.3.2 Match Existing Span Layout over the Railroad Yard with Modified River Spans

This option utilizes existing pier locations in the railroad yard and three shorter spans over the Arkansas River. The intent of this layout is to reduce the long spans at the west end of the bridge to reduce structure cost. Figures 4.3 and 4.4 show this layout option. Like the previous layout, slight modifications to the pier locations in the railroad yard were made due to slight deviations of the railroad tracks to the north of the existing bridge. There are a total of eight spans and five piers in the railroad yard with this layout. A span of 184 feet in the yard crosses thirteen (13) UPRR tracks. Remaining spans are shorter with lengths of 138 feet or less.

As with the previous layout, there are no significant functional improvements in the railroad yard. Pier 2 is located in the Arkansas River channel raising concerns of scour and impacts to recreational use of the river. Preliminary hydraulic studies have concluded that significant scour is possible with this layout. If this option is chosen, further detailed study will be required to ensure that the floodwall is not undermined.

Possible structure types include precast spliced post-tensioned concrete bulb-T and U girders, steel plate girders, steel box girders, and precast segmental box girders. Of these structure types, precast spliced post-tensioned bulb-T and U girders are the most appropriate choices. The moderate 184-foot span in the UPRR yard requires splicing for

bulb-T and U girder solutions since the span is outside the range of pre-tensioning and girders are too long to handle and transport. All other spans are within the range of precast pre-tensioned girders. Precast segmental box girders are not as economical for this site due to the relatively short bridge length and the cantilever erection required for the 184-foot span.

The numerous piers for this layout option and ground-based construction techniques for the most feasible structure types adversely affect the railroads.

4.3.3 Moderate Span Layout 1

This span layout limits the maximum span length to 145 feet, which is a typical economical span range for precast concrete girders. The intent of this option is to optimize span lengths and study effects to the railroad yard, river, and floodwall. A total of eight (8) spans and five pier locations in the railroad yard are the result of this layout, which is illustrated in figures 4.5 and 4.6. Pier locations in the BNSF yard are similar to the existing layout while locations in the UPRR yard are significantly different due to elimination of the existing 182 foot span.

The most economical structure types for this layout are precast bulb-T girders and precast U girders. Precast segmental box girders are another possibility, but are not likely to be as economical as precast girders due to the relatively short bridge length.

Moderate Span 1 is the least functional of all layouts investigated. A total of nine tracks are affected. Two UPRR tracks would need to be closed due to the location of piers 3 and 5, and two tracks due to the location of Pier 4. Many of the remaining tracks do not meet the minimum required horizontal clearances. The Arkansas River is also affected by Pier 2 located in the river channel, near the floodwall. As with other options considering a pier in the river, scour and impacts to recreational use of the river should be considered. Ground-based construction techniques are likely to adversely affect railroad operations.

4.3.4 Moderate Span Layout 2

Moderate Span 2 has six spans, one less span than the existing bridge. Figures 4.7 and 4.8 show this option. Three pier locations are in the railroad yard, however, horizontal clearance is achieved for two of these. Piers are located against the floodwall and just off the east yard access road. Two tracks remain with less than the required clearance. The moderate span in the UPRR yard is increased to 234 feet, which moves Pier 4 to the west side of the east access road. The span over the BNSF tracks is increased to 206 feet eliminating a pier in the BNSF yard. The span over the Arkansas River is increased to 207 feet to place Pier 1 on the west riverbank.

Probable structure types for this layout are steel plate and steel box girders due to the longer spans and variability in span length. The longer spans over the UPRR and BNSF yards are less desirable for spliced bulb-T or U girders, and balanced cantilever construction with precast concrete box girders is undesirable due to multiple cantilevers and the short bridge length. Longer span options discussed below are better solutions for cast-in-place construction. As with the previous options, ground-based construction techniques will adversely affect railroad operations.

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. These two tracks at Pier 3, however, have a clearance of 10.8 feet, significantly less than the minimum required 18'-0" with pier protection. Impacts to the Arkansas River and floodwall with this option are minimal.

4.3.5 Moderate Span Layout 3

Moderate Span Layout 3 has six spans in a more consistent arrangement, as shown in figures 4.9 and 4.10. The intent of this layout is to create a more uniform span arrangement in the moderate span category by utilizing space occupied by the floodwall. There are typical spans of approximately 177 feet over the Arkansas River and BNSF yard and the span over the UPRR yard has been extended to 255 feet.

Applicable structure types include steel plate girders, steel box girders, and cast-in-place concrete box girders erected with form travelers from above. Three balanced cantilever operations and erection on falsework would be required for the concrete box solution. Steel plate girders and steel box girders require splicing and ground based erection techniques.

The location of Pier 2 near the center of the floodwall raises significant concerns with this layout option. Construction of Pier 2 would be difficult and has the potential of compromising the floodwall. Careful practices would be required to ensure no adverse effects during construction and in the final configuration. Pier isolation is possible to ensure no load sharing between the floodwall and pier. A minimum horizontal clearance of 10.8 feet is provided for the UPRR tracks at Pier 3, less than minimum railroad requirements. Pier 1 is placed along the western bank of the Arkansas River similar to where a pier is currently located.

4.3.6 Long Span Layout 1

Long Span Layout 1 is a four span structure with the least number of piers of any layout studied. Figures 4.11 and 4.12 illustrate this layout option. The main spans are 352 feet and 326 feet and the end spans are 215 feet and 202 feet. The appropriate structure type for this layout is a concrete segmental box girder cast-in-place from above with form travelers. Three cantilever operations are required to complete the bridge without the

need for falsework. Working from above minimizes impacts to the railroads, floodwall, and river during construction of the superstructure. Impacts during substructure construction are limited to form erection and concrete placement and are minimal due to fewer piers, less excavation, and less foundation installation.

Due to the location of Pier 3, a modification to the proposed vertical profile is required for this layout to provide vertical clearance over the tracks as required by the railroads. Raising the profile may result in increased amounts of fill, grade adjustments, and reconstruction of intersections off the east end of the bridge. Four railroad tracks adjacent to piers 2 and 3 do not have the required horizontal clearance. The minimum clearance provided is 10.8 feet at Pier 2. There is no effect to the floodwall since it is spanned. Pier 1 is placed near the west bank of the Arkansas River.

4.3.7 Long Span Layout 2

Long Span Layout 2 has five spans that decrease in length towards the east end of the bridge to allow for a reduced superstructure depth where railroad vertical clearances are critical. This layout option utilizes the higher proposed vertical profile and is shown in figures 4.13 and 4.14. Long Span Layout 2 is a significant functional improvement over existing conditions. The number of tracks with less than the minimum horizontal clearance to a pier is limited to two at Pier 2. The provided clearance at Pier 2 is 10.8 feet. Pier 1 is near the west bank of the Arkansas River and Pier 3 is next to an existing access road between the UPRR and BNSF yards. Pier 4 is placed outside of the railroad yard completely. Piers 3 and 4 satisfy the 18'-0" minimum railroad horizontal clearance requirements. The floodwall is spanned.

The structure type for this layout is a concrete segmental box girder cast-in-place from above with form travelers. Three cantilever operations are required to complete the bridge, along with falsework for the span over the Loop Ramp. Working from above minimizes impacts to the railroads, floodwall, and river during construction of the superstructure. Impacts during substructure construction are limited to form erection and concrete placement and are minimal due to fewer piers, less excavation, and less foundation installation.

4.3.8 Long Span Layout 3

Long Span Layout 3 has five spans arranged somewhat symmetrically. Both the UPRR and BNSF railroad yards are completely spanned. Figures 4.15 and 4.16 illustrate this option. All other span arrangements and layout options studied have a pier positioned between UPRR yard tracks 13 and 14 which does not meet minimum railroad horizontal clearance requirements. To eliminate this situation, the main span for this layout is shifted such that piers are placed adjacent to the foot of the floodwall and next to the access road separating the UPRR and BNSF yards. This increases the main span to 374

feet over the UPRR yard, with spans of 248 feet and 206 feet over the Arkansas River and BNSF yard, respectively.

The appropriate structure type for this layout is a concrete segmental box girder cast-in-place with form travelers from above. Two cantilever operations are required to complete the bridge, one less than the other options considering this structure type. Falsework is likely for the end spans over the Loop Ramp and west riverbank, although continuation of form travel operations is also possible for these spans. Working from above minimizes impacts to the railroads, floodwall, and river during construction of the superstructure. Impacts during substructure construction are limited to form erection and concrete placement and are minimal due to fewer piers, less excavation, and less foundation installation.

Long Span Layout 3 is the most functional of all layouts studied and is the only layout that satisfies current railroad clearance requirements. Therefore, negotiated reduced clearances are not required and the new bridge will not rate functionally deficient. Piers 2 and 3 have a clear distance of 18 feet to the nearest adjacent track. Pier 4 has a clear distance of 25 feet to the nearest track and will not require pier protection. This layout does not affect the Arkansas River and the planned recreational improvements to this site. Pier 1 is placed midway between the Arkansas River and the trail. Pier 2 is placed at the foot of the floodwall on the railroad side. The higher of the two proposed vertical profiles is used to provide adequate vertical clearance over the railroad tracks.

4.4 Foundation Considerations

Limited access and necessary coordination with railroad personnel and track operations complicate construction of foundations in the railroad yard. Also, foundation construction in or near the Arkansas River may require cofferdams and dewatering. The preferred foundation type is the least intrusive to this challenging site. The preliminary geotechnical report identifies three possible foundation types for the given subsurface conditions including drilled shafts, driven piles, and spread footings.

Drilled shafts are the most practical foundation solution. These 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 required greatly reducing or eliminating the pile cap. The smaller footprint of drilled shaft foundations requires less excavation and smaller temporary retaining structures, which is a significant advantage given the congestion of the railroad yard.

