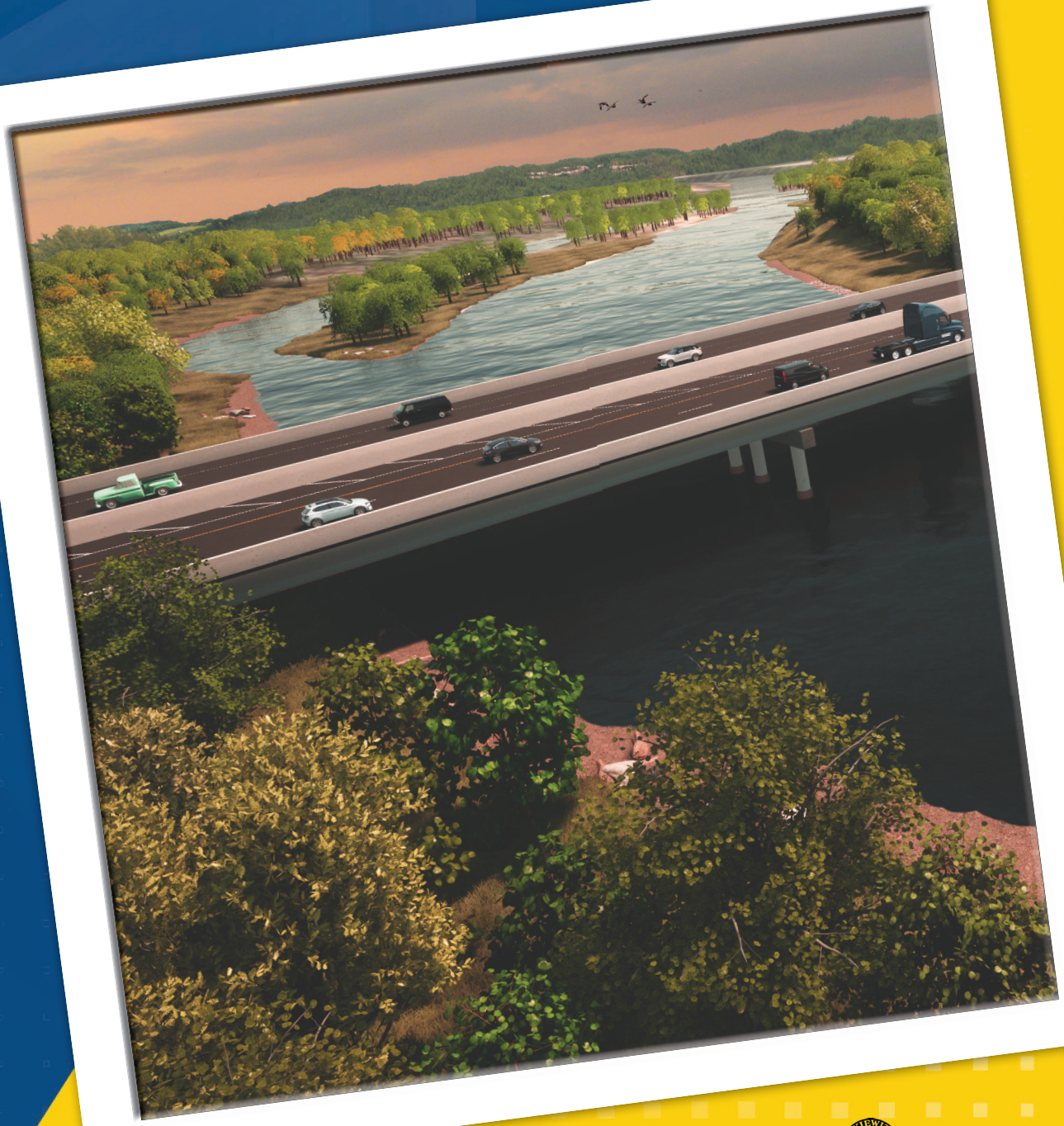
Design-Build Project

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations, Kershaw County

TECHNICAL PROPOSAL

Contract ID 2847360



TECHNICAL PROPOSAL NARRATIVE

WHY KIEWIT?

Exhibit 1: The Kiewit Team's single, six-lane bridge concept provides SCDOT a best value solution.

The integrated team of Kiewit Infrastructure South Co. (KISC)/Kiewit Engineering Group, Inc. (KEGI) (the Kiewit Team) is eager to work on the I-20 Over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build Project (the Project) to meet South Carolina Department of Transportation's (SCDOT) goals. The Kiewit Team has developed a single, **six-lane bridge concept** to provide SCDOT **added value for future I-20 widening and traffic control during construction** (**Exhibit 1**). This single bridge concept reduces the bridge reconstruction by five months vs. the dual bridge concept. Other benefits of our approach, including accepted Alternative Technical Concepts (ATC), are described throughout this narrative. ATCs and their benefits are identified with icons. A complete list of the seven accepted and incorporated ATCs is provided in *Section 2*.

OVERVIEW OF HOW WE WILL ACHIEVE SCDOT'S PROJECT GOALS

Complete the project on original contract schedule

Our schedule achieves substantial completion in 1,552 calendar days, 182 calendar days ahead of the RFP requirement.

Reduction of impacts to the traveling public

ATC 4 *Alternate Construction Access and* **ATC 5** *Work Zone Access Using Inside-Outside Shoulder* reduce lane closures and impacts to the traveling public while improving safety. Further methods to achieve this goal are described in our construction sequencing and traffic control plans later in this section.

Use quality construction methods to produce durable structures with enhanced service life

ATC 2 *ChromX Reinforcing Bar* provides an increased service life of up to 100 years vs. black or galvanized rebar. In addition, Kiewit's ISO 9001:2015 Corporate Quality Management plan provides proper planning of work operations that includes pre-planning, work plans, pre-activity meetings, hold point inspections, and verification.

Minimize impacts to the environment

We have reduced in-water work using a gantry crane and a trestle with limited foundations in the water.

No changes orders/Cost certainty

Construction-focused engineers have worked with our integrated design team to provide constructability input and innovative solutions that account for field constraints and efficient sequencing. SCDOT benefits from this approach because permanent and temporary designs are performed by the same group of engineers.

1. PROJECT DELIVERY & APPROACH

1.a Proposed Schedule

Our comprehensive critical path method (CPM) schedule is provided in Appendix A.4 and includes all Request for Proposal (RFP)-required items. We have provided a realistic and achievable schedule that contains all work activities and milestones, fully integrated for both design and construction.

SCHEDULE RISK MITIGATION

Section 1.e outlines several risk mitigation strategies to avoid schedule impacts and delays associated with limited site access, traffic control, and environmental and permitting challenges. Our strategies include improved construction access, using SmartZone technologies and demolition shields to prevent materials entering the water.

Summary Schedule

Exhibit 2 shows a summary schedule with planned milestones and project phases. Our schedule finishes the **Project** 182 **days sooner** than the allowed 1,734 calendar days, and we **reach final completion within** 122 **days of substantial completion** versus the allowed 180 calendar days as specified in the RFP.

Exhibit 2: Our CPM Schedule Provides Realistic Durations for Key Milestones

		2023			2024				2025				2026				2027				2028			
Scope	Days	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Contractual Substantial Completion																					★			
Contractual Final Completion																							★	
Notice to Proceed		★																						
Design -Early MOT & Rehab	342																							
Design	395																							
Permitting	382																							
Overflow Bridges Rehabilitation Work	566																							
Create Construction Access	80																							
Phase 0 - Shoulder Rehab Work	25																							
Phase 1 - Median Section of Bridge	360																							
Phase 2 - EB Section of Bridge	396																							
Phase 3 - WB Section of Bridge	411																							
Phase 4 - Final Paving and Finishes	16																							
Kiewit Substantial Completion	1,552																			★				
Kiewit Final Completion	122																				★			

Schedule Management Process: During construction, the CPM Schedule is used to monitor progress, optimize labor and equipment resources, and identify opportunities for improvement in the field. Using time-tested scheduling tools such as the Project CPM Schedule, 90-day and three-week schedules, and a Play-of-the-Day meeting, the management team will communicate effectively and drive the project team to early completion.

Sequence of Construction

Our approach to construction sequencing and phasing begins with minimizing traffic shifts while creating the largest possible work zones, increasing construction productivity, and enhancing public safety. This philosophy places traffic in interim configurations for the longest time frames and reduces driver confusion.

Exhibit 3: This phasing sequence is based on our innovative MOT and ATC plans

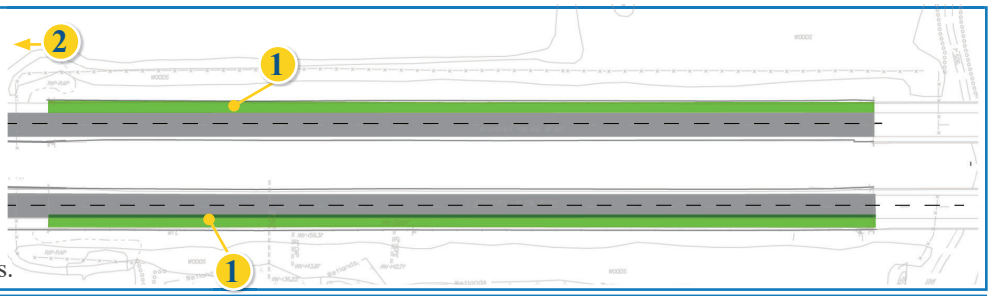
Legend Full Depth Shoulder · Previous Construction · Temporary Barrier Wall · Bridge Workzone

PHASE 0

1. Replace existing shoulders to accommodate future temporary traffic patterns.
2. Perform rehab on overflow Bridges

Solutions and Benefits

- Ensures performance of roadway during future revised traffic movements.

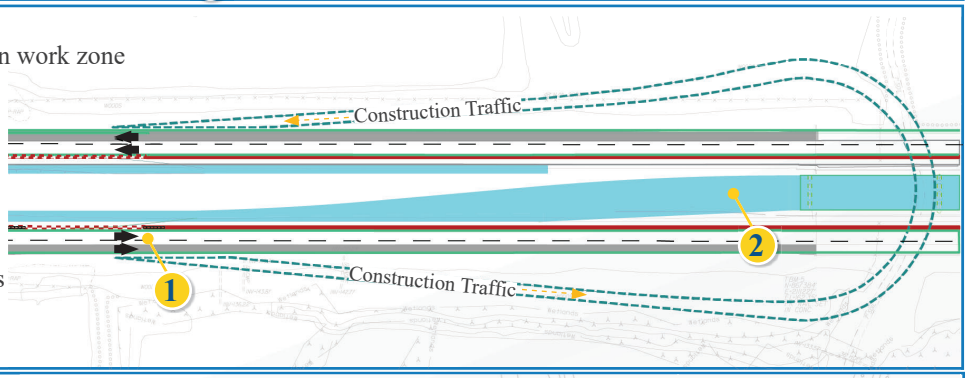


PHASE 1

1. Shift traffic to outside and establish median work zone
2. Construct the center portion of the Wateree bridge and temporary approaches

Solutions and Benefits

- Utilizing gantry system to construct center bridge allows for efficient construction operations
- Permanent bridge with capacity for 6 lanes allows for future widening and less waste of materials and resources.

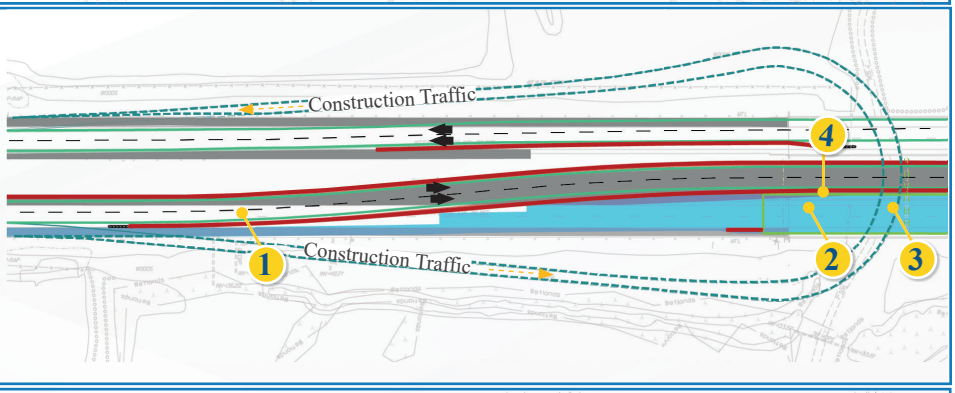


PHASE 2

1. Shift EB traffic onto newly constructed center bridge and temporary approaches
2. Demo existing EB bridge
3. Construct proposed EB bridge and associated approaches.
4. Complete closure pours and tie EB portion into center portion

Solutions and Benefits

- Constructing bridge from center to outside allows for operations efficiency

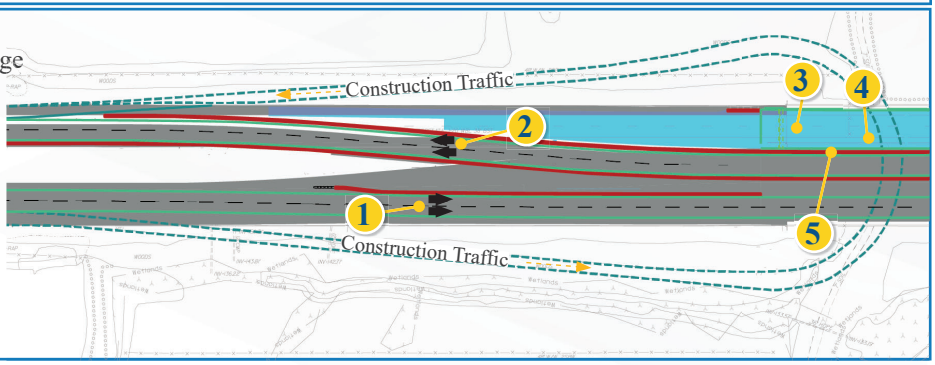


PHASE 3

1. Shift EB traffic to newly constructed EB Bridge
2. Shift WB traffic to center bridge
3. Demo existing WB bridge
4. Construct proposed WB portion of bridge
5. Complete closure pours to tie WB portion into center portion

Solutions and Benefits

- Efficiency of repetitive operations and equipment and supplies

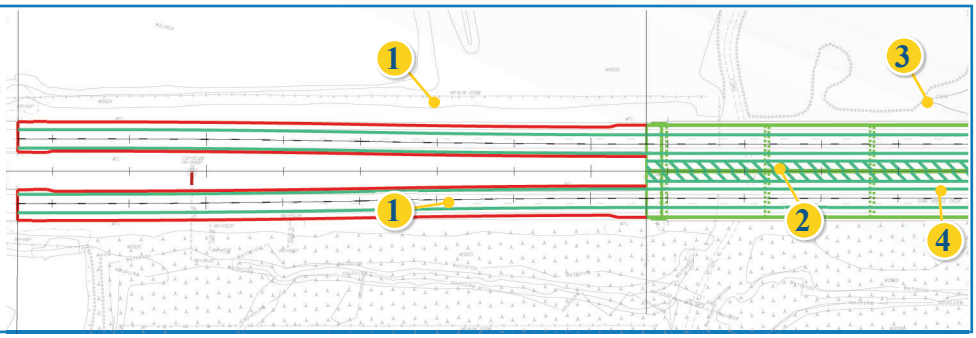


PHASE 4

1. Shift traffic to final configuration
2. Construct center median barrier on bridge
3. Final grinding and grooving on bridge
4. Complete removal of bridge access and complete site restoration

Solutions and Benefits

- Traffic is in final configuration 1,536 days after NTP



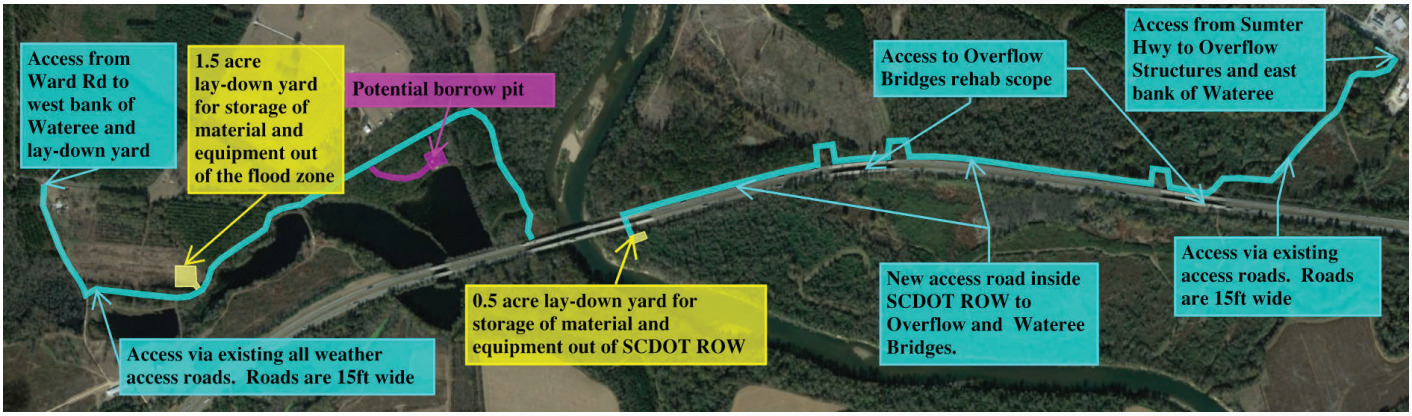
Methods to Reduce Overall Construction Schedule

During the pursuit phase, the Kiewit Team developed the following innovative solutions to reduce schedule:

Single Bridge Concept: Our single bridge concept reduces bridge reconstruction duration by five months by minimizing the number of phases and eliminates the removal of the temporary bridge at the end of the job. SCDOT receives the benefit of additional future I-20 capacity using a permanent, as opposed to a temporary, structure. This concept also reduces project risk and maintenance, and enhances schedule certainty.

Construction Access: To provide optimal construction access (which decreases schedule duration) and reduce impacts to the traveling public, our team developed an integrated access plan using **ATCs 4 and 5**, designed for all project phases. This plan enables access to our work areas outside of allowable lane closure hours and mitigates impacts to the traveling public by minimizing lane closures with dedicated construction access lanes. We have also worked with adjacent property owners to develop feasible methods to access the Project without utilizing I-20, which accomplishes the same goals. These access solutions and ATCs are listed on the Quality Credit Matrix in *Appendix B.j.*

Exhibit 4: Alternate Access Solutions



We have also planned our lay-down areas to reduce impacts from high-water events - access is designed for flooding with minimal rework required. Using the gantry crane in Phase 1 optimizes construction efficiency under tight working conditions and reduces lane closures for bridge and girder operations. Using a trestle with limited foundation in the water during Phases 1, 2, and 3 further reduces in-water work.

Working Multiple Repair Locations Concurrently With Other Scopes: During overflow bridge rehabilitation, work will be performed in multiple locations with only one lane closure. During operations that require load transfer of the existing bridge (Type 3, 4, and 5 joint repairs and bent cap retrofits), we will transfer loads on multiple spans concurrently to optimize work areas and reduce required lane closures.

ATC 6 *Elimination of End Diaphragms* reduces schedule, they can be cast using stay-in-place deck form-work and easily poured with the deck, eliminating wood-built form-work systems.

Gantry System for Bridge and Girder Operations: Using a gantry crane to optimize construction operations during Phase 1 reduces traffic and environmental impacts (**Exhibit 5**). The gantry crane system will be positioned with wheels centered over the two innermost existing girders and deck, while the remaining girders and deck accommodate through traffic. Kiewit has performed a structural analysis of the existing bridges using the provided as-builts. The results of this analysis indicate that the existing bridges have sufficient capacity to handle the described configuration.

Exhibit 5: Use of a gantry crane in Phase 1 reduces lane closures and traffic impacts and increases efficiency for bridge and girder operations in tight working conditions.

VALUE ADDED ATC 11 **ATC 11** *60-MPH & Method 2 Crossover* removes asphalt overlays on the Buck Creek and Wateree Bridges.

1.b Approach for Maintaining Traffic

SCDOT Goal – Reduction of impacts to the Traveling Public

ACHIEVING PROJECT GOALS GOAL

During the execution phase, our traffic management team will refine our traffic control design plans and develop the Traffic Management Plan. This plan supports safe and prompt project delivery while minimizing public impacts.

Team Approach to Traffic Control: Weekly Maintenance of Traffic (MOT) task force meetings with SCDOT composed of all discipline-specific design, construction, and traffic control personnel will provide an avenue for direct communication. Daily Play-of-the-Day meetings provide the opportunity to discuss upcoming construction and required traffic control operations. The Kiewit Team will communicate upcoming traffic switches and other information to SCDOT for notification to the traveling public. Our traffic management team will perform daily inspections of traffic control devices to ensure they are clean, operational, and are providing clear and concise messages to drivers. SmartZone technologies will be used to assure safety during merging of construction traffic.

VALUE ADDED ATC 4 VALUE ADDED ATC 5 **Safety of the Traveling Public:** The Kiewit Team developed an access plan that considers all scopes of work and improves on the project goals of safe access and minimal impacts to the traveling public. Our construction entrances and exits facilitate safe and efficient flow of construction traffic through acceleration and deceleration lanes as described in **ATCs 4** and **5**. Traffic phasing is detailed in *Appendix A.2* Conceptual MOT Plans.

Designing for Temporary Configurations: The Kiewit Team has analyzed each construction phase and stage as detailed in our MOT conceptual plans (*Appendix A.2*). Specific collaboration and task force meetings were held to refine the temporary design, optimize the permanent pavement sections and provide the safest possible alignment. Due to the tight horizontal constraints between the existing Buck Creek Bridges and the proposed Wateree Bridge, a standard Method 5

superelevation design was not attainable without the asphalt runoff encroaching on the newly constructed bridge. To account for this, the Kiewit Team used a Method 2 design **ATC 11** *60-MPH & Method 2 Crossover* to provide a horizontal curve radii small enough to keep the runoff clear of the permanent bridge deck yet large enough to be well below the allowable friction factor for a 60 mph design speed. The Method 2 design also reduces the overlap between the mainline and the crossover pavement, opening up much larger work areas, reducing lane closures, and providing a safer site for both the traveling public and crews. Temporary drainage features were considered and provided in the design to account for the median crossover construction. The allowable lane closures required during traffic switches and specific construction operations are optimized so multiple scopes of work can take advantage of each lane closure with advance notice to all parties. Our understanding of the Traffic Control Plan requirements and approval process will fast track any required closures and ensures input by all parties in advance of execution.

1.c Design Submittal Process

Anticipated Deliverables

The design submittal process will be broken into three submittals as noted in **Exhibit 6**, Chart of Anticipated Design Deliverables. Each package will include Preliminary, Final, and Released for Construction (RFC) submissions and include a 15 working day review by SCDOT as well as allowing a minimum 5-day staggering of package submissions.

Exhibit 6: Chart of Anticipated Design Deliverables to drive schedule certainty.

Design Package	Description
DP1 – Early MOT	Early MOT package for Phase 0 and Phase 1 access to the Wateree Bridge and access to the overflow bridges. Includes the temporary trestle structure for drilling access in the river.
DP2 – Rehabilitation Structures	Early package to begin rehabilitation of the overflow bridges to the east.
DP3 – Wateree Bridge	Design package for the Wateree Bridge. Includes the Geotechnical Report, Hydraulics Design and Report, Civil Design, and the remaining MOT Design.

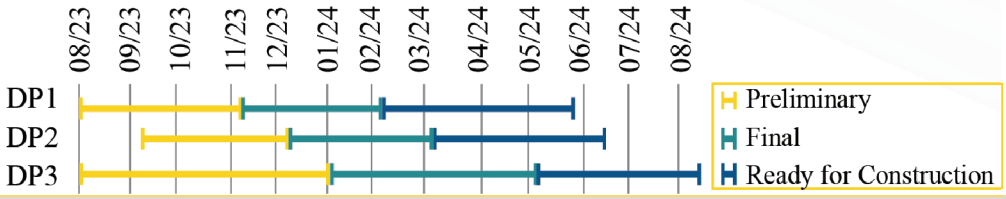
Phasing/Segmentation Addressed in Design Submittal and Review Process

Early Design and Construction Packages to Allow Work to Begin on Critical Path Items

As shown in Exhibit 7, the Early MOT and Rehabilitation Structures packages will be segmented to allow time for the permit process and for limited early work permits, so limited work can begin earlier. The Early MOT package will allow construction crews to prepare the Wateree Bridge site access in anticipation of the foundations and substructure work for the center portion of the bridge in Phase 1. Once the package is approved, initial shoulder work and construction of the crossovers can begin. Full clearing of the site, including between the two existing bridges, can commence and, upon approval of in-water access, installation of the initial center trestle can begin.

The Rehabilitation Structures package allows Kiewit to start rehabilitating two of the four overflow bridges to the east of the

Exhibit 7: MOT and Rehabilitation Structures packages



main bridge. Work on the remaining two structures will not begin until approval to the wetlands areas is granted. The full Wateree Bridge package follows these two packages, to include all remaining work needed to complete the Project. Acceptance of these two early packages reduces the overall schedule and allows Kiewit to efficiently work while the remainder of the design is completed.

1.d Approach to Quality Control and Understanding of Quality Assurance Program

SCDOT Goal: Use Quality Construction Methods to Produce Durable Structures with Enhanced Service Life

Kiewit's Corporate-wide Quality Management System (QMS) addresses processes used successfully on previous projects that focus on consistent communication, accountability, measured results, and continuous improvements to meet the project goals, comply with contract requirements, and use materials to meet or exceed those requirements and specifications.

Design Quality Control Plan (DQCP)

The Kiewit Team will provide SCDOT with a DQCP that details the quality control process that Kiewit will follow to ensure a design is produced in accordance with the RFP. The DQCP will make sure that SCDOT receives a product that meets quality and durability requirements and that the Project serves its intended purpose. The DQCP will outline comprehensive procedures for design checking, documentation, and submittal processes for all design drawings, calculations, and specifications prior to being provided to SCDOT for review and approval.

As shown in **Exhibit 8**, the design team will follow our proven approach to Quality to ensure that all parties have a chance to review, comment and agree on the final design.

Exhibit 8: Design Quality Approach

01 Design Self-Check
Each engineer internally checks their own work against a predetermined checklist of items

02 Technical Risk Assessment
An independent team of Subject Matter Experts performs a critical eye review of the plans to ensure previously identified risks are rectified and no new risks are identified

03 Quality Control
An independent engineer, a PE or identified qualified reviewer, reviews the design calculations, plans and reports for correctness and quality

04 Quality Assurance
Review by the Quality Team to ensure conformance to the quality processes.

05 Interdisciplinary Review/ Constructability Review
A review by the discipline leads and the construction team will provide a critical eye to conflicts and constructability of the designs.

Construction Quality Control Plan (CQCP)

Our CQCP will ensure compliance with contract documents, applicable regulatory requirements, and SCDOT standards. Our CQCP will define the project processes for quality and be supported by detailed procedures.

The project executive committee will assign a dedicated Construction Quality Manager (CQM), to be approved by SCDOT, with sole responsibilities to quality management and the implementation of the CQCP. Under the direction of the CQM, we will staff our quality control team with an adequate number of SCDOT personnel for quality management,

inspections and third-party testing. Our team's quality management staff will be functionally independent from production and will report directly to the Executive Committee.

To build quality into the Project, we will employ a four-step work-planning process (**Exhibit 10**).

Corrective action procedures are the outcome of a causal analysis investigation and are appropriate to the significance of the non-conformity. Records will be continuously available for SCDOT to review. Using a four-square matrix, we will monitor our performance against these objectives and guiding principles requiring continual improvement (**Exhibit 9**). The matrix identifies areas that exceed quality requirements and those needing improvement. By comparing the two, we can turn unacceptable trends into superior results. We will examine this matrix and will assess performance metrics at regular quality assurance meetings with SCDOT.

Exhibit 9: Four-Square Matrix

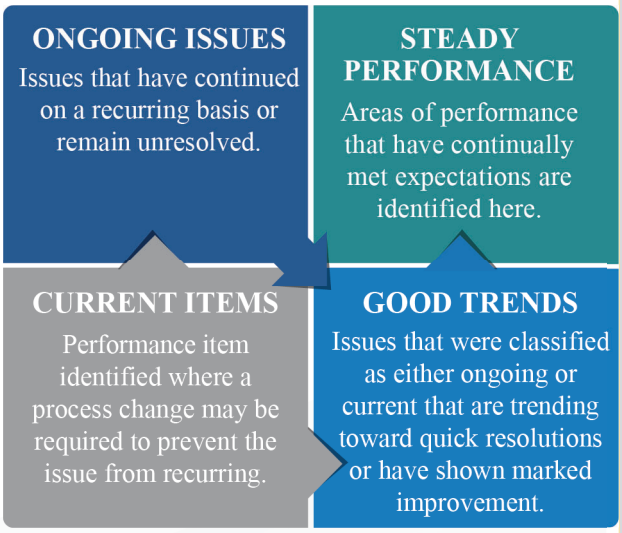


Exhibit 10: Four-step work-planning process

Coordination of Design Quality Assurance and Construction Quality Control

Effective communication between the project team and SCDOT Quality Assurance will keep the schedule on track and enhance quality management from this RFP phase through completion. Through regular communications with SCDOT Quality Assurance, we will address project quality performance and provide opportunities for SCDOT Quality Assurance to voice concerns, give feedback, and ask questions.

Kiewit will comply with SCDOT's QAP. We have developed a corporate quality culture that places a premium on delivering high-quality work to our clients. Our CQM — named in our project-specific Construction Quality Control Plan (CQCP) — will work directly with the SCDOT Quality Assurance team to ensure effective collaboration with inspection/testing requirements. A weekly QC/QA meeting will be established to: Review and discuss quality trends, coordinate upcoming activities and needed inspection and testing resources, review the completeness of testing records for submittals, and conduct pre-activity meetings with the operations team for upcoming activities.

Roles of Proposer and SCDOT

Exhibit 11 shows the roles of the Contractor and SCDOT.

Exhibit 11: Roles of the Contractor and SCDOT

Contractor Roles	SCDOT Roles
Submittal of QC Plan to SCDOT for review and approval	Acceptance testing
Provide SCDOT-certified personnel	Independent assurance testing
Establish required and additional sampling and testing	CSL Testing
Provide HMA testing laboratories with SCDOT certification	Preparation of materials certification
Submit HMA and PCC mix designs to SCDOT	
Submit material certifications to SCDOT	

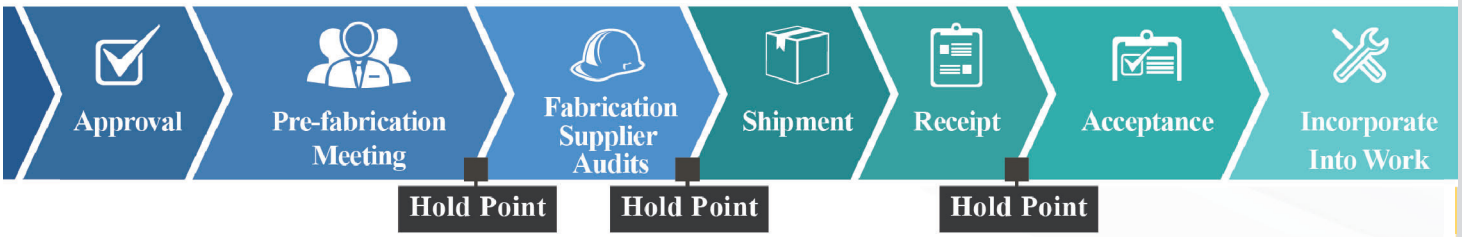
Compliance with Required Standards, Testing Laboratories, Mix Designs and Material Certification Processes

Kiewit works with a number of local Third-Party QC Testing Firms. They are experienced working on SCDOT projects and familiar with the standards and test requirements, we will evaluate which firms are suited to complete work for each of the work packages. Our CQCP will include the QC testing and sampling frequencies and will indicate the frequency at which the CQM will provide QC test results to SCDOT. The Third-Party QC Testing Firm will be integrated into Kiewit's quality program as a vital member of the team.

All hot mix asphalt tests for the project will be tested at an SCDOT certified laboratory. All other testing laboratories for the project will be AASHTO certified and SCDOT approved. The QC team will be involved in reviewing all asphalt mix design and Portland Cement mix designs and supporting data prior to submittal to SCDOT to ensure their conformance with the specifications. All hot-mix asphalt mix designs will be prepared by personnel certified in Mix Design Methods and all Portland Cement Concrete mix designs will be prepared by a certified concrete technician or professional engineer.

Kiewit understands the importance of material traceability and the material certification process. Our CQM will review all material certifications to submit to SCDOT. SCDOT will prepare the Material Certifications as required by FHWA on the project. **Exhibit 12** shows our material certification and acceptance processes.

Exhibit 12: Material Certification Processes



1.e Approach to Addressing Unique Characteristics and Mitigating Risk Items

Proactive Approach to Risk Analysis – Identify, Analyze, Quantify, Mitigate, Monitor

Our proactive risk management approach will be based on maintaining a collaborative relationship with SCDOT, key stakeholders, and third parties to identify and resolve challenges. We have developed a Risk Matrix that

includes mitigation strategies, collaboratively assigns ownership of each risk based on ability to best control it, and address magnitude of cost and quantity impacts. Kiewit will collaborate with SCDOT to look for innovative ways to mitigate or remove unnecessary Project risk through active management, transparency, and communication.

We have built upon our risks from the SOQ and have eliminated risk, developed mitigation strategies to reduce risk, and identified new risks. We have summarized the most significant risks, along with our proposed mitigation approaches in **Exhibit 13**. These items are considered our top issues because they will require the most attention throughout the Project. Kiewit understands the severity of these risks and their potential impacts on project delivery.

Exhibit 13: Top risks and mitigation strategies

Risk Item / Unique Characteristic and Potential Impact	Proposed Risk Mitigation Strategies
Limited Site Access • Construction inefficiencies • Additional cost and schedule impacts • Safety concerns with the traveling public	• Access has been designed for each phase of the project • Construct the new bridge with a gantry crane • Approved ATCs 4 and 5 for construction access on and off the shoulders • SmartZone and truck warning technologies to assure safety during merging of construction traffic • Met with landowners on west and east banks to establish additional construction access and lay-down yards outside of SCDOT Right of Way
Maintenance of Traffic • Incidents involving the traveling public • Excessive traffic shifts • Excessive lane closures	• Provide timely and useful information for SCDOT's Community and Public Relations Program • Early engagement with SCDOT engineering staff and local emergency personnel • Immediate and continuous construction operations once lane closures are in place to shorten duration of lane closures. Optimize closures so they can be shared by multiple operations. • Consistent MOT control devices to ensure smooth traffic operations and minimize hazards • Implement SmartZone Technologies
Environmental and Permitting • Schedule delays • Flood events • Polluting the water bodies • Environmental impacts	• Design permanent and temporary construction concepts to utilize 2.5 acres of the allowed 3-acre threshold for wetland impacts • Worked with adjacent landowners to provide lay-down areas out of the flood plain • Design and build temporary construction flood-resistent access • Comprehensive SWPPP and BMPs in place with ongoing inspections and repairs as needed • Use of demo shields and construction means and methods to prevent materials entering water
Repairs for Overflow Bridges • Additional quantity growth • Safety of traveling public	• Daily collaboration between SCDOT and to inspect existing conditions and monitor the overflow bridges to identify additional repairs so they can be quickly repaired • KEGI to provide in-house construction engineering services to develop plan to safely support the existing flat slab • Meet with landowners to access bridges from underneath
Schedule Delays • Design delays • Procurement / Supply Chain Issues	• Advance early packages to begin shop drawings and procurement sooner • Kiewit's collaborative approach provides better integration of design and construction, schedule transparency, and timely decision making • Use of standard items such as Florida I Beams, Silicoflex joint system, and Wabo FS Bridge Seal • Relationships between Kiewit Supply Network (KSN) and rebar suppliers to quickly procure ChromX reinforcing steel

2. INNOVATION AND ADDED VALUE

Innovations

During the pursuit phase, designers, construction, and estimating team members co-located and worked together to develop a design and plan that brought forth many innovations and approved ATCs. The ATCs that Kiewit has elected to pursue are attached in Appendix C.

Quality Credit Matrix

See the Quality Credit Matrix in Appendix B.j.

Appendix A –
Conceptual Plans

APPENDIX A – CONCEPTUAL PLANS

Please see the conceptual plans listed below in the following pages.

A.1 – Roadway Plans

A.2 – Maintenance of Traffic Plans and/or Documents

A.3 – Bridge Plans

A.4 – CPM Schedule

A.1 – Roadway Plans

SHEET NO.	TOTAL SHEETS
1	

INDEX OF SHEETS
SEE SHEET IL1 FOR INDEX

BRIDGE PLANS BOUND
UNDER SEPARATE COVER

SCDOT
South Carolina Department of Transportation

PROPOSED PLANS FOR

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER

BRIDGE REPLACEMENT AND SWAMP OVERFLOW BRIDGE REHABILITATIONS

Hydraulic Design Reference for these plans is the:
2009
Edition of SCDOT's "Requirements for Hydraulic Design Studies"

Design Reference for these plans is the:
2021
SCDOT Roadway Design Manual

NPDES PERMIT INFORMATION

Disturbed Area = _____ Acre(s)

Permitted Area = _____ Acre(s)

Approximate Location of Roadway is

Begin
Latitude _____
Longitude _____

End
Latitude _____
Longitude _____

Hydraulic and NPDES Design provided by:

_____

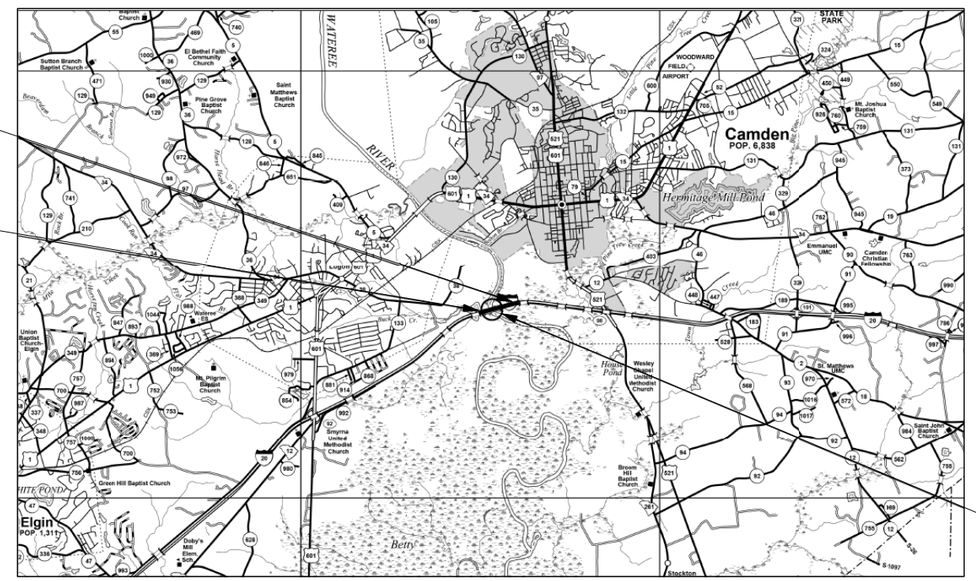
Designs may be obtained from the SCDOT Regional Production Group

CONTRACT ID 2847360
I-20
END CONSTRUCTION
STA. 1836+49.25

END

CONTRACT ID 2847360
I-20
BEGIN CONSTRUCTION
STA. 1792+55.00

BEGIN



(2) 1515.33' x48.25' CONCRETE BRIDGES
FROM STA. 1800+92.38 TO STA. 1816+07.71

LAYOUT

SCALE 1 INCH = 7,000 FEET

ENVIRONMENTAL PERMIT INFORMATION

USACE PERMIT	___YES	___NO	
NEPA DOCUMENT	___YES	___NO	
401 CERTIFICATION	___YES	___NO	
OCRM CAP	___YES	___NO	
NAVIGABLE WATERS___SC	___USCG	___USACE	___N/A

3 DAYS BEFORE DIGGING IN
SOUTH CAROLINA

CALL 811

SOUTH CAROLINA 811 (SC811)
WWW.SC811.COM
ALL UTILITIES MAY NOT BE A MEMBER OF SC811

RAILROAD INVOLVEMENT?
YES (NO)

TRAFFIC DATA

_____ ADT_____

_____ ADT_____

TRUCKS _____%

NET LENGTH OF ROADWAY	MILES
NET LENGTH OF BRIDGES	MILES
NET LENGTH OF PROJECT	MILES
LENGTH OF EXCEPTIONS	MILES
GROSS LENGTH OF PROJECT	MILES

EQUALITIES IN STATIONING

NOTE: EXCEPT AS MAY OTHERWISE BE SPECIFIED ON THE PLANS OR IN THE SPECIAL PROVISIONS. ALL MATERIALS AND WORKMANSHIP ON THIS PROJECT SHALL CONFORM TO THE SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (2007 EDITION) AND THE STANDARD DRAWINGS FOR ROAD CONSTRUCTION IN EFFECT AT THE TIME OF LETTING.

CONSULTING ENGINEERING FIRM

Kiewit

ENGINEER OF RECORD

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

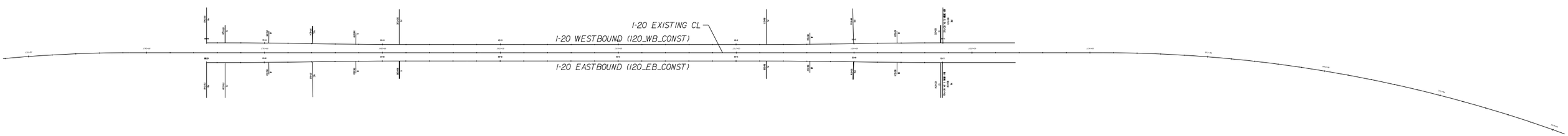
FOR CONSTRUCTION : _____ _____
DATE

ecitt sli3.dgn

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	2

INDEX OF SHEETS

SHEET NO.	DESCRIPTION	SHEET SUBTOTALS
1	TITLE SHEET	1
2	INDEX/LAYOUT SHEET	1
NA	SUMMARY OF ESTIMATED QUANTITIES	OMITTED
NA	DEMOLITION AND MOVING ITEMS; RESET/NEW FENCES	OMITTED
3	TYPICAL SECTIONS	1
NA	RIGHT-OF-WAY DATA SHEET	OMITTED
NA	PROPERTY STRIP MAP	OMITTED
NA	GENERAL CONSTRUCTION NOTES	OMITTED
4-7	REFERENCE DATA SHEETS	4
8,10,12,14-17	PLAN SHEETS	7
9,11,13	PROFILE SHEETS	3
18-38	CROSS SECTIONS	21
	TOTAL SHEETS	38



SCALE IN FEET

0 200' 400' 800'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
2			
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
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SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

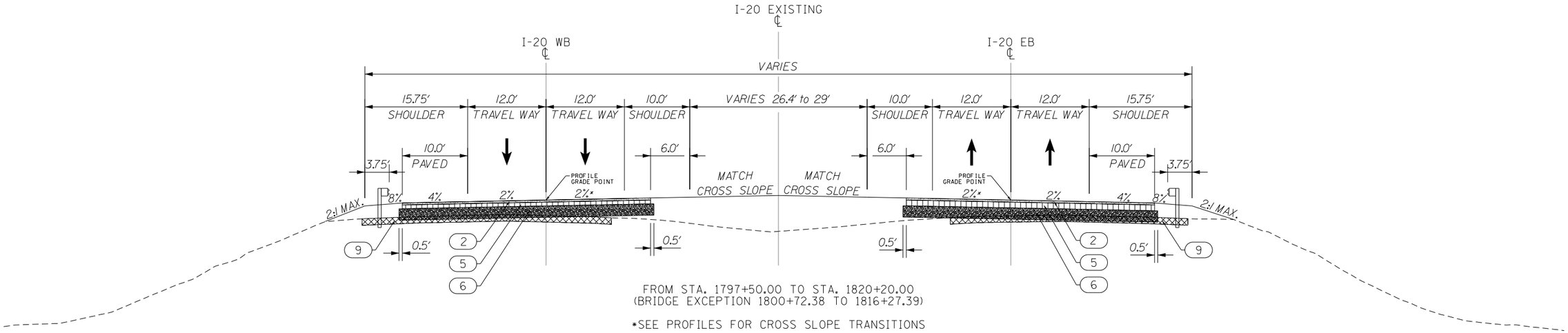
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
INDEX/LAYOUT SHEET

SCALE 1"=400' RTE. DWG. NO.

BORDER1.58.DGN

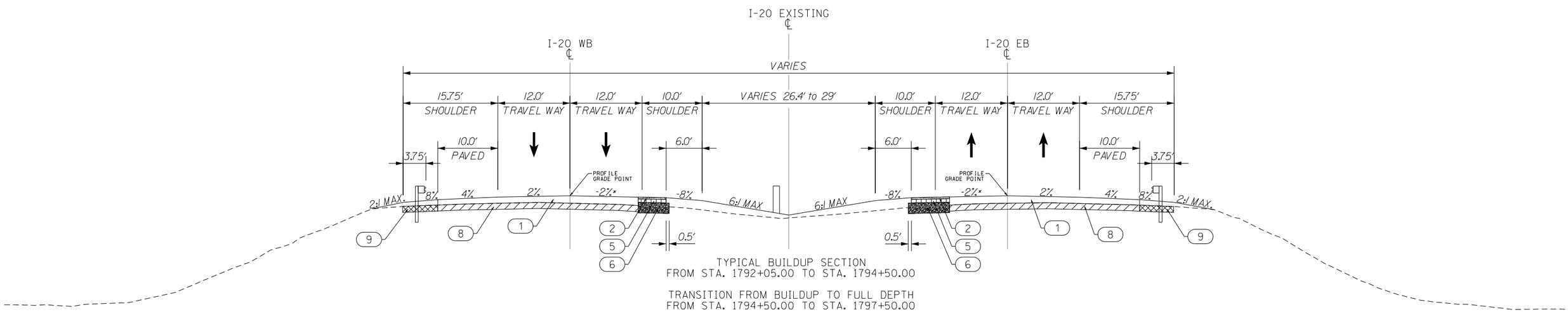
FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
3	S.C.				3

TYPICAL SECTION OF IMPROVEMENT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.



FROM STA. 1797+50.00 TO STA. 1820+20.00
(BRIDGE EXCEPTION 1800+72.38 TO 1816+27.39)

*SEE PROFILES FOR CROSS SLOPE TRANSITIONS



TYPICAL BUILDUP SECTION
FROM STA. 1792+05.00 TO STA. 1794+50.00

TRANSITION FROM BUILDUP TO FULL DEPTH
FROM STA. 1794+50.00 TO STA. 1797+50.00

TYPICAL BUILDUP SECTION
FROM 1822+50.00 TO 1826+84.00

TRANSITION FROM BUILDUP TO FULL DEPTH
FROM 1820+20.00 TO 1822+50.00

*SEE PROFILES FOR CROSS SLOPE TRANSITIONS

LEGEND

1. HOT MIX ASPHALT TYPE B FOR BUILD-UP
2. HOT MIX ASPHALT TYPE 200 PSY SURFACE A
3. HOT MIX ASPHALT TYPE 200 PSY HMA SURFACE TYPE B
4. HOT MIX ASPHALT TYPE 300 PSY HMA INTERMEDIATE TYPE A
5. HOT MIX ASPHALT TYPE 400 PSY INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 1150 PSY BASE A
7. HOT MIX ASPHALT TYPE 750 PSY BASE A
8. RETAIN EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

NO.	FUNCTIONAL CLASSIFICATION	DESIGN SPEED MPH	FROM STA.	TO STA.	PAVEMENT DESIGN
	Rural Freeway	75	1792+05.00	1826+84.00	
	Rural Freeway	75	1792+05.00	1826+84.00	

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

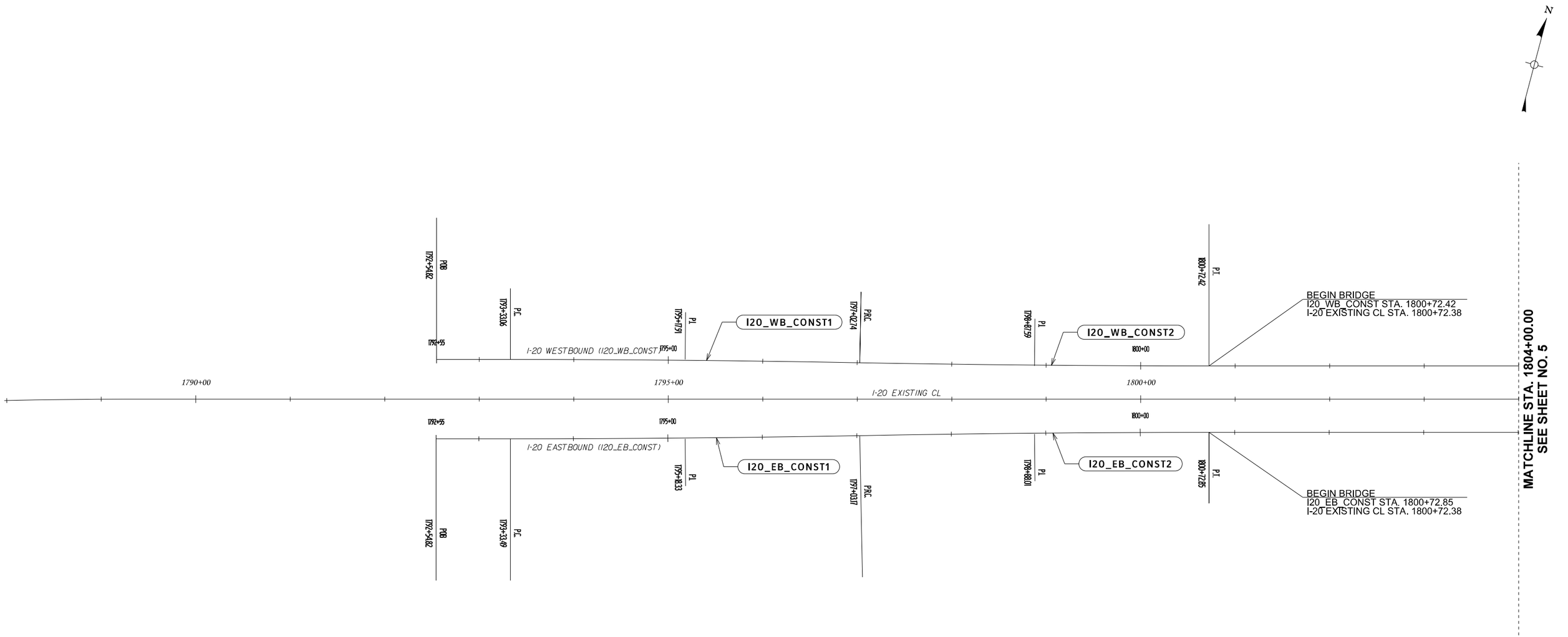
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.

TYPICAL SECTION

SCALE 1"V = NTS SCALE 1"H = NTS

03.Typical.Section

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	4



SCALE IN FEET

0 50' 100' 200'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

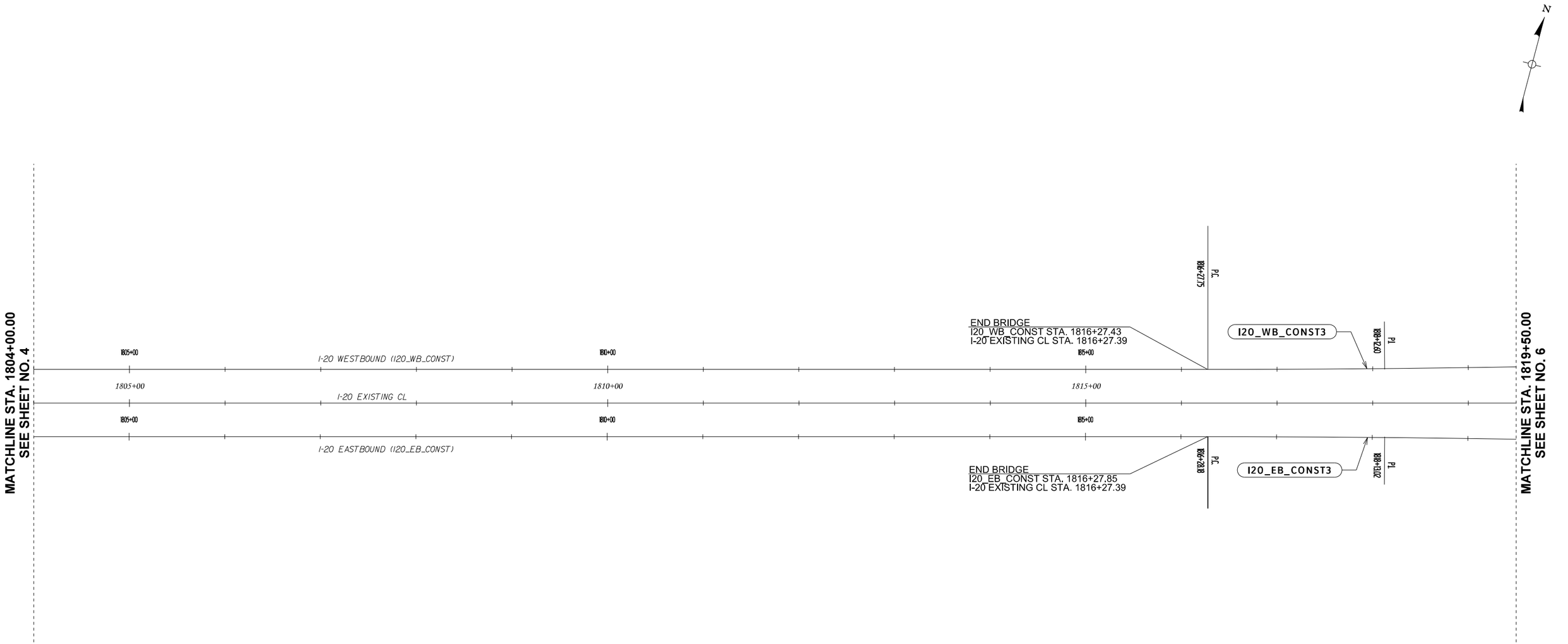
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
REFERENCE DATA SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	5



SCALE IN FEET

0 50' 100' 200'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

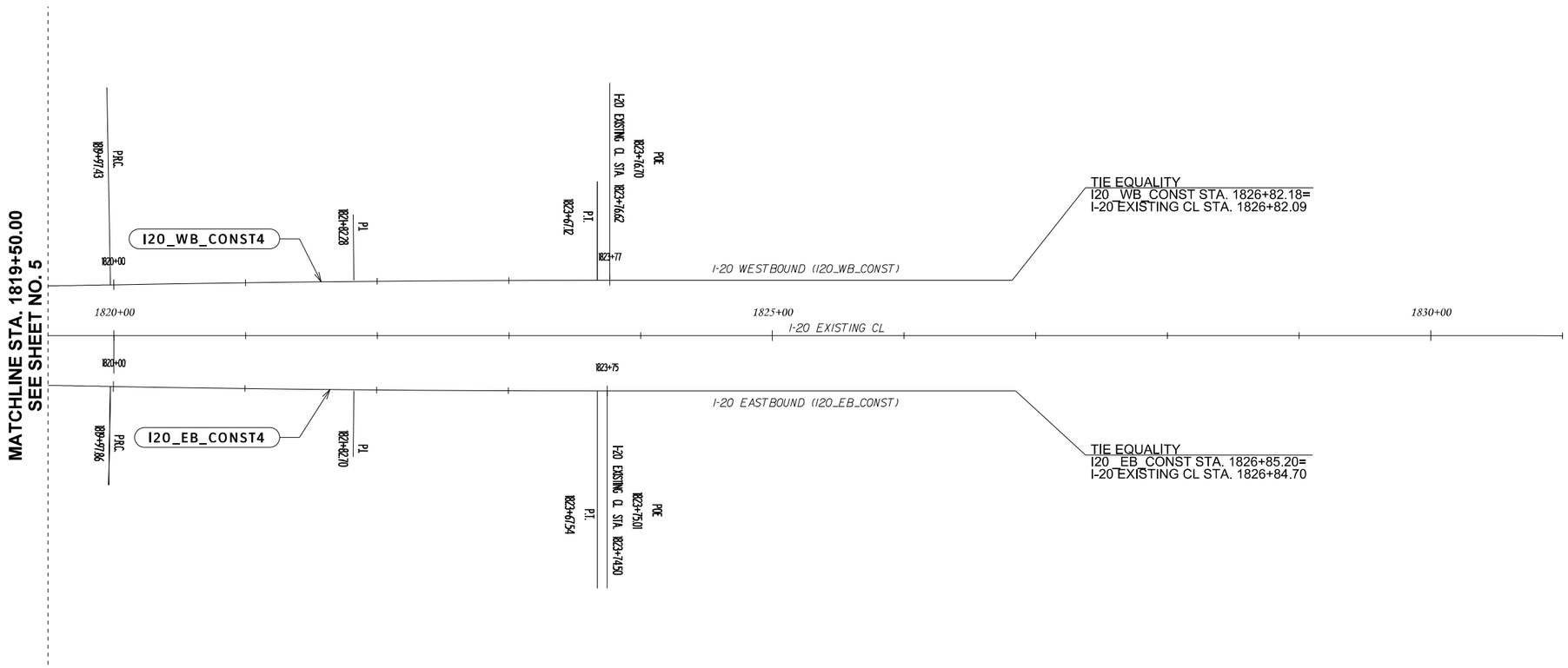
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
REFERENCE DATA SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	6



SCALE IN FEET

0 50' 100' 200'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
REFERENCE DATA SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	7

I-20 EXISTING CL

Beginning chain CL description
==========

Point 10000 N 864,504.4990 E 2,106,246.6612 Sta 1741+99.52

Course from 10000 to PC C1 N 47°09' 51.34" E Dist 1,928.8500

Curve Data

Curve C1
Feature: DEFAULT
P.I. Station 1775+56.43 N 866,786.8609 E 2,108,708.3059
Delta = 27° 59' 27.44" (RT)
Degree = 1° 00' 00.00"
Tangent = 1,428.0639
Length = 2,799.0955
Radius = 5,729.5780
External = 175.2870
Long Chord = 2,771.3431
Mid.Ord. = 170.0836
P.C. Station 1761+28.37 N 865,815.9219 E 2,107,661.0983
P.T. Station 1789+27.47 N 867,152.7328 E 2,110,088.7059
C.C. N 861,614.3885 E 2,111,556.6317
Back = N 47° 09' 51.34" E
Ahead = N 75° 09' 18.78" E
Chord Bear = N 61° 09' 35.06" E

Course from PT C1 to PC C2 N 75° 09' 18.78" E Dist 4,126.7358

Curve Data

Curve C2
Feature: DEFAULT
P.I. Station 1841+76.49 N 868,497.5398 E 2,115,162.5346
Delta = 22° 09' 54.41" (RT)
Degree = 1° 00' 00.00"
Tangent = 1,122.2872
Length = 2,216.5115
Radius = 5,729.5780
External = 108.8801
Long Chord = 2,202.7159
Mid.Ord. = 106.8496
P.C. Station 1830+54.20 N 868,210.0082 E 2,114,077.7055
P.T. Station 1852+70.71 N 868,354.5418 E 2,116,275.6744
C.C. N 862,671.6639 E 2,115,545.6312
Back = N 75° 09' 18.78" E
Ahead = N 82° 40' 46.81" E
Chord Bear = N 86° 14' 15.98" E

Course from PT C2 to 10001 S 82° 40' 46.81" E Dist 5,717.4036

Point 10001 N 867,626.0499 E 2,121,946.4771 Sta 1909+88.12

==========
Ending chain CL description

I-20 WB CONST.

Beginning chain I20_WB_CONST description
==========

Point WB001 N 867,193.3310 E 2,110,077.9455 Sta 1792+54.82

Course from WB001 to PC I20_WB_CONST1 N 75°09' 18.78" E Dist 78.242

Curve Data

Curve I20_WB_CONST1
P.I. Station 1795+17.91 N 867,344.6035 E 2,110,648.6823
Delta = 1° 03' 32.61" (RT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1793+33.06 N 867,297.2458 E 2,110,470.0062
P.T. Station 1797+02.74 N 867,388.6507 E 2,110,828.2033
C.C. N 847,964.773 E 2,115,594.0338
Back = N 75° 09' 18.78" E
Ahead = N 76° 12' 51.38" E
Chord Bear = N 75° 41' 05.08" E

Curve Data

Curve I20_WB_CONST2
P.I. Station 1798+87.59 N 867,432.6979 E 2,111,007.7242
Delta = 1° 03' 32.61" (LT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1797+02.74 N 867,388.6507 E 2,110,828.2033
P.T. Station 1800+72.42 N 867,480.0556 E 2,111,186.4004
C.C. N 886,812.5241 E 2,106,062.3727
Back = N 76° 12' 51.38" E
Ahead = N 75° 09' 18.78" E
Chord Bear = N 75° 41' 05.08" E

Course from PT I20_WB_CONST2 to PC I20_WB_CONST3 N 75° 09' 18.78" E
Dist 1,555.3300

Curve Data

Curve I20_WB_CONST3
P.I. Station 1818+12.60 N 867,925.8909 E 2,112,868.4947
Delta = 1° 03' 32.61" (LT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1816+27.75 N 867,878.5332 E 2,112,689.8186
P.T. Station 1819+97.43 N 867,976.5430 E 2,113,046.2650
C.C. N 887,211.0018 E 2,107,565.7910
Back = N 75° 09' 18.78" E
Ahead = N 74° 05' 46.17" E
Chord Bear = N 74° 37' 32.47" E

I-20 WB CONST.

Curve Data

Curve I20_WB_CONST4
P.I. Station 1821+82.28 N 868,027.1951 E 2,113,224.0354
Delta = 1° 03' 32.61" (RT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.00
External = 0.8540
Long Chord = 369.6750
Mid.Ord. = 0.8540
P.C. Station 1819+97.43 N 867,976.5430 E 2,113,046.2651
P.T. Station 1823+67.12 N 868,074.5528 E 2,113,402.7114
C.C. N 848,742.0939 E 2,118,526.7365
Back = N 74° 05' 46.17" E
Ahead = N 75° 09' 18.78" E
Chord Bear = N 74° 37' 32.47" E

Course from PT I20_WB_CONST4 to WB002 N 75° 09' 18.78" E Dist 315.061

Point WB002 N 868,250.6064 E 2,114,066.945 Sta 1826+82.18

==========
Ending chain I20_WB_CONST description

I-20 EB CONST.

Beginning chain I20_EB_CONST description
==========

Point EB001 N 867,112.1346 E 2,110,099.4664 Sta 1792+54.82

Course from EB001 to PC I20_EB_CONST1 N 75°09' 18.78" E Dist 78.666

Curve Data

Curve I20_EB_CONST1
P.I. Station 1795+18.33 N 867,263.4071 E 2,110,670.2031
Delta = 1° 03' 32.61" (LT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.00
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1793+33.49 N 867,216.0494 E 2,110,491.5270
P.T. Station 1797+03.17 N 867,314.0592 E 2,110,847.9734
C.C. N 886,548.5170 E 2,105,367.4996
Back = N 75° 09' 18.78" E
Ahead = N 74° 05' 46.17" E
Chord Bear = N 74° 37' 32.47" E

Curve Data

Curve I20_EB_CONST2
P.I. Station 1798+88.01 N 867,364.7113 E 2,111,025.7438
Delta = 1° 03' 32.61" (RT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1797+03.17 N 867,314.0592 E 2,110,847.9734
P.T. Station 1800+72.85 N 867,412.0690 E 2,111,204.4199
C.C. N 848,079.6006 E 2,116,328.4475
Back = N 74° 05' 46.17" E
Ahead = N 75° 09' 18.78" E
Chord Bear = N 74° 37' 32.47" E

Course from PT I20_EB_CONST2 to PC I20_EB_CONST3 N 75° 09' 18.78" E
Dist 1,555.3300

Curve Data

Curve I20_EB_CONST3
P.I. Station 1818+13.02 N 867,857.9044 E 2,112,886.5144
Delta = 1° 03' 32.61" (RT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1816+28.18 N 867,810.5467 E 2,112,707.8383
P.T. Station 1819+97.86 N 867,901.9516 E 2,113,066.0353
C.C. N 848,478.0782 E 2,117,831.8659
Back = N 75° 09' 18.78" E
Ahead = N 76° 12' 51.38" E
Chord Bear = N 75° 41' 05.08" E

I-20 EB CONST.

Curve Data

Curve I20_EB_CONST4
P.I. Station 1821+82.70 N 867,945.9987 E 2,113,245.5563
Delta = 1° 03' 32.61" (LT)
Degree = 0° 17' 11.32"
Tangent = 184.8460
Length = 369.6810
Radius = 20,000.0000
External = 0.8540
Long Chord = 369.6760
Mid.Ord. = 0.8540
P.C. Station 1819+97.86 N 867,901.9516 E 2,113,066.0353
P.T. Station 1823+67.54 N 867,993.3565 E 2,113,424.2324
C.C. N 887,325.8250 E 2,108,300.2048
Back = N 76° 012' 51.38" E
Ahead = N 75° 09' 18.78" E
Chord Bear = N 75° 41' 05.08" E

Course from PT I20_EB_CONST4 to EB002 N 75° 09' 18.78" E Dist 317.6630

Point EB002 N 868,250.6064 E 2,114,066.945 Sta 1826+85.20

==========
Ending chain I20_EB_CONST description

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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DWG. _____ DATE _____ GROUP ____ - _____
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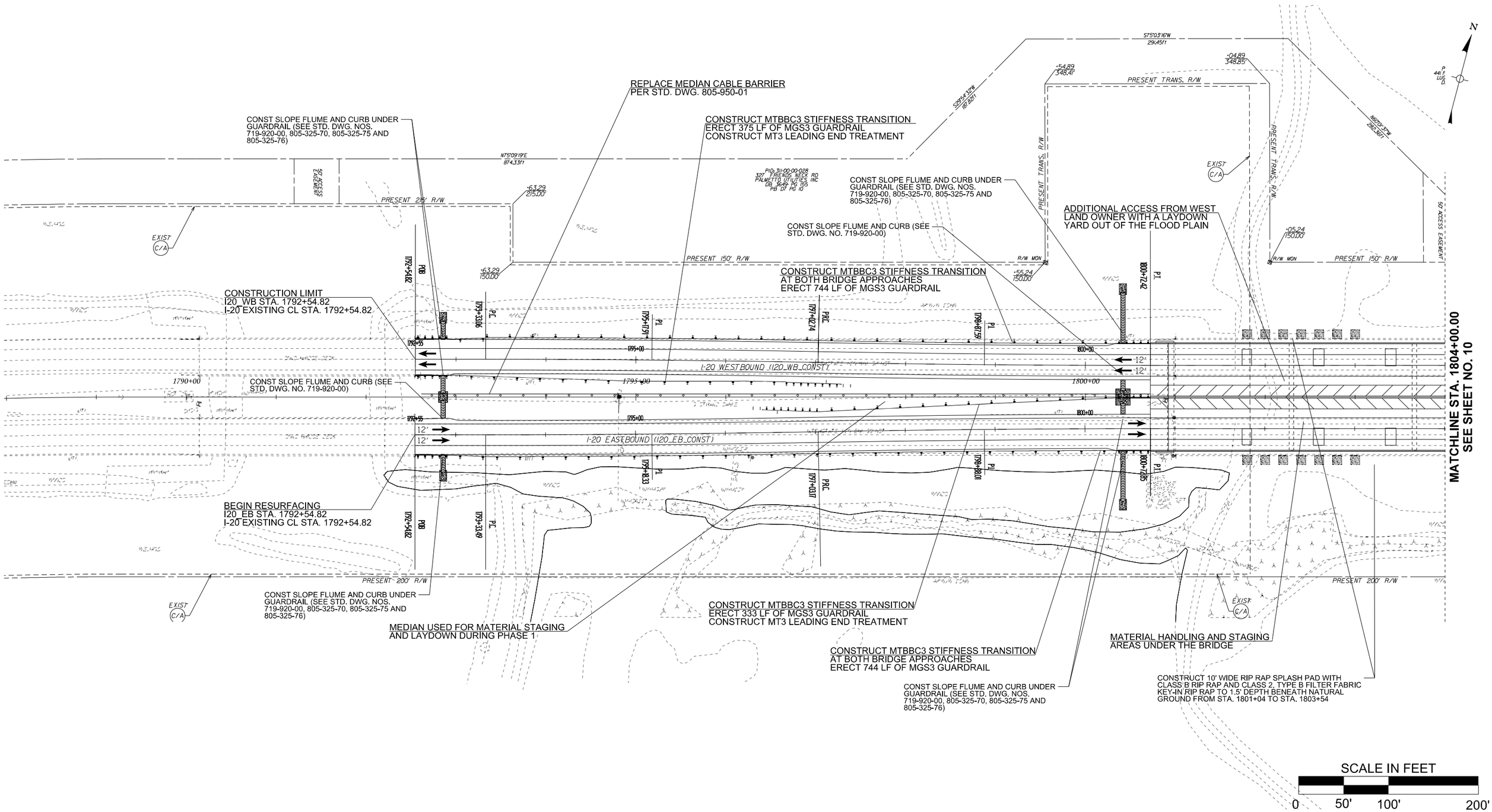
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
REFERENCE DATA SHEET

SCALE 1"= NTS RTE. DWG. NO.

