US 51 OHIO RIVER BRIDGE ENGINEERING AND ENVIRONMENTAL STUDY

ENGINEERING CONSIDERATIONS WHITE PAPER

ITEM NOS. 1-100.00 and 1-1140.00

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EXECUTIVE SUMMARY

The existing US 51 Bridge (also known as the Cairo Bridge) carries US 51, US 60, and US 62 traffic across the Ohio River between Wickliffe, Kentucky and Cairo, Illinois. The scope of work for the US 51 Ohio River Bridge Engineering and Environmental Study (KYTC Items 1-100.00 and 1-1140.00) is to perform preliminary engineering and environmental studies to replace or rehabilitate the existing bridge and evaluate the feasibility of a new bridge for the US 51 crossing of the Ohio River. The purpose of this report is to outline engineering design guidelines and considerations and to discuss the recommended alignment scenarios for the proposed alternatives.

The US 51 Ohio River Bridge carries approximately 5,400 vehicles per day today; approximately 35 percent of these vehicles are trucks. With a 0.5 percent annual growth rate, the 2040 design year traffic volume is projected at 6,200 vehicles per day. Capacity analysis suggests a two lane structure is sufficient to serve anticipated future traffic volumes. The existing US 51 Ohio River Bridge has an overall roadway width of 22.5 feet and a 2.0 percent cross slope. The existing curb dimension from back-of-curb to back-of-curb is approximately 24 feet. The existing bridge is classified as both structurally deficient and functionally obsolete.

A range of alternatives were considered, as documented in the *Alternative Screening Report* for the project. In addition to the No-Build Alternative, Rehabilitation, Superstructure Replacement (Alternative 1), and three build alternatives on new alignment (Alternatives Combined 2, 3A, and 4) were considered. Combined Alternative 2 is recommended to advance for any future project development phases.

Three typical sections are proposed to be advanced for further study: the Practical Solutions Typical Section, the Common Practices Typical Section, and the Desirable Typical Section. Between the three options, the bridge cross-section would include two 12-foot lanes with 4-10 foot wide paved shoulders.

The recommended minimum design speed is 45 mph for build alternatives beyond the Rehabilitation Alternative; a 55 mph design speed is preferred where feasible. The proposed maximum superelevation rate is 6 percent. The proposed maximum vertical grade is 5 percent. However, the goal is to use a maximum vertical grade of 3 percent for improvements on new alignment.

Coordination with the United States Coast Guard provided necessary guidance for horizontal clearances, span arrangements, and vertical clearance. No significant right-of-way or utility issues were identified during this phase of study.

1. INTRODUCTION

1.1. PROJECT OVERVIEW

The existing US 51 Bridge (also known as the Cairo Bridge) carries US 51, US 60, and US 62 traffic across the Ohio River between Wickliffe, Kentucky and Cairo, Illinois. The existing US 51 Bridge is located at Kentucky Mile Point 7.372 along US 51 and at Ohio River navigation Mile Point 980.4 near the confluence of the Mississippi and Ohio Rivers. The truss bridge was opened to traffic in 1938 after construction was completed by the Cairo Bridge Commission. After initially opening as a toll facility, the tolls were removed on November 11, 1948, when the highway departments of Kentucky and Illinois took over maintenance of the structure.

The scope of work for the US 51 Ohio River Bridge Engineering and Environmental Study (KYTC Item Nos. 1-100.00 and 1-1140.00) is to perform preliminary engineering and environmental studies to replace or rehabilitate the existing bridge. The study evaluates the feasibility of constructing a new bridge for the US 51 crossing of the Ohio River. The purposes of this report are to outline engineering design guidelines established by the FHWA, KYTC, and IDOT; to describe project-specific engineering considerations; and to discuss the recommended alignment elements for the proposed alternatives.

1.2. EXISTING BRIDGE CONDITIONS AND NO-BUILD ALTERNATIVE

US 51 is classified as a rural principal arterial in both Kentucky and Illinois. Today, the US 51 Ohio River Bridge carries approximately 5,400 vehicles per day across the Ohio River. Approximately 35% of these vehicles are trucks. With a 0.5 percent annual growth rate, the 2040 design year traffic volume is projected at 6,200 vehicles per day.

The US 60/US 62 bridge over the Mississippi River leading to Missouri is located approximately half a mile south of the Illinois approach to the US 51 Bridge. The nearest alternative upstream river crossing is the I-24 Ohio River Bridge in Paducah, Kentucky. The nearest alternative downstream crossings are the Dorena-Hickman Ferry and the I-155 Mississippi River Bridge between Dyersburg, Tennessee and Caruthersville, Missouri.

The *Needs and Deficiencies Report* for this project identifies substandard geometric features on the existing bridge:

- The existing US 51 Ohio River Bridge has two lanes with an overall roadway width of 22.5 feet and a 2.0 percent cross slope. The existing curb dimension from back-of-curb to back-of-curb is approximately 24 feet. The existing curb is directly adjacent to the truss superstructure.
- One sag vertical curve on the Illinois approach does not meet headlight sight distance requirements for the posted speed limit of 40 miles per hour (mph).
- The horizontal curve on the Kentucky approach is currently signed with a speed limit of 20 mph; the curve does not meet AASHTO or KYTC geometric design standards.
- The bridge is functionally obsolete (due to geometry) and structurally deficient (because the bridge was designed to carry less than today's design load).