Driven piles and spread footing foundations would be much more difficult to construct in the railroad yard. Pile driving operations cause significant vibrations in the surrounding soil which may lead to damage to the existing bridge or ballast supporting nearby tracks. Driven pile foundations also require a larger number of piles and a bigger pile cap compared to drilled shaft foundations. Spread footings have the largest footprint of any

foundation option and require the greatest amount of excavation. The large amount of excavation required for pile caps and spread footings also risks undermining existing tracks. Load sharing between the tracks and the foundations in the final configuration is also undesirable. With tracks close to foundations, the pile groups or footings may experience forces and vibration from the heavy rail traffic.

4.5 Summary

Eight different span layouts have been presented with spans ranging from 108 feet to 374 feet. The complexity of the site and the diversity of layouts investigated allow for a variety of structure types and construction methods. Table 4.1 below summarizes each of these layouts and possible structure types. For each layout, pier clearances, the number of piers with less than 18'-0" horizontal clearance, and the level of impact to the floodwall and Arkansas River are summarized. In the next section, these layouts will be evaluated against the project criteria.

Table 4.1 Summary of Possible Structure Types and Functional Characteristics

Pier Layout	Possible Structure Types	Horizontal Clearance From Face of Pier to Centerline Railroad Tracks						Tracks Without Minimum Clearance to a Pier	Impact to Arkansas River	Impact to River Floodwall
		Pier 2	Pier 3	Pier 4	Pier 5	Pier 6	Pier 7			
Match Existing	Steel Plate or Steel Box Girders	11.2’	11.4’	11.2’	13.4’	18.0’	N/A	7	Minor	Minor
Match Existing With Moderate River Spans	Spliced Bulb-T or Spliced U Girders	N/A	11.2’	11.4’	11.2’	13.4’	18.0’	7	Moderate	Minor
Moderate Span 1	Bulb-T or U Girders	N/A	0.0’	0.0’	0.0’	13.4’	18.0’	9	Moderate	None
Moderate Span 2	Steel Plate or Steel Box Girders	18.0’	10.8’	18.0’	25.0’	N/A	N/A	2	None	Minor
Moderate Span 3	Steel Plate, Steel Box, or C.I.P. Concrete Box W/ Form Travelers	N/A	11.4’	18.0’	25.0’	N/A	N/A	2	None	Major
Long Span 1	C.I.P. Concrete Box W/ Form Travelers	10.8’	16.7’	N/A	N/A	N/A	N/A	4	Minor	None
Long Span 2	C.I.P. Concrete Box W/ Form Travelers	10.8’	18.0’	18.0’	25.0’	N/A	N/A	2	Minor	None
Long Span 3	C.I.P. Concrete Box W/ Form Travelers	18.0’	18.0’	25.0’	N/A	N/A	N/A	0	None	Minor