BORDER1_58.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	8



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PRELIMINARY PLANS
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REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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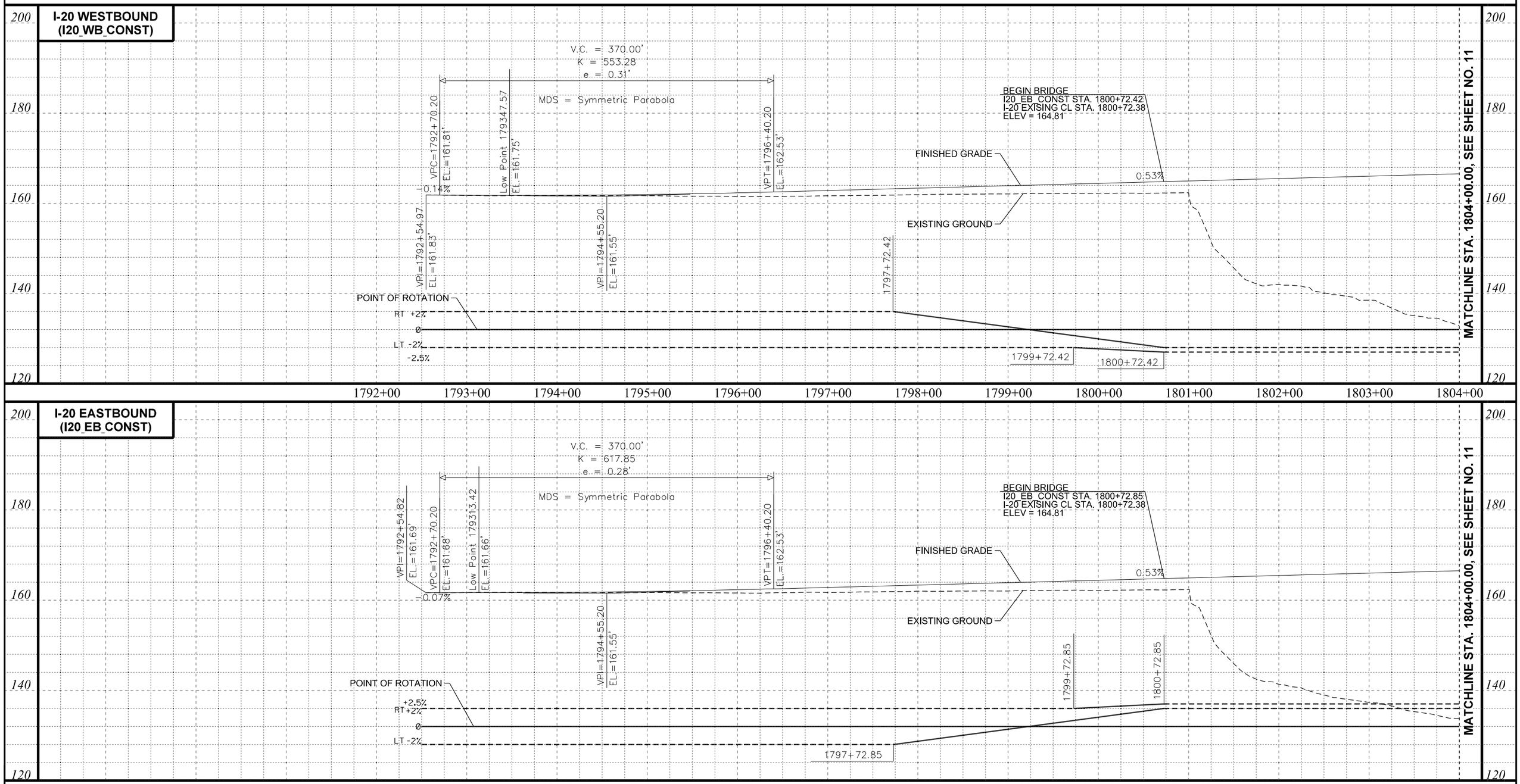
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	9



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PRELIMINARY PLANS
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REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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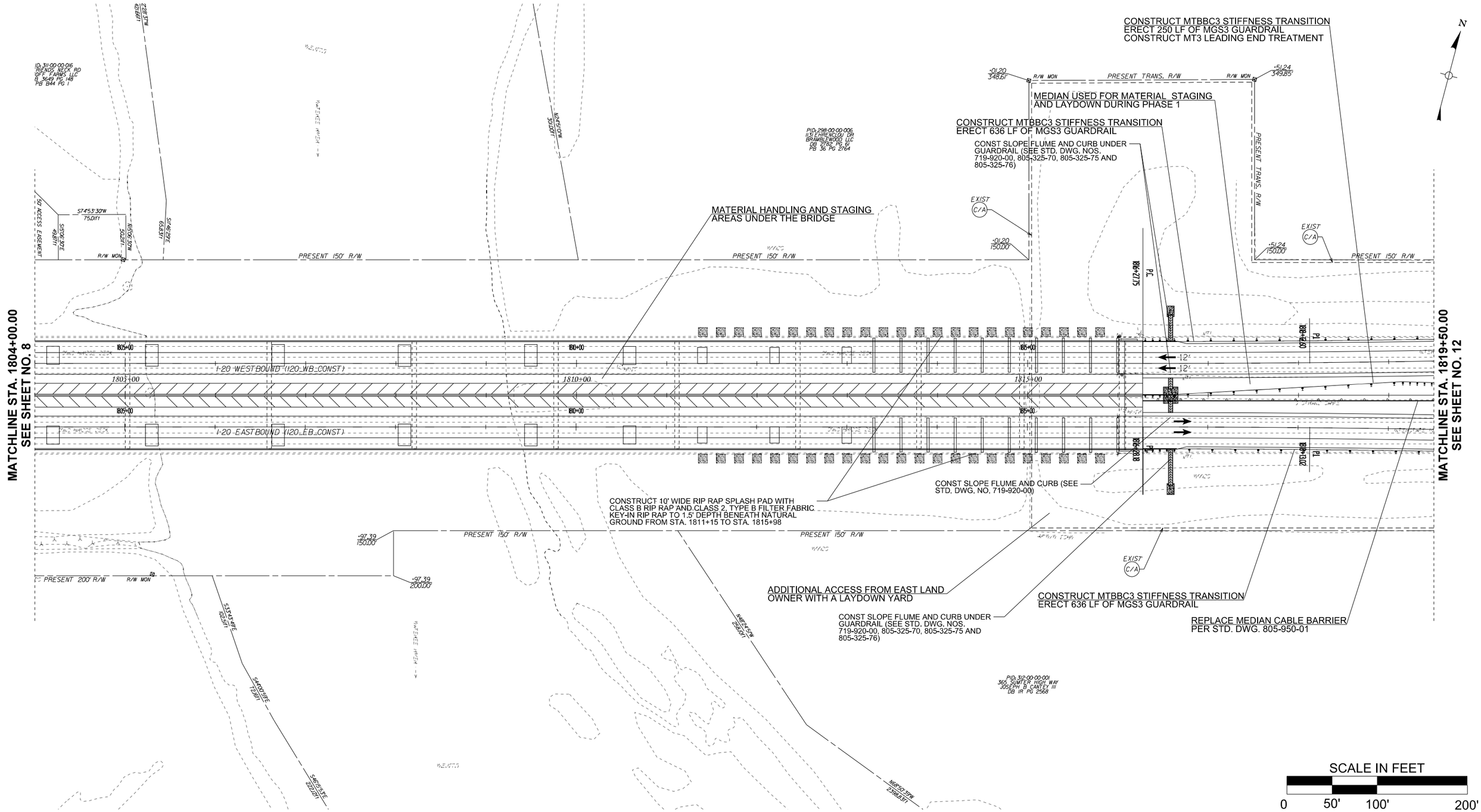
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PROFILE SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	10



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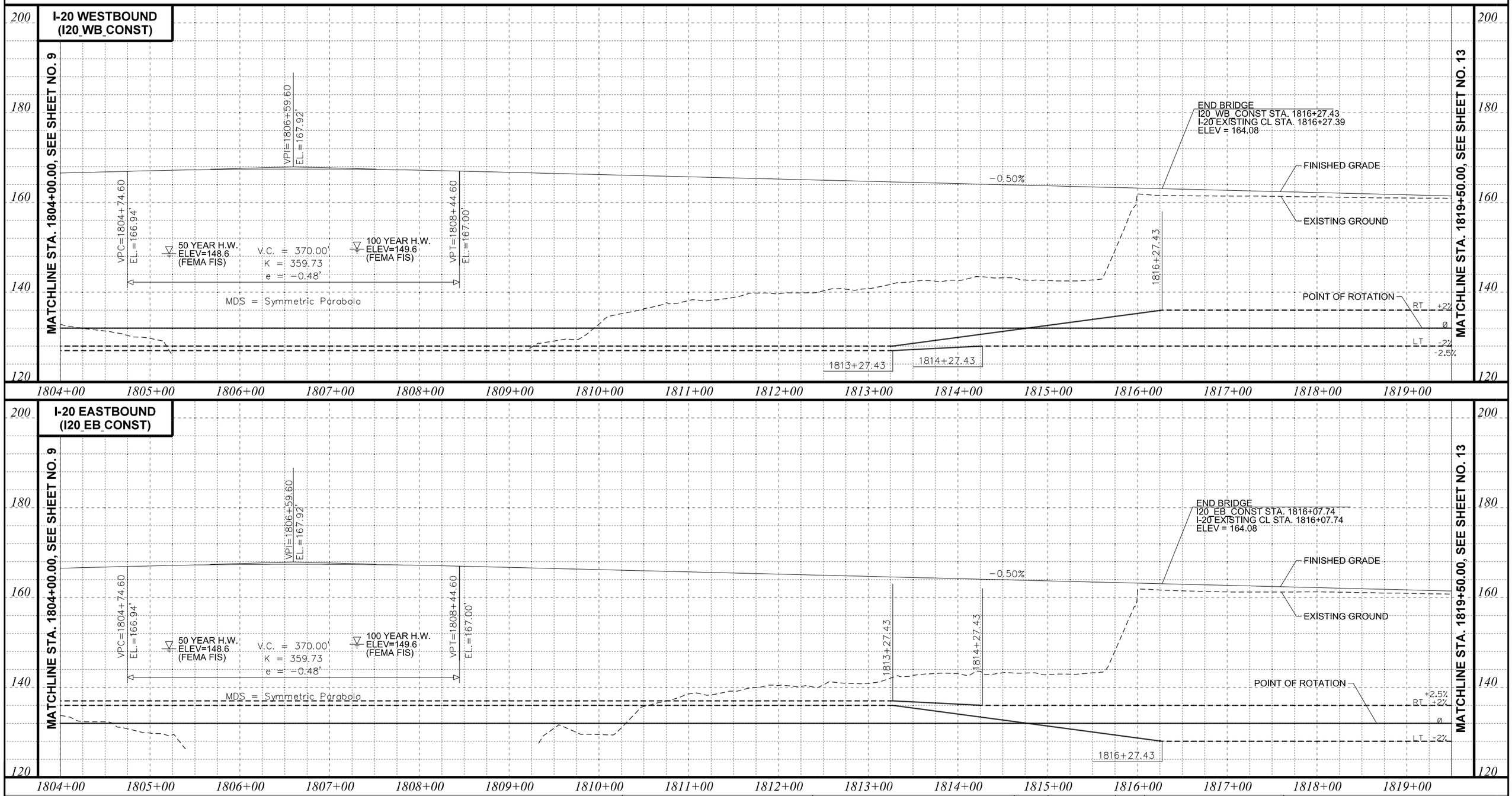
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1_58.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	11



Kiewit

PRELIMINARY PLANS
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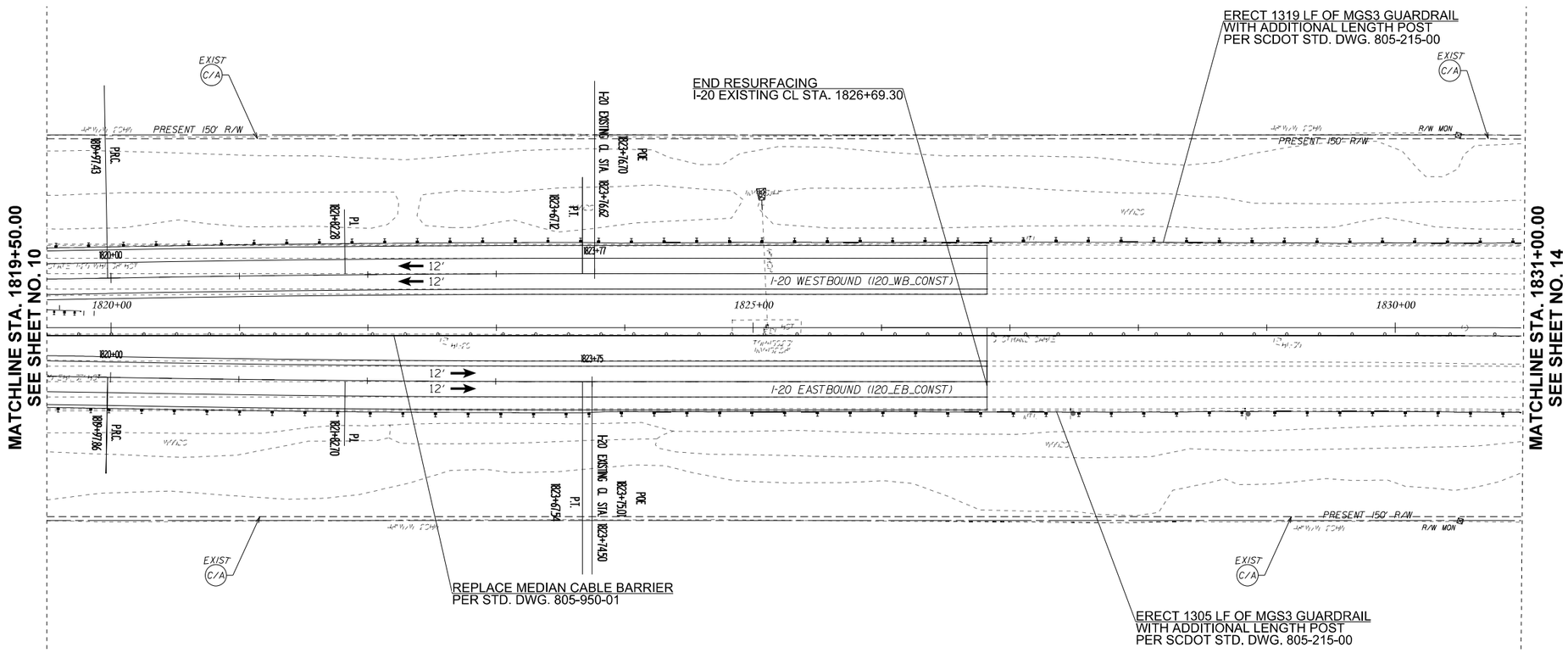
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PROFILE SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	12



SCALE IN FEET

0 50' 100' 200'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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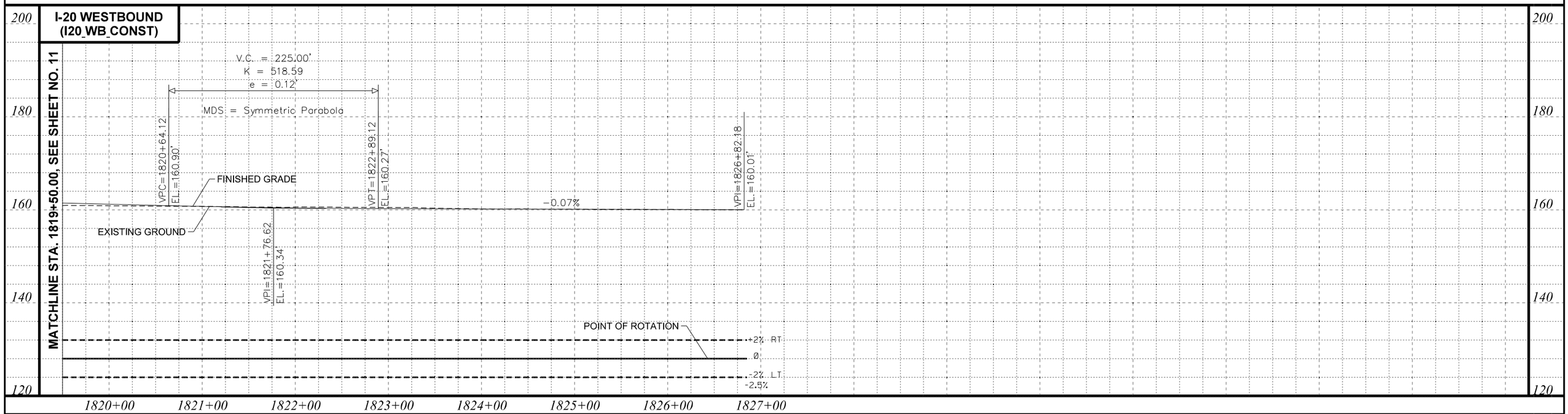
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

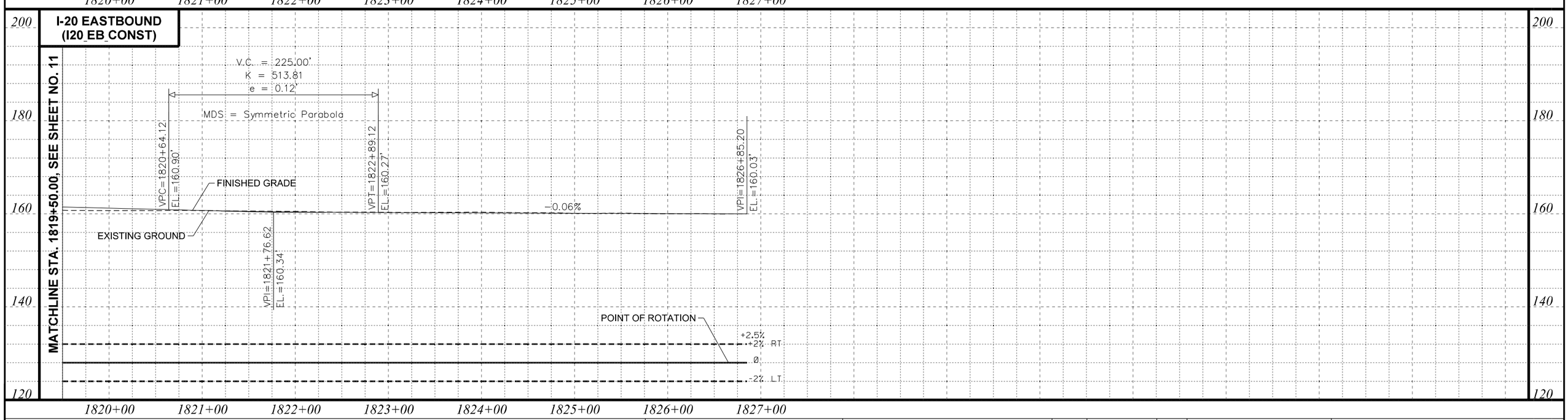
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	13





Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

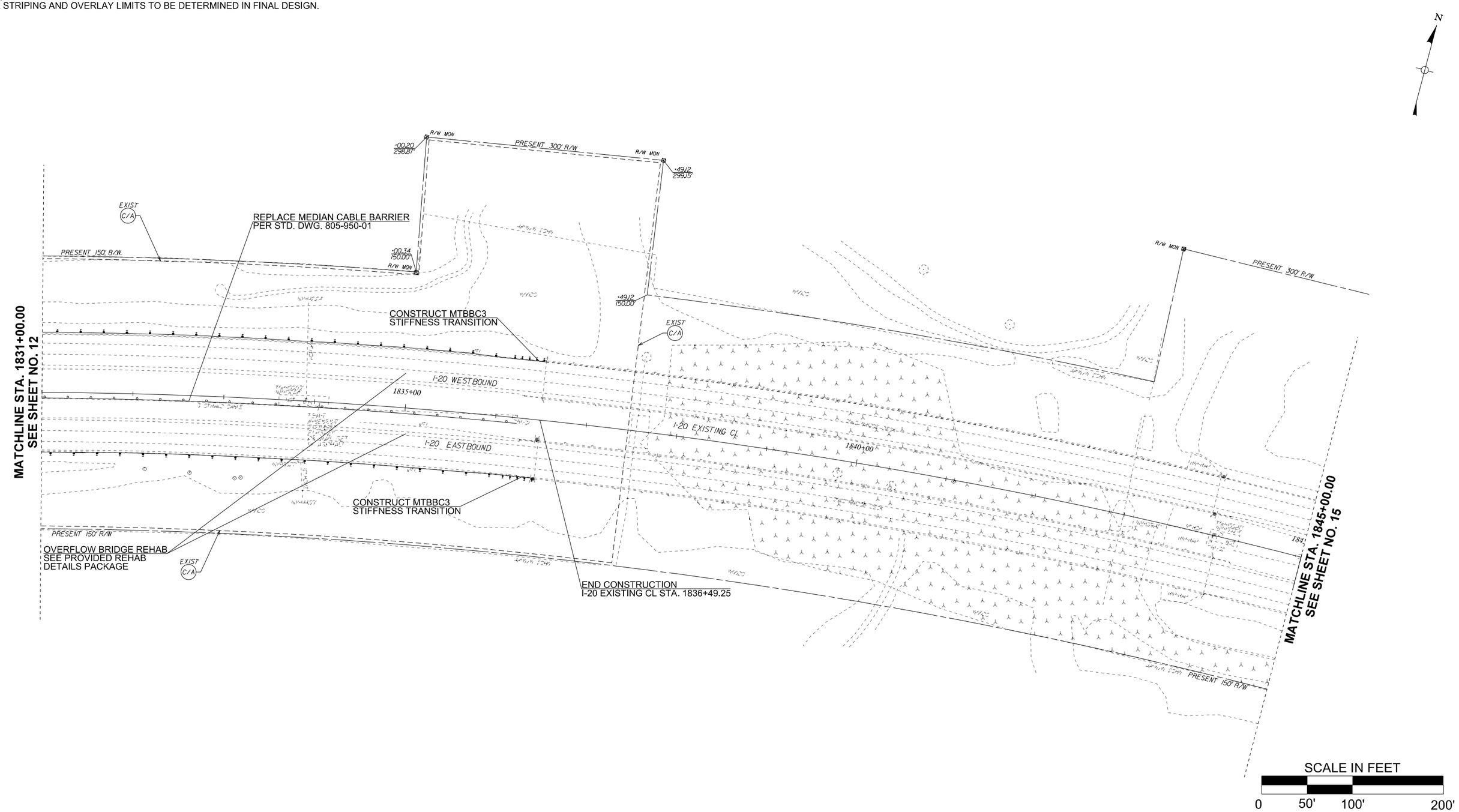
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PROFILE SHEET

SCALE 1"=100' RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	14

NOTE:
FINAL STRIPING AND OVERLAY LIMITS TO BE DETERMINED IN FINAL DESIGN.



Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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TOPO. _____ DATE _____
DWG. _____ DATE _____
R/W _____ DATE _____

GROUP ____ - _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

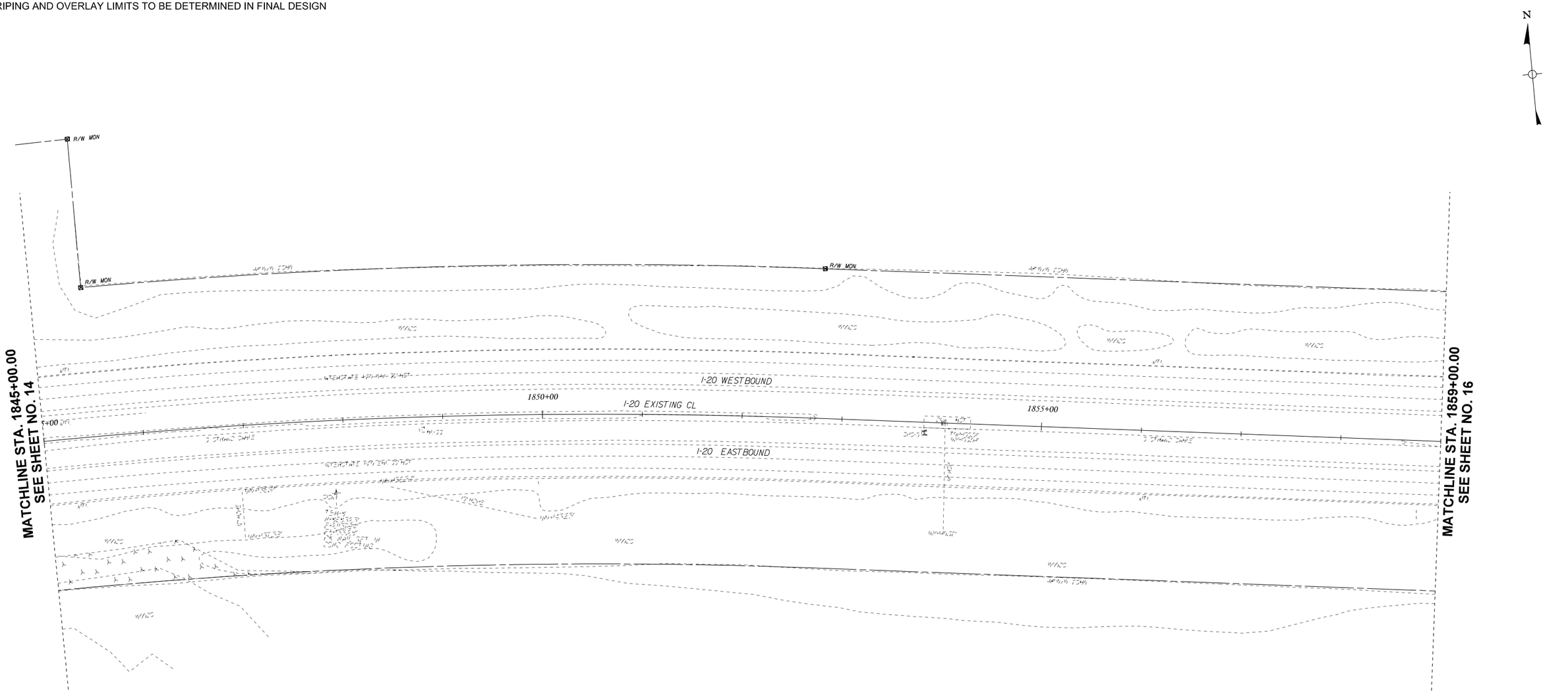
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	15

NOTE:
FINAL STRIPING AND OVERLAY LIMITS TO BE DETERMINED IN FINAL DESIGN



SCALE IN FEET

0 50' 100' 200'

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
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TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

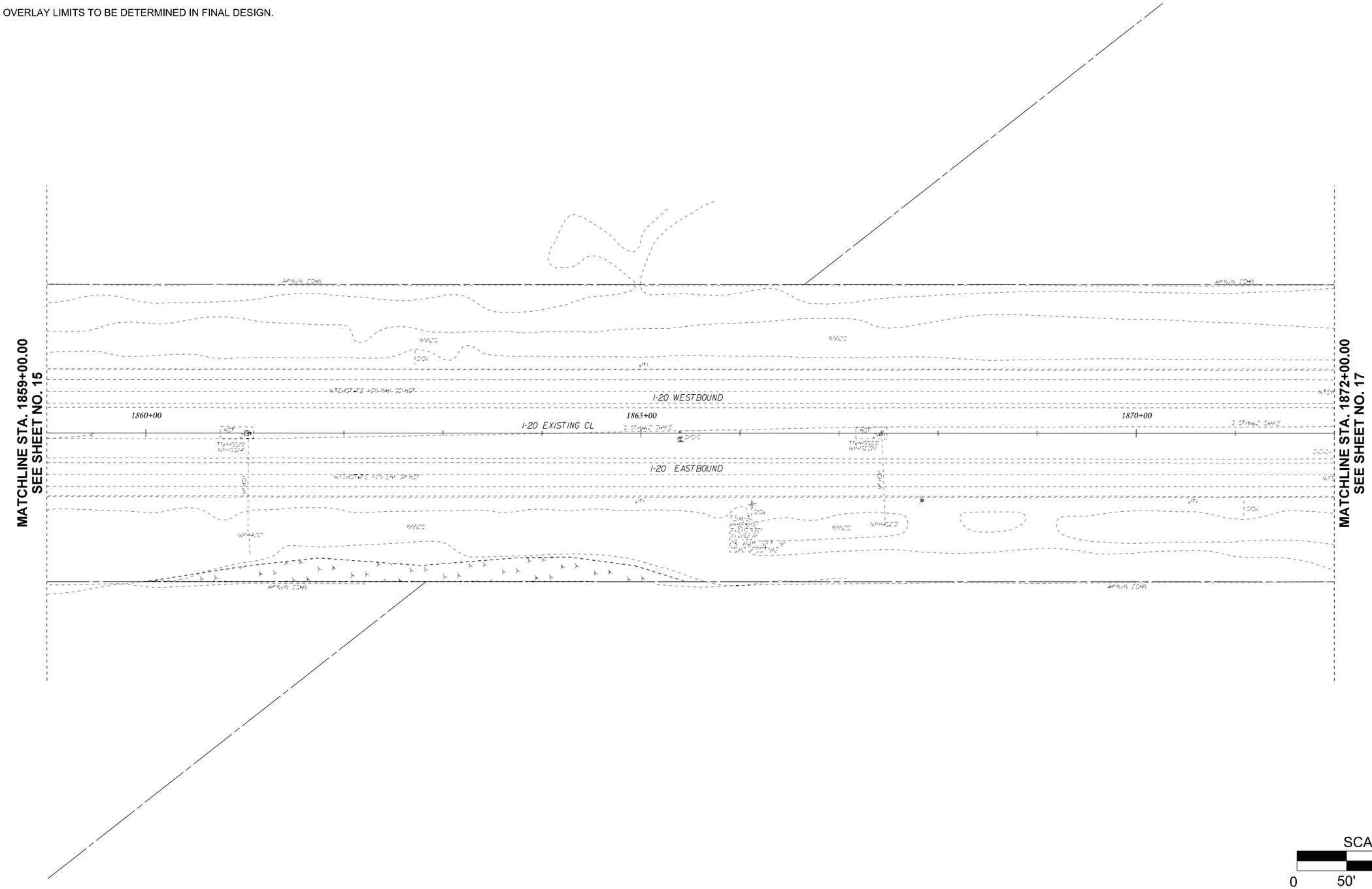
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1.50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	16

NOTE:
FINAL STRIPING AND OVERLAY LIMITS TO BE DETERMINED IN FINAL DESIGN.



Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
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1			

TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - ____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

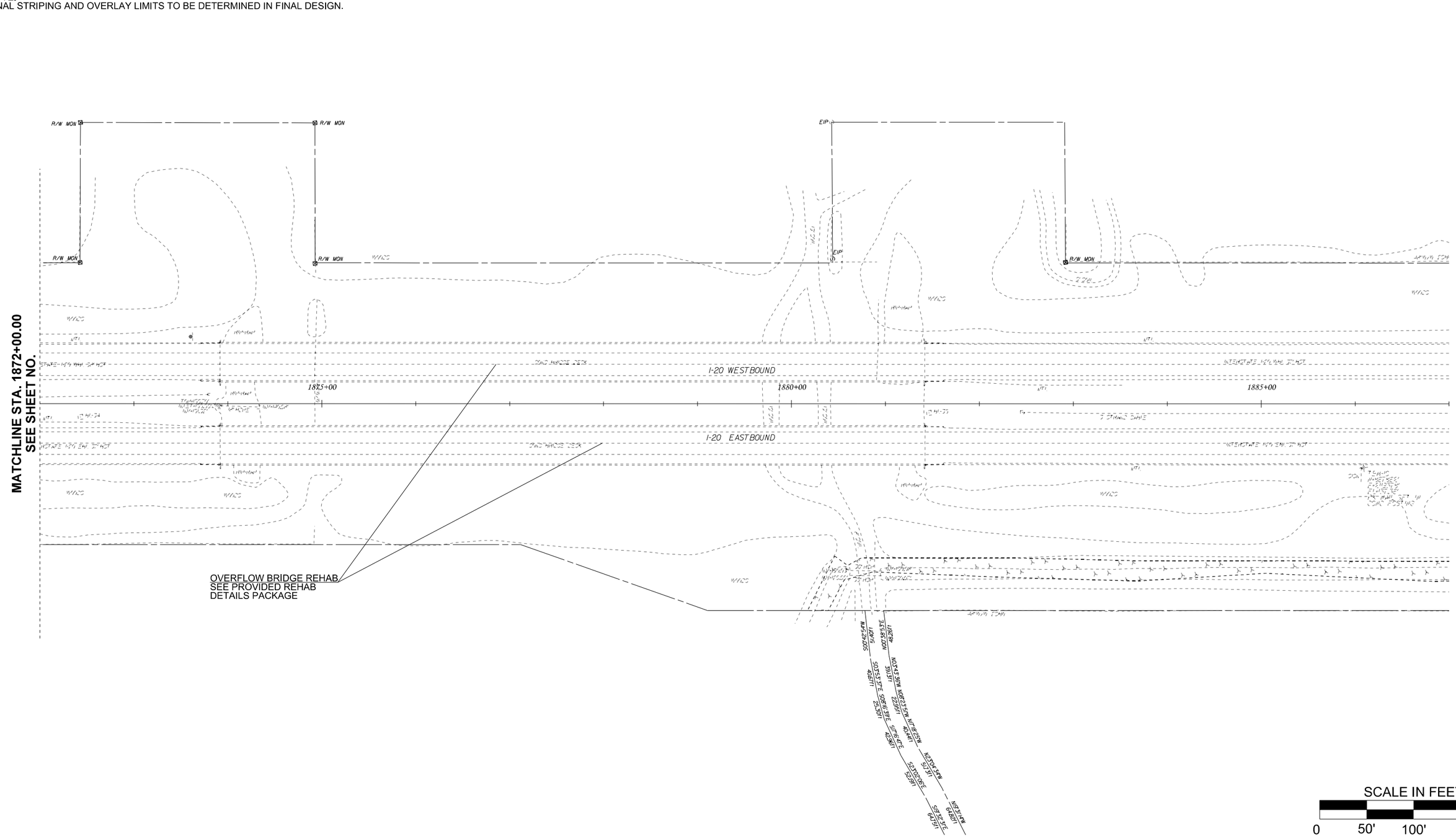
KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1.58.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	17

NOTE:
FINAL STRIPING AND OVERLAY LIMITS TO BE DETERMINED IN FINAL DESIGN.



Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
2			
1			

TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

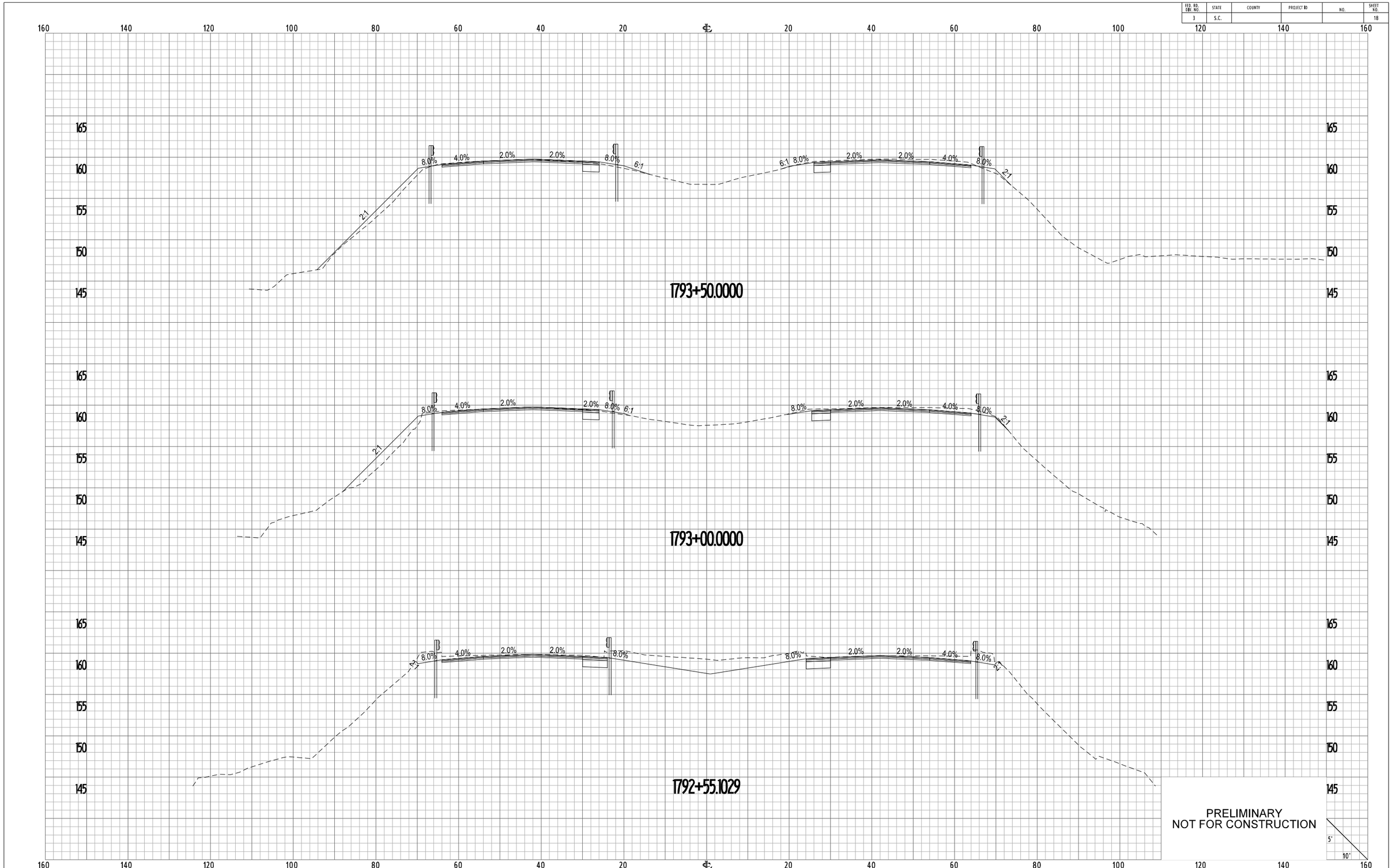
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

KERSHAW COUNTY
CONTRACT ID 2847360
I-20 OVER WATEREE RIVER
TWIN BRIDGES REPLACEMENT
PLAN SHEET

SCALE 1"=100' RTE. I-20 DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
3	S.C.				18



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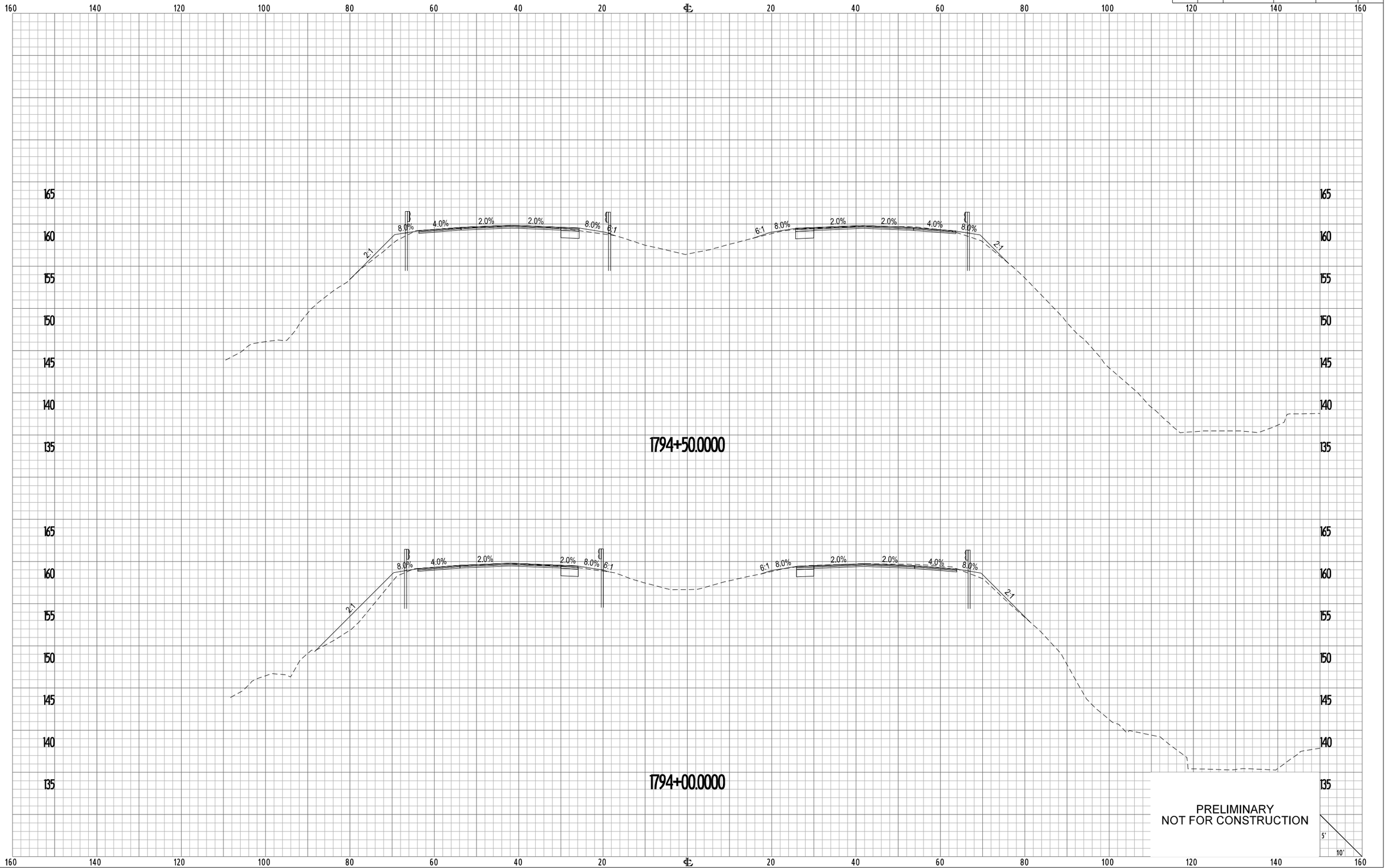
FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
3	S.C.				19



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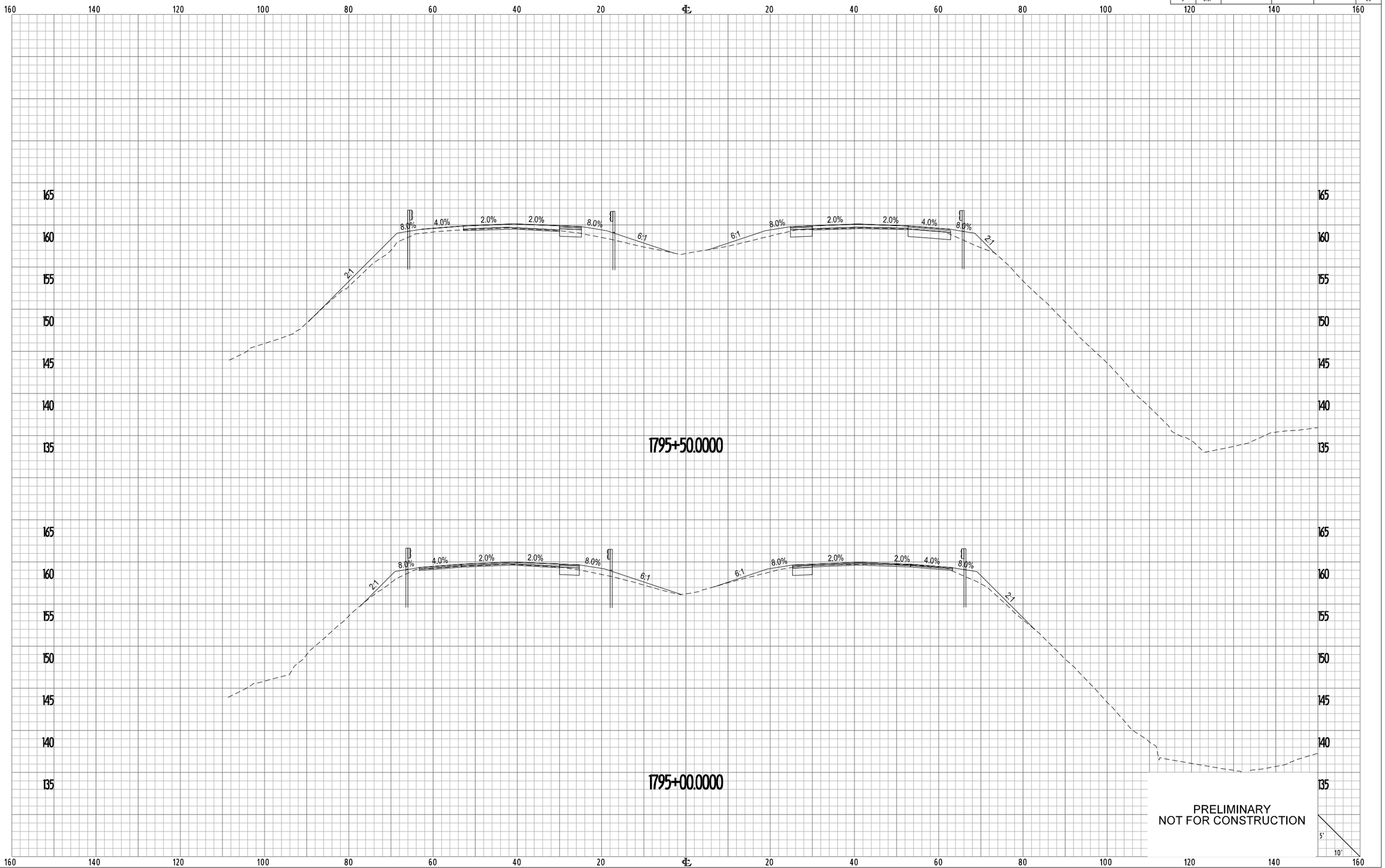
3	S.C.				20



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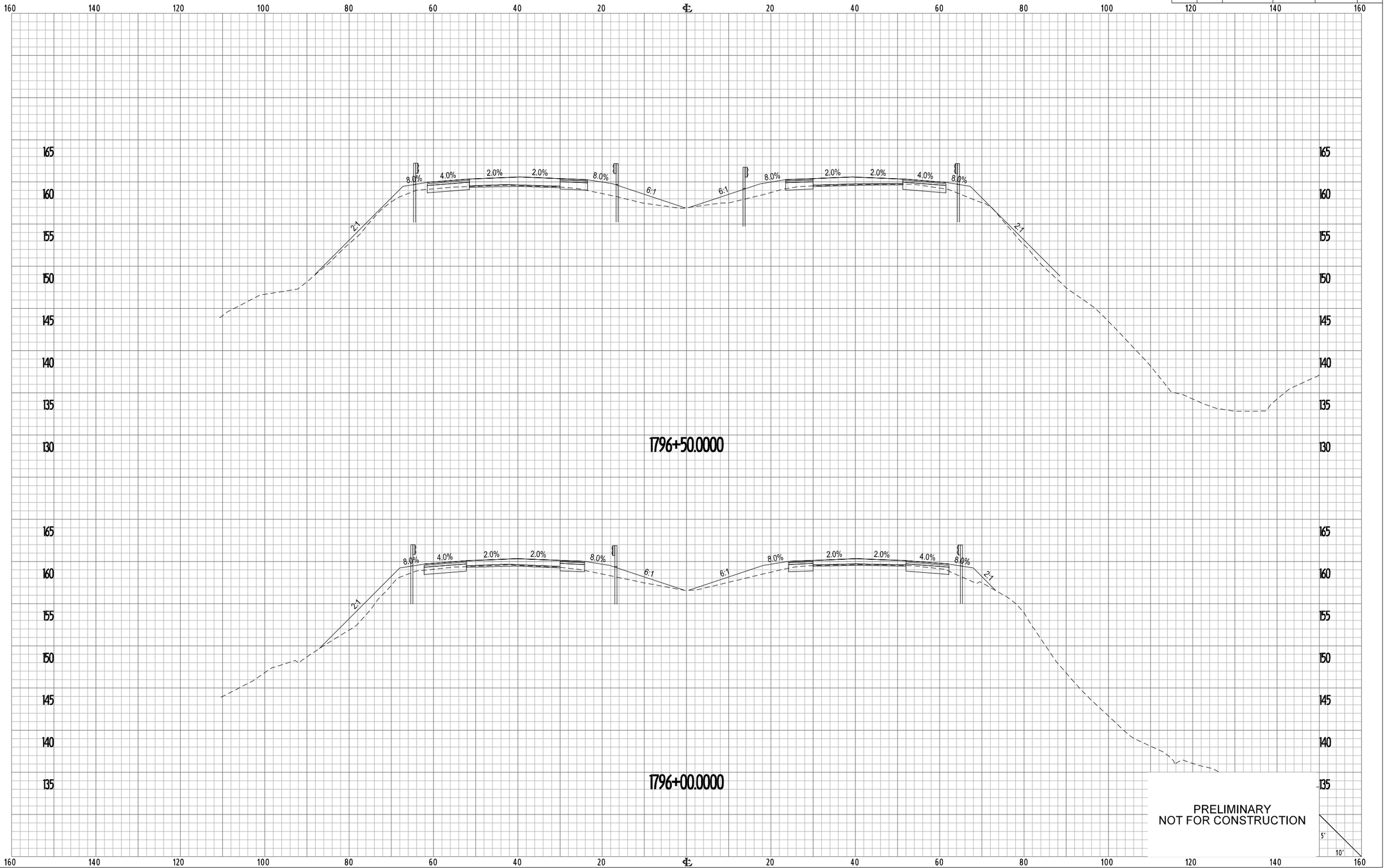
3	S.C.				21



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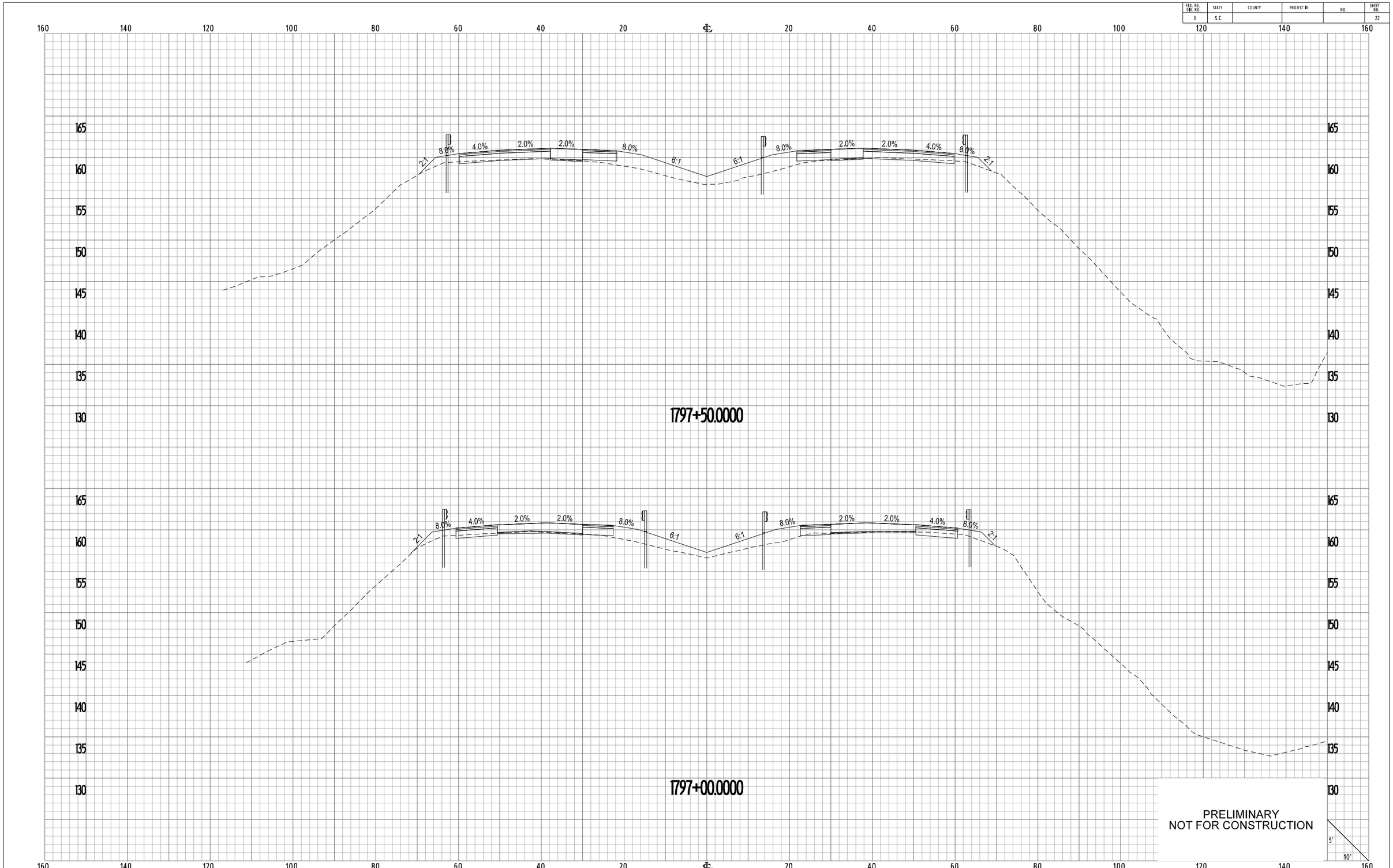

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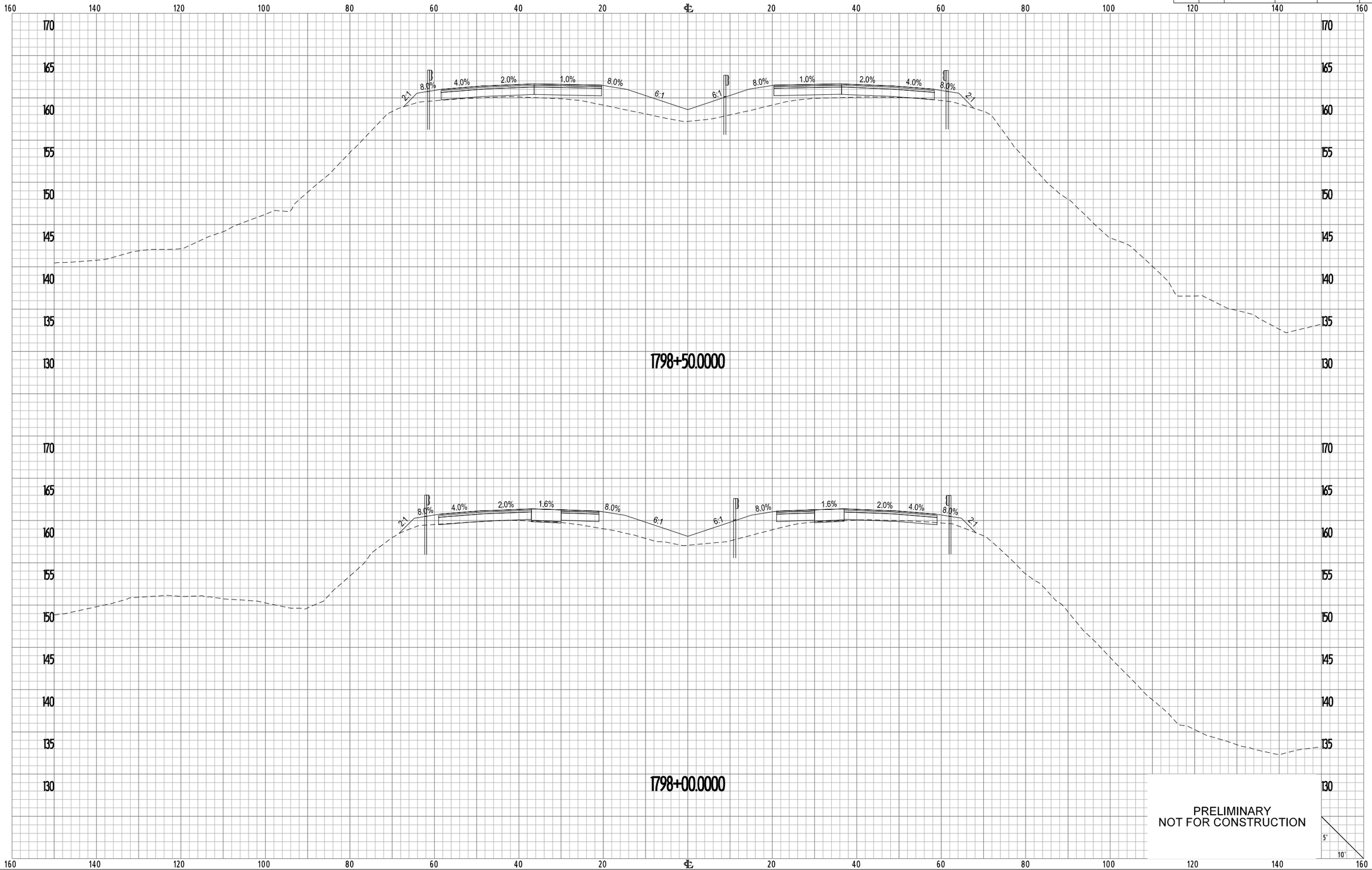
FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
3	S.C.				23



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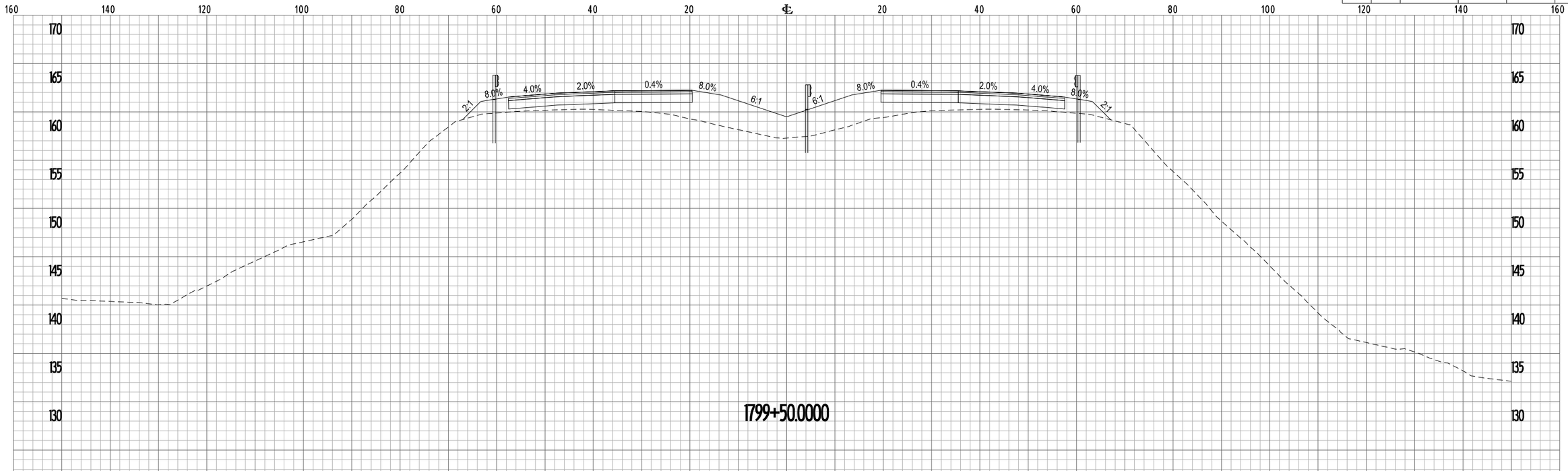
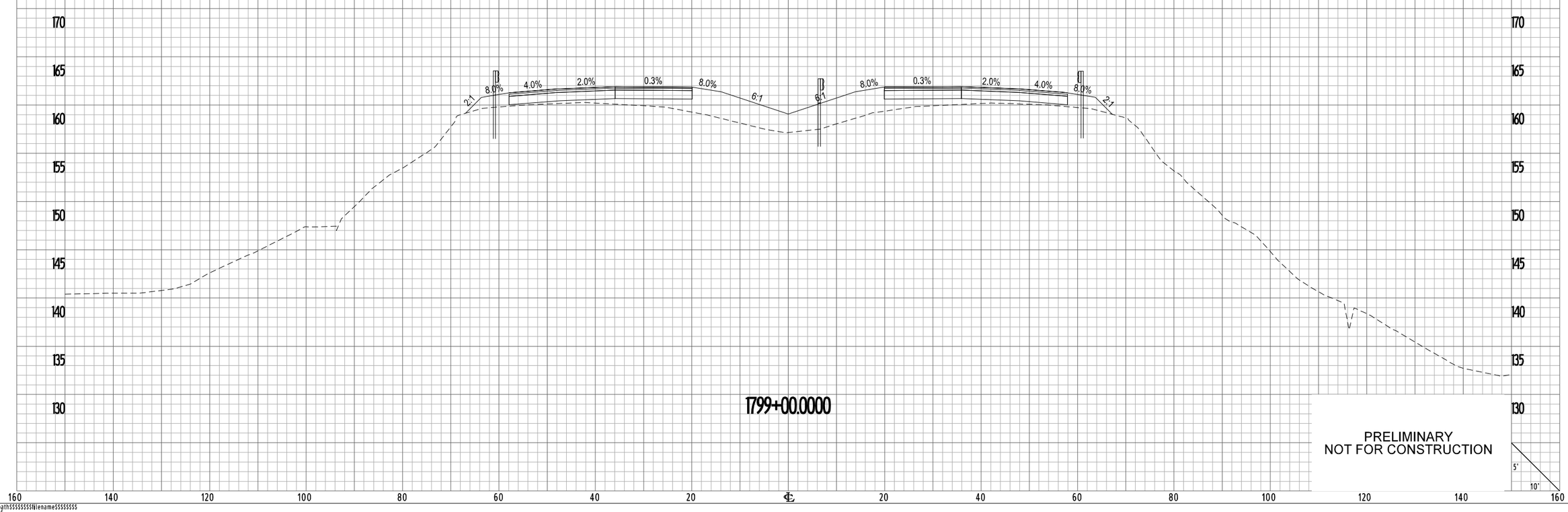
FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
3	S.C.				24





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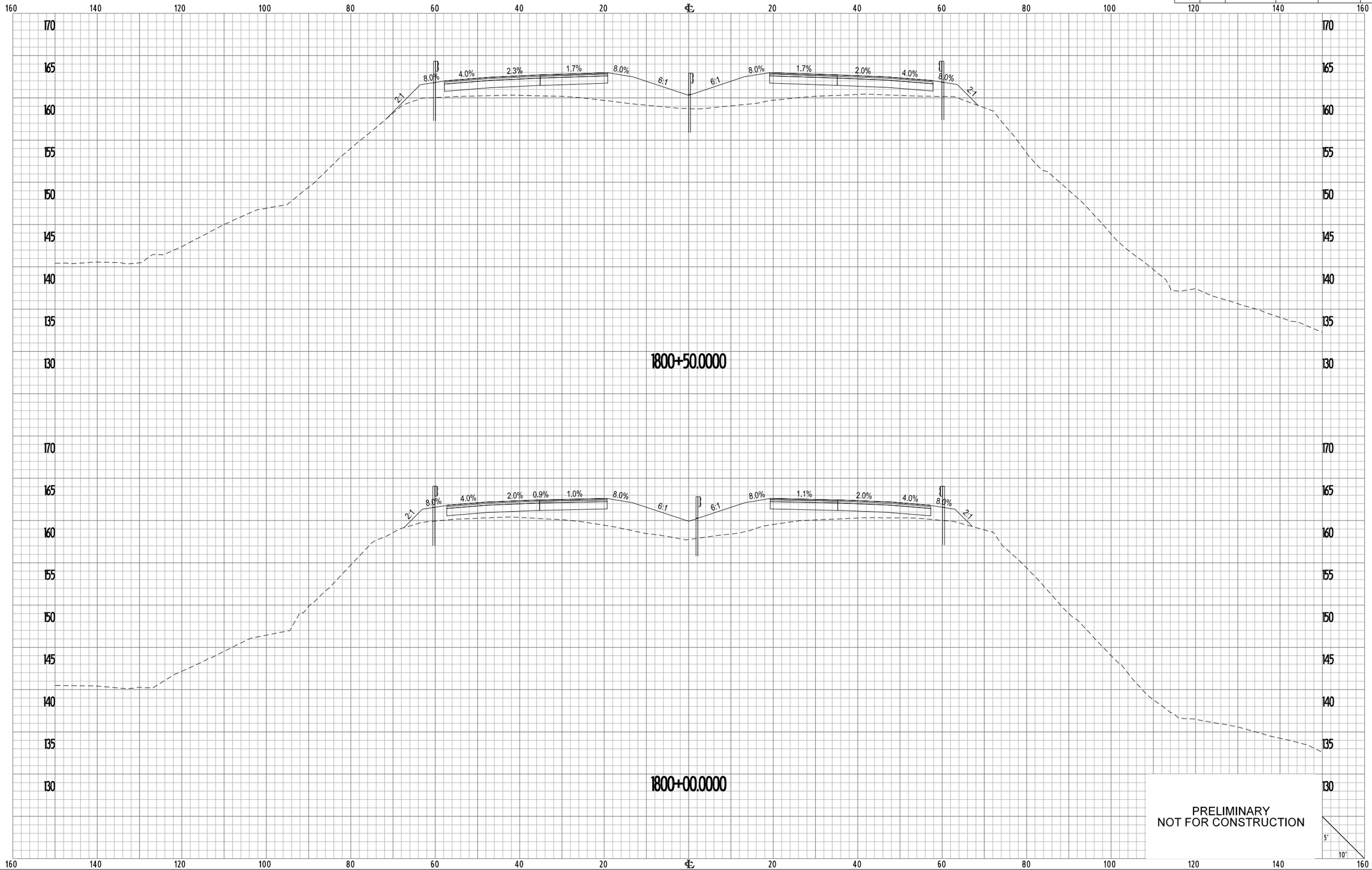

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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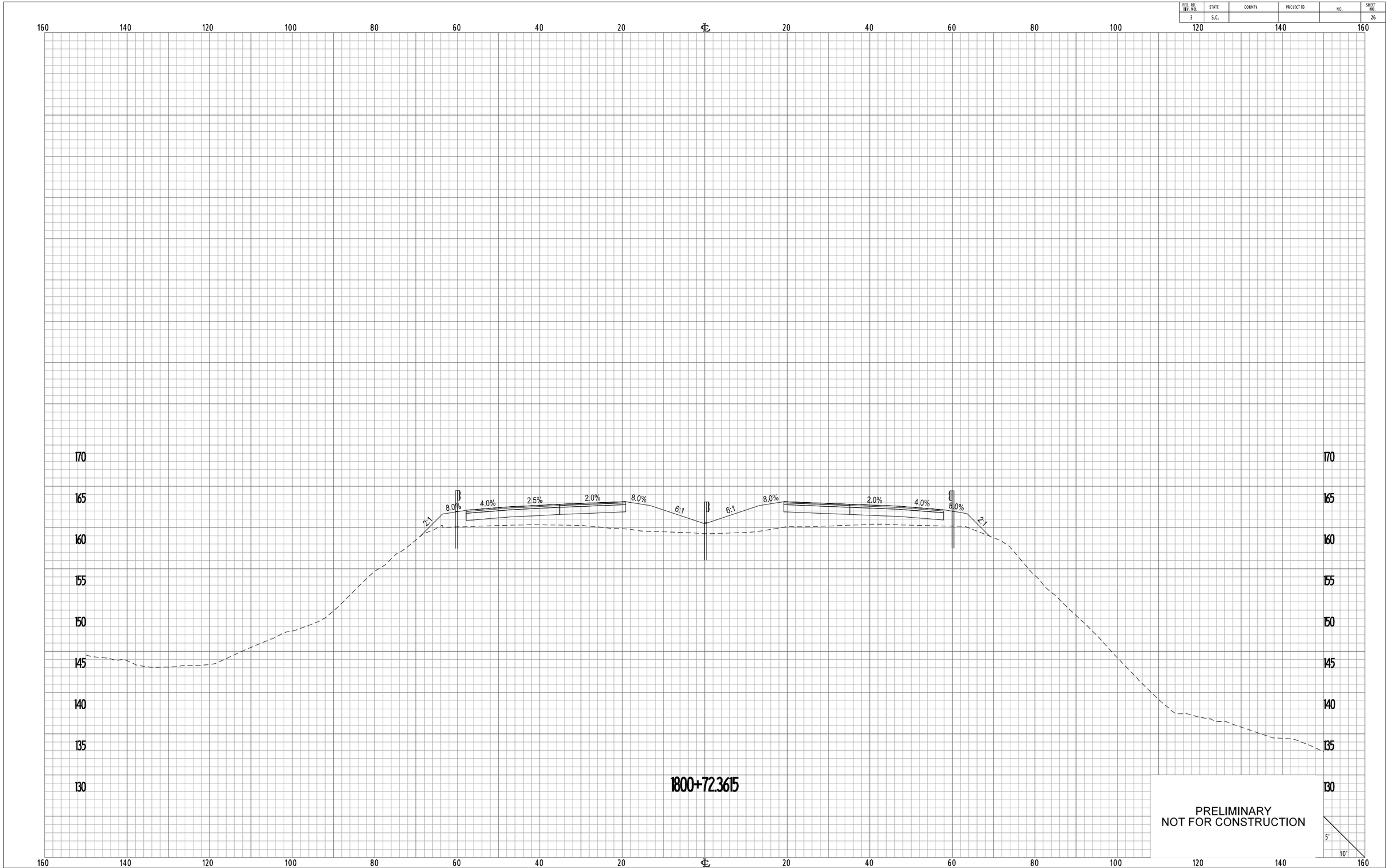

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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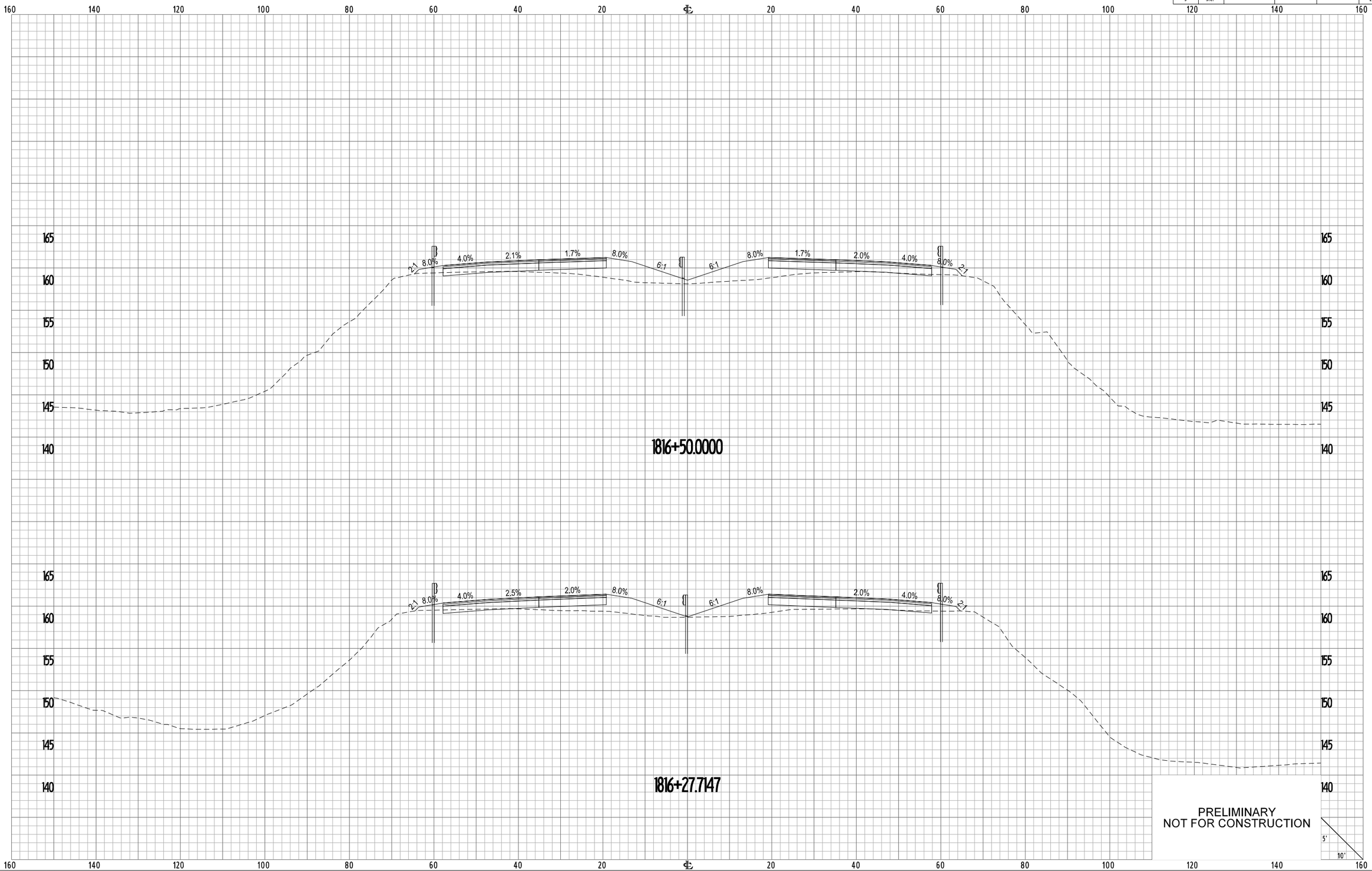

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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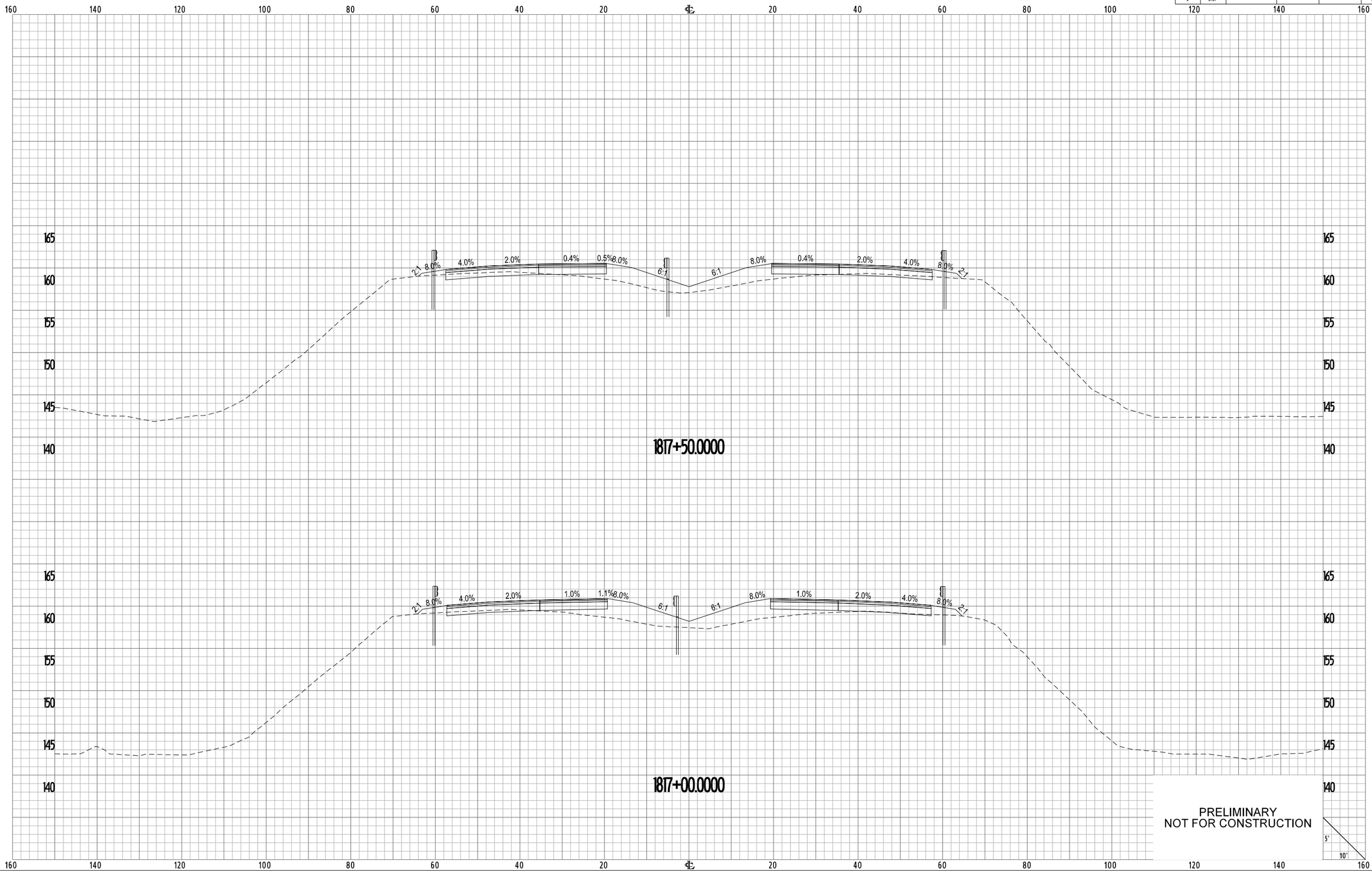

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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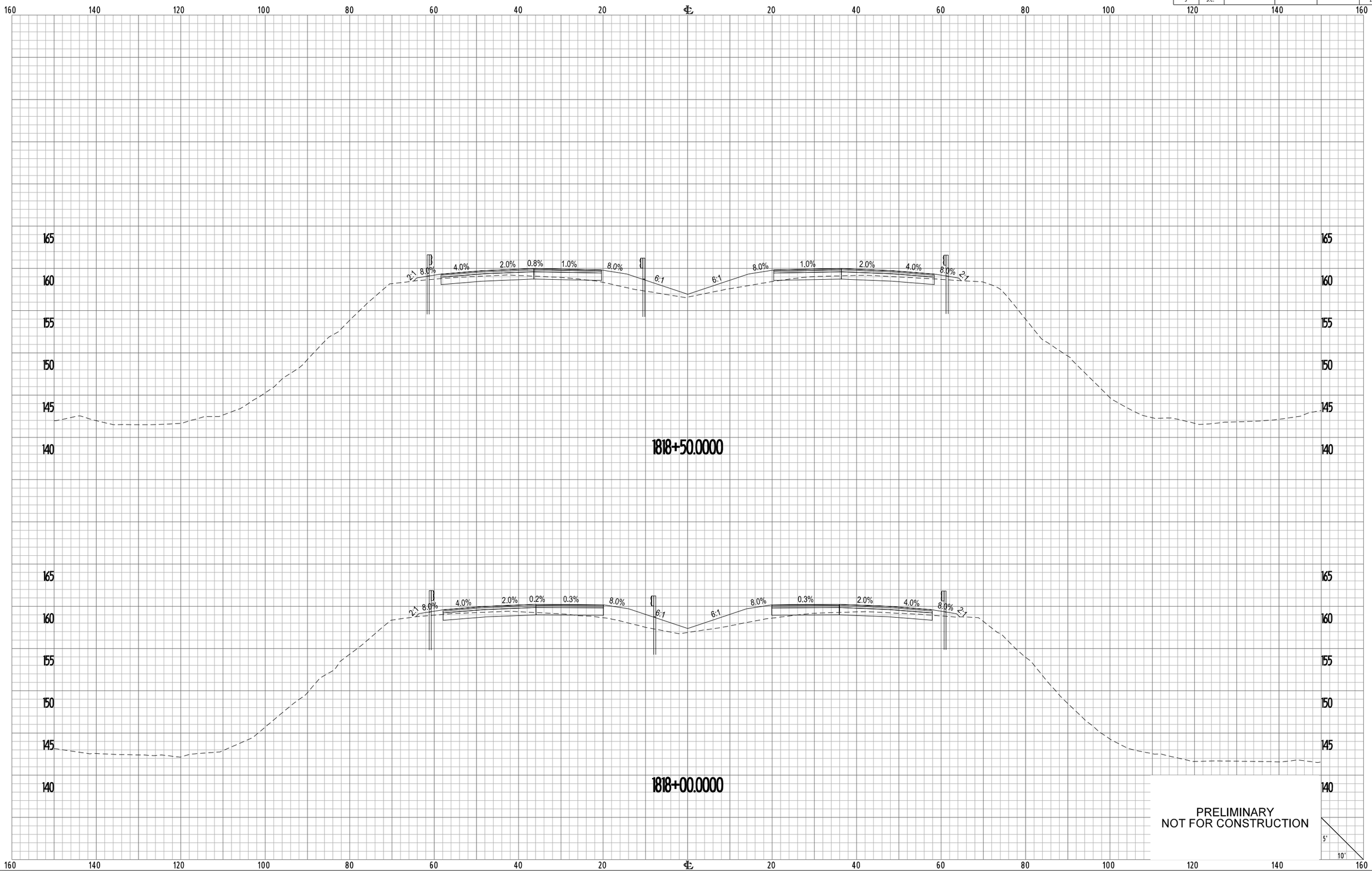

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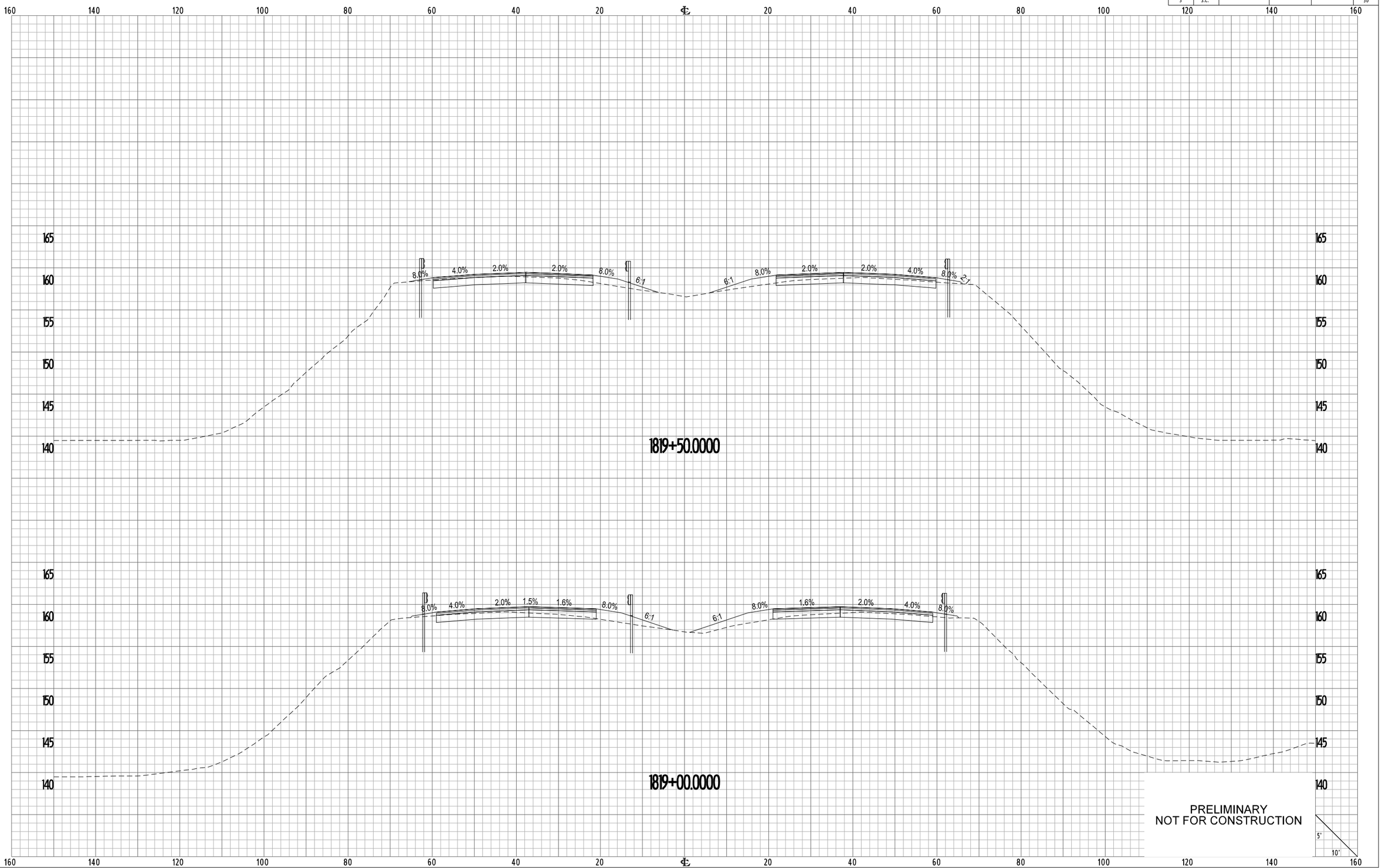

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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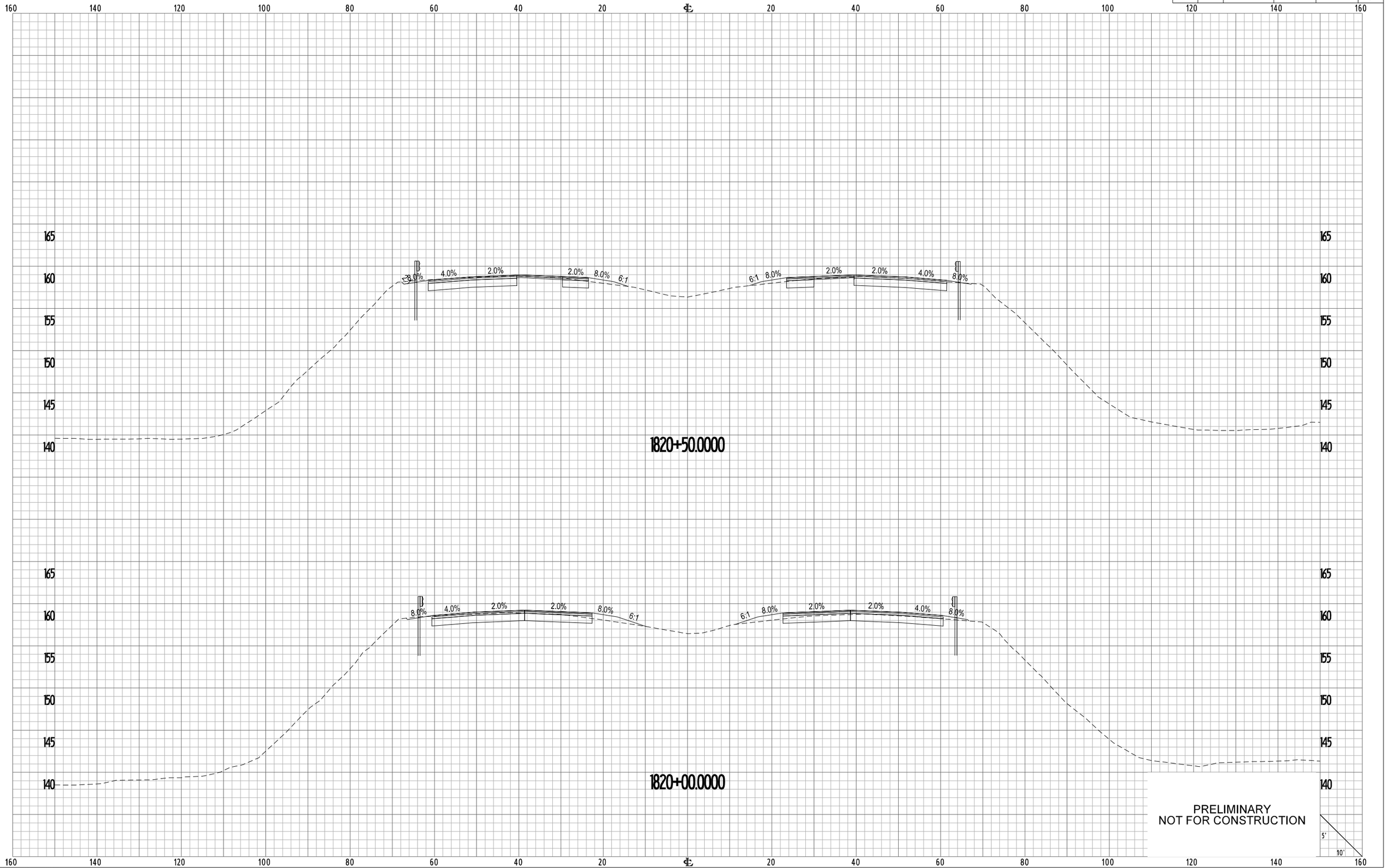