In addition to the rehabilitation and build options discussed below, the No-Build alternative will also be considered by the Project Team. The goal of this alternative is to continue current maintenance practices to keep the bridge open to traffic while the structure can safely remain in service. Current estimates indicate that the bridge could remain open to all traffic until approximately 2020. Then a weight limit would be placed on the bridge to restrict truck traffic; all truck traffic would be prohibited around 2025. The existing bridge would be closed to all traffic around 2030. Under the No-Build Alternative, the existing bridge would continue to be classified as structurally deficient and functionally obsolete.

1.3. BUILD ALTERNATIVES

The project team previously defined a broad study area with multiple possible location alternatives. As outlined in the US 51 *Purpose & Need Statement*, the primary purposes of the project are to:

- Improve or replace the functionally obsolete/structurally deficient US 51 Bridge;
- Maintain cross-river connectivity between Wickliffe, Kentucky and Cairo, Illinois; and
- Improve safety on the bridge and its approaches.

As documented in the *Alternatives Screening Report* and based on the purpose and need screening criteria, the possible build alignment alternatives were reduced to the following:

- Alternative 1 (Superstructure Replacement)
- Combined Alternative 2,
- Alternative 3A, and
- Alternative 4, along with
- the Rehabilitation Alternative.

The build alternatives are shown in **Figure 1**. Large buffers are shown for each alternative to allow flexibility for design in future phases of the project, and to allow for consideration of Coast Guard requirements for new structures adjacent to existing structures in the river.

The Rehabilitation Alternative would invest in a major rehabilitation of the existing bridge and approaches to maintain the existing bridge until the year 2045. Potential rehabilitation actions include a new paint system, new bridge deck, strengthening and repair of structural steel members, and concrete patching on the substructure. A seismic retrofit to meet the requirements of the 350- to 500-year return period should be considered if this alternative is developed in future phases. Because the cross-section would remain unchanged, the bridge still would be considered functionally obsolete. A minimum operating rating of 36 tons would be provided for the desired remaining service life of 25 years. The existing termini in Kentucky and Illinois would stay the same.

Alternative 1, Superstructure Replacement, would replace the entire existing superstructure, including a wider cross sectional width, vertical and horizontal geometric improvements, and a seismic retrofit to meet the requirements of a 1000-year return period. The bridge would no longer be considered structurally deficient or functionally obsolete. The existing termini in Kentucky and Illinois would stay the same.

Alternatives Combined 2, 3A, and 4 all include a new Ohio River crossing in a new location. All intersections at the Illinois termini are proposed to be a three legged intersection.

1.4. BASIS FOR ENGINEERING DESIGN CONSIDERATIONS

US 51 is classified as a rural principal arterial by KYTC and IDOT. This classification was used in development of the following engineering design considerations. AASHTO's *A Policy on Geometric Design of Highways and Streets, 2011*, indicates that rural principal arterials may be designed for speeds of 40 mph to 75 mph depending on terrain, driver expectancy, and alignment of the existing facility. KYTC and IDOT design standards for this roadway classification are also referenced throughout the following sections.

The Kentucky and Illinois sections of US 51 have an existing speed limit of 55 mph on the roadway approaches. The speed limit on the existing bridge is 40 mph. One curve on the Kentucky approach is posted at 20 mph.

This white paper describes the requirements associated with a range of potential design speeds.

- For the Rehabilitation Alternative, no geometric improvements are included so the recommended design speed is assumed to correspond to the posted speed limit: 40 mph.
- All other build alternatives include a recommended minimum design speed of 45 mph for the bridge and approach structures. If a 45 mph design speed cannot be obtained, design exceptions should be evaluated.
- To the extent possible, all build alternatives excluding the Rehabilitation Alternative should include a preferred design speed of 55 mph for the roadway approaches.

Key publications used in identifying applicable design criteria include:

- AASHTO's *A Policy on Geometric Design of Highways and Streets,* 2011 (Green Book)
- AASHTO's *Roadside Design Guide*, 2011
- KYTC's *Highway Design Manual*, 2006
- KYTC's *Structural Design Guidance Manual*, 2005
- KYTC's *Pedestrian & Bicycle Travel Policy*, 2002
- IDOT's *Bureau of Design and Environmental Manual*, 2012 (BDE Manual)
- IDOT's *Bridge Manual*, 2012

Figure 1

US 51 Ohio River Bridge

2. TYPICAL SECTIONS

2.1. GUIDANCE REQUIREMENTS

The following subsections describe design standards established by FHWA, IDOT, and KYTC for various cross-sectional elements: lane/shoulder widths, cross slope, clear zone width, guardrail, and bicycle/pedestrian facilities. Section 2.2 contains typical section recommendations for a Major Rural Arterial.

Table 1 summarizes cross-sectional requirements identified for a new bridge or reconstructed bridge (not a 3R project).

Element	AASHTO standard	IDOT standard	KYTC Common Practices
Lane Width	12 ft	12 ft	12 ft
Shoulder Width	8 ft usable	10 ft paved	8 ft graded widen 3 ft for Guardrail*
Clear Width for Bridges	Full approach width preferred but for new bridges over 200 ft long a minimum of 4 ft per side (new bridge) is acceptable.	44 ft (new bridge)	Match Approach Roadway Width
Cross Slope	1.5%-2.0%	1.56%	2.0%
Fill Slope	45 mph: 20-28 ft at 1:4 55 mph: 22-32 ft at 1:4	1:6 in clear zone 1:3 to toe of slope	1:4 or Flatter 1:2 with Protection
Cut Slope	45 mph: 14-22 ft at 1:3 55 mph: 16-24 ft at 1:3	1:3	45 mph: 14-22 ft at 1:3 55 mph: 16-24 ft at 1:3
Bike/Ped Facility	n/a	Consider case-by-case	Consider case-by-case

* Common Geometric Practice

Table 1: Cross-Sectional Requirements by Agency

2.1.1. NUMBER OF LANES

The projected traffic volume for the 2040 design year (6,200 vehicles per day) warrants a two lane bridge. According to the 2010 *Highway Capacity Manual*, the capacity of a two lane highway under base conditions is 3,200 passenger cars per hour with two way traffic. Because anticipated future traffic volumes fall well below this threshold, a two lane structure is recommended.