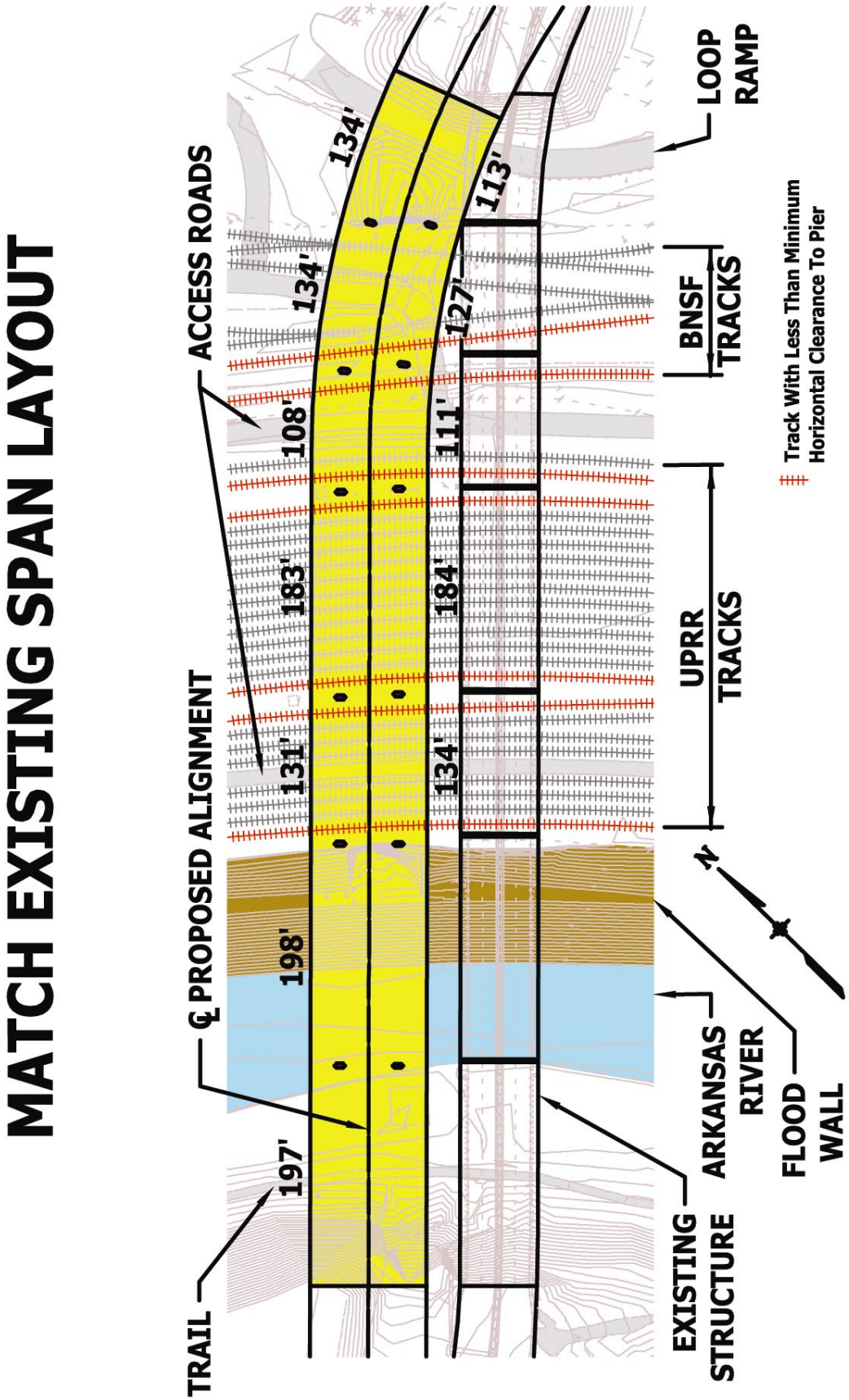


Figure 4.1 Match Existing Span Layout - Plan

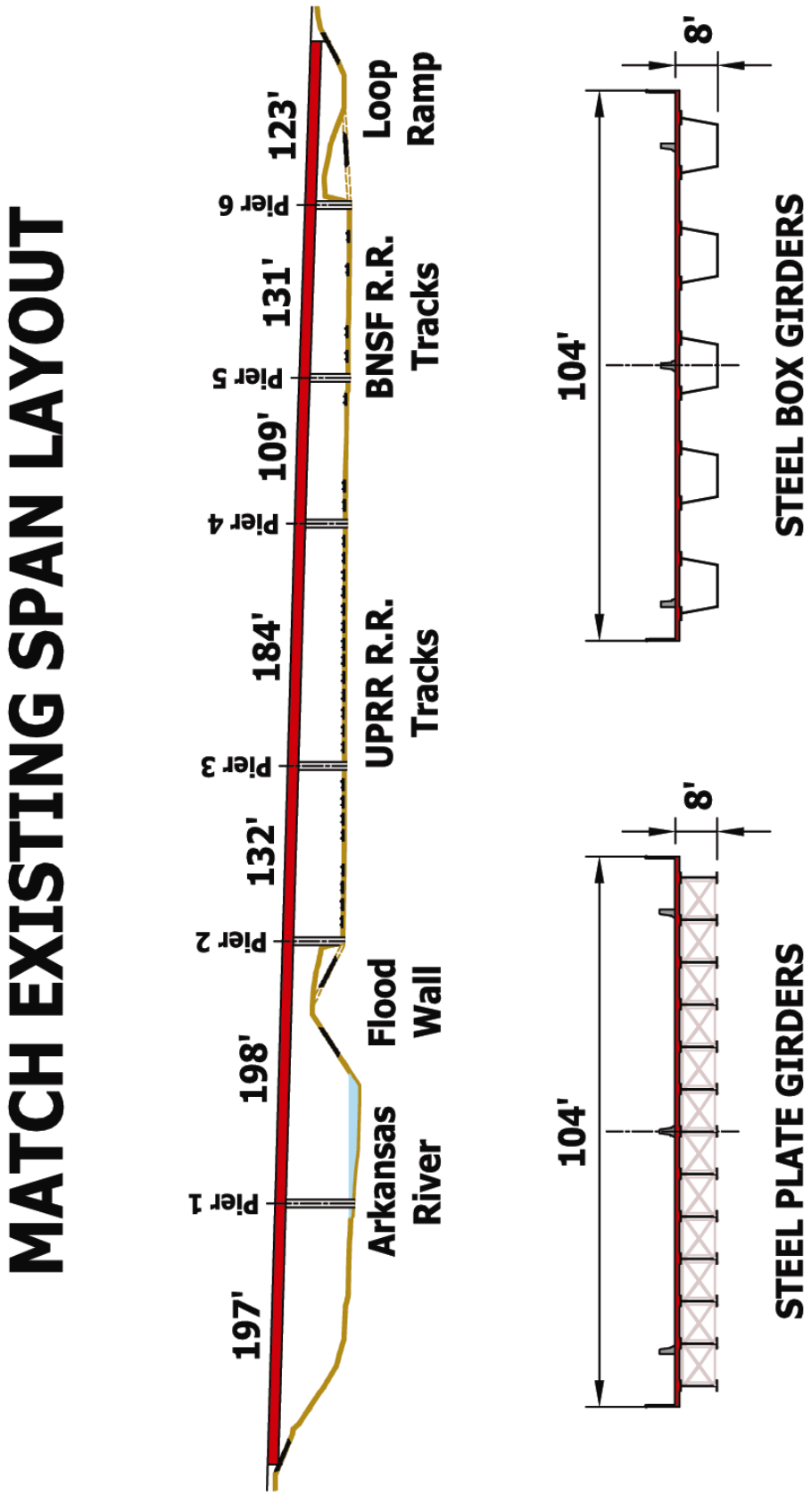


Figure 4.2 Match Existing Span Layout - Elevation

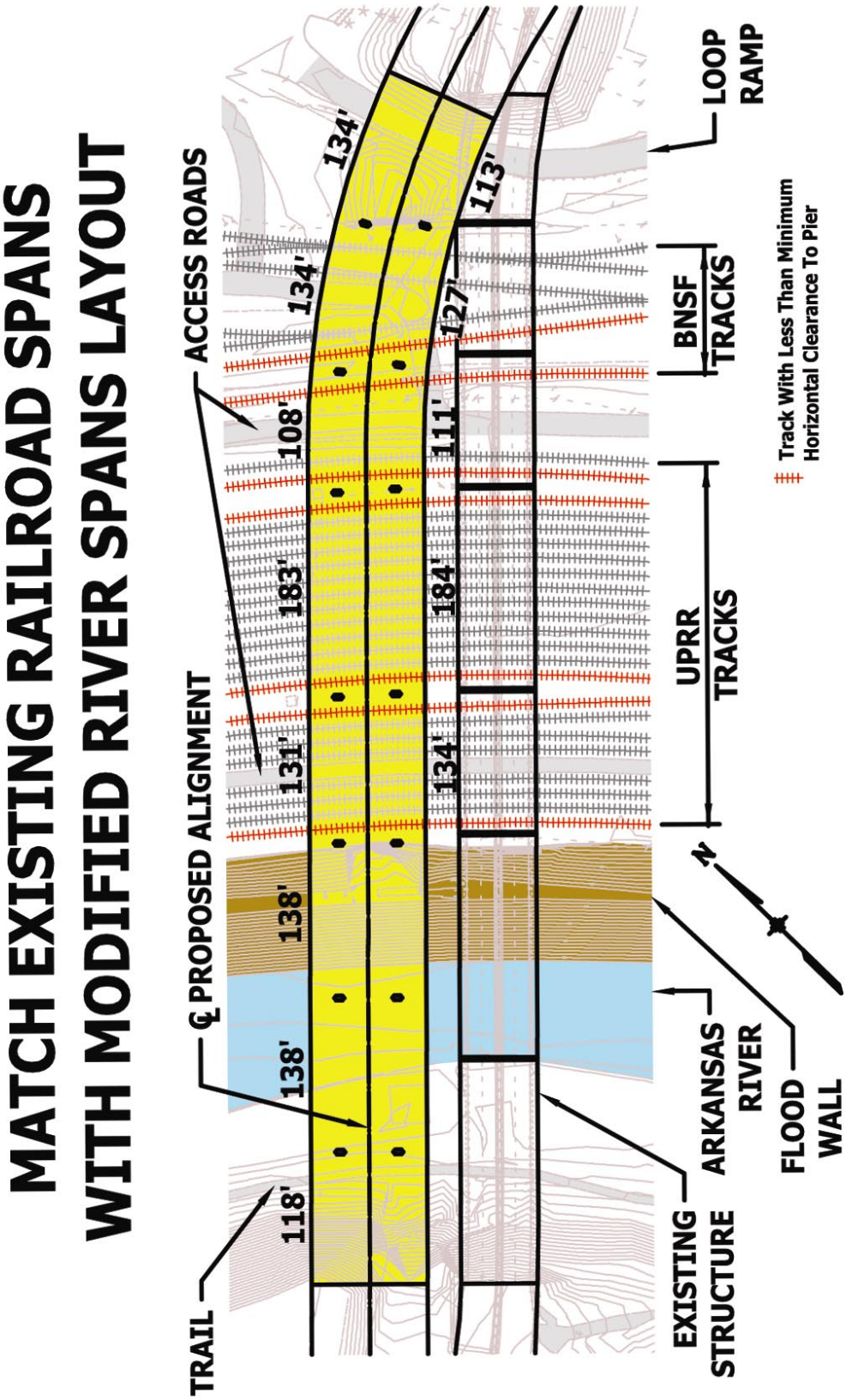


Figure 4.3 Match Existing RR Spans w/ Modified River Spans - Plan