PRELIMINARY
NOT FOR CONSTRUCTION

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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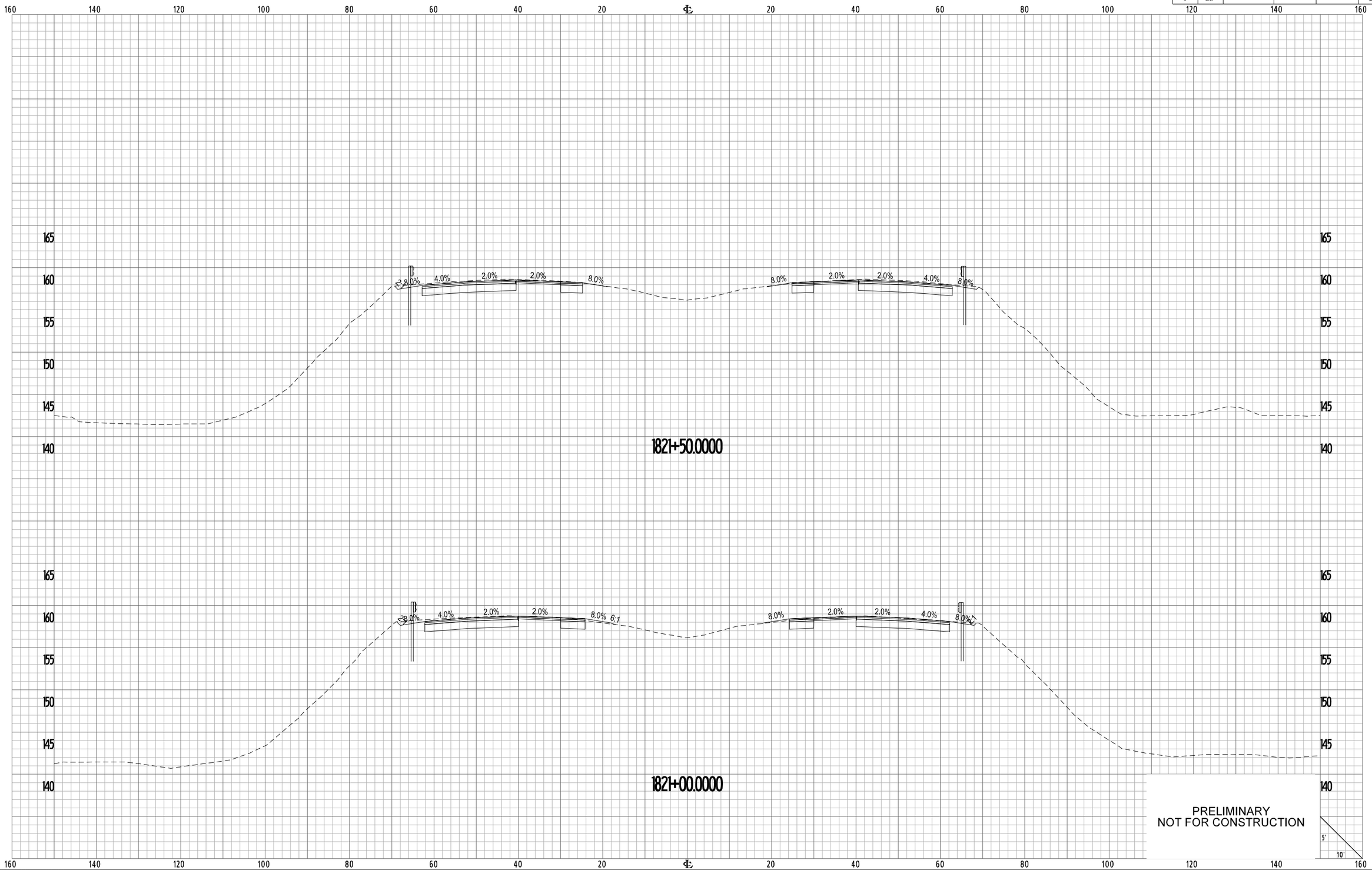

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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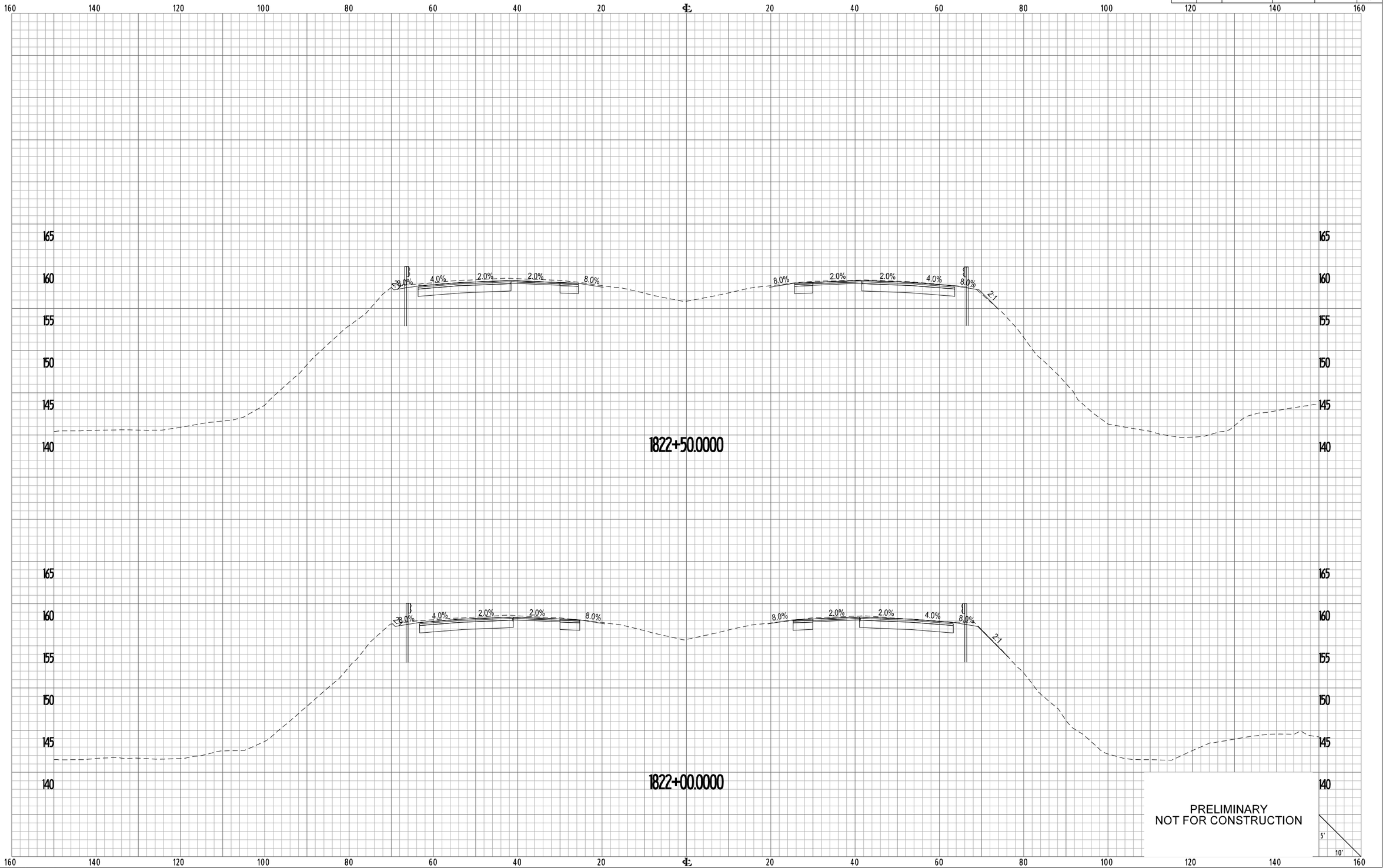

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FED. RD. DIV. NO.	STATE	COUNTY	PROJECT ID	NO.	SHEET NO.
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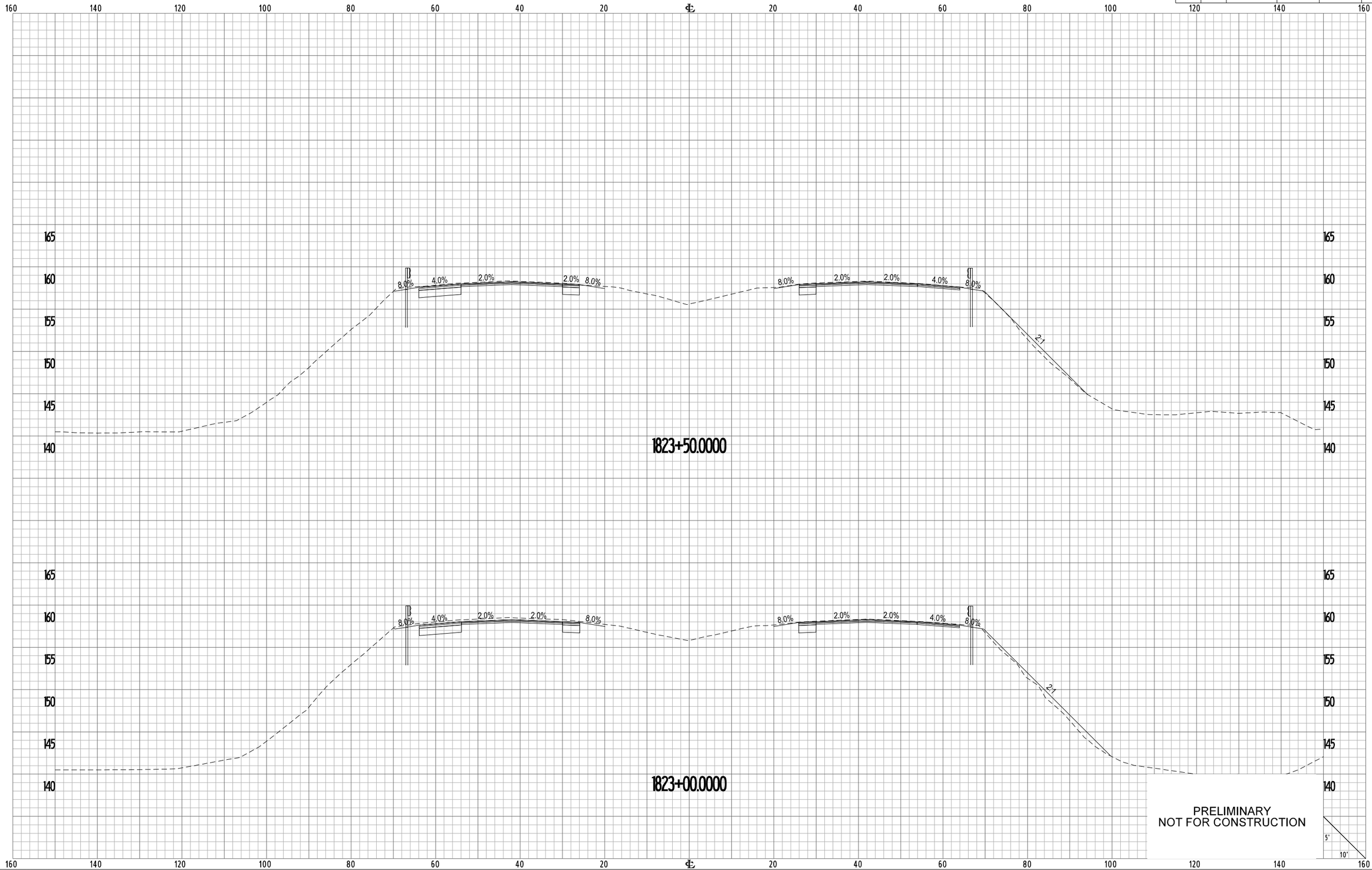

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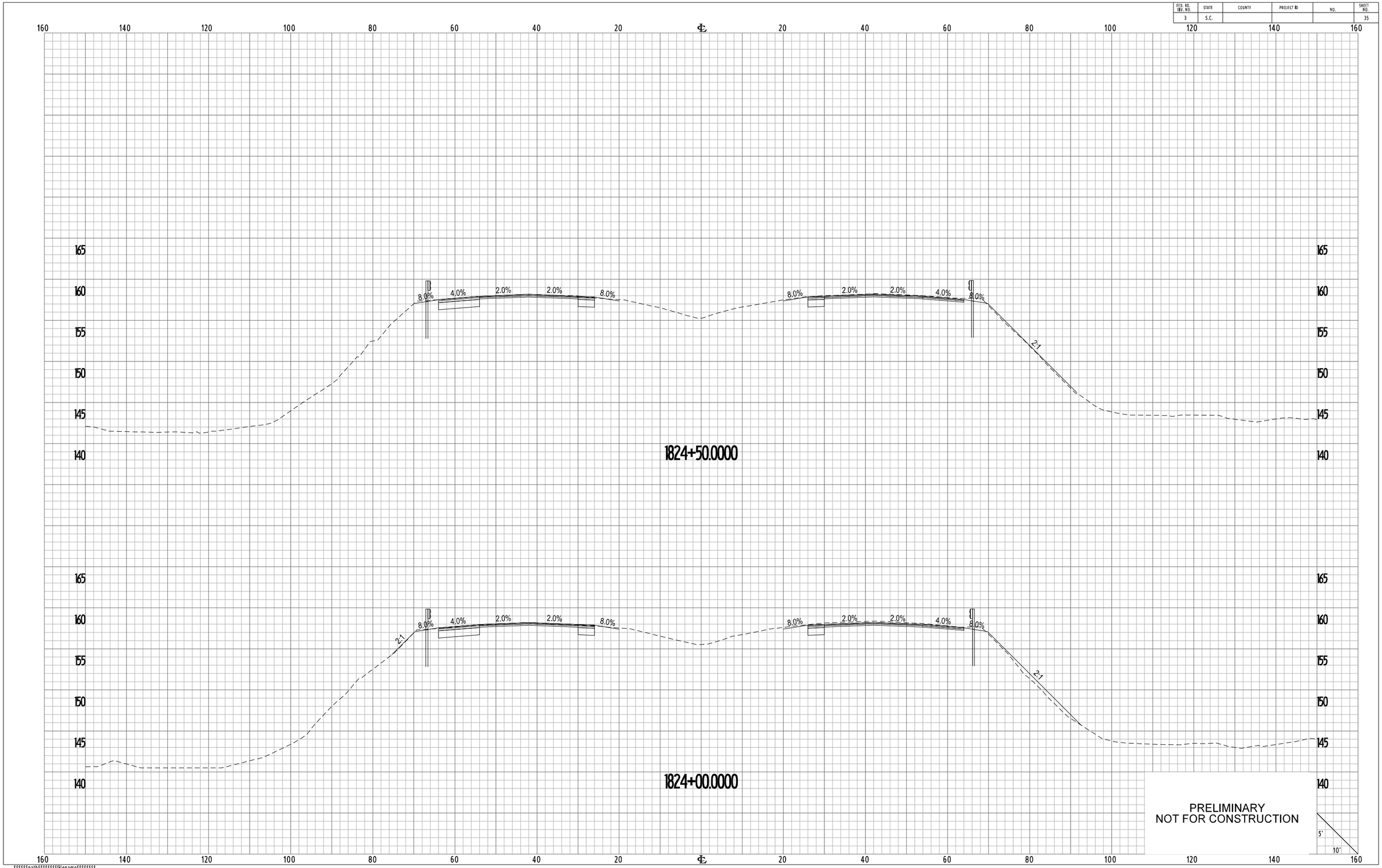

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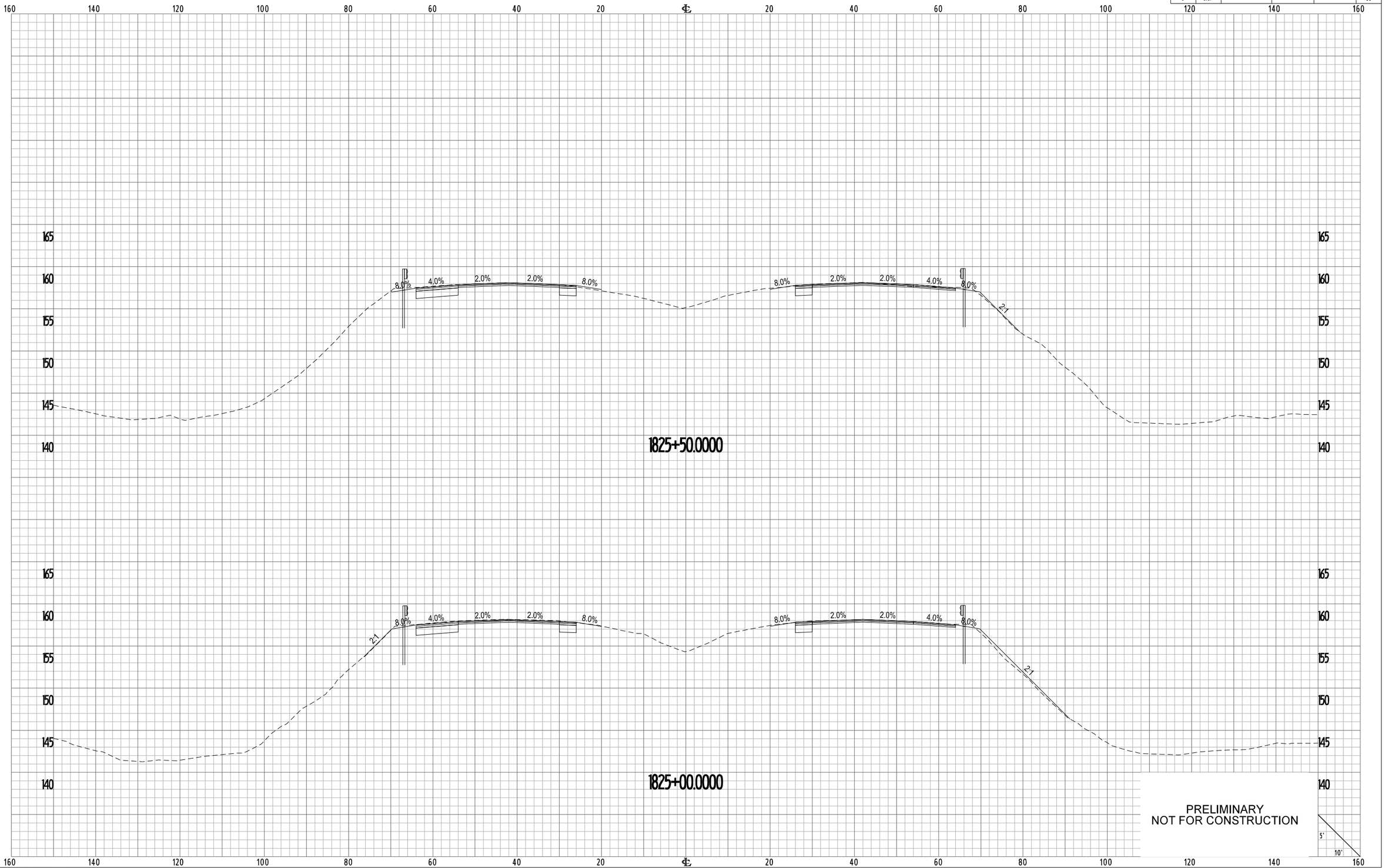

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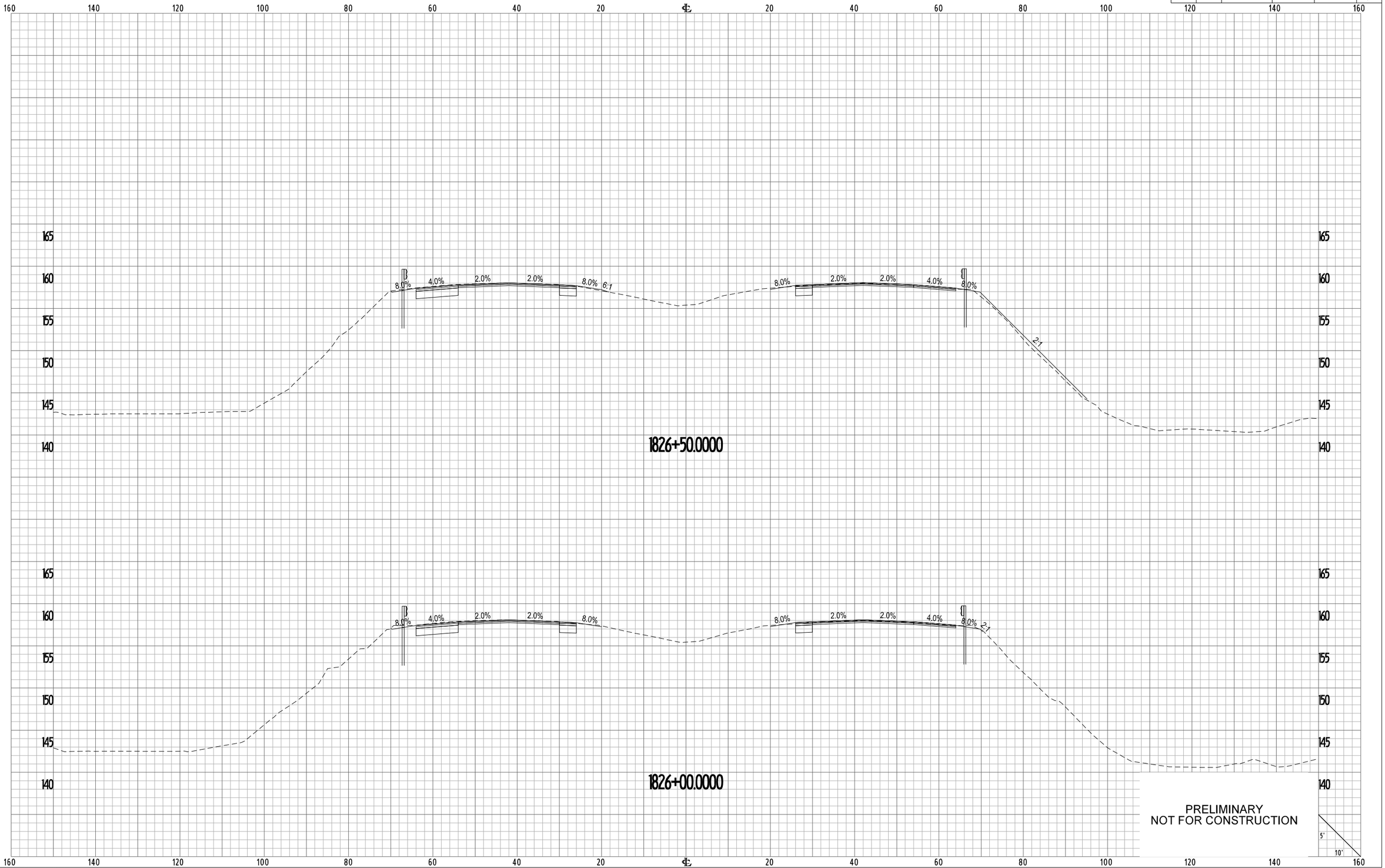
3	S.C.				37



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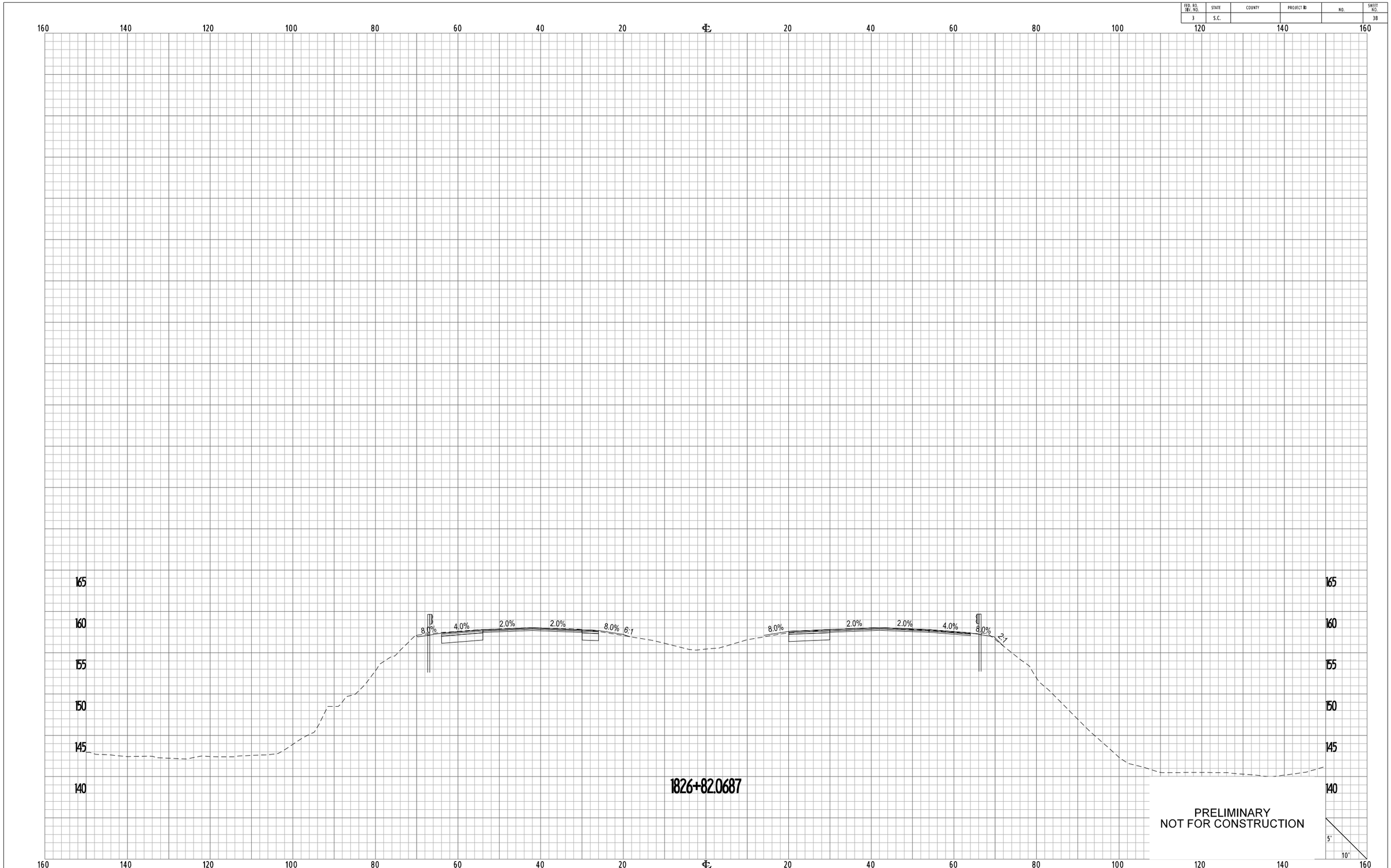

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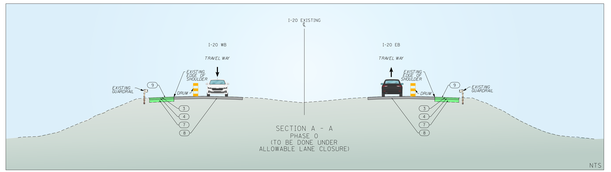
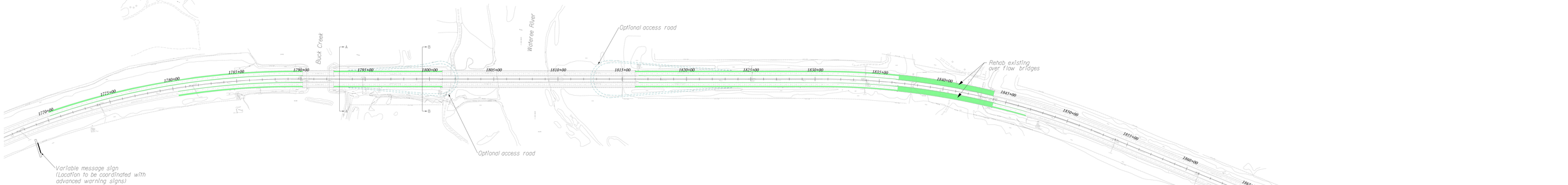
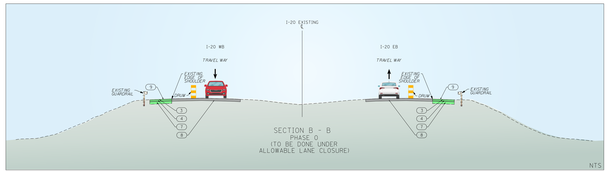
XLB_Sheet_10x5

A.2 – Maintenance of Traffic Plans and/or Documents







Narrative - Phase 0:

- Approximate duration: 6/3/2024 - 6/28/2024 (25 days)
- Full depth replacement of the inside and outside shoulders using the temporary pavement mix.
- Build optional construction access roads tied in to reconstructed shoulders or landowner access roads.
- Both of these activities are being done with no traffic shifts, only allowable lane closures.
- Over flow bridge rehab ongoing during allowable lane closures.

LEGEND

1. HOT MIX ASPHALT TYPE B FOR BUILDUP
2. HOT MIX ASPHALT TYPE 200 PSI SURFACE A
3. HOT MIX ASPHALT TYPE 200 PSI HMA SURFACE TYPE B (TEMP)
4. HOT MIX ASPHALT TYPE 300 PSI HMA INTERMEDIATE TYPE A (TEMP)
5. HOT MIX ASPHALT TYPE 400 PSI INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 150 PSI BASE A
7. HOT MIX ASPHALT TYPE 750 PSI BASE A (TEMP)
8. RETAIN EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

PHASE 0 CONSTRUCTION
DRUM
TEMPORARY CONCRETE BARRIER

0 100' 200' 400'
SCALE : 1" = 200'

Kiewit

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE 1" = 200'

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
5			
4			
3			
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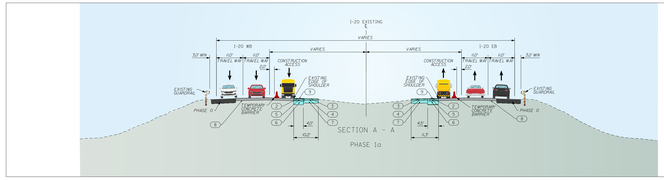
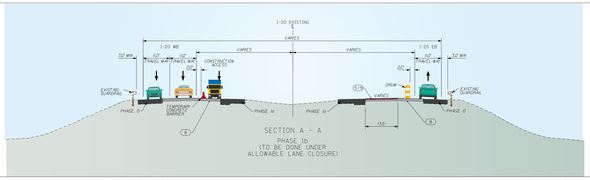
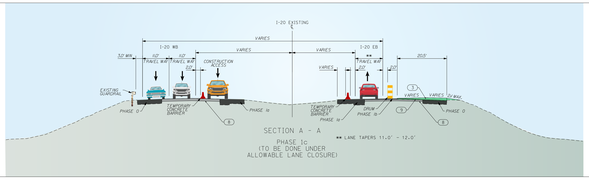
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.

WATEREE RIVER

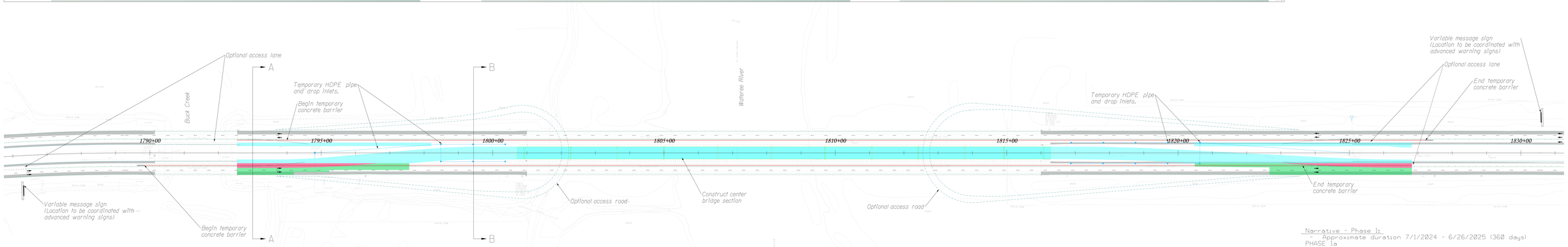
MOT I-20 PHASE 0 PLAN

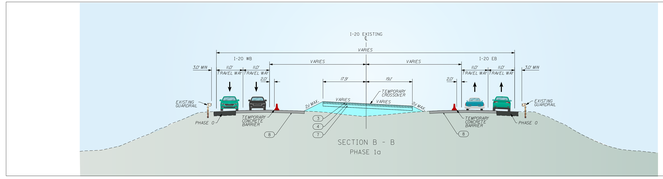


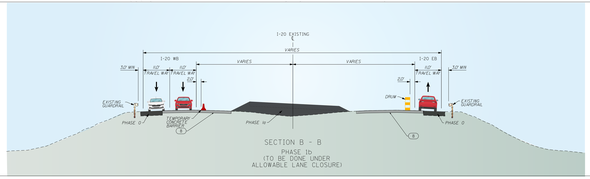


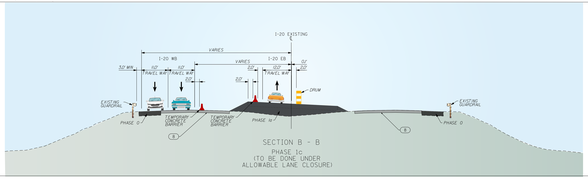


Note:
1. Phase 1a shown in plan view. Refer to cross sections and narrative for information about additional Phases.









Narrative - Phase 1:
- Approximate duration 7/1/2024 - 6/26/2025 (360 days)

PHASE 1a
- Traffic shift #1
- Both directions are restriped and shifted 9.5' to the outside.
- Allows for Mi-jack to be used for center bridge construction.
- Install temporary drainage HDPE pipe and drop inlets.
- Construct the center 36' of the Wateree six lane single structure.
- Girder delivery performed under allowable lane closures.
- Construct temporary asphalt in median at either end of the Wateree structure.

PHASE 1b
- Set allowable 90hr single lane closure.
- Close inside EB lane of I-20.
- Complete mill and overlay asphalt tie-in of crossover.

PHASE 1c
- Traffic shift #2
- Shift single EB lane onto inside lane of crossover.
- Traffic is now using asphalt crossover and traveling on the center segment of permanent Wateree structure.
- Complete asphalt build-up of crossover superelevation on existing surface.
- Open both EB lanes.
- Work to be completed during allowable 90hr single lane closure set in Phase 1b.

LEGEND
1. HOT MIX ASPHALT TYPE B FOR BUILDUP
2. HOT MIX ASPHALT TYPE 200 PSY SURFACE A
3. HOT MIX ASPHALT TYPE 200 PSY MAX SURFACE TYPE B
4. HOT MIX ASPHALT TYPE 300 PSY MAX INTERMEDIATE TYPE A
5. HOT MIX ASPHALT TYPE 400 PSY INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 150 PSY BASE A
7. HOT MIX ASPHALT TYPE 750 PSY BASE A
8. RETAIN EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

PHASE 1a CONSTRUCTION
PHASE 1b CONSTRUCTION
PHASE 1c CONSTRUCTION
PREVIOUS CONSTRUCTION

DRUM
TEMPORARY CONCRETE BARRIER

0 50' 100' 200'
SCALE : 1" = 100'

Kiewit

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE 1" = 100'

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
5			
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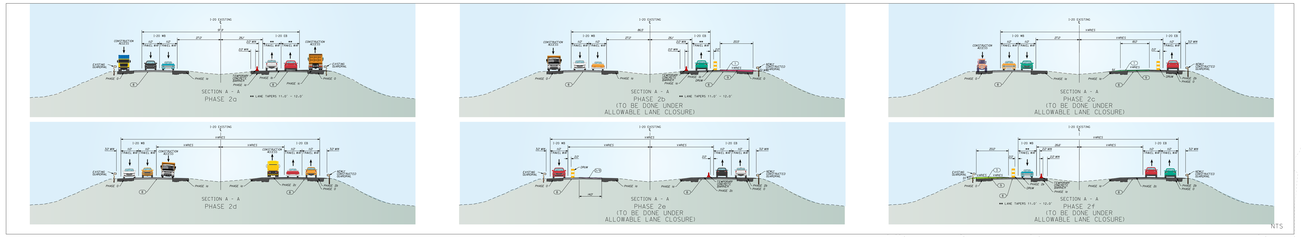
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.

WATEREE RIVER

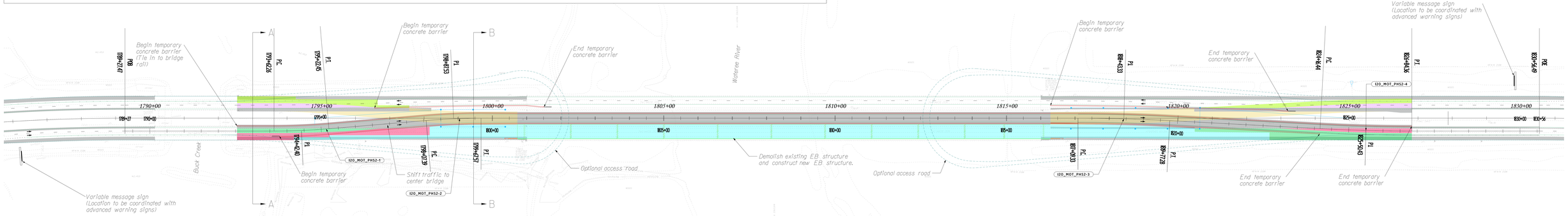
MOT I-20 PHASE 1 PLAN

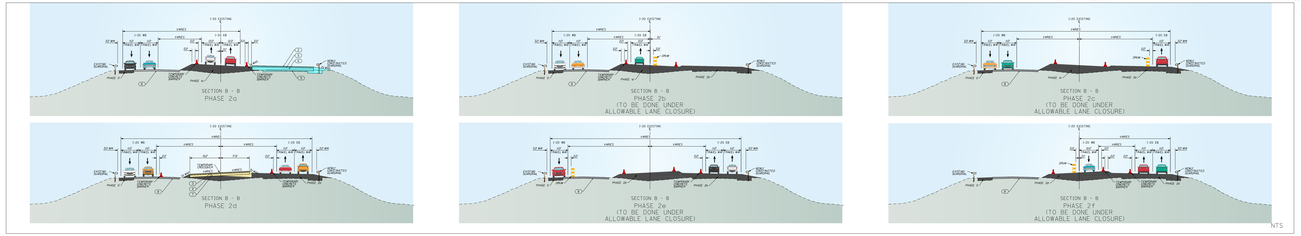


Note:
1. Phase 2a shown in plan view. Refer to cross sections and narrative for information about additional Phases.

I20_MOT_PHS2-1	I20_MOT_PHS2-2	I20_MOT_PHS2-3	I20_MOT_PHS2-4
P.I. = 1794+42.40	P.I. = 1798+87.53	P.I. = 1818+43.33	P.I. = 1825+50.43
Δ = 4° 49' 50" (LT)	Δ = 4° 49' 49" (RT)	Δ = 3° 02' 24" (RT)	Δ = 3° 02' 23" (LT)
D = 3° 00' 56"	D = 3° 00' 56"	D = 1° 08' 05"	D = 1° 08' 05"
T = 80.14'	T = 80.14'	T = 134.00'	T = 133.99'
L = 160.19'	L = 160.18'	L = 267.95'	L = 267.92'
E = 1.69'	E = 1.69'	E = 1.78'	E = 1.78'
R = 1,900.00'	R = 1,900.00'	R = 5,050.00'	R = 5,050.00'
D.S. = 70 MPH	D.S. = 70 MPH	D.S. = 70 MPH	D.S. = 70 MPH
eMAX = 8%	eMAX = 8%	eMAX = 8%	eMAX = 8%
e = 4%	e = 4%	e = 4%	e = 4%
P.C. - LG% = 33%	P.C. - LG% = 33%	P.C. - LG% = 50%	P.C. - LG% = 50%
P.T. - LG% = 33%	P.T. - LG% = 33%	P.T. - LG% = 50%	P.T. - LG% = 50%

N





Narrative - Phase 2:
- Approximate duration: 6/27/2025 - 7/28/2026 (396 days)

PHASE 2a
- Existing EB structure demolished.
- Construct remaining portion of EB Wateree structure.
- Construct full depth asphalt portions of permanent bridge approaches, with work occurring behind temporary concrete barrier.
- Complete outside permanent guardrail and grading.

PHASE 2b
- Close outside EB lane through crossover detour during allowable 90hr closure.
- Complete mill and overlay operations of approach tie ins for outside lane.

PHASE 2c
- Traffic shift #3
- Shift EB single lane traffic to outside lane, it is now traveling on permanently constructed EB Wateree structure and permanent asphalt approaches.
- Complete mill and overlay operations to tie in the inside permanent lane.
- Work to be completed during allowable 90hr single lane closure set in Phase 2b.

Cont.

PHASE 2d
- Rebuild center median crossover asphalt to accommodate Stage 3 WB superelevation.
- Work to be completed behind temporary concrete barrier.

PHASE 2e
- Close inside WB lane through crossover detour during allowable 69 hr closure.
- Complete mill and overlay operations of approach tie ins for inside lane.

PHASE 2f
- Traffic shift #4
- Shift WB single lane traffic onto inside lane of crossover.
- WB traffic is now on temporary crossover and the permanently constructed center segment of the Wateree structure.
- Complete asphalt buildup for superelevation to tie in Stage 3 temporary crossover.
- Work to be completed during allowable 69hr single lane closure set in Phase 2e.

LEGEND
1. HOT MIX ASPHALT TYPE B FOR BUILDUP
2. HOT MIX ASPHALT TYPE 200 PSI SURFACE A
3. HOT MIX ASPHALT TYPE 200 PSI HMA SURFACE TYPE B (ITEM9)
4. HOT MIX ASPHALT TYPE 300 PSI HMA INTERMEDIATE TYPE A (ITEM9)
5. HOT MIX ASPHALT TYPE 400 PSI INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 150 PSI BASE A
7. HOT MIX ASPHALT TYPE 750 PSI BASE A (ITEM9)
8. RETAIN EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

PHASE 2a CONSTRUCTION
PHASE 2b CONSTRUCTION
PHASE 2c CONSTRUCTION
PHASE 2d CONSTRUCTION
PHASE 2e CONSTRUCTION
PHASE 2f CONSTRUCTION
PREVIOUS CONSTRUCTION

DRUM
TEMPORARY CONCRETE BARRIER

0 50' 100' 200'
SCALE : 1" = 100'

Kiewit

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE 1" = 100'

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
5			
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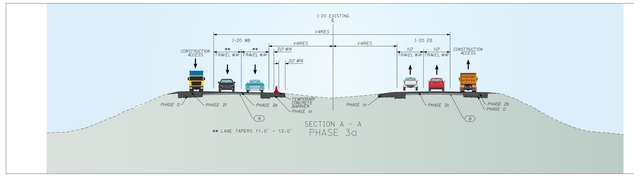
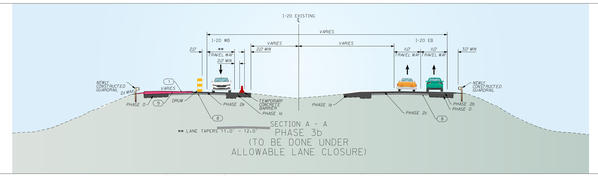
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.

WATEREE RIVER

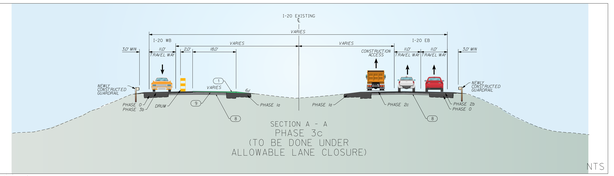
MOT I-20 PHASE 2 PLAN



SECTION A - A
PHASE 3a



SECTION A - A
PHASE 3b
(TO BE DONE UNDER
ALLOWABLE LANE CLOSURE)

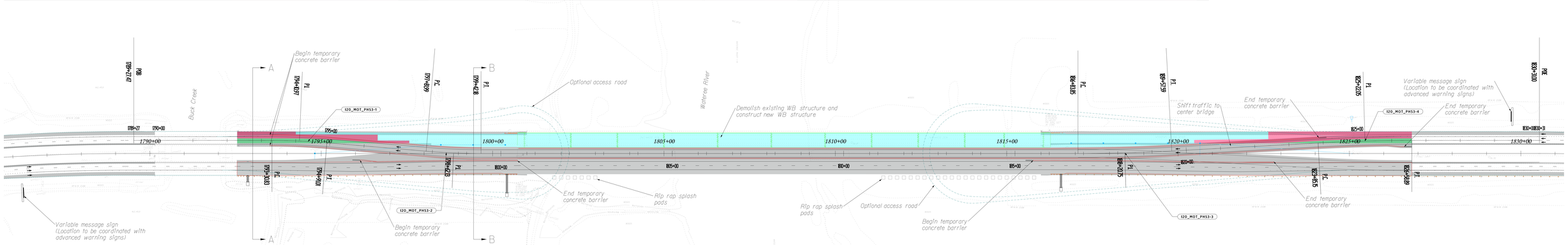


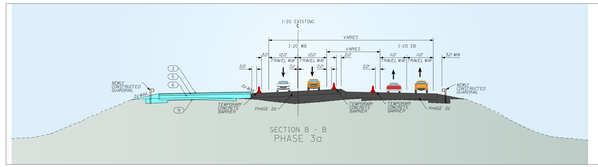
SECTION A - A
PHASE 3c
(TO BE DONE UNDER
ALLOWABLE LANE CLOSURE)

NTS

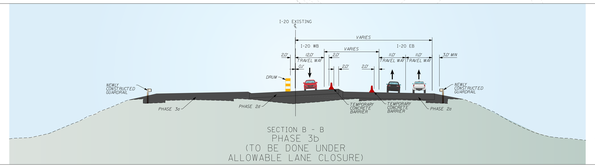
I20_MOT_PHS3-1	I20_MOT_PHS3-2	I20_MOT_PHS3-3	I20_MOT_PHS3-4
P.I. = 1794+10.97	P.I. = 1798+62.13	P.I. = 1818+20.75	P.I. = 1825+22.05
Δ = 4° 49' 50" (RT)	Δ = 4° 49' 49" (LT)	Δ = 3° 06' 21" (LT)	Δ = 3° 06' 20" (LT)
D = 3° 00' 56"	D = 3° 00' 56"	D = 1° 08' 04"	D = 1° 08' 04"
T = 80.14'	T = 80.14'	T = 136.90'	T = 136.90'
L = 160.19'	L = 160.14'	L = 273.74'	L = 273.74'
E = 1.69'	E = 1.69'	E = 1.86'	E = 1.86'
R = 1,900.00'	R = 1,900.00'	R = 5,050.00'	R = 5,050.00'
D.S. = 60 MPH	D.S. = 60 MPH	D.S. = 70 MPH	D.S. = 70 MPH
eMAX = 8%	eMAX = 8%	eMAX = 8%	eMAX = 8%
e = 4%	e = 4%	e = 4%	e = 4%
P.C. - LG% = 33%	P.C. - LG% = 33%	P.C. - LG% = 50%	P.C. - LG% = 50%
P.T. - LG% = 33%	P.T. - LG% = 33%	P.T. - LG% = 50%	P.T. - LG% = 50%

N

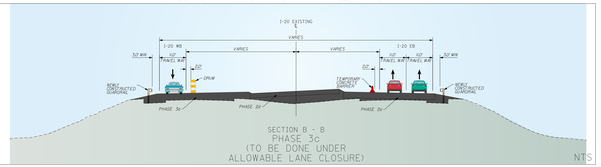




SECTION B - B
PHASE 3a



SECTION B - B
PHASE 3b
(TO BE DONE UNDER
ALLOWABLE LANE CLOSURE)



SECTION B - B
PHASE 3c
(TO BE DONE UNDER
ALLOWABLE LANE CLOSURE)

NTS

Narrative - Phase 3:
Approximate duration: 7/29/2026 - 9/13/2027 (411 days)

PHASE 3a
- Existing WB structure demolished.
- Construct remaining portion of WB direction of the Wateree structure.
- Construct full depth asphalt portions of permanent bridge approaches.
- This work occurs behind TCB.
- Complete outside permanent guardrail and grading.

PHASE 3b
- Close outside EB lane through crossover detour during allowable 69 hr closure.
- Complete mill and overlay operations of approach tie ins for outside lane.
- This occurs on both ends of Wateree structure.

PHASE 3c
- Traffic shift #5
- Shift WB traffic to outside lane.
- Traffic is now traveling on permanently constructed WB Wateree structure and asphalt approaches.
- Complete mill and overlay operations to tie in the inside permanent lane.
- Work to be completed during allowable 69hr single lane closure set in Phase 3b.

Note:
1. Phase 3a shown in plan view. Refer to cross sections and narrative for information about additional Phases.

LEGEND
1. HOT MIX ASPHALT TYPE B FOR BUILDUP
2. HOT MIX ASPHALT TYPE 200 PSI SURFACE A
3. HOT MIX ASPHALT TYPE 200 PSI HMA SURFACE TYPE B (TEMP)
4. HOT MIX ASPHALT TYPE 300 PSI HMA INTERMEDIATE TYPE A (TEMP)
5. HOT MIX ASPHALT TYPE 400 PSI INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 150 PSI BASE A
7. HOT MIX ASPHALT TYPE 750 PSI BASE A (TEMP)
8. REPAIR EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

PHASE 3a CONSTRUCTION
PHASE 3b CONSTRUCTION
PHASE 3c CONSTRUCTION
PREVIOUS CONSTRUCTION

DR DRUM
TCB TEMPORARY CONCRETE BARRIER

0 50' 100' 200'
SCALE : 1" = 100'

Kiewit

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE 1" = 100'

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
5			
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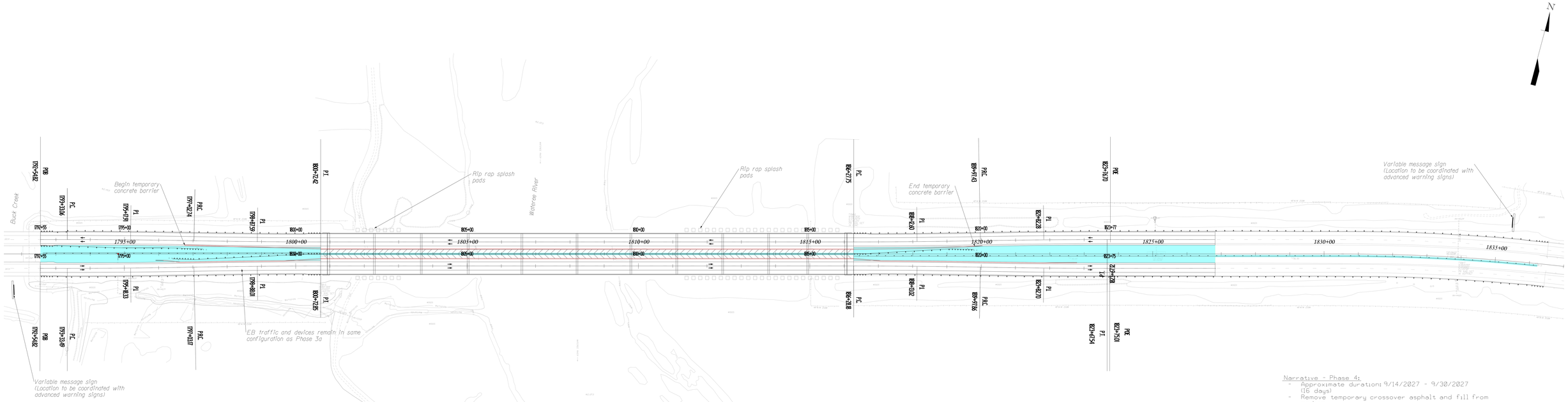
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
COLUMBIA, S.C.

WATEREE RIVER

MOT I-20 PHASE 3 PLAN



Narrative - Phase 4:

- Approximate duration: 9/14/2027 - 9/30/2027 (16 days)
- Remove temporary crossover asphalt and fill from median.
- Construct permanent centerline concrete barrier on Wateree structure.
- Complete various grinding and grooving operations using allowable single lane closures.
- Complete permanent guardrail and final grading in median.
- Complete deck repairs from pinned temporary concrete barrier using allowable single lane closures.
- Final temporary pavement removals to be completed under allowable single lane closures after permanent guardrail and barrier rail is in place and devices are removed.

LEGEND

1. HOT MIX ASPHALT TYPE B FOR BUILDUP.
2. HOT MIX ASPHALT TYPE 200 PSI SURFACE A.
3. HOT MIX ASPHALT TYPE 200 PSI HMA SURFACE TYPE B (TEMP).
4. HOT MIX ASPHALT TYPE 300 PSI HMA INTERMEDIATE TYPE A (TEMP).
5. HOT MIX ASPHALT TYPE 400 PSI INTERMEDIATE B
6. HOT MIX ASPHALT TYPE 100 PSI BASE A
7. HOT MIX ASPHALT TYPE 750 PSI BASE A (TEMP)
8. RETAIN EXISTING PAVEMENT
9. REMOVE EXISTING PAVEMENT

PHASE 4 CONSTRUCTION

0 50' 100' 200'

SCALE : 1" = 100'

Kiewit

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE 1" =100

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
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SOUTH CAROLINA
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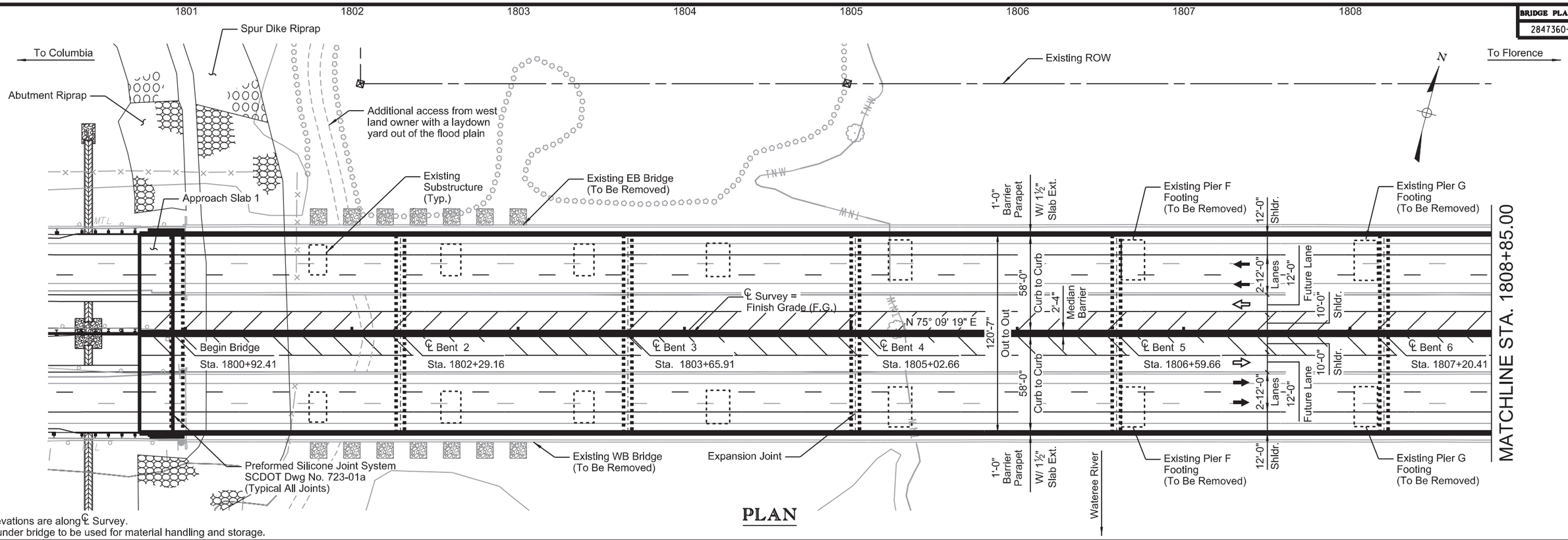
COLUMBIA, S.C.

WATEREE RIVER

I-20 PHASE 4

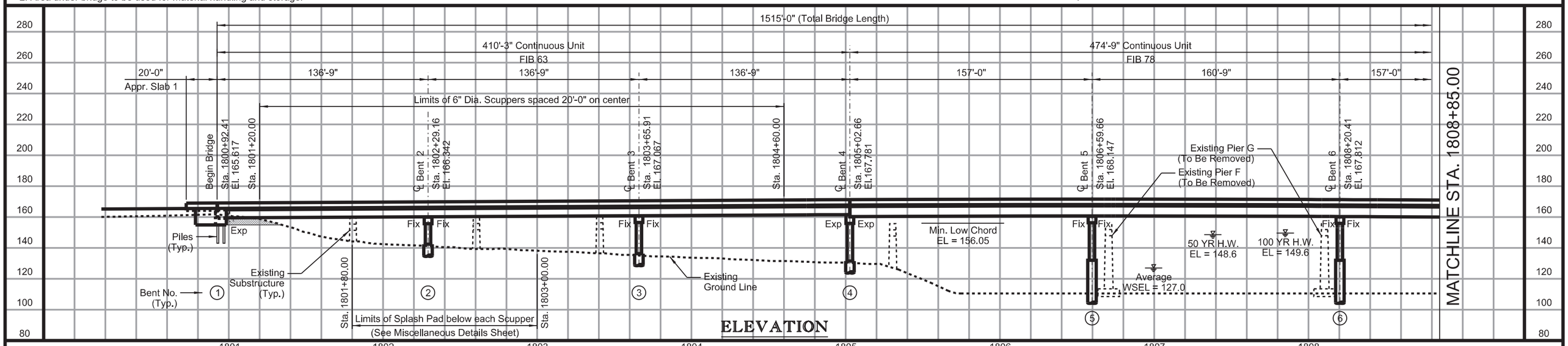
A.3 – Bridge Plans

BRIDGE PLANS ID	SHEET NO.
2847360-B1	1



PLAN

Notes:
1. All Elevations are along ℄ Survey.
2. Area under bridge to be used for material handling and storage.



ELEVATION

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

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REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

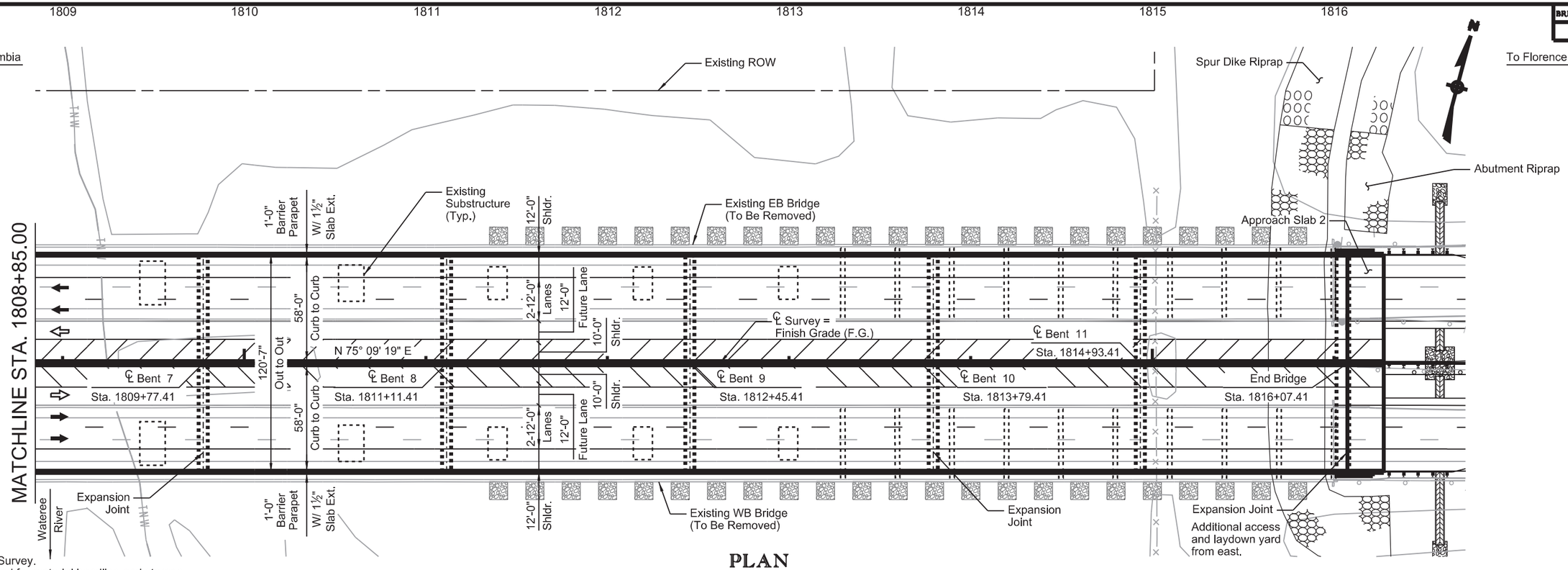
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

PLAN AND PROFILE
(1 OF 2)

REPLACE I-20 OVER WATEREE RIVER

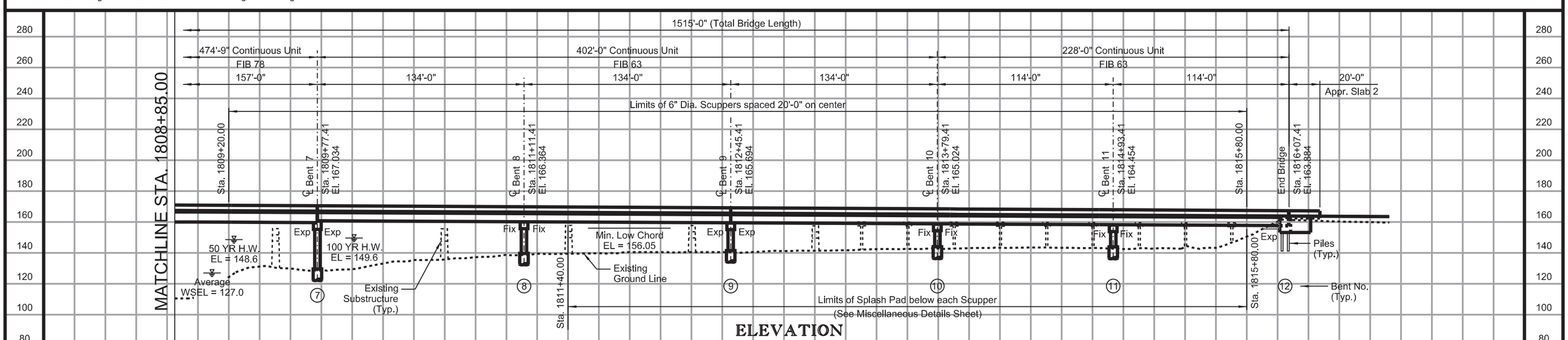
COUNTY	ROUTE
KERSHAW	I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	2



Notes:
1. All Elevations are along ℄ Survey.
2. Area under bridge to be used for material handling and storage.

PLAN



ELEVATION

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

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REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

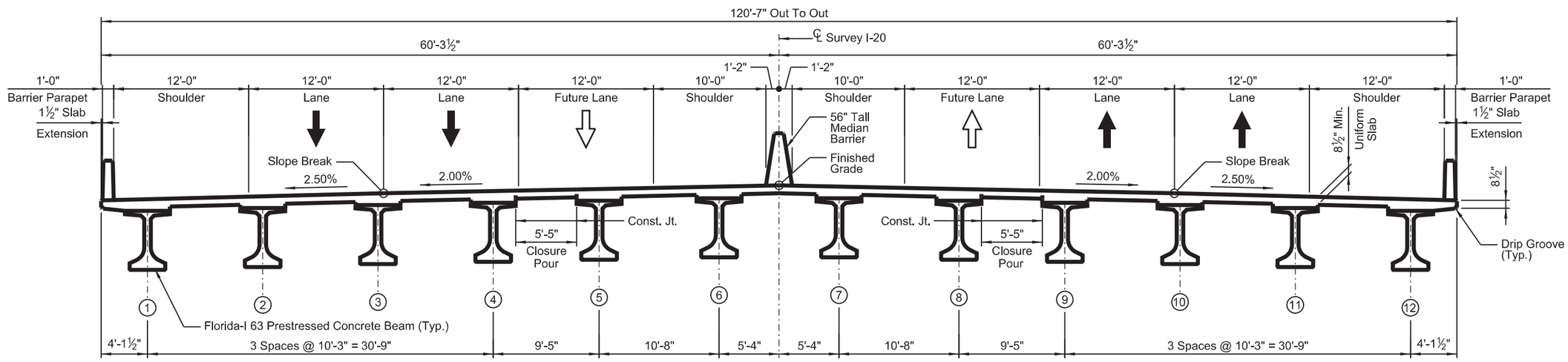
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

PLAN AND PROFILE
(2 OF 2)

REPLACE I-20 OVER WATEREE RIVER

COUNTY: KERSHAW
ROUTE: I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	3



TYPICAL SECTION

(Looking in the direction of stationing)

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

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QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

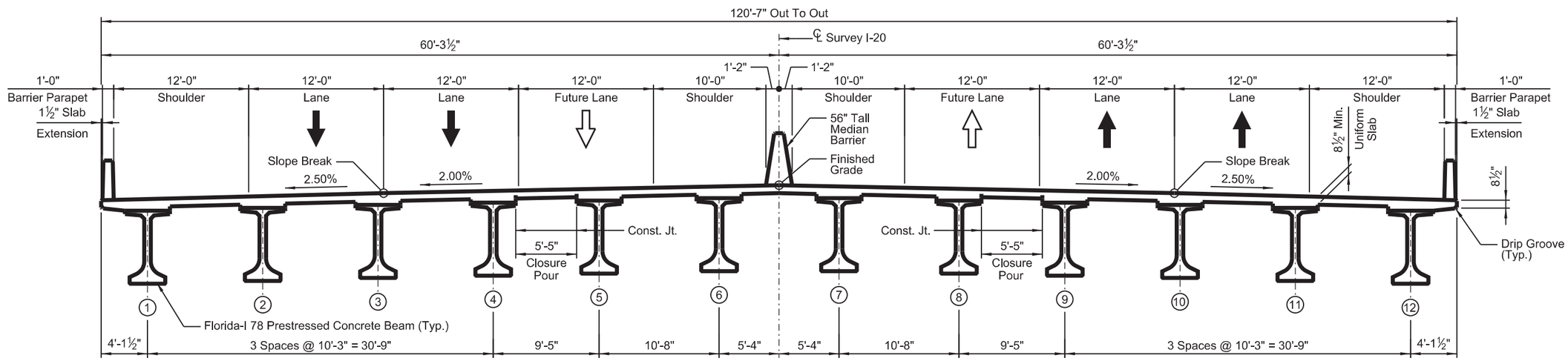
TYPICAL SECTION
UNITS 1, 3 AND 4

REPLACE I-20 OVER WATEREE RIVER

COUNTY: KERSHAW

ROUTE: I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	4



TYPICAL SECTION

(Looking in the direction of stationing)

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV.			
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REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

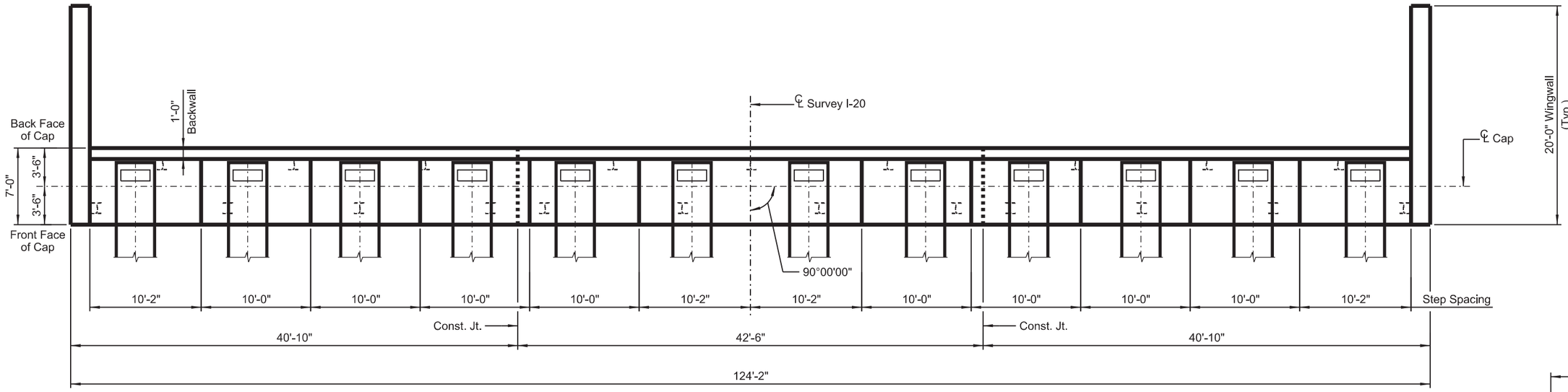
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTION
UNIT 2

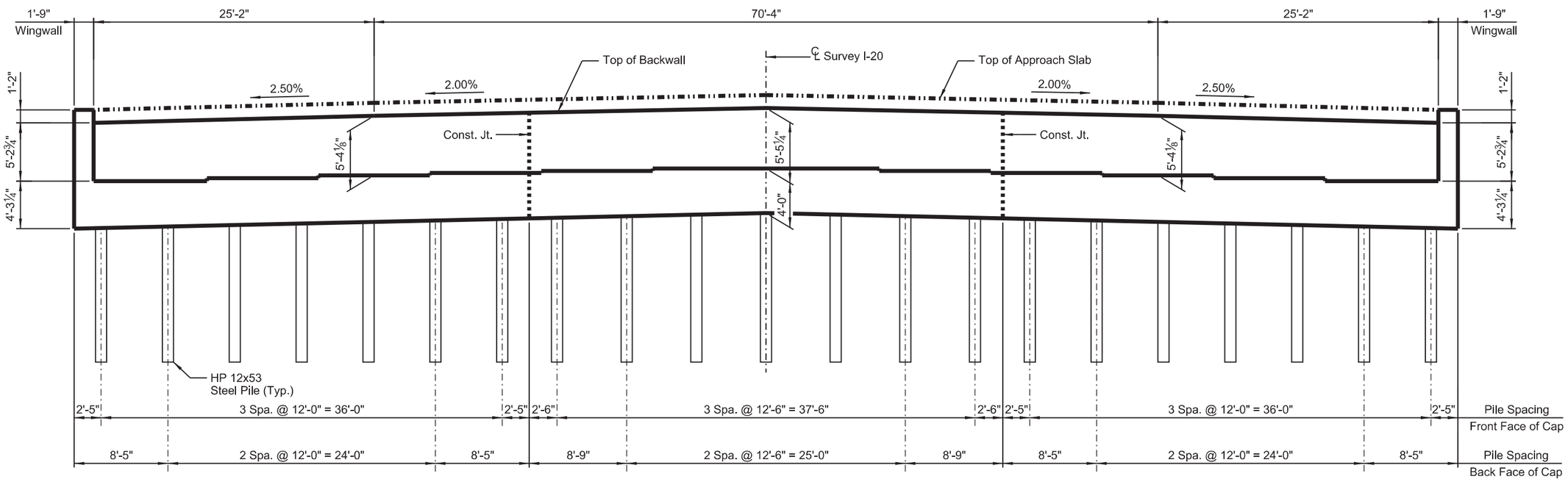
REPLACE I-20 OVER WATEREE RIVER

COUNTY	ROUTE
KERSHAW	I-20

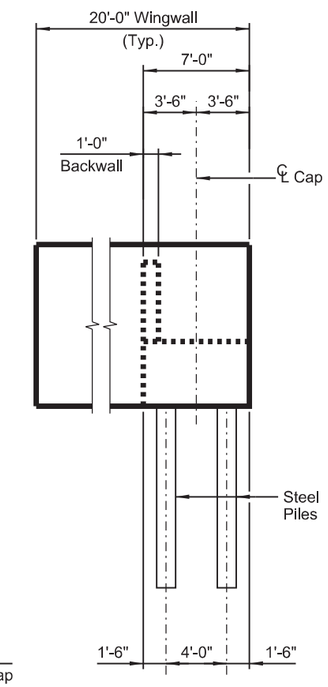
BRIDGE PLANS ID	SHEET NO.
2847360-B1	5B



PLAN



FRONT ELEVATION



END ELEVATION

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV.			
REV.			
REV.			
REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

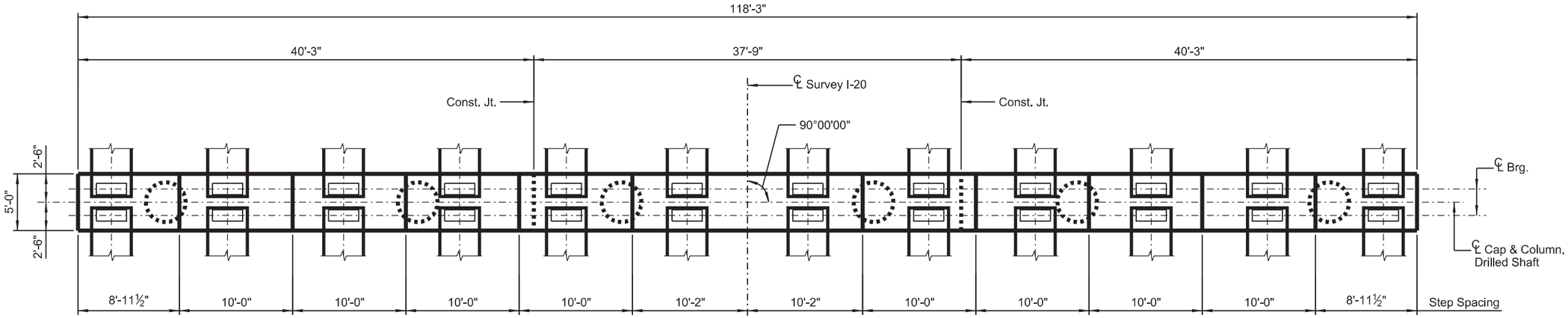
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

END BENT PLAN AND ELEVATION

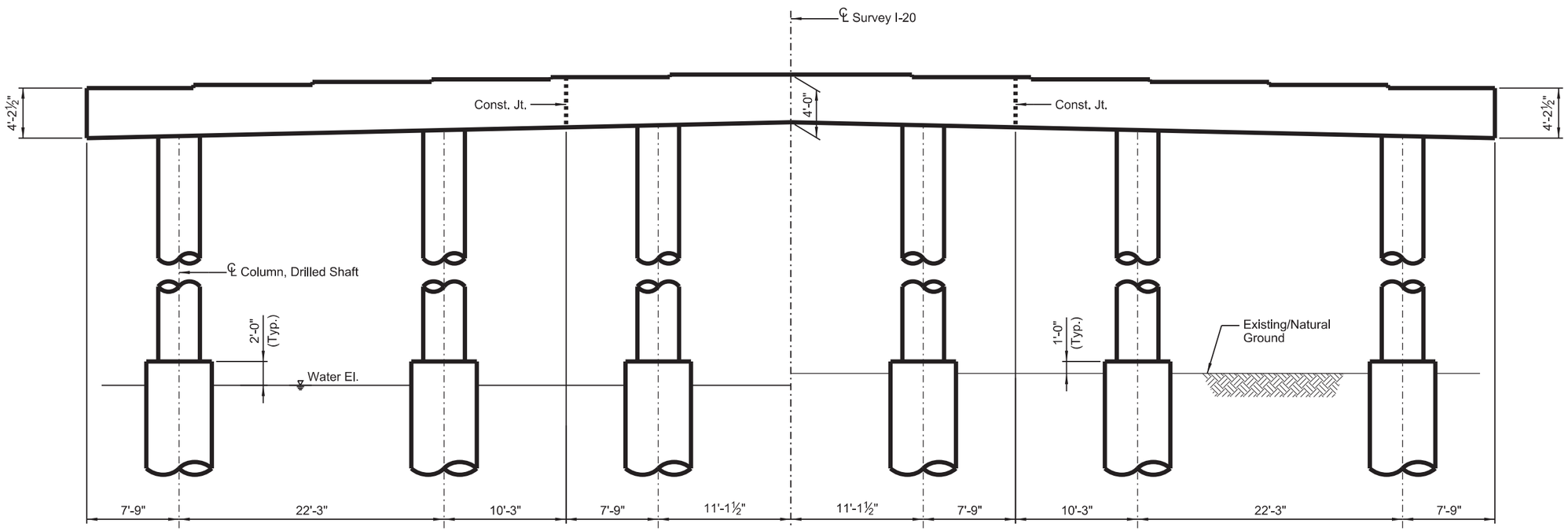
REPLACE I-20 OVER WATEREE RIVER

COUNTY	ROUTE
KERSHAW	I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	6

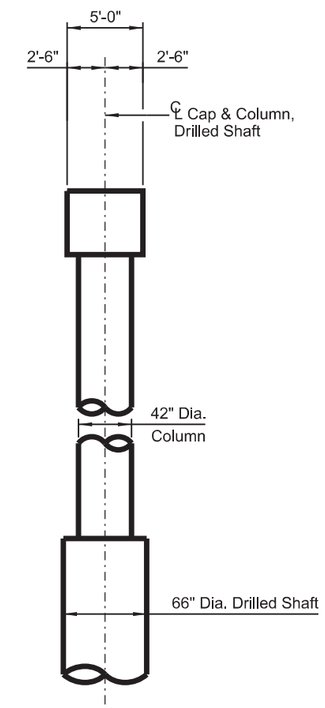


PLAN



HALF ELEVATION - BENT IN RIVER

HALF ELEVATION - BENT ON LAND



END ELEVATION

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

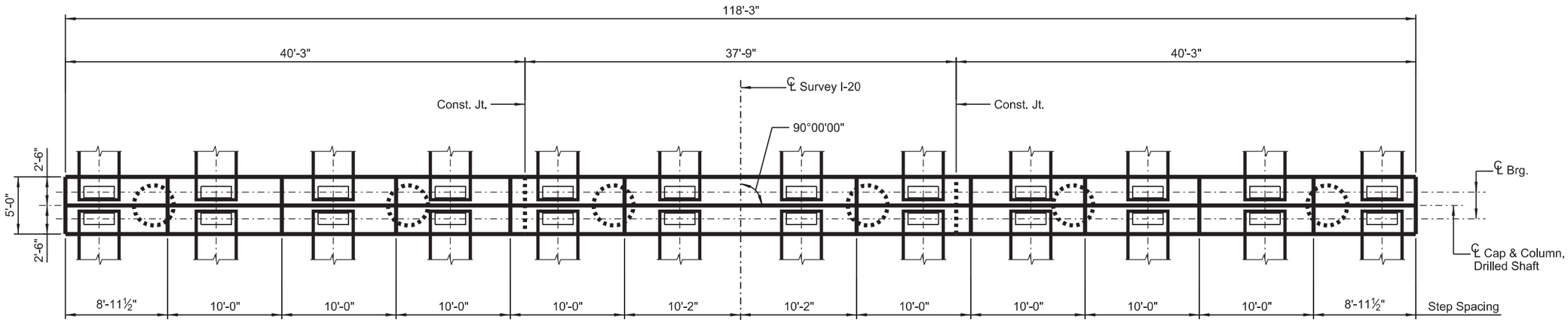
REV.			
REV.			
REV.			
REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

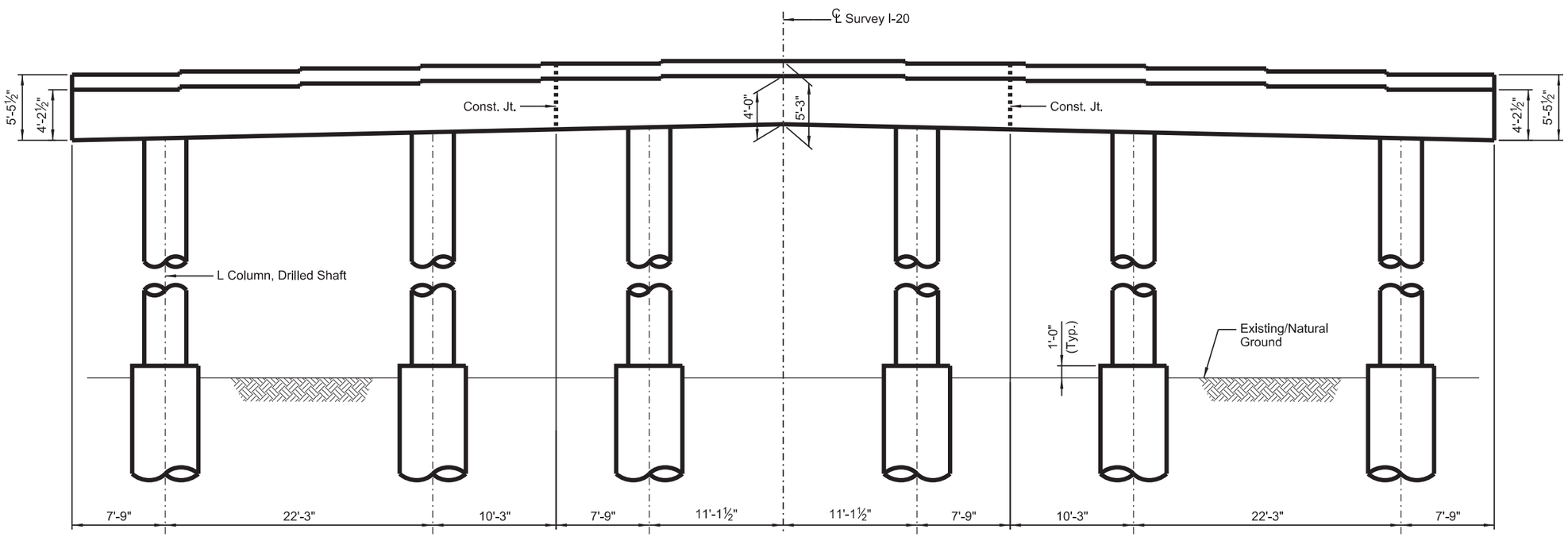
INTERIOR BENTS
2, 3, 5, 6, 8, 9, 10 AND 11
PLAN AND ELEVATION
REPLACE I-20 OVER WATEREE RIVER