2.1.2. LANE AND SHOULDER WIDTHS

In accordance with AASHTO's *Green Book* (Table 7-3), the minimum width of traveled way for a 45-55 mph design speed is 24 feet for rural arterial traffic volumes over 2,000 vehicles per day. The corresponding usable shoulder width for rural arterials is 8 feet.

The "Common Geometric Practices" (Exhibit 700-003) in the *Highway Design Manual* recommends a minimum graded shoulder width of 8 feet for rural arterial roads with more than 2,000 Average Daily Traffic (ADT).

The IDOT *BDE Manual* requires a minimum 24-foot wide travel width and 10-foot paved shoulders for all new construction or major reconstruction of two lane principal arterials. The manual further indicates that a 24-foot travel width and 8-foot shoulder (minimum of 3-foot paved) is required for 3R projects.

AASHTO's *Green Book* also indicates that long bridges, defined as bridges having an overall length in excess of 200 feet, should provide an offset to parapet, rail, or barrier of at least 4 feet measured from the traveled way on both sides of the roadway for a rural arterial. For existing bridges to remain in place, the width should match that of the traveled way plus 2-foot clearance on either side.

Per the "Common Geometric Practices" (Exhibit 700-003) in the KYTC *Highway Design Manual*, the minimum clear roadway width of new and reconstructed bridges should equal the approach roadway width. KYTC *Structural Design Guidance Manual* (section SD-302) also indicates that the bridge width between gutters should generally be matched to the approach roadway width between faces of guardrail. Per KYTC's design manual (section HD-702), the minimum bridge width on a two lane bidirectional roadway is 22 feet.

IDOT requires 44 feet of clear roadway width (measured from face to face of parapet/rails) for new or reconstructed bridges and 38-40 feet for existing bridges that will remain in place. Typically, bridge widths equate to the traveled way width plus the width of paved shoulders.

2.1.3. CROSS SLOPE

The AASHTO *Green Book* states that cross slopes for rural two lane roadways are normally between 1.5 and 2.0 percent; no requirements are identified.

Common practice (KYTC Manual Exhibit 700-03) identifies 2.0 percent as normal.

IDOT's BDE design policies require a minimum cross slope of 1.56 percent (3/16-inch per foot) for the traveled way and 4.17 percent (1/2-inch per foot) for shoulders for rural two lane principal arterials (Figure 47-2.J).

2.1.4. SIDE SLOPES, CLEAR ZONES, AND GUARDRAIL

The clear zone of a roadway is the area outside the edge of the travel lane, including the shoulder that is free of obstructions and used for vehicle recovery. Guidelines for clear zone widths are provided in the AASHTO *Roadside Design Guide.*

Based on the AASHTO *Roadside Design Guide,* a foreslope of 1V:4H or flatter is considered recoverable and foreslopes between 1V:3H and 1V:4H are considered traversable but non-recoverable. AASHTO (*Roadside Design Guide* Table 3-1) further indicates that the clear zone range is 22-32 feet for recoverable embankment slopes (1V:4H or flatter) on a roadway with a design speed of 55 mph and ADT greater than 6,000 vehicles. For a 45 mph design speed, this distance drops to 20-28 feet. For conditions with foreslopes steeper than 1V:4H, AASHTO indicates that obstructions should not be present within the limits of the toes of these slopes. Guardrail placement may be required if this condition cannot be met.

For fill sections, the IDOT *BDE Manual* recommends 1V:6H side slopes within the clear zone for rural two lane principal arterials, increasing to 1V:3H maximum to the toe of slope. For fill heights greater than 30 feet, a 1V:2H uniform slope with a barrier is recommended.

KYTC follows recommendations within the AASHTO *Roadside Design Guide*: side slopes in fill sections of 1V:4H or 1V:2H with guardrail.

For a roadway in an excavation section, the clear zone for backslopes of 1V:3H or flatter varies from 16-24 feet for a 55 mph design speed and 14-22 feet for a 45 mph design speed based on the AASHTO *Roadside Design Guide*. IDOT recommends a maximum cut slope of 1V:3H, increasing to 1V:2H beyond the clear zone if the height exceeds 10 feet. KYTC follows recommendations within the AASHTO *Roadside Design Guide.*

Chapter 5 of the AASHTO *Roadside Design Guide* addresses the application and situation of guardrail placement. Guardrail warrants are based on a subjective analysis of roadside conditions. Warrants may also be established by using a benefit-to-cost analysis where factors such as design speed and traffic volumes are evaluated in relation to barrier need.

2.1.5. PEDESTRIAN AND BICYCLE FACILITIES

No sidewalk or accommodations for pedestrians and bicyclists are present on the existing US 51 Bridge or on either of the approaches. The *IDOT BDE Manual* and the *KYTC Pedestrian & Bicycle Policy* require that the addition of a pedestrian and/or bicycle facility should be considered on a case-by-case basis. The inclusion of bicycle and pedestrian facilities should be further evaluated during future phases for project development.