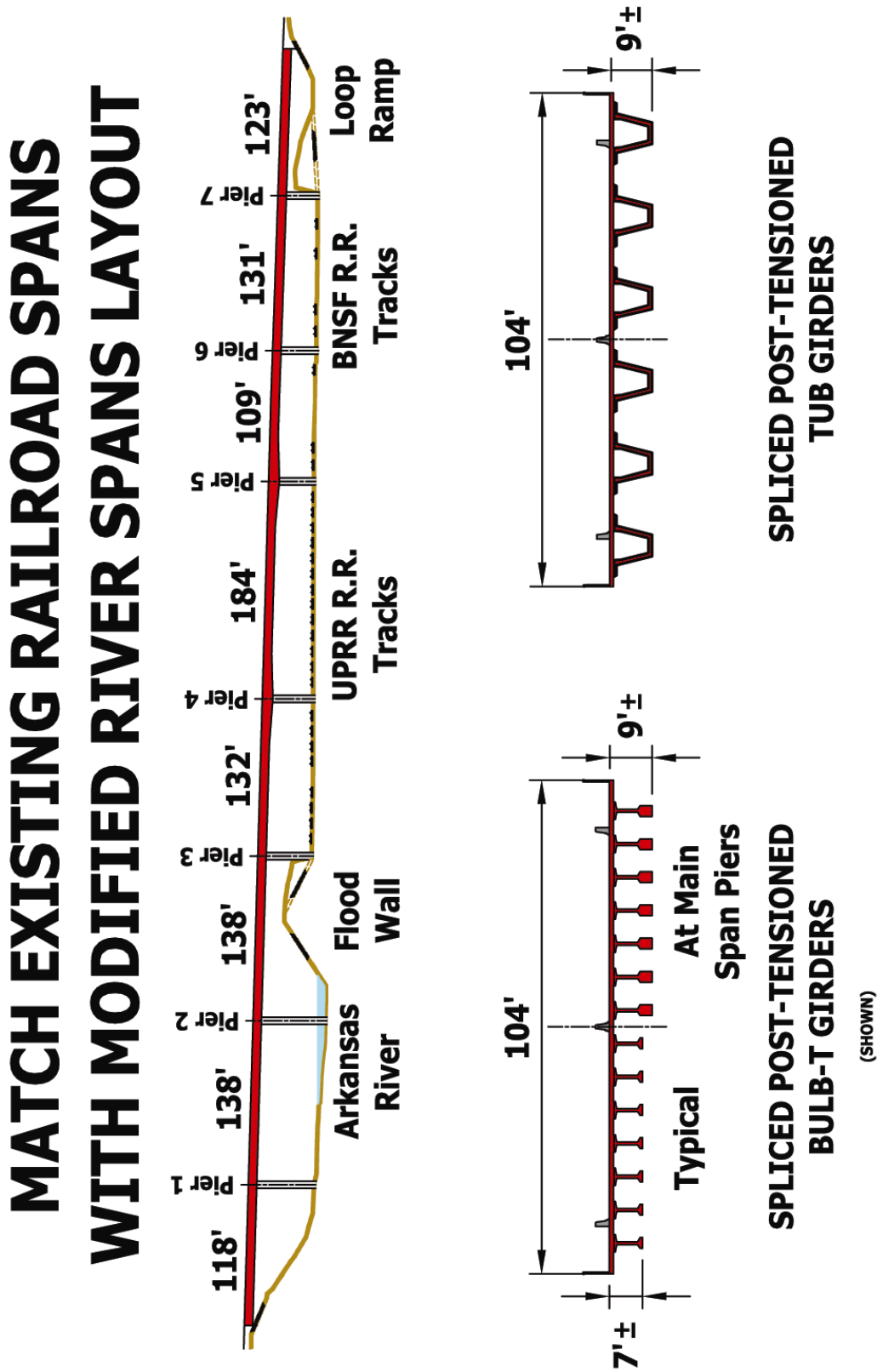


Figure 4.4 Match Existing RR Spans w/ Modified River Spans - Elevation

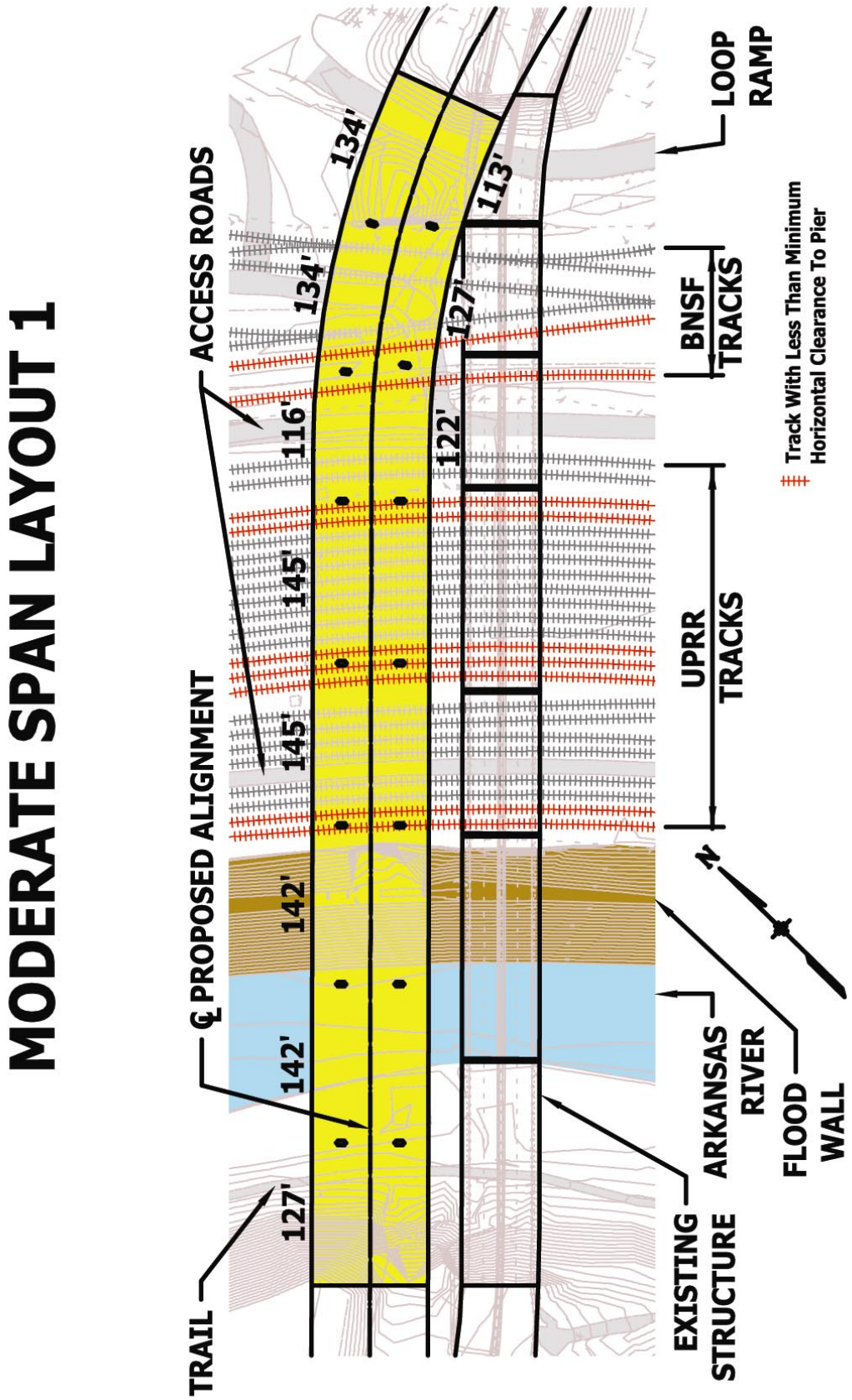


Figure 4.5 Moderate Span Layout 1 - Plan

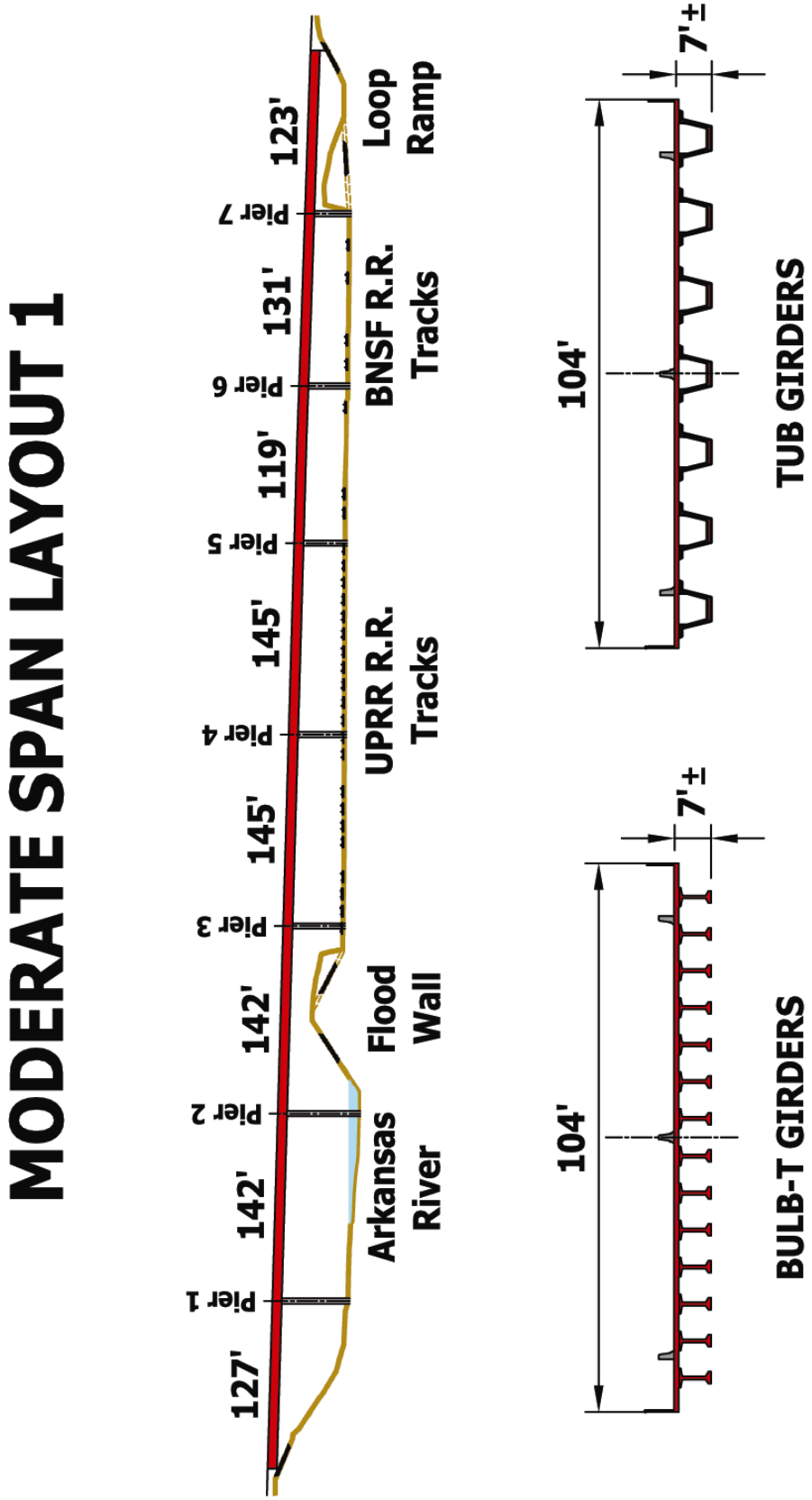


Figure 4.6 Moderate Span Layout 1 - Elevation