COUNTY	ROUTE
KERSHAW	I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	7

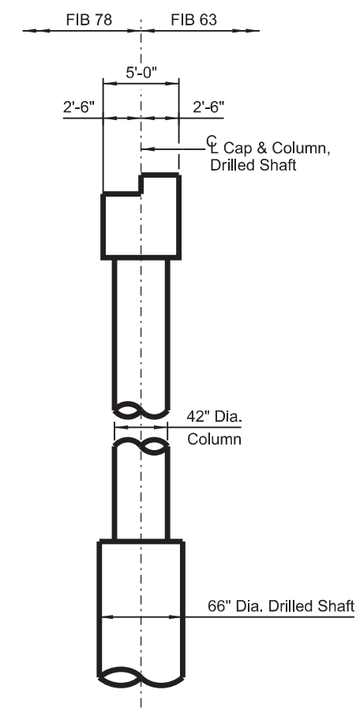


PLAN



ELEVATION

(Bent 7 shown, Bent 4 similar)



END ELEVATION

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

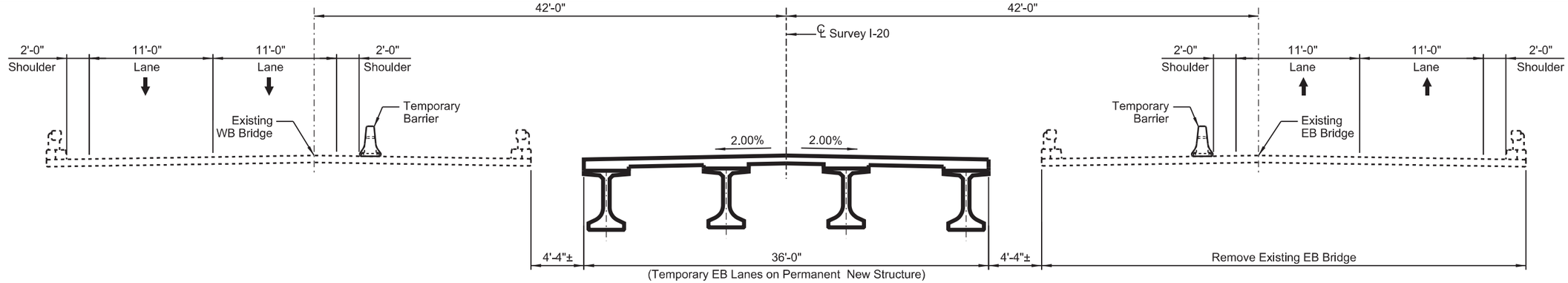
REV.			
REV.			
REV.			
REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

INTERIOR BENTS 4 AND 7
PLAN AND ELEVATION
REPLACE I-20 OVER WATEREE RIVER

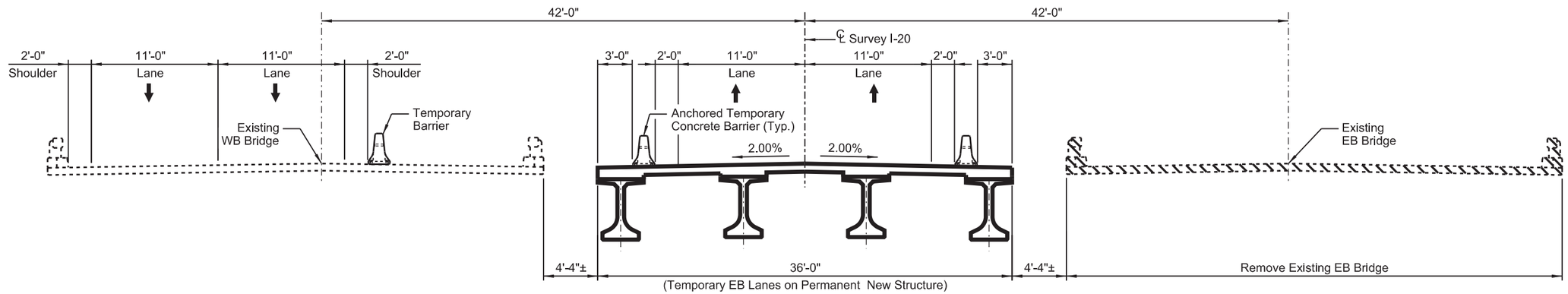
COUNTY	ROUTE
KERSHAW	I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	8



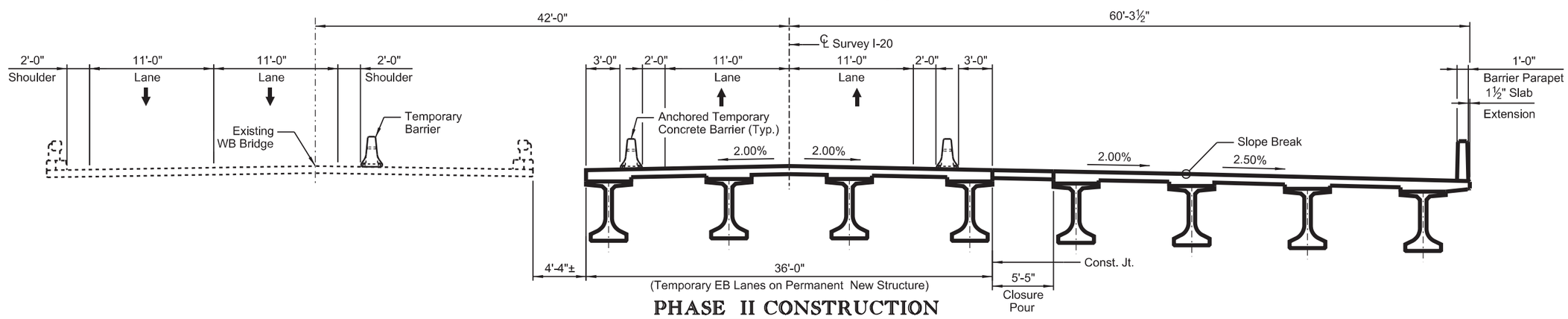
PHASE I

(Looking in the direction of stationing)



PHASE II DEMO

(Looking in the direction of stationing)



PHASE II CONSTRUCTION

(Looking in the direction of stationing)

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV.			
REV.			
REV.			
REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

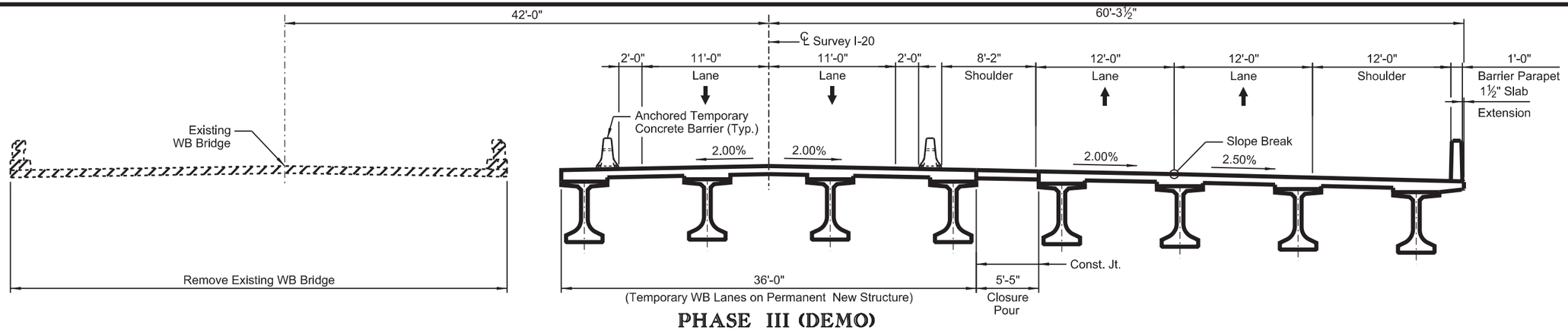
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

PHASED CONSTRUCTION SEQUENCE (1 OF 2)

REPLACE I-20 OVER WATEREE RIVER

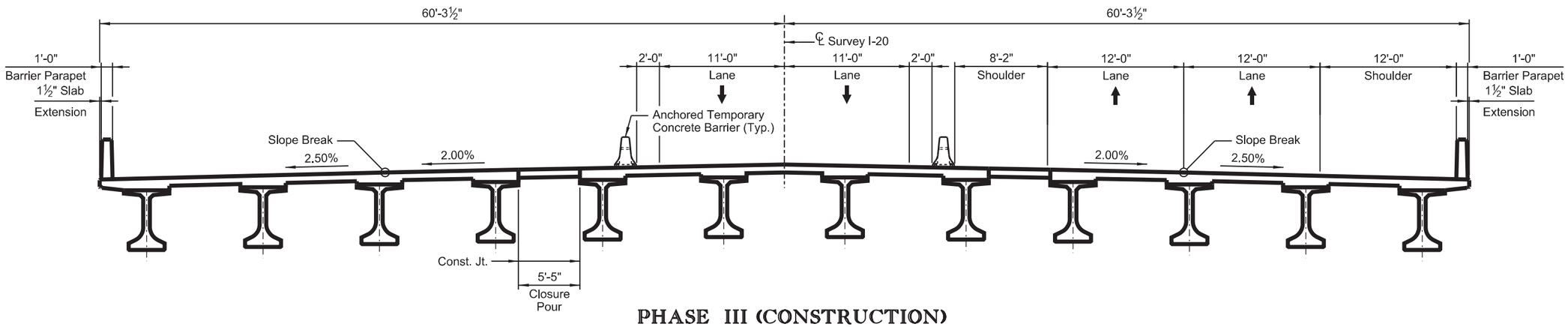
COUNTY	ROUTE
KERSHAW	I-20

BRIDGE PLANS ID	SHEET NO.
2847360-B1	8



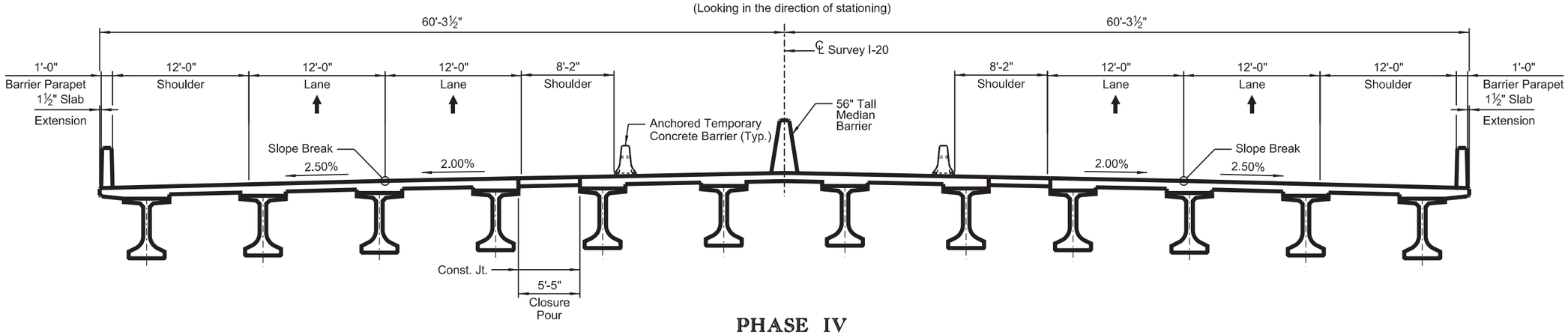
PHASE III (DEMO)

(Looking in the direction of stationing)



PHASE III (CONSTRUCTION)

(Looking in the direction of stationing)



PHASE IV

(Looking in the direction of stationing)

Notes:

1. For final phase, see "TYPICAL SECTION" sheets.

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV.			
REV.			
REV.			
REVIEWED			
QUAN.			
DR.	EBS		01-23
DES.			
	BY	CHK.	DATE

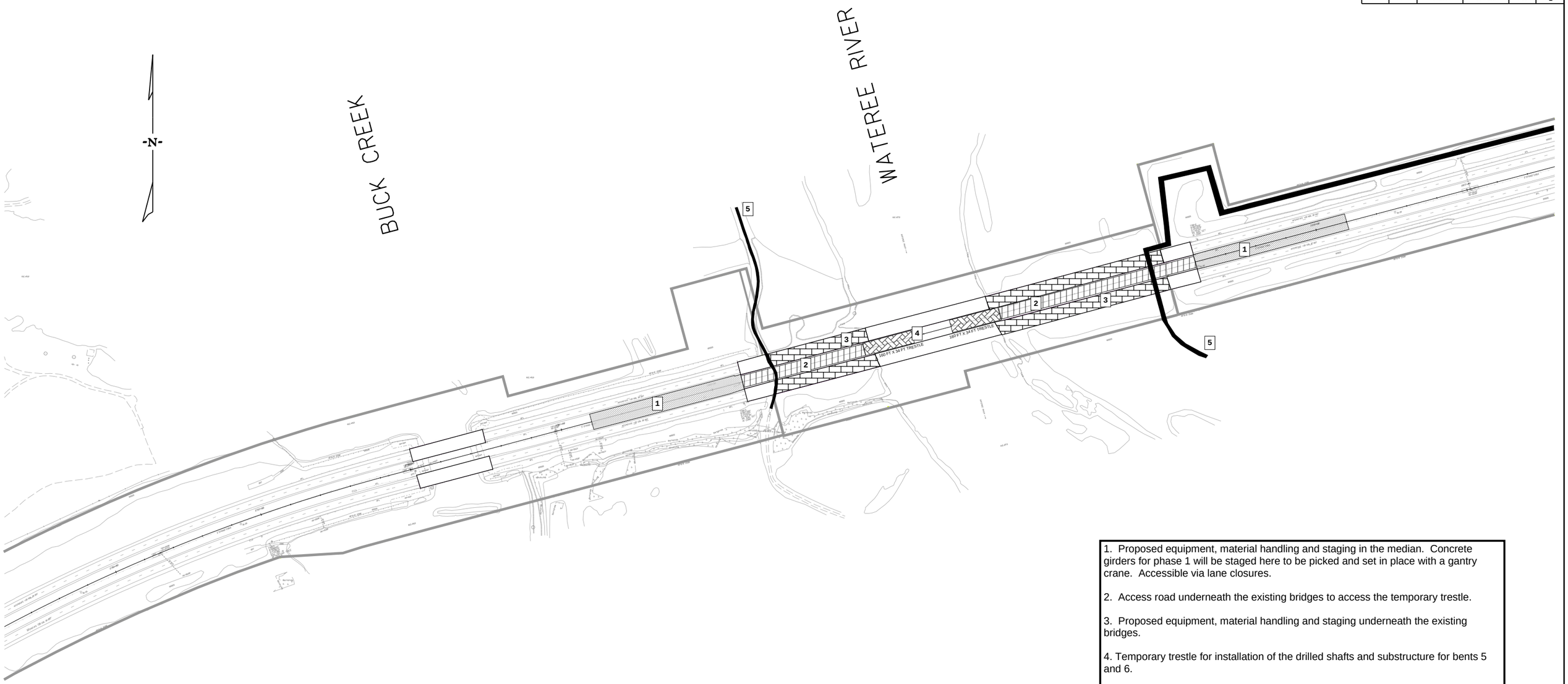
SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION

PHASED CONSTRUCTION SEQUENCE (2 OF 2)

REPLACE I-20 OVER WATEREE RIVER

COUNTY	ROUTE
KERSHAW	I-20

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2047360	I-20	1



1. Proposed equipment, material handling and staging in the median. Concrete girders for phase 1 will be staged here to be picked and set in place with a gantry crane. Accessible via lane closures.

2. Access road underneath the existing bridges to access the temporary trestle.

3. Proposed equipment, material handling and staging underneath the existing bridges.

4. Temporary trestle for installation of the drilled shafts and substructure for bents 5 and 6.

5. Optional access roads to site via landowners. Additional lay-down yard on landowners' property that is out of the flood plain.

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
2			
1			

TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

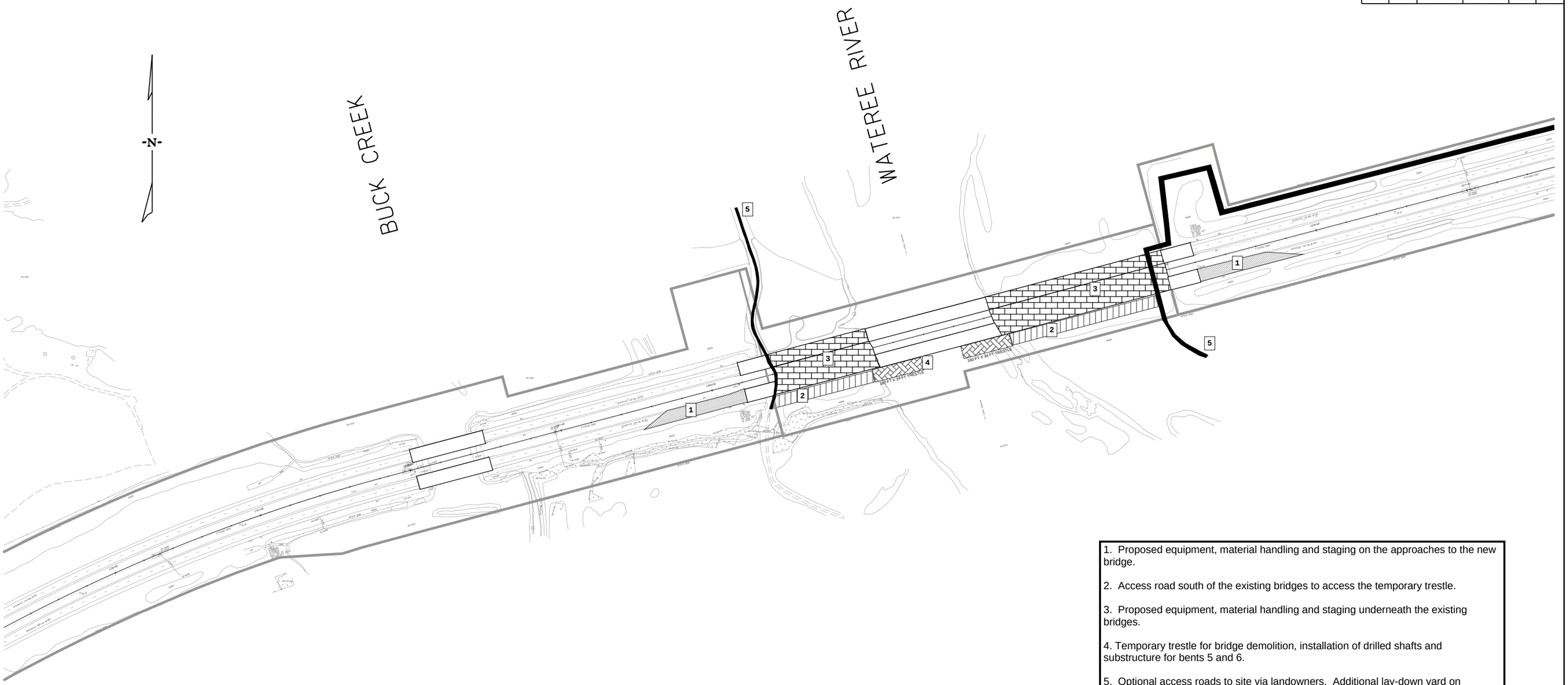
WATEREE RIVER PHASE 1

BRIDGE CONSTRUCTION ACCESS PLAN

SCALE 1"= RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2047360	I-20	2



1. Proposed equipment, material handling and staging on the approaches to the new bridge.

2. Access road south of the existing bridges to access the temporary trestle.

3. Proposed equipment, material handling and staging underneath the existing bridges.

4. Temporary trestle for bridge demolition, installation of drilled shafts and substructure for bents 5 and 6.

5. Optional access roads to site via landowners. Additional lay-down yard on landowners' property that is out of the flood plain.

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
2			
1			

TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

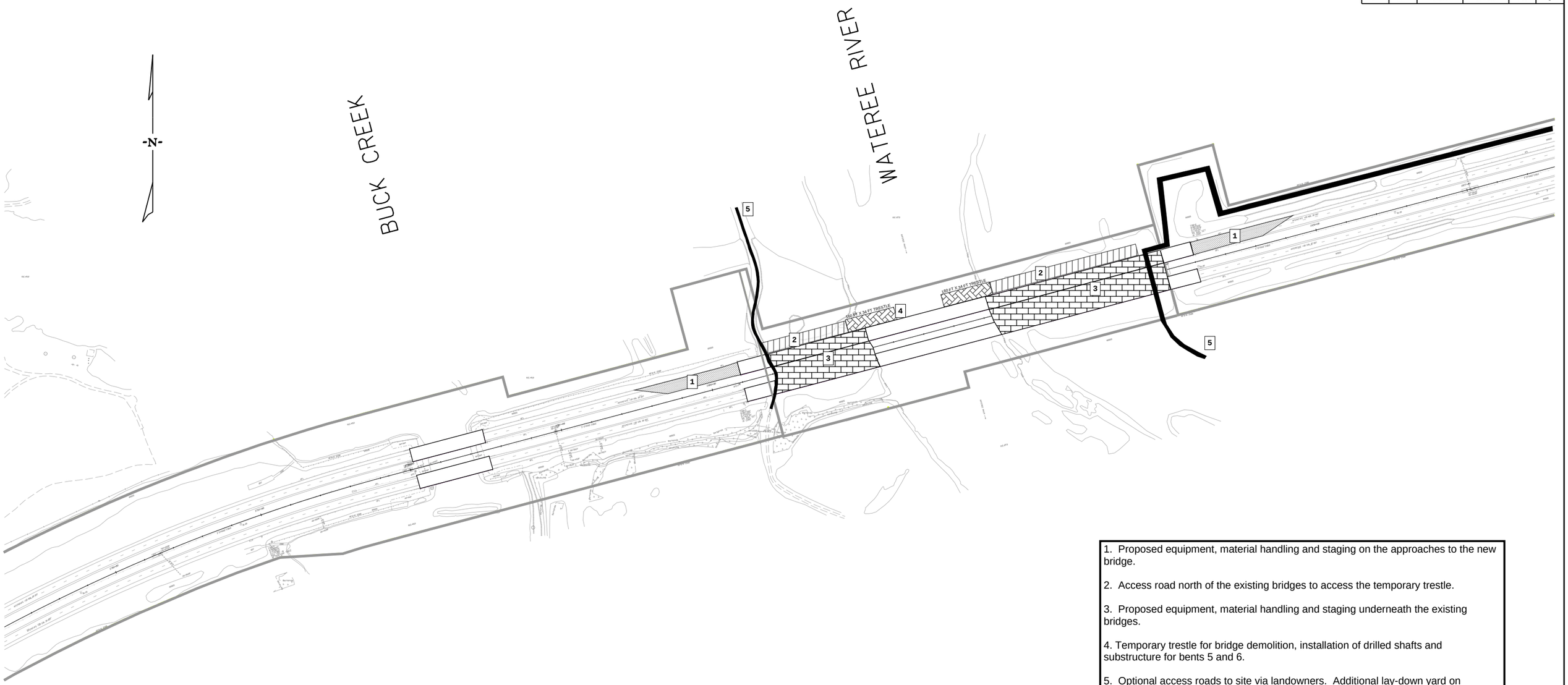
WATEREE RIVER PHASE 2

BRIDGE CONSTRUCTION ACCESS PLAN

SCALE 1"= RTE. DWG. NO.

BORDER1_50.DGN

FED. RD. DIV. NO.	STATE	COUNTY	CONTRACT NO	ROUTE NO.	SHEET NO.
3	S.C.	KERSHAW	2847360	I-20	3



1. Proposed equipment, material handling and staging on the approaches to the new bridge.

2. Access road north of the existing bridges to access the temporary trestle.

3. Proposed equipment, material handling and staging underneath the existing bridges.

4. Temporary trestle for bridge demolition, installation of drilled shafts and substructure for bents 5 and 6.

5. Optional access roads to site via landowners. Additional lay-down yard on landowners' property that is out of the flood plain.

Kiewit

PRELIMINARY PLANS
NOT FOR CONSTRUCTION

REV. NO.	BY	DATE	DESCRIPTION OF REVISION
4			
3			
2			
1			

TOPO. _____ DATE _____
DWG. _____ DATE _____ GROUP ____ - _____
R/W _____ DATE _____

SOUTH CAROLINA
DEPARTMENT OF TRANSPORTATION
ROAD DESIGN COLUMBIA, S.C.

WATEREE RIVER PHASE 3

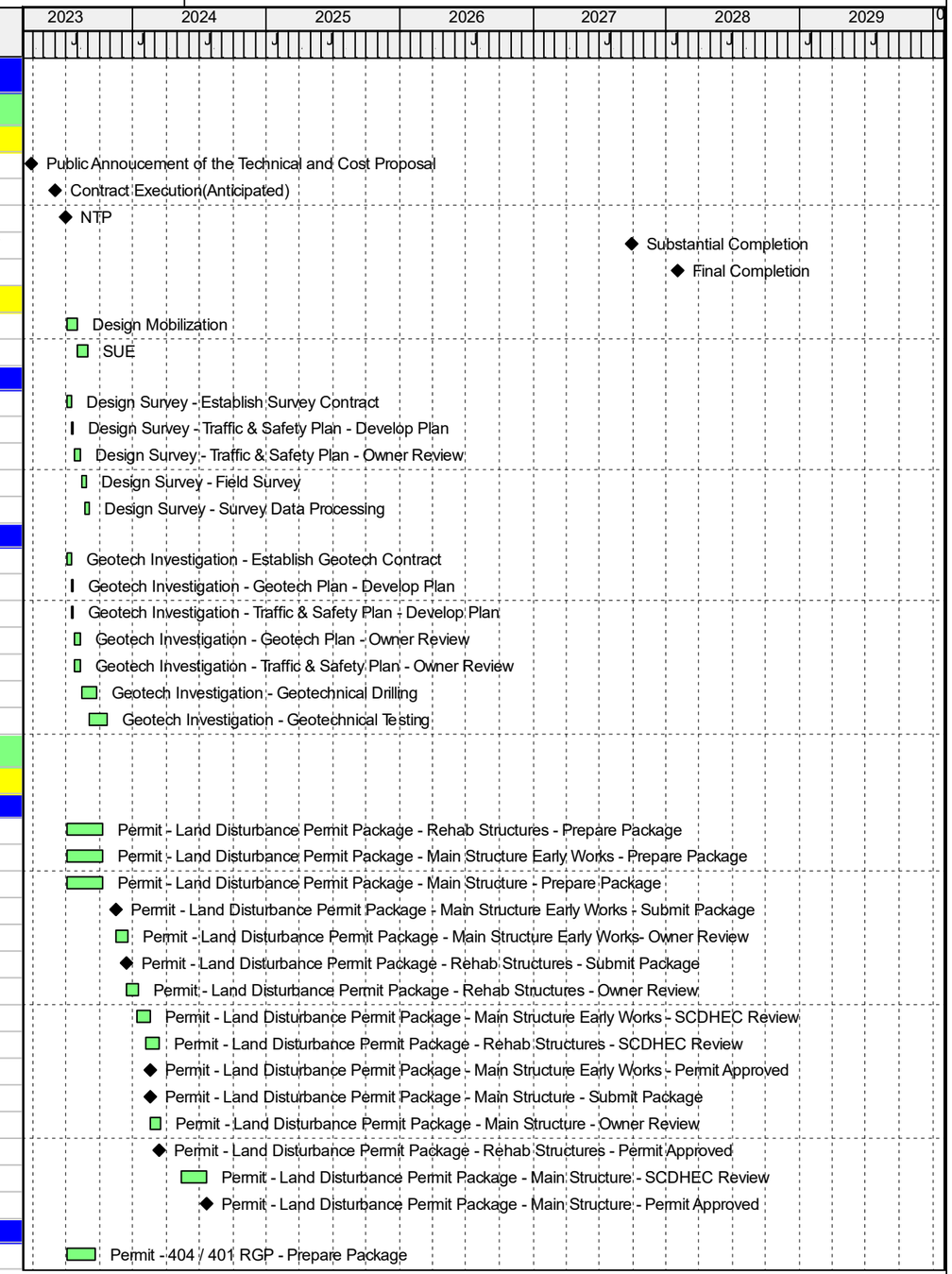
BRIDGE CONSTRUCTION ACCESS PLAN

SCALE 1"= RTE. DWG. NO.

BORDER1_50.DGN

A.4 – CPM Schedule

#	Activity ID	Activity Name	Original Duration	Start	Finish
1	**I-20 Over Wateree - Proposal Construction**		1264	29-Mar-23	31-Jan-28
2	**Project Wide**		1264	29-Mar-23	31-Jan-28
3	**Project Milestones**		1991	29-Mar-23	31-Jan-28
4	MIL.1081	Public Annoucement of the Technical and Cost Proposal	0	29-Mar-23*	
5	MIL.1091	Contract Execution(Anticipated)	0		01-Jun-23
6	NTP	NTP	0	01-Jul-23	
7	MIL.1051	Substantial Completion	0		30-Sep-27*
8	MIL.1061	Final Completion	0		31-Jan-28
9	**Project Mobilization**		80	03-Jul-23	20-Oct-23
10	E2010	Design Mobilization	20	03-Jul-23	31-Jul-23
11	E2040	SUE	20	01-Aug-23	28-Aug-23
12	**Design Survey**		45	03-Jul-23	01-Sep-23
13	A1070	Design Survey - Establish Survey Contract	10	03-Jul-23	14-Jul-23
14	A1090	Design Survey - Traffic & Safety Plan - Develop Plan	5	17-Jul-23	21-Jul-23
15	A1110	Design Survey - Traffic & Safety Plan - Owner Review	15	24-Jul-23	11-Aug-23
16	A1120	Design Survey - Field Survey	10	14-Aug-23	25-Aug-23
17	A1130	Design Survey - Survey Data Processing	10	21-Aug-23	01-Sep-23
18	**Geotechnical Investigation**		80	03-Jul-23	20-Oct-23
19	A1000	Geotech Investigation - Establish Geotech Contract	10	03-Jul-23	14-Jul-23
20	A1010	Geotech Investigation - Geotech Plan - Develop Plan	5	17-Jul-23	21-Jul-23
21	A1020	Geotech Investigation - Traffic & Safety Plan - Develop Plan	5	17-Jul-23	21-Jul-23
22	A1030	Geotech Investigation - Geotech Plan - Owner Review	15	24-Jul-23	11-Aug-23
23	A1040	Geotech Investigation - Traffic & Safety Plan - Owner Review	15	24-Jul-23	11-Aug-23
24	A1050	Geotech Investigation - Geotechnical Drilling	30	14-Aug-23	22-Sep-23
25	A1060	Geotech Investigation - Geotechnical Testing	35	04-Sep-23	20-Oct-23
26	**Engineering**		1109	03-Jul-23	30-Sep-27
27	**Permits**		275	03-Jul-23	19-Jul-24
28	**Land Disturbance Permit Package**		275	03-Jul-23	19-Jul-24
29	PERLDP10	Permit - Land Disturbance Permit Package - Rehab Structures - Prepare Package	69	03-Jul-23	09-Oct-23
30	PERLDP60	Permit - Land Disturbance Permit Package - Main Structure Early Works - Prepare Package	69	03-Jul-23	09-Oct-23
31	PERLDP110	Permit - Land Disturbance Permit Package - Main Structure - Prepare Package	69	03-Jul-23	09-Oct-23
32	PERLDP70	Permit - Land Disturbance Permit Package - Main Structure Early Works - Submit Package	0		15-Nov-23
33	PERLDP80	Permit - Land Disturbance Permit Package - Main Structure Early Works- Owner Review	21	16-Nov-23	18-Dec-23
34	PERLDP20	Permit - Land Disturbance Permit Package - Rehab Structures - Submit Package	0		13-Dec-23
35	PERLDP30	Permit - Land Disturbance Permit Package - Rehab Structures - Owner Review	21	13-Dec-23	16-Jan-24
36	PERLDP90	Permit - Land Disturbance Permit Package - Main Structure Early Works - SCDHEC Review	25	11-Jan-24	15-Feb-24
37	PERLDP40	Permit - Land Disturbance Permit Package - Rehab Structures - SCDHEC Review	25	05-Feb-24	12-Mar-24
38	PERLDP100	Permit - Land Disturbance Permit Package - Main Structure Early Works - Permit Approved	0		15-Feb-24
39	PERLDP120	Permit - Land Disturbance Permit Package - Main Structure - Submit Package	0		15-Feb-24
40	PERLDP130	Permit - Land Disturbance Permit Package - Main Structure - Owner Review	21	16-Feb-24	18-Mar-24
41	PERLDP50	Permit - Land Disturbance Permit Package - Rehab Structures - Permit Approved	0		12-Mar-24
42	PERLDP140	Permit - Land Disturbance Permit Package - Main Structure - SCDHEC Review	75	14-May-24	19-Jul-24
43	PERLDP150	Permit - Land Disturbance Permit Package - Main Structure - Permit Approved	0		19-Jul-24
44	**404 / 401 RGP Package**		220	03-Jul-23	03-May-24
45	PER40410	Permit - 404 / 401 RGP - Prepare Package	54	03-Jul-23	18-Sep-23



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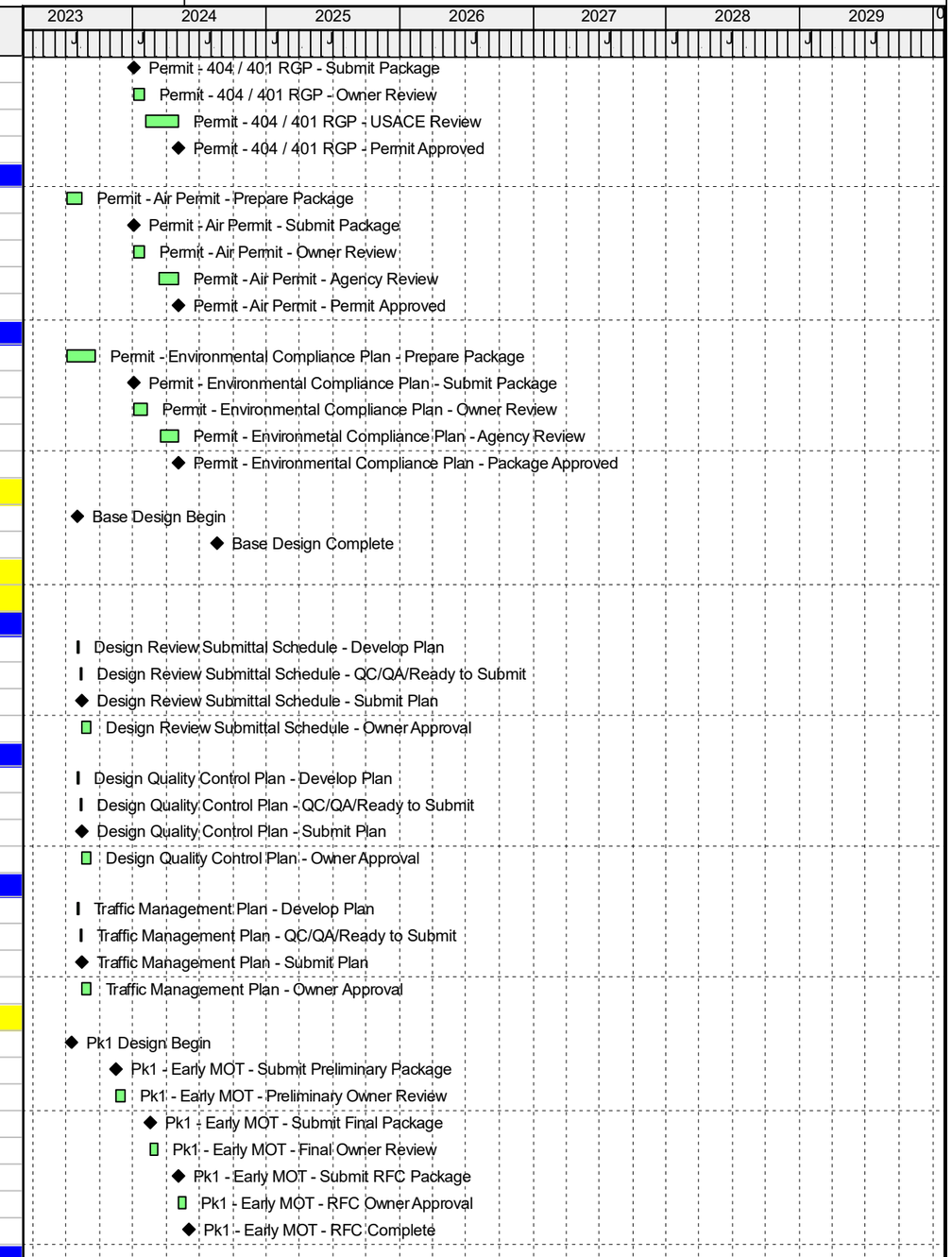
#	Activity ID	Activity Name	Original Duration	Start	Finish
46	PER40420	Permit - 404 / 401 RGP - Submit Package	0		03-Jan-24
47	PER40430	Permit - 404 / 401 RGP - Owner Review	21	04-Jan-24	02-Feb-24
48	PER40440	Permit - 404 / 401 RGP - USACE Review	100	05-Feb-24	03-May-24
49	PER40450	Permit - 404 / 401 RGP - Permit Approved	0		03-May-24
50	**Air Permit**		220	03-Jul-23	03-May-24
51	PERAIR10	Permit - Air Permit - Prepare Package	31	03-Jul-23	15-Aug-23
52	PERAIR20	Permit - Air Permit - Submit Package	0		03-Jan-24
53	PERAIR30	Permit - Air Permit - Owner Review	21	04-Jan-24	02-Feb-24
54	PERAIR40	Permit - Air Permit - Agency Review	37	14-Mar-24	03-May-24
55	PERAIR50	Permit - Air Permit - Permit Approved	0		03-May-24
56	**Environmental Compliance Plan**		220	03-Jul-23	03-May-24
57	PERECP10	Permit - Environmental Compliance Plan - Prepare Package	54	03-Jul-23	18-Sep-23
58	PERECP20	Permit - Environmental Compliance Plan - Submit Package	0		03-Jan-24
59	PERECP30	Permit - Environmental Compliance Plan - Owner Review	25	04-Jan-24	08-Feb-24
60	PERECP40	Permit - Environmetal Compliance Plan - Agency Review	35	18-Mar-24	03-May-24
61	PERECP50	Permit - Environmental Compliance Plan - Package Approved	0		03-May-24
62	**Design Milestones**		265	01-Aug-23	16-Aug-24
63	E1000	Base Design Begin	0	01-Aug-23	
64	E2000	Base Design Complete	0		16-Aug-24
65	**Projectwide**		1051	01-Aug-23	30-Sep-27
66	**Early Plan Submittals**		26	01-Aug-23	05-Sep-23
67	**Design Review Submittal Schedule**		26	01-Aug-23	05-Sep-23
68	ESUBCD000DSS	Design Review Submittal Schedule - Develop Plan	5	01-Aug-23	07-Aug-23
69	ESUBCQ000DSS	Design Review Submittal Schedule - QC/QA/Ready to Submit	5	08-Aug-23	14-Aug-23
70	ESUBCS000DSS	Design Review Submittal Schedule - Submit Plan	0		14-Aug-23
71	ESUBCO000DSS	Design Review Submittal Schedule - Owner Approval	15	15-Aug-23	05-Sep-23
72	**Design Quality Control Plan**		26	01-Aug-23	05-Sep-23
73	ESUBCD000DQC	Design Quality Control Plan - Develop Plan	5	01-Aug-23	07-Aug-23
74	ESUBCQ000DQC	Design Quality Control Plan - QC/QA/Ready to Submit	5	08-Aug-23	14-Aug-23
75	ESUBCS000DQC	Design Quality Control Plan - Submit Plan	0		14-Aug-23
76	ESUBCO000DQC	Design Quality Control Plan - Owner Approval	15	15-Aug-23	05-Sep-23
77	**Traffic Management Plan**		26	01-Aug-23	05-Sep-23
78	ESUBCD000TMP	Traffic Management Plan - Develop Plan	5	01-Aug-23	07-Aug-23
79	ESUBCQ000TMP	Traffic Management Plan - QC/QA/Ready to Submit	5	08-Aug-23	14-Aug-23
80	ESUBCS000TMP	Traffic Management Plan - Submit Plan	0		14-Aug-23
81	ESUBCO000TMP	Traffic Management Plan - Owner Approval	15	15-Aug-23	05-Sep-23
82	**Early MOT**		229	18-Jul-23	31-May-24
83	E1010	Pk1 Design Begin	0	18-Jul-23	
84	EPK1IS000MOT	Pk1 - Early MOT - Submit Preliminary Package	0		15-Nov-23
85	EPK1IO000MOT	Pk1 - Early MOT - Preliminary Owner Review	15	16-Nov-23	08-Dec-23
86	EPK1RS000MOT	Pk1 - Early MOT - Submit Final Package	0		15-Feb-24
87	EPK1RO000MOT	Pk1 - Early MOT - Final Owner Review	15	16-Feb-24	08-Mar-24
88	EPK1CS000MOT	Pk1 - Early MOT - Submit RFC Package	0		02-May-24
89	EPK1CO000MOT	Pk1 - Early MOT - RFC Owner Approval	15	03-May-24	23-May-24
90	EPK1CC000MOT	Pk1 - Early MOT - RFC Complete	0		31-May-24
91	**Pavement**		221	18-Jul-23	31-May-24



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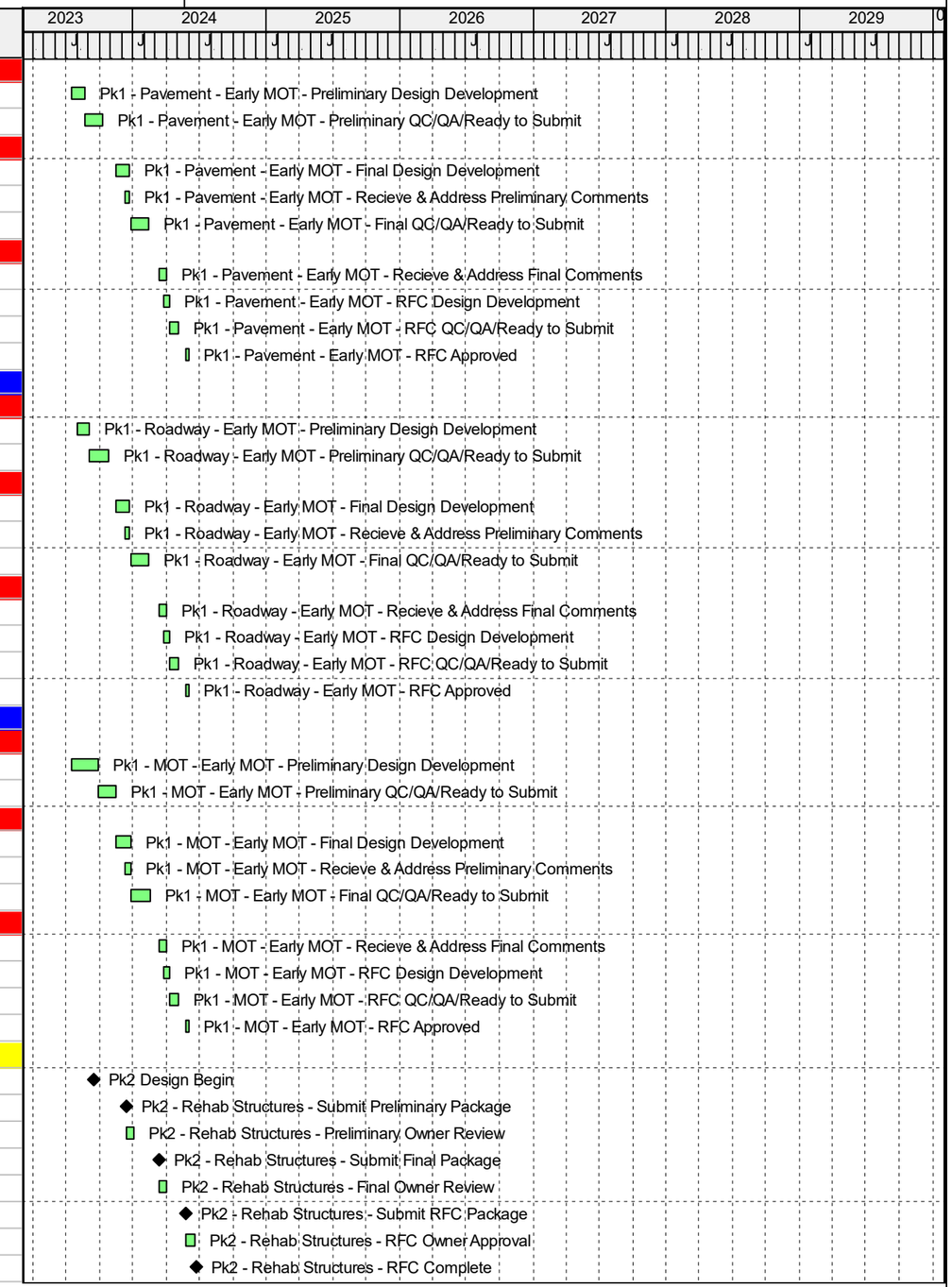
#	Activity ID	Activity Name	Original Duration	Start	Finish
92	**Preliminary**		61	18-Jul-23	11-Oct-23
93	EPK1CIDNPV000MOT	Pk1 - Pavement - Early MOT - Preliminary Design Development	25	18-Jul-23	21-Aug-23
94	EPK1CIQNPV000MOT	Pk1 - Pavement - Early MOT - Preliminary QC/QA/Ready to Submit	36	22-Aug-23	11-Oct-23
95	**Final**		61	15-Nov-23	14-Feb-24
96	EPK1CRDNPV000MOT	Pk1 - Pavement - Early MOT - Final Design Development	25	15-Nov-23	21-Dec-23
97	EPK1CR8NPV000MOT	Pk1 - Pavement - Early MOT - Recieve & Address Preliminary Comments	9	11-Dec-23	21-Dec-23
98	EPK1CRQNPV000MOT	Pk1 - Pavement - Early MOT - Final QC/QA/Ready to Submit	36	26-Dec-23	14-Feb-24
99	**RFC**		58	11-Mar-24	31-May-24
100	EPK1CCRNPV000MOT	Pk1 - Pavement - Early MOT - Recieve & Address Final Comments	15	11-Mar-24	01-Apr-24
101	EPK1CCDNPV000MOT	Pk1 - Pavement - Early MOT - RFC Design Development	10	25-Mar-24	08-Apr-24
102	EPK1CCQNPV000MOT	Pk1 - Pavement - Early MOT - RFC QC/QA/Ready to Submit	18	09-Apr-24	02-May-24
103	EPK1CCFNPV000MOT	Pk1 - Pavement - Early MOT - RFC Approved	5	24-May-24	31-May-24
104	**Civil - Roadway**		212	31-Jul-23	31-May-24
105	**Interim**		61	31-Jul-23	24-Oct-23
106	EPK1CIDNRW000MOT	Pk1 - Roadway - Early MOT - Preliminary Design Development	25	31-Jul-23	01-Sep-23
107	EPK1CIQNRW000MOT	Pk1 - Roadway - Early MOT - Preliminary QC/QA/Ready to Submit	36	05-Sep-23	24-Oct-23
108	**Final**		61	15-Nov-23	14-Feb-24
109	EPK1CRDNRW000MOT	Pk1 - Roadway - Early MOT - Final Design Development	25	15-Nov-23	21-Dec-23
110	EPK1CR8NRW000MOT	Pk1 - Roadway - Early MOT - Recieve & Address Preliminary Comments	9	11-Dec-23	21-Dec-23
111	EPK1CRQNRW000MOT	Pk1 - Roadway - Early MOT - Final QC/QA/Ready to Submit	36	26-Dec-23	14-Feb-24
112	**IFC**		58	11-Mar-24	31-May-24
113	EPK1CCRNRW000MOT	Pk1 - Roadway - Early MOT - Recieve & Address Final Comments	15	11-Mar-24	01-Apr-24
114	EPK1CCDNRW000MOT	Pk1 - Roadway - Early MOT - RFC Design Development	10	25-Mar-24	08-Apr-24
115	EPK1CCQNRW000MOT	Pk1 - Roadway - Early MOT - RFC QC/QA/Ready to Submit	18	09-Apr-24	02-May-24
116	EPK1CCFNRW000MOT	Pk1 - Roadway - Early MOT - RFC Approved	5	24-May-24	31-May-24
117	**Civil - Maintenance of Traffic**		221	18-Jul-23	31-May-24
118	**Preliminary**		86	18-Jul-23	15-Nov-23
119	EPK1CIDNMT000MOT	Pk1 - MOT - Early MOT - Preliminary Design Development	50	18-Jul-23	26-Sep-23
120	EPK1CIQNMT000MOT	Pk1 - MOT - Early MOT - Preliminary QC/QA/Ready to Submit	36	27-Sep-23	15-Nov-23
121	**Final**		61	16-Nov-23	15-Feb-24
122	EPK1CRDNMT000MOT	Pk1 - MOT - Early MOT - Final Design Development	25	16-Nov-23	26-Dec-23
123	EPK1CR8NMT000MOT	Pk1 - MOT - Early MOT - Recieve & Address Preliminary Comments	10	11-Dec-23	26-Dec-23
124	EPK1CRQNMT000MOT	Pk1 - MOT - Early MOT - Final QC/QA/Ready to Submit	36	27-Dec-23	15-Feb-24
125	**RFC**		58	11-Mar-24	31-May-24
126	EPK1CCRNMT000MOT	Pk1 - MOT - Early MOT - Recieve & Address Final Comments	15	11-Mar-24	01-Apr-24
127	EPK1CCDNMT000MOT	Pk1 - MOT - Early MOT - RFC Design Development	10	25-Mar-24	08-Apr-24
128	EPK1CCQNMT000MOT	Pk1 - MOT - Early MOT - RFC QC/QA/Ready to Submit	18	09-Apr-24	02-May-24
129	EPK1CCFNMT000MOT	Pk1 - MOT - Early MOT - RFC Approved	5	24-May-24	31-May-24
130	**Rehab Structures**		201	15-Sep-23	24-Jun-24
131	E1020	Pk2 Design Begin	0	15-Sep-23	
132	EPK2IS000REH	Pk2 - Rehab Structures - Submit Preliminary Package	0		13-Dec-23
133	EPK2IO000REH	Pk2 - Rehab Structures - Preliminary Owner Review	15	13-Dec-23	05-Jan-24
134	EPK2RS000REH	Pk2 - Rehab Structures - Submit Final Package	0		12-Mar-24
135	EPK2RO000REH	Pk2 - Rehab Structures - Final Owner Review	15	12-Mar-24	02-Apr-24
136	EPK2CS000REH	Pk2 - Rehab Structures - Submit RFC Package	0		24-May-24
137	EPK2CO000REH	Pk2 - Rehab Structures - RFC Owner Approval	15	24-May-24	17-Jun-24
138	EPK2CC000REH	Pk2 - Rehab Structures - RFC Complete	0		24-Jun-24



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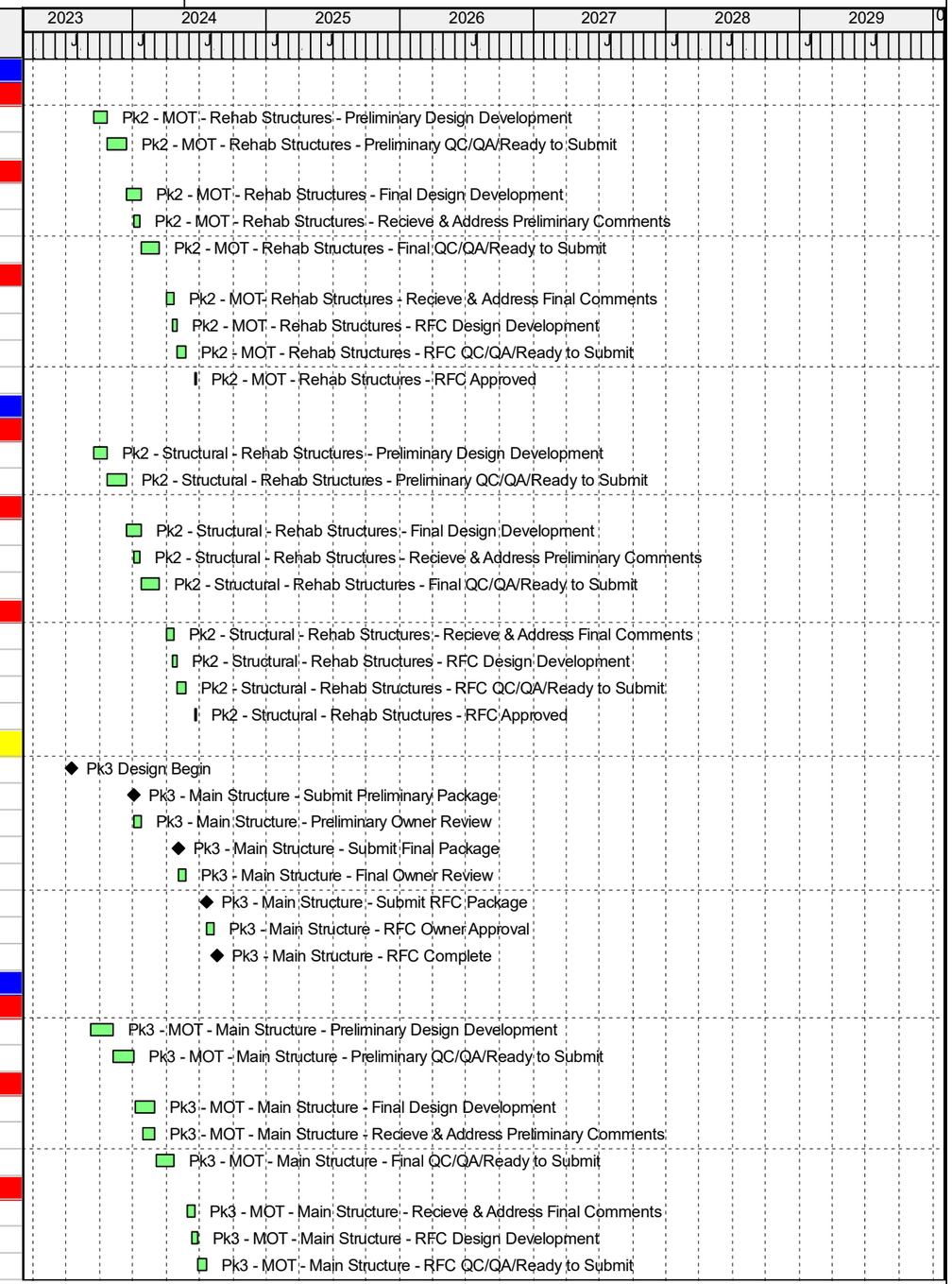
#	Activity ID	Activity Name	Original Duration	Start	Finish
139	**Maintenance of Traffic**		194	15-Sep-23	24-Jun-24
140	**Preliminary**		61	15-Sep-23	13-Dec-23
141	EPK2CIDNMT000REH	Pk2 - MOT - Rehab Structures - Preliminary Design Development	25	15-Sep-23	20-Oct-23
142	EPK2CIQNMT000REH	Pk2 - MOT - Rehab Structures - Preliminary QC/QA/Ready to Submit	36	20-Oct-23	13-Dec-23
143	**Final**		61	13-Dec-23	12-Mar-24
144	EPK2CRDNMT000REH	Pk2 - MOT - Rehab Structures - Final Design Development	25	13-Dec-23	22-Jan-24
145	EPK2CR8NMT000REH	Pk2 - MOT - Rehab Structures - Recieve & Address Preliminary Comments	9	05-Jan-24	18-Jan-24
146	EPK2CRQNMT000REH	Pk2 - MOT - Rehab Structures - Final QC/QA/Ready to Submit	36	22-Jan-24	12-Mar-24
147	**RFC**		58	02-Apr-24	24-Jun-24
148	EPK2CCRNMT000REH	Pk2 - MOT- Rehab Structures - Recieve & Address Final Comments	15	02-Apr-24	23-Apr-24
149	EPK2CCDNMT000REH	Pk2 - MOT - Rehab Structures - RFC Design Development	10	16-Apr-24	30-Apr-24
150	EPK2CCQNMT000REH	Pk2 - MOT - Rehab Structures - RFC QC/QA/Ready to Submit	18	30-Apr-24	24-May-24
151	EPK2CCFNMT000REH	Pk2 - MOT - Rehab Structures - RFC Approved	5	17-Jun-24	24-Jun-24
152	**Structural**		194	15-Sep-23	24-Jun-24
153	**Preliminary**		61	15-Sep-23	13-Dec-23
154	EPK2SIDNTS000REH	Pk2 - Structural - Rehab Structures - Preliminary Design Development	25	15-Sep-23	20-Oct-23
155	EPK2SIQNTS000REH	Pk2 - Structural - Rehab Structures - Preliminary QC/QA/Ready to Submit	36	20-Oct-23	13-Dec-23
156	**Final**		61	13-Dec-23	12-Mar-24
157	EPK2SRDNTS000REH	Pk2 - Structural - Rehab Structures - Final Design Development	25	13-Dec-23	22-Jan-24
158	EPK2SR8NTS000REH	Pk2 - Structural - Rehab Structures - Recieve & Address Preliminary Comments	9	05-Jan-24	18-Jan-24
159	EPK2SRQNTS000REH	Pk2 - Structural - Rehab Structures - Final QC/QA/Ready to Submit	36	22-Jan-24	12-Mar-24
160	**RFC**		58	02-Apr-24	24-Jun-24
161	EPK2SCRNTS000REH	Pk2 - Structural - Rehab Structures - Recieve & Address Final Comments	15	02-Apr-24	23-Apr-24
162	EPK2SCDNTS000REH	Pk2 - Structural - Rehab Structures - RFC Design Development	10	16-Apr-24	30-Apr-24
163	EPK2SCQNTS000REH	Pk2 - Structural - Rehab Structures - RFC QC/QA/Ready to Submit	18	30-Apr-24	24-May-24
164	EPK2SCFNTS000REH	Pk2 - Structural - Rehab Structures - RFC Approved	5	17-Jun-24	24-Jun-24
165	**Main Structure**		284	18-Jul-23	16-Aug-24
166	E1030	Pk3 Design Begin	0	18-Jul-23	
167	EPK3IS000MS1	Pk3 - Main Structure - Submit Preliminary Package	0		03-Jan-24
168	EPK3IO000MS1	Pk3 - Main Structure - Preliminary Owner Review	15	04-Jan-24	25-Jan-24
169	EPK3RS000MS1	Pk3 - Main Structure - Submit Final Package	0		03-May-24
170	EPK3RO000MS1	Pk3 - Main Structure - Final Owner Review	15	06-May-24	24-May-24
171	EPK3CS000MS1	Pk3 - Main Structure - Submit RFC Package	0		19-Jul-24
172	EPK3CO000MS1	Pk3 - Main Structure - RFC Owner Approval	15	22-Jul-24	09-Aug-24
173	EPK3CC000MS1	Pk3 - Main Structure - RFC Complete	0		16-Aug-24
174	**Civil - Maintenance of Traffic**		240	06-Sep-23	16-Aug-24
175	**Preliminary**		81	06-Sep-23	03-Jan-24
176	EPK3CIDNMT000MS1	Pk3 - MOT - Main Structure - Preliminary Design Development	45	06-Sep-23	07-Nov-23
177	EPK3CIQNMT000MS1	Pk3 - MOT - Main Structure - Preliminary QC/QA/Ready to Submit	36	08-Nov-23	03-Jan-24
178	**Final**		76	08-Jan-24	23-Apr-24
179	EPK3CRDNMT000MS1	Pk3 - MOT - Main Structure - Final Design Development	40	08-Jan-24	01-Mar-24
180	EPK3CR8NMT000MS1	Pk3 - MOT - Main Structure - Recieve & Address Preliminary Comments	26	26-Jan-24	01-Mar-24
181	EPK3CRQNMT000MS1	Pk3 - MOT - Main Structure - Final QC/QA/Ready to Submit	36	04-Mar-24	23-Apr-24
182	**RFC**		58	28-May-24	16-Aug-24
183	EPK3CCRNMT000MS1	Pk3 - MOT - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
184	EPK3CCDNMT000MS1	Pk3 - MOT - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
185	EPK3CCQNMT000MS1	Pk3 - MOT - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24



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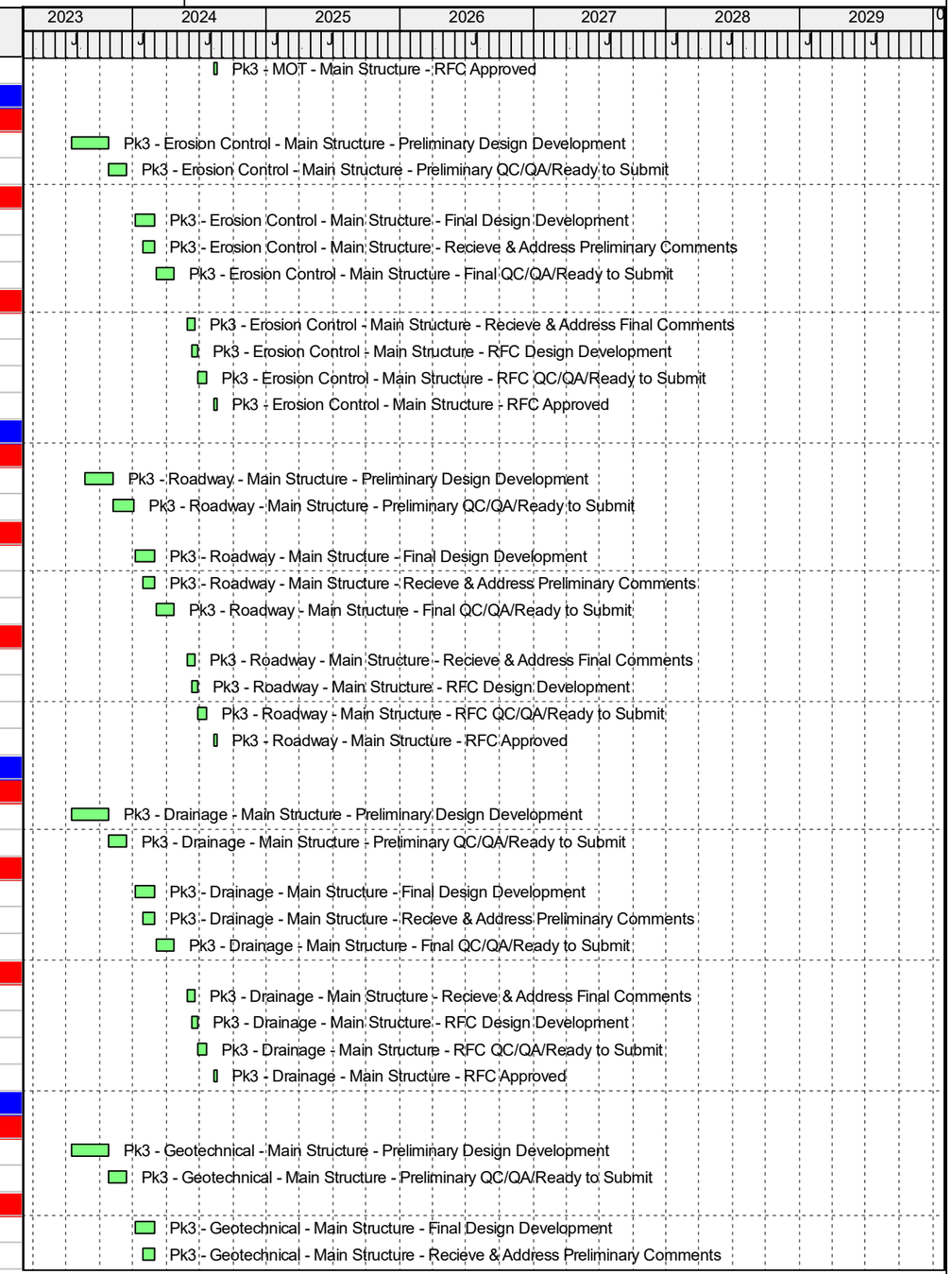
#	Activity ID	Activity Name	Original Duration	Start	Finish
186	EPK3CCFNMT000MS1	Pk3 - MOT - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
187	**Civil - Erosion Control**		275	18-Jul-23	16-Aug-24
188	**Preliminary**		106	18-Jul-23	15-Dec-23
189	EPK3CIDMYH004MS1	Pk3 - Erosion Control - Main Structure - Preliminary Design Development	70	18-Jul-23	24-Oct-23
190	EPK3CIQMYH004MS1	Pk3 - Erosion Control - Main Structure - Preliminary QC/QA/Ready to Submit	36	25-Oct-23	15-Dec-23
191	**Final**		76	08-Jan-24	23-Apr-24
192	EPK3CRDMYH004MS1	Pk3 - Erosion Control - Main Structure - Final Design Development	40	08-Jan-24	01-Mar-24
193	EPK3CR8MYH004MS1	Pk3 - Erosion Control - Main Structure - Recieve & Address Preliminary Comments	26	26-Jan-24	01-Mar-24
194	EPK3CRQMYH004MS1	Pk3 - Erosion Control - Main Structure - Final QC/QA/Ready to Submit	36	04-Mar-24	23-Apr-24
195	**RFC**		58	28-May-24	16-Aug-24
196	EPK3CCRMYH004MS1	Pk3 - Erosion Control - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
197	EPK3CCDMYH004MS1	Pk3 - Erosion Control - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
198	EPK3CCQMYH004MS1	Pk3 - Erosion Control - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24
199	EPK3CCFMYH004MS1	Pk3 - Erosion Control - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
200	**Civil - Roadway**		250	22-Aug-23	16-Aug-24
201	**Preliminary**		91	22-Aug-23	03-Jan-24
202	EPK3CIDNRW000MS1	Pk3 - Roadway - Main Structure - Preliminary Design Development	55	22-Aug-23	07-Nov-23
203	EPK3CIQNRW000MS1	Pk3 - Roadway - Main Structure - Preliminary QC/QA/Ready to Submit	36	08-Nov-23	03-Jan-24
204	**Final**		76	08-Jan-24	23-Apr-24
205	EPK3CRDNRW000MS1	Pk3 - Roadway - Main Structure - Final Design Development	40	08-Jan-24	01-Mar-24
206	EPK3CR8NRW000MS1	Pk3 - Roadway - Main Structure - Recieve & Address Preliminary Comments	26	26-Jan-24	01-Mar-24
207	EPK3CRQNRW000MS1	Pk3 - Roadway - Main Structure - Final QC/QA/Ready to Submit	36	04-Mar-24	23-Apr-24
208	**RFC**		58	28-May-24	16-Aug-24
209	EPK3CCRNRW000MS1	Pk3 - Roadway - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
210	EPK3CCDNRW000MS1	Pk3 - Roadway - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
211	EPK3CCQNRW000MS1	Pk3 - Roadway - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24
212	EPK3CCFNRW000MS1	Pk3 - Roadway - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
213	**Drainage**		275	18-Jul-23	16-Aug-24
214	**Preliminary**		106	18-Jul-23	15-Dec-23
215	EPK3DIDNDG004MS1	Pk3 - Drainage - Main Structure - Preliminary Design Development	70	18-Jul-23	24-Oct-23
216	EPK3DIQNDG004MS1	Pk3 - Drainage - Main Structure - Preliminary QC/QA/Ready to Submit	36	25-Oct-23	15-Dec-23
217	**Final**		76	08-Jan-24	23-Apr-24
218	EPK3DRDNDG004MS1	Pk3 - Drainage - Main Structure - Final Design Development	40	08-Jan-24	01-Mar-24
219	EPK3DR8NDG004MS1	Pk3 - Drainage - Main Structure - Recieve & Address Preliminary Comments	26	26-Jan-24	01-Mar-24
220	EPK3DRQNDG004MS1	Pk3 - Drainage - Main Structure - Final QC/QA/Ready to Submit	36	04-Mar-24	23-Apr-24
221	**RFC**		58	28-May-24	16-Aug-24
222	EPK3DCRNDG004MS1	Pk3 - Drainage - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
223	EPK3DCDNDG004MS1	Pk3 - Drainage - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
224	EPK3DCQNDG004MS1	Pk3 - Drainage - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24
225	EPK3DCFNDG004MS1	Pk3 - Drainage - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
226	**Geotechnical**		275	18-Jul-23	16-Aug-24
227	**Preliminary**		106	18-Jul-23	15-Dec-23
228	EPK3GIDNGR000MS1	Pk3 - Geotechnical - Main Structure - Preliminary Design Development	70	18-Jul-23	24-Oct-23
229	EPK3GIQNGR000MS1	Pk3 - Geotechnical - Main Structure - Preliminary QC/QA/Ready to Submit	36	25-Oct-23	15-Dec-23
230	**Final**		76	08-Jan-24	23-Apr-24
231	EPK3GRDNGR000MS1	Pk3 - Geotechnical - Main Structure - Final Design Development	40	08-Jan-24	01-Mar-24
232	EPK3GR8NGR000MS1	Pk3 - Geotechnical - Main Structure - Recieve & Address Preliminary Comments	26	26-Jan-24	01-Mar-24



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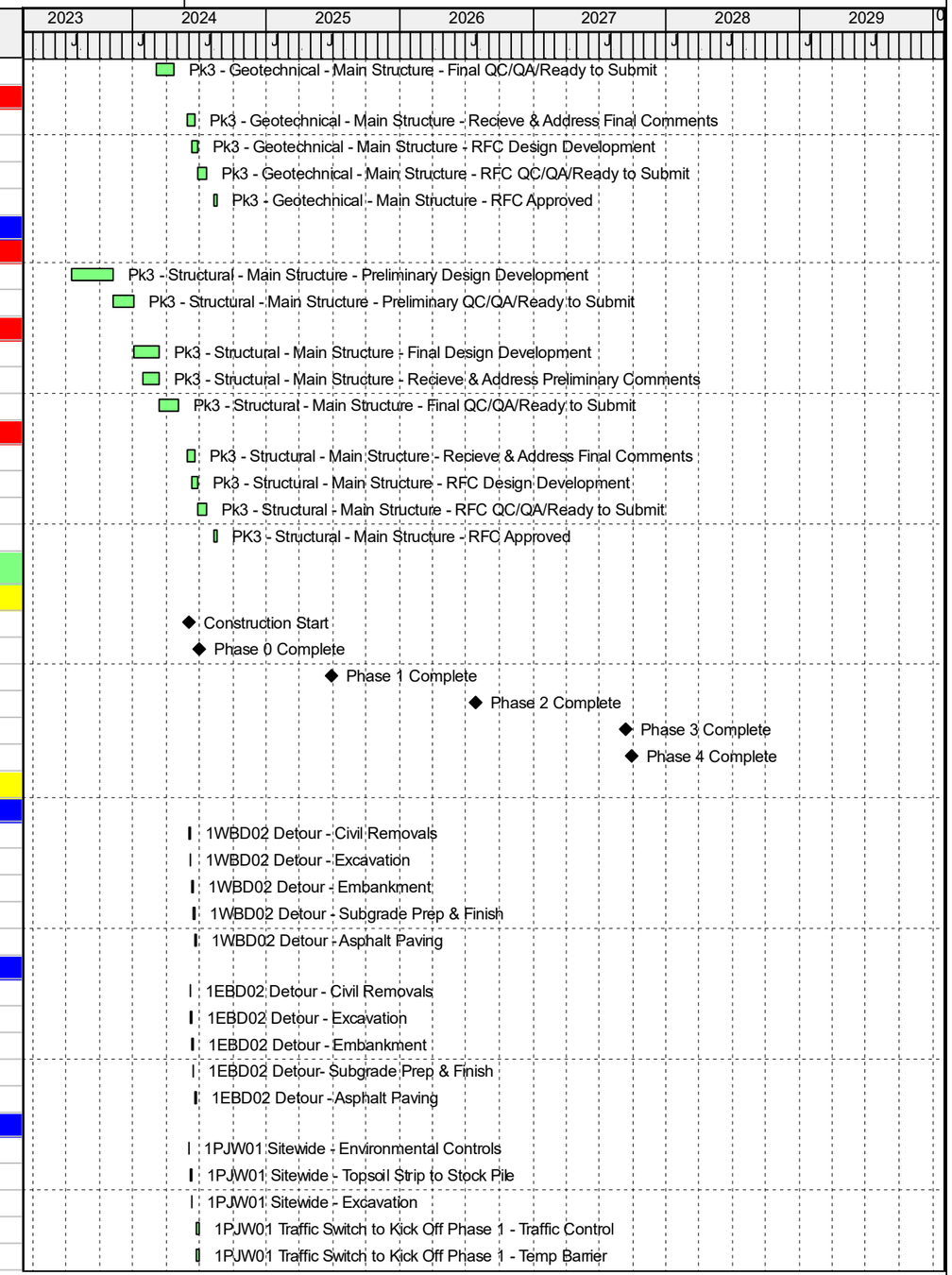
#	Activity ID	Activity Name	Original Duration	Start	Finish
233	EPK3GRQNGR000MS1	Pk3 - Geotechnical - Main Structure - Final QC/QA/Ready to Submit	36	04-Mar-24	23-Apr-24
234	**RFC**		58	28-May-24	16-Aug-24
235	EPK3GCRNGR000MS1	Pk3 - Geotechnical - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
236	EPK3GCDNGR000MS1	Pk3 - Geotechnical - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
237	EPK3GCQNGR000MS1	Pk3 - Geotechnical - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24
238	EPK3GCFNGR000MS1	Pk3 - Geotechnical - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
239	**Structural**		275	18-Jul-23	16-Aug-24
240	**Preliminary**		116	18-Jul-23	03-Jan-24
241	EPK3SIDNTS000MS1	Pk3 - Structural - Main Structure - Preliminary Design Development	80	18-Jul-23	07-Nov-23
242	EPK3SIQNTS000MS1	Pk3 - Structural - Main Structure - Preliminary QC/QA/Ready to Submit	36	08-Nov-23	03-Jan-24
243	**Final**		86	04-Jan-24	03-May-24
244	EPK3SRDNTS000MS1	Pk3 - Structural - Main Structure - Final Design Development	50	04-Jan-24	13-Mar-24
245	EPK3SR8NTS000MS1	Pk3 - Structural - Main Structure - Recieve & Address Preliminary Comments	34	26-Jan-24	13-Mar-24
246	EPK3SRQNTS000MS1	Pk3 - Structural - Main Structure - Final QC/QA/Ready to Submit	36	14-Mar-24	03-May-24
247	**RFC**		58	28-May-24	16-Aug-24
248	EPK3SCRNTS000MS1	Pk3 - Structural - Main Structure - Recieve & Address Final Comments	15	28-May-24	17-Jun-24
249	EPK3SCDNTS000MS1	Pk3 - Structural - Main Structure - RFC Design Development	10	11-Jun-24	24-Jun-24
250	EPK3SCQNTS000MS1	Pk3 - Structural - Main Structure - RFC QC/QA/Ready to Submit	18	25-Jun-24	19-Jul-24
251	EPK3SCFNTS000MS1	PK3 - Structural - Main Structure - RFC Approved	5	12-Aug-24	16-Aug-24
252	**Construction**		869	03-Jun-24	30-Sep-27
253	**Milestones/ Admin**		869	03-Jun-24	30-Sep-27
254	MIL.1001	Construction Start	0	03-Jun-24	
255	MIL.1011	Phase 0 Complete	0		28-Jun-24
256	MIL.1021	Phase 1 Complete	0		26-Jun-25
257	MIL.1031	Phase 2 Complete	0		28-Jul-26
258	MIL.1041	Phase 3 Complete	0		13-Sep-27
259	MIL.1071	Phase 4 Complete	0		30-Sep-27
260	**Phase 0**		20	03-Jun-24	28-Jun-24
261	**I-20 Westbound Outside Shoulder**		15	03-Jun-24	21-Jun-24
262	C1WBD02DTR.CRIN	1WBD02 Detour - Civil Removals	2	03-Jun-24	04-Jun-24
263	C1WBD02DTR.EXIN	1WBD02 Detour - Excavation	2	05-Jun-24	06-Jun-24
264	C1WBD02ZZZ.EMIN	1WBD02 Detour - Embankment	2	12-Jun-24	13-Jun-24
265	C1WBD02ZZZ.SPIN	1WBD02 Detour - Subgrade Prep & Finish	2	14-Jun-24	17-Jun-24
266	C1WBD02DTR.APIN	1WBD02 Detour - Asphalt Paving	4	18-Jun-24	21-Jun-24
267	**I-20 Eastbound Outside Shoulder**		12	05-Jun-24	20-Jun-24
268	C1EBD02DTR.CRIN	1EBD02 Detour - Civil Removals	2	05-Jun-24	06-Jun-24
269	C1EBD02DTR.EXIN	1EBD02 Detour - Excavation	2	07-Jun-24	10-Jun-24
270	C1EBD02ZZZ.EMIN	1EBD02 Detour - Embankment	2	11-Jun-24	12-Jun-24
271	C1EBD02ZZZ.SPIN	1EBD02 Detour- Subgrade Prep & Finish	2	13-Jun-24	14-Jun-24
272	C1EBD02DTR.APIN	1EBD02 Detour - Asphalt Paving	4	17-Jun-24	20-Jun-24
273	**Sitewide Phase 0 & 1 Work**		20	03-Jun-24	28-Jun-24
274	C1PJW01ZZZ.ECIN	1PJW01 Sitewide - Environmental Controls	1	03-Jun-24	03-Jun-24
275	C1PJW01ZZZ.STIN	1PJW01 Sitewide - Topsoil Strip to Stock Pile	5	04-Jun-24	10-Jun-24
276	C1PJW01ZZZ.EXIN	1PJW01 Sitewide - Excavation	1	11-Jun-24	11-Jun-24
277	C1PJW01TE1.TCIN	1PJW01 Traffic Switch to Kick Off Phase 1 - Traffic Control	5	24-Jun-24	28-Jun-24
278	C1PJW01TE1.TDIN	1PJW01 Traffic Switch to Kick Off Phase 1 - Temp Barrier	5	24-Jun-24	28-Jun-24