2.2. ALTERNATIVE OPTIONS

A range of three alternative typical section options have been considered by the Project Team. Evaluating a range of options will provide flexibility for designers to address budgetary constraints, engineering constraints, and environmental considerations. Three cross-sectional options are presented below:

1. Practical Solutions Typical Section - A typical section with these dimensions is considered the minimum typical section that should be considered based on the AASHTO Minimum and other similar size projects such as the Ironton-Russell Ohio River Bridge between Parkersburg, West Virginia and Cincinnati, Ohio. Some design exceptions would be required.
2. Common Practices Typical Section - This typical section show common practices used in Kentucky and provides a full shoulder for disabled vehicles or maintenance vehicles to pull off the road. Some design exceptions could be required.
3. Desirable Typical Section - This typical section has been derived to meet criteria presented in AASHTO, KYTC, and IDOT guidelines. No design exceptions would be involved with this typical section.

These typical sections are detailed in **Figure 2** for both the roadway and bridge. All typical sections that are being considered include two 12-foot driving lanes with a 2.0 percent cross slope and shoulders. These typical sections would apply to all alternatives except the Rehabilitation Alternative. Shoulder widths for the roadway range from 6 feet (4-foot paved) to 12 feet (10-foot paved).

Figure 2 also illustrates the range in curb-to-curb bridge widths. Bridge widths vary from 32 feet to 44 feet. The range in bridge widths vary based on the approach widths for the driving lanes and paved shoulders.

Evaluating a range of roadway and bridge widths will allow the project team to evaluate impacts and costs associated with the roadway and bridge footprint impact on possible environmental concerns in the next phase of work (e.g., endangered/protected species or habitat, wetland impacts, and floodplain).

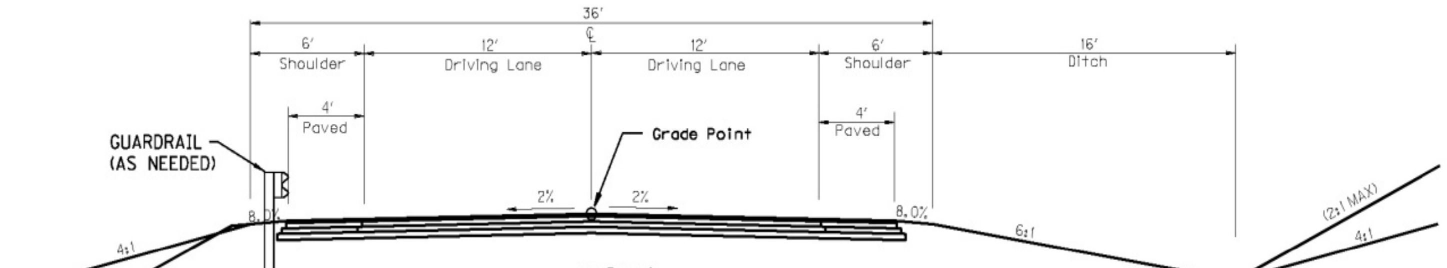
Two ongoing Ohio River Bridge replacement projects are constructing river crossings with similar cross-sections.

- The US 421 Milton-Madison Bridge includes a reconstructed superstructure over the Ohio River between Indiana and Kentucky with a total width of 40 feet.
- A new cable stay bridge between Russell, Kentucky and Ironton, Ohio is under construction with a total width of 32 feet.

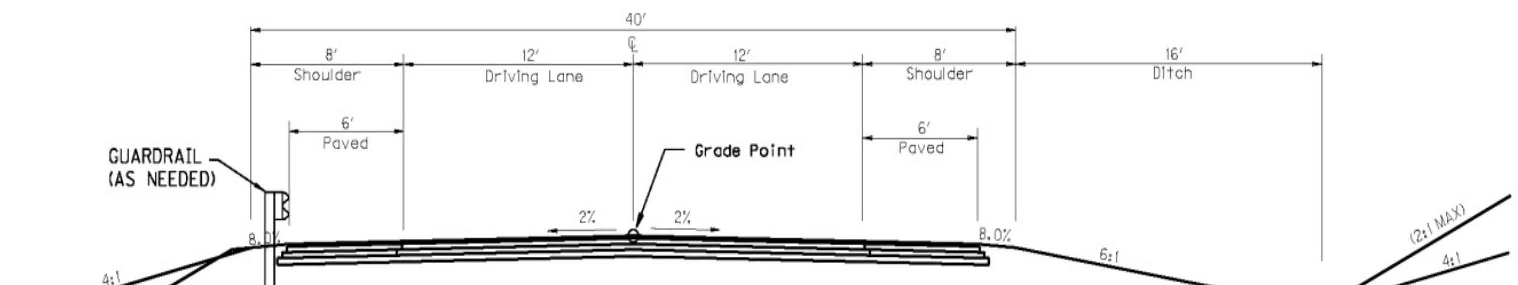
In 1992, a portion of US 51 was reconstructed approximately one-half mile south of the US 51 Ohio River Bridge (Kentucky milepoints 6.6 to 6.8). This project included upgrading the typical section to two 12-foot lanes with a 10-foot paved shoulder and a 2-foot unpaved shoulder. This improvement project corresponds to the Desirable Typical Section option shown in **Figure 2**.

For the Rehabilitation Alternative, the total width from back-of-curb to back-of-curb will remain at approximately 24 feet.