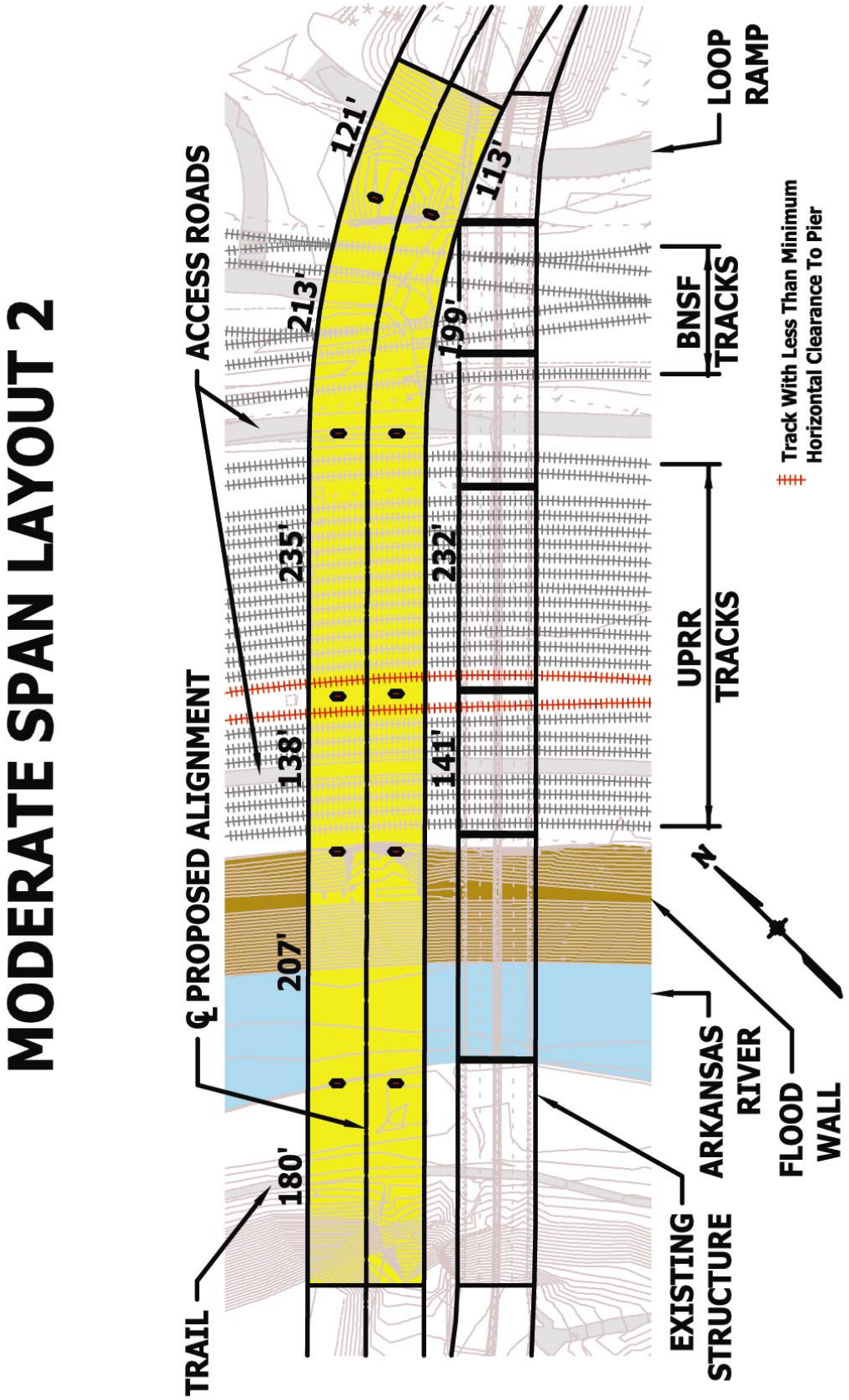


Figure 4.7 Moderate Span Layout 2 - Plan

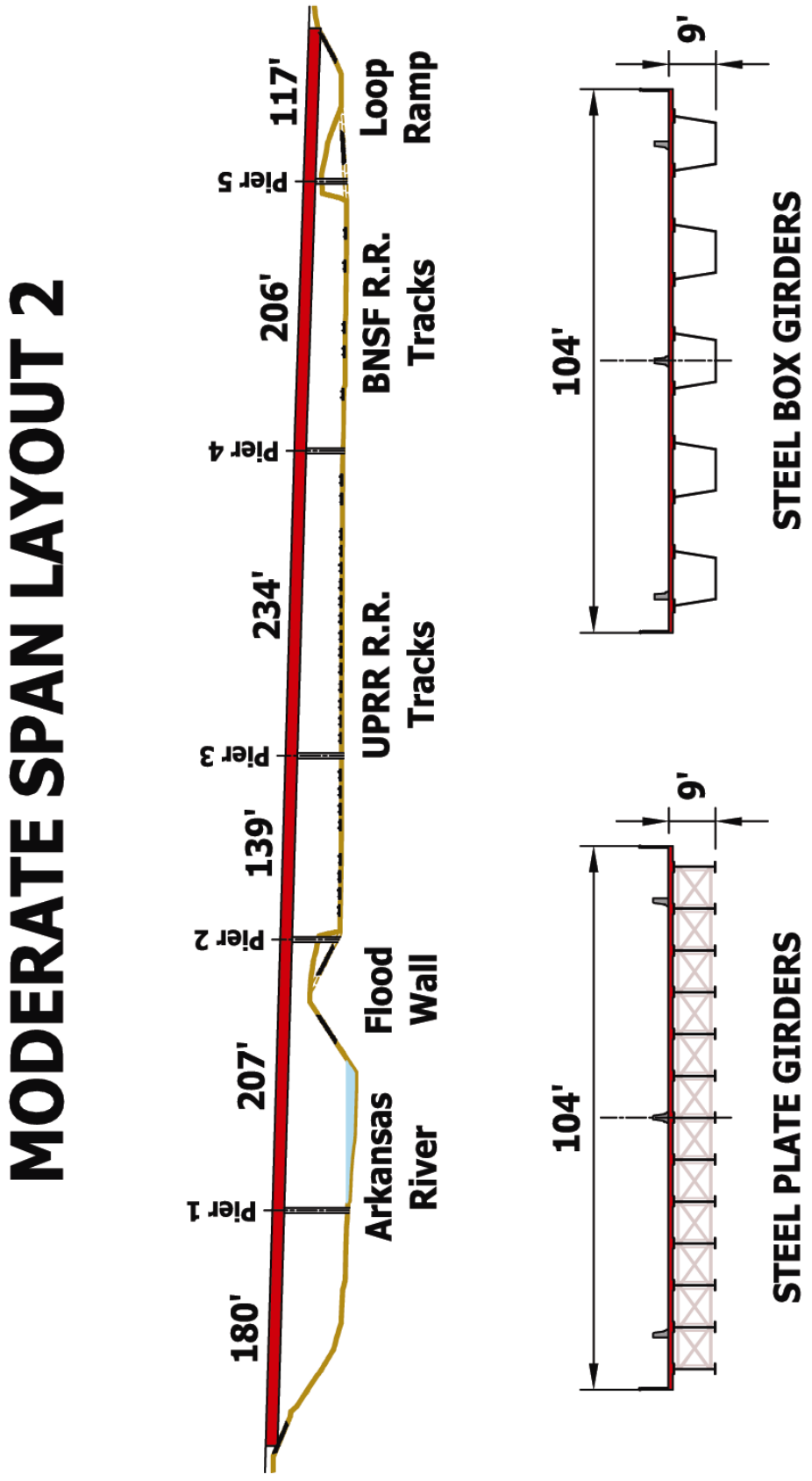


Figure 4.8 Moderate Span Layout 2 - Elevation

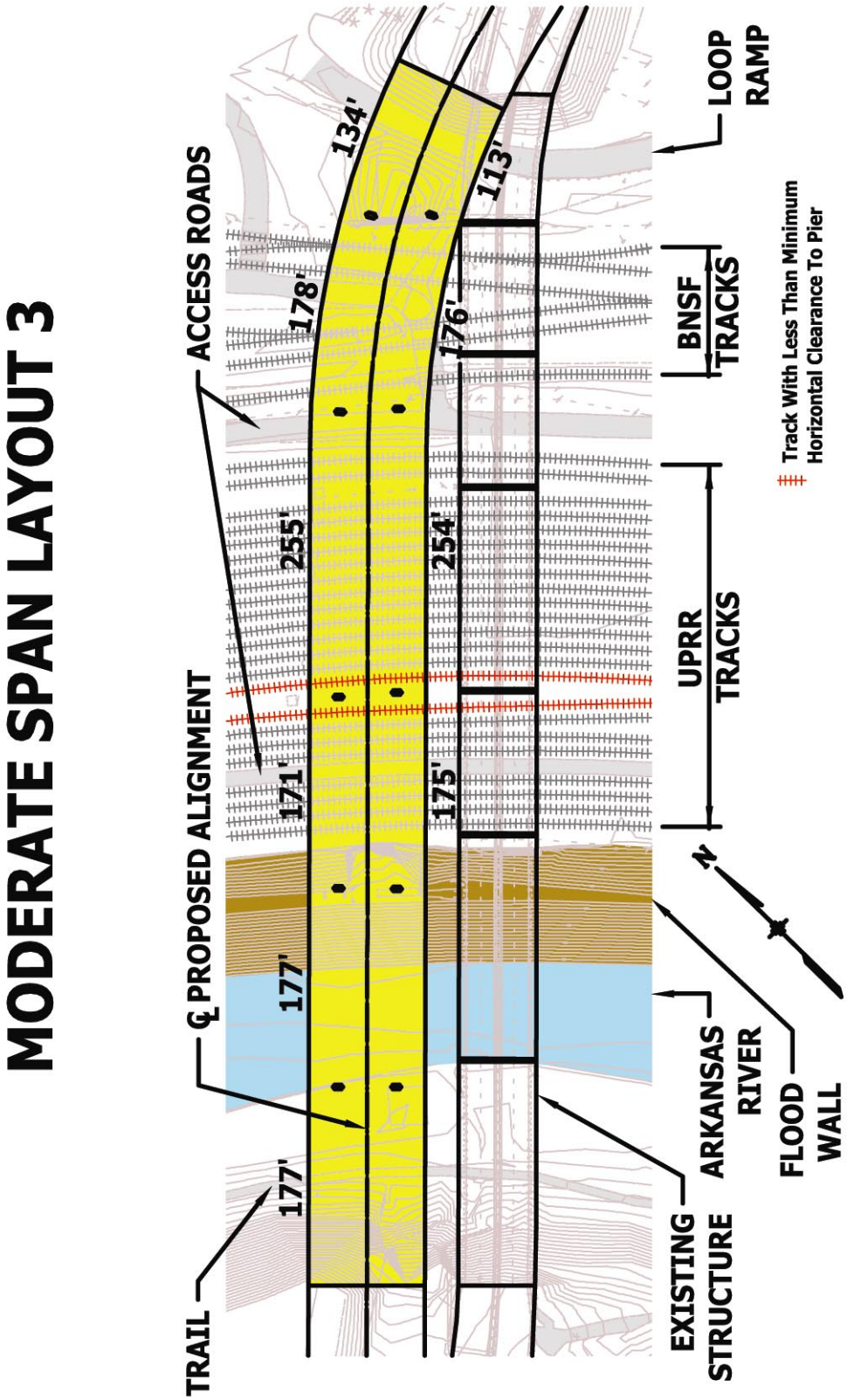


Figure 4.9 Moderate Span Layout 3 - Plan

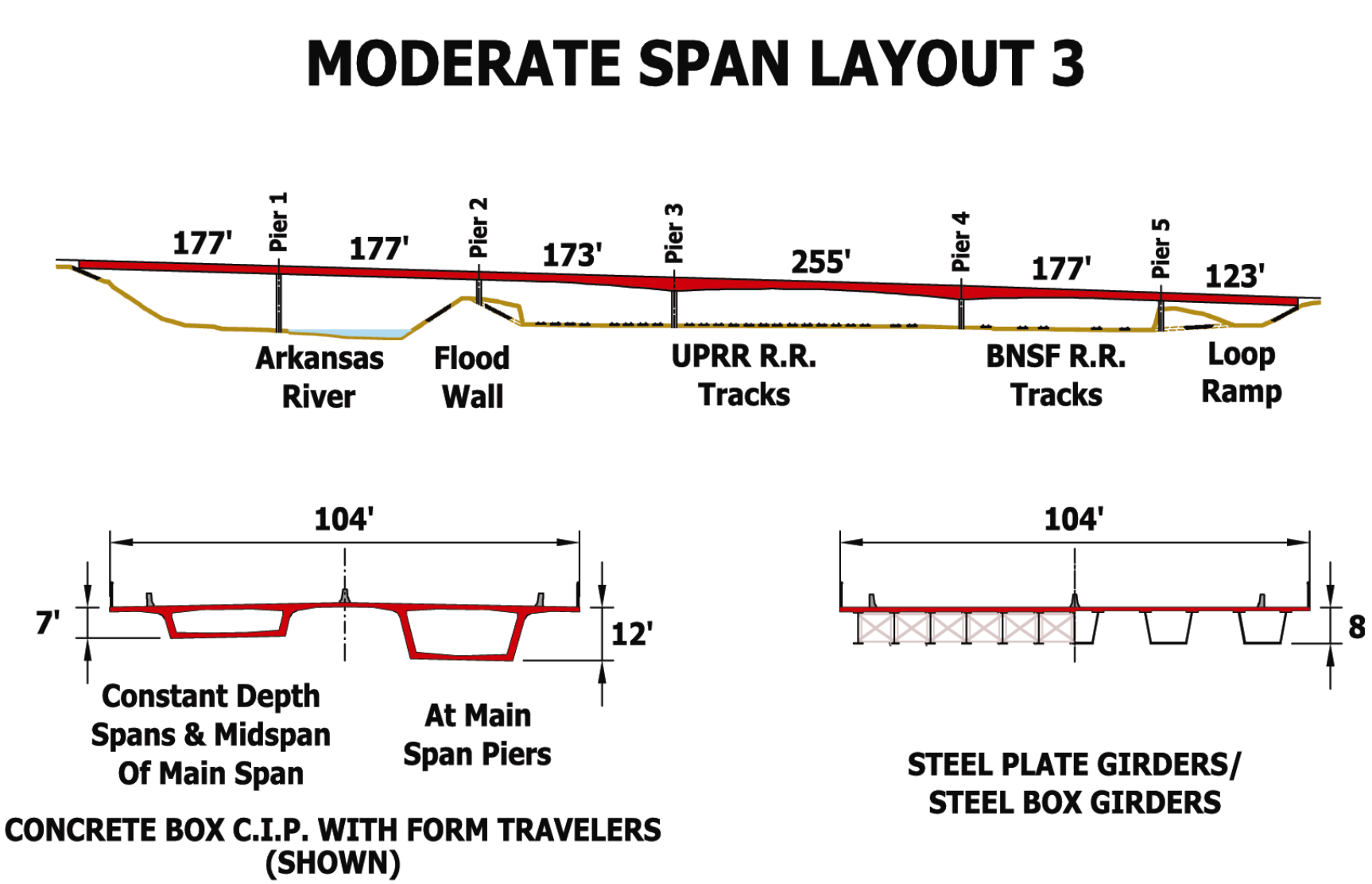