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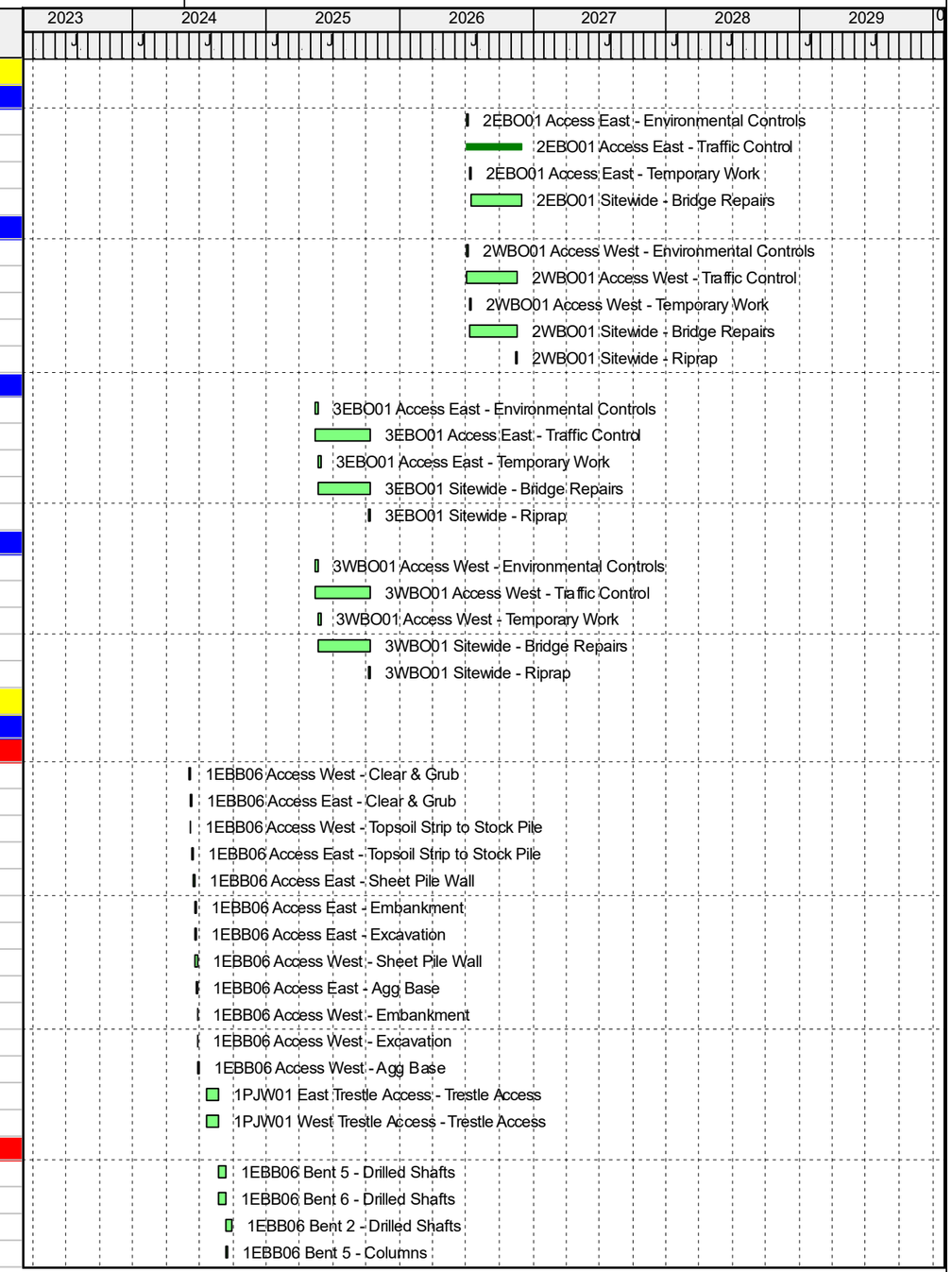
#	Activity ID	Activity Name	Original Duration	Start	Finish
279	**Overflow Bridges Rehabilitation**		391	14-May-25	01-Dec-26
280	**Bridge 5780 Rehabilitation**		105	02-Jul-26	01-Dec-26
281	C2EBO01ACE.ECIN	2EBO01 Access East - Environmental Controls	5	02-Jul-26	09-Jul-26
282	C2EBO01ACE.TCIN	2EBO01 Access East - Traffic Control	105	02-Jul-26	01-Dec-26
283	C2EBO01ACE.TWIN	2EBO01 Access East - Temporary Work	5	10-Jul-26	16-Jul-26
284	C2EBO01ZZZ.SMIN	2EBO01 Sitewide - Bridge Repairs	95	17-Jul-26	01-Dec-26
285	**Bridge 5785 Rehabilitation**		100	02-Jul-26	20-Nov-26
286	C2WBO01ACW.ECIN	2WBO01 Access West - Environmental Controls	5	02-Jul-26	09-Jul-26
287	C2WBO01ACW.TCIN	2WBO01 Access West - Traffic Control	100	02-Jul-26	20-Nov-26
288	C2WBO01ACW.TWIN	2WBO01 Access West - Temporary Work	5	10-Jul-26	16-Jul-26
289	C2WBO01ZZZ.SMIN	2WBO01 Sitewide - Bridge Repairs	95	10-Jul-26	20-Nov-26
290	C2WBO01ZZZ.RRIN	2WBO01 Sitewide - Riprap	5	16-Nov-26	20-Nov-26
291	**Bridge 5781 Rehabilitation**		105	14-May-25	10-Oct-25
292	C3EBO01ACE.ECIN	3EBO01 Access East - Environmental Controls	5	14-May-25	20-May-25
293	C3EBO01ACE.TCIN	3EBO01 Access East - Traffic Control	105	14-May-25	10-Oct-25
294	C3EBO01ACE.TWIN	3EBO01 Access East - Temporary Work	5	21-May-25	28-May-25
295	C3EBO01ZZZ.SMIN	3EBO01 Sitewide - Bridge Repairs	100	21-May-25	10-Oct-25
296	C3EBO01ZZZ.RRIN	3EBO01 Sitewide - Riprap	5	06-Oct-25	10-Oct-25
297	**Bridge 5786 Rehabilitation**		105	14-May-25	10-Oct-25
298	C3WBO01ACW.ECIN	3WBO01 Access West - Environmental Controls	5	14-May-25	20-May-25
299	C3WBO01ACW.TCIN	3WBO01 Access West - Traffic Control	105	14-May-25	10-Oct-25
300	C3WBO01ACW.TWIN	3WBO01 Access West - Temporary Work	5	21-May-25	28-May-25
301	C3WBO01ZZZ.SMIN	3WBO01 Sitewide - Bridge Repairs	100	21-May-25	10-Oct-25
302	C3WBO01ZZZ.RRIN	3WBO01 Sitewide - Riprap	5	06-Oct-25	10-Oct-25
303	**Phase 1**		261	03-Jun-24	02-Jun-25
304	**New Wateree Bridge Median Construction**		261	03-Jun-24	02-Jun-25
305	**Phase 1 Early Access Work**		58	03-Jun-24	22-Aug-24
306	C1EBB06ACW.CGIN	1EBB06 Access West - Clear & Grub	3	03-Jun-24	05-Jun-24
307	C1EBB06ACE.CGIN	1EBB06 Access East - Clear & Grub	3	06-Jun-24	10-Jun-24
308	C1EBB06ACW.STIN	1EBB06 Access West - Topsoil Strip to Stock Pile	2	06-Jun-24	07-Jun-24
309	C1EBB06ACE.STIN	1EBB06 Access East - Topsoil Strip to Stock Pile	2	11-Jun-24	12-Jun-24
310	C1EBB06ACE.SHIN	1EBB06 Access East - Sheet Pile Wall	4	13-Jun-24	18-Jun-24
311	C1EBB06ACE.EMIN	1EBB06 Access East - Embankment	2	19-Jun-24	20-Jun-24
312	C1EBB06ACE.EXIN	1EBB06 Access East - Excavation	2	19-Jun-24	20-Jun-24
313	C1EBB06ACW.SHIN	1EBB06 Access West - Sheet Pile Wall	4	19-Jun-24	24-Jun-24
314	C1EBB06ACE.ABIN	1EBB06 Access East - Agg Base	2	21-Jun-24	24-Jun-24
315	C1EBB06ACW.EMIN	1EBB06 Access West - Embankment	2	25-Jun-24	26-Jun-24
316	C1EBB06ACW.EXIN	1EBB06 Access West - Excavation	2	25-Jun-24	26-Jun-24
317	C1EBB06ACW.ABIN	1EBB06 Access West - Agg Base	2	27-Jun-24	28-Jun-24
318	C1PJW01TRE.TJIN	1PJW01 East Trestle Access - Trestle Access	24	22-Jul-24	22-Aug-24
319	C1PJW01TRW.TJIN	1PJW01 West Trestle Access - Trestle Access	24	22-Jul-24	22-Aug-24
320	**Phase 1 New Bridge Construction**		202	23-Aug-24	02-Jun-25
321	C1EBB06B05.DSIN	1EBB06 Bent 5 - Drilled Shafts	12	23-Aug-24	10-Sep-24
322	C1EBB06B06.DSIN	1EBB06 Bent 6 - Drilled Shafts	12	23-Aug-24	10-Sep-24
323	C1EBB06B02.DSIN	1EBB06 Bent 2 - Drilled Shafts	12	11-Sep-24	26-Sep-24
324	C1EBB06B05.CMIN	1EBB06 Bent 5 - Columns	5	11-Sep-24	17-Sep-24



Remaining Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work

TASK filter: All Activities

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#	Activity ID	Activity Name	Original Duration	Start	Finish
325	C1EBB06B06.CMIN	1EBB06 Bent 6 - Columns	5	11-Sep-24	17-Sep-24
326	C1EBB06B11.DSIN	1EBB06 Bent 11 - Drilled Shafts	12	11-Sep-24	26-Sep-24
327	C1EBB06B05.CMIN10	1EBB06 Bent 5 - Columns Cure	3	18-Sep-24	20-Sep-24
328	C1EBB06B06.CMIN10	1EBB06 Bent 6 - Columns Cure	3	18-Sep-24	20-Sep-24
329	C1EBB06B05.PCIN	1EBB06 Bent 5 - Pier Caps	6	20-Sep-24	30-Sep-24
330	C1EBB06B06.PCIN	1EBB06 Bent 6 - Pier Caps	6	20-Sep-24	30-Sep-24
331	C1EBB06B01.PLIN	1EBB06 Bent 1 - Piling	4	27-Sep-24	02-Oct-24
332	C1EBB06B02.CMIN	1EBB06 Bent 2 - Columns	5	27-Sep-24	03-Oct-24
333	C1EBB06B03.DSIN	1EBB06 Bent 3 - Drilled Shafts	12	27-Sep-24	14-Oct-24
334	C1EBB06B10.DSIN	1EBB06 Bent 10 - Drilled Shafts	12	27-Sep-24	14-Oct-24
335	C1EBB06B12.PLIN	1EBB06 Bent 12 - Piling	4	27-Sep-24	02-Oct-24
336	C1EBB06B11.CMIN	1EBB06 Bent 11 - Columns	5	27-Sep-24	03-Oct-24
337	C1EBB06B05.PCIN10	1EBB06 Bent 5 - Pier Caps Cure	14	30-Sep-24	13-Oct-24
338	C1EBB06B06.PCIN10	1EBB06 Bent 6 - Pier Caps Cure	14	30-Sep-24	13-Oct-24
339	C1EBB06B01.SBIN	1EBB06 Bent 1 - Structure Exc	4	03-Oct-24	08-Oct-24
340	C1EBB06B12.SBIN	1EBB06 Bent 12 - Structure Exc	4	03-Oct-24	08-Oct-24
341	C1EBB06B11.CMIN10	1EBB06 Bent 11 - Columns Cure	3	04-Oct-24	06-Oct-24
342	C1EBB06B02.CMIN10	1EBB06 Bent 2 - Columns Cure	3	04-Oct-24	06-Oct-24
343	C1EBB06B02.PCIN	1EBB06 Bent 2 - Pier Caps	6	07-Oct-24	14-Oct-24
344	C1EBB06B11.PCIN	1EBB06 Bent 11 - Pier Caps	5	07-Oct-24	11-Oct-24
345	C1EBB06B11.PCIN10	1EBB06 Bent 11 - Pier Caps Cure	14	12-Oct-24	24-Oct-24
346	C1EBB06TRE.TJIN.1	1EBB06 Remove East Trestle Access - Trestle Access	8	14-Oct-24	23-Oct-24
347	C1EBB06TRW.TJIN.1	1EBB06 Remove West Trestle Access - Trestle Access	8	14-Oct-24	23-Oct-24
348	C1EBB06B03.CMIN	1EBB06 Bent 3 - Columns	5	15-Oct-24	21-Oct-24
349	C1EBB06B04.DSIN	1EBB06 Bent 4 - Drilled Shafts	12	15-Oct-24	30-Oct-24
350	C1EBB06B09.DSIN	1EBB06 Bent 9 - Drilled Shafts	12	15-Oct-24	30-Oct-24
351	C1EBB06B10.CMIN	1EBB06 Bent 10 - Columns	5	15-Oct-24	21-Oct-24
352	C1EBB06B02.PCIN10	1EBB06 Bent 2 - Pier Caps Cure	14	15-Oct-24	27-Oct-24
353	C1EBB06B10.CMIN10	1EBB06 Bent 10 - Columns Cure	3	22-Oct-24	24-Oct-24
354	C1EBB06B03.CMIN10	1EBB06 Bent 3 - Columns Cure	3	22-Oct-24	24-Oct-24
355	C1EBB06B03.PCIN	1EBB06 Bent 3 - Pier Caps	6	24-Oct-24	01-Nov-24
356	C1EBB06B10.PCIN	1EBB06 Bent 10 - Pier Caps	6	24-Oct-24	01-Nov-24
357	C1EBB06B04.CMIN	1EBB06 Bent 4 - Columns	5	31-Oct-24	06-Nov-24
358	C1EBB06B08.DSIN	1EBB06 Bent 8 - Drilled Shafts	12	31-Oct-24	15-Nov-24
359	C1EBB06B09.CMIN	1EBB06 Bent 9 - Columns	5	31-Oct-24	06-Nov-24
360	C1EBB06B10.PCIN10	1EBB06 Bent 10 - Pier Caps Cure	14	01-Nov-24	14-Nov-24
361	C1EBB06B03.PCIN10	1EBB06 Bent 3 - Pier Caps Cure	14	01-Nov-24	14-Nov-24
362	C1EBB06B01.AWIN	1EBB06 Bent 1 - Abutments & Wing Walls	7	07-Nov-24	15-Nov-24
363	C1EBB06B04.CMIN10	1EBB06 Bent 4 - Columns Cure	3	07-Nov-24	09-Nov-24
364	C1EBB06B09.CMIN10	1EBB06 Bent 9 - Columns Cure	3	07-Nov-24	09-Nov-24
365	C1EBB06B04.PCIN	1EBB06 Bent 4 - Pier Caps	6	11-Nov-24	18-Nov-24
366	C1EBB06B09.PCIN	1EBB06 Bent 9 - Pier Caps	6	11-Nov-24	18-Nov-24
367	C1EBB06B01.47IN	1EBB06 Bent 1 - Structural Backfill	4	18-Nov-24	21-Nov-24
368	C1EBB06B07.DSIN	1EBB06 Bent 7 - Drilled Shafts	12	18-Nov-24	05-Dec-24
369	C1EBB06B08.CMIN	1EBB06 Bent 8 - Columns	5	18-Nov-24	22-Nov-24
370	C1EBB06B01.RRIN	1EBB06 Bent 1- Riprap	5	18-Nov-24	22-Nov-24

Remaining Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

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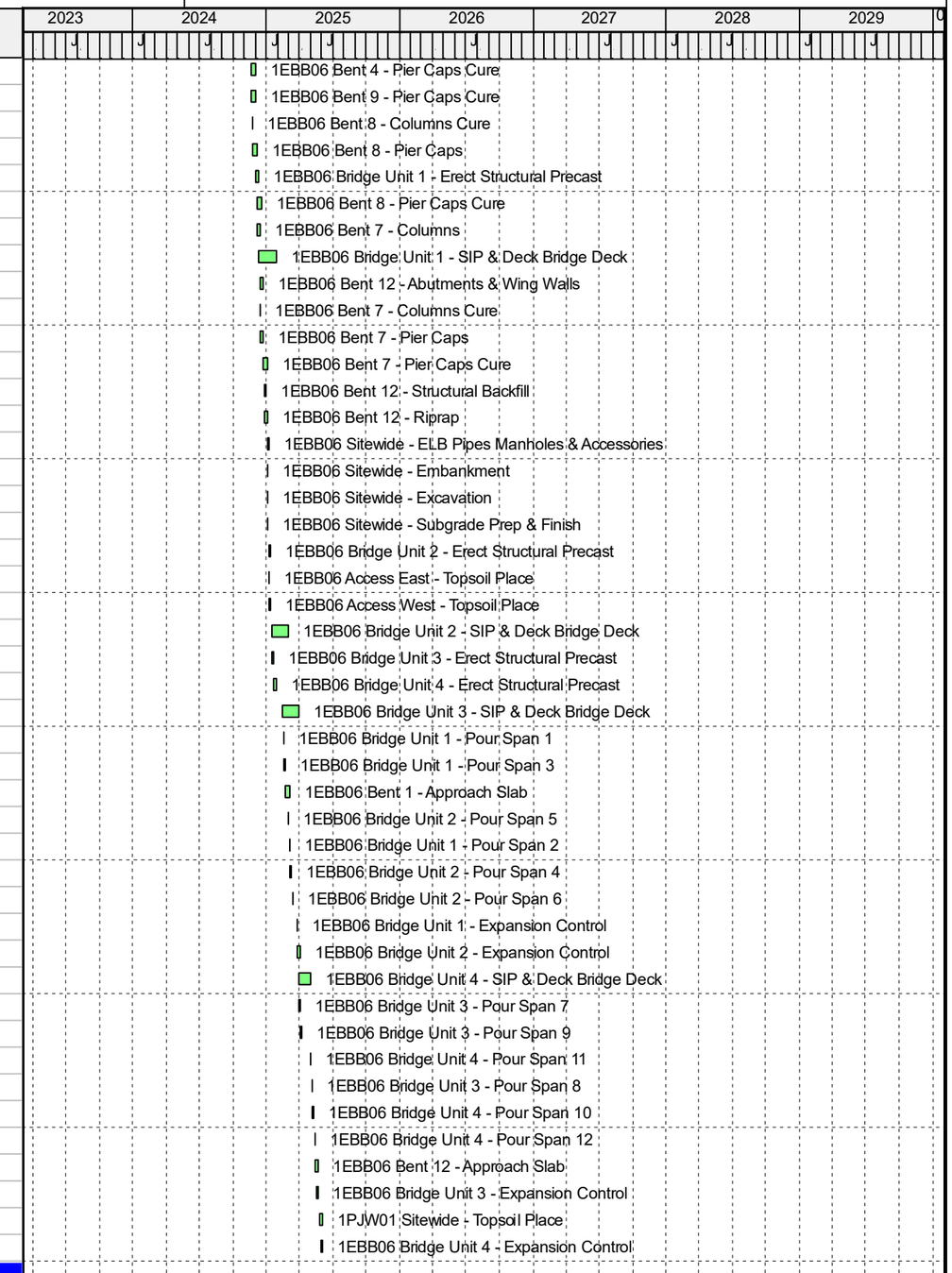
#	Activity ID	Activity Name	Original Duration	Start	Finish
371	C1EBB06B04.PCIN10	1EBB06 Bent 4 - Pier Caps Cure	14	19-Nov-24	01-Dec-24
372	C1EBB06B09.PCIN10	1EBB06 Bent 9 - Pier Caps Cure	14	19-Nov-24	01-Dec-24
373	C1EBB06B08.CMIN10	1EBB06 Bent 8 - Columns Cure	3	23-Nov-24	25-Nov-24
374	C1EBB06B08.PCIN	1EBB06 Bent 8 - Pier Caps	6	25-Nov-24	05-Dec-24
375	C1EBB06U01.EPIN	1EBB06 Bridge Unit 1 - Erect Structural Precast	6	02-Dec-24	09-Dec-24
376	C1EBB06B08.PCIN10	1EBB06 Bent 8 - Pier Caps Cure	14	05-Dec-24	18-Dec-24
377	C1EBB06B07.CMIN	1EBB06 Bent 7 - Columns	5	06-Dec-24	12-Dec-24
378	C1EBB06U01.BNIN	1EBB06 Bridge Unit 1 - SIP & Deck Bridge Deck	34	10-Dec-24	29-Jan-25
379	C1EBB06B12.AWIN	1EBB06 Bent 12 - Abutments & Wing Walls	7	13-Dec-24	23-Dec-24
380	C1EBB06B07.CMIN10	1EBB06 Bent 7 - Columns Cure	3	13-Dec-24	15-Dec-24
381	C1EBB06B07.PCIN	1EBB06 Bent 7 - Pier Caps	6	16-Dec-24	23-Dec-24
382	C1EBB06B07.PCIN10	1EBB06 Bent 7 - Pier Caps Cure	14	24-Dec-24	05-Jan-25
383	C1EBB06B12.47IN	1EBB06 Bent 12 - Structural Backfill	4	26-Dec-24	31-Dec-24
384	C1EBB06B12.RRIN	1EBB06 Bent 12 - Riprap	5	26-Dec-24	02-Jan-25
385	C1EBB06ZZZ.EBIN	1EBB06 Sitewide - ELB Pipes Manholes & Accessories	5	02-Jan-25	08-Jan-25
386	C1EBB06ZZZ.EMIN	1EBB06 Sitewide - Embankment	1	02-Jan-25	02-Jan-25
387	C1EBB06ZZZ.EXIN	1EBB06 Sitewide - Excavation	1	02-Jan-25	02-Jan-25
388	C1EBB06ZZZ.SPIN	1EBB06 Sitewide - Subgrade Prep & Finish	1	03-Jan-25	03-Jan-25
389	C1EBB06U02.EPIN	1EBB06 Bridge Unit 2 - Erect Structural Precast	6	06-Jan-25	13-Jan-25
390	C1EBB06ACE.TEIN	1EBB06 Access East - Topsoil Place	1	09-Jan-25	09-Jan-25
391	C1EBB06ACW.TEIN	1EBB06 Access West - Topsoil Place	2	09-Jan-25	10-Jan-25
392	C1EBB06U02.BNIN	1EBB06 Bridge Unit 2 - SIP & Deck Bridge Deck	34	14-Jan-25	28-Feb-25
393	C1EBB06U03.EPIN	1EBB06 Bridge Unit 3 - Erect Structural Precast	6	14-Jan-25	21-Jan-25
394	C1EBB06U04.EPIN	1EBB06 Bridge Unit 4 - Erect Structural Precast	6	22-Jan-25	29-Jan-25
395	C1EBB06U03.BNIN	1EBB06 Bridge Unit 3 - SIP & Deck Bridge Deck	34	12-Feb-25	31-Mar-25
396	C1EBB06U01.BNIN10	1EBB06 Bridge Unit 1 - Pour Span 1	1	17-Feb-25	17-Feb-25
397	C1EBB06U01.BNIN30	1EBB06 Bridge Unit 1 - Pour Span 3	2	19-Feb-25	20-Feb-25
398	C1EBB06B01.ASIN	1EBB06 Bent 1 - Approach Slab	8	21-Feb-25	04-Mar-25
399	C1EBB06U02.BNIN20	1EBB06 Bridge Unit 2 - Pour Span 5	1	03-Mar-25	03-Mar-25
400	C1EBB06U01.BNIN20	1EBB06 Bridge Unit 1 - Pour Span 2	1	05-Mar-25	05-Mar-25
401	C1EBB06U02.BNIN10	1EBB06 Bridge Unit 2 - Pour Span 4	2	07-Mar-25	10-Mar-25
402	C1EBB06U02.BNIN30	1EBB06 Bridge Unit 2 - Pour Span 6	2	12-Mar-25	13-Mar-25
403	C1EBB06U01.ENIN	1EBB06 Bridge Unit 1 - Expansion Control	3	25-Mar-25	27-Mar-25
404	C1EBB06U02.ENIN	1EBB06 Bridge Unit 2 - Expansion Control	3	28-Mar-25	01-Apr-25
405	C1EBB06U04.BNIN	1EBB06 Bridge Unit 4 - SIP & Deck Bridge Deck	21	01-Apr-25	30-Apr-25
406	C1EBB06U03.BNIN10	1EBB06 Bridge Unit 3 - Pour Span 7	2	01-Apr-25	02-Apr-25
407	C1EBB06U03.BNIN30	1EBB06 Bridge Unit 3 - Pour Span 9	2	04-Apr-25	07-Apr-25
408	C1EBB06U04.BNIN20	1EBB06 Bridge Unit 4 - Pour Span 11	1	01-May-25	01-May-25
409	C1EBB06U03.BNIN20	1EBB06 Bridge Unit 3 - Pour Span 8	1	05-May-25	05-May-25
410	C1EBB06U04.BNIN10	1EBB06 Bridge Unit 4 - Pour Span 10	2	07-May-25	08-May-25
411	C1EBB06U04.BNIN30	1EBB06 Bridge Unit 4 - Pour Span 12	2	12-May-25	13-May-25
412	C1EBB06B12.ASIN	1EBB06 Bent 12 - Approach Slab	8	14-May-25	23-May-25
413	C1EBB06U03.ENIN	1EBB06 Bridge Unit 3 - Expansion Control	3	20-May-25	22-May-25
414	C1PJW01ZZZ.TEIN	1PJW01 Sitewide - Topsoil Place	5	27-May-25	02-Jun-25
415	C1EBB06U04.ENIN	1EBB06 Bridge Unit 4 - Expansion Control	3	29-May-25	02-Jun-25
416	**I-20 West Approach Construction**		122	11-Sep-24	06-Mar-25



Remaining Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

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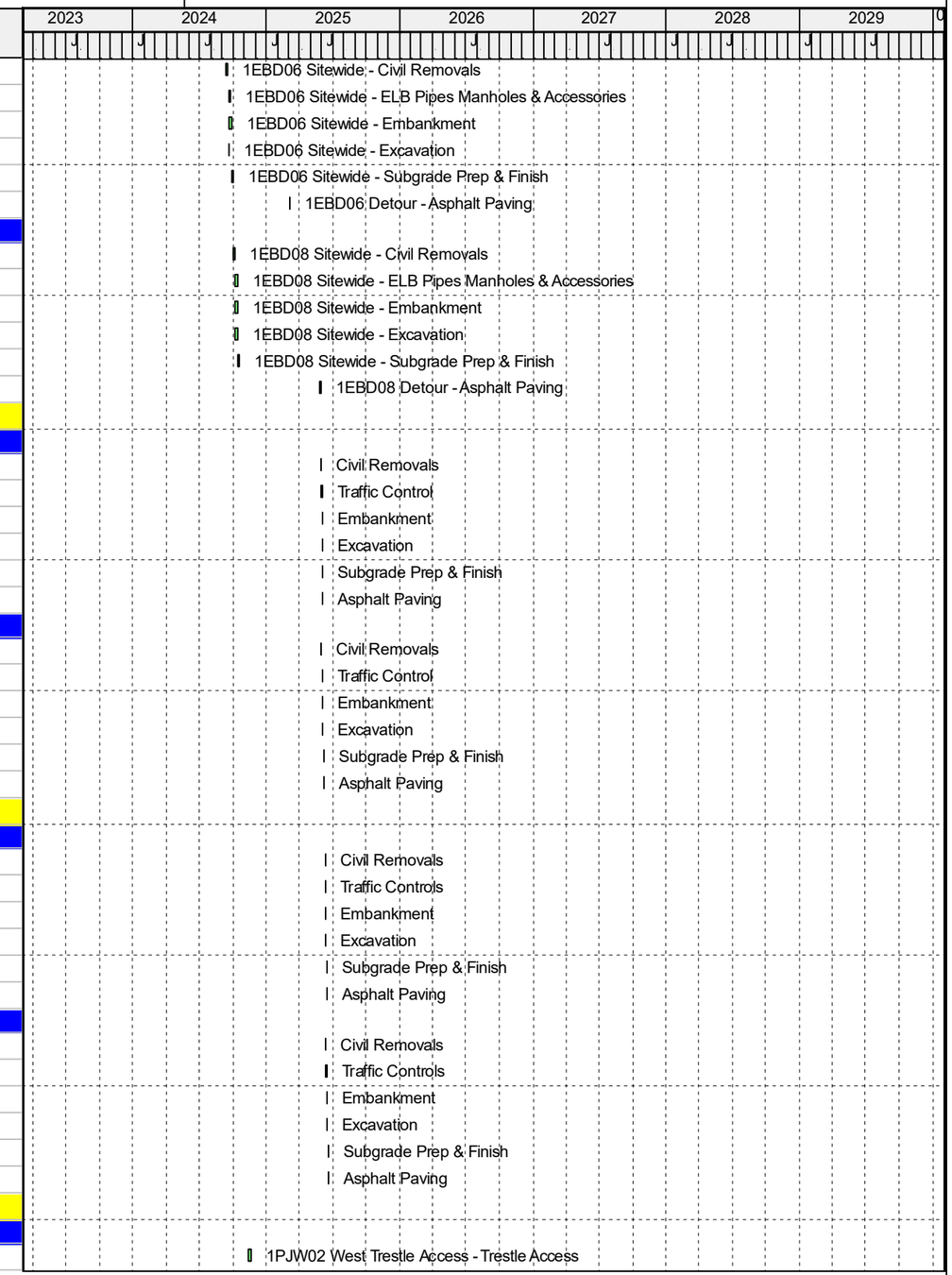
#	Activity ID	Activity Name	Original Duration	Start	Finish
417	C1EBD06ZZZ.CRIN	1EBD06 Sitewide - Civil Removals	5	11-Sep-24	17-Sep-24
418	C1EBD06ZZZ.EBIN	1EBD06 Sitewide - ELB Pipes Manholes & Accessories	5	18-Sep-24	24-Sep-24
419	C1EBD06ZZZ.EMIN	1EBD06 Sitewide - Embankment	7	18-Sep-24	26-Sep-24
420	C1EBD06ZZZ.EXIN	1EBD06 Sitewide - Excavation	1	18-Sep-24	18-Sep-24
421	C1EBD06ZZZ.SPIN	1EBD06 Sitewide - Subgrade Prep & Finish	2	27-Sep-24	30-Sep-24
422	C1EBD06DTR.APIN	1EBD06 Detour - Asphalt Paving	2	05-Mar-25	06-Mar-25
423	**I-20 East Approach Construction**		165	01-Oct-24	28-May-25
424	C1EBD08ZZZ.CRIN	1EBD08 Sitewide - Civil Removals	5	01-Oct-24	07-Oct-24
425	C1EBD08ZZZ.EBIN	1EBD08 Sitewide - ELB Pipes Manholes & Accessories	5	08-Oct-24	14-Oct-24
426	C1EBD08ZZZ.EMIN	1EBD08 Sitewide - Embankment	5	08-Oct-24	14-Oct-24
427	C1EBD08ZZZ.EXIN	1EBD08 Sitewide - Excavation	5	08-Oct-24	14-Oct-24
428	C1EBD08ZZZ.SPIN	1EBD08 Sitewide - Subgrade Prep & Finish	2	15-Oct-24	16-Oct-24
429	C1EBD08DTR.APIN	1EBD08 Detour - Asphalt Paving	2	27-May-25	28-May-25
430	**Phase 1B**		8	29-May-25	09-Jun-25
431	**I-20 Eastbound Lanes Tranistion to New Middle Bridge - West Approach**		6	29-May-25	05-Jun-25
432	C1EBD06ZZZ.CRIN10	Civil Removals	1	29-May-25	29-May-25
433	C1EBD06ZZZ.CRIN20	Traffic Control	2	30-May-25	02-Jun-25
434	C1EBD06ZZZ.EMIN10	Embankment	1	03-Jun-25	03-Jun-25
435	C1EBD06ZZZ.EXIN10	Excavation	1	03-Jun-25	03-Jun-25
436	C1EBD06ZZZ.SPIN10	Subgrade Prep & Finish	1	04-Jun-25	04-Jun-25
437	C1EBD06ZZZ.APIN10	Asphalt Paving	1	05-Jun-25	05-Jun-25
438	**I-20 Eastbound Lanes Tranistion to New Middle Bridge - East Approach**		7	30-May-25	09-Jun-25
439	C1EBD06ZZZ.CRIN30	Civil Removals	1	30-May-25	30-May-25
440	C1EBD06ZZZ.CRIN40	Traffic Control	2	03-Jun-25	04-Jun-25
441	C1EBD06ZZZ.EMIN20	Embankment	1	05-Jun-25	05-Jun-25
442	C1EBD06ZZZ.EXIN20	Excavation	1	05-Jun-25	05-Jun-25
443	C1EBD06ZZZ.SPIN20	Subgrade Prep & Finish	1	06-Jun-25	06-Jun-25
444	C1EBD06ZZZ.APIN20	Asphalt Paving	1	09-Jun-25	09-Jun-25
445	**Phase 1C**		8	10-Jun-25	19-Jun-25
446	**I-20 Eastbound Lanes Tranistion to New Middle Bridge - West Approach**		6	10-Jun-25	17-Jun-25
447	C1EBD08ZZZ.CRIN10	Civil Removals	1	10-Jun-25	10-Jun-25
448	C1EBD08ZZZ.CRIN20	Traffic Controls	2	11-Jun-25	12-Jun-25
449	C1EBD08ZZZ.EMIN10	Embankment	1	13-Jun-25	13-Jun-25
450	C1EBD08ZZZ.EXIN10	Excavation	1	13-Jun-25	13-Jun-25
451	C1EBD08ZZZ.SPIN10	Subgrade Prep & Finish	1	16-Jun-25	16-Jun-25
452	C1EBD08DTR.APIN10	Asphalt Paving	1	17-Jun-25	17-Jun-25
453	**I-20 Eastbound Lanes Tranistion to New Middle Bridge - East Approach**		7	11-Jun-25	19-Jun-25
454	C1EBD08ZZZ.CRIN30	Civil Removals	1	11-Jun-25	11-Jun-25
455	C1EBD08ZZZ.CRIN40	Traffic Controls	2	13-Jun-25	16-Jun-25
456	C1EBD08ZZZ.EMIN20	Embankment	1	17-Jun-25	17-Jun-25
457	C1EBD08ZZZ.EXIN20	Excavation	1	17-Jun-25	17-Jun-25
458	C1EBD08ZZZ.SPIN20	Subgrade Prep & Finish	1	18-Jun-25	18-Jun-25
459	C1EBD08DTR.APIN20	Asphalt Paving	1	19-Jun-25	19-Jun-25
460	**Phase 2**		453	24-Oct-24	20-Jul-26
461	**Sitewide Phase 2 Work**		155	13-Nov-24	26-Jun-25
462	C1PJW02TRW.TJIN	1PJW02 West Trestle Access - Trestle Access	5	13-Nov-24	19-Nov-24



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#	Activity ID	Activity Name	Original Duration	Start	Finish
463	C1PJW02TRE.TJIN	1PJW02 East Trestle Access - Trestle Access	5	18-Nov-24	22-Nov-24
464	C1PJW02TE2.TCIN	1PJW02 Traffic Switch to Kick Off Phase 2 - Traffic Control	5	20-Jun-25	26-Jun-25
465	C1PJW02TE2.TDIN	1PJW02 Traffic Switch to Kick Off Phase 2 - Temp Barrier	5	20-Jun-25	26-Jun-25
466	**New Wateree Bridge Eastbound Construction**		453	24-Oct-24	20-Jul-26
467	**Phase 2 Early Access Work**		17	24-Oct-24	15-Nov-24
468	C1EBB04ACW.CGIN	1EBB04 Access West - Clear & Grub	3	24-Oct-24	28-Oct-24
469	C1EBB04ACE.CGIN	1EBB04 Access East - Clear & Grub	3	29-Oct-24	31-Oct-24
470	C1EBB04ACW.STIN	1EBB04 Access West - Topsoil Strip to Stock Pile	2	29-Oct-24	30-Oct-24
471	C1EBB04ACW.SKIN	1EBB04 Access West - Wall Remove	2	31-Oct-24	01-Nov-24
472	C1EBB04ACE.STIN	1EBB04 Access East - Topsoil Strip to Stock Pile	2	01-Nov-24	04-Nov-24
473	C1EBB04ACW.EMIN	1EBB04 Access West - Embankment	5	04-Nov-24	08-Nov-24
474	C1EBB04ACW.EXIN	1EBB04 Access West - Excavation	5	04-Nov-24	08-Nov-24
475	C1EBB04ACE.SKIN	1EBB04 Access East - Wall Remove	2	05-Nov-24	06-Nov-24
476	C1EBB04ACE.EMIN	1EBB04 Access East - Embankment	5	07-Nov-24	13-Nov-24
477	C1EBB04ACE.EXIN	1EBB04 Access East - Excavation	5	07-Nov-24	13-Nov-24
478	C1EBB04ACW.ABIN	1EBB04 Access West - Agg Base	2	11-Nov-24	12-Nov-24
479	C1EBB04ACE.ABIN	1EBB04 Access East - Agg Base	2	14-Nov-24	15-Nov-24
480	**Exsisting Bridge Demolition**		135	27-Jun-25	12-Jan-26
481	C1EBB04D07.BRIN	1EBB04 Bridge Demo Span 7 - Bridge Removal	55	27-Jun-25	15-Sep-25
482	C1EBB04D06.BRIN	1EBB04 Bridge Demo Span 6 - Bridge Removal	5	11-Aug-25	15-Aug-25
483	C1EBB04D05.BRIN	1EBB04 Bridge Demo Span 5 - Bridge Removal	5	18-Aug-25	22-Aug-25
484	C1EBB04D04.BRIN	1EBB04 Bridge Demo Span 4 - Bridge Removal	5	25-Aug-25	29-Aug-25
485	C1EBB04D03.BRIN	1EBB04 Bridge Demo Span 3 - Bridge Removal	5	02-Sep-25	08-Sep-25
486	C1EBB04D02.BRIN	1EBB04 Bridge Demo Span 2 - Bridge Removal	5	09-Sep-25	15-Sep-25
487	C1EBB04D01.BRIN	1EBB04 Bridge Demo Span 1 - Bridge Removal	5	16-Sep-25	22-Sep-25
488	C1EBB04D08.BRIN	1EBB04 Bridge Demo Span 8 - Bridge Removal	5	23-Sep-25	29-Sep-25
489	C1EBB04D09.BRIN	1EBB04 Bridge Demo Span 9 - Bridge Removal	5	30-Sep-25	06-Oct-25
490	C1EBB04D10.BRIN	1EBB04 Bridge Demo Span 10 - Bridge Removal	5	07-Oct-25	13-Oct-25
491	C1EBB04D11.BRIN	1EBB04 Bridge Demo Span 11 - Bridge Removal	5	14-Oct-25	20-Oct-25
492	C1EBB04D12.BRIN	1EBB04 Bridge Demo Span 12 - Bridge Removal	5	21-Oct-25	27-Oct-25
493	C1EBB04D13.BRIN	1EBB04 Bridge Demo Span 13 - Bridge Removal	5	28-Oct-25	03-Nov-25
494	C1EBB04D14.BRIN	1EBB04 Bridge Demo Span 14 - Bridge Removal	5	04-Nov-25	10-Nov-25
495	C1EBB04D15.BRIN	1EBB04 Bridge Demo Span 15 - Bridge Removal	5	11-Nov-25	17-Nov-25
496	C1EBB04D16.BRIN	1EBB04 Bridge Demo Span 16 - Bridge Removal	5	18-Nov-25	24-Nov-25
497	C1EBB04D17.BRIN	1EBB04 Bridge Demo Span 17 - Bridge Removal	5	25-Nov-25	03-Dec-25
498	C1EBB04D18.BRIN	1EBB04 Bridge Demo Span 18 - Bridge Removal	5	04-Dec-25	10-Dec-25
499	C1EBB04D19.BRIN	1EBB04 Bridge Demo Span 19 - Bridge Removal	5	11-Dec-25	17-Dec-25
500	C1EBB04D20.BRIN	1EBB04 Bridge Demo Span 20 - Bridge Removal	5	18-Dec-25	26-Dec-25
501	C1EBB04D21.BRIN	1EBB04 Bridge Demo Span 21 - Bridge Removal	5	29-Dec-25	05-Jan-26
502	C1EBB04D22.BRIN	1EBB04 Bridge Demo Span 22 - Bridge Removal	5	06-Jan-26	12-Jan-26
503	**New Bridge Construction**		220	16-Sep-25	20-Jul-26
504	C1EBB04B05.DSIN	1EBB04 Bent 5 - Drilled Shafts	12	16-Sep-25	01-Oct-25
505	C1EBB04B02.DSIN	1EBB04 Bent 2 - Drilled Shafts	12	02-Oct-25	17-Oct-25
506	C1EBB04B05.CMIN	1EBB04 Bent 5 - Columns	5	02-Oct-25	08-Oct-25
507	C1EBB04B05.CMIN10	1EBB04 Bent 5 - Columns Cure	3	09-Oct-25	11-Oct-25
508	C1EBB04B05.PCIN	1EBB04 Bent 5 - Pier Caps	6	13-Oct-25	20-Oct-25

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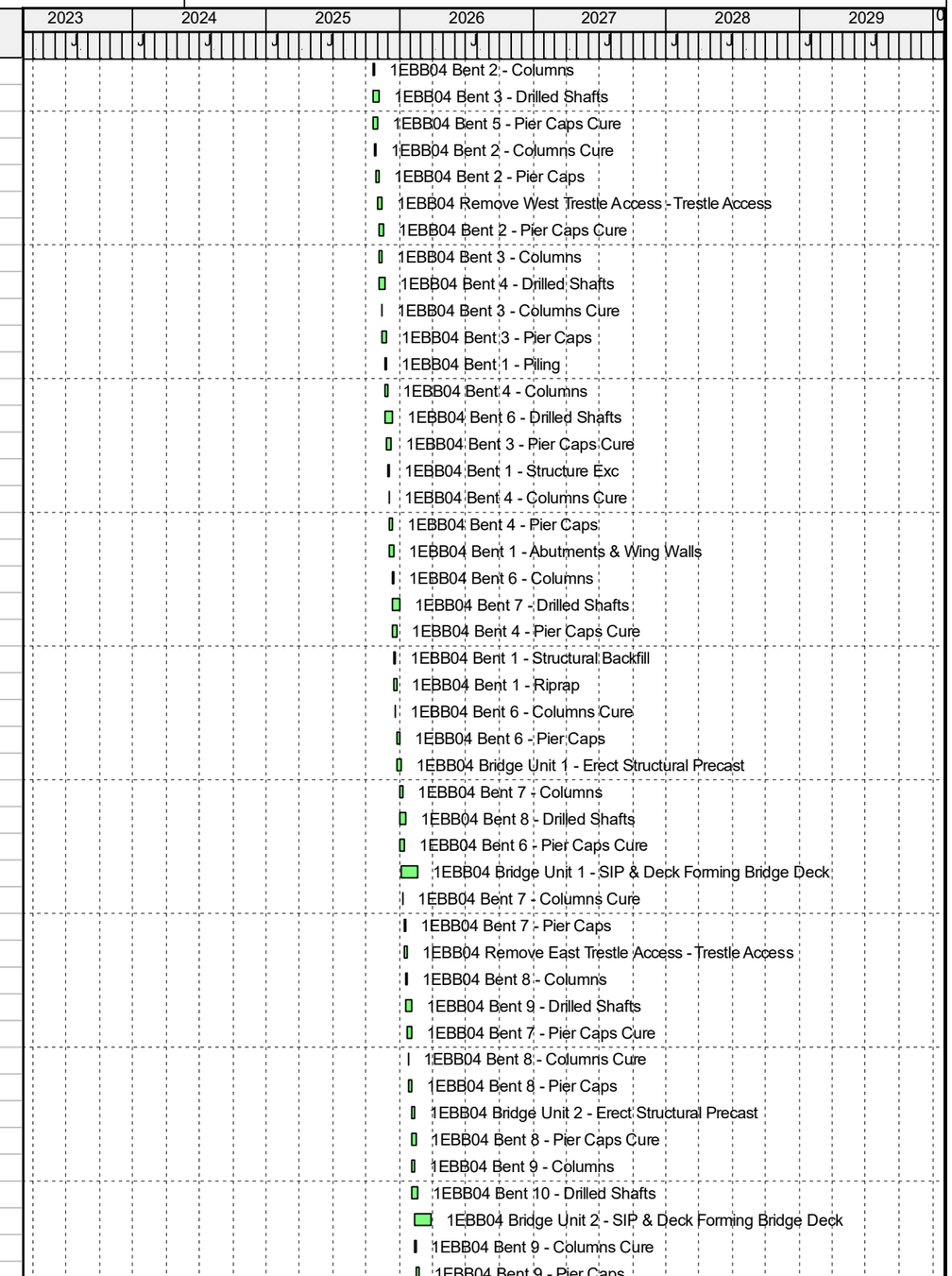
#	Activity ID	Activity Name	Original Duration	Start	Finish
509	C1EBB04B02.CMIN	1EBB04 Bent 2 - Columns	5	20-Oct-25	24-Oct-25
510	C1EBB04B03.DSIN	1EBB04 Bent 3 - Drilled Shafts	12	20-Oct-25	04-Nov-25
511	C1EBB04B05.PCIN10	1EBB04 Bent 5 - Pier Caps Cure	14	21-Oct-25	02-Nov-25
512	C1EBB04B02.CMIN10	1EBB04 Bent 2 - Columns Cure	3	25-Oct-25	27-Oct-25
513	C1EBB04B02.PCIN	1EBB04 Bent 2 - Pier Caps	6	27-Oct-25	04-Nov-25
514	C1EBB04TRW.TJIN.1	1EBB04 Remove West Trestle Access - Trestle Access	8	03-Nov-25	12-Nov-25
515	C1EBB04B02.PCIN10	1EBB04 Bent 2 - Pier Caps Cure	14	04-Nov-25	17-Nov-25
516	C1EBB04B03.CMIN	1EBB04 Bent 3 - Columns	5	05-Nov-25	11-Nov-25
517	C1EBB04B04.DSIN	1EBB04 Bent 4 - Drilled Shafts	12	05-Nov-25	20-Nov-25
518	C1EBB04B03.CMIN10	1EBB04 Bent 3 - Columns Cure	3	12-Nov-25	14-Nov-25
519	C1EBB04B03.PCIN	1EBB04 Bent 3 - Pier Caps	6	14-Nov-25	24-Nov-25
520	C1EBB04B01.PLIN	1EBB04 Bent 1 - Piling	4	21-Nov-25	26-Nov-25
521	C1EBB04B04.CMIN	1EBB04 Bent 4 - Columns	5	21-Nov-25	01-Dec-25
522	C1EBB04B06.DSIN	1EBB04 Bent 6 - Drilled Shafts	12	21-Nov-25	10-Dec-25
523	C1EBB04B03.PCIN10	1EBB04 Bent 3 - Pier Caps Cure	14	24-Nov-25	07-Dec-25
524	C1EBB04B01.SBIN	1EBB04 Bent 1 - Structure Exc	4	01-Dec-25	04-Dec-25
525	C1EBB04B04.CMIN10	1EBB04 Bent 4 - Columns Cure	3	02-Dec-25	04-Dec-25
526	C1EBB04B04.PCIN	1EBB04 Bent 4 - Pier Caps	6	04-Dec-25	12-Dec-25
527	C1EBB04B01.AWIN	1EBB04 Bent 1 - Abutments & Wing Walls	7	05-Dec-25	15-Dec-25
528	C1EBB04B06.CMIN	1EBB04 Bent 6 - Columns	5	11-Dec-25	17-Dec-25
529	C1EBB04B07.DSIN	1EBB04 Bent 7 - Drilled Shafts	12	11-Dec-25	30-Dec-25
530	C1EBB04B04.PCIN10	1EBB04 Bent 4 - Pier Caps Cure	14	12-Dec-25	25-Dec-25
531	C1EBB04B01.47IN	1EBB04 Bent 1 - Structural Backfill	4	16-Dec-25	19-Dec-25
532	C1EBB04B01.RRIN	1EBB04 Bent 1 - Riprap	5	16-Dec-25	22-Dec-25
533	C1EBB04B06.CMIN10	1EBB04 Bent 6 - Columns Cure	3	18-Dec-25	20-Dec-25
534	C1EBB04B06.PCIN	1EBB04 Bent 6 - Pier Caps	6	22-Dec-25	31-Dec-25
535	C1EBB04U01.EPIN	1EBB04 Bridge Unit 1 - Erect Structural Precast	6	26-Dec-25	05-Jan-26
536	C1EBB04B07.CMIN	1EBB04 Bent 7 - Columns	5	31-Dec-25	07-Jan-26
537	C1EBB04B08.DSIN	1EBB04 Bent 8 - Drilled Shafts	12	31-Dec-25	16-Jan-26
538	C1EBB04B06.PCIN10	1EBB04 Bent 6 - Pier Caps Cure	14	01-Jan-26	13-Jan-26
539	C1EBB04U01.BNIN	1EBB04 Bridge Unit 1 - SIP & Deck Forming Bridge Deck	34	06-Jan-26	20-Feb-26
540	C1EBB04B07.CMIN10	1EBB04 Bent 7 - Columns Cure	3	08-Jan-26	10-Jan-26
541	C1EBB04B07.PCIN	1EBB04 Bent 7 - Pier Caps	6	12-Jan-26	19-Jan-26
542	C1EBB04TRE.TJIN.1	1EBB04 Remove East Trestle Access - Trestle Access	8	13-Jan-26	23-Jan-26
543	C1EBB04B08.CMIN	1EBB04 Bent 8 - Columns	5	19-Jan-26	23-Jan-26
544	C1EBB04B09.DSIN	1EBB04 Bent 9 - Drilled Shafts	12	19-Jan-26	03-Feb-26
545	C1EBB04B07.PCIN10	1EBB04 Bent 7 - Pier Caps Cure	14	20-Jan-26	01-Feb-26
546	C1EBB04B08.CMIN10	1EBB04 Bent 8 - Columns Cure	3	24-Jan-26	26-Jan-26
547	C1EBB04B08.PCIN	1EBB04 Bent 8 - Pier Caps	6	26-Jan-26	03-Feb-26
548	C1EBB04U02.EPIN	1EBB04 Bridge Unit 2 - Erect Structural Precast	6	02-Feb-26	09-Feb-26
549	C1EBB04B08.PCIN10	1EBB04 Bent 8 - Pier Caps Cure	14	03-Feb-26	16-Feb-26
550	C1EBB04B09.CMIN	1EBB04 Bent 9 - Columns	5	04-Feb-26	10-Feb-26
551	C1EBB04B10.DSIN	1EBB04 Bent 10 - Drilled Shafts	12	04-Feb-26	19-Feb-26
552	C1EBB04U02.BNIN	1EBB04 Bridge Unit 2 - SIP & Deck Forming Bridge Deck	34	10-Feb-26	27-Mar-26
553	C1EBB04B09.CMIN10	1EBB04 Bent 9 - Columns Cure	3	11-Feb-26	13-Feb-26
554	C1EBB04B09.PCIN	1EBB04 Bent 9 - Pier Caps	6	13-Feb-26	23-Feb-26



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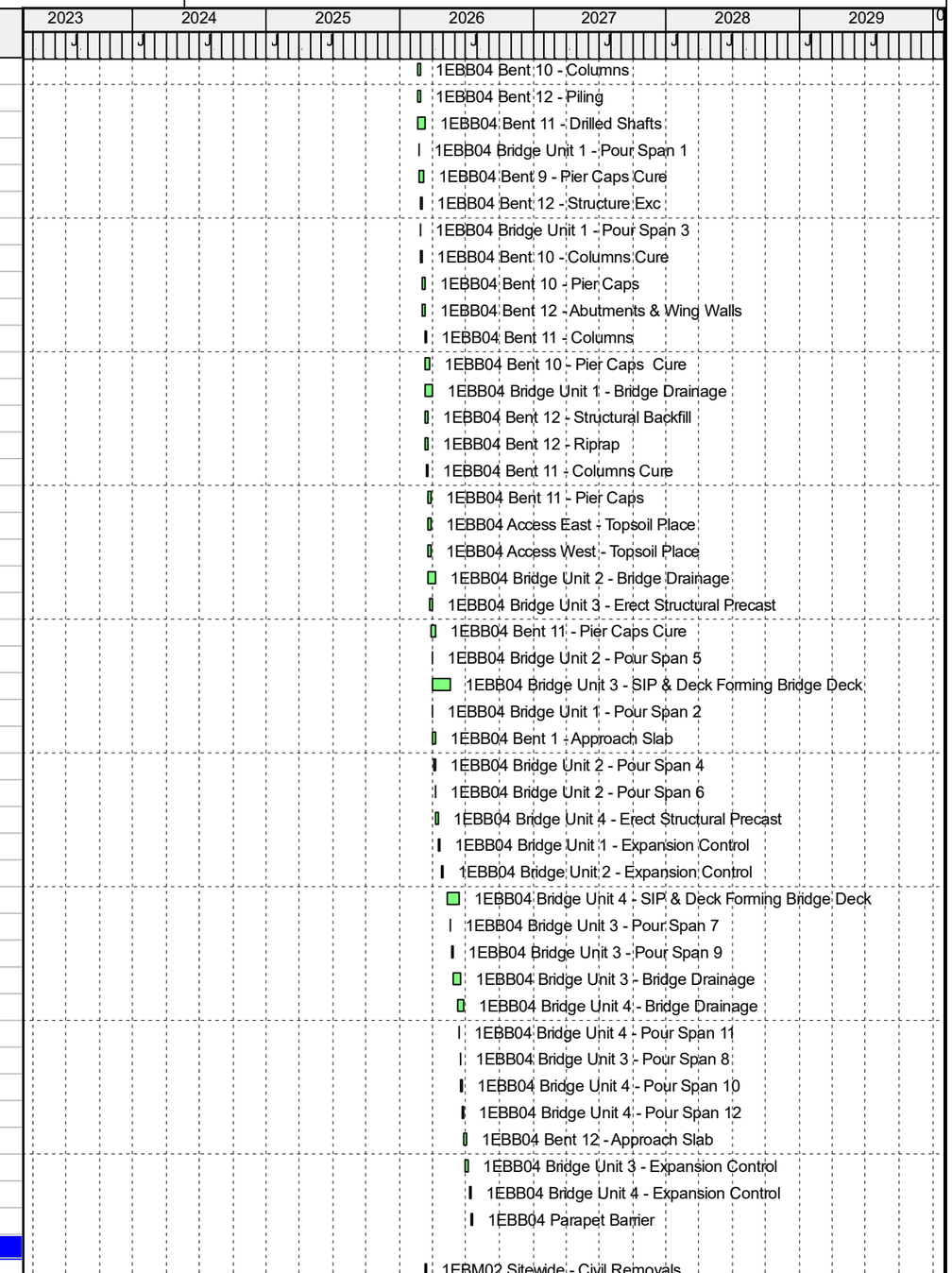
#	Activity ID	Activity Name	Original Duration	Start	Finish
555	C1EBB04B10.CMIN	1EBB04 Bent 10 - Columns	5	20-Feb-26	26-Feb-26
556	C1EBB04B12.PLIN	1EBB04 Bent 12 - Piling	4	20-Feb-26	25-Feb-26
557	C1EBB04B11.DSIN	1EBB04 Bent 11 - Drilled Shafts	12	20-Feb-26	09-Mar-26
558	C1EBB04U01.BNIN10	1EBB04 Bridge Unit 1 - Pour Span 1	2	23-Feb-26	24-Feb-26
559	C1EBB04B09.PCIN10	1EBB04 Bent 9 - Pier Caps Cure	14	23-Feb-26	08-Mar-26
560	C1EBB04B12.SBIN	1EBB04 Bent 12 - Structure Exc	4	26-Feb-26	03-Mar-26
561	C1EBB04U01.BNIN30	1EBB04 Bridge Unit 1 - Pour Span 3	2	26-Feb-26	27-Feb-26
562	C1EBB04B10.CMIN10	1EBB04 Bent 10 - Columns Cure	3	27-Feb-26	01-Mar-26
563	C1EBB04B10.PCIN	1EBB04 Bent 10 - Pier Caps	6	02-Mar-26	09-Mar-26
564	C1EBB04B12.AWIN	1EBB04 Bent 12 - Abutments & Wing Walls	7	04-Mar-26	12-Mar-26
565	C1EBB04B11.CMIN	1EBB04 Bent 11 - Columns	5	10-Mar-26	16-Mar-26
566	C1EBB04B10.PCIN10	1EBB04 Bent 10 - Pier Caps Cure	14	10-Mar-26	22-Mar-26
567	C1EBB04U01.BDIN	1EBB04 Bridge Unit 1 - Bridge Drainage	15	12-Mar-26	01-Apr-26
568	C1EBB04B12.47IN	1EBB04 Bent 12 - Structural Backfill	4	13-Mar-26	18-Mar-26
569	C1EBB04B12.RRIN	1EBB04 Bent 12 - Riprap	5	13-Mar-26	19-Mar-26
570	C1EBB04B11.CMIN10	1EBB04 Bent 11 - Columns Cure	3	17-Mar-26	19-Mar-26
571	C1EBB04B11.PCIN	1EBB04 Bent 11 - Pier Caps	6	19-Mar-26	27-Mar-26
572	C1EBB04ACE.TEIN	1EBB04 Access East - Topsoil Place	5	20-Mar-26	26-Mar-26
573	C1EBB04ACW.TEIN	1EBB04 Access West - Topsoil Place	5	20-Mar-26	26-Mar-26
574	C1EBB04U02.BDIN	1EBB04 Bridge Unit 2 - Bridge Drainage	15	20-Mar-26	10-Apr-26
575	C1EBB04U03.EPIN	1EBB04 Bridge Unit 3 - Erect Structural Precast	6	23-Mar-26	30-Mar-26
576	C1EBB04B11.PCIN10	1EBB04 Bent 11 - Pier Caps Cure	14	27-Mar-26	09-Apr-26
577	C1EBB04U02.BNIN20	1EBB04 Bridge Unit 2 - Pour Span 5	1	30-Mar-26	30-Mar-26
578	C1EBB04U03.BNIN	1EBB04 Bridge Unit 3 - SIP & Deck Forming Bridge Deck	34	31-Mar-26	18-May-26
579	C1EBB04U01.BNIN20	1EBB04 Bridge Unit 1 - Pour Span 2	1	01-Apr-26	01-Apr-26
580	C1EBB04B01.ASIN	1EBB04 Bent 1 - Approach Slab	5	02-Apr-26	09-Apr-26
581	C1EBB04U02.BNIN10	1EBB04 Bridge Unit 2 - Pour Span 4	2	06-Apr-26	07-Apr-26
582	C1EBB04U02.BNIN30	1EBB04 Bridge Unit 2 - Pour Span 6	2	09-Apr-26	10-Apr-26
583	C1EBB04U04.EPIN	1EBB04 Bridge Unit 4 - Erect Structural Precast	6	09-Apr-26	17-Apr-26
584	C1EBB04U01.ENIN	1EBB04 Bridge Unit 1 - Expansion Control	3	17-Apr-26	21-Apr-26
585	C1EBB04U02.ENIN	1EBB04 Bridge Unit 2 - Expansion Control	3	27-Apr-26	29-Apr-26
586	C1EBB04U04.BNIN	1EBB04 Bridge Unit 4 - SIP & Deck Forming Bridge Deck	21	13-May-26	11-Jun-26
587	C1EBB04U03.BNIN10	1EBB04 Bridge Unit 3 - Pour Span 7	2	19-May-26	20-May-26
588	C1EBB04U03.BNIN30	1EBB04 Bridge Unit 3 - Pour Span 9	2	22-May-26	26-May-26
589	C1EBB04U03.BDIN	1EBB04 Bridge Unit 3 - Bridge Drainage	15	27-May-26	16-Jun-26
590	C1EBB04U04.BDIN	1EBB04 Bridge Unit 4 - Bridge Drainage	10	11-Jun-26	24-Jun-26
591	C1EBB04U04.BNIN20	1EBB04 Bridge Unit 4 - Pour Span 11	1	12-Jun-26	12-Jun-26
592	C1EBB04U03.BNIN20	1EBB04 Bridge Unit 3 - Pour Span 8	1	16-Jun-26	16-Jun-26
593	C1EBB04U04.BNIN10	1EBB04 Bridge Unit 4 - Pour Span 10	2	18-Jun-26	19-Jun-26
594	C1EBB04U04.BNIN30	1EBB04 Bridge Unit 4 - Pour Span 12	2	23-Jun-26	24-Jun-26
595	C1EBB04B12.ASIN	1EBB04 Bent 12 - Approach Slab	5	25-Jun-26	01-Jul-26
596	C1EBB04U03.ENIN	1EBB04 Bridge Unit 3 - Expansion Control	3	01-Jul-26	06-Jul-26
597	C1EBB04U04.ENIN	1EBB04 Bridge Unit 4 - Expansion Control	3	10-Jul-26	14-Jul-26
598	C1EBB04B12.47IN1	1EBB04 Parapet Barrier	4	15-Jul-26	20-Jul-26
599	**I-20 Eastbound West Approach Construction**		79	13-Mar-26	06-Jul-26
600	C1EBM02ZZZ.CRIN	1EBM02 Sitewide - Civil Removals	2	13-Mar-26	16-Mar-26



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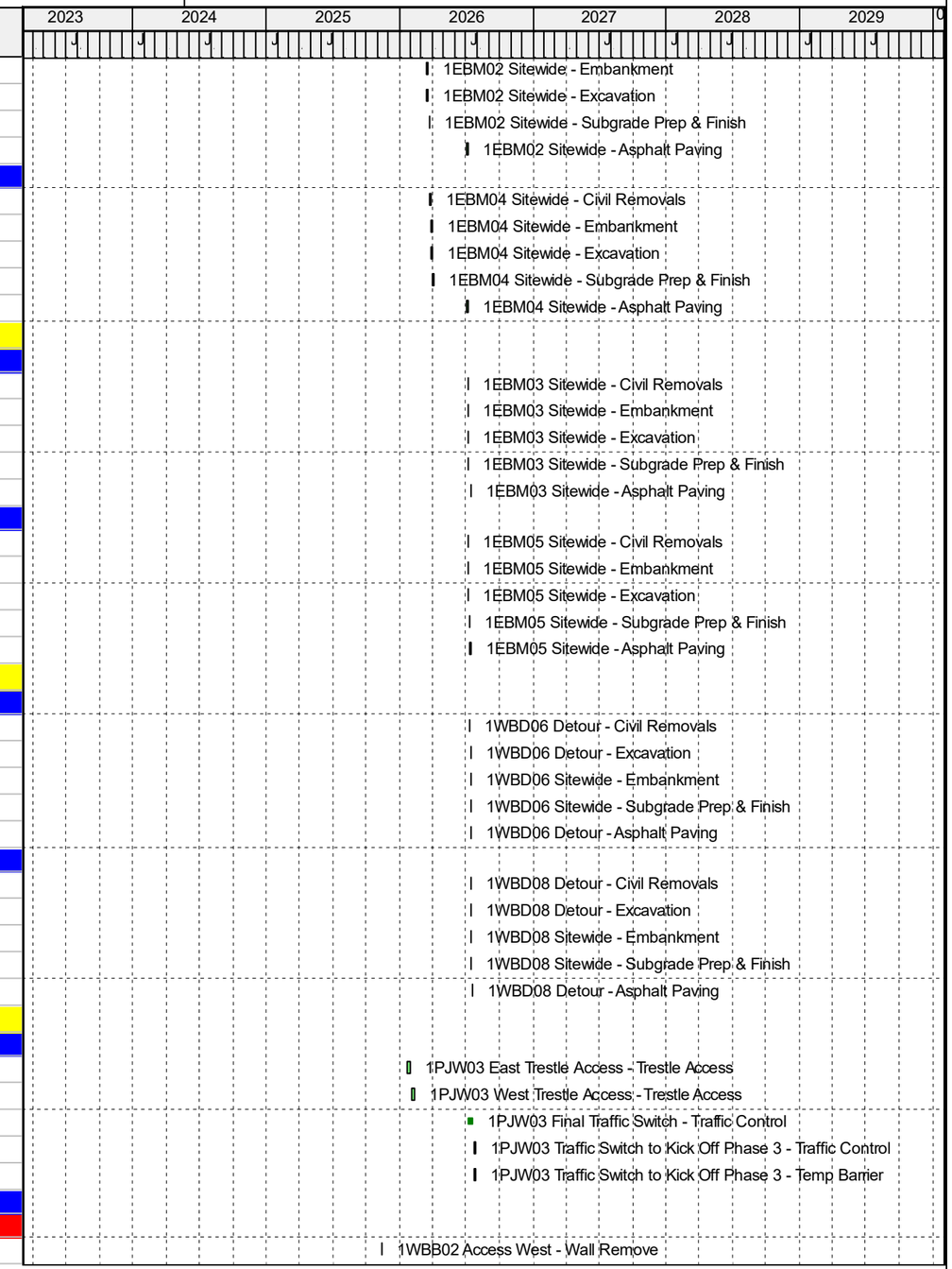
#	Activity ID	Activity Name	Original Duration	Start	Finish
601	C1EBM02ZZZ.EMIN	1EBM02 Sitewide - Embankment	4	17-Mar-26	20-Mar-26
602	C1EBM02ZZZ.EXIN	1EBM02 Sitewide - Excavation	2	17-Mar-26	18-Mar-26
603	C1EBM02ZZZ.SPIN	1EBM02 Sitewide - Subgrade Prep & Finish	2	23-Mar-26	24-Mar-26
604	C1EBM02ZZZ.APIN	1EBM02 Sitewide - Asphalt Paving	2	02-Jul-26	06-Jul-26
605	**I-20 Eastbound East Approach Construction**		71	25-Mar-26	06-Jul-26
606	C1EBM04ZZZ.CRIN	1EBM04 Sitewide - Civil Removals	2	25-Mar-26	26-Mar-26
607	C1EBM04ZZZ.EMIN	1EBM04 Sitewide - Embankment	4	27-Mar-26	01-Apr-26
608	C1EBM04ZZZ.EXIN	1EBM04 Sitewide - Excavation	2	27-Mar-26	30-Mar-26
609	C1EBM04ZZZ.SPIN	1EBM04 Sitewide - Subgrade Prep & Finish	2	02-Apr-26	06-Apr-26
610	C1EBM04ZZZ.APIN	1EBM04 Sitewide - Asphalt Paving	2	02-Jul-26	06-Jul-26
611	**Phase 2B & 2C**		8	07-Jul-26	16-Jul-26
612	**I-20 Eastbound Lanes Transition to New Eastbound Bridge - West Approach**		8	07-Jul-26	16-Jul-26
613	C1EBM03ZZZ.CRIN	1EBM03 Sitewide - Civil Removals	1	07-Jul-26	07-Jul-26
614	C1EBM03ZZZ.EMIN	1EBM03 Sitewide - Embankment	1	08-Jul-26	08-Jul-26
615	C1EBM03ZZZ.EXIN	1EBM03 Sitewide - Excavation	1	08-Jul-26	08-Jul-26
616	C1EBM03ZZZ.SPIN	1EBM03 Sitewide - Subgrade Prep & Finish	1	09-Jul-26	09-Jul-26
617	C1EBM03ZZZ.APIN	1EBM03 Sitewide - Asphalt Paving	2	15-Jul-26	16-Jul-26
618	**I-20 Eastbound Lanes Transition to New Eastbound Bridge - East Approach**		5	08-Jul-26	14-Jul-26
619	C1EBM05ZZZ.CRIN	1EBM05 Sitewide - Civil Removals	1	08-Jul-26	08-Jul-26
620	C1EBM05ZZZ.EMIN	1EBM05 Sitewide - Embankment	1	09-Jul-26	09-Jul-26
621	C1EBM05ZZZ.EXIN	1EBM05 Sitewide - Excavation	1	09-Jul-26	09-Jul-26
622	C1EBM05ZZZ.SPIN	1EBM05 Sitewide - Subgrade Prep & Finish	1	10-Jul-26	10-Jul-26
623	C1EBM05ZZZ.APIN	1EBM05 Sitewide - Asphalt Paving	2	13-Jul-26	14-Jul-26
624	**Phase 2D - 2F**		7	13-Jul-26	21-Jul-26
625	**I-20 Westbound Lanes Transition to New Median Wateree Bridge - West Approach**		5	13-Jul-26	17-Jul-26
626	C1WBD06DTR.CRIN	1WBD06 Detour - Civil Removals	1	13-Jul-26	13-Jul-26
627	C1WBD06DTR.EXIN	1WBD06 Detour - Excavation	1	14-Jul-26	14-Jul-26
628	C1WBD06ZZZ.EMIN	1WBD06 Sitewide - Embankment	1	14-Jul-26	14-Jul-26
629	C1WBD06ZZZ.SPIN	1WBD06 Sitewide - Subgrade Prep & Finish	1	15-Jul-26	15-Jul-26
630	C1WBD06DTR.APIN	1WBD06 Detour - Asphalt Paving	2	16-Jul-26	17-Jul-26
631	**I-20 Westbound Lanes Transition to New Median Wateree Bridge - East Approach**		6	14-Jul-26	21-Jul-26
632	C1WBD08DTR.CRIN	1WBD08 Detour - Civil Removals	1	14-Jul-26	14-Jul-26
633	C1WBD08DTR.EXIN	1WBD08 Detour - Excavation	1	15-Jul-26	15-Jul-26
634	C1WBD08ZZZ.EMIN	1WBD08 Sitewide - Embankment	1	15-Jul-26	15-Jul-26
635	C1WBD08ZZZ.SPIN	1WBD08 Sitewide - Subgrade Prep & Finish	1	16-Jul-26	16-Jul-26
636	C1WBD08DTR.APIN	1WBD08 Detour - Asphalt Paving	2	20-Jul-26	21-Jul-26
637	**Phase 3**		461	13-Nov-25	19-Aug-27
638	**Sitewide Phase 3 Work**		130	23-Jan-26	28-Jul-26
639	C1PJW03TRE.TJIN	1PJW03 East Trestle Access - Trestle Access	5	23-Jan-26	30-Jan-26
640	C1PJW03TRW.TJIN	1PJW03 West Trestle Access - Trestle Access	5	03-Feb-26	10-Feb-26
641	C1PJW03TE4.TCIN	1PJW03 Final Traffic Switch - Traffic Control	11	07-Jul-26	21-Jul-26
642	C1PJW03TE3.TCIN	1PJW03 Traffic Switch to Kick Off Phase 3 - Traffic Control	5	22-Jul-26	28-Jul-26
643	C1PJW03TW3.TDIN	1PJW03 Traffic Switch to Kick Off Phase 3 - Temp Barrier	5	22-Jul-26	28-Jul-26
644	**New Wateree Bridge Westbound Construction**		461	13-Nov-25	19-Aug-27
645	**Phase 3 Early Access Work**		54	13-Nov-25	03-Feb-26
646	C1WBB02ACW.SKIN	1WBB02 Access West - Wall Remove	2	13-Nov-25	14-Nov-25



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#	Activity ID	Activity Name	Original Duration	Start	Finish
647	C1WBB02TRW.EMIN	1WBB02 West Trestle Access - Embankment	1	17-Nov-25	17-Nov-25
648	C1WBB02TRW.EXIN	1WBB02 West Trestle Access - Excavation	1	17-Nov-25	17-Nov-25
649	C1WBB02TRW.SPIN	1WBB02 West Trestle Access - Subgrade Prep & Finish	1	18-Nov-25	18-Nov-25
650	C1WBB02TRW.ABIN	1WBB02 West Trestle Access - Agg Base	3	19-Nov-25	21-Nov-25
651	C1WBB02ACE.SKIN	1WBB02 Access East - Wall Remove	2	23-Jan-26	27-Jan-26
652	C1WBB02TRE.EMIN	1WBB02 East Trestle Access - Embankment	1	27-Jan-26	28-Jan-26
653	C1WBB02TRE.EXIN	1WBB02 East Trestle Access - Excavation	1	27-Jan-26	28-Jan-26
654	C1WBB02TRE.SPIN	1WBB02 East Trestle Access - Subgrade Prep & Finish	1	28-Jan-26	29-Jan-26
655	C1WBB02TRE.ABIN	1WBB02 East Trestle Access - Agg Base	3	29-Jan-26	03-Feb-26
656	**Exsisting Bridge Demolition**		135	29-Jul-26	10-Feb-27
657	C1WBB02D07.BRIN	1WBB02 Bridge Demo Span 7 - Bridge Removal	55	29-Jul-26	14-Oct-26
658	C1WBB02D06.BRIN	1WBB02 Bridge Demo Span 6 - Bridge Removal	5	10-Sep-26	16-Sep-26
659	C1WBB02D05.BRIN	1WBB02 Bridge Demo Span 5 - Bridge Removal	5	17-Sep-26	23-Sep-26
660	C1WBB02D04.BRIN	1WBB02 Bridge Demo Span 4 - Bridge Removal	5	24-Sep-26	30-Sep-26
661	C1WBB02D03.BRIN	1WBB02 Bridge Demo Span 3 - Bridge Removal	5	01-Oct-26	07-Oct-26
662	C1WBB02D02.BRIN	1WBB02 Bridge Demo Span 2 - Bridge Removal	5	08-Oct-26	14-Oct-26
663	C1WBB02D01.BRIN	1WBB02 Bridge Demo Span 1 - Bridge Removal	5	15-Oct-26	21-Oct-26
664	C1WBB02D08.BRIN	1WBB02 Bridge Demo Span 8 - Bridge Removal	5	22-Oct-26	28-Oct-26
665	C1WBB02D09.BRIN	1WBB02 Bridge Demo Span 9 - Bridge Removal	5	29-Oct-26	04-Nov-26
666	C1WBB02D10.BRIN	1WBB02 Bridge Demo Span 10 - Bridge Removal	5	05-Nov-26	11-Nov-26
667	C1WBB02D11.BRIN	1WBB02 Bridge Demo Span 11 - Bridge Removal	5	12-Nov-26	18-Nov-26
668	C1WBB02D12.BRIN	1WBB02 Bridge Demo Span 12 - Bridge Removal	5	19-Nov-26	25-Nov-26
669	C1WBB02D13.BRIN	1WBB02 Bridge Demo Span 13 - Bridge Removal	5	30-Nov-26	04-Dec-26
670	C1WBB02D14.BRIN	1WBB02 Bridge Demo Span 14 - Bridge Removal	5	07-Dec-26	11-Dec-26
671	C1WBB02D15.BRIN	1WBB02 Bridge Demo Span 15 - Bridge Removal	5	14-Dec-26	18-Dec-26
672	C1WBB02D16.BRIN	1WBB02 Bridge Demo Span 16 - Bridge Removal	5	21-Dec-26	29-Dec-26
673	C1WBB02D17.BRIN	1WBB02 Bridge Demo Span 17 - Bridge Removal	5	30-Dec-26	06-Jan-27
674	C1WBB02D18.BRIN	1WBB02 Bridge Demo Span 18 - Bridge Removal	5	07-Jan-27	13-Jan-27
675	C1WBB02D19.BRIN	1WBB02 Bridge Demo Span 19 - Bridge Removal	5	14-Jan-27	20-Jan-27
676	C1WBB02D20.BRIN	1WBB02 Bridge Demo Span 20 - Bridge Removal	5	21-Jan-27	27-Jan-27
677	C1WBB02D21.BRIN	1WBB02 Bridge Demo Span 21 - Bridge Removal	5	28-Jan-27	03-Feb-27
678	C1WBB02D22.BRIN	1WBB02 Bridge Demo Span 22 - Bridge Removal	5	04-Feb-27	10-Feb-27
679	**New Bridge Construction**		221	15-Oct-26	19-Aug-27
680	C1WBB02B05.DSIN	1WBB02 Bent 5 - Drilled Shafts	12	15-Oct-26	30-Oct-26
681	C1WBB02B02.DSIN	1WBB02 Bent 2 - Drilled Shafts	12	02-Nov-26	17-Nov-26
682	C1WBB02B05.CMIN	1WBB02 Bent 5 - Columns	5	02-Nov-26	06-Nov-26
683	C1WBB02B05.CMIN10	1WBB02 Bent 5 - Columns Cure	3	07-Nov-26	09-Nov-26
684	C1WBB02B05.PCIN	1WBB02 Bent 5 - Pier Caps	6	09-Nov-26	17-Nov-26
685	C1WBB02B05.PCIN10	1WBB02 Bent 5 - Pier Caps Cure	14	17-Nov-26	30-Nov-26
686	C1WBB02B01.PLIN	1WBB02 Bent 1 - Piling	4	18-Nov-26	23-Nov-26
687	C1WBB02B02.CMIN	1WBB02 Bent 2 - Columns	5	18-Nov-26	24-Nov-26
688	C1WBB02B03.DSIN	1WBB02 Bent 3 - Drilled Shafts	12	18-Nov-26	07-Dec-26
689	C1WBB02B01.SBIN	1WBB02 Bent 1 - Structure Exc	4	24-Nov-26	01-Dec-26
690	C1WBB02B02.CMIN10	1WBB02 Bent 2 - Columns Cure	3	25-Nov-26	27-Nov-26
691	C1WBB02B02.PCIN	1WBB02 Bent 2 - Pier Caps	6	30-Nov-26	07-Dec-26
692	C1WBB02TRW.TJIN.1	1WBB02 Remove West Trestle Access - Trestle Access	8	30-Nov-26	10-Dec-26