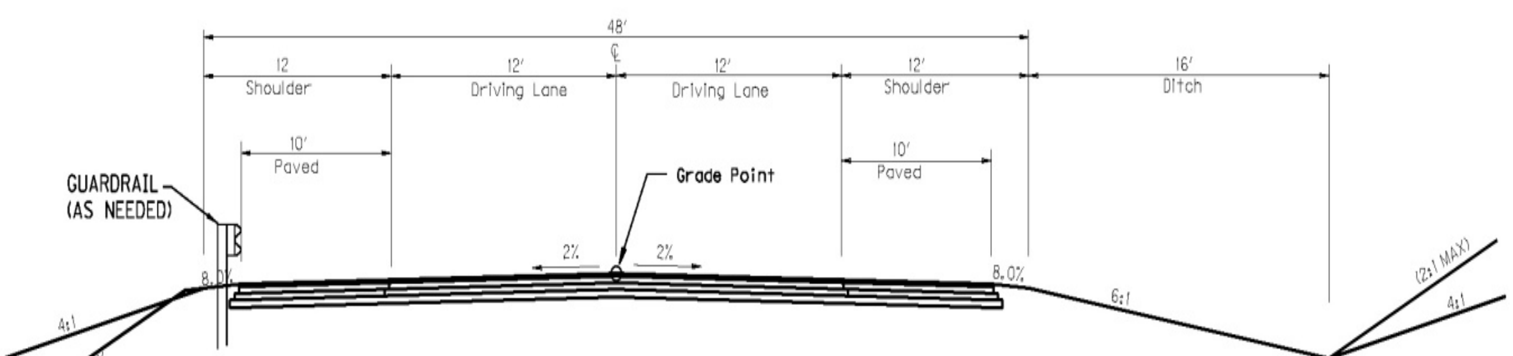
Roadway Typical Sections



US 51
PRACTICAL SOLUTIONS TYPICAL SECTION

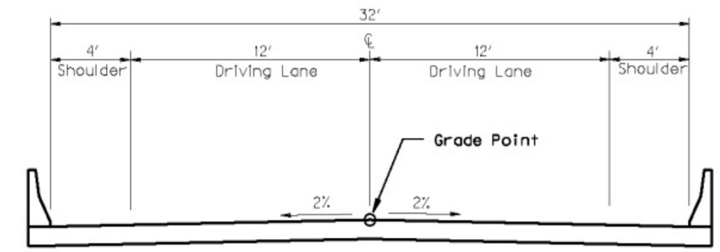


US 51
COMMON PRACTICES TYPICAL SECTION



US 51
DESIRABLE TYPICAL SECTION

Bridge Typical Sections



US 51
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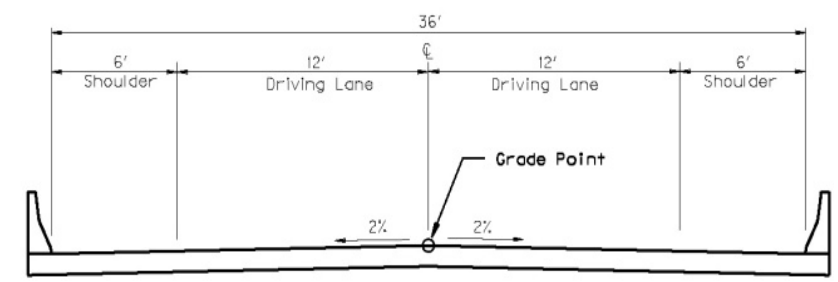
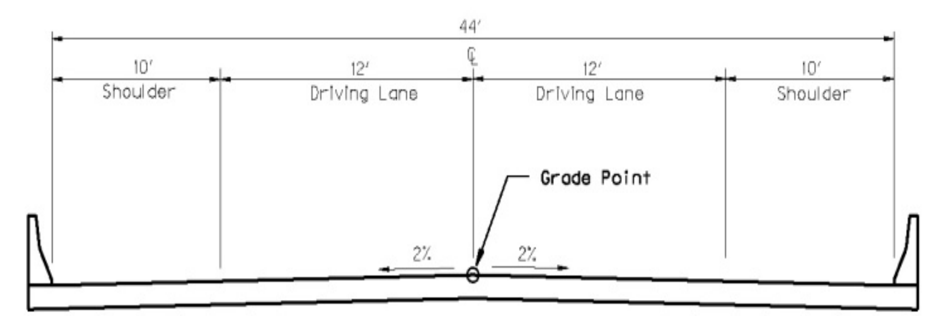


US 51
COMMON PRACTICES TYPICAL SECTION



US 51
DESIRABLE TYPICAL SECTION

Figure 2: Range of Typical Sections – Roadway and Bridge

3. HORIZONTAL ALIGNMENTS

3.1. GUIDANCE REQUIREMENTS

Proposed horizontal alignment guidance is based on the superelevation rate in horizontal curves. According to AASHTO's *Green Book*, the maximum superelevation rate used should be a function of climate, terrain conditions, characteristics of the area, and frequency of slow-moving vehicles. Given the relatively high volume of truck traffic (greater than 30 percent), a maximum superelevation rate of 6 percent is recommended. For a 6 percent maximum superelevation rate and a design speed of 45 mph, the minimum radius is 643 feet according to AASHTO. For 55 mph design speed, this increases to 1,060 feet.

KYTC Common Practices identify a minimum radius of 660 feet for a horizontal curvature for a 45 mph design speed and 6 percent superelevation. For a 55 mph design speed, this increases to 1,065 feet.

IDOT's *BDE Manual* (Figure 32-2E) establishes a 665-foot minimum radius for a 45 mph design speed and 6 percent superelevation rate. For a 55 mph design speed, this increases to 1,065 feet.

3.2. ALTERNATIVE OPTIONS

Where feasible, new location build alternatives would be designed to satisfy the 55 mph design standards described above. At a minimum, the 45 mph design standards should be followed. Buffers along each new location build alternative (shown in **Figure 1**) provide flexibility for horizontal alignments in future design stages. Alternative 1 (Superstructure Replacement) would also be designed to satisfy the 45-55 mph design standards described above.