Figure 4.10 Moderate Span Layout 3 - Elevation

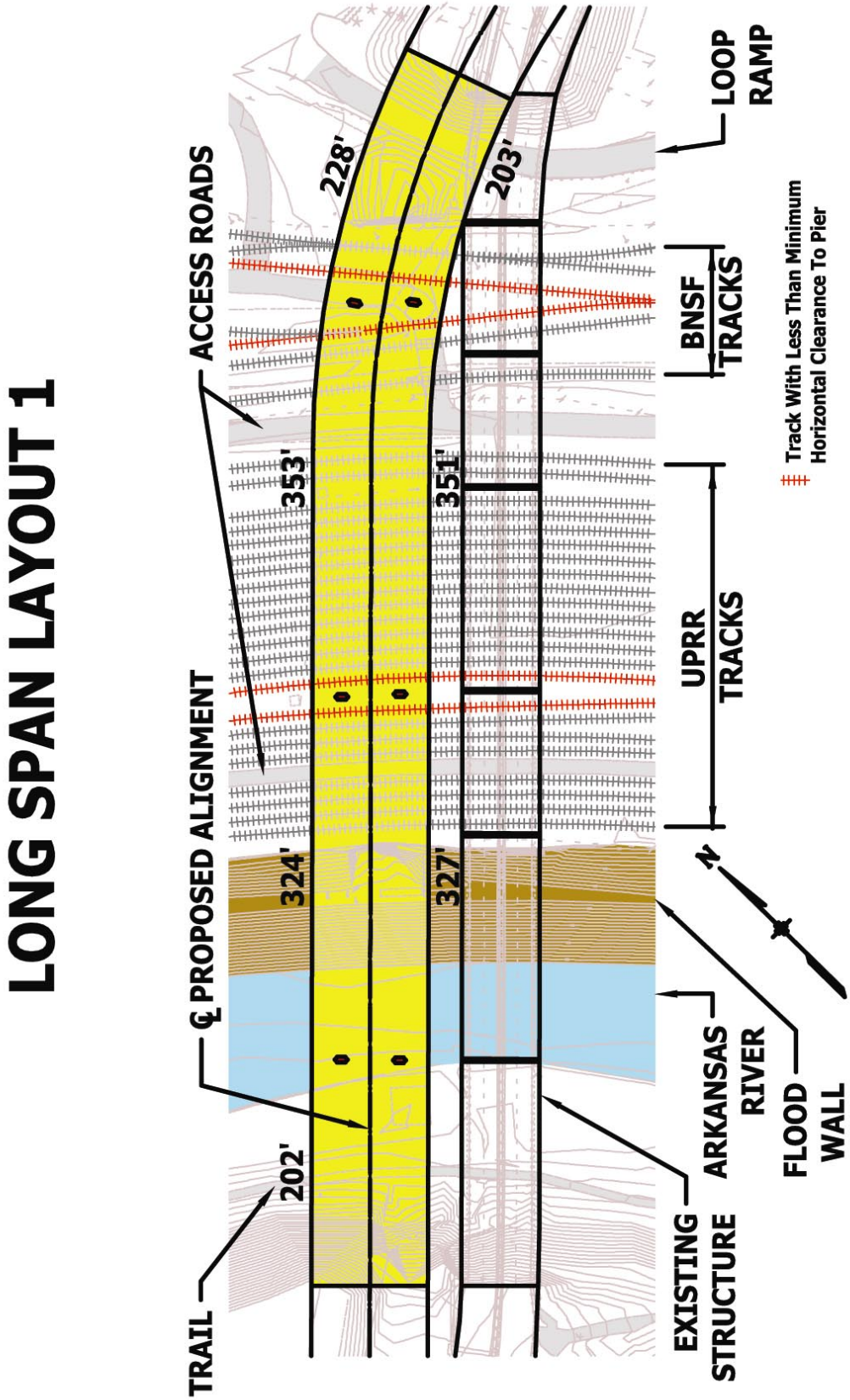


Figure 4.11 Long Span Layout 1 - Plan

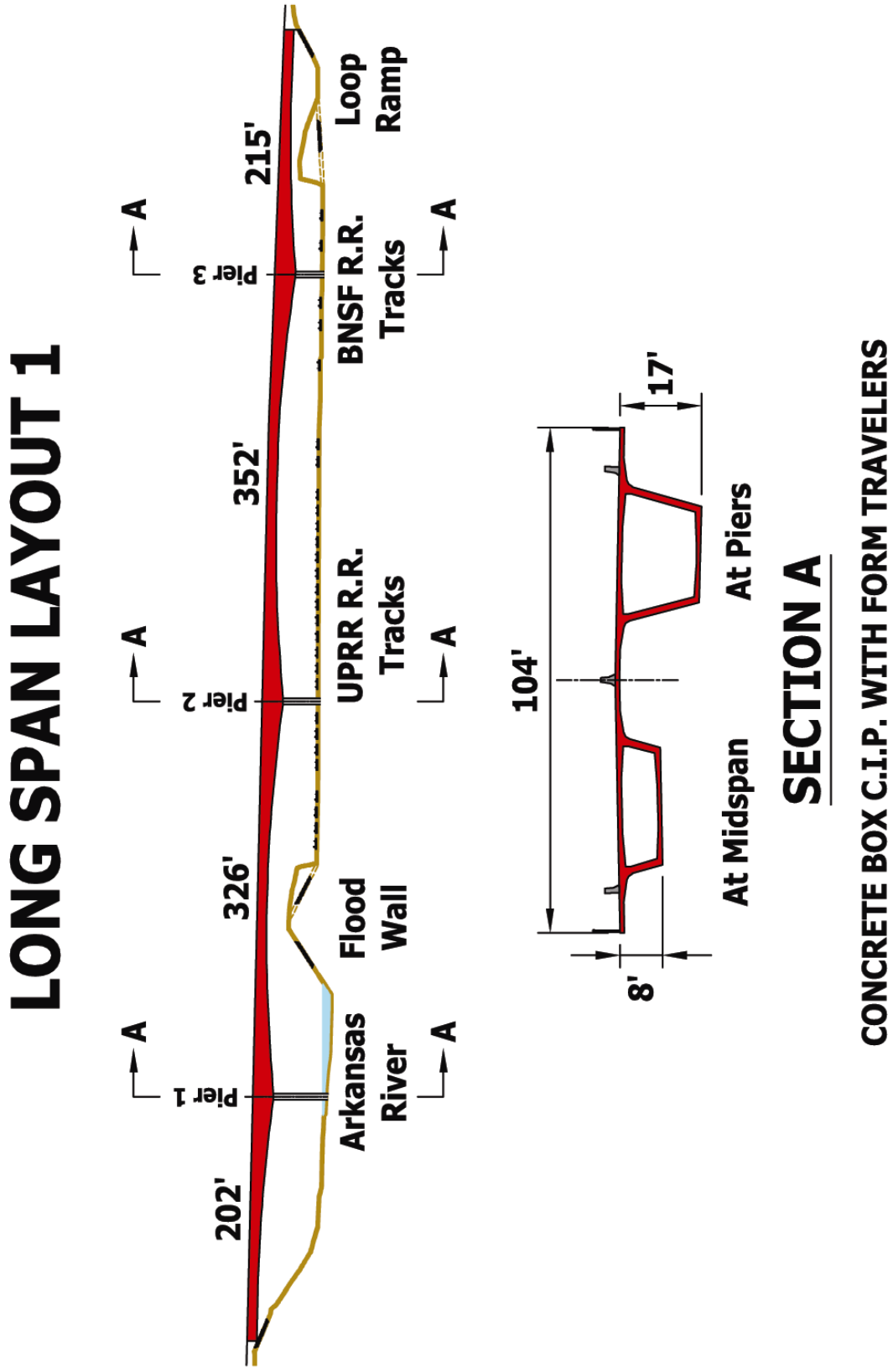


Figure 4.12 Long Span Layout 1 - Elevation

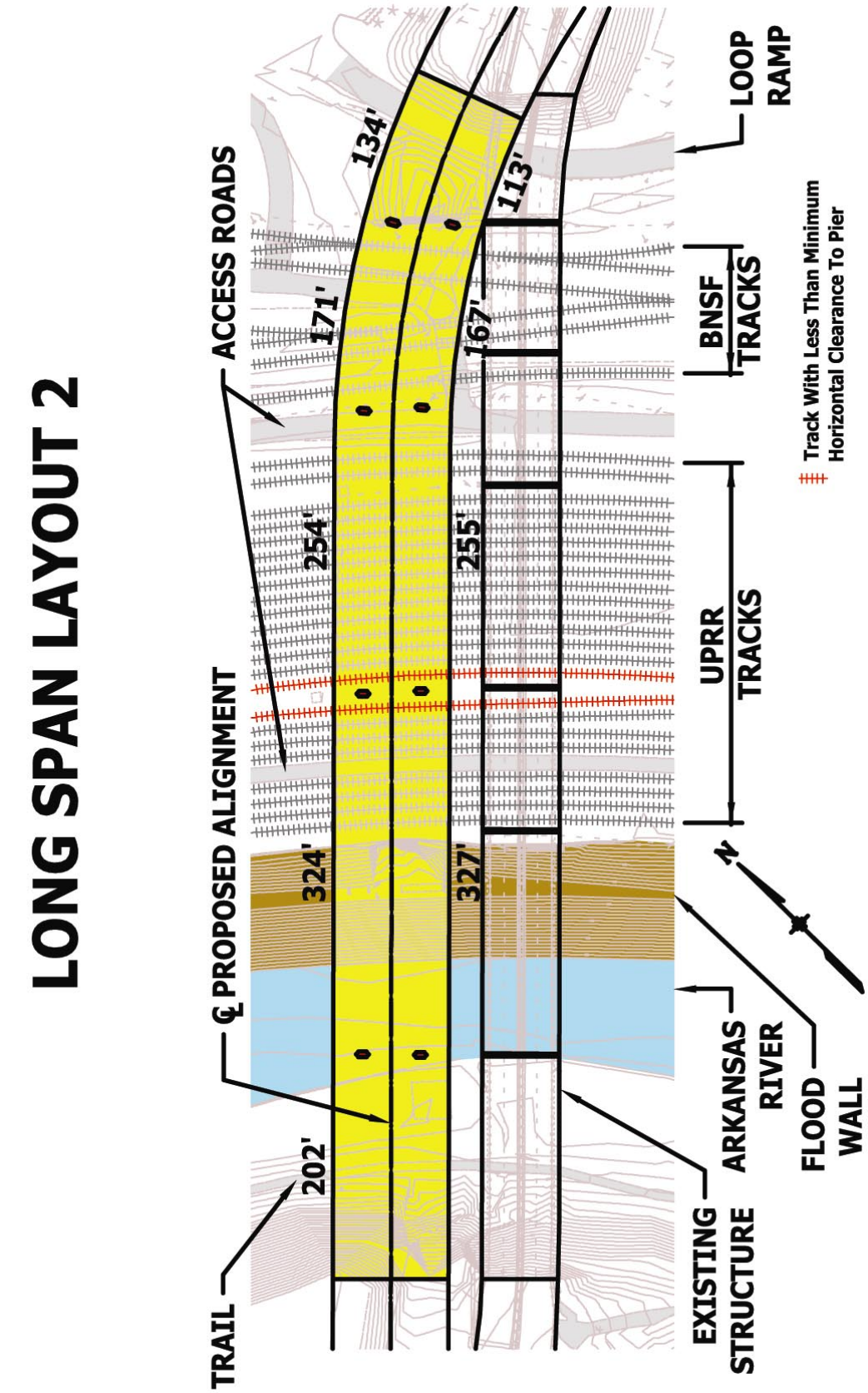