Remaining Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

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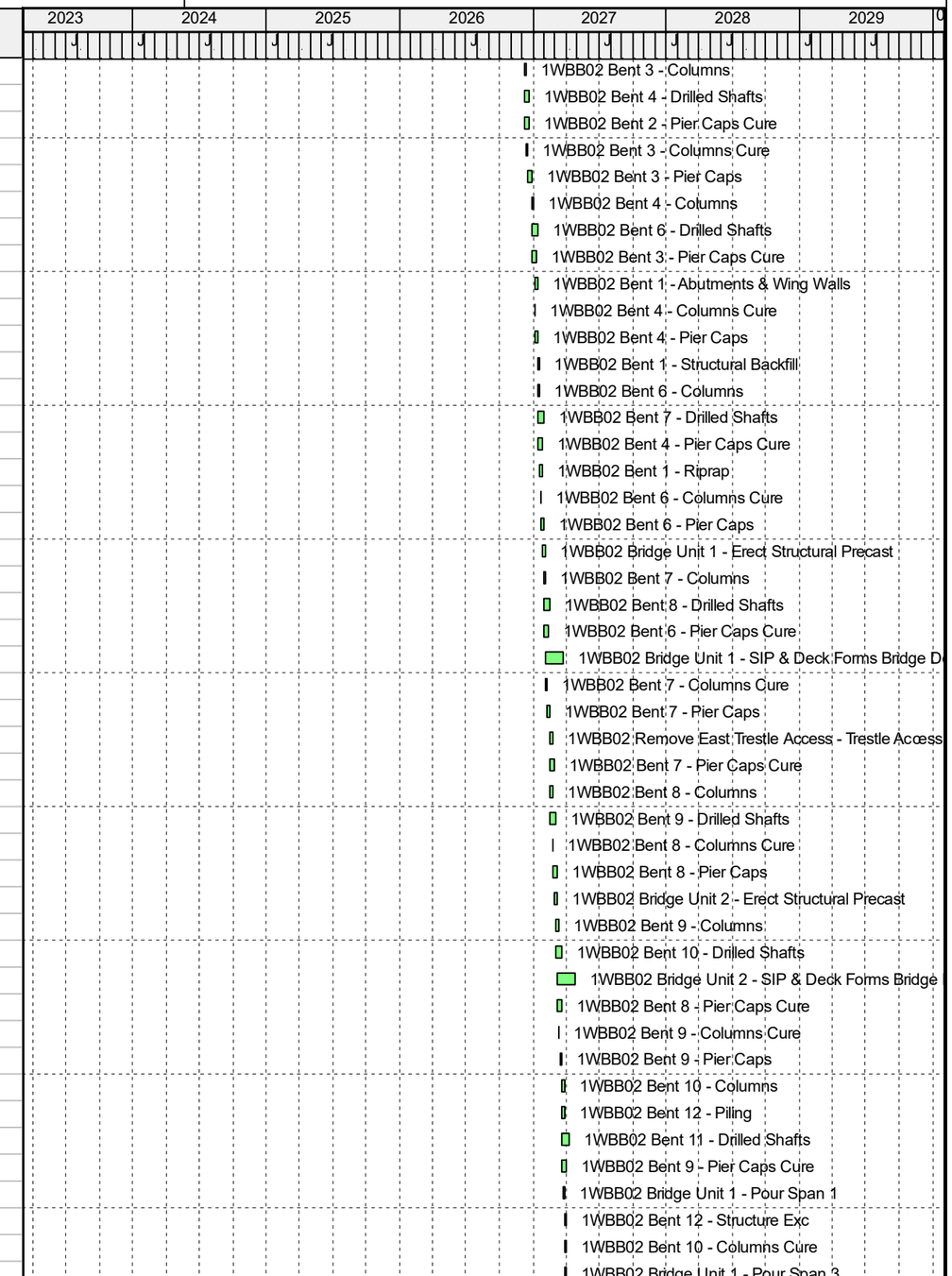
#	Activity ID	Activity Name	Original Duration	Start	Finish
693	C1WBB02B03.CMIN	1WBB02 Bent 3 - Columns	5	08-Dec-26	14-Dec-26
694	C1WBB02B04.DSIN	1WBB02 Bent 4 - Drilled Shafts	12	08-Dec-26	23-Dec-26
695	C1WBB02B02.PCIN10	1WBB02 Bent 2 - Pier Caps Cure	14	08-Dec-26	20-Dec-26
696	C1WBB02B03.CMIN10	1WBB02 Bent 3 - Columns Cure	3	15-Dec-26	17-Dec-26
697	C1WBB02B03.PCIN	1WBB02 Bent 3 - Pier Caps	6	17-Dec-26	29-Dec-26
698	C1WBB02B04.CMIN	1WBB02 Bent 4 - Columns	5	28-Dec-26	04-Jan-27
699	C1WBB02B06.DSIN	1WBB02 Bent 6 - Drilled Shafts	12	28-Dec-26	13-Jan-27
700	C1WBB02B03.PCIN10	1WBB02 Bent 3 - Pier Caps Cure	14	29-Dec-26	11-Jan-27
701	C1WBB02B01.AWIN	1WBB02 Bent 1 - Abutments & Wing Walls	7	05-Jan-27	13-Jan-27
702	C1WBB02B04.CMIN10	1WBB02 Bent 4 - Columns Cure	3	05-Jan-27	07-Jan-27
703	C1WBB02B04.PCIN	1WBB02 Bent 4 - Pier Caps	6	07-Jan-27	15-Jan-27
704	C1WBB02B01.47IN	1WBB02 Bent 1 - Structural Backfill	4	14-Jan-27	19-Jan-27
705	C1WBB02B06.CMIN	1WBB02 Bent 6 - Columns	5	14-Jan-27	20-Jan-27
706	C1WBB02B07.DSIN	1WBB02 Bent 7 - Drilled Shafts	12	14-Jan-27	29-Jan-27
707	C1WBB02B04.PCIN10	1WBB02 Bent 4 - Pier Caps Cure	14	15-Jan-27	28-Jan-27
708	C1WBB02B01.RRIN	1WBB02 Bent 1 - Riprap	5	20-Jan-27	26-Jan-27
709	C1WBB02B06.CMIN10	1WBB02 Bent 6 - Columns Cure	3	21-Jan-27	23-Jan-27
710	C1WBB02B06.PCIN	1WBB02 Bent 6 - Pier Caps	6	25-Jan-27	01-Feb-27
711	C1WBB02U01.EPIN	1WBB02 Bridge Unit 1 - Erect Structural Precast	6	28-Jan-27	05-Feb-27
712	C1WBB02B07.CMIN	1WBB02 Bent 7 - Columns	5	01-Feb-27	05-Feb-27
713	C1WBB02B08.DSIN	1WBB02 Bent 8 - Drilled Shafts	12	01-Feb-27	16-Feb-27
714	C1WBB02B06.PCIN10	1WBB02 Bent 6 - Pier Caps Cure	14	02-Feb-27	14-Feb-27
715	C1WBB02U01.BNIN	1WBB02 Bridge Unit 1 - SIP & Deck Forms Bridge Deck	34	05-Feb-27	25-Mar-27
716	C1WBB02B07.CMIN10	1WBB02 Bent 7 - Columns Cure	3	06-Feb-27	08-Feb-27
717	C1WBB02B07.PCIN	1WBB02 Bent 7 - Pier Caps	6	08-Feb-27	16-Feb-27
718	C1WBB02TRE.TJIN.1	1WBB02 Remove East Trestle Access - Trestle Access	8	15-Feb-27	24-Feb-27
719	C1WBB02B07.PCIN10	1WBB02 Bent 7 - Pier Caps Cure	14	16-Feb-27	01-Mar-27
720	C1WBB02B08.CMIN	1WBB02 Bent 8 - Columns	5	17-Feb-27	23-Feb-27
721	C1WBB02B09.DSIN	1WBB02 Bent 9 - Drilled Shafts	12	17-Feb-27	04-Mar-27
722	C1WBB02B08.CMIN10	1WBB02 Bent 8 - Columns Cure	3	24-Feb-27	26-Feb-27
723	C1WBB02B08.PCIN	1WBB02 Bent 8 - Pier Caps	6	26-Feb-27	08-Mar-27
724	C1WBB02U02.EPIN	1WBB02 Bridge Unit 2 - Erect Structural Precast	5	01-Mar-27	08-Mar-27
725	C1WBB02B09.CMIN	1WBB02 Bent 9 - Columns	5	05-Mar-27	11-Mar-27
726	C1WBB02B10.DSIN	1WBB02 Bent 10 - Drilled Shafts	12	05-Mar-27	22-Mar-27
727	C1WBB02U02.BNIN	1WBB02 Bridge Unit 2 - SIP & Deck Forms Bridge Deck	34	08-Mar-27	26-Apr-27
728	C1WBB02B08.PCIN10	1WBB02 Bent 8 - Pier Caps Cure	14	08-Mar-27	21-Mar-27
729	C1WBB02B09.CMIN10	1WBB02 Bent 9 - Columns Cure	3	12-Mar-27	14-Mar-27
730	C1WBB02B09.PCIN	1WBB02 Bent 9 - Pier Caps	6	15-Mar-27	22-Mar-27
731	C1WBB02B10.CMIN	1WBB02 Bent 10 - Columns	5	23-Mar-27	30-Mar-27
732	C1WBB02B12.PLIN	1WBB02 Bent 12 - Piling	4	23-Mar-27	29-Mar-27
733	C1WBB02B11.DSIN	1WBB02 Bent 11 - Drilled Shafts	12	23-Mar-27	08-Apr-27
734	C1WBB02B09.PCIN10	1WBB02 Bent 9 - Pier Caps Cure	14	23-Mar-27	04-Apr-27
735	C1WBB02U01.BNIN10	1WBB02 Bridge Unit 1 - Pour Span 1	2	25-Mar-27	30-Mar-27
736	C1WBB02B12.SBIN	1WBB02 Bent 12 - Structure Exc	4	30-Mar-27	02-Apr-27
737	C1WBB02B10.CMIN10	1WBB02 Bent 10 - Columns Cure	3	31-Mar-27	02-Apr-27
738	C1WBB02U01.BNIN30	1WBB02 Bridge Unit 1 - Pour Span 3	2	31-Mar-27	02-Apr-27



Remaining Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

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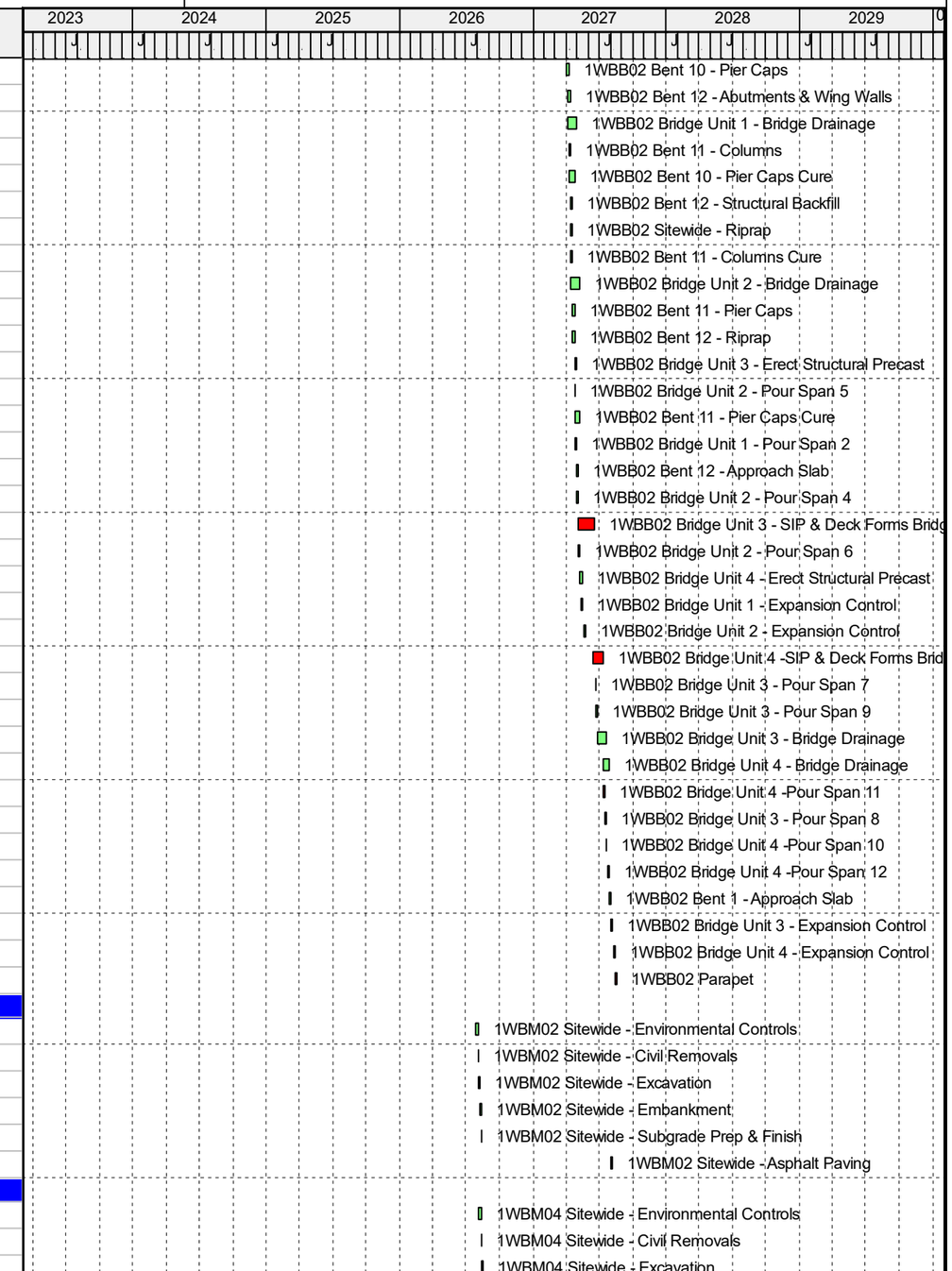
#	Activity ID	Activity Name	Original Duration	Start	Finish
739	C1WBB02B10.PCIN	1WBB02 Bent 10 - Pier Caps	6	02-Apr-27	12-Apr-27
740	C1WBB02B12.AWIN	1WBB02 Bent 12 - Abutments & Wing Walls	7	05-Apr-27	13-Apr-27
741	C1WBB02U01.BDIN	1WBB02 Bridge Unit 1 - Bridge Drainage	15	08-Apr-27	29-Apr-27
742	C1WBB02B11.CMIN	1WBB02 Bent 11 - Columns	5	09-Apr-27	15-Apr-27
743	C1WBB02B10.PCIN10	1WBB02 Bent 10 - Pier Caps Cure	14	12-Apr-27	25-Apr-27
744	C1WBB02B12.47IN	1WBB02 Bent 12 - Structural Backfill	4	14-Apr-27	19-Apr-27
745	C1WBB02ZZZ.RRIN	1WBB02 Sitewide - Riprap	5	14-Apr-27	20-Apr-27
746	C1WBB02B11.CMIN10	1WBB02 Bent 11 - Columns Cure	3	16-Apr-27	18-Apr-27
747	C1WBB02U02.BDIN	1WBB02 Bridge Unit 2 - Bridge Drainage	15	16-Apr-27	07-May-27
748	C1WBB02B11.PCIN	1WBB02 Bent 11 - Pier Caps	6	19-Apr-27	26-Apr-27
749	C1WBB02B12.RRIN	1WBB02 Bent 12 - Riprap	5	20-Apr-27	26-Apr-27
750	C1WBB02U03.EPIN	1WBB02 Bridge Unit 3 - Erect Structural Precast	5	26-Apr-27	30-Apr-27
751	C1WBB02U02.BNIN20	1WBB02 Bridge Unit 2 - Pour Span 5	1	26-Apr-27	27-Apr-27
752	C1WBB02B11.PCIN10	1WBB02 Bent 11 - Pier Caps Cure	14	27-Apr-27	09-May-27
753	C1WBB02U01.BNIN20	1WBB02 Bridge Unit 1 - Pour Span 2	1	28-Apr-27	29-Apr-27
754	C1WBB02B12.ASIN	1WBB02 Bent 12 - Approach Slab	5	29-Apr-27	06-May-27
755	C1WBB02U02.BNIN10	1WBB02 Bridge Unit 2 - Pour Span 4	2	30-Apr-27	04-May-27
756	C1WBB02U03.BNIN	1WBB02 Bridge Unit 3 - SIP & Deck Forms Bridge Deck	34	03-May-27	18-Jun-27
757	C1WBB02U02.BNIN30	1WBB02 Bridge Unit 2 - Pour Span 6	2	05-May-27	07-May-27
758	C1WBB02U04.EPIN	1WBB02 Bridge Unit 4 - Erect Structural Precast	6	10-May-27	17-May-27
759	C1WBB02U01.ENIN	1WBB02 Bridge Unit 1 - Expansion Control	3	13-May-27	18-May-27
760	C1WBB02U02.ENIN	1WBB02 Bridge Unit 2 - Expansion Control	3	21-May-27	26-May-27
761	C1WBB02U04.BNIN	1WBB02 Bridge Unit 4 -SIP & Deck Forms Bridge Deck	21	15-Jun-27	14-Jul-27
762	C1WBB02U03.BNIN10	1WBB02 Bridge Unit 3 - Pour Span 7	2	21-Jun-27	22-Jun-27
763	C1WBB02U03.BNIN30	1WBB02 Bridge Unit 3 - Pour Span 9	2	24-Jun-27	25-Jun-27
764	C1WBB02U03.BDIN	1WBB02 Bridge Unit 3 - Bridge Drainage	15	28-Jun-27	19-Jul-27
765	C1WBB02U04.BDIN	1WBB02 Bridge Unit 4 - Bridge Drainage	10	14-Jul-27	27-Jul-27
766	C1WBB02U04.BNIN20	1WBB02 Bridge Unit 4 -Pour Span 11	1	15-Jul-27	15-Jul-27
767	C1WBB02U03.BNIN20	1WBB02 Bridge Unit 3 - Pour Span 8	1	19-Jul-27	19-Jul-27
768	C1WBB02U04.BNIN10	1WBB02 Bridge Unit 4 -Pour Span 10	2	21-Jul-27	22-Jul-27
769	C1WBB02U04.BNIN30	1WBB02 Bridge Unit 4 -Pour Span 12	2	26-Jul-27	27-Jul-27
770	C1WBB02B01.ASIN	1WBB02 Bent 1 - Approach Slab	5	28-Jul-27	03-Aug-27
771	C1WBB02U03.ENIN	1WBB02 Bridge Unit 3 - Expansion Control	3	03-Aug-27	05-Aug-27
772	C1WBB02U04.ENIN	1WBB02 Bridge Unit 4 - Expansion Control	3	11-Aug-27	13-Aug-27
773	C1WBB02B12.47IN1	1WBB02 Parapet	4	16-Aug-27	19-Aug-27
774	**I-20 Westbound West Approach Construction**		258	29-Jul-26	05-Aug-27
775	C1WBM02ZZZ.ECIN	1WBM02 Sitewide - Environmental Controls	5	29-Jul-26	04-Aug-26
776	C1WBM02ZZZ.CRIN	1WBM02 Sitewide - Civil Removals	2	05-Aug-26	06-Aug-26
777	C1WBM02ZZZ.EXIN	1WBM02 Sitewide - Excavation	2	07-Aug-26	10-Aug-26
778	C1WBM02ZZZ.EMIN	1WBM02 Sitewide - Embankment	2	11-Aug-26	12-Aug-26
779	C1WBM02ZZZ.SPIN	1WBM02 Sitewide - Subgrade Prep & Finish	1	13-Aug-26	13-Aug-26
780	C1WBM02ZZZ.APIN	1WBM02 Sitewide - Asphalt Paving	2	04-Aug-27	05-Aug-27
781	**I-20 Westbound East Approach Construction**		191	05-Aug-26	10-May-27
782	C1WBM04ZZZ.ECIN	1WBM04 Sitewide - Environmental Controls	5	05-Aug-26	11-Aug-26
783	C1WBM04ZZZ.CRIN	1WBM04 Sitewide - Civil Removals	2	12-Aug-26	13-Aug-26
784	C1WBM04ZZZ.EXIN	1WBM04 Sitewide - Excavation	2	14-Aug-26	17-Aug-26



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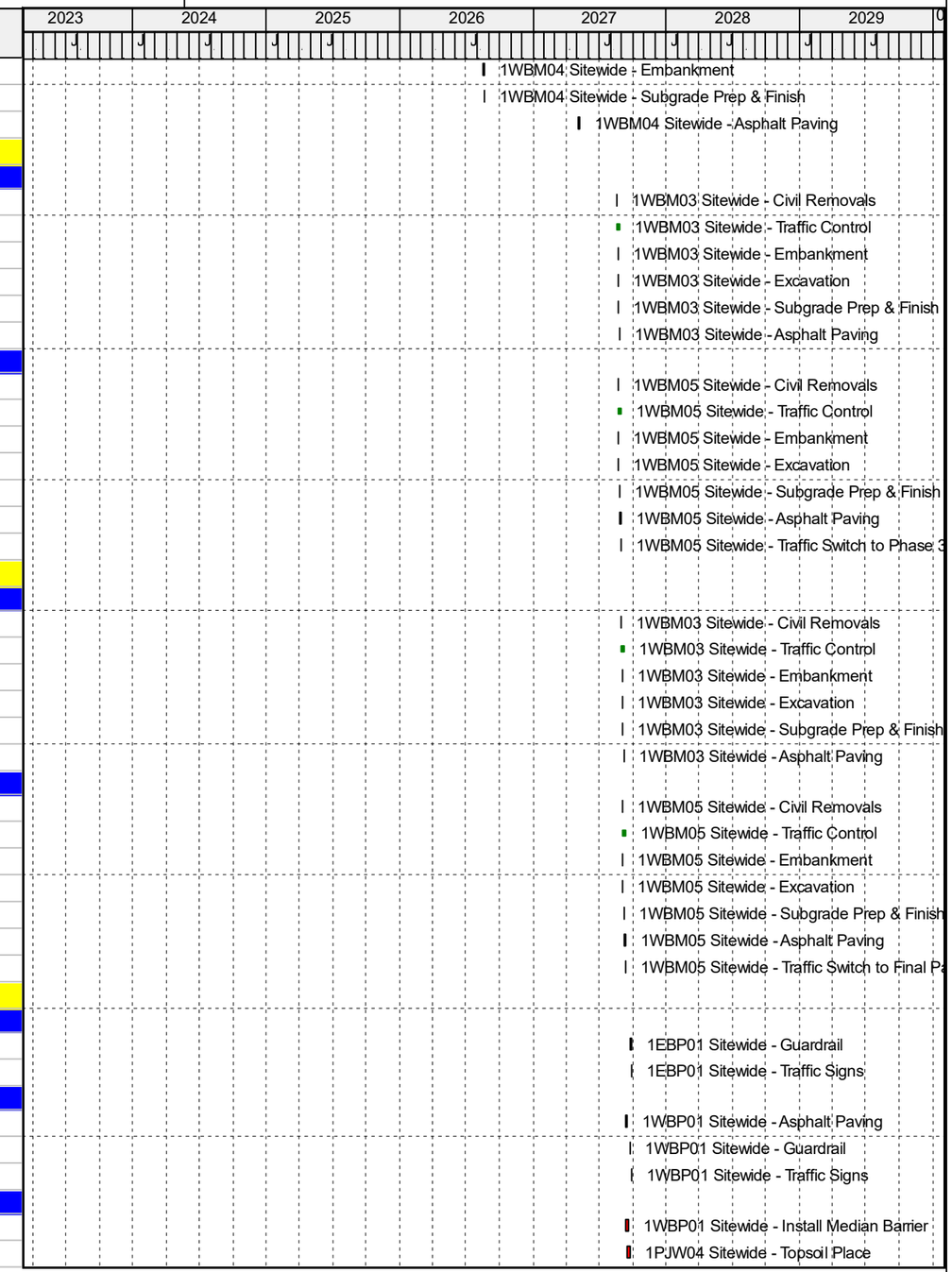
#	Activity ID	Activity Name	Original Duration	Start	Finish
785	C1WBM04ZZZ.EMIN	1WBM04 Sitewide - Embankment	2	18-Aug-26	19-Aug-26
786	C1WBM04ZZZ.SPIN	1WBM04 Sitewide - Subgrade Prep & Finish	1	20-Aug-26	20-Aug-26
787	C1WBM04ZZZ.APIN	1WBM04 Sitewide - Asphalt Paving	2	06-May-27	10-May-27
788	**Phase 3B**		8	20-Aug-27	31-Aug-27
789	**I-20 Westbound Lanes Transition to New Westbound Bridge - West Approach**		5	20-Aug-27	26-Aug-27
790	C1WBM03ZZZ.CRIN	1WBM03 Sitewide - Civil Removals	1	20-Aug-27	20-Aug-27
791	C1WBM03ZZZ.TCIN	1WBM03 Sitewide - Traffic Control	5	20-Aug-27	26-Aug-27
792	C1WBM03ZZZ.EMIN	1WBM03 Sitewide - Embankment	1	23-Aug-27	23-Aug-27
793	C1WBM03ZZZ.EXIN	1WBM03 Sitewide - Excavation	1	23-Aug-27	23-Aug-27
794	C1WBM03ZZZ.SPIN	1WBM03 Sitewide - Subgrade Prep & Finish	1	24-Aug-27	24-Aug-27
795	C1WBM03ZZZ.APIN	1WBM03 Sitewide - Asphalt Paving	2	25-Aug-27	26-Aug-27
796	**I-20 Westbound Lanes Transition to New Westbound Bridge - East Approach**		7	23-Aug-27	31-Aug-27
797	C1WBM05ZZZ.CRIN	1WBM05 Sitewide - Civil Removals	1	23-Aug-27	23-Aug-27
798	C1WBM05ZZZ.TCIN	1WBM05 Sitewide - Traffic Control	6	23-Aug-27	30-Aug-27
799	C1WBM05ZZZ.EMIN	1WBM05 Sitewide - Embankment	1	24-Aug-27	24-Aug-27
800	C1WBM05ZZZ.EXIN	1WBM05 Sitewide - Excavation	1	24-Aug-27	24-Aug-27
801	C1WBM05ZZZ.SPIN	1WBM05 Sitewide - Subgrade Prep & Finish	1	25-Aug-27	25-Aug-27
802	C1WBM05ZZZ.APIN	1WBM05 Sitewide - Asphalt Paving	2	27-Aug-27	30-Aug-27
803	C1WBM05ZZZ.APIN20	1WBM05 Sitewide - Traffic Switch to Phase 3C	1	31-Aug-27	31-Aug-27
804	**Phase 3C**		8	01-Sep-27	13-Sep-27
805	**I-20 Westbound Lanes Transition to New Westbound Bridge - West Approach**		5	01-Sep-27	08-Sep-27
806	C1WBM03ZZZ.CRIN10	1WBM03 Sitewide - Civil Removals	1	01-Sep-27	01-Sep-27
807	C1WBM03ZZZ.TCIN10	1WBM03 Sitewide - Traffic Control	5	01-Sep-27	08-Sep-27
808	C1WBM03ZZZ.EMIN10	1WBM03 Sitewide - Embankment	1	02-Sep-27	02-Sep-27
809	C1WBM03ZZZ.EXIN10	1WBM03 Sitewide - Excavation	1	02-Sep-27	02-Sep-27
810	C1WBM03ZZZ.SPIN10	1WBM03 Sitewide - Subgrade Prep & Finish	1	03-Sep-27	03-Sep-27
811	C1WBM03ZZZ.APIN10	1WBM03 Sitewide - Asphalt Paving	2	07-Sep-27	08-Sep-27
812	**I-20 Westbound Lanes Transition to New Westbound Bridge - East Approach**		7	02-Sep-27	13-Sep-27
813	C1WBM05ZZZ.CRIN10	1WBM05 Sitewide - Civil Removals	1	02-Sep-27	02-Sep-27
814	C1WBM05ZZZ.TCIN10	1WBM05 Sitewide - Traffic Control	6	02-Sep-27	10-Sep-27
815	C1WBM05ZZZ.EMIN10	1WBM05 Sitewide - Embankment	1	03-Sep-27	03-Sep-27
816	C1WBM05ZZZ.EXIN10	1WBM05 Sitewide - Excavation	1	03-Sep-27	03-Sep-27
817	C1WBM05ZZZ.SPIN10	1WBM05 Sitewide - Subgrade Prep & Finish	1	07-Sep-27	07-Sep-27
818	C1WBM05ZZZ.APIN10	1WBM05 Sitewide - Asphalt Paving	2	09-Sep-27	10-Sep-27
819	C1WBM05ZZZ.APIN30	1WBM05 Sitewide - Traffic Switch to Final Paving Phase	1	13-Sep-27	13-Sep-27
820	**Phase 4**		13	14-Sep-27	30-Sep-27
821	**I-20 Eastbound Mainlanes Work**		6	23-Sep-27	30-Sep-27
822	C1EBP01ZZZ.GDIN	1EBP01 Sitewide - Guardrail	4	23-Sep-27	28-Sep-27
823	C1EBP01ZZZ.GNIN	1EBP01 Sitewide - Traffic Signs	2	29-Sep-27	30-Sep-27
824	**I-20 Westbound Mainlanes Work**		11	14-Sep-27	28-Sep-27
825	C1WBP01ZZZ.APIN	1WBP01 Sitewide - Asphalt Paving	2	14-Sep-27	15-Sep-27
826	C1WBP01ZZZ.GDIN	1WBP01 Sitewide - Guardrail	2	23-Sep-27	24-Sep-27
827	C1WBP01ZZZ.GNIN	1WBP01 Sitewide - Traffic Signs	2	27-Sep-27	28-Sep-27
828	**I-20 Median and Outside Shoulders Work**		13	14-Sep-27	30-Sep-27
829	C1WBP01ZZZ.GNIN10	1WBP01 Sitewide - Install Median Barrier	6	14-Sep-27	21-Sep-27
830	C1PJW04ZZZ.TEIN	1PJW04 Sitewide - Topsoil Place	5	16-Sep-27	22-Sep-27



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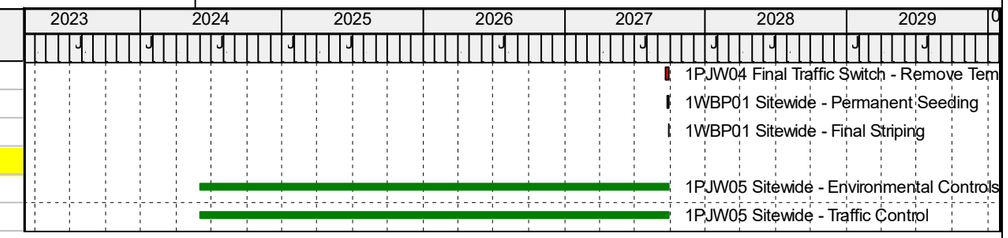
#	Activity ID	Activity Name	Original Duration	Start	Finish
831	C1PJW04TW4.TDIN	1PJW04 Final Traffic Switch - Remove Temp Barrier	5	22-Sep-27	28-Sep-27
832	C1WBP01ZZZ.MIIN	1WBP01 Sitewide - Permanent Seeding	5	23-Sep-27	29-Sep-27
833	C1WBP01ZZZ.MIIN10	1WBP01 Sitewide - Final Striping	2	29-Sep-27	30-Sep-27
834	**Projectwide Support Work**		840	03-Jun-24	30-Sep-27
835	C1PJW05ZZZ.ECIN	1PJW05 Sitewide - Environmental Controls	840	03-Jun-24	30-Sep-27
836	C1PJW05ZZZ.TCIN	1PJW05 Sitewide - Traffic Control	840	03-Jun-24	30-Sep-27



Remaining Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

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Appendix B –
Required Forms

APPENDIX B – REQUIRED FORMS

Please see the required forms listed below in the following pages.

a. Stipend Acknowledgement Form
b. Stipend Agreement
c. EEO Certificate
d. Non-Collusion Certificate
e. Notice of Receipt of Addendum
f. Updated Organization Chart and Notarized Statement's of Availability of Key Individuals

- ✓ Written Statement of Availability of Key Individuals - KISC
- ✓ Officer's Certificate - KISC
- ✓ Written Statement of Availability of Key Individuals - KEGI
- ✓ Officer's Certificate - KEGI

g. Confidential and Proprietary Information Page List
h. Prequalification Certificate
i. Joint Venture Organizational Agreement
j. Quality Credit Matrix

a. Stipend Acknowledgement Form

Please see the attached Stipend Acknowledgment Form.

12. STIPEND ACKNOWLEDGEMENT FORM

Stipend Acknowledgement Form

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Kershaw County

Proposer: Kiewit Infrastructure South Co.

ADDRESS: 5617 North Rhett Avenue, Suite 124 D&E, North Charleston, SC 29406

The undersigned Proposer, hereby:

☐ Waives the stipend for this Project.

☒ Accepts the stipend for this Project.

By accepting the stipend for this Project, Proposer agrees:

1) to execute and include the Stipend Agreement in Article XIII of the RFP with its RFP response;

2) to submit an invoice with FEIN number for the stipend amount to the SCDOT POC after SCDOT's posting of the Notice of Award on SCDOT's Design-Build Website.;

3) to transfer all rights to its Work Product used to develop the Proposal as of the date of this acknowledgement. "Work Product" " means all submittals, including ATCs, ideas, innovations, solutions, methods, processes, design concepts, materials, electronic files, marked up drawings, cross sections, quantity lists and intellectual property, made by Proposer during the RFP process, including the Proposal, exchange of information during the pre-Proposal and post-Proposal period.

SCDOT will pay the stipend to each eligible unsuccessful Proposer, who has signed a Stipend Agreement, within ninety (90) days after execution of the Contract or the decision to not award a contract.

2/9/2023
Date

Kiewit Infrastructure South Co.
Proposer

Benjamin J. Carnazzo
Print Name

b. Stipend Agreement

Please see the attached Stipend Agreement.

13. STIPEND AGREEMENT

STIPEND AGREEMENT
Project ID: 2847360

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations
Kershaw County

THIS STIPEND AGREEMENT (the "Agreement") is made and entered into as of the 9TH day of FEBRUARY, 2023 by and between the SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION (hereinafter "SCDOT"), and Kiewit Infrastructure South Co. ("Proposer"), with reference to the following facts:

SCDOT issued a Request for Proposal ("RFP") for design and construction of the above-referenced Design-Build Project ("Project"), pursuant to procurement authority granted in Section 57-5-1625 of the S.C. Code of Laws, 1976, as amended. The RFP provided for payment of stipends as provided herein. Capitalized terms used, but not defined, have the meanings ascribed in the RFP.

NOW, THEREFORE, Proposer hereby agrees as follows:

1. Work Product.

1.1 Proposer shall prepare and submit a responsible and responsive Technical Proposal and Cost Proposal that conforms in all material respects to the requirements and provisions of the RFP, as determined by SCDOT, and are timely received by SCDOT in accordance with the RFP Milestone Schedule.

1.2 By signing this Stipend Agreement, Proposer agrees to transfer full and complete ownership to SCDOT of all Work Product. The Work Product (as defined below) shall become the property of SCDOT without restriction or limitation on its use, without further compensation or consideration, and can be used in connection with this Project or any future projects by SCDOT. Neither Proposer nor any of its team members shall copyright any of the material developed under this Agreement.

1.3 The term "Work Product" shall mean the Proposal and all material, electronic files, marked up drawings, cross sections, quantity lists, submittals, alternative technical concepts (ATC), ideas, innovations, solutions, methods, processes, design concepts, Trade Secrets or confidential information, and intellectual property, made by or produced for Proposer in the development and submission of the Technical and Cost Proposal, including exchanges of information during the pre-Proposal and post-Proposal period.

2. Compensation and Payment.

2.1 A stipend to Proposer for the Work Product described herein shall be $145,000.00 and is payable to Proposer that was determined to be responsible and (1) submitted a responsive Technical Proposal and responsive Cost Proposal to the RFP which is not selected for award of this Project, or (2) was awarded the Contract but the Contract was terminated by SCDOT for convenience after the Submittal of Proposal Due Date (See Final RFP Milestone schedule) but prior to the Notice to Proceed #1. Responsibility of Proposers and responsiveness of the Technical Proposal and Cost Proposal will be determined by SCDOT as a condition of payment.

2.2 SCDOT will pay the stipend to Proposer as follows, subject (as applicable) to the following conditions:

(a) Proposer has submitted this signed Stipend Agreement, unchanged with its response to the RFP.

(b) After posting of the Notice of Award on SCDOT's Design-Build Website, Proposer has submitted to SCDOT an invoice, with FEIN Number, for the Stipend amount.

(c) After execution of the Contract or the decision not to award a contract, SCDOT will pay the invoice for the stipend amount to the unsuccessful Proposer meeting the criteria of Section 2.1 within 90 calendar days of receipt of the invoice from Proposer.

(d) If the procurement is suspended or cancelled prior to the Proposal Due Date (see FINAL RFP Milestone schedule), no stipend will be paid to Proposer.

(e) After the submittal of Proposals, but prior to award, if the procurement is cancelled, all Proposers that provide a responsive Technical Proposal and Cost Proposal to the final RFP and submitted a signed Stipend Agreement with their RFP shall receive the stipend

(f) In the event of a Best and Final Offer, only one stipend will be paid to each Proposer that executed a Stipend Agreement and met the other criteria and conditions herein.

(g) No stipends will be paid for submitting RFQ responses.

(h) No stipends will be paid to a Proposer who withdraws at any time from this procurement.

2.3 Acceptance by the Proposer of payment of the stipend amount from SCDOT shall constitute a waiver by Proposer of any and all right, equitable or otherwise, to bring any claim in connection with this procurement, procurement process, award of the Contract, or cancellation of this procurement.

2.4 The Proposer awarded the contract shall be not eligible to receive a stipend.

2.5 If Proposer elects to waive payment of the stipend, SCDOT will not use the ideas or information contained in that Proposer's Proposal for this Project. However, the Proposer's Proposal will be subject to the South Carolina Freedom of Information Act.

3. Indemnities.

3.1 Subject to the limitations contained in Section 3.2, Proposer shall indemnify, protect and hold harmless SCDOT and its directors, officers, employees and contractors from, and Proposer shall defend at its own expense, all claims, costs, expenses, liabilities, demands, or suits at law or equity arising, in whole or in part, from the negligence or willful misconduct of Proposer or any of its agents, officers, employees, representatives or subcontractors or breach of any of Proposer's obligations under this Agreement.

3.2 This indemnity shall not apply with respect to any claims, demands or suits arising from use of the Work Product by SCDOT.

4. Compliance With Laws.

4.1 Proposer shall comply with all federal, state, and local laws, ordinances, rules, and regulations applicable to the work performed or paid for under this Agreement and covenants and agrees that it and its employees shall be bound by the standards of conduct provided in applicable laws, ordinances, rules, and regulations as they relate to work performed under this Agreement. Proposer agrees to incorporate the provisions of this paragraph in any subcontract into which it might enter with reference to the work performed pursuant to this Agreement.

4.2 The Proposer agrees (a) not to discriminate in any manner against an employee or applicant for employment because of race, color, religion, creed, age, sex, marital status, national origin, ancestry or disability of a qualified individual with a disability; (b) to include a provision similar to that contained in subsection (a) in any subcontract; and (c) to post and to cause subcontractors to post in conspicuous places available to employees and applicants for employment, notices setting forth the substance of this clause.

5. Assignment.

Proposer shall not assign this Agreement without SCDOT's prior written consent. Any assignment of this Agreement without such consent shall be null and void.

6. Miscellaneous.

6.1 Proposer and SCDOT agree that Proposer, its team members, and their respective employees are not agents of SCDOT as a result of this Agreement.

6.2 This Agreement, together with the RFP, as amended from time to time, the provisions of which are incorporated herein by reference, embodies the entire agreement of the parties. There are no promises, terms, conditions, or obligations other than those contained herein or in the RFP, and this Agreement shall supersede all previous communications, representation, or agreements, either oral or written, between the parties hereto.

6.3 It is understood and agreed by the parties hereto that if any part, term, or provision of this Agreement is by the courts held to be illegal or in conflict with any law of the State of South Carolina, the validity of the remaining portions or provisions shall not be affected, and the rights and obligations of the parties shall be construed and enforced as if the Agreement did not contain the particular part, term, or provisions to be invalid.

6.4 This Agreement shall be governed by and construed in accordance with the laws of the State of South Carolina.

IN WITNESS WHEREOF, the parties have executed this Agreement as of the date first written above.

Witness:

_____

Recommended:

_____
{INSERT NAME}
Alternative Delivery Program Manager

Witness:

_____

_____

SOUTH CAROLINA DEPARTMENT
OF TRANSPORATION

By: _____
{INSERT NAME}
Alternative Delivery Engineer

Proposer

Kiewit Infrastructure South Co.
Name of Proposer

By: _____

Its: Senior Vice President

c. EEO Certificate

Please see the attached EEO Certificate.

11. EQUAL EMPLOYMENT OPPORTUNITY CERTIFICATION

(COMPLETE THIS SECTION FOR FEDERAL PROJECTS ONLY)
EQUAL EMPLOYMENT OPPORTUNITY PERFORMANCE

Select the Certification that applies to the PROPOSER:

Certification (1) [X] or Certification (2) [ ]

Select the appropriate responses in the applicable Certification:

Certification (1): Pursuant to 41 C.F.R. §60-1.7(b)(1), Previous Equal Employment Opportunity Performance Certification, as the Prospective Prime Contractor, I HEREBY CERTIFY THAT I:

(a) **(HAVE / HAVE NOT)** developed and filed an Affirmative Action Program pursuant to 41C.F.R. §60-2 and/or 60-4;

(b) **(HAVE / HAVE NOT)** participated in a previous contract or subcontract subject to the equal opportunity clause;

(c) **(HAVE / HAVE NOT)** filed with the Joint Reporting Committee, the Director of Office of Federal Contract Compliance, or the Equal Employment Opportunity Commission, all reports due under the applicable filing requirements,

OR

Certification (2): I, HEREBY CERTIFY that as the Prospective Prime Contractor submitting this Proposal, **(CLAIM / DO NOT CLAIM)** exemption from the submission of the Standard Form 100 (EEO-1) due to the fact that it employs a total of less than fifty (50) employees under C.F.R. §60-1.7, or qualifies for an exempted status under 41 C.F.R. §60-1.5.

I FURTHER CERTIFY that the above Certification will be made part of any Subcontract Agreement, or other agreement involved with this project.

Executed on 2/9, 2023.

Signed: _____
(Officer/PROPOSER)

Title: Senior Vice President

Company: Kiewit Infrastructure South Co.

Address: 450 Dividend Drive, Peachtree City, GA 30269

Note: The above certification is required by the Equal Employment Opportunity Regulations of the Secretary of Labor (41 CFR 60-1.7(b)(1)), and must be submitted by PROPOSERS only in connection with contracts which are subject to the equal opportunity clause. Contracts that are exempt from the equal opportunity clause are set forth in 41 CFR 60-1.5. (Generally, only contracts of $10,000 or under are exempt.)

Currently, Standard Form 100 (EEO-1) is the only report required by Executive Orders or their implementing regulations.

Proposers, Primary Members, or proposed Subcontractors (any tier) and Consultants who have participated in a previous contract subject to the Executive Orders and have not filed the required reports shall note that 41 CFR 60-1.7(b)(1) prevents the award of contracts and subcontracts unless such contractor submits a report covering the delinquent period or such other period specified by the Federal Highway Administration or by the Director, Office of Federal Contract Compliance, U.S. Department of Labor.

d. Non-Collusion Certificate

Please see the attached Non-Collusion Certificate.

10. NON-COLLUSION CERTIFICATION

NON-COLLUSION CERTIFICATION

Contract ID: 2847360

IN ACCORDANCE WITH THE PROVISIONS OF S.C. CODE ANN. §§ 39-3-10 ET.SEQ., 39-5-10 ET. SEQ., 15 U.S.C. §45; 23 C.F.R. §635.112(F); AND 28 U.S.C. §1746, I HEREBY ACKNOWLEDGE THAT I AM AN OFFICER OF THE PROPOSER FIRM AND, UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE UNITED STATES AND SOUTH CAROLINA, DECLARE, BY MY CERTIFICATION BELOW, THAT THE FOLLOWING IS TRUE AND CORRECT, AND FURTHER, THAT THIS JOINT-VENTURE, FIRM, PARTNERSHIP, ASSOCIATION OR CORPORATION, OR ANY OTHER LEGAL ENTITY HAS NOT, EITHER DIRECTLY OR INDIRECTLY, ENTERED INTO ANY AGREEMENT, PARTICIPATED IN ANY COLLUSION, OR OTHERWISE TAKEN ANY ACTION IN RESTRAINT OF FREE COMPETITIVE BIDDING IN CONNECTION WITH THE SUBMISSION OF A BID PROPOSAL ON THE ABOVE REFERENCED PROJECT.

BY CHECKING THIS BOX ☑, I CERTIFY THAT I HAVE READ, UNDERSTAND, ACCEPT, AND ACKNOWLEDGE ALL OF THE ABOVE STATEMENTS.

Executed on 2/9/2023
(Date)

Signed: Benjamin [illegible]
(Officer/Proposer)

Senior Vice President
(Title)

5617 North Rhett Avenue, Suite 125 D&E
North Charleston, SC 29406
(Address)

e. Notice of Receipt of Addendum

Please see the attached Notices of Receipt of Addendum listed below in the following pages:

- Addendum 1
- Addendum 2
- Addendum 3
- Addendum 4

South Carolina
Department of Transportation

NOTICE OF RECEIPT

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build Project– Contract ID 2847360
Kershaw County

Addendum 1

The information in this addendum shall be made part of the contract documents. PROPOSERS are instructed to incorporate the information into the previously provided RFP documents.

PROPOSERS are required to sign this document and enclose it with their Technical Proposal. Receipt of this signed document by The South Carolina Department of Transportation serves as confirmation that the PROPOSER has received and incorporated this Addendum into the contract documents.

Confirmation Statement:

I, the PROPOSER confirm that I have received this addendum package and have incorporated the information provided in the addendum into the contract documents.

Benjamin J. Carnazzo
PROPOSER's Signature

2/9/2023
Date

Benjamin J. Carnazzo
Printed Name

For: Kiewit Infrastructure South Co.
Design-Build Team Name

South Carolina
Department of Transportation

NOTICE OF RECEIPT

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build – Contract ID 2847360
Kershaw County

Addendum 2

The information in this addendum shall be made part of the contract documents. PROPOSERS are instructed to incorporate the information into the previously provided RFP documents.

PROPOSERS are required to sign this document and enclose it with their Technical Proposal. Receipt of this signed document by The South Carolina Department of Transportation serves as confirmation that the PROPOSER has received and incorporated this Addendum into the contract documents.

Confirmation Statement:

I, the PROPOSER confirm that I have received this addendum package and have incorporated the information provided in the addendum into the contract documents.

Benjamin J. Carnazzo
PROPOSER's Signature

2/9/2023
Date

Benjamin J. Carnazzo
Printed Name

For: Kiewit Infrastructure South Co.
Design-Build Team Name

South Carolina
Department of Transportation

NOTICE OF RECEIPT

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build – Contract ID 2847360
Kershaw County

Addendum 3

The information in this addendum shall be made part of the contract documents. PROPOSERS are instructed to incorporate the information into the previously provided RFP documents.

PROPOSERS are required to sign this document and enclose it with their Technical Proposal. Receipt of this signed document by The South Carolina Department of Transportation serves as confirmation that the PROPOSER has received and incorporated this Addendum into the contract documents.

Confirmation Statement:

I, the PROPOSER confirm that I have received this addendum package and have incorporated the information provided in the addendum into the contract documents.

Benjamin J. Carnazzo
PROPOSER's Signature

2/9/2023
Date

Benjamin J. Carnazzo
Printed Name

For: Kiewit Infrastructure South Co.
Design-Build Team Name

South Carolina
Department of Transportation

NOTICE OF RECEIPT

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build – Contract ID 2847360
Kershaw County

Addendum 4

The information in this addendum shall be made part of the contract documents. PROPOSERS are instructed to incorporate the information into the previously provided RFP documents.

PROPOSERS are required to sign this document and enclose it with their Technical Proposal. Receipt of this signed document by The South Carolina Department of Transportation serves as confirmation that the PROPOSER has received and incorporated this Addendum into the contract documents.

Confirmation Statement:

I, the PROPOSER confirm that I have received this addendum package and have incorporated the information provided in the addendum into the contract documents.

PROPOSER's Signature

2/9/2023
Date

Benjamin J. Carnazzo
Printed Name

For: Kiewit Infrastructure South Co.
Design-Build Team Name

f. Updated Organization Chart and Notarized Statement of Availability of Key Individuals

Kiewit has not replaced any Key Individuals since short-listing.

Please see notarized statements of availaibilty of key individuals from KISC and KEGI, cosigned by Kiewit's Project Manager Michael Luke Graham on the following pages.

Kiewit

February 9, 2023

Ms. Carmen Wright
Office of Project Delivery
South Carolina Department of Transportation
955 Park Street, Room 101
Columbia, South Carolina 29202-0191

Subject: Notarized Statement of Availability of Key Individuals

Dear Ms. Wright:

This letter is to confirm that each of the Key Individuals identified on the original organization chart submitted with the SOQ will be available, barring any unforeseen circumstances, at the earliest of the times and durations identified in the RFQ and RFP, until expiration of the Warranty Period, or such earlier date as the Contract is terminated or SCDOT releases, in writing, such Key Individual from this requirement.

Thank you for the opportunity to be involved in this program. Please contact me via email at Ben.Carnazzo@kiewit.com or my office phone number at (770) 487-2300 to discuss any further requirements from Kiewit Infrastructure South Co.

Sincerely,

Benjamin J. Carnazzo
Senior Vice President
Kiewit Infrastructure South Co.

State of Georgia
County of Coweta
Subscribed and sworn to before me on this:
2/7/2023
Jessica Wolfe
My commission expires: 1-27-2024

JESSICA WOLFE
Notary Public, Georgia
Coweta County
My Commission Expires
January 27, 2024

Michael Luke Graham
Project Manager
Kiewit Infrastructure South Co.

State of Colorado
County of Douglas
Subscribed and sworn to before me on this:
2/7/2023
My commission expires: 1-27-2024

KATHLEEN L ALFANO
Notary Public
State of Colorado
Notary ID # 20154043589
My Commission Expires 01-27-2024

KIEWIT ENGINEERING GROUP INC.
10055 Trainstation Circle, Lone Tree, CO 80124
(303) 325-0300

OFFICER'S CERTIFICATE
OF
KIEWIT INFRASTRUCTURE SOUTH CO.

I, the undersigned, hereby certify that I am an Assistant Secretary of Kiewit Infrastructure South Co., a Delaware corporation (the "Corporation"), and further certify on behalf of the Corporation that:

1. Benjamin J. Carnazzo ("Signing Officer") is a duly appointed and acting Senior Vice President of the Corporation.

2. Thomas J. Boyle is a duly appointed and acting Assistant Secretary of the Corporation

3. The Corporation intends to submit a bid proposal (the "Proposal") to [South Carolina Department of Transportation] for the [I-20 over Wateree Bridge Replacement and Swamp Overflow Bridge Rehabilitations] [Contract ID 2847360] in [Kershaw County, SC] (the "Project").

4. The Signing Officer, as a Senior Vice President, is authorized to execute and deliver the Proposal on behalf of the Corporation, and upon award of the Project, to execute and deliver the Project contract and any related documents for the Project, and Thomas J. Boyle, as an Assistant Secretary of the Corporation, is authorized to witness such execution of documents and further certify on behalf of the Corporation that the foregoing information provided in the Proposal is true, full and correct

SIGNED on behalf of the Corporation on this 3rd day of February, 2023.

KIEWIT INFRASTRUCTURE SOUTH CO. CORPORATE SEAL A DELAWARE CORPORATION

KIEWIT INFRASTRUCTURE SOUTH CO.

By: _____
Name: Thomas J. Boyle
Title: Assistant Secretary

STATE OF Georgia)
)ss.
COUNTY OF Coweta)

The foregoing instrument was acknowledged before me this 3rd day of February, 2023, by Thomas J. Boyle, Assistant Secretary of Kiewit Infrastructure South Co., a Delaware corporation, on behalf of the corporation.

_____
Notary Public

My commission expires: 1.27.2024

JESSICA WOLFE
Notary Public, Georgia
Coweta County
My Commission Expires
January 27, 2024

Kiewit

February 9, 2023

Ms. Carmen Wright
Office of Project Delivery
South Carolina Department of Transportation
955 Park Street, Room 101
Columbia, South Carolina 29202-0191

Subject: Notarized Statement of Availability of Key Individuals

Dear Ms. Wright:

This letter is to confirm that each of the Key Individuals identified on the original organization chart submitted with the SOQ will be available, barring any unforeseen circumstances, at the earliest of the times and durations identified in the RFQ and RFP, until expiration of the Warranty Period, or such earlier date as the Contract is terminated or SCDOT releases, in writing, such Key Individual from this requirement.

Thank you for the opportunity to be involved in this program. Please contact me via email at John.Donatelli@kiewit.com or my office phone number at (402) 332-9262 to discuss any further requirements from Kiewit Engineering Group Inc.

Sincerely,

John A. Donatelli
President-Infrastructure Engineering
Kiewit Engineering Group Inc.

State of Colorado
County of Douglas
Subscribed and sworn to before me on this:
2/6/2023
My commission expires: 1-27-2024

KATHLEEN L ALFANO
Notary Public
State of Colorado
Notary ID # 20154043589
My Commission Expires 01-27-2024

Michael Luke Graham
Project Manager
Kiewit Infrastructure South Co.

State of Colorado
County of Douglas
Subscribed and sworn to before me on this:
2/7/2023
My commission expires: 1-27-2024

KATHLEEN L ALFANO
Notary Public
State of Colorado
Notary ID # 20154043589
My Commission Expires 01-27-2024

KIEWIT ENGINEERING GROUP INC.
10055 Trainstation Circle, Lone Tree, CO 80124
(303) 325-0300

OFFICER'S CERTIFICATE
OF
KIEWIT ENGINEERING GROUP INC.

I, the undersigned, hereby certify that I am the Secretary of Kiewit Engineering Group Inc., a Delaware corporation (the "Corporation"), and further certify on behalf of the Corporation that:

1. John A. Donatelli ("Signing Officer") is the duly appointed and acting President-Infrastructure Engineering of the Corporation.

2. The Corporation intends to submit a response to the Request for Proposals (the "RFP"), to the South Carolina Department of Transportation (the "SCDOT"), for the I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations Design-Build Project, Contract ID 2847360, Kershaw County, South Carolina (the "Project").

3. The Signing Officer, as the President-Infrastructure Engineering, is authorized to execute and deliver the RFP and any related documents for the Project to the SCDOT on behalf of the Corporation, and upon award of the Project, to execute and deliver the Project Contract and related documents.

4. The Signing Officer further certifies on behalf of the Corporation that the foregoing information provided in the RFP is true, full and correct.

SIGNED on behalf of the Corporation on this 7th day of February, 2023.

KIEWIT ENGINEERING GROUP INC.

By: _____
Name: Michael F. Norton
Title: Secretary

KIEWIT ENGINEERING GROUP INC. CORPORATE SEAL A DELAWARE CORPORATION

STATE OF NEBRASKA)
)ss.
COUNTY OF DOUGLAS)

On this 7th day of February, 2023, the foregoing instrument was acknowledged before me, the undersigned Notary Public, in and for said State, by Michael F. Norton, Secretary of Kiewit Engineering Group Inc., a Delaware corporation, on behalf of the corporation.

Stacey A. Lamb
Notary Public

GENERAL NOTARY - State of Nebraska
STACEY A. LAMB
My Comm. Exp. October 10, 2023

My commission expires: 10/10/2023

g. Confidential and Proprietary Information Page List

Kiewit does not have any information that will be considered confidential and/or proprietary.

h. Prequalification Certificate

Please see the attached Prequalification Certificate.

South Carolina Department of Transportation

Columbia, South Carolina

SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION

PRIME CONTRACTOR

PREQUALIFICATION CERTIFICATE

This Certifies that your company has complied with the rules and regualtions of the Department and the State of South Carolina, and subject to the rules and regulations for a prime contractor, is declared eligible to submit a bid and be awarded any construction contract issued by the Department, subject to obtaining proper bonds and insurance acceptable to the Department and complying with all other statutory and contract requirements.

All BIDS SUBMITTED TO THE DEPARTMENT MUST BE IN THE NAME AS SHOWN BELOW.

KIEWIT INFRASTRUCTURE SOUTH CO.

Vendor ID: **1GI002**

Issued : **November 16, 2022**

Expires: **November 30, 2023**

Approved By: Maria A. Clement

Prequalification Coordinator

i. Joint Venture Organizational Agreement

Kiewit Infrastructure South Co. is the sole bidding entity of this project.

j. Quality Credit Matrix

Please see the Quality Credit Matrix on the following pages.

Number	Description	Added Value/Benefits	Cost/Schedule Impacts	Self-imposed Assurance
1	Permanent Design - **Providing a single 6-lane bridge** upon project completion	SCDOT will receive a single 6-lane bridge that is built to accommodate 3 lanes in each direction for when SCDOT expands I-20. Additionally, there is no temporary or throw away work. Maintenance of traffic will be more effective during construction since driver expectation will be improved by driving on a permanent bridge versus a temporary bridge.	Additional cost of $195,000 to build the single 6-lane bridge. However, it is a better value now to SCDOT. The single 6-lane bridge has a five month schedule reduction in bridge construction versus the dual bridge concept.	N/A
2	Permanent Design - ATC 6 *Elimination of End Diaphragms*	Operation and maintenance will be easier during future bearing replacement as the diaphragms will not hamper repair or replacement of the joint.	**Cost reduction of $690,000**. No schedule impacts.	N/A
3	Permanent Design - ATC 7 *Alternate Intermediate Diaphragm*	Provides comparable maximum moments in the girders with reduced quantities. This ATC reduces the intermediate steel quantity and, as such, the procurement lead time. There are fewer connections to the web resulting in simpler and faster installation, and reduced future maintenance requirements.	**Cost reduction of $130,000**. No schedule impacts.	N/A
4	Permanent Design - ATC 11 *60-MPH & Method 2 Crossover* : Using 3-D software, we have fully modeled the crossovers. The revised design criteria allows for detours to fit between the farm pond bridges and the new Wateree bridge without the need to install asphalt runouts onto the bridge decks	Provides a detour crossover on the west side of the Wateree River without the need to place asphalt on new or existing bridges.	**Cost reduction of $197,000**. No schedule impacts	N/A
5	Means and Methods - Use of a gantry crane in phase 1 to optimize tight working conditions, reduce traffic impacts, and reduce environmental impacts	Reduces number of lane closures and impacts to the traveling public. Reduction of crane access required for building below the bridge.	**Additional cost of $169,000** to bring in gantry cranes vs. traditional crawler cranes. No schedule impacts.	N/A
6	Means and Methods - ATC 8 *Drilled Shaft Polymer Slurry*	Improved quality due to use of better products to maintain shaft integrity during drilling. Reduced environmental impacts in the event of a spill.	**Cost reduction of $49,000**. No schedule impacts.	N/A
7	Expedited Schedule - **Substantial completion is 91 days sooner** than the allowed 1,734 calendar days	Shorten construction schedule and impacts to the traveling public. Reduced cost to SCDOT.	**Cost reduction of $600,000**. Reduced schedule and management costs to SCDOT	We will increase the liquidated damages from $8,000 / day to $12,000 / day
8	Expedited Schedule - **Reach final completion within 122 days of substantial completion** versus the 180 calendar days that are allowed in the RFP	Shorten construction schedule and management cost by both SCDOT and Kiewit.	Cost reduction included in Item #7. Reduced schedule and management costs to SCDOT	We will increase the liquidated damages from $2,500 / day to $5,000 / day
9	Expedited Schedule - Permanent and temporary design features and access plan that minimizes environmental and hydraulic impacts thus **improving the permit approval process**. Our plan impacts 2.5 acres of wetland and 220 lineal feet of streambed, which is below the thresholds of 3 acres of wetland and 300 linear feet of streambed.	Streamlined process for environmental reviews reduces the risk of schedule delays.	**Cost reduction of $188,000** for compensatory mitigation No impacts to schedule	N/A
10	Expedited Schedule - Accelerating Early MOT and Overflow Structure Rehabilitation design packages to **start work early by 28 days**	Able to start work sooner while permanent design progresses. Reduces the risk of schedule delays.	**Schedule reduction of 28 days** and management cost reduction to SCDOT	N/A
11	Schedule Certainty - Greater control over the design since Kiewit Engineering Group Inc. is the lead designer	Reduces the risk of design delays due to Kiewit's ability to pull more resources as needed to meet the schedule.	**Increased schedule certainty** for design activities	N/A
12	Schedule Certainty - Availability and procurement schedule of ChromX vs galvanized reinforcing steel	Increased schedule certainty and reduced schedule duration as ChromX rebar does not need to be galvanized after fabrication (a process that requires 4 - 6 additional weeks).	**Cost reduction of $674,000**. No overall schedule impacts, but there are reduced procurement times on ChromX 4100 vs galvanized bar.	N/A
13	Schedule Certainty - Kiewit controls self-perform capabilities and equipment resources	We will self-perform most of the scope on the critical path which will help maintain schedule.	No impacts to cost. **Increased schedule certainty**.	N/A
14	Minimizing Impacts to Traffic Safety - In Phase 0 we will replace the existing outside shoulders so they will withstand the vehicle counts and loading when traffic is shifted to the outside during Phase 1	Less maintenance and repairs during construction and overall less maintenance by SCDOT in the future.	Additional cost of $915,000 and 25 day schedule increase upfront to replace the existing shoulders, but improved traffic operations for SCDOT	N/A
15	Minimizing Impacts to Traffic Safety - Use of a gantry crane to reduce lane closures for structure and girder operations. Girders can be brought into the median to be off-loaded and trammed into place	Reduced lane closure durations and impacts to the traveling public.	**Additional cost of $169,000**, which will allow productivity improvements and shortens project schedule	N/A
16	Minimizing Impacts to Traffic Safety - ATC 4 *Alternate Construction Access* : Construction access has dedicated acceleration and deceleration lanes for outside shoulders thereby reducing impacts to the traveling public and reducing the overall number of lane closures.	Safe access for construction operations while reducing impacts to the traveling public - allows for unlimited construction operations without the need for lane closures to access the right-of-way.	**Additional cost of $926,000** to construct on- and off-ramps, which will allow productivity improvements and shortens project schedule	N/A

Number	Description	Added Value/Benefits	Cost/Schedule Impacts	Self-imposed Assurance
17	Minimizing Impacts to Traffic Safety - ATC 5 *Work Zone Access Using Inside-Outside Shoulder* : Construction access has dedicated acceleration and deceleration lanes for inside and outside shoulder work areas thereby reducing impacts to the traveling public and reducing the overall number of lane closures.	Reduced lane closure durations and impacts to the traveling public.	**Cost reduction of $400,000** for reduced lane closures installation. No impacts to schedule	N/A
18	Laydown yard located on west landowner's property.	Provides additional storage out of SCDOT right-of-way and floodplain.	Additional cost of $131,000 and no impacts to schedule	N/A
19	Minimizing Impacts to Traffic Safety - Additional access to jobsite via adjacent land owners - which promotes better separation of construction and the traveling public	Increased safety due to less potential interaction between the construction vehicles and the travelling public. Reduction of lane closures.	Additional cost of $323,000 for access and no impacts to schedule	N/A
20	Minimizing Impacts to Traffic Safety - Construction vehicle egress warning signs and lights	Safer operations for traveling public.	Additional cost of $25,000 for warning system and no impacts to schedule	N/A
21	Minimizing Impacts to Traffic Safety - Kiewit will increase the penalty for violating lane closure restrictions from the amount specified in Section 605, Exhibit 5 - Special Provisions and Contract Requirements. See Self-Imposed Assurance.	More assurance that lane closures will be removed before the times specified in the Traffic Design Criteria.	No impacts to cost or schedule	Should lane closures remain in place or not be completely removed by the time specified in the Traffic Design Criteria, an increased penalty will be assessed at the rate of from $2,500.00 to $3,500 for each 1/4 hour interval (or any portion thereof) for each lane closed. Should lane closures remain in place or not be completely removed for a period of longer than one hour beyond the time specified by the Traffic Design Criteria the penalty will increase from $5,000.00 to $7,500 for each 1/4 hour interval (or any portion thereof) for each lane closed.
22	Minimizing Impacts to Traffic Safety - Providing dedicated staff to assist SCDOT with public involvement and outreach for lane closure information	A collaborative effort that promotes accurate and timely information to the public.	Additional cost of $45,000 to improve schedule certainty	N/A
23	Reducing In Water Work - Use of gantry crane for first phase of construction to reduce requirement for creating access at ground-level and in the Wateree River	Reduces amount of wetland and environmental impacts. Allows for work to continue during high water events.	**Additional cost of $169,000**, but increased schedule certainty	N/A
24	Reducing In Water Work - Use of trestle with limited foundations in the water for phases 1, 2, and 3 for constructing the new Wateree Bridge.	Less intrusive type of access. For bridge construction, our plan avoids the requirement for floating in-river barges or placing fill material in the river.	No impacts to cost or schedule	N/A
25	Reducing in Water Work - Less environmental impacts than what is allowed by the Regional General Permit. Kiewit's impacts are 0.5 acres and 80 lineal feet less than what is allowed.	Streamlined process for environmental reviews and approvals. Reduces the risk of schedule delays.	Reduction in cost of $188,000 for compensatory mitigation. No impacts to schedule	N/A
26	Minimize Maintenance Cost - ATC 2 *ChromX Reinforcing Bar*	ChromX provides an increased service life over galvanized rebar. Using a higher KSI reduces the quantity of reinforcing steel in the deck. ChromX is available in 60ft lengths versus 40ft lengths for galvanized steel thereby reducing the number of splices. ChromX does not contain fragile coatings and can be handled like conventional rebar. ChromX offers increased corrosion resistance that will reduce the amount of maintenance required for spall and crack repairs over the life of the deck structure.	**Cost reduction of $674,000**. No overall schedule impacts, but there are reduced procurement times on ChromX 4100 versus galvanized bar.	N/A
27	Other - Provide an extended warranty beyond the three-year period to a five-year period on Approach slabs, Bridge deck, Bridge barrier wall, Bridge bearings, Bridge expansion joints.	Improved initial quality, and Kiewit takes responsibility for repair on these items for the first five years.	Reduced costs to SCDOT for future repairs on these items	Kiewit will perform the warranty work on these items or be responsible for all costs for the corrections if work is not performed by Kiewit
28	Other - Kiewit has an ISO 9001:2015 certified Corporate Quality Management Plan which means this project will be ISO 9001:2015 compliant. Kiewit will implement quality control procedures such as proper planning of work operations that include pre-planning, work plan, pre activity meetings, hold point inspections and verification.	Proven and repeatable quality control procedures. Overall better construction quality.	No impacts to cost or schedule	N/A

Number	Description	Added Value/Benefits	Cost/Schedule Impacts	Self-imposed Assurance
29	Other - Project Management Plan (PMP) Dashboard - This reporting tool is accessed via computer or remote device to provide SCDOT access to project-wide real-time data on safety, quality, traffic control, environmental compliance, administration and DBE, among others.	This innovative database tool provides SCDOT customizable, real-time data/audit visualizations for each management plan component. The dashboard is available 24/7, promotes transparency, and gives SCDOT updated, accurate information, demonstrating progress (or flagging areas needing attention). Access to real-time data facilitates informed decision-making, provides consistent project-wide communication and information, and gives timely and accurate status of our key performance Indicators, including DBE performance data; all of which are vital to Project success.	No impacts to cost or schedule	N/A
30	Other - Dedicated Subcontract Managers	Each subcontract will be assigned to a Kiewit manger as the single point of contact. The Kiewit manager will be responsible for ensuring the subcontractor's work and employees are integrated into the project's safety, quality, and schedule performance accountability systems. SCDOT and the public will benefit from this consistency by receiving the same high level of safety, quality workmanship, and dependability regardless of the entity providing it.	No impacts to cost or schedule	N/A
31	Other - Subcontractor/DBE On-Boarding Process	Kiewit will develop and implement a comprehensive subcontractor on-boarding process to support DBE integration into the team. The process will be documented in an onboarding guide that will provide instruction regarding key project requirements and administrative procedures ranging from safety training to invoicing and issue management. Kiewit will conduct monthly (minimum) on-boarding sessions to provide newly contracted firms an overview of procedures and expectations, access to key project contacts, and initiate ongoing processes for addressing issues and questions. Clear, consistent, and transparent communication will enhance successful integration and performance of DBE partners and mitigate challenges typically encountered.	No impacts to cost or schedule	N/A
32	Other - Integrated Design and Construction Team	An advantage of the Kiewit team is an integrated and in-house design and construction team, which will provide collaboration and streamlined decision making across all phases of the Project. From the design phase, Kiewit Engineering Group Inc. (KEGI) provides oversight of all in-house designers and design subconsultants. They will establish and maintain an efficient strategy for design deliverables, design quality, and design reviews to meet construction schedule requirements. KEGI will lead the design team in providing construction engineering services and constructible plans and specifications that conform to SCDOT design criteria.	No impacts to cost or schedule	N/A
33	Other - Environmental Integration	Our integrated design and construction staff began collaborating on environmental risks and permitting opportunities before the RFP was released. This collaboration has continued through the bid phase and will remain active through project execution. The entire team is aware of all real-time aspects of our environmental commitments. Staying updated allows for streamlined interface with SCDOT through use of an environmental permits issues and commitments matrix. The matrix tracks responsibility to provide unified communication to stakeholders.	No impacts to cost or schedule	N/A
34	Other - Life Saving Actions (LSA) Program	Our LSA program supports the goal of our safety program: “Nobody Gets Hurt”. The LSA program will identify the potential outcome of all incidents or events, then develop meaningful plans to eliminate them. The benefits of this program include a higher standard of identification, communication, training, and elimination of exposures that cause injuries. Categories for the LSA program include unplanned events or possible conditions involving confined spaces, lifting and rigging, cranes, MOT, energy isolation, temporary structures, excavation, utilities, human equipment interface: possible exposure to equipment operations or collisions, and working at heights.	No impacts to cost or schedule	N/A
35	Other - Craft Voice In Safety (CVIS) Program	Kiewit’s unique craft-engagement program will contribute to the success of safe work procedures by creating a culture where everyone has a voice. Craft are taking care of craft, in partnership with management, through ownership, communication, and prevention to achieve the goal of “Nobody Gets Hurt.” Craft, including from subcontractors, volunteer to serve on the CVIS team and perform weekly project site tours, gather feedback and training suggestions from craft personnel, and review safety policies and procedures for effectiveness. Kiewit promotes a safety culture where each employee is looking out for the other. This bottom-up approach to safety empowers our craft workers to assume active leadership in cultivating a safe work site for the traveling public and their co-workers.	No impacts to cost or schedule	N/A

Number	Description	Added Value/Benefits	Cost/Schedule Impacts	Self-imposed Assurance
36	Other - Kiewit will establish a construction field office.	During the design phase, Kiewit's team of in-house engineers will co-locate in a centralized office to integrate design and construction professionals. This office location will house design and construction staff during initial “ramp-up” mobilization, and SCDOT will be welcome to co-locate staff to this office as well for key milestone participation. Additionally, a dedicated project field office will further enhance our Project Management teams ability to hold construction staff accountable week to week, and discuss status and challenges with timeliness and transparency with SCDOT.	Additional $496,000 to establish the field office, which will further enhance collaboration.	N/A

Appendix C – Approved Formal ATCs being incorporated into the Cost Proposal

APPENDIX C – APPROVED FORMAL ATCS BEING INCORPORATED INTO THE COST PROPOSAL

Please see the Approved Formal ATCs being incorporated into the Cost Proposal listed below in the following pages.

ATCS APPROVED

- VALUE ADDED ATC 2 — CHROMX REINFORCING BAR
- VALUE ADDED ATC 4 — ALTERNATE CONSTRUCTION ACCESS
- VALUE ADDED ATC 5 — WORK ZONE ACCESS USING INSIDE-OUTSIDE SHOULDER
- VALUE ADDED ATC 6 — ELIMINATION OF END DIAPHRAGMS
- VALUE ADDED ATC 7 — ALTERNATE INTERMEDIATE DIAPHRAGM
- VALUE ADDED ATC 8 — DRILLED SHAFT POLYMER SLURRY
- VALUE ADDED ATC 11 — 60-MPH & METHOD 2 CROSSOVER

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 2 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Description (required):

This ATC requests using Martensitic Microcomposite Formable Steel (MMFX), also known as ChromX 4100, reinforcing bar (ASTM A1035) in lieu of the galvanized rebar (ASTM A767) for corrosion protection of the bridge deck.

Usage:

ASTM A1035 reinforcing will be used for all bars located in or extending into the new deck. ASTM A706, Grade 60 reinforcing will be used in all other locations.

Deviations (required):

This ATC is a deviation from the RFP, Exhibit 4b Section 2.1.3, Corrosion Protection (Page 160 of 344), which states: "Provide galvanized rebar in all new bridge decks and their concrete appurtenances including barriers on this project." It also deviates from Section 15.2.2 of the SCDOT Bridge Design Manual - Reinforcing Bars (Page 15-6), which states: "Reinforcing Bars shall conform to ASTM A706, Grade 60 with 60 ksi yield strength." This ATC requests the acceptance of Martensitic Microcomposite Formable Steel (MMFX), also known as ChromX 4100, reinforcing bar, in lieu of the specified galvanized rebar.

Justification:

ChromX provides an increased service life over either black or galvanized rebar. AASHTO LRFD Article 5.4.3.1 allows the use of 75 to 100 ksi steel, and the use of the higher grade steel will reduce the reinforcing steel quantity in the deck. The number of splices are reduced, since ChromX is available in 60-ft. lengths vs. the 40-ft. length for galvanized bar. Using higher strength ChromX (100 ksi) results in a reduction of the overall weight of steel in the bridge deck by approximately 20%. It also reduces bar congestion, especially at the traffic barrier splice. Since there are no fragile coatings, ChromX can be handled and fabricated just like conventional rebar. The attached file provides a list of reference publications, reports and papers that provide a detailed review of the corrosion and structural characteristics of ASTM A1035 Types CS, CM and CL (ChromX Series 9000, 4000, and 2000) and AASHTO M334 Grade 100 (ASTM A1035 Type CS – ChromX® 9100). Since ChromX was introduced into the market place in 2001, it has been used in more than 100 bridge projects, located in: 27 states, 4 Canadian provinces, Puerto Rico and the Bahamas. A list of the agencies that have designed or constructed projects with ChromX is attached.

Schedule:

There is a potential savings of 4 to 6 weeks in procurement lead time over hot-dipped galvanized rebar. There are no overall project schedule savings anticipated.

Impacts:

No vehicular traffic, safety, community, utility, right-of-way or environmental impacts are anticipated.

History:

ChromX has been shown in several independent studies to outperform epoxy-coated and galvanized rebar for corrosion protection, providing an increased service life of up to 100 years. A list of the agencies that have designed or constructed projects with ChromX is attached.

Post Office Box 191
Columbia, South Carolina 29202-0191

Phone: (803) 737-2314
TTY: (803) 737-3870

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AFFIRMATIVE ACTION EMPLOYER

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 2 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Risks:

There are no additional risks to SCDOT or other persons/entities with implementing this ATC.

Costs (required):

Cost Savings: $674,000

Quality:

ChromX has improved long-term performance over black or galvanized reinforcing bar. The RFP does not require steel extending from girders into the deck to be galvanized. Higher strength steel facilitates concrete consolidation during casting due to less reinforcement in the deck, with less potential for finishing issues.

Operations & Maintenance:

This ATC increases corrosion resistance that will reduce the deck maintenance required for spall and crack repairs over the life of structure.

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Kiewit ATC 02 – CHROMX - REFERENCE PUBLICATIONS

ChromX® 9000 (ASTM A1035 Type CS Grade 100 [690] and AASHTO M334M/M334 Grade 100 [690]) and ChromX® 4000 (ASTM A1035 Type CM Grade 100 [690]) steel's corrosion performance has been demonstrated by various test methods at different universities and DOT laboratories, as illustrated under the reference section.

Table 1 summarizes the Chloride Threshold and Estimated Propagation Time for different types of reinforcing bars as referenced by Tourney Consultant Group "Reinforcing Steel Comparative Durability Assessment for 100-Years' Service Life". The chloride threshold values of the different competing products are illustrated in Figure 2.

Table 1 Chloride Threshold and Propagation Time

Reinforcing Bar Type	Chloride Threshold, PPM[1]	Estimated Chloride Threshold, ppm with 2 Gpy of CNI	Estimated Propagation Time, Years
Conventional BB (A615)	500		5 - 7
Epoxy Coated Bars (A775)[2]	500		10 - 15
Epoxy Coated Bars (A775) 2 layers[2]	900		10 - 15
Galvanized Bars (A767)[3]	1500		15 - 20
ChromX® 9000 (ASTM A1035 CS)	2000	2400	15 - 20
ChromX® 4000 (ASTM A1035 CM)	1600	2200	15 - 20
ChromX® 2000 (ASTM A1035 CL)	850	1875	15 - 20
UNS S32304 (ASTM A955)	3750		>50

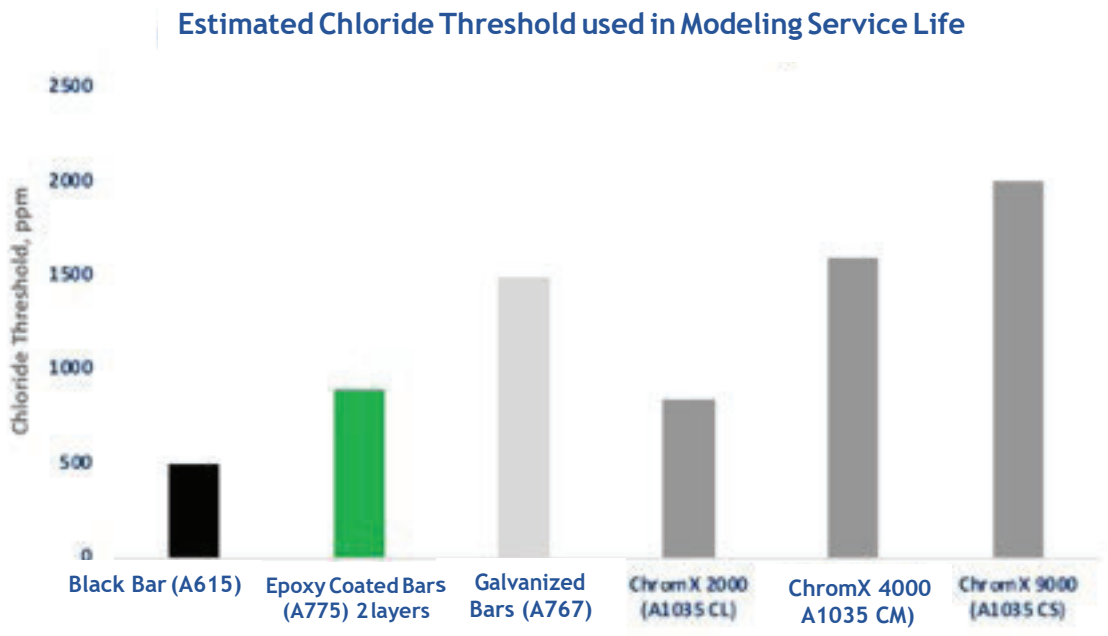

Figure 2 Comparison of Chloride Threshold values of the Different Competing Bars

Material Service Life

An assessment of ChromX® Steel conforming to ASTM A1035 Type CM and CL and ASTM A1035 Type CS conforming to AASHTO M334M/M334 Grade 100 [690] rebar's corrosion resistance performance is made through the measure of its service life and/or critical chloride threshold level (CT), as noted in 5.A *"Corrosion Test Reports."* The references for service life studies are listed below:

- Berke reported that A1035 Type CS and CM with CNI (Calcium Nitrate) bars exceeded a 100-year service life in the study's comparative analysis of various CRR materials in bridge decks, marine and soil piles structures, located within various environmental settings
- Berke reported that A1035 Type CS and ASTM A1035 Type CM with CNI (Calcium Nitrate) can provide 100-year service life in bridges.
- Williamson and Weyers indicated that A1035 Type CS, when used in conjunction with LCP (low-permeability concrete), provides greater than 200-year service life.
- Cui and Krause noted that A1035 Type CS would provide about 2 times the service life and had approximately 3 times the chloride threshold of carbon steel.
- Darwin and Browning said that corrosion initiation in un-cracked bridge decks would take about 3.8 times longer than black steel; and 2.4 times longer than galvanized (zinc coated) rebar. This study replicated some of the findings of Pianca and Schell concerning galvanized (zinc coated) rebar.
- LaNier and Springston states that on the US Navy's modular pier project, A1035 Type CS saved about $2.8 million over the original proposed design, while providing a 75-yr service life.
- Clemeña and Virmani reports that A1035's chloride threshold is about 5 to 6 times that of black bar and 2 times that of 2101 LDX bars.

These studies consistently demonstrate ChromX® steel ability to provide long-term corrosion performance and added value to structures in corrosive environments.

The Service Life of a reinforced concrete structure goes through three corrosion related stages. Figure 3 illustrates a schematic graphic comparing ChromX® steel's corrosion protection in relation to conventional black steel, where Stage 1 is time to corrosion initiation, Stage 2 is time for corrosion propagation, and Stage 3 is time through expected repairs until the structure's end of economic service life.

1. Stage one (corrosion initiation) - time for chlorides to penetrate the concrete to the level of the steel, reach the CT and initiate corrosion.
2. Stage two (propagation) - time from initiation of corrosion to initiation of first concrete spalls.
3. Stage three (repair) - time during the service life interval requiring repairs.