For the Rehabilitation Alternative, the approach would not be realigned to meet the horizontal alignment design criteria above. Specifically, the horizontal curve on the Kentucky approach would retain its 465-foot radius and 20 mph posted speed.

4. VERTICAL ALIGNMENTS

4.1. GUIDANCE REQUIREMENTS

The following subsections describe design standards established by FHWA, IDOT, and KYTC for various vertical alignment elements: vertical grades, stopping sight distance, and navigational clearances. Section 4.2 contains typical section recommendations.

4.1.1. VERTICAL GRADE

AASHTO (*Green Book* Table 7-2) establishes a maximum grade for rural arterials of 5 percent for rolling terrain and 4 percent for level terrain, based on a 55 mph design speed. KYTC Common Practice (Exhibit 700-03) identifies the maximum allowable grade for rolling terrain as 6 percent and the maximum allowable grade for level terrain as 5 percent at a 55 mph design speed. IDOT (Figure 47-2M) establishes a maximum grade of 4 percent for rolling terrain and 3 percent for level terrain for a 60 mph design speed on rural two lane highways.

For a proposed roadway typical section with curb, the AASHTO *Green Book* and KYTC Manual reference a 0.5 percent minimum grade but will allow a 0.3 percent grade with a satisfactorily crowned pavement in order to provide adequate drainage. The *IDOT BDE Manual* (Section 33-2.03) references that new bridges provide a minimum longitudinal gradient of 0.5 percent across the bridge.

4.1.2. STOPPING SIGHT DISTANCE

Stopping sight distance is the distance that a driver can see while traveling in a typical vehicle and still maintaining the ability to stop within that distance. The design of vertical curves is critical to stopping sight distance. Design speed, length of vehicle light beam distance, and approach and departing grades determine the required length of crest and sag vertical curves.

In accordance with AASHTO's *Green Book*, the minimum stopping sight distance is 360 ft for a 45 mph design speed and 495 ft for a 55 mph design speed on a rural arterial. KYTC and IDOT cite these same values.

4.1.3. VERTICAL CLEARANCE FOR NAVIGATIONAL CHANNEL

The vertical clearance from the water surface of the Ohio River to the minimum low steel elevation has been coordinated with the US Coast Guard Bridge Division to meet the navigation needs of the river. Correspondence provided by the US Coast Guard indicated that all new build alternatives presented shall provide for a vertical clearance of at least 105.3 feet above zero on the Cairo gauge at the piers of the primary navigation channel and at least 113 feet above zero on the Cairo gauge for the mid portion of the primary navigation channel. Additional information regarding river hydraulics is summarized in a separate document.

4.1.4. VERTICAL CLEARANCE OVER RAILROAD

An existing railroad runs parallel to the current location of US 51 in Kentucky and crosses over the railroad in the approach spans for the US 51 Ohio River Bridge. Specific vertical clearance requirements will be coordinated with the owner of the railroad during the next phase of the project, but approximately 23 feet of vertical clearance from the railroad bed to the minimum low steel elevation is expected.

4.2. ALTERNATIVE OPTIONS

For all alternatives except the Rehabilitation Alternative, a maximum vertical grade of 5.0 percent would be used. However, the goal of the project team is to develop vertical grades that do not exceed 3.0 percent.

The existing US 51 Ohio River Bridge has a 5.0 percent vertical grade for the Illinois approach. Thus, meeting the 3 percent maximum grade for the Superstructure Replacement option (Alternative 1) may not be feasible.

A minimum vertical grade of 0.5 percent would be used on the bridge and approach bridges. Because of the level terrain in the area, a minimum grade of 0.3 percent vertical grade is proposed for the roadway approaches and extensions. The roadway approaches and extensions would have a 2.0 percent cross slope to provide for adequate drainage. The stopping sight distances would be met for the vertical curves in all options except the Rehabilitation Alternative.

Alternative 1 and Combined Alternative 2 must cross the existing railroad in Kentucky while Alternatives 3A and 4 run parallel to the existing railroad but do not cross it. The Superstructure Replacement (Alternative 1) and Combined Alternative 2 would maintain a minimum of approximately 23 feet of vertical clearance from the railroad bed to the minimum low steel elevation on the approach bridge unless otherwise coordinated with the owner of the railroad. The Rehabilitation Alternative will maintain the existing vertical clearance over the railroad bed, which is approximately 30 feet.

The Rehabilitation Alternative will maintain the existing vertical alignment, so no improvements would be made to the vertical grade or curves. As previously noted, the existing US 51 Ohio River Bridge has a 5.0 percent vertical grade coming from the Illinois approach. The vertical sag curve from the Illinois approach to the section of the bridge is a 5.0 percent grade (in Span 2 and 3) and does not meet the criteria for stopping sight distance (headlight beam controls for a 40 mph design speed).