Figure 4.13 Long Span Layout 2 - Plan

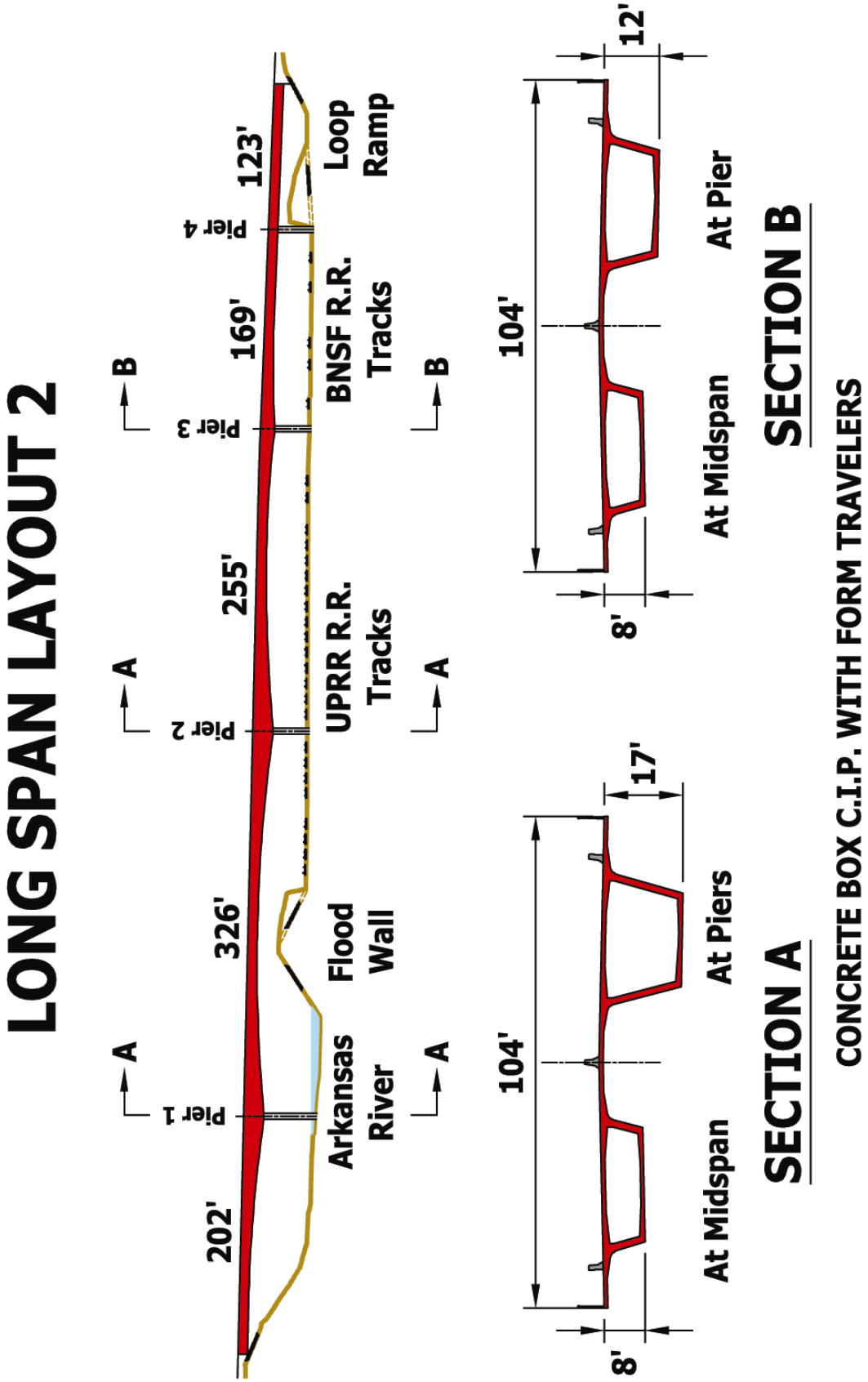


Figure 4.14 Long Span Layout 2 - Elevation

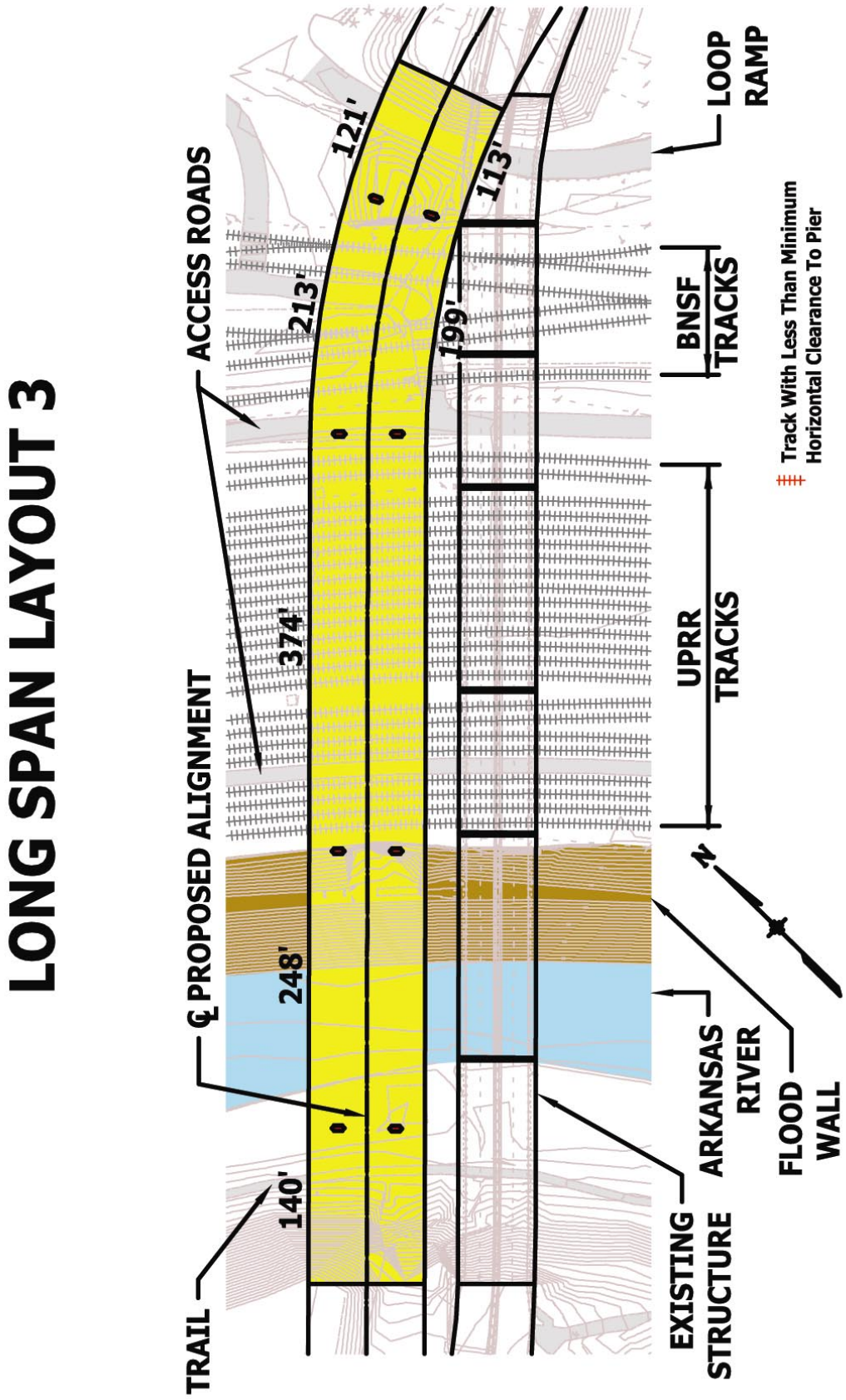


Figure 4.15 Long Span Layout 3 - Plan

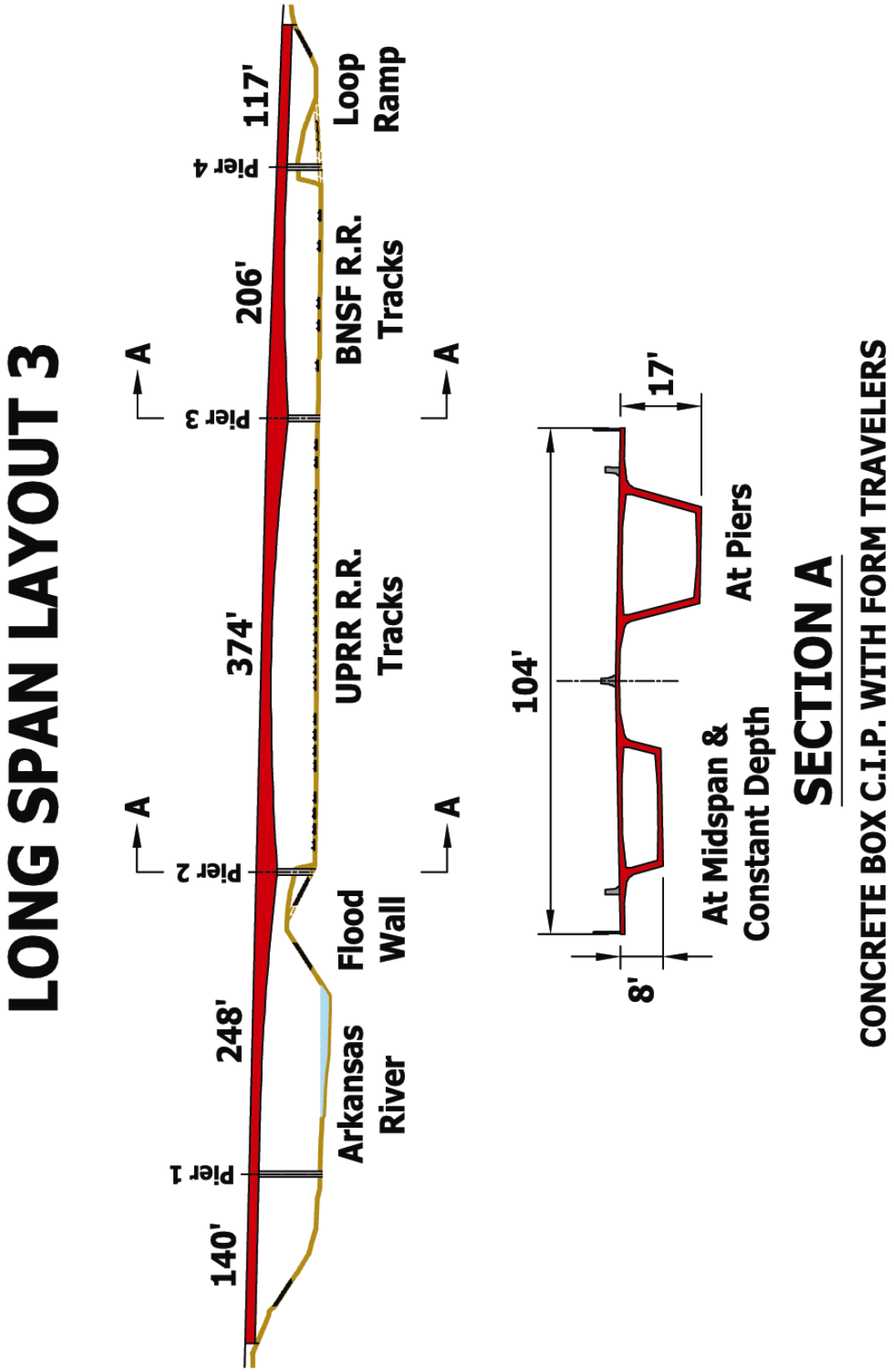
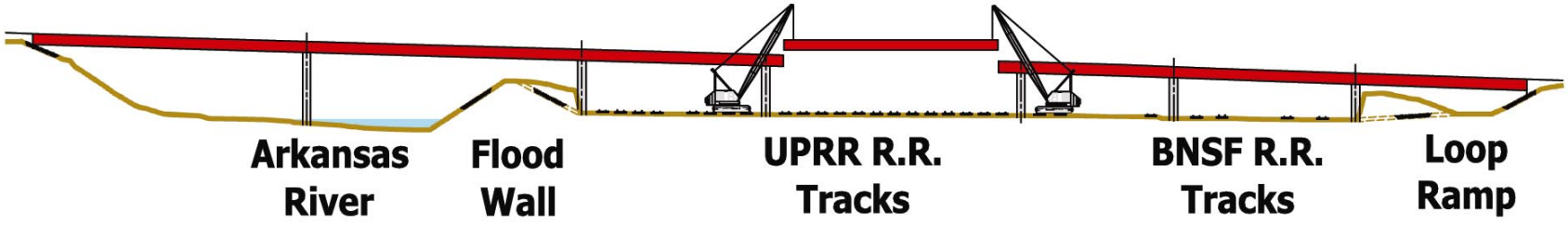