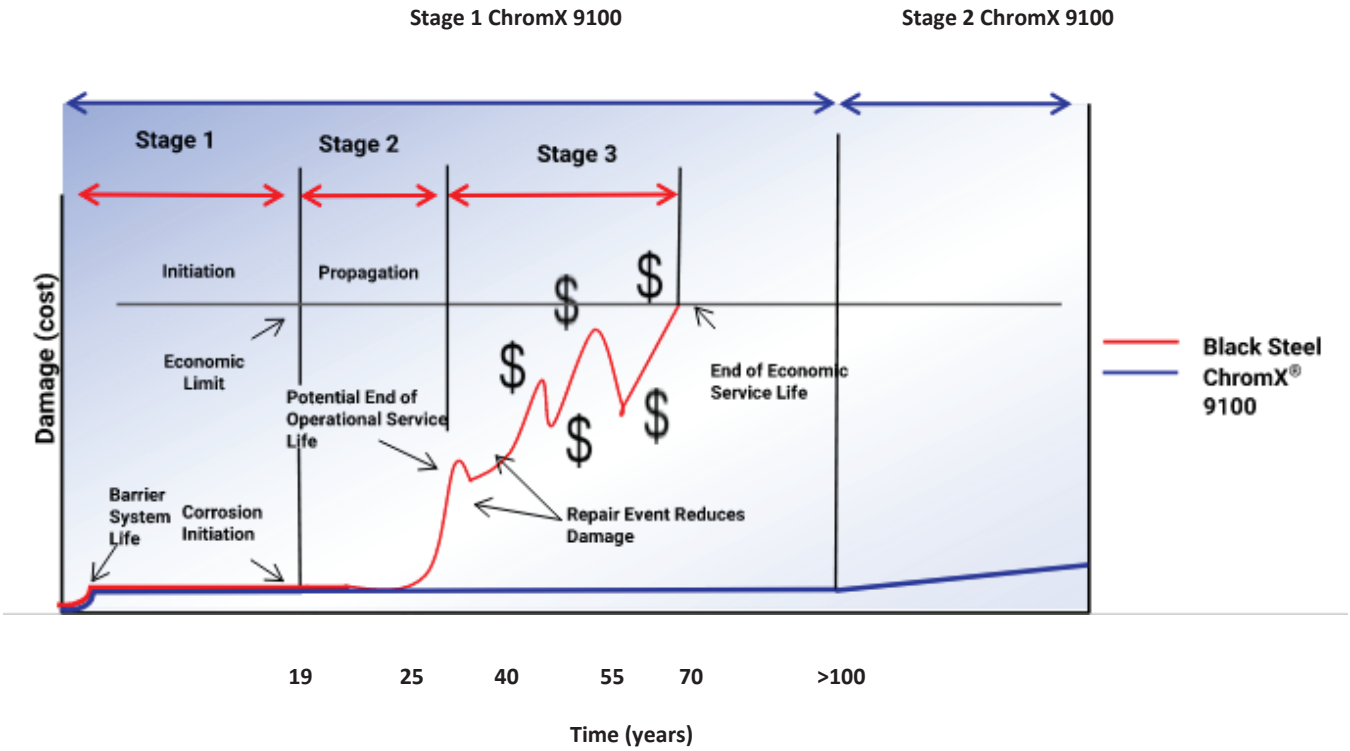

Figure 3 Schematic Graphic Illustration Comparing ChromX® steel's corrosion protection in relation to conventional black steel.

Applicability of the ChromX® Steel bars in Corrosive Environments:

Taking into consideration of all the available literature on the chloride threshold and corrosion rate of the different ChromX® product series and the estimated service life for initiation and repairs, the following table summarizes the service life and replacement strategy for alternative reinforcements:

The ChromX® Series Choice Replacing Alternate Reinforcement for the Specific Application and Service Life Requirements

Application	Required Service Life (Years)	ChromX® Series* Choice for Replacing Alternate Reinforcement	Alternate Reinforcement replaced by ChromX®
Bridges	100	• ChromX® 9000 • ChromX® 4100 with 2 gpy CNI	Stainless Steel
Bridges	75	• ChromX® 9000 • ChromX® 4100	Epoxy Coated Steel Galvanized Steel
Marine	100	• ChromX® 9000	Stainless Steel
Marine	75	• ChromX® 9000 • ChromX® 4000 with 2 gpy CNI	Stainless Steel
Marine	50	• ChromX® 4000	Epoxy Coated Steel Galvanized Steel

* Lowest cost for the service life required for the application

Reference Publications / Reports / Papers

Many of these studies mention MMFX2 when referring to the ChromX® ® 9000 series because they were written before ChromX expanded its product line. The following reference documents provide a more detailed review of ASTM A1035 Types CS, CM and CL (ChromX® Series 9000, 4000, and 2000) and AASHTO M334 Grade 100 (ASTM A1035 Type CS – ChromX® 9100) rebar's corrosion and structural characteristics.

Corrosion Test Reports, Papers, and Analysis References

1. **Reinforcing Steel Comparative Durability Assessment and 100-year Service Life Cost Analysis Report Tourney Consulting Group–N. Berke–June 2016 – (68 pages):**

   This study focused on modeling and evaluating concrete reinforcement for corrosion; and estimating the service life for various reinforcing steel alternatives. The evaluation included engineering analysis and laboratory test data from Tourney Consulting Group's internal database. The engineering analysis included modeling of concrete service life using STADIUM® software. The investigation centered on the ChromX® 9100 (ASTM A1035 Type CS/AASHTO M334 "MP 18") and ChromX® 4100 (ASTM A1035 Type CM) bars versus black bar (BB), epoxy- coated (ECR), hot-dip galvanized (HDG), and stainless steel (SS2304) reinforcements.

   The following three project scenarios were analyzed, using a specific geographical project location, and representing differing climatic and other environmental settings.

   - Bridge deck exposed to deicing salts (Ohio River bridge near Louisville, KY
   - Marine pile (Cape Hatteras, NC)
   - Pile in corrosive soil with high sulfate content Gulf Cooperation Council (GCC) country

   In addition, a Life Cycle Cost Analysis (LCCA) was performed on the bridge deck.

   The following table summarizes the result of the bridge deck analyze.

   Service Life Analysis for Bridge Deck with Repairs

Concrete Type	Bridge Low Permeability (LP)				
Exposure	Deicing Salts		Rebar Initial Cost	1st Repair NPR	TotalCost Initial +All Repairs NPR
Cover (min.)	1.5 inches		$/ft^2	$/ft^2	$/ft^2
Reinforcement Type	Estimate to Initiation (y) / 1st Repair (y)				
Black Bar (BB)	19	25	7.32	5.62	19.30
ChromX® 9100 Gr 60	>100	>100	14.52	0	14.52
ChromX® 9100 Gr 75	>100	>100	11.52	0	11.52
ChromX® 9100 Gr 100	>100	>100	8.76	0	8.76
ChromX® 4100 GR 60	43	61	9.72	1.37	12.28

Concrete Type	Bridge Low Permeability (LP)				
Exposure	Deicing Salts		Rebar Initial Cost	1st Repair NPR	TotalCost Initial +All Repairs NPR
Cover (min.)	1.5 inches		$/ft^2	$/ft^2	$/ft^2
Reinforcement Type	Estimate to Initiation (y) / 1st Repair (y)				
ChromX® 4100 GR 75	43	61	7.80	1.37	10.36
ChromX® GR 100	43	61	5.88	1.37	8.44
ChromX® 4100 Gr 60 2 gpy CNI	>100	>100	10.03	0	10.03
ChromX® 4100 Gr 75 2 gpy CNI	>100	>100	8.01	0	8.01
ChromX® 4100 Gr 100 2 gpy CNI	>100	>100	6.16	0	6.16
Epoxy Coated (ECR)	19	34	10.08	3.95	18.50
Galvanized (GS)	59	76	13.68	0.76	14.86
UNS S32304 (SS2304)	>100	>100	25.32	0	25.32

Notes:

1. Repairs every 15 years starting at 1st repair at $150/ft2 (Traffic + Repair)
2. 10% of the surface area is repaired at each time
3. Discount rate at 4%
4. Only ASTM A1035-CS (ChromX® 9100), ASTM A1035-CM (ChromX® 4100) with 2 gal/cy CNI, and SS2304 options meet requirement of no significant repairs in either 75 or 100 years.

2. Case Studies for 100-Year Service Life Utilizing High Strength Low Chromium Reinforcing Bars NACE-Concrete Service Life Extension Conference- N Berke, R. Vijayakumar, July 2015 (19 pages):

This paper is based on testing, which is part of a NCHRP Idea project that included: black steel rebar (BB), A1035 Type CS and CM rebar (A1035 9-Cr "ChromX® 9100") and (A1035 4-Cr "ChromX® 4100"), epoxy-coated rebar (ECR), hot-dipped galvanized rebar (HDG), and stainless steel rebar (S32304) versus zinc coated bar with (TZD) and without (TZE) a hand painted epoxy coating.

The paper concluded:

"All of the corrosion resistant reinforcing bars in this study outperformed black steel in both un-cracked and cracked and fatigued concrete specimens.

For cracked beams after 26 cycles of testing:

- *The corrosion resistant bars have more than a two times reduction in macrocell currents versus the BB.*
- *The A1035 9-Cr and 4-Cr showed a longer time to high macrocell rates vs. the HDG and TZD steels.*
- *Macrocell corrosion for A1035-9Cr+CNI equivalent to better than that of S32304 and the*

A1035-4CrNI is approximately order of magnitude less than of HDG and TZD.

- *Cracking data indicate the A1035-9Cr with CNI is the best performer along with S32304. The most severe cracking behavior is on the HDG specimens."*

"A service life and life-cycle case study was performed to compare the various corrosion resistant steels to BB and each other. The results for this case study show that:

- *All of the corrosion resistant steels, with the exception of S32304, reduce life cycle costs, even without taking account of indirect user costs.*
- *Only A1035-9Cr, A1035-4Cr with CNI, and S32304 met 100 years of service before major repairs would be needed.*
- *Significant cost savings are possible when the designer can utilize the higher strength grades available for A1035."*

3. **Exposure Testing of Chloride Exposed Reinforced Concrete and Potential Misrepresentation of Service Performance Paper No. 5460 NACE Corrosion 2015 Conference–W. Hartt, March 2015 (19 pages):**

   This paper's conclusions included: *"1. Failure to assure that the chloride ingress mechanism (sorption versus diffusion) for test specimens reflects what is anticipated for the structures intended to be represented. This is particularly true when comparing different corrosion resistant reinforcements (CRR). Misleading indications of service performance and of relative performance of CRR can result. 2. Leakage of chlorides from top surface mounted ponding baths onto reinforcements where these penetrate the concrete can result in active potentials and macrocell currents that indicate corrosion. However, embedded steel beneath ponding baths may be un-corroded. 3. Moisture accumulation at reinforcement-concrete interfaces where the former penetrates the latter can result in situations similar to that in (2). 4. Design of concrete exposures such that time to achieve a steady-state mean surface chlorides concentration is not short compared to time- to-corrosion initiation can lead to incorrect conclusions regarding relative performance of different reinforcement types. 5. Failure to assure that the mean surface chloride concentration during testing of concrete slabs is representative of what occurs in the service application at issue can lead to underestimation of actual performance in service of intermediately alloyed CRR such as A1035 and UNS-S41003."*

4. **Increasing Bridge Deck Service Life: Volume I Technical Evaluation - FHWA/IN/JTRP-2014/16 – Purdue Univ. – R. Frosch, S. Labi, C. Sim - December 2014 (289 pages):**

   This report indicates results of concrete: bond lap splice, slab cracking behavior; and corrosion resistance under uncracked and cracked conditions tests using four types of stainless steel, MMFX (ASTM A1035), hot-dip galvanized, and Zbar (dual-coated) reinforcing bars.

   Following test results were reported:

   - *Stainless-steel, MMFX II microcomposite [ASTM A1035], hot-dip galvanized, and Zbar (dual-coated) reinforcing bars have bond strengths comparable to black bars. Coated bars other than galvanized and dual-coated have reduced bond strengths. Epoxy coated bars had on average 11% less bond strength than black while un-plated zinc-clad and tin-plated zinc-clad bar had on average 18% and 26% less bond strength than black bars, respectively.*

- *Slabs with MMFX II [ASTM A1035] bars at 6 in. and 12 in. bar spacing produced crack widths comparable to slabs with black bars, specimens with MMFX bars at an 18 in. spacing resulted in the smallest crack widths compared to the other bars including black bars at every stress level.*
- *All four stainless steels also perform significantly better compared to the control black bar. MMFX II microcomposite [ASTM A1035] steel, however, demonstrates more corrosion than the stainless-steel reinforcement. This result is expected because the steel includes less chromium. In addition, the MMFX II [ASTM A1035] reinforcement also retains its mill scale. However, for MMFX II [ASTM A1035], it is evident that the initiation of corrosion is delayed as compared to the black bar.*

5. **Corrosion Sensitivity of Concrete Mix Designs FHWA/VCTIR 14-R19 - Virginia Center for Transportation Innovation and Research - S. Sharp, C. Ozyildirim, D. Mokarem June 2014 (32 pages):**

   This study compared the durability of concrete mixtures containing supplementary cementitious materials (SCMs) by evaluating the permeability, absorption, and corrosion resistance of seven mix designs and two types of reinforcement. This study also demonstrated that the corrosion-resistant reinforcement plays the most vital role in minimizing corrosion. SCMs provide durable concretes and in combination with the corrosion-resistant reinforcement ensure reinforced concrete structures with longer service lives. ASTM A615 and ASTM A1035 were used as a baseline to enable comparisons with other corrosion studies.

6. **Acceptance Procedures for New and Quality Control Procedures for Existing Types of Corrosion- Resistant Reinforcing Steel FHWA/VCTIR 11-R21- 7. S. Sharp, L. Lundy, H. Nair et al. - June 2011 (80 pages):**

   This study was made to provide VDOT's Materials Division with a method/specification for evaluating CRR bars. Bar types and tests are indicated in the following table, which included "MMFX 2" AASHTO M 334 "MP 18"/ASTM A1035 Type CS bars.

Table 3. Tests Performed on Various Types of Rebar

Rebar Type	X-Ray Fluorescence	Magnetic Sorting	Hardness Test	Uniaxial Tensile Test	Elongation	Reduction in Cross - Sectional Area	Bar Finish	Mill ID Markings	Relative Rib Area	Concrete / Steel Bond Strength	Corrosion Resistance
2101 LDX	X	X									X
2205	X	X		X	X			X	X	X	X
2304	X	X			X		X				X
304		X									
316L Clad (NX)	X			X	X	X	X	X	X	X	X
316LN	X	X		X		X			X	X	X
ASTM A615 Grade 60				X	X	X			X	X	
ASTM A615 Grade 75	X	X		X			X		X	X	X
ASTM A615 Grade 75 w/Zn	X										X
Duracorr	X		X		X	X	X	X			X
EnduraMet 32	X	X		X	X	X		X	X	X	X
MMFX 2	X	X	X	X	X	X			X	X	X
ECR	X						X				X
Zbar	X			X			X		X	X	X

7. **A Critical Review of Corrosion Performance for Epoxy-Coated and Select Corrosion Resistant Reinforcements in Concrete Exposed to Chlorides – W. Hartt, Hartt and Associates, Inc.-April 2011 (8 pages):**

   This paper reviews the corrosion performance of Corrosion Resistant Reinforcing (CRR) materials, including epoxy coated reinforcement (ECR), using numerous studies from 1987 thru 2010. It notes: *"A finding from a number of the above referenced studies was that ECR experiences corrosion at coating defects along with cathodic disbondment of the adjacent coating. Also noted was wet adhesion loss and under film corrosion*." The report states: "*A fundamental difficulty in projecting future ECR performance is that, first, long-term deterioration processes are, for the most part, not necessarily reflected by results from short-term exposures and, second, it is not possible to perform first-principles based modeling of the coating disbondment, embrittlement, and under film corrosion processes. Such modeling can be performed for uncoated bars, …*" The paper indicates that long term studies of uncoated bars including MMFX 2 ChromX® 9100 (ASTM A1035- Type CS) and UNS-S41003 (3Cr12) indicate these uncoated bars provide mean critical chloride threshold (C_T) values at 4 times that of black steel. In conclusion, the paper states: *"In summary, long-term performance of ECR in chloride contaminated concrete is uncertain; and no first-principles based analytical tools are available for projecting this. On the other hand, sufficient data are available, along with a first-principles based methodology, for projecting long-term performance of uncoated BB and CRR such as 3Cr12 and MMFX2™. Results from the latter analysis indicate that in the case of these CRR a low maintenance service life of 75 and even 100 years can be expected.*"

8. **Corrosion Initiation Projection for Reinforced Concrete Exposed to Chlorides – Part II: Corrosion Resistant Bars – NACE Corrosion 11–W. Hartt-March 2011 (11 pages):**

   This paper presents the results of a study utilizing an equation from the literature to analyze the growth of reinforcement corrosion initiation (Ti) in concrete exposed to chlorides. The study's analytical method was comparatively applied to black bar (BB) and to corrosion resistance reinforcement (CRR) steels (ASTM A1035 Type CS and UNS-S41003 - 3Cr12 stainless steel), varying 1) the surface Cl^- concentration (C_S), 2) the effective diffusion coefficient (D) in the equation. The analysis used previously published CRR steel's critical Cl^- concentration threshold values (C_T), at four (4) times that of BB. The study's findings included:

   - Analyses projected the T_i for initial occurrence of CRR corrosion to be almost ten (10) times greater than for BB
   - An analysis comparing the T_i trend of BB in high performance concrete (HPC) with the T_i trend of CRR in Portland Cement Concrete (PCC), indicated that almost 50 percent less of the CRR/PCC system initiated active corrosion than the BB/HPC system after 100 years. If the analysis had considered the greater tendency of HPC compared to PCC to exhibit shrinkage cracking, then the difference between the two trends would have been greater.

9. **Critical Chloride Corrosion Threshold of Galvanized Reinforcing Bars ACI Material Journal -Technical Paper M106-M22–D. Darwin, J. Browning et. al. -Mar-Apr 2010 (8 pages):**

   This technical paper based on research as part of the International Lead Zinc Research Organization, Inc. under Project Code ZC-24-2 (See also Ref. 5.A.23) indicated the following: "*The average critical corrosion threshold for galvanized reinforcement, 2.57 lb/yd^3 (1.5 kg/m^3), is higher than the observed critical corrosion threshold of conventional (A615) steel, 1.63 lb/yd^3 (0.97 kg/m^3), and lower than the value for*

A1035 steel, 6.34 lb/yd^3 (3.76 kg/m^3), and the lower-bound value for 316LN stainless steel, 19.14 lb/yd3 (11.36 kg/m^3). " "Based on chloride surveys of cracked bridge decks, galvanized steel can be expected to increase the average time to corrosion initiation at crack locations from 2.3 years for conventional steel to 4.8 years for bars with 3 in. (76 mm) of concrete cover. Corrosion initiation would be expected to occur at an average age of 15 years for ASTM A1035 reinforcement and not to occur for bars consisting of 316LN stainless steel." (Copy of this paper may be obtained from the American Concrete Institute (ACI) Farmington Hills, MI.)

10. **The Use of Corrosion Resistant Reinforcement as a Sustainable Technology for Bridge Deck Construction TRB Annual Meeting 2010 Paper #10-2214 - A. Moruza, S. Sharp–January 2010- (24 pages)**:

    "*As part of the Innovative Bridge Research and Construction Program (IBRCP), this study used the full-scale construction project of the Route 123 Bridge over the Occoquan River in Northern Virginia to identify differences in the installation practices and comprehensive placement costs of epoxy-coated reinforcing steel (ECR) and corrosion-resistant reinforcing steel (CRR), specifically an ASTM A1035 steel. Internal VDOT construction records provided construction costs specifically associated with one of the two reinforcement materials. … For this project, the cost advantage of ECR at the time of contract award was not preserved after inclusion of unanticipated construction costs directly related to ECR. Specifically, adding the cost of deck sealing operations to the bid cost of ECR produced an in-place cost estimate of $.804/lb compared to $.780/lb for CRR. Inclusion of the indirect costs of the sealing operations, however, more than quadrupled the unit cost of ECR over bid, predominantly because of road user costs to the public. … CRR was ultimately cost-competitive with ECR in this project when costs of common VDOT practices related to ECR were included, but CRR potentially possesses superior longevity benefits as a sustainable choice for deck reinforcement, especially since significant traffic growth is expected on this new structure."*

11. **Laboratory Study of Corrosion Performance of Different Reinforcing Steels for Use in Concrete Structures - National Research Council of Canada - Research Report IRC-RR-284 - J. Zhang, S. Qian, B. Baldock- September 2009 (55 pages):**

    This report presents the results of a two-year program comparing the corrosion performance of ASTM A 615 (carbon steel), ASTM A 1035 Type CS "ChromX® 9100" (referred to as "Cr steel" in the report); and stainless steels 316LN, 304LN and 2205 bars. The primary testing program was performed in electrochemical cells by using different electrochemical techniques (simulated concrete pore solutions), and concrete prisms using sand blasted bars. Comparing A615 to ASTM A1035 bars, the report states: "*In the simulated concrete pore solution (pH=12.6), it was found that the average chloride threshold of carbon steel was about 1.0% by weight; the average chloride threshold of Cr steel was about 5.0%." … "Pitting corrosion was observed to initiate on Cr steel at a range of chloride concentrations from 0.18% to 0.3%. Pitting corrosion was initiated on carbon steel, at a much lower chloride concentration around 0.06%."* The following observations were made concerning concrete prism testing program: "*In concrete containing 1.5% of chlorides, Cr steel remained in passive state before undergoing active corrosion at ten months of age… As the chloride concentration increased from 1.5% to 3.0%, Cr steel showed lower corrosion rate than carbon steel". "…the corrosion rate of Cr steel did not increase significantly as the chloride concentration was increased from 3.0% to 6.0%. …" The corrosion rate was within a range of low to moderate at these concentrations."* The report also made the following observation concerning concrete prism testing of A1035 bars with mill scale: "*The corrosion rate of as-received Cr steel (non-sandblasted) was found to be much higher than that of sandblasted Cr steel, and the difference became greater with increasing chloride concentrations. The difference was about half an order of magnitude at*

1.5% and 3.0% of chlorides, and increased to about one order of magnitude at 4.5% and 6.0% of chlorides."

12. **Field Comparison of the Installation and Cost of Placement of Epoxy-Coated and MMFX 2 Steel Deck Reinforcement: Establishing a Baseline for Future Deck Monitoring S. Sharp, A. Moruza - VTRC 09-R9– May 2009 (84 Pages):**

    This study identifies and compares differences in the installation practices and comprehensive placement costs of epoxy-coated reinforcing steel (ECR) and MMFX 2 ChromX® 9100 (ASTM A1035 Type CS/AASHTO M 334 "MP 18"), as part of the FHWA Innovative Bridge Research and Construction Program (IBRCP). The report was based on costs associated with Virginia DOT's construction of the Route 123 Bridge over the Occoquan River. Two separate bridge decks were constructed as part of the project: A. southbound deck using ECR, and the northbound deck using MMFX2, a corrosion-resistant reinforcing steel (CRR). Field surveys conducted after completion of construction resulted in crack sealing of certain spans of the ECR portion of the deck and modification for added bolster material above one of the northbound (MMFX 2) abutments. Final installation costs, including cracking sealing of certain ECR deck span sections and the additional work for the MMFX deck, indicated that that total direct in place unit costs for ECR were $0.90/lb and MMFX were $0.87/lb. The report indicates that indirect costs (i.e., VDOT inspection, special traffic control, and public travel delay) for required sealing of ECR deck cracking placed the total installed ECR unit cost between $2.34 and $2.90/lb. Labor records for the contract's ironworkers indicated that they placed: 329.9 lb/labor hour for ECR and 358.8 lb/labor hour for MMFX 2. The study notes: "*Average labor productivity estimates from this study suggested that the handling requirements of ECR led to additional supervisory costs and additional ironworker costs relative to those associated with uncoated CRR. Inspectors' records indicated that the subcontractor billed 15% more supervisor hours to place ECR in the southbound deck than to place MMFX 2 in the northbound deck, yet almost 16% less ECR than MMFX 2 was placed by weight …. The special handling requirements for ECR are a plausible explanation for the lower average labor productivity in the placement of ECR compared to that for MMFX 2…"* The report concludes by stating: *"ECR appears to have been far less cost-effective per unit than MMFX 2 when both anticipated and unanticipated costs of ECR in this study are estimated. MMFX 2 showed both labor productivity and comprehensive in-place cost advantages over ECR in this application."*

13. **Risk of Macro-Cell Corrosion Associated with Black Bar MMFX 2 (ASTM A1035) Combinations in Concrete - W. Hartt - Hartt and Associates, Inc.-May 2009 (10 pages):**

    This report was based on testing of concrete specimens to determine if adverse dissimilar metal effects occur when connecting MMFX 2 "ChromX® 9100" (ASTM A1035 Type CS) bars to black steel bars. The report makes the following statement: "… *there is no technical reason why black bar and MMFX2 reinforcements cannot be combined in concrete construction, including situations involving, first, field repairs and, second, new construction."*

14. **Corrosion Resistant Alloys for Reinforced Concrete FHWA HRT 09-020 – W. Hartt, R. Powers, P. Virmani et. al – May 2009 (150 pages):**

    This report documents the findings of a 6 year study of the corrosion resistance of various concrete reinforcing bars using four specimen types: simulated deck slabs (SDS), macrocell slabs (MS), 3 Bar tombstone columns (3BTC) and Field columns (FC) and three types of concrete mixtures: STD 1 (5 bag W/C 0.50), STD 2 (7 bag W/C 0.41) and STD 3 (7 bag W/C 0.50) Reinforcements included stainless steels: 316, 304, 2304, 2101, and 3Cr12 ; two types of 316 clad, AASHTO MP 13M/MP 13-04, and MMFX-2

"ChromX® 9100" (ASTM A1035 Type CS); and BB (ASTM A615), with BB used a comparator. The report indicates: " *The reinforcements, other than BB, were classified into two groups as either improved performance*" … (alloys with corrosion initiation during project) "*or high performance*" (alloys without corrosion initiation during project). *"Improved performers were 3Cr12, MMFX- 2, and 2101 …. These alloys ranked according to time for corrosion to initiate as BB < 2101 < 3Cr12 < MMFX- 2." "*Chloride threshold for corrosion initiation of 3Cr12 and MMFX-2 reinforced SDS specimens was about four times greater than for BB specimens and slightly less than four times greater in the case of 2101 specimens. For STD2 MS specimens, however, T_i for MMFX-2 and 2101 was from 3.4 to more than 5.7 times greater than for BB (limited data precluded this determination for 3Cr12)."

15. **Effect of Concrete Crack Width on Corrosion of Embedded Reinforcement W. Hartt - Hartt and Associates, Inc.- March 2009 (10 pages):**

    This commentary reviews existing literature pertaining to the effect of concrete crack width on reinforcement corrosion in various project environments with different exposure zones encountered in the Middle East. The literature indicates that crack width does not significantly influence long-term durability of reinforced concrete, for crack widths up to 1.6 mm (0.063 in.). The report indicates that the time to corrosion initiation is six times greater and the corrosion rate for MMFX 2 "ChromX® 9100" (ASTM 1035 Type CS) is six times less than that for black steel in cracked concrete.

16. **Effect of crack width on corrosion of reinforcing steel D. Darwin- February 2009 (2 pages):**

    This report states: "*Within the range of 0.1 to 0.6 mm, crack width does not affect the corrosion of reinforcing steel. Corrosion is, however, affected by concrete cover, water-cement ratio, and the orientation of the crack with respect to the reinforcing steel*." This discussion notes that the steel's corrosion rate is not affected when crack widths are under 0.6mm but are by their critical chloride threshold level. A 75mm concrete cover, the report indicates "*…provides protection against not only corrosion in the presence of cracks abut also against carbonation …*" and states "*For severe chloride exposure conditions, the ACI Building Code limits the water-cement ratio to a maximum of 0.40*."

17. **Periodic Overload Corrosion Fatigue of MMFX and Stainless Reinforcing Steels Journal of Materials in Civil Engineering, Vol. 21, No. 1 - S. DeJong, P. Heffernan, C. MacDougall - January 2009 (9 pages):**

    "*This study presents the periodic overload and corrosion-fatigue resistance of machined specimens made from two corrosion resistant reinforcing steels: MMFX Microcomposite [ASTM A1035/AASHTO MP18] and 316LN stainless steel. MMFX had reduced constant amplitude performance in the corrosive environment, whereas 316LN stainless steel showed no environmental reduction under constant amplitude loading (except at high loads). Corrosion fatigue reduced the periodic overload performance of both materials, although both materials retained their intrinsic fatigue limit (250 MPa stress range) in the corrosive environment, a drastic improvement over the periodic overload corrosion-fatigue performance of conventional reinforcing steel*."

18. **Concrete and Steel Type Influence on Probabilistic Corrosion Service Life ACI Materials Journal V. 106, No. 1 - G. Williamson, R. Weyers, et. al., Jan.-Feb. 2009 (7 pages):**

    This technical paper presents comparative service life predictions for Microcomposite (MMFX 2 "ChromX® 9100" /ASTM A1035 Type CS), stainless steel (SS), galvanized steel (GS) and carbon (black) steel reinforcing bars, utilizing low- permeability concrete (LPC with admixtures) and standard (without admixtures) concrete. Service lives were established using a computer model based on: a. time to corrosion initiation of 2% of the reinforcing steel; b. time from corrosion initiation to concrete cracking

and spalling of the concrete over 2% of the reinforcing steel; and c. time for corrosion propagation from 2% to 12%. ASTM A1035 steel was noted to provide > 200 years of service life when used in conjunction with LPC; and 2 to 3 times the service life of black steel depending on the surface chloride concentration levels of standard concrete. (Copy of this paper may be obtained from the American Concrete Institute (ACI) -, Farmington Hills, MI.)

19. **Evaluation of Corrosion Resistance of Steel Dowels Used for Concrete Pavements Journal of Materials in Civil Engineering- M. Mancio, C. Carlos, J. Zhang, J. Harvey, P. Monteiro; A. Ali– October 2008 (9 pages**):

    This study investigated the corrosion performance of several types of steel dowels cast in concrete beams using accelerated laboratory tests. This paper indicates: "*. that the microcomposite [ASTM A1035 Type CS] steel dowels exhibit much greater resistance to corrosion propagation than carbon steel dowels, but not as much as the stainless clad and stainless hollow bars*"." In addition, the study states: "*Visual inspections of the corroded dowels revealed heavy and mostly uniform corrosion along the carbon steel dowels, light corrosion in the microcomposite steel dowels, and no visible corrosion in the stainless steel clad and stainless steel hollow bars. For the epoxy coated dowels, the visual inspections generally revealed that visible corrosion was not widespread, but did occur at a few localized defective areas, generally at holidays and at the edges of the bar ends. No significant difference was observed on the performance of nonflexible and flexible epoxy-coated dowels*."

20. **Electrochemical and in-situ SERS study of passive film characteristics and corrosion performance of microcomposite steel in simulated concrete pore solutions University of California Berkeley (UCB) – M. Mancio, G. Kusinski, et. al. – March 2008 (104 pages).**

    This testing program provides the basis for AASHTO Standard Method of Test for *Comparative Qualitative Corrosion Characterization of Steel Bars Used for Concrete Reinforcement (Linear Polarization Resistance and Potentiodynamic Polarization Tests)*. The report states: *"After passivation, the current density for microcomposite steel [ASTM A1035 Type CS] was around 11 µA/cm^2 while that for carbon steel was about 140 µA/cm^2 (~13 times higher). If these values were used to estimate corrosion rates, one would get approximately 1627 µm/yr (1.63 mm/yr) for carbon steel and 128 µm/yr (0.128 mm/yr) for microcomposite steel [ASTM A1035]."*

21. **"Comparative Corrosion Testing and Analysis of MMFX 2 Rebars for Reinforced Concrete Applications" Wiss, Janney, Elstner Associates, Inc. - Final Report WJE No. 2003.0707.0 – F. Cui, P. Krauss, et. al.- January 2008 (57 pages):**

    This report is based on ASTM G109 and time-to-corrosion (a.k.a. Southern Exposure) tests, stating: "*MMFX 2 [ASTM A1035 Type CS] steel bars have higher chloride thresholds than A615 bars, but less than Type 304 stainless steel. The ASTM G-109 test program suggested that the chloride threshold of MMFX bars is about three times of that of black bars ... The removal of mill scale was found to have slightly increased the corrosion resistance of MMFX bars in the G-109 test. … Modeling analyses of a marine pile and a northern bridge deck exposed to deicers showed that the use of MMFX bars in lieu of black bars may extend the structure service life by about 1.8 times, assuming a chloride threshold for the MMFX bars of three times that of the A615 black bars. Slower corrosion rates for the MMFX bars during the propagation period could increase the service life further, to about twice that of A615 bars."*

22. **Corrosion of Reinforcing Bars in Concrete - R&D Serial No. 3013 Portland Cement Association - C. Hansson, A. Poursaee; S. Jaffer– 2007 (33 pages):**

    The primary focus of this report is chloride-induced corrosion of steel reinforcement: the factors affecting it and its influence on durability. This review describes the corrosion process, the lack of a

single chloride threshold concentration for initiation of corrosion and the relative contributions of micro-cell and macro-cell corrosion in sound concretes. The report indicates that a two-fold approach to corrosion resistant structures should include:

"The use of high performance concrete (HPC) to lower concrete's permeability and reduce the rate of ingress of chlorides or carbonation and, thereby, increase the effectiveness of the physical barrier.

The use of more resistant reinforcing bar materials to provide better chemical resistance. In those parts of structures exposed to very severe chloride environments, stainless steel is recommended. Despite the initial expense, it is a cost-effective solution in these circumstances when both direct and indirect costs (such as user costs) are taken into account. In the somewhat less severe chloride environments, corrosion resistant alloys such as MMFX [ASTM A1035 Type CS] or 2101LDX, which are more resistant to chlorides than black steel - but less corrosion resistant and much less costly than stainless steel - should be considered."

23. Critical Chloride Corrosion Threshold for Galvanized Reinforcing Bars SL Report 07-2 –Univ. of Kansas Center for Research– D. Darwin, J. Browning et. al.- Dec. 2007 (36 pages):

This report prepared for the International Lead Zinc Research Organization indicated the following: "*… test results show that galvanized reinforcement has an average critical chloride corrosion threshold of 2.57 lb/yd^3, which is greater than conventional steel (1.63 lb/yd^3) and lower than MMFX [ASTM A1035 Type CS] steel (6.34 lb/yd^3)." "Based on chloride surveys of cracked bridge decks in Kansas, galvanized steel can be expected to increase the average time to corrosion initiation at crack locations from 2.3 years for conventional steel to 4.8 years for bars with 3 in. of concrete cover. Corrosion initiation can be expected to occur at an average age of 14.8 years for MMFX [ASTM A1035] steel. All three systems will exhibit significantly longer times to corrosion initiation in uncracked concrete." …." the average times to corrosion initiation in uncracked regions on bridge decks would be 26, 41, and 100 years for conventional, galvanized, and MMFX reinforcement, respectively, demonstrating that uncracked concrete provides excellent protection against chloride penetration. These values closely match those used in life-cycle models in which chloride penetration is based on diffusion through uncracked concrete."*

24. Corrosion Resistant Alloy Steel (MMFX) Reinforcing Bar in Bridge Decks Michigan DOT Report R- 1499– S. Kahl– September 2007 (36 pages):

This report compiles the findings of Michigan DOT corrosion research and structural analysis (See Appendix B "MMFX Reinforced Bridge Deck LRFD Design Example") of bridges using MMFX "ChromX® 9100" (ASTM A1035 Type CS) reinforcing bars. The report states: "...*MMFX steel does exhibit corrosion resistance, higher yield strength, and a lower life cycle cost than epoxy coated reinforcement. Due to the high yield strength, MMFX use in bridge deck construction should be limited to structures that are designed in accordance with AASHTO LRFD code, and for 75 ksi steel reinforcement design yield strength…*" This statement was made after making an economic analysis comparing a MMFX (ASTM A1035 Gr 75) AASHTO LRFD design to an epoxy-coated rebar (ECR) design using Michigan's standard design (LFD).

25. Corrosion Resistant Alloys for Reinforced Concrete - FHWA-HRT-07-039 W. Hartt, R. Powers et. al.- July 2007 (135 pages):

This test program included MMFX-II™ "ChromX® 9100" (ASTM A1035 Type CS), solid stainless steels 3Cr12 (UNS-S41003), 2201LDX (ASTM A955-98), 2205 (UNS 31803), and two 316L (UNS S31603) alloys; and two 316 stainless steel clad black bar products, black bar (ASTM A615) reinforcement included for

comparison purposes. The report states: "*For black bar slabs, it was considered that active corrosion commenced once potential dropped to −280 mVSCE, at which point the average macro- cell current density was about 0.26 µA/cm^2. If it is assumed that this same current density denotes onset of active corrosion for the other reinforcement types as well, then the corresponding potentials are −390, −350, and −195 mVSCE for 3Cr12, MMFX-II™, and 2201, respectively. These potentials were achieved after 35 days (black bar), 64 to 140 days (3Cr12), 91 to 140 days (MMFX-II™), and 64 to 94 days (2201).*"

26. **Laboratory Evaluation of Corrosion Resistance of Steel Dowels in Concrete Pavement Final Report UCPRC-RR-2005-10 – FHWA No S/CA/RI-2006/27 – M. Mancio, J. Harvey, et al.- January 2007 (127 pages)**:

    This pavement dowel corrosion report indicates that Microcomposite (MMFX 2 "ChromX® 9100") pavement dowel bar had approximately 35 times the polarization resistance of carbon steel dowels. The report makes the following recommendations: *"It is recommended that the use of stainless steel-clad, hollow stainless steel, or microcomposite [MMFX 2] steel dowels be considered for locations with high risk of high chloride exposure (such as on mountain passes and marine environments)* ..." Furthermore, the report states**: "***Epoxy dowels present some risk of corrosion, primarily localized at holidays and the ends of the bars." The report notes that: "Bar ends should be coated with epoxy and care must be taken with epoxy- coated dowels during shipping, storage, and installation. Corrosion will be exacerbated if the bar ends are not coated (observed on various Caltrans construction sites) or if the coated ends are damaged during storage, transport, and installation***."**

27. **"Comparative Performance of MMFX Microcomposite Reinforcing Steel and Other Types of Steel with Respect to Corrosion Resistance and Service Life Prediction in Reinforced Concrete Structures" AMEC Earth & Environmental- D. Morgan-- June 2006 (48 pages):**

    This report makes the following conclusion after evaluating 14 studies and reports concerning the corrosion resistance properties of MMFX "ChromX® 9100") (Microcomposite) Steel reinforcement and other products: *"Studies evaluated in this report indicate that MMFX corrosion resistance is similar to or better than that of certain stainless steels such as 2101 and 3Cr12. … stainless steels (i.e., SS304 and SS316 series) appear to be more effective than MMFX for use in bridge and other structures exposed to chlorides, the lack of availability in North America of many the types of stainless steel evaluated, and their high costs compared to MMFX, make them less attractive from a life- cycle cost perspective for most applications."*

28. **Summary Report on the Performance of Epoxy-Coated Reinforcing Steel in Virginia VTRC Report 06- R29- R. Weyers, M. Sprinkel, M. Brown- June 2006 (37 pages)**:

    This report based on 14 years of research by VTRC of corrosion resistant reinforcing steel alternates states: *"because ECR cannot provide adequate corrosion protection for structures designed for a 100-year+ service life as currently recommended by FHWA, the report recommends that the Virginia Department of Transportation amend its specifications regarding the use of ECR to require the use of corrosion-resistant metallic reinforcing bars such as MMFX 2 ["ChromX® 9100"]," Based on the times to cracking, MMFX2 reinforcement is worth 5 times more than ECR."* This study reiterated some of the findings of Hansson, Haas et al concerning epoxy-coated rebar (ECR)

29. **Evaluation of corrosion resistance of different steel reinforcement types Final Report - Iowa State University Bridge Center - CTRE Project 02-103 - May 2006 (75 pages):** Voltage and current results from field monitoring of an instrumented bridge constructed half with MMFX steel and half with ECR indicated:

    1. The MMFX half remained within the normal range at less than 100mV; appeared to have no ongoing corrosion activity. 2. In contrast, ECR had readings that were two times greater than

MMFX, close to 200 mV. This led to the report's speculation that defects in the coatings had occurred during construction.

30. **ASM Handbook, Volume 13C, Corrosion: Environments and Industries Corrosion in Bridges and Highways –ASM International – J. Tinnea, W. Hartt, F. Pianca; et. al.- 2006 (39 pages):**

    This handbook chapter discusses the various aspects of corrosion associated with bridge structural elements in corrosive environments and describes alternative corrosion-resistant reinforcement systems. ASTM A1035 Type CS (MMFX 2 Steel "ChromX® 9100") is noted as having the same Cl^-/OH^- ratio of 4.9, as 316 stainless steel cladded reinforcement, as a measure of its corrosion resistance. (Copy of this reference is available from the American Society for Metals - ASM).

31. **Evaluation of MMFX Steel for NCDOT Concrete Bridges FHWA/NC/2006-31, NCDOT Report 2004- 27– S. Rekala, P. Zia et. al.– December 2005 (131 pages):**

    This publication states the following conclusions based on testing of full-scale bridge deck sections and corrosion tests at North Carolina State University: *"1. Substituting MMFX steel directly for Grade 60 steel in a design … is an overly-conservative approach. 2. MMFX steel [ASTM A1035 Type CS] can be used as the main flexural reinforcement for cast-in- place concrete bridge decks at a reinforcement ratio corresponding to 33% less than that required for Grade 60 steel. Therefore, a design of reinforced concrete bridge decks using MMFX steel may utilize an equivalent yield stress of 90 ksi for the MMFX steel bars. 3. Design of concrete bridge decks utilizing the high tensile strength characteristics of the MMFX steel should satisfy all minimum reinforcement ratios required by the AASHTO LRFD Bridge Design Specifications as well as the serviceability requirements of the specifications. 4. MMFX steel [ASTM A1035] has a much lower corrosion rate compared to conventional Grade 60 steel. Therefore, the use of MMFX steel could increase the service life of concrete bridges and lower repair costs."*

32. **Corrosion Resistance of Duplex Stainless Steels and MMFX Microcomposite Steel for Reinforced Concrete Bridge Decks University of Kansas Center for Research, Inc.- SM Report No.80- J. Ji, D. Darwin; et. al- December 2005 (507 pages):**

    This report indicated that MMFX 2 "ChromX® 9100" (ASTM A1035 Type CS) bars had ½ the corrosion rate of conventional black bar and approximately 3 to 4 times black bars critical chloride threshold value. 2101 stainless steel (SS) was reported to have 1.35 times the corrosion rate of black bar in an un-pickled surface condition, with a slightly higher corrosion rate as ASTM A1035 with a pickled surface condition.

33. **New Technologies Proven in Precast Concrete Modular Floating Pier for U.S. Navy– PCI Journal – M. LaNier, P. Springston; et. al.- Jul-Aug 2005 (26 pages):**

    This article notes that the Navy's Modular Hybrid Pier (MHP) project received Precast/Pre-stressed Concrete Institute's (PCI's) Henry N. Edwards award and updates - Preston Springston's ASCE paper. Project review procedures are discussed demonstrating why MMFX ASTM (A1035 Type CS) rebar was included in one of the project's two Navy MHP modules. The article noted that use of MMFX saved approximately $2.8 million over the original proposed design, while providing a 75-yr service life. MMFX's corrosion resistance performance was analyzed by the STADIUM computer model.

34. **The Long Term Performance of Three Ontario Bridges Constructed with Galvanized Reinforcement Ontario Ministry of Transportation– F. Pianca; H. Schell– June 2005 (29 pages)**:

    This report makes the following conclusions: *"Corrosion of galvanized reinforcing bars was initiated soon after the chloride corrosion threshold (for black steel) was reached…"* [and] *"…caused significant damage*

to the concrete, in the form of delamination and cracking." "…they [galvanized bars] *do not provide effective long-term protection from corrosion."*

35. **Surface Condition Effects on Critical Chloride Threshold of Steel Reinforcement ACI Materials Journal 102-M12 – D. Trejo; R. Pillai– Mar–Apr 2005 (6 pages):** This publication compared the critical chloride threshold level (CCTL) values of various uncoated steel reinforcement types using their as- received (with mill scale) and polished surface conditions. MMFX 2 "ChromX® 9100" (ASTM A1035 Type CS) was determined to have approximately 9 times the CCTL value of A615 in the as-received condition and approximately 12 times the CCTL of A615 in the polished condition. These values were determined using the accelerated chloride threshold (ACT) test procedure developed at Texas A&M University. (Copy of this paper may be obtained from the American Concrete Institute (ACI), Farmington Hills, MI)

36. **Comparing the Chloride Resistances of Reinforcing Bars - Concrete International - G. Clemeña, P. Virmani– - November 2004 (11 pages):** This article evaluates new, economical metallic reinforcement for its ability to withstand high salt concentration. The comprehensive study, on which the article is based shows that the chloride threshold of MMFX "ChromX® 9100" (ASTM A1035 Type CS) Microcomposite bars is about 5 to 6 times better than A615 steels and approximately 2 times chloride threshold of stainless steel 2101 LDX bars. (Copy of this paper may be obtained from the American Concrete Institute (ACI), Farmington Hills, MI)

37. **Evaluation of Mechanical and Corrosion Properties of MMFX Reinforcing Steel for Concrete - University of Kansas Center for Research, Inc. Report No. FHWA-KS-02-8 - SM Report No. 70 – L. Gong, D. Darwin; et. al. - February 2004 (132 Pages):**

    This report based on Southern Exposure corrosion testing, indicated that MMFX 2 "ChromX® 9100" (ASTM A1035 Type CS) has a corrosion rate of approximately 30% less, when compared to black (ASTM A615) steel bars.

38. **Investigation of the Resistance of Several New Metallic Reinforcing Bar to Chloride-Induced Corrosion in Concrete -Virginia Transportation Research Council (VTRC) Report 04-R7 G. Clemeña– December 2003 (27 pages):**

    This report describes testing, analysis and recommendations concerning various metallic bars, including MMFX 2 "ChromX® 9100" (ASTM A1035 Type CS), that were found to be more durable and corrosion resistant than epoxy-coated rebar, with the program's investigation serving as the basis for an ACI Materials Journal paper co-authored by Dr. Gerardo Clemeña of the VTRC and Dr. Y. Paul Virmani of the FHWA. In conclusion, the report recommends MMFX 2 rebar for use by Virginia DOT in corrosive environments.

39. Appraisal Report High Corrosion Resistance MMFX Microcomposite Reinforcing Steels CIAS (Concrete Innovations Appraisal Service) Report 03-2– P. Zia, T. Bremner, M. Malhotra, M. Schupack, P. Tourney– May 2003 (50 pages):

    This document reports on the findings of the CIAS's MMFX corrosion panel concluding that MMFX 2's "ChromX® 9100" corrosion resistance provides a longer service life and is more cost effective than A615 reinforcement.

40. **Corrosion Protection Strategies for Ministry Bridges - Final Report Amended - University of Waterloo -C. Hansson, R. Haas, R. Green, R. C. Evers, O. Gepraegs, and R. Al Assar- July 2000 (210 pages):**

This report states: "*Major concerns exist with the inability of maintaining a flaw-free coating on ECR during handling, placement, and compaction of the concrete, and with disbondment of the coating ... In turn, concern exists that this provides easy access to chlorides and, thus, allows corrosion at flaws and along the bar under the dis-bonded coating. … There is additional concern regarding the difficulty of monitoring the condition of ECR and of repair/rehabilitation cycles over the 75 years." …. "The conclusion is that options involving ECR present no cost or performance advantages over Black Steel Reinforcement. …the further use of ECR is not recommended on the basis of both technical and life cycle cost analysis.*"

Structural Test Reports, Papers, and Analysis References

1. **Design, Installation, and Condition Assessment of a Concrete Bridge Deck Constructed With ASTM A1035 CS No. 4 Bars Final Report VTRC 17-R16 - A. Salomon; C. Moen- June 2017 – 21 pages:**

This report indicated: *Recently developed corrosion-resistant reinforcing structural design guidelines were used to design, construct, and assess a reinforced concrete bridge deck with high-strength ASTM A1035 CS steel bars. The bridge replacement is located along the North Scenic Highway over the Wolf Creek in Bland County, Virginia. The bridge deck design used the higher yield stress available from ASTM A1035 CS steel to replace No. 5 bars with No. 4 bars that saved 23% by weight of steel in the deck and reduced reinforcement bar congestion, especially near the traffic barrier-bridge deck splice.* This project's design yield strength was 75 ksi in the positive moment region and 83 ksi in the negative moment region

2. **Anchorage Strength of Reinforcing Bars with Standard Hooks - University of Kansas Center for Research, Inc. - SM Report No. 125 – A. Ajaam, D. Darwin, and M. O'Reilly - April 2017 (372 pages):**

This report that included testing of ChromX® 9100 bars indicated:

The following conclusions are based on the data and the analysis presented in the report:

1. *The provisions in ACI 318-14 for the development length for hooked bars overestimate the contribution of concrete compressive strength and bar size on the anchorage strength.*
2. *The incorporation of the modification factors based on concrete cover and confining reinforcement in the current Code provisions for development length overestimate the anchorage strength of hooked bars, particularly for large hooked bars and closely-spaced hooked bars.*
3. *The contribution of concrete compressive strength on the anchorage strength of hooked bars is best represented by the concrete compressive strength to the 0.295 power. Compressive strength to the 0.25 power works well for design.*
4. *The anchorage strength of hooked bars increases with an increase in the amount of confining reinforcement, even for confining reinforcement below the value required by ACI 318-14 to reduce development length by 20 percent.*
5. *Hooked bars with a center-to-center spacing below six bar diameters exhibit lower anchorage strengths than hooked bars with wider spacing. The reduction in anchorage strength of closely-spaced hooked bars is a function of the spacing between the hooked bars and amount of confining reinforcement.*
6. *The straight portion of hooked bars contributes to anchorage strength of hooked bars even at*

failure.

7. *For hooked bars with a bend angle of 90°, at peak load, confining reinforcement provided in form of hoops within the joint region generally exhibit the greatest strain at the hoop closest to the straight portion of the bar, with strains decreasing as the distance from the bar increases. For hooked bars with a bend angle of 180°, at peak load, the hoop adjacent to the tail extension of the hooked bars exhibits the greatest strain; the strains in hoops above and below the hoop with the highest strain decrease as the distance from the hoop with the highest strain increases.*
8. *The anchorage strength of staggered hooked bars can be represented by considering the minimum spacing between hooked bars.*
9. *Hooked bars anchored in beam-column joints with a ratio of beam effective depth to embedment length (d/eh) greater than 1.5 exhibit low anchorage strengths.*
10. *The amount of confining reinforcement provided above the joint region, within a range of 0.25 to 1.29 times the area of the hooked bars, does not affect the anchorage strength of the hooked bars within the joint region.*
11. *The proposed provisions for ACI 318 provide conservative criteria for the development length of reinforcing bars anchored with standard hooks for reinforcing steel with yield strengths up to 120,000 psi and concrete with compressive strengths up to 16,000 psi.*

3. **Anchorage Strength of Standard Hooked Bars in Simulated Exterior Beam Column Joints - University of Kansas Center for Research, Inc. - SM Report No. 124 – S. Yasso, D. Darwin, M. O'Reilly- April 2017 (330 pages):**

This report that included testing of ChromX® 9100 bars indicated:

Based on the current study, the following conclusions are drawn:

1. *Front failure was the dominant failure mode for specimens containing more than two hooked bars.*
2. *The anchorage strength of hooked bars in joints with three or four bars decreased for values of center- to-center spacing below seven bar diameters. The addition of confining reinforcement mitigated but did not eliminate this effect.*
3. *The modification to the descriptive equation by Sperry et al. (2015b, 2017b) to calculate the anchorage strength of two widely-spaced hooked bars to account for the effect of low spacing between hooked bars provides a reasonable representation of the anchorage strength of closely-spaced hooked bars.*
4. *As the force per bar decreased as the number of bars within a given width increased, the total anchorage force for the hooked bars in the simulated beam-column joints remained constant or increased moderately as the number of hooked bars increased.*
5. *Placing hooked bars outside the column core results in a significantly lower anchorage strength than placing hooked bars inside the column core. In this study, the reduction ranged from 4 to 34%, producing an average anchorage strength equal to about 84% of the average strength of hooked bars placed inside the column core.*
6. For hooked bars are placed outside the column core, the dominant failure mode was front failure for No. 5 (No. 16) bars and side failure for No. 8 and No. 11 (No. 25 and No. 36) hooked bars.

7. Hooked bars anchored halfway through the column depth exhibit reductions in anchorage strength compared to those anchored at the far side of the column, with front failure as the dominant mode of failure for all specimens.
8. Hooked bars extended to the far side of the column in simulated beam-columns joints exhibit reduced strength where the ratio of effective depth to the embedment length is greater than 1.5 compared to specimens where the ratio of effective depth to the embedment length less than 1.5.
9. The anchorage strength of hooked bars with a 90 bend angle is not affected by tail kickout at failure or hook tail covers as low as 0.75 in. (19 mm). The likelihood of tail kickout increases with increasing bar size and for hooks with tail cover less than 2 in. (50 mm) and no confining reinforcement.
10. The proposed descriptive equations for anchorage force and design expressions for development length that include the spacing modification factor account for the spacing effect between hooked bars.
11. A development length modification factor of 1.25 accounts for lower anchorage strength resulting from placing hooked bars outside the column core or not extending hooked bars to the back of the column.
12. Hooked bars not in a beam-column joint with side cover more than 7db behave similarly to those inside the column core of a beam-column joint.
13. The proposed design provisions show a better correlation with the experimental results and less scatter than those in ACI 318-14.

4. **Plasticity Spread in Columns Reinforced with High Strength Steel 16th World Conference on Earthquake, 16WCEE 2017 Santiago Chile, - Paper N° 234 - D. Sokoli, A. Limantono, M. Ghannoum - Jan. 2017 (11 pages):**

   This paper indicated: *Test results therefore indicate that higher grade reinforcing bars, up to Grade 100 (100 ksi specified yield strength (690 MPa)) may be suitable for use in both longitudinal and transverse reinforcement in regions of high seismicity.*

   A limit in the form of shear stresses or member minimum length is advised for higher strength bars to avoid bond failures. Accounting for the loss of bond strength within plastic hinge regions is also advised for all bar grades. Higher strain demands were observed in higher strength longitudinal bars. This trend was attributed in part to differences in the tensile-to-yield strength (T/Y) ratios of various bars used in the experimental program. T/Y ratio of the bars used in this study dropped as the bar strength increased. Lower T/Y ratios reduce the ability of bars to spread their inelastic strains away from flexural crack locations, which results in amplified peak strain demands. The higher strain demands on higher-strength bars in turn raised concerns about their low-cycle fatigue behavior and possible premature fractures in application with high strain-cycle demands.

5. **MMFX Steel Alternative to Post-Tensioning for Pier Cap –eConstruct USA -A. Girgis, A. Sevenker, M. Tadros- July 2015 (10 pages):**

   This report indicated: "*The results of the study given below demonstrate that use of ASTM A1035 steel reinforcing bars supplied by MMFX result in several advantages including simplified construction steps, reduced pier cap weight and concrete quantities and reduced reinforcement cost."*

   "The alternative design resulted in a much lighter and prismatic section which will significantly improve

the production and construction cost." (As noted in Table 1)

Table 1. Total material quantities of flexural steel and concrete

Item	Original Design		Alternative Design - MMFX Conforming to ASTM A1035	
	Weight (tons)	Volume (Yard^3)	Weight (tons)	Volume (Yard^3)
Concrete	123	61	58	29
	Weight (tons)	Grade (Ksi)	Weight (tons)	Grade (Ksi)
Flexure Reinforcement	2.8	270	2.7	100
Shear Reinforcement	5.6	60	3.5	75
Ledger Reinforcement			2.2	75

6. **Structural Design Guidelines for Concrete Bridge Decks Reinforced with Corrosion-Resistant Reinforcing Bars VCTIR 15-R10 -A. Salomon; C. Moen –October 2014 (49 pages)**:

   The findings of this experimental structural report indicate: "*This research program develops and validates structural design guidelines and details for concrete bridge decks with corrosion-resistant reinforcing (CRR) bars. A two-phase experimental program was conducted where a control test set consistent with a typical Virginia Department of Transportation bridge deck design using Grade 60 steel (ASTM A615, f_y = 60 ksi) and epoxy-coated reinforcing steel was compared to deck slab specimens where Grade 60 is replaced with CRR bars.*

   The experimental program was designed to evaluate how flexural performance at service and ultimate limit states are affected by a one-to-one replacement of Grade 60 with CRR bars, a reduction of concrete clear cover, and a reduction in rebar size. Structural analysis models were developed using Response 2000 in order to predict the CRR bridge deck moment-curvature and the moment-crack width relationships."

   Program conclusions include:

   - *For ASTM A1035 and UNS S32304 specimens, a decrease in bar size and clear cover (2.0 in instead 2.50 in) proved to have similar deformability ratios and crack widths that comply with current AASHTO requirements, with as much as 36% less steel. Bridge deck slabs employing high strength rebar without a defined yield plateau can still provide ductility consistent with AASHTO and ACI ductility limits at an ultimate limit state.*
   - *CRR bridge deck designs can be identified that meet current code serviceability and strength requirements, with the added benefit of corrosion resistance, by using programs like Response 2000.*

7. **Use of High-Strength Reinforcement in Earthquake-Resistant Concrete Structures -NIST GCR 14-917-30 - NEHRP Consultants -D. Kelly, A. Lepage, D. Mar, J. Restrepo, J. Sanders, A. Taylor – March 2014 (231 pages):**

   Applications for use of ASTM A1035 Grade 100 and 120 bars were included as a part of this; high strength seismic research and study program. The report concluded*: "Based on the research reviewed*

and the studies performed, it was observed that concrete members reinforced with reduced amounts of high- strength reinforcement (with yield strengths of 80 ksi or stronger) are capable of reaching comparable strength and deformation capacity to those achieved by members reinforced with conventional strength reinforcement. This observation applies to members having reinforcement details that provide concrete confinement and inhibit brittle failures related to shear, bond stress, and bar buckling.

Use of high-strength reinforcement can result in cost reductions and improved constructability. Benefits include reduced reinforcement quantity, reduced reinforcement congestion, improved placement of concrete, and accelerated reduced construction schedule. The cost benefits will not be fully achieved in the United States without the associated increase in production, however, until there is increased demand for high- strength reinforcement.

8. **Interim 5 Year Report Alternative Dowel Bar Material Study -WAY-30-11.5 -Ohio DOT – March 2013 (11 pages):**

   This report concerning MMFX "ChromX® 9100" (ASTM A1035) and three other dowel bar types indicated: **"***After five years, the epoxy coated steel dowels, the MMFX dowels, and the Lifejacket [zinc bonded] dowels have LTE [load transfer efficiency] greater than the 70% criteria typically used*" and that the FRP bars had LTEs that varied between 55 and 23%. Visual observation of the bars after taking joint core samples indicated: "*The MMFX bar was also in very good condition with slight pitting on the top of the bar in the area of the joint.*" It also noted under film corrosion occurred on some of the epoxy coated dowel bars, and that some of zinc bonded dowels were oxidized and slightly abraded.

9. **Design Guide For Use Of ASTM A1035 High-Strength Reinforcement In Concrete Bridge Elements In AASHTO Seismic Zone 2 - S. K. Ghosh - S. K. Ghosh Associates Inc.– July 2012 (20 pages):** This document is a supplement to **Design Guide for Use of ASTM A1035 High-Strength Reinforcement in Concrete Bridge Elements with Consideration of Seismic Performance – H. Russell, S. Ghosh, M. Saiidi- August 2011 (27 pages),** as AASHTO Seismic Zone 2 was not a part of the original design guide.

   This paper also analyzes the revisions voted to be included into the *AASHTO LRFD Design Specifications,* as result of the approval of AASHTO Committee T-10 "Concrete" Agenda Item (WAI 163) by AASHTO Subcommittee on Bridges and Structures (SCOBS) at their July 2012 meeting.

   The following table summarizes the report's conclusions concerning the maximum yield strengths of reinforcement that may be used in the design of the different structural elements of bridges in AASHTO Seismic Zone 2.

Maximum Yield Strengths of Reinforcement for Use in Design in Seismic Zone 2

Yield Strength, ksi	Foundations			Columns/Walls		Decks	Beams/Girders		
	Abutments	Piles	Pile Caps	Vertical	Confinement	Top and Bottom	Tension	Compression	Shear
100	X	X	X	X (2)	X	X	X	X	X
75				X (2)					
60	X (3)	X (3)	X (3)	X (2)	X (3)				X (1)

(1) Yield strength limited to of 60 ksi for shear-friction calculations.
(2) Required shear strength must be calculated per Articles 8.3.2 and 8.6.1 of the *AASHTO Guide Specifications for LRFD Bridge Design* and minimum shear reinforcement must be provided per Article 8.6.5.
(3) Yield strength of transverse reinforcement limited to 60 ksi for shear strength computations.

10. **High-Performance Steel Bars and Fibers as Concrete Reinforcement for Seismic-Resistant Frames Hindawi Publishing Corporation -Advances in Civil Engineering -A. Lepage, H. Tavallali, S. Pujol, J. Rautenberg- February 2012 (13 pages)**:

This paper presents the results of nonlinear cyclic response testing of concrete frame members with drift reversals up to 5%. The test members were reinforced with advanced high-strength steel (AHSS). Testing was conducted on concrete members longitudinally reinforced with steel bars 60 ksi (410 MPa), 97 ksi (670 MPa) and 120 ksi (830 MPa) along with a volume fraction of hooked steel fibers ranging between 0 and 1.5%.

The paper states: "The test data indicate that replacing conventional Grade-410 longitudinal reinforcement with reduced amounts of Grade-670 or Grade-830 steel bars did not cause a decrease in usable deformation capacity nor a decrease in flexural strength. The evidence presented shows that the use of advanced high- strength steel as longitudinal reinforcement in frame members is a viable option for earthquake-resistant construction.

a. *Replacing conventional Grade-410 longitudinal reinforcement with reduced amounts of AHSS reinforcement maintained flexural strength and did not decrease the usable member deformation capacity. The tested beams tolerated drift ratios in excess of 10% without failure while the column specimens tolerated drift ratios of 5% before failure. Column failures in RC specimens were due to buckling of the longitudinal reinforcement while failures in HPFRC specimens were due to fracture of the longitudinal reinforcement.*

b. *Increasing the spacing of Grade-410 transverse reinforcement from d/4 in RC specimens to d/2 in HPFRC specimens, did not reduce the member deformation capacity.*

c. *Reducing the amount of longitudinal reinforcement while increasing the yield strength of the reinforcement decreased the post cracking stiffness and increased the yield deformation of the member, leading to a reduction of the area inside the load deformation hysteresis loops. Reductions in the amount of longitudinal reinforcement achieved by reducing bar diameter may lead to increased vulnerability to bar buckling.*

d. *Nonlinear seismic analyses of SDOF systems with identical strength indicated that the mean ratio of calculated maximum displacements for systems representing RC with AHSS reinforcement to those calculated for RC with conventional Grade-410 reinforcement were about 1.1 for Grade-670 systems and 1.3 for Grade-830 systems.*

e. *These observations suggest that AHSS reinforcement is a viable option for frame members in earthquake-resistant construction. Additional studies are needed to investigate the nonlinear seismic response of multistory concrete frames reinforced with AHSS bars."*

11. **Design Guide for Use of ASTM A1035 High-Strength Reinforcement in Concrete Bridge Elements with Consideration of Seismic Performance H. Russell, S. K. Ghosh, M. Saiidi- August 2011– (25 pages)–**

This study evaluates the maximum strengths of reinforcement that may be used in the design of the different structural elements of bridges in Seismic Zones 1, 3 and 4. The report's conclusions are summarized the Table 1 (below), based on the information presented in this report, which differentiates Seismic Zone 1 conclusions from Seismic Zones 3 and 4. It is noted that the application of high-strength reinforcing steel in bridges Seismic Zone 2 was beyond the scope of this study.

The report states: "*In view of the fact that (1) bridge decks, girders, and bent cap beam**s** are capacity-protected, (2) satisfactory performance in field studies has been documented, and (3) research findings that the use of MMFX [ASTM A1035 Type CS Gr 100] bars in close proximity with black steel bars in*

chloride- contaminated environments does not lead to enhanced corrosion of the reinforcing bars, there should be no reservation about permitting MMFX reinforcing bars in bridge decks, girders, and bent cap beams in Seismic Zones 3 and 4, provided the guidelines in Part 1 of this report are followed.

Pending further testing, MMFX steel should not be used as longitudinal reinforcement in bridge columns in Seismic Zones 3 or 4. The use of MMFX steel as transverse reinforcement in such members should be permitted, provided the transverse reinforcement yield strength is restricted to no more than 60 ksi for the purposes of computing shear strength. The full yield strength of the transverse reinforcement may be utilized for purposes of confinement of the concrete.

The above recommendation should also apply to pier walls, back walls, and wing walls, which are preferable locations for inelastic behavior in most bridges.

The welding of ASTM A1035 reinforcement should be prohibited in plastic hinge regions of columns and other structural members that are not capacity-protected in bridges located in AASHTO Seismic Zones 3 and 4, until approved procedures for butt-welding of hoops become available.

In general, MMFX reinforcing bars should be permitted to be used in any foundation element such as a footing or a Type II pile shaft in Seismic Zones 3 and 4 that is capacity protected, provided the guidelines in Part 1 of this report are followed.

When MMFX reinforcing bars are used as transverse reinforcement in pile shafts, the transverse reinforcement yield strength should be restricted to no more than 60 ksi for the purposes of computing shear strength. The full yield strength of the transverse reinforcement may be utilized for purposes of confinement of the concrete."

Table 1 Maximum Tensile Strengths of Reinforcement for Use in Design

Yield Strength ksi	Foundations			Columns/Walls		Decks	Beams/Girders		
	Abutments	Piles	Pile Caps	Vertical	Confine-ment	Top and Bottom	Tension	Compres-sion	Shear
Non-Seismic (Zone 1)									
100	X	X	X	X	X	X	X	X	X
75									
60									X (1)
Seismic (Zones 3 and 4)									
100	X	X	X	N (2)	X	X	X	X	X
75				N (2)					
60	X (3)	X (3)	X (3)	N (2)	X (3)				X (1)

(1) Yield strength limited to of 60 ksi for shear-friction calculations.
(2) Not recommended.
(3) Yield strength of transverse reinforcement limited to 60 ksi for shear strength computations.

Note: Application of high-strength reinforcement in bridges located in Seismic Zone 2 was beyond the scope of this study.

12. <u>Cyclic Response of Concrete Columns Reinforced with High-Strength Steel</u> - 10th Canadian Conference on Earthquake Engineering - Paper No 996 - J. Rautenberg, S. Pujol et. al – July 2010 – (9 pages):

This paper compares the results of columns designed with ASTM A1035 120 ksi (830 MPa) longitudinal reinforcement to those of columns with ASTM 706 60 ksi (410 MPa) reinforcement and variable axial loads with all columns having the same confinement steel. It is reported that the flexural strength of these columns is controlled by the strength of the steel; and that two sections with different grades of

steel have similar moment capacities as long as the product of reinforcement ratio and yield stress is similar for both sections. Tests of columns under cyclic load reversals show that columns reinforced with ASTM A1035 120-ksi (830 MPa) steel reinforcement can reach drift ratios of 4%; and have smaller drift capacities than columns reinforced with (twice as much) A706 60-ksi steel.

13. **Towards Earthquake-Resistant Concrete Structures with Ultra High-Strength Steel Reinforcement 14th World Conference on Earthquake Engineering–A. Lepage, H. Tavallali, S. Pujol; J. Rautenberg- October 2008– (9 pages)**

    This paper describes a collaborative experimental program between Penn State University and Purdue University is underway to investigate the deformation capacity of reinforced concrete members reinforced with ultra-high-strength steel reinforcement well in excess of 80 ksi (550 MPa). Test beams and columns are subjected to combined shear, moment, and axial load, applied through controlled increasing displacement reversals. Main variables of the experiments include: yield strength of main longitudinal reinforcement, 60, 100, and 120 ksi [410, 690, and 830 MPa]; yield strength of transverse reinforcement, 60, 120, and 185 ksi [410, 830, and 1280 MPa]; spacing of transverse reinforcement, $d/2$ and $d/4$; volume fraction of steel fibers, 0 and 1.5%; ratio of compression-to-tension longitudinal reinforcement, $\rho'/\rho = 0.5$ and 1.0; and type of loading, monotonic and cyclical. Within the range of code-accepted limits on reinforcement ratios, shear stress levels, and length-to-depth ratios, it is expected that the deformation capacity of ultra-high-strength steel reinforced concrete members is going to be increased by (1) reductions in spacing of transverse reinforcement; (2) increases in the ratio of compression-to-tension longitudinal reinforcement, and/or (3) addition of engineered fibers.

14. **Behavior of Concrete Bridge Decks Reinforced with High-Performance Steel ACI Structural Journal, V. 105, No. 1– G. Lucier, S. Rizkalla, P. Zia, P. Hatem - Jan --Feb 2008 (9 pages):**

    This paper describes the behavior of concrete bridge decks reinforced with MMFX 2 "ChromX® 9100" (ASTM A1035) high- performance (HP) steel, characterizing its high strength in comparison with conventional ASTM A615-06 Grade 60 steel. The paper makes the following conclusions: *"1. The ultimate load-carrying capacity of the three bridge decks investigated in this study was on the order of 10 times the service load prescribed by the AASHTO Specifications; 2. Punching shear was the primary mode of failure for the three bridge decks. Due to continuity used in the test models, flexural-shear failure was observed as a secondary mode of failure; 3. The cracking load of the three tested bridge decks was more than twice the service load prescribed by the AASHTO Specifications. Hence, under service load level, the three bridge decks behaved as uncracked sections. Therefore, using 33% less HP [ASTM A1035] steel should not alter the serviceability behavior of concrete bridge decks; 4. The bridge deck reinforced with 33% less HP steel developed the same ultimate load-carrying capacity as that reinforced with Grade 60 steel. This performance is attributed to the higher strength of HP [ASTM A1035] steel compared with Grade 60 steel; and 5. Behavior of bonded HP [ASTM A1035] steel bent bars is similar to the behavior of straight bars. De-bonded bent bars exhibit similar behavior to straight bars, including the linear and the nonlinear behavior up to a strain of 1.5%. Its ultimate strength, however, is reduced by 6% and its ultimate strain by 70%." The papers also make the following design guideline recommendations: "1. Substituting HP [ASTM A1035] steel directly for conventional Grade 60 steel in a design, … is a conservative approach; 2. HP [ASTM A1035] steel can be used as the main flexural reinforcement for cast-in-place concrete bridge decks at a reinforcement ratio corresponding to 33% less than that required for Grade 60 steel. Therefore, design of reinforced concrete bridge decks using HP [ASTM A1035] steel can use a yield stress of 90 ksi (621 MPa) for the HP [ASTM A1035] steel bars; 3. Reduced reinforcement ratio of HP [ASTM A1035] steel shall satisfy all minimum reinforcement ratios prescribed by the AASHTO Specifications. In addition, the reduced reinforcement ratio of HP [ASTM*

A1035] steel must comply with the crack control requirement of the AASHTO Specifications; and 4. HP [ASTM A1035] steel bars can be bent up to 90 degrees without reducing their ultimate strength or strain provided that the bend is fully encased and bonded to concrete."

15. **Report on Structural Design and Detailing for High-Strength Concrete in Moderate to High Seismic Applications - ACI ITG -4·3R-07 – ACI Innovation Task Group 4 (S. Ghosh, Chairman) -2007 (Pages 62)**:

    This report presents a literature review on seismic design using high-strength concrete. Included as part of the report are a series of recommended modifications to "BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE" ACI 318-05. Subsequently, ACI 318-08 allowed an upper limit of 100 ksi (690 MPa) on the yield strength of high-strength confinement reinforcement for members resisting earthquake-induced forces in structures assigned to SDC (Seismic Design Category) D, E, or F. (Copy of this report may be obtained from American Concrete Institute (ACI), Farmington Hills, MI)

16. **"High-Strength Rebar Called Revolutionary" – McGraw Hill Construction - Engineering News Record- July 2007 (2 pages):**

    This magazine article describes the first use of MMFX 2 "ChromX® 9100" (ASTM A1035) rebar in a high seismic zone (Seattle, WA) high rise building for column and shear wall boundary element confinement." The article notes that use of ASTM A1035 at 100 ksi (690 MPa) design, reduced rebar requirements by 40% in comparison to conventional design practices. In addition, use of ASTM A1035 rebar simplified the project's beam to column connections, reducing the construction time to make these connections by up to 25%.

17. **Effects of Confinement and Gauging on the Performance of MMFX High Strength Reinforcing Bar Tension Lap Splices University of Texas (Austin)–K. Hoyt (Master's Thesis)–May 2007 (65 pages):**

    This program reports on testing of beam-splice specimens using ASTM A1035 Grade 100 No. 8 bar splices in a constant moment region, with varied amounts of No. 4 Grade 60 transverse reinforcement and spacing. It was found that: 1. ACI 408 equation provided a good estimate of failure stresses at high stress levels, but with predicted lower strengths than measured in beams with confinement. 2. The linear nature of the current development length code equation is acceptable. 3. Behavior of the interior splices was nearly identical to that of the exterior splice. 4. High steel stresses resulted in greater crack widths than currently acceptable for service load stresses using Grade 60 steel. The equation used to determine serviceability limits only appears to be effective for stress levels of 60 ksi (410 MPa) or less.

18. **Performance of Tension Lap Splices with MMFX High Strength Reinforcing Bars University of Texas (Austin)–G. Glass–May 2007 (141 pages):**

    This paper reports on tests from beam-splice specimens at the University of Texas, North Carolina State University, and the University of Kansas, making the following conclusions concerning ASTM A1035 reinforcement: A. A1035 lap splices developed bar stresses up to 155 ksi (410 MPa). B. ACI 408 development length equation provided relatively accurate estimates of failure stresses for splices with and without confining transverse reinforcement. C. ACI 318 and AASHTO LRFD development length equations provided un-conservative calculated failure stresses for unconfined splices, while providing reasonable calculated failure stresses for confined splices. D. The addition of confining transverse reinforcement provided an increase in failure stress and was greater than predicted by either the ACI 408 or ACI 318 equation. E. The addition of confining transverse reinforcement provided an increase in beam deflections at failure; and was greater than proportional to the increase in confining reinforcement. F. Service level crack widths were greater than the limits used as a basis for serviceability provisions included in pre-1999 editions of ACI 318. G. Bar splices with stresses greater than 75 ksi (515

MPa) should be designed using the ACI 408 development length equation with the modification factor,, equal to 0.82. H. A minimum level of transverse reinforcement should be included for all splices above 75 ksi (515 MPa) except for those with No. 5 or smaller bars with large bar spacing and cover.

19. **Behavior of Concrete Bridges Reinforced with High-Performance Steel Reinforcing Bars—North Carolina State Univ.–H. Seliem (Dissertation)–2007 (287 pages):**

    This paper describes the testing of reinforced concrete structural members with MMFX "ChromX® 9100" (ASTM A1035 Grade 100) reinforcing bars and made the following conclusions: "*Yield strength of 90 ksi (621 MPa) can be used in design of bridge decks reinforced with MMFX steel reinforcing bars without impairing the ultimate load carrying capacity or altering the serviceability behavior. … Up to #8 (NO. 25), spliced MMFX reinforcing bars can develop a stress of 90 ksi (621 MPa) without the use of confinement by transverse reinforcement. … Minimum amount of transverse reinforcement is required to confine spliced bars to ensure a ductile behavior of concrete members with spliced bars as well as sufficient warning prior to failure. … MMFX steel bars can be bent up to 90 degrees without impairing their ultimate strength if they are fully bonded to concrete.*"

20. **Fatigue Behavior of MMFX Corrosion-Resistant Reinforcing Steel Canada 7th International Conference on Short and Medium Span Bridges, Montreal, Canada—S. DeJong, C. MacDougall- 2006 (11 pages):**

    This study indicates that MMFX "ChromX® 9100" (ASTM A1035 Grade 100) was tested to have a fatigue life of 1 x 10^6 cycles at a stress range of approximately 310 MPa [45 ksi], compared to conventional steel 1 x 10^6 cycles at a stress range of approximately 166 MPa [24 ksi]. The study made the following conclusion: "Thus, MMFX exhibits superior fatigue resistance under constant amplitude loading in an air environment than conventional steel reinforcing bars."

21. **Evaluation of MMFX Steel for NCDOT Concrete Bridges FHWA/NC/2006-31, NCDOT Report 2004- 27– S. Rizkalla, P. Zia et. al.– December 2005 (131 pages):**

    This publication states the following conclusions based on testing of full-scale bridge deck sections and corrosion tests at North Carolina State University: *"1. Substituting MMFX steel directly for Grade 60 steel in a design … is an overly-conservative approach. 2. MMFX steel [ASTM A1035] can be used as the main flexural reinforcement for cast-in-place concrete bridge decks at a reinforcement ratio corresponding to 33% less than that required for Grade 60 steel. Therefore, a design of reinforced concrete bridge decks using MMFX steel may utilize an equivalent yield stress of 90 ksi for the MMFX steel bars. 3. Design of concrete bridge decks utilizing the high tensile strength characteristics of the MMFX steel should satisfy all minimum reinforcement ratios required by the AASHTO LRFD Bridge Design Specifications as well as the serviceability requirements of the specifications. 4. MMFX steel [ASTM A1035] has a much lower corrosion rate compared to conventional Grade 60 steel. Therefore, the use of MMFX steel could increase the service life of concrete bridges and lower repair costs."*

22. "Seismic Behavior of Bridge Columns Built Incorporating MMFX Steel" University of California, San Diego– Report No. SSRP–2003/09– B. Stephan, J. Restrepo, F. Seible – October 2003 (37 pages):

    Testing was performed on two similar column units constructed using ASTM A706 Grade 60 and MMFX 2 "ChromX® 9100" (ASTM A1035 Grade 100) reinforcing bars. The ASTM unit was designed according to the CALTRANS Bridge Design Specifications (July 2002) and the MMFX unit incorporated MMFX's design strength resulting in approximately half the steel requirement of the ASTM unit. The tests conclusively showed that both units can be designed to form ductile flexural plastic hinges and can sustain drift levels of approximately 4% without failure and complied with CALTRANS column seismic failure criteria. (See

also "**Seismic Testing of Bridge Columns Incorporating High-Performance Materials"** **–ACI Structural Journal Vol. 103, No. 4 -J. Restrepo, F. Seible, B. Stephan, M. J. Schoettler - Jul-Aug 2006 - 9 pages**) (Copy of this paper may be obtained from American Concrete Institute (ACI), Farmington Hills, MI).