5. SPAN ARRANGEMENT FOR RIVER BRIDGE AND APPROACH SPANS

5.1. GUIDANCE REQUIREMENTS

5.1.1. BRIDGE HORIZONTAL CLEARANCE

The Project Team has coordinated with the US Coast Guard Bridge Branch and has obtained the following comments in regard to proposed Alternatives:

- Alternative 1 (Superstructure Replacement) – "*Reducing the Illinois and center navigational channels each by 30 feet is not conducive to the overall flow of navigation through a smaller horizontal navigational opening with the existing piers in place. This alternative is not recommended.*" Follow-up discussions with the US Coast Guard indicated that this alternative would not be preferred and is not recommended by the USCG, but it is not specifically disallowed. The Project Team will evaluate potential solutions to reduce the impacts to navigation associated with this alternative. The 30-foot channel reductions are associated with the pier strengthening that would be required with this alternative.
- Alternatives 2, 2A, and 2B – "*No navigational issues. Proposed pier in the water acts like a protection for fleeting on the Illinois bank. This alternative would satisfy the reasonable needs of navigation and is recommended for further development.*"
- Alternatives 3 and 3A – "*These alternatives are recommended based on proposed pier alignments; however, a 1,200-foot horizontal navigation is recommended versus a 1,000-foot.*" In follow-up discussions, it was discussed that the right descending pier for this alternative should align with the pier on the right descending bank for the railroad bridge. A 1,200-foot clearance into the river is then required.
- Alternatives 4 and 5 – "*The middle pier on Alternative 5 needs to be shifted toward the left descending bank approximately 200 feet, and the horizontal clearance needs to be increased to 1,000 feet versus 900 feet. Both alternative locations are in a less congestive area, and each would satisfy the reasonable needs of navigation; both are recommended for further development.*"

5.1.2. PIER PROTECTION IN VICINITY OF RAILROAD

The American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering* indicates that in order to limit damage by the redirection or deflection of railroad equipment, piers supporting bridges over railways with a clear distance of 25 feet or less from the centerline of a railroad track shall be of heavy construction or shall be protected by a crash wall. Crash walls for piers from 12 to 25 feet clear from the centerline of the track shall have a minimum height of six feet above the top of rail. Piers less than 12 feet clear from the centerline of the track shall have a minimum crash wall height of 12 feet above the top of rail.

5.2. ALTERNATIVE OPTIONS

The horizontal clearances for the US 51 Ohio River Bridge would be implemented as outlined in Section 5.1.1, unless otherwise directed by the US Coast Guard. For Superstructure Replacement (Alternative 1) and Combined Alternative 2, the guidelines for pier protection near railways would be followed as described in Section 5.1.2. The pier location for the Rehabilitation Alternative would not be altered from the existing conditions.

6. MAINTENANCE OF TRAFFIC

For the No-Build Alternative, maintenance of traffic to perform routine upkeep of the bridge would be required. The following schedule is estimated for the existing remaining bridge life from 2015 to 2030:

- Single-Lane Closure — 2 weeks / year (30.0 weeks)
- Full Closure for Emergency Repairs — 1 week / 2 year (7.5 weeks)
- Posted to Truck Traffic — 2020
- Closed to Truck Traffic — 2025
- Closed to All Traffic — 2030

For the Rehabilitation Alternative, rehabilitation is anticipated to take 12 months to complete. Work on the structure would be intermittent and may be limited during the winter months. The following schedule is estimated for the remaining bridge life for the rehabilitated structure from 2020 to 2045:

- Single-Lane Closure During Rehab — 52 weeks
- Single-Lane Closure (2020-2045) — 10 weeks (miscellaneous maintenance)
- Closed to All Traffic — 2045

For Superstructure Replacement (Alternative 1), construction is anticipated to take 12 to 18 months. Complete closure of the bridge is anticipated for the entire time period. Traffic would have to be detoured to the nearest alternative upstream river crossing at the I-24 Ohio River Bridge in Paducah, Kentucky or the nearest alternative downstream crossings at the Dorena-Hickman Ferry or the I-155 Mississippi River Bridge between Dyersburg, Tennessee and Caruthersville, Missouri. These detours would add approximately two hours of travel time to the trip from Cairo, Illinois to Wickliffe, Kentucky.

The existing US 51 Ohio River Bridge would be used for maintenance of traffic for Alternatives Combined 2, 3A, or 4. Temporary bypass lanes would be needed at the Illinois termini for connection to the existing roadway. Traffic should not be significantly impacted during construction for Alternatives Combined 2, 3A, and 4. It is anticipated that bridge construction would take 12 to 18 months. Work on the structure would be intermittent and may be limited during the winter months.

7. PRELIMINARY COST ESTIMATES

Table 2 illustrates anticipated costs for NEPA/Design, Right-of-Way Acquisition, Utility Relocation, and Construction for the range of typical sections illustrated in **Figure 2**. Assumptions used in developing cost estimates are noted below the table.