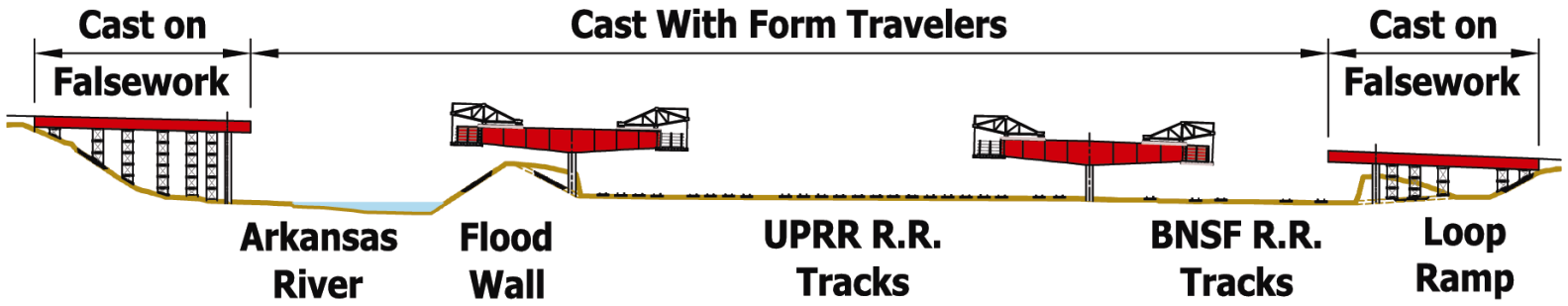


Figure 4.16 Long Span Layout 3 - Elevation



ERECTION SCHEMATIC FOR GIRDERS

Figure 4.17 Girder Erection with Ground Based Cranes



ERECTION SCHEMATIC FOR CIP

Figure 4.18 Cast-In-Place Balanced Cantilever Erection with Form Travelers (Long Span 3 Shown)