US 51 Ohio River Bridge - Planning Level Cost Estimates					
Alternate	**NEPA/DESIGN²**	**CONSTRUCTION**	**RIGHT OF WAY**	**UTLITIES**	**TOTAL**
Alternate 1 (Rehab) *(does not include seismic rehabilitation costs)*	$3,000,000	$50,000,000	$0	$0	$60,000,000
DESIRABLE (44 ft clear roadway width on bridge including 10 foot shoulders)	**NEPA/DESIGN²**	**CONSTRUCTION¹**	**RIGHT OF WAY**	**UTLITIES**	**TOTAL**
Alternate 1 (New Superstructure)	$26,400,000	$220,000,000	$200,000	$100,000	$250,000,000
Alternate 2	$24,000,000	$200,000,000	$600,000	$100,000	$230,000,000
Alternate 2A	$25,200,000	$210,000,000	$900,000	$100,000	$240,000,000
Alternate 2B	$25,200,000	$210,000,000	$800,000	$100,000	$240,000,000
Alternate 3A	$48,000,000	$400,000,000	$6,100,000	$300,000	$460,000,000
Alternate 4	$39,600,000	$330,000,000	$4,500,000	$400,000	$380,000,000
COMMON PRACTICE CRITERIA (36 ft clear roadway width on bridge including 6 foot shoulders)	**NEPA/DESIGN²**	**CONSTRUCTION¹**	**RIGHT OF WAY**	**UTLITIES**	**TOTAL**
Alternate 1 (New Superstructure)	$25,200,000	$210,000,000	$200,000	$100,000	$240,000,000
Alternate 2	$22,800,000	$190,000,000	$600,000	$100,000	$220,000,000
Alternate 2A	$23,880,000	$199,000,000	$900,000	$100,000	$230,000,000
Alternate 2B	$24,000,000	$200,000,000	$800,000	$100,000	$230,000,000
Alternate 3A	$44,400,000	$370,000,000	$6,100,000	$300,000	$430,000,000
Alternate 4	$36,000,000	$300,000,000	$4,500,000	$400,000	$350,000,000
PRACTICAL SOLUTIONS (32 ft clear roadway including on bridge with 4 foot shoulders)	**NEPA/DESIGN²**	**CONSTRUCTION¹**	**RIGHT OF WAY**	**UTLITIES**	**TOTAL**
Alternate 1 (New Superstructure)	$25,200,000	$210,000,000	$200,000	$100,000	$240,000,000
Alternate 2	$21,600,000	$180,000,000	$600,000	$100,000	$210,000,000
Alternate 2A	$22,800,000	$190,000,000	$900,000	$100,000	$220,000,000
Alternate 2B	$22,800,000	$190,000,000	$800,000	$100,000	$220,000,000
Alternate 3A	$42,000,000	$350,000,000	$6,100,000	$300,000	$400,000,000
Alternate 4	$34,800,000	$290,000,000	$4,500,000	$400,000	$330,000,000
¹ Construction Costs include a 25% Contingency.					
² Design Cost Assumptions					
Alternate 1 (Rehab) = 5% of Construction Cost (40% Phase 1, 60% Phase 2) + NEPA (1% of Construction Cost)					
Other Alternates = 10% of Construction Cost (40% Phase 1, 60% Phase 2) + NEPA (2% of Construction Cost)					

Table 2: Preliminary Cost Estimates

Table 3 summarizes the total cost for preliminary cost estimates illustrated in **Table 2**. It can be seen from **Table 3** that the Combined Alternative 2 (Alternative 2, 2A, and 2B) is expected to have the least cost overall with the exception of the Rehabilitation Alternative. However, the Rehabilitation Alternative has a shorter life expectancy (25 years versus 75 years or greater) and also is not anticipated to meet the same level of seismic design as the other alternatives.

Alternate	Total Cost (All Phases)		
	Low	Medium	High
Alternate 1 (Rehab)	$60,000,000		
Alternate 1 (New Superstructure)	$240,000,000	$240,000,000	$250,000,000
Alternate 2	$210,000,000	$220,000,000	$230,000,000
Alternate 2A	$220,000,000	$230,000,000	$240,000,000
Alternate 2B	$220,000,000	$230,000,000	$240,000,000
Alternate 3A	$400,000,000	$430,000,000	$460,000,000
Alternate 4	$330,000,000	$350,000,000	$380,000,000

Table 3: Range of Total Cost (All Phases)

8. PRELIMINARY RIGHT-OF-WAY

For preliminary right-of-way estimates, a 150-foot corridor was assumed along each proposed alternative. In areas where the proposed alternatives include an existing road (requiring only widening and minor improvements), an additional 25 feet of right-of-way on each side was assumed to be required for construction. Estimated areas for right-of-way also were inflated by 10 percent to account for potential variations in side slopes that may be required for seismic conditions.

9. UTILITIES

Preliminary utility locations were obtained by the Project Team in the vicinity of the alignment alternatives as shown in **Figure 3**. No known utilities are on the Kentucky side in the vicinity of the existing US 51 Bridge. No other utility information was available in Kentucky. No known utilities besides electric used for lighting on the bridge are located on the existing US 51 Bridge itself.

Several known utility lines exist in the vicinity of Alternative 1 and Combined Alternative 2 on the Illinois side, including a waterline to the north of US 51, as well as gas, underground telephone, sanitary sewer, and overhead electric lines to the south of US 51. In the vicinity of Alternatives 3A and 4 on the Illinois side, the known utilities include overhead electric lines and water to the east and overhead electric lines, water, gas, and underground telephone to the west. Coordination on impacts and possible relocations will be necessary during the next phase of the project. The information collected may not be complete and a more detailed investigation will be required in future phases of the project.

Figure 3. Preliminary Utility Locations

10. CONCLUSIONS

Information presented in this document summarizes engineering considerations associated with evaluation of the existing conditions and development of proposed alternative concepts that can be advanced to the next phase of design. Information has been presented describing a range of typical sections that will be further evaluated during the next phase of design. A series of key issues that will be carried into the next phase of design includes:

- Combined Alternative 2 is recommended to advance for future project development phases.
- A range of cross-section options are recommended which include two 12-foot lanes, 4-10 foot wide paved shoulders, and a 2.0 percent cross slope.
- The minimum proposed design speed is 45 mph, with a 55 mph design speed preferred where practical.
- The proposed maximum superelevation rate is 6 percent.
- The proposed maximum vertical grade is 5 percent; a maximum of 3 percent is preferred where practical.
- For all new build alternatives a vertical clearance of at least 105.3 feet above zero on the Cairo gauge is recommended at the piers of the primary navigation channel and at least 113 feet above zero on the Cairo gauge is recommended for the mid portion of the primary navigation channel.
- A 900-foot wide navigational channel is recommended.
- No significant right-of-way and utility issues were identified during this phase of study.