1. **MMFX 2 (ASTM A 1035, Grade 100) Steel Rebar Corrosion Performance Testing in Accordance with AASHTO MP 18M/MP 18-09** **Tourney Consulting Group (TCG) – Report TCG # 11072- August 2011 (29 pages):** This test report indicates the result of corrosion test of AASHTO M 334 "MP 18"/ ASTM A1035 Type CS certified bars in accordance with AASHTO T 334M (formerly AASHTO MP 18 – Annex A) Standard Method of Test for *Comparative Qualitative Corrosion Characterization of Steel Bars Used for Concrete Reinforcement (Linear Polarization Resistance and Potentiodynamic Polarization Tests)* on No. 3 through No. 11 test bars. Results of these corrosion tests indicated that all bars met the corrosion test requirements of AASHTO M 334. In addition, micrographs of etched specimens were taken as an index for confirmation of the microstructure for each of the test bars. The metallographic examination showed Martensite, fine grain microstructure structure for each of the MMFX 2 test bars at a 500x magnification.
2. **CRSI – Specialty & Corrosion Resistant Steel Reinforcement – Product Guide** **Concrete Reinforcing Steel Institute– July 2013 (28 pages)**: CRSI's Product Guide provides a comparison of fabrication, estimating, detailing and placement information for Corrosion Resistant Reinforcing (CRR) bars: ChromX® 9100 (AASHTO M 334/ASTM A1035 Type CS), epoxy coated (ECR), galvanized, stainless steel (SS) and dual coated (Z-bar). A summary comparison of these CRR bars is provided in **MMFX's CRR CRSI Product Guide Comparison,** which indicates that fabrication, estimating, detailing and placement of ChromX® 9100 bars is easier than the other CRR bars included in the CRSI Product Guide.
3. **Frequently Asked Questions (FAQ) About Low-Carbon, Chromium ASTM A1035 Types CS, CM and CL Steel Reinforcing Bar** **CRSI ETN-M-11-17 FAQ – April 2017 (6 pages):** *CRSI's FAQ is divided into the following Sections: 1. Basic Material Characteristics, 2. Engineering Design Issues, 3. Fabrication and Construction Issues, 3. Finish Quality and 4. References. This FAQ provides information concerning: A. ASTM A1035 types of chemical composition, B. Available bar types, sizes and lengths, C. Figure of typical stress-strain curve, D. IBC building code and AASHTO LRFD Bridge Design Specifications high strength design guidelines, E. Corrosion resistance properties, F. High strength design benefits, G. Fabrication equipment and procedures, H. Handling, storage, or placing requirements, I. Effect of mill scale oxidation on the bars service life, J. Reference documents identified in the FAQ.*

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 4 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

Description (required):

This ATC proposes temporary acceleration and deceleration lanes along the outside shoulder of I-20 to allow construction vehicle access to our work zones without the use of an active lane closure. We are requesting a deviation from Exhibit 5 - Division 600 - Maintenance and Control of Traffic Subsection 601.4.2. We are also requesting to do these shoulder closures outside of the allowable closure windows indicated in Exhibit 4d- 2.2.2. We are requesting this for each end of the main (Wateree) bridges. Work zone access locations would provide the items below:
1.) Deceleration and acceleration lengths will follow AASHTO Tables 9-20 and 10-4 for the appropriate design speeds (70 mph). Exhibit attached is shown for the west end of Wateree structure only; east end is similar.
2.) Pavement markings and signing to delineate the acceleration and deceleration lanes from the adjacent through lanes and prevent traffic from following construction vehicles.
3.) Existing ROW and pond will not be impacted by access road grading. Attached exhibit shows fill limits related to both.

Usage:

This ATC will be used to provide construction access during all stages of construction.

Deviations (required):

This ATC deviates from Exhibit 5 Division 600 Subsection 601.4.2 by providing ingress and egress of construction traffic along the outside shoulders at all times without providing a lane closure. This ATC deviates from the Access Lane standard plan provided in the SCDOT Standard drawings, number 605-430-00, by using AASHTO acceleration and deceleration lengths adjacent to a construction access lane as well as the separation of the access lane and through traffic using raised pavement delineators instead of concrete barrier.

Justification:

This ATC will allow us to bring construction vehicles in and out of our work zones without the presence of an active lane closure and outside of the allowable closure windows shown in Exhibit 4d- 2.2.2. Based upon the location of the West Pond bridges, our acceleration and deceleration lanes will extend onto and past the existing bridge. We will ensure safe vehicle entry and exit by extending our temporary raised pavement markers past the bridge in order to separate traffic far in advance and allow safe ingress and egress from our work zones. In order to provide efficient and safe construction traffic flow, our plan is then to bring the traffic under the bridges in order to provide a dedicated acceleration lane separate from the deceleration lane. This approach will ensure safe and efficient flow of construction traffic and will limit disturbance to the traveling public.

Schedule:

There are no overall project schedule savings anticipated for this ATC.

Impacts:

This ATC will impact vehicular traffic by reducing the amount of lane closures introduced and by removing slowing construction vehicles from the normal flow of traffic. This ATC improves safety of the traveling public and workers by reducing the direct interaction of traffic and construction. The impact to the surrounding community will be to reduce

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TTY: (803) 737-3870

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Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 4 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

traffic congestion and accidents. There will be minimal temporary impacts to the environment due to the addition of construction access roads and no impact to Right of Way or utilities.

History:

This ATC is specific to this Project, but the layout follows industry standards (AASHTO) 70 mph design speed for required acceleration and deceleration of truck traffic for safety of the traveling public.

Risks:

Risks to the traveling public will be reduced as well impacts to the level of service during construction.

Costs (required):

Cost Savings: $0

Quality:

Quality to the traveling public will be better during construction.

Operations & Maintenance:

This ATC does not affect the Operations & Maintenance of the Project.

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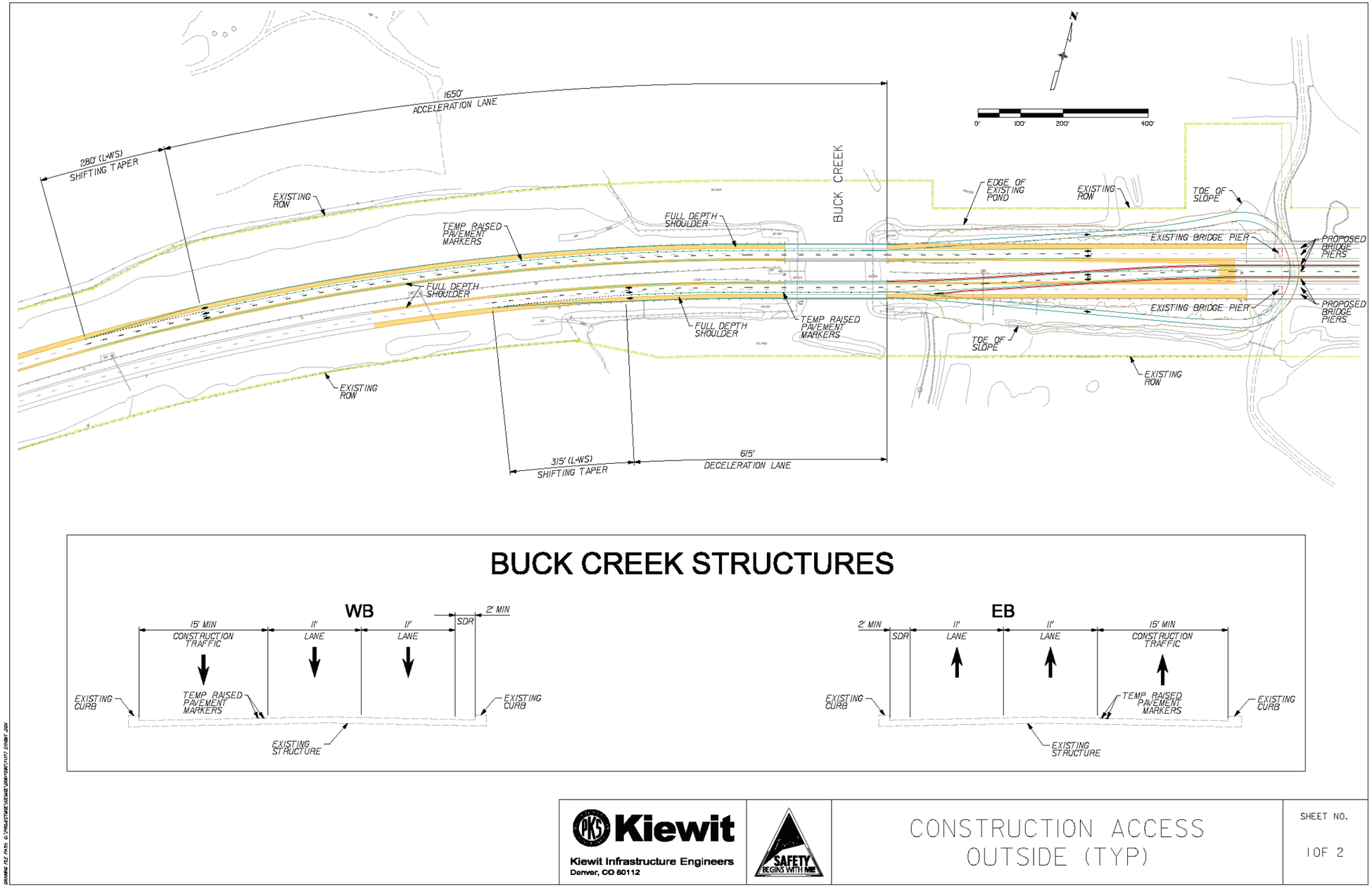
ATC 04 – CONSTRUCTION ACCESS



Kiewit
Kiewit Infrastructure Engineers
Denver, CO 80112

SAFETY BEGINS WITH ME

CONSTRUCTION ACCESS
OUTSIDE (TYP)

SHEET NO.
1 OF 2

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 5 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

Description (required):

This ATC proposes to utilize acceleration and deceleration lanes (70mph design speed) along the inside or outside shoulder of I-20 to allow construction vehicle access to our work zones without the use of an active lane closure. One location we anticipate using this detail is east of the Wateree structure. We are requesting a deviation from Exhibit 5 - Division 600 - Maintenance and Control of Traffic sub section 601.4.2. We are also requesting to do these shoulder closures outside of the allowable closure windows indicated in Exhibit 4d- 2.2.2.

Usage:

This ATC will be used as needed to provide construction access for the inside or outside shoulder workzones east of the Wateree structure. This detail will also be used for EB and WB inside shoulder access at the overflow bridges for the rehabiliation work.

Deviations (required):

This ATC deviates from Exhibit 5 Division 600 Subsection 601.4.2 by providing ingress and egress of construction traffic along the inside and outside shoulders without providing a lane closure. This ATC deviates from the Exhibit 4d-2.2.2 by allowing access to occur inside of prohibited lane closure times.

Justification:

This ATC will allow us to bring construction vehicles in and out of our work zones without the presence of an active lane closure and will reduce the total amount of lane closure needed to construct the Project. This will also provide access to both inside and outside work zones.

Schedule:

There are no overall project schedule savings anticipated by this ATC.

Impacts:

This ATC will reduce the amount of lane closures required and improve safety by limiting worker exposure to live traffic.

History:

This concept was implemented for the NCDOT I-440 Beltline reconstruction project in Raleigh, North Carolina (2015-2018).

Risks:

Risks to the traveling public will be reduced as well impacts to the level of service during construction.

Costs (required):

Cost Savings: $0

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Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 5 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

Quality:

This ATC improves safety during construction by reducing the amount of lane closures and the number of times workers are exposed to traffic.

Operations & Maintenance:

This ATC does not affect the Operations & Maintenance of the Project.

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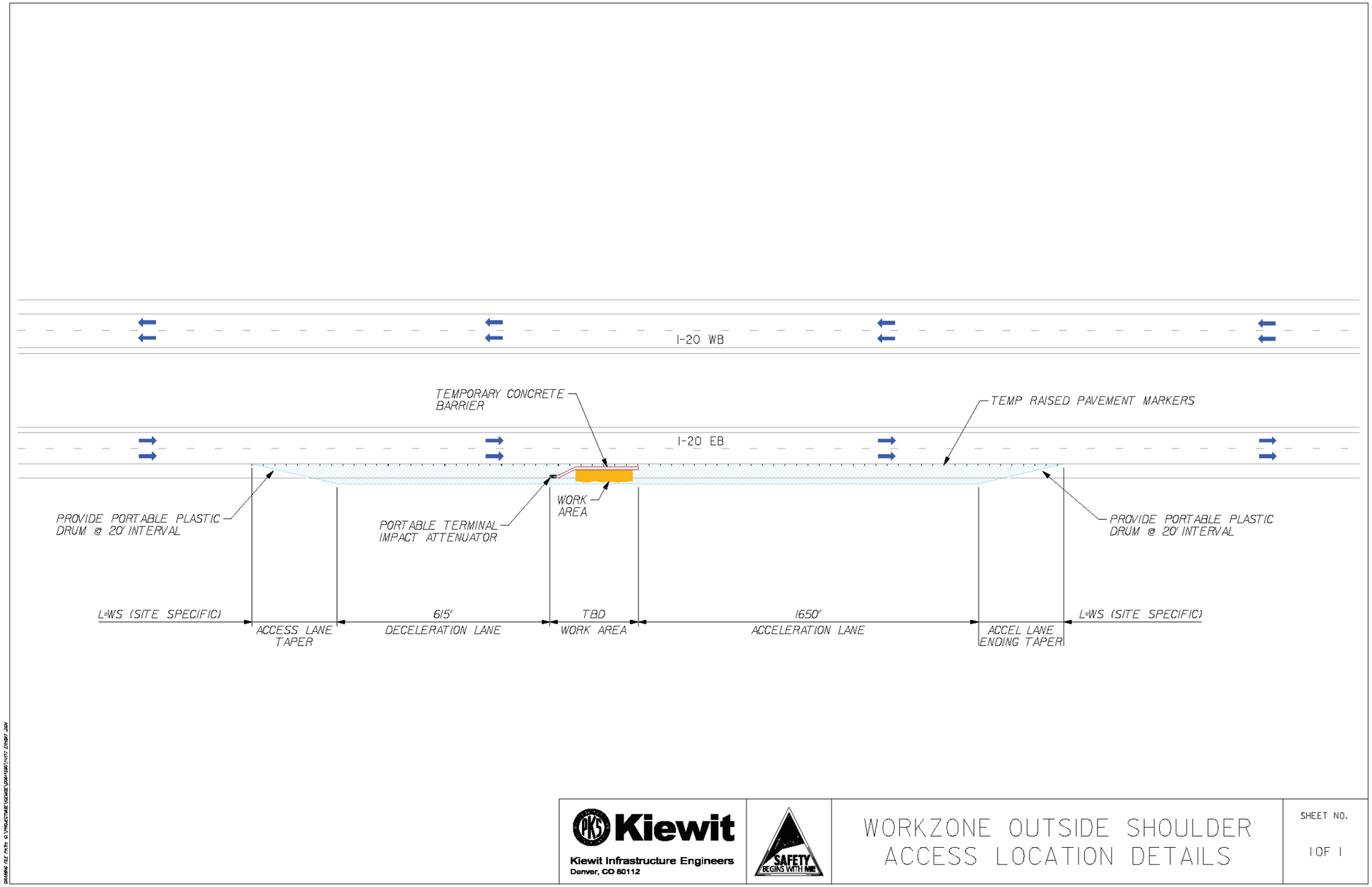
ATC 05 – WORKZONE ACCESS USING INSIDE-OUTSIDE SHOULDER



Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 6 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Description (required):

Since Prestressed Florida I-Beams have been shown as the preferred beam alternative in the conceptual plans provided with the RFP, this ATC proposes to use the standard details applicable to FDOT Index 20010. This ATC eliminates full height diaphragms at expansion joint locations and replaces it with a Thickened Slab End at all locations of slab discontinuity. See FDOT Structures Design Manual Chapter 15 for suggested details (see attached exhibit).

Usage:

This ATC is requested at all locations of new bridge deck slab discontinuity, i.e. expansion joint locations.

Deviations (required):

This ATC deviates from the SCDOT Bridge Design Manual Section 15.5.7 - Diaphragms (Page 15-34), which states: "For prestressed beam spans, cast-in-place concrete diaphragms shall be used at all supports with the beams embedded a minimum of 3 inches into the diaphragm" and from SCDOT Standard Full-Depth End Diaphragm Details (see exhibit). This ATC requests acceptance of the FDOT Thickened End Slab Details in lieu of the Full-Depth End Diaphragm.

Justification:

This ATC is consistent with standard details used with Florida I-Beam Index 20010 which has been successfully used in various locations in Florida.

Schedule:

This ATC allows the use of standard stay-in-place formwork to form the thickened slab, reducing the required time to fabricate and cast the diaphragms. Although this ATC increases project efficiency, there is no overall project schedule savings anticipated.

Impacts:

No vehicular traffic, safety, community, utility, right-of-way or environmental impacts are anticipated.

History:

This detail has tenured use by the Florida Department of Transportation.
Robert V. Robertson, Jr., PE, State Structures Design Engineer (retired 12/2021)
Florida Dept of Transportation
(850) 496-6147, Srobertson2813@hotmail.com

Risks:

There are no additional risks to SCDOT or other persons/entities with implementing this ATC.

Costs (required):

Cost Savings: $690,000

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Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 6 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Quality:

Final deck quality will be equal to the typical SCDOT deck detailing.

Operations & Maintenance:

Operations & Maintenance will be easier during bearing replacement as the diaphragms will not hamper repair or replacement of the joint.

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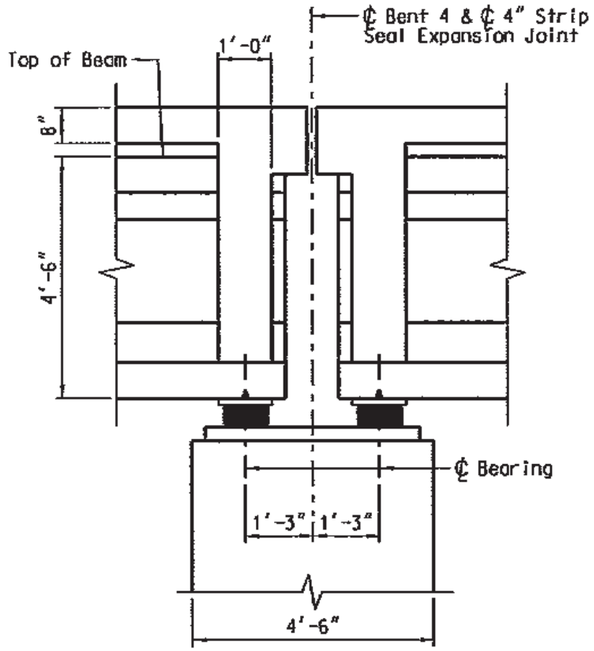
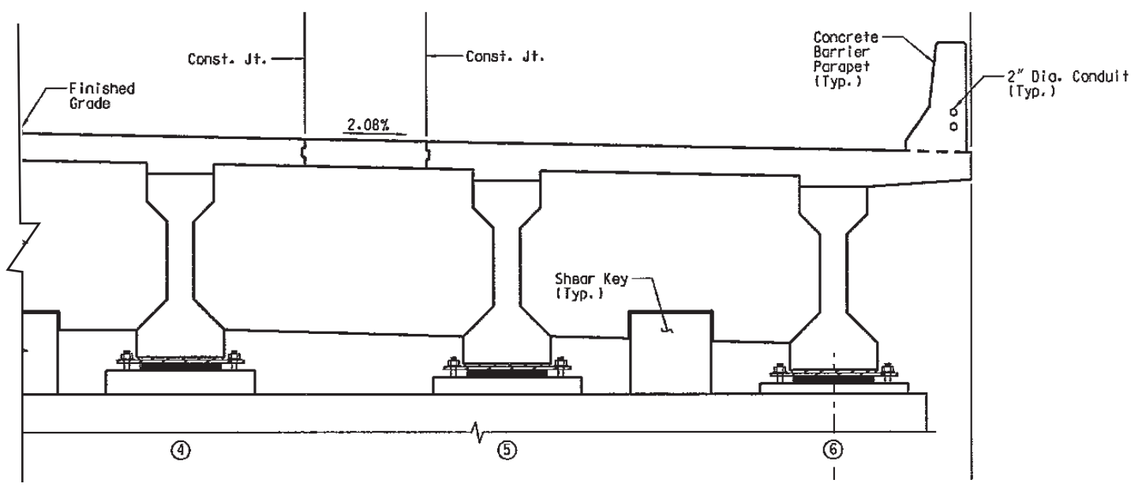
ATC 06 - ELIMINATE END GIRDER DIAPHRAGM





SCDOT Details at Expansion Joint

Figure 15.5-2 Thickened Deck End at Interior Support

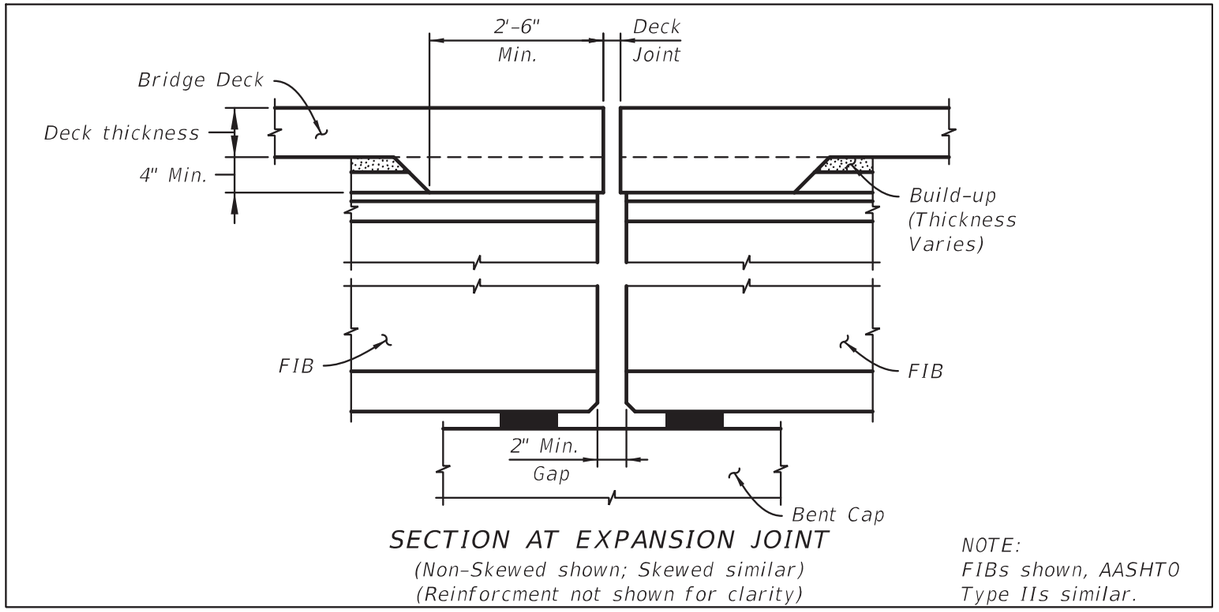
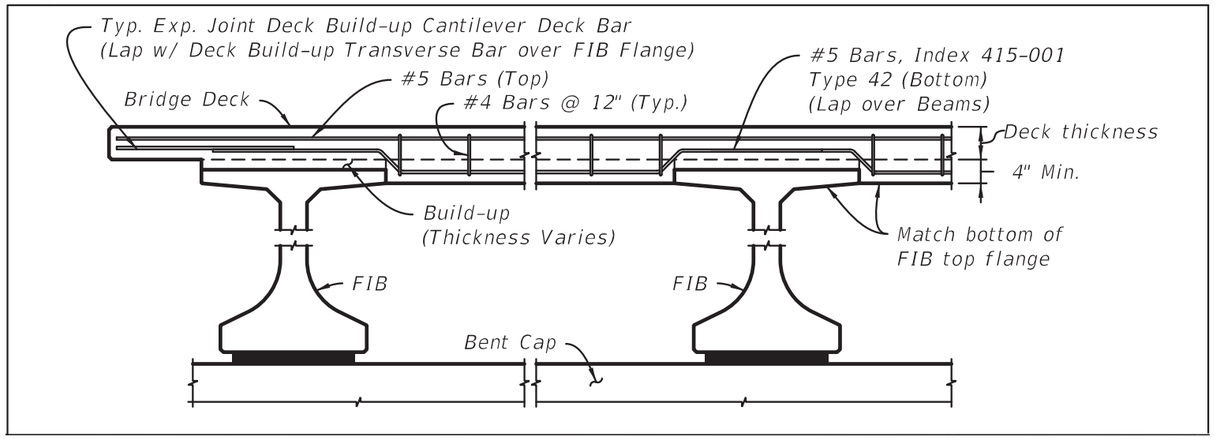


Figure 15.5-1 Thickened Deck End Details



Proposed ATC
FDOT Details at Expansion Joint

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 7 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Description (required):

This ATC requests the substitution of a lightweight cross-frame fabricated from steel angles (shown in the attached exhibit) in lieu of the SCDOT standard steel diaphragm. The standard steel framing detail is much more robust than as required for the lateral stability of the Florida I-Beams. (See attached calculations)

Usage:

This ATC requests use of the lightweight cross-frames at all required intermediate diaphragm locations for all new deck construction.

Deviations (required):

This ATC deviates from the SCDOT Standard Steel Intermediate Diaphragm Details.
This ATC requests to use the attached lightweight steel intermediate diaphragms in lieu of the standard details.

Justification:

This ATC has been successfully used on NCDOT's US 17 Washington Bypass Project in Washington, NC for the 2.5-mile crossing of the Tar River and adjoining wetlands using 78-inch Florida Bulb-T Beams. A calculation is attached showing that the resulting maximum moments in the girders from both the SCDOT standard diaphragm and the proposed cross-frame alternate are comparable.

Schedule:

This ATC reduces the intermediate steel quantity and, as such, the procurement lead time. There are fewer connections to the web resulting in simpler and faster installation. There are no overall project schedule savings anticipated.

Impacts:

No vehicular traffic, safety, community, utility, right-of-way or environmental impacts are anticipated.

History:

This ATC has been successfully used on NCDOT's US 17 Washington Bypass Project in Washington, NC for the 2.5-mile crossing of the Tar River and adjoining wetlands using 78-inch Florida Bulb-T Beams. Brian Hanks, PE, State Structures Engineer, North Carolina Department of Transportation. 919-707-6419, bhanks@ncdot.gov

Risks:

There are no additional risks to SCDOT or other persons/entities with implementing this ATC.

Costs (required):

Cost Savings: $130,000

Quality:

Final quality will be equal to the original standard detail, as the distribution factor to each girder is similar regardless of the selected steel intermediate diaphragm. The substitution of the cross-frame will have no impact on the final structure behavior or service life.

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Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 7 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 11/2/22

Operations & Maintenance:

This ATC does not affect the Operations & Maintenance of the project.

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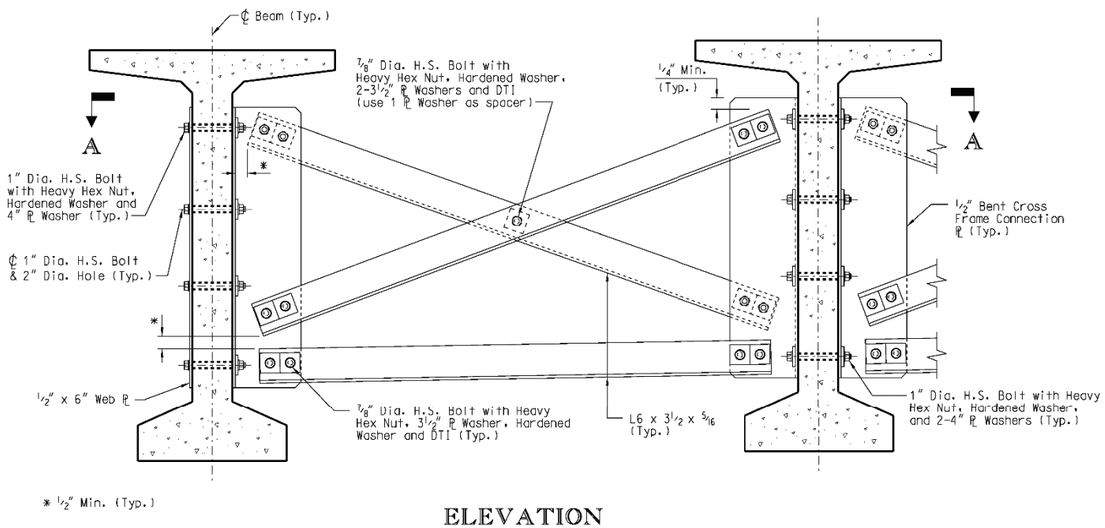
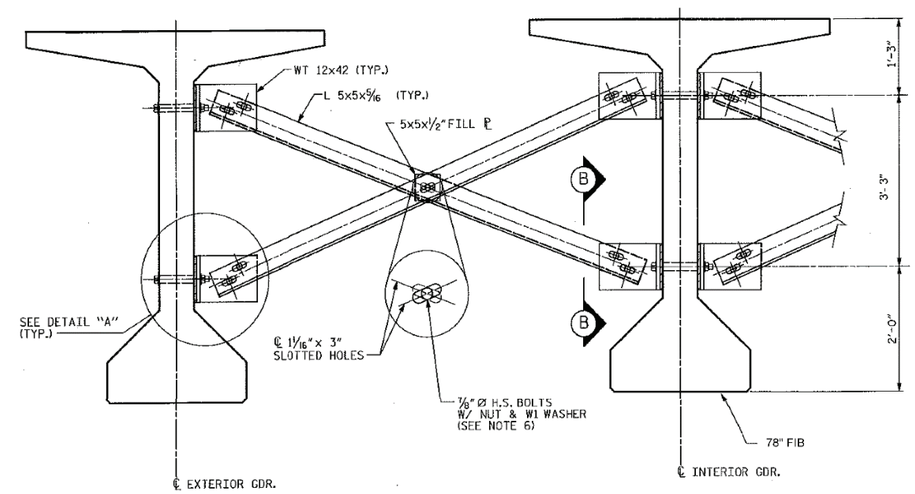
ATC 07 – ALTERNATE INTERMEDIATE DIAPHRAGMS



ELEVATION



TYPICAL INTERMEDIATE DIAPHRAGM

SCDOT Standard
Steel Intermediate Diaphragm
Drawing No. 704-05c

Proposed Alternative
Steel Intermediate Diaphragm
NCDOT US 17 Washington Bypass

ATC 07 CALCULATIONS

I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehabilitations

Kershaw County, South Carolina

A Design-Build Project

Contract ID 2847360

Prepared by:

Cedric Kashosi
Henry Wolf
John W. (Wally) Jordan, PE

October 28, 2022

Document history and status

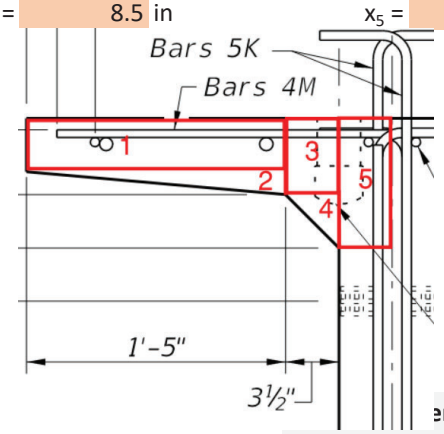
Version	Date	Description	By	Reviewed
ATC Submittal	10/28/2022	Intermediate Diaphragm Alternate	C. Kashosi	W. Jordan

Kiewit

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/28/22
	CHECKED BY:	H. Wolf	DATE:	10/28/22

Girder Top Plate

b_{tf} =	48	in						
t_1 =	3.5	in	x_1 =	17	in	y_1 =	$(t_1)/2$ =	1.75 in
t_2 =	1.5	in	x_2 =	17	in	y_2 =	$t_1 + (t_2)/3$ =	4.00 in
t_3 =	5	in	x_3 =	3.5	in	y_3 =	$(t_3)/2$ =	2.50 in
t_4 =	3.5	in	x_4 =	3.5	in	y_4 =	$t_3 + (t_4)/3$ =	6.17 in
t_5 =	8.5	in	x_5 =	3.5	in	y_5 =	$(t_5)/2$ =	4.25 in

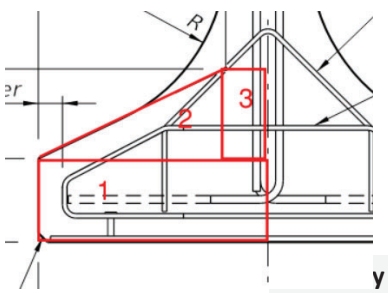


A_1 =	$(x_1) * (y_1)$ =	59.50	in^2
A_2 =	$0.5 *(x_2) * (y_2)$ =	12.75	in^2
A_3 =	$(x_3) * (y_3)$ =	17.50	in^2
A_4 =	$0.5 *(x_4) * (y_4)$ =	6.13	in^2
A_5 =	$(x_5) * (y_5)$ =	29.75	in^2
$\sum A$ =	$\sum(A_i)$=	125.63	in^2
$\sum Ay$ =	$\sum[(Ai) * (y_i)]$=	328.83	in^3

entroid of Girder Top Plate	**y_{tf} =**	**$\sum(A * y) / \sum(A)$ =**	**2.62 in**
thickness of Girder Top Plate	**t_{tf} =**	**$[2*(\sum A)]/ b_{tf}$ =**	**5.23 in**
Girder Top Plate thickness offset	**o_{ff} =**	**(t/2) - y =**	**0.00 in**

Girder Bottom Plate

b_{bf} =	38	in						
t_1 =	7	in	x_1 =	19	in	y_1 =	$(t_1)/2$ =	3.50 in
t_2 =	7.5	in	x_2 =	15.5	in	y_2 =	$t_1 + (t_2)/3$ =	9.50 in
t_3 =	7.5	in	x_3 =	3.5	in	y_3 =	$(t_3)/2$ =	10.75 in



A_1 =	$(x_1) * (y_1)$ =	133.00	in^2
A_2 =	$0.5 *(x_2) * (y_2)$ =	58.13	in^2
A_3 =	$(x_3) * (y_3)$ =	26.25	in^2
$\sum A$ =	$\sum(A_i)$=	217.38	in^2
$\sum Ay$ =	$\sum[(Ai) * (y_i)]$=	1299.875	in^3

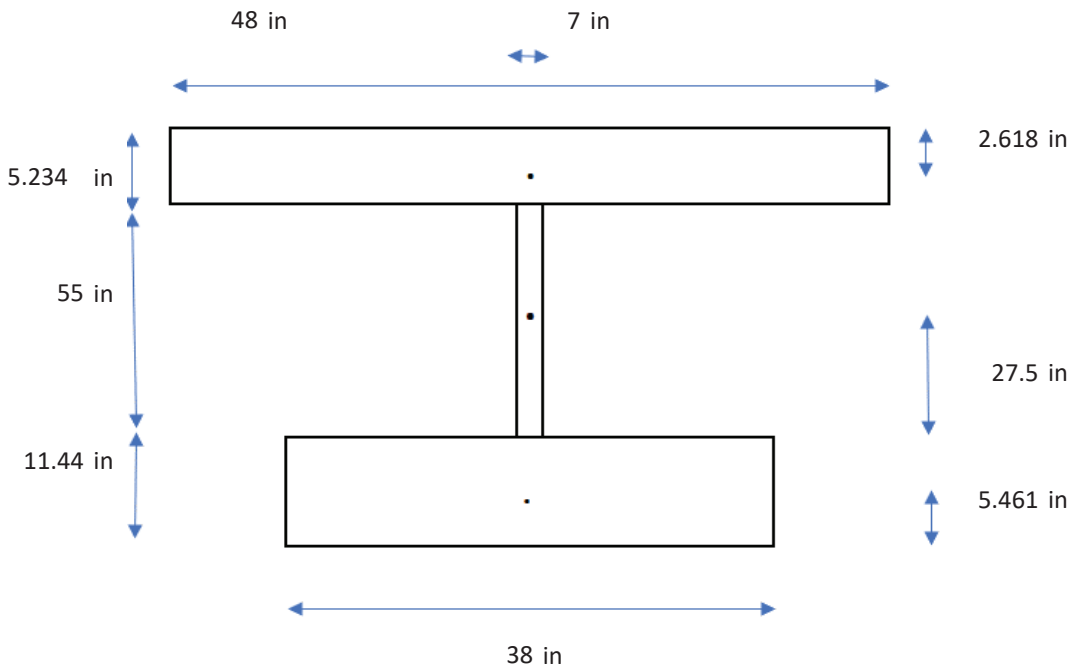
y - centroid of Girder Top Plate	**y_{bf} =**	**$\sum(A * y) / \sum(A)$ =**	**5.98 in**
thickness of Girder Top Plate	**t_{bf} =**	**$[2*(\sum A)]/ b_{tf}$ =**	**11.44 in**
Girder Top Plate thickness offset	**o_{ff} =**	**(t-y)-(t/2) =**	**-0.26 in**

Girder Web Plate

h_w =	55	in
t_w =	7	in

DESIGNED BY:	C. Kashosi	**DATE:**	10/28/22
CHECKED BY:	H. Wolf	**DATE:**	10/28/22

Section Properties



A_{tf} =	$(b_{tf}) * (t_{tf})$ =	251.25	in^2
A_w =	$(h_w) * (t_w)$ =	385	in^2
A_{bf} =	$(b_{bf}) * (t_{bf})$ =	434.75	in^2
d_{tf} =	$(h_w/2) + (t_{tf}-y_{tf})$ =	30.12	in
d_{bf} =	$(h_w/2) + (t_{bf}-y_{bf})$ =	32.96	in
$I_{y\text{-}tf}$ =	$[(b_{tf}) * (t_{tf})^3 /12] + [A_{tf} * (d_{tf})^2]$=	228462.79	in^4
$I_{y\text{-}w}$ =	$[(h_w)^3 * (t_w)] /12$ =	97052.083	in^4
$I_{y\text{-}bf}$ =	$[(b_{bf}) * (t_{bf})^3 /12] + [A_{bf} * (d_{bf})^2]$=	492054.21	in^4
$I_{x\text{-}tf}$ =	$[(b_{tf}) * (t_{tf})^3 /12]$ =	48240	in^4
$I_{x\text{-}w}$ =	$[(h_w)^3 * (t_w)] /12$ =	1572.0833	in^4
$I_{x\text{-}bf}$ =	$[(b_{bf})^3 * (t_{bf}) /12]$ =	52314.917	in^4

Minor axis moment of inertia	I_{xx} =	$(I_{x\text{-}tf} + I_{x\text{-}w} + I_{x\text{-}bf})$ =	**102127**	**in^4**
Major axis moment of inertia	I_{yy} =	$(I_{y\text{-}tf} + I_{y\text{-}w} + I_{y\text{-}bf})$ =	**817569.08**	**in^4**
Cross sectional Area of Girder	A_T =	$(A_{tf} + A_w + A_{bf})$ =	**1071**	**in^2**

DESIGNED BY:	C. Kashosi	**DATE:**	10/28/22
CHECKED BY:	H. Wolf	**DATE:**	

FIB-78 Girder: Midas Properties

The following proprerties will be used to create the FIB-78 Girder in midas,Civil

Concrete Properties

$f'_{c\text{-}D}$ = 4 ksi (Deck)

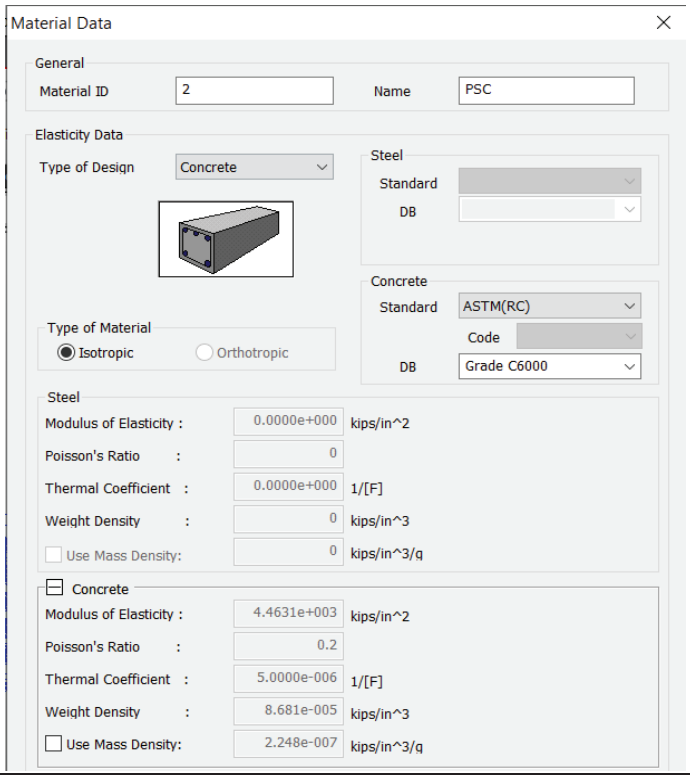
$f'_{c\text{-}B}$ = 6 ksi (Girder)

$E_{c\text{-}B}$ = $1820\,(f'c)^{0.5}$ = 3640 ksi

$E_{c\text{-}B}$ = $1820\,(f'c)^{0.5}$ = 4458.07 ksi

(C5.4.2.4-3, AASHTO LRFD)

Concrtete properties from midas.Civil



Thickness Properties

t_{deck} = 8.5 in

t_{tf} = 5.23 in

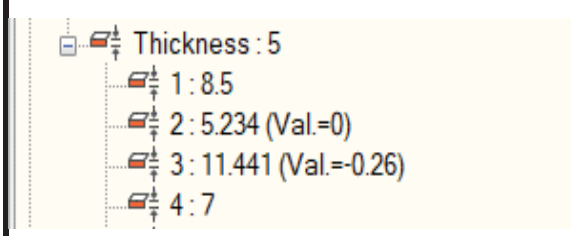
o_{ff} = 0.00 in

t_{bf} = 11.44 in

o_{ff} = -0.26 in

t_w = 7 in

Thickness properties from midas



Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/28/22
	CHECKED BY:	H. Wolf	DATE:	

Section Properties Validation

In order to validate the stiffness of the FIB-78 Plate Girder we have just created in midas, let create a beam element in midas and assign the section properties of the FIB-78 Plate Girder.

FIB-78 Plate Girder

$H = t_{tf} + h_w + t_{bf}$

$H =$ 71.68 in

$B_1 = b_{tf}$

$B_1 =$ 48 in

$t_w =$ 7 in

$t_{f1} = t_{tf}$

$t_{f1} =$ 5.23 in

$B_2 = b_{bf}$

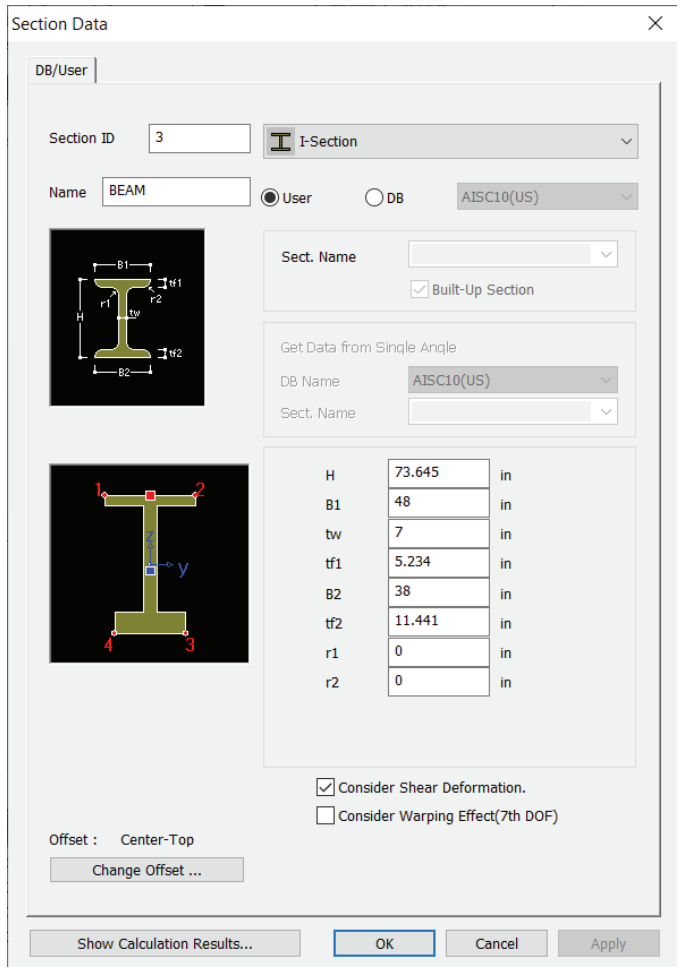
$B_2 =$ 38.00 in

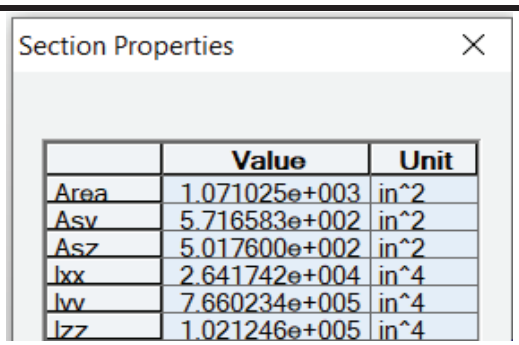
$t_{f2} = t_{bf}$

$t_{f2} =$ 11.44 in

$I_{xx} =$	102127	in^4
$I_{yy} =$	817569.1	in^4
$A_T =$	1071	in^2

Section properties of Beam-element Girder in midas.Civil





	Value	Unit
Area	1.071025e+003	in^2
Asy	5.716583e+002	in^2
Asz	5.017600e+002	in^2
Ixx	2.641742e+004	in^4
Iyy	7.660234e+005	in^4
Izz	1.021246e+005	in^4

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Now let apply an arbitrary load of 1k/in to this beam and check both the Maximum Bending Moment and the resulting deflection. Then let do the same by hand and compare the two.

Deflection

w =	1	k/in
L =	1881	in
E	4458.07	ksi
I	817569	in^4

Δ_{act} = $(5wL^4)/(384EI)$

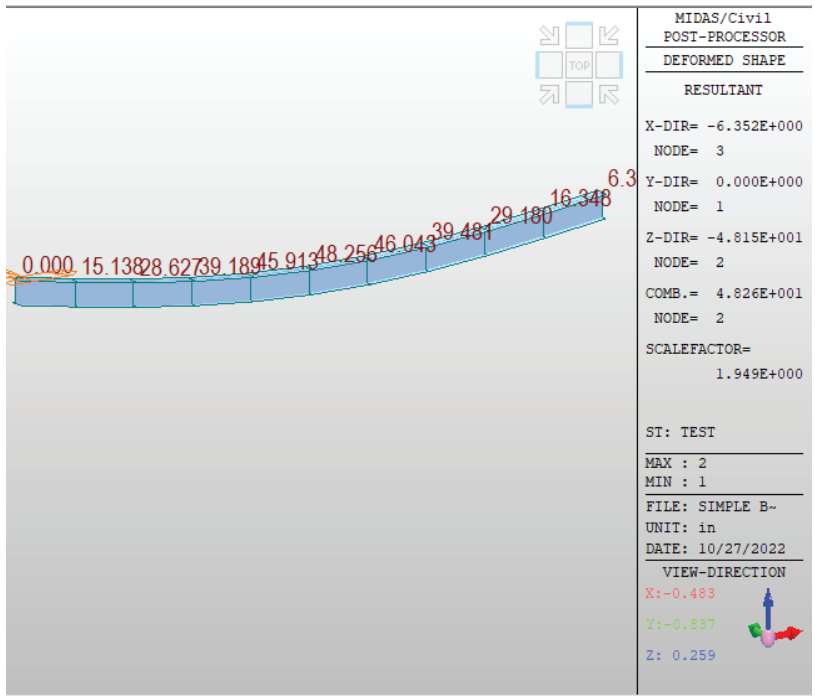
Δ_{act} = 44.7221 in

I_{midas} = 766023 in^4

Δ_{midas} = 48.26 in

$\frac{\Delta_{act}}{\Delta_{midas}}$ **0.93**

$\frac{I_{midas}}{I_{act}}$ **0.94**



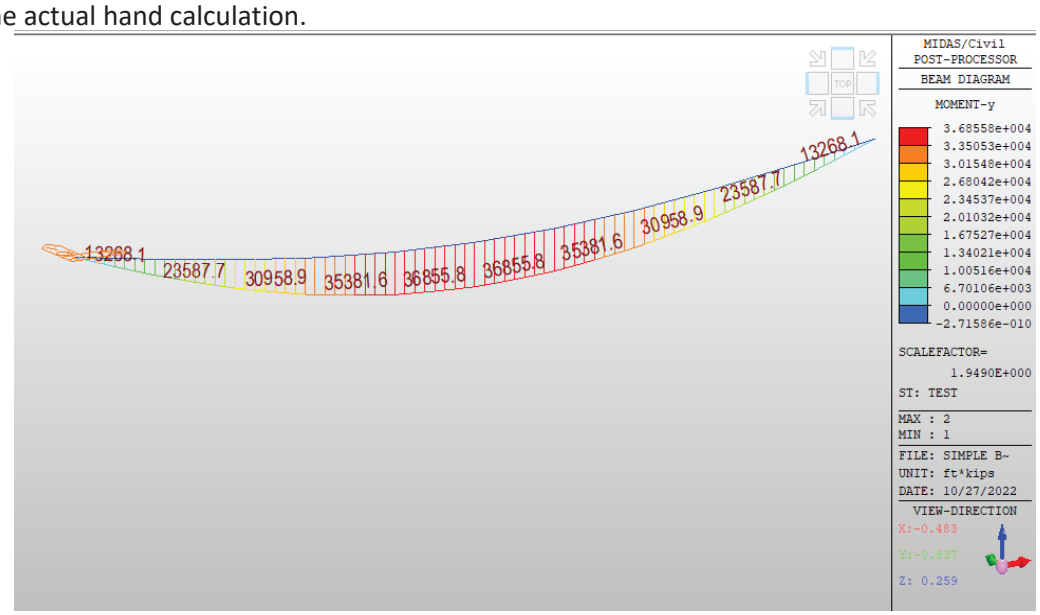
Therefore we can conclude that the correlation in between the stiffness and deflection of both the Plate Girder model and the actual hand calculation.

Moment

M_{act} = $wL_2/8$

M_{act} = 36855.8 k-ft

M_{midas} = 36855.8 k-ft



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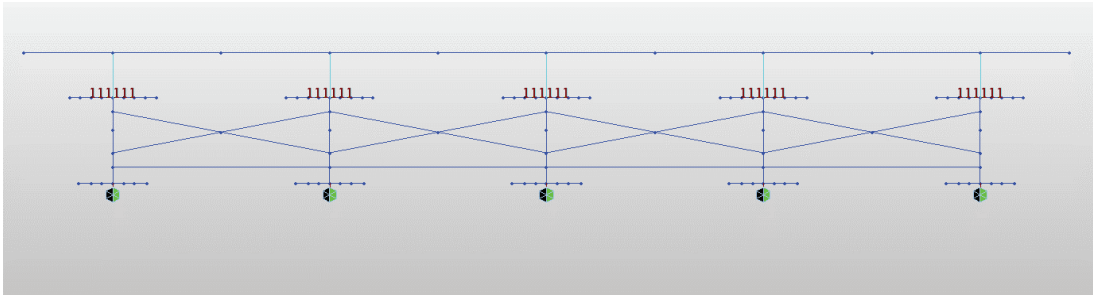
CHECKED BY:	H. Wolf	**DATE:**	

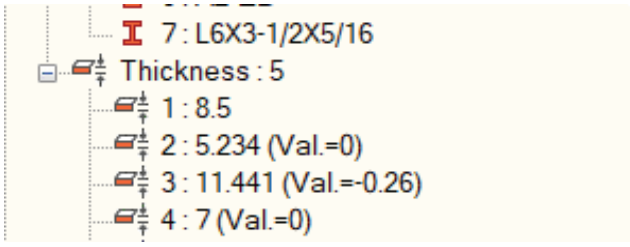
Using the SCDOT Cross frame details

Midas bridge cross-section using the SCDOT cross frame details with plate deck and girders



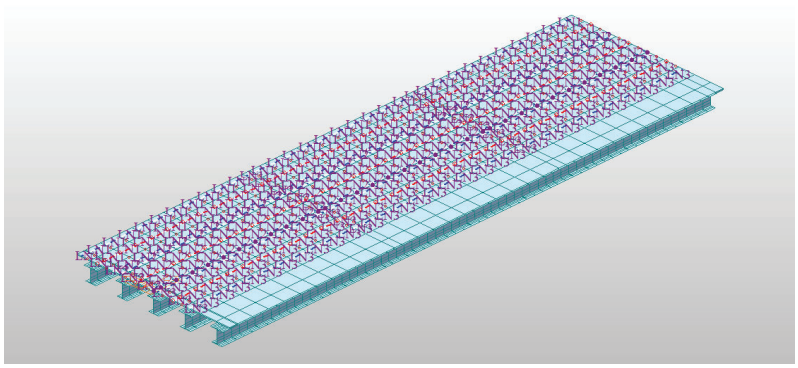
The rigid links are used to connect the plate girder to the deck, and the boundry contidion at both supports are pinned.

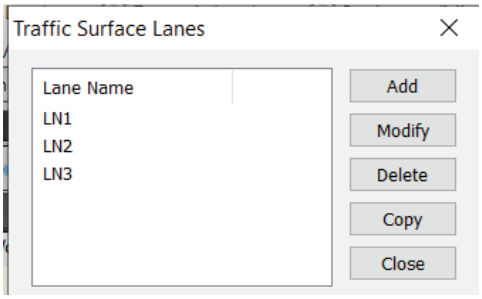
The cross frames are L6 x3.5 x5/16 beam elements with end-release members to ensure they do not transfert moment to ensure they do not transfert moment



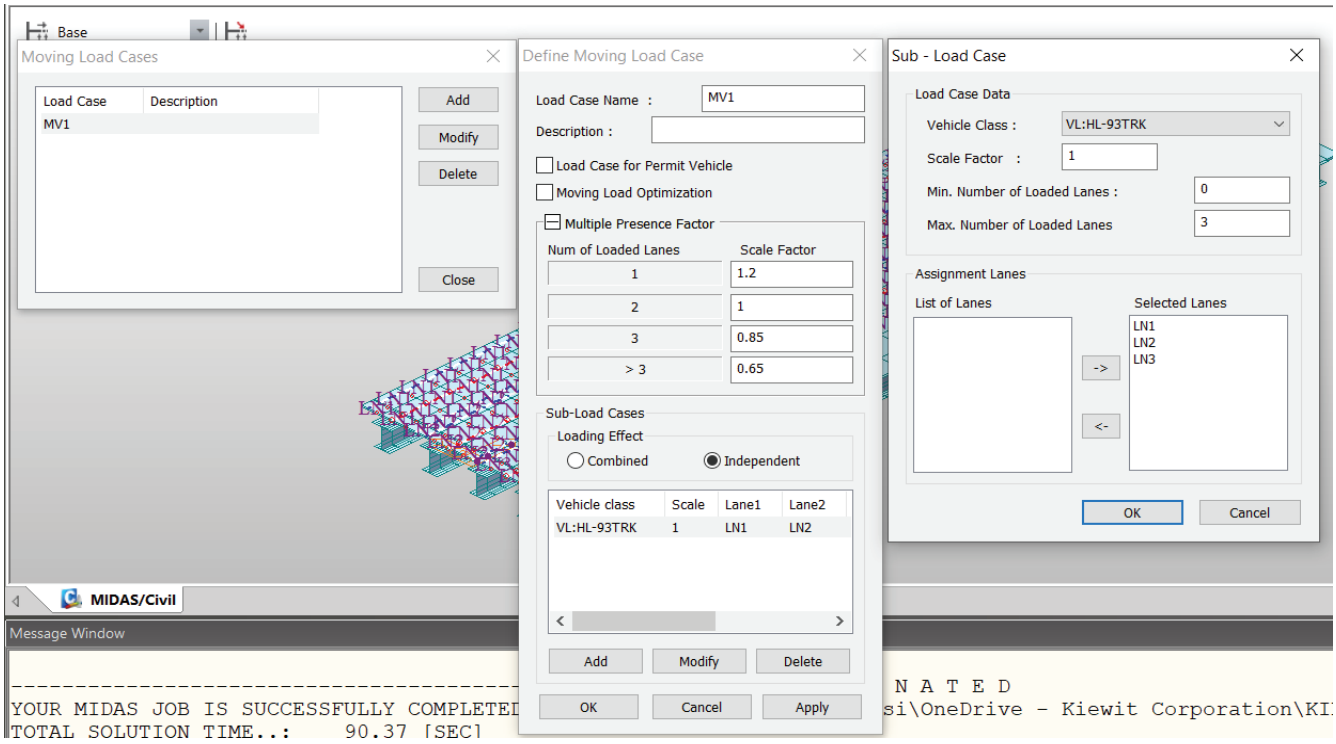
Traffic lanes

From the Cross-section of the Bridge, we deducted that 3 design lanes could be applied to this bridge (i.e. two 12-ft traffic lanes and one 12-ft shoulder) as shown here below



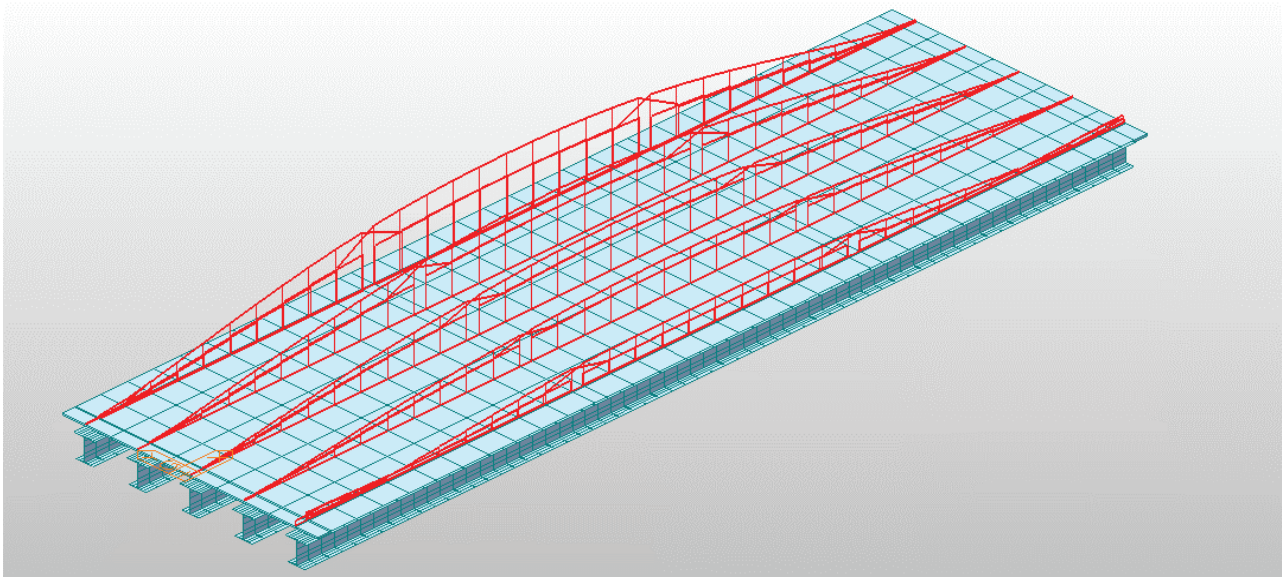


Using the AASTHO moving load and moving vehicle as shown in the picture below

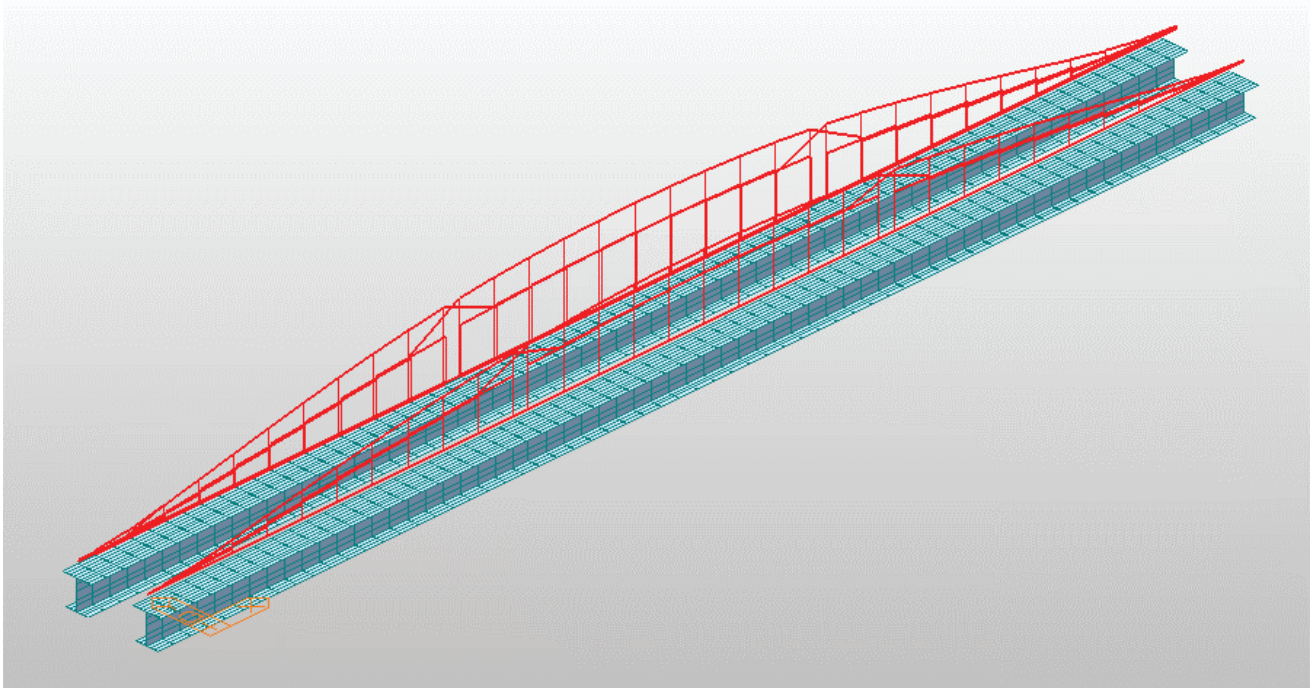


DESIGNED BY:	C. Kashosi	**DATE:**	10/28/22
CHECKED BY:	H. Wolf	**DATE:**	

Bending Moment Under Live Load Only



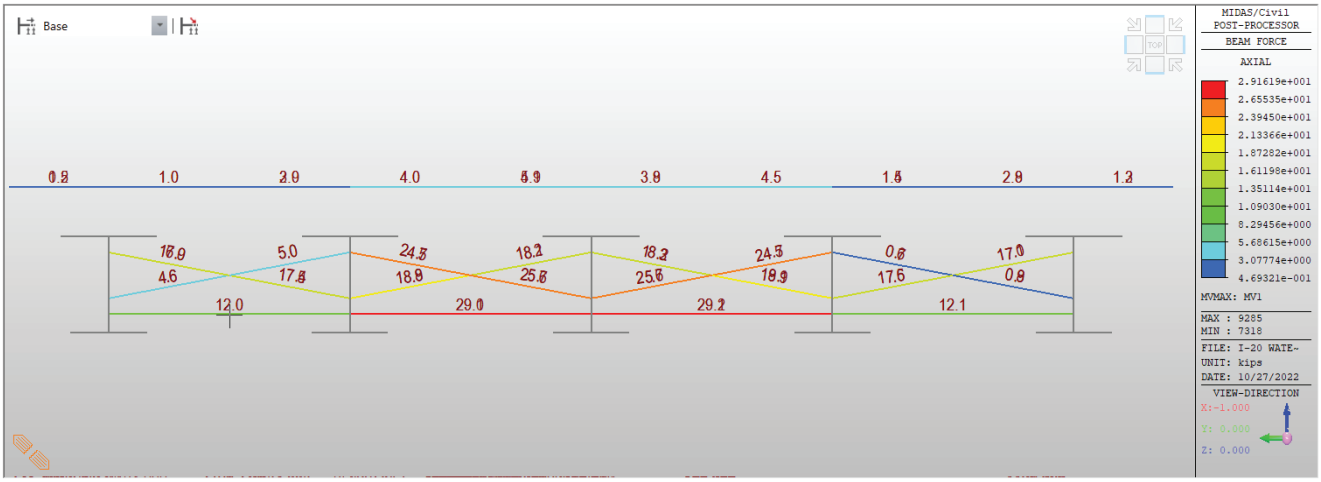
As we can see, the two far left girders are the most critical one and thus the one we will focus on.



DESIGNED BY:	C. Kashosi	**DATE:**	10/28/22
CHECKED BY:	H. Wolf	**DATE:**	

	Exterior Girder	Interior Girder
Moment (k-ft)	2835.004	2401.261

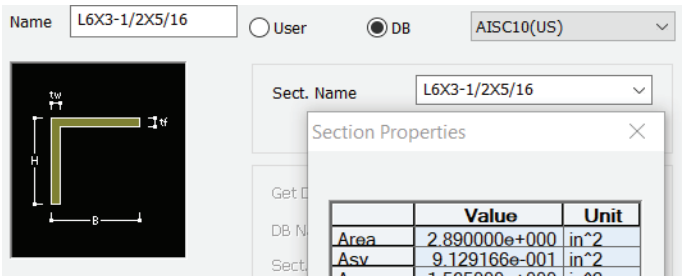
Looking the at cross frame forces, we ca see that the maximum tension force in memebers is 29kips



We need to check if the resistance of cross section elements are adequate to resist the applied tension.

Pu =	29	ksi
Fy =	36	ksi
ø =	0.9	
Ag =	2.89	in^2

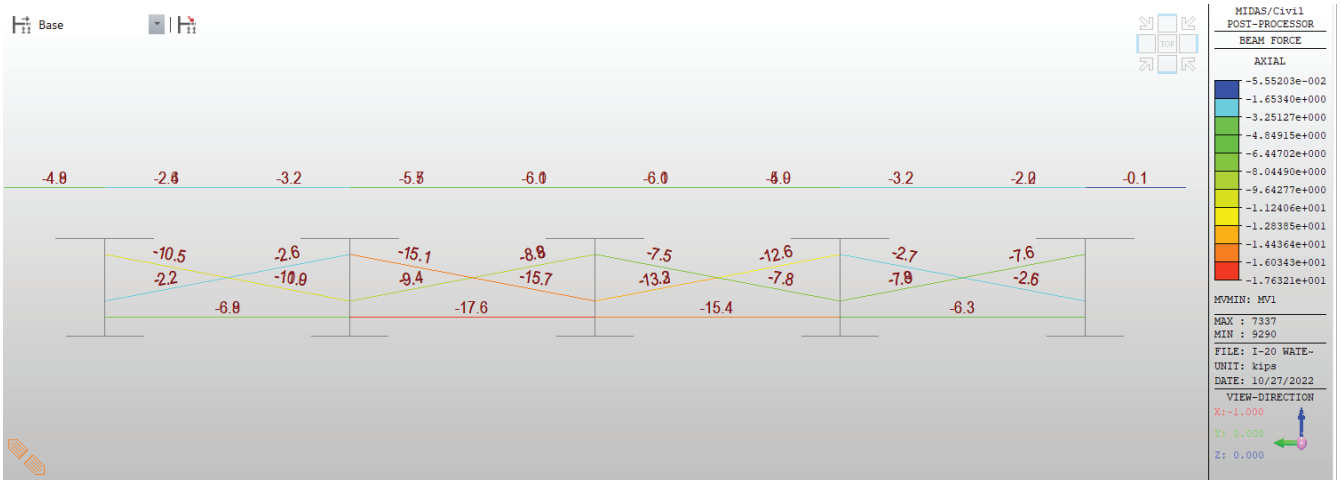
(D2-1, AISC Manual)



øPn = ø*Fy*Ag

øPn = 93.636 ksi > 29 ksi **OK**

Now looking at the Compression forces in the cross frames, the maximum compression is 17.6 kips



Checking if the resistance of cross section elements are adequate to resist the applied compression.

Pu =	17.6	kips
L =	10	ft

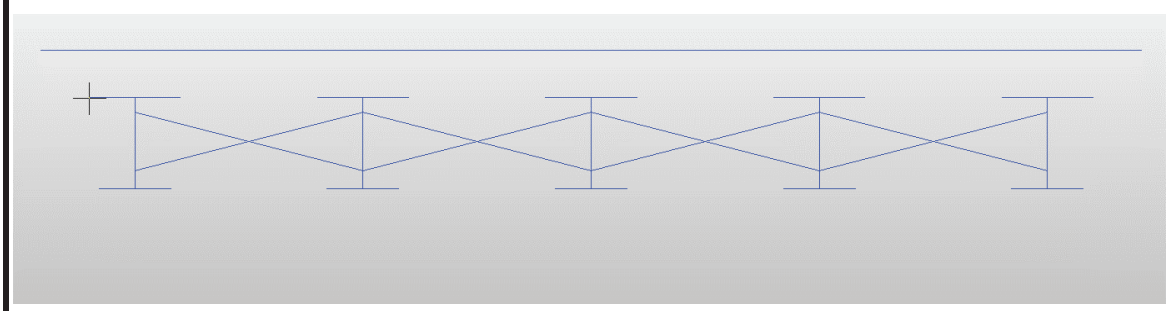
øPn =	31.4	kips	>	17.6 kips	**OK**	(Table 4-11, AISC Manual)

Thus the L6 x 3.5 x 5/16 section will be adequate to resist the applied forces

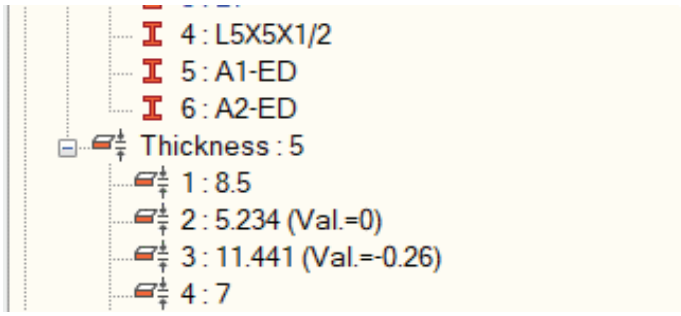
Now let take a look the second cross-frame details (Kiewit option)
This option has the same design lanes, design truck and bridge cross section, thus we will not repeat those details for simplicity of calculation

<u>Using the Kiewit Cross frame details</u>

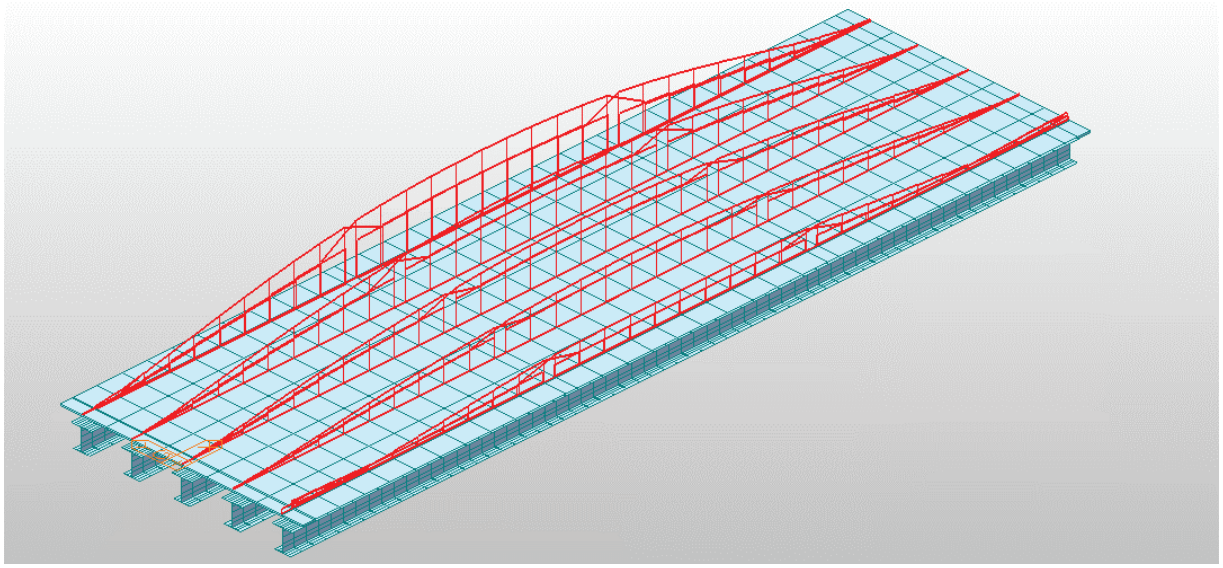
Midas bridge cross-section using the Kiewit cross frame details with plate deck and girders



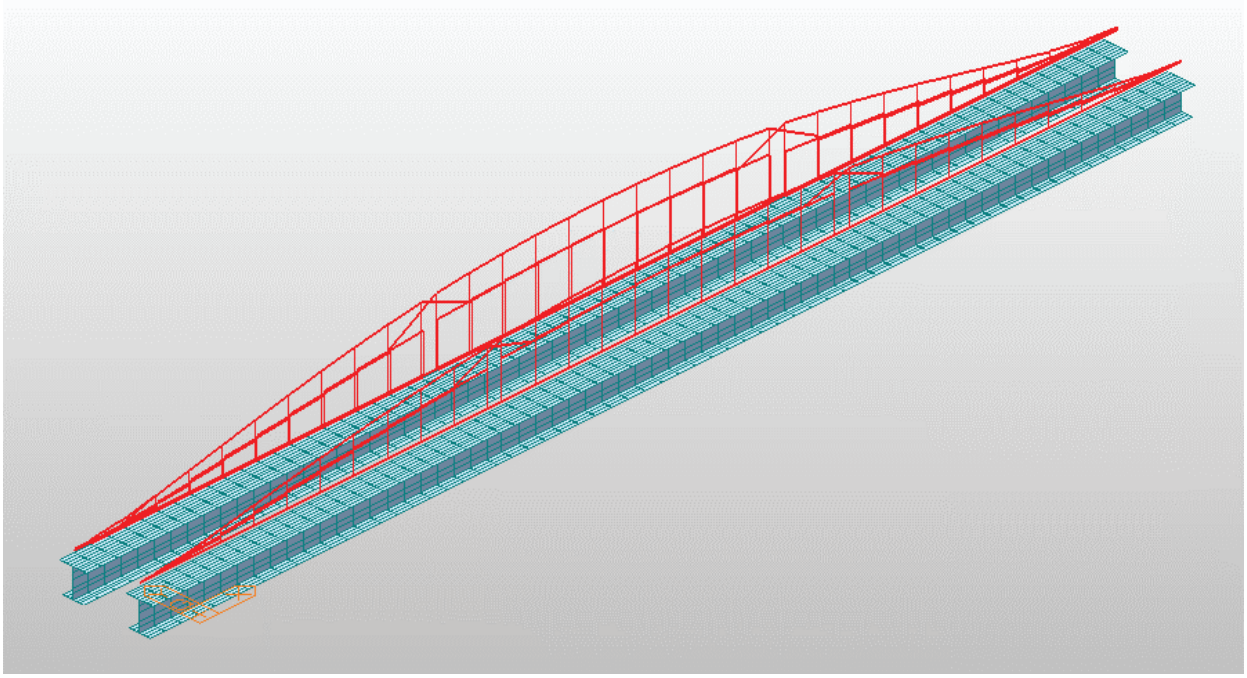
The cross frames are L5 x5 x 1/2 beam elements with end-release members to ensure they do not transfert moment to ensure they do not transfert moment



Bending Moment Under Live Load Only



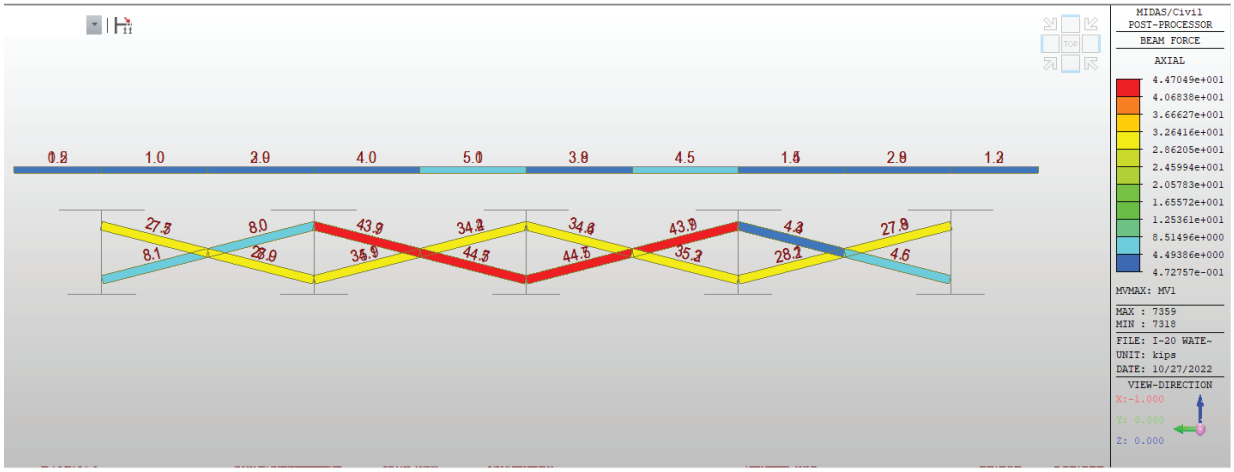
similarly, the two far left girders are the most critical one and thus the one we will focus on.



Kiewit	DESIGNED BY:	C. Kashosi	DATE: 10/28/22
	CHECKED BY:	H. Wolf	DATE:

	Exterior Girder	Interior Girder
Moment (k-ft)	2834.855	2402.224

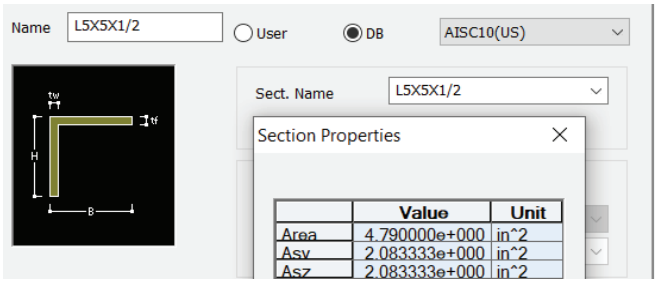
Looking the at cross frame forces, we ca see that the maximum tension force in members is 44.7kip



We need to check if the resistance of cross section elements are adequate to resist the applied tension.

Pu =	44.7	kips
Fy =	36	ksi
ø =	0.9	
Ag =	4.79	in^2

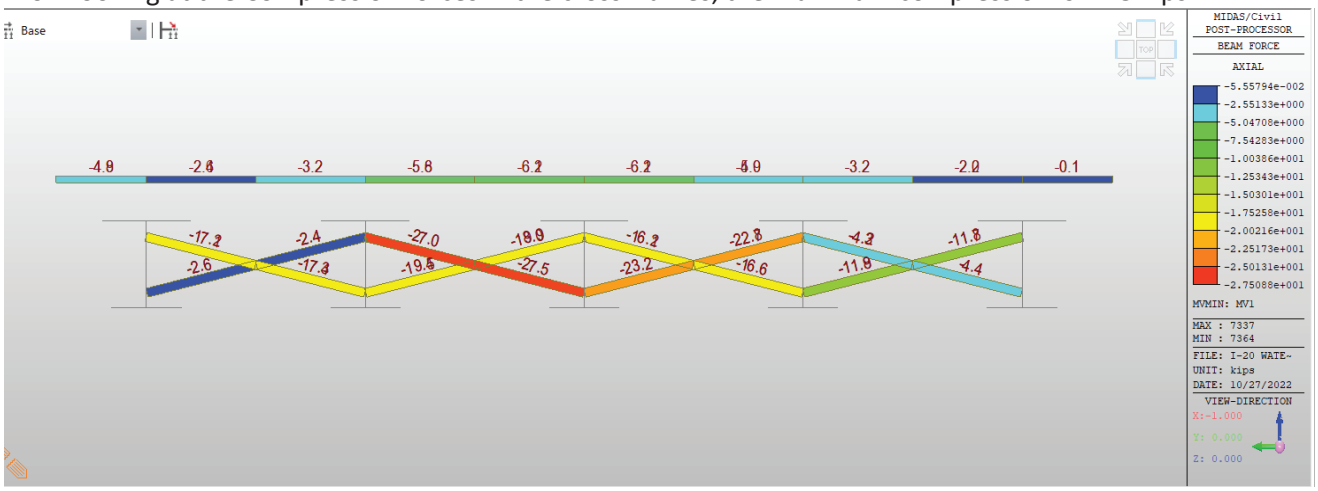
(D2-1, AISC Manual)



øPn = ø*Fy*Ag

øPn = 155.196 kips > 44.7 kips **OK**

Now looking at the Compression forces in the cross frames, the maximum compression is 27.5 kips



Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/28/22
	CHECKED BY:	H. Wolf	DATE:	

Checking if the resistance of cross section elements are adequate to resist the applied compression.

Pu =	27.5	kips
L =	10	ft

øPn =	70.5	kips	>	27.5 kips	**OK**	(Table 4-11, AISC Manual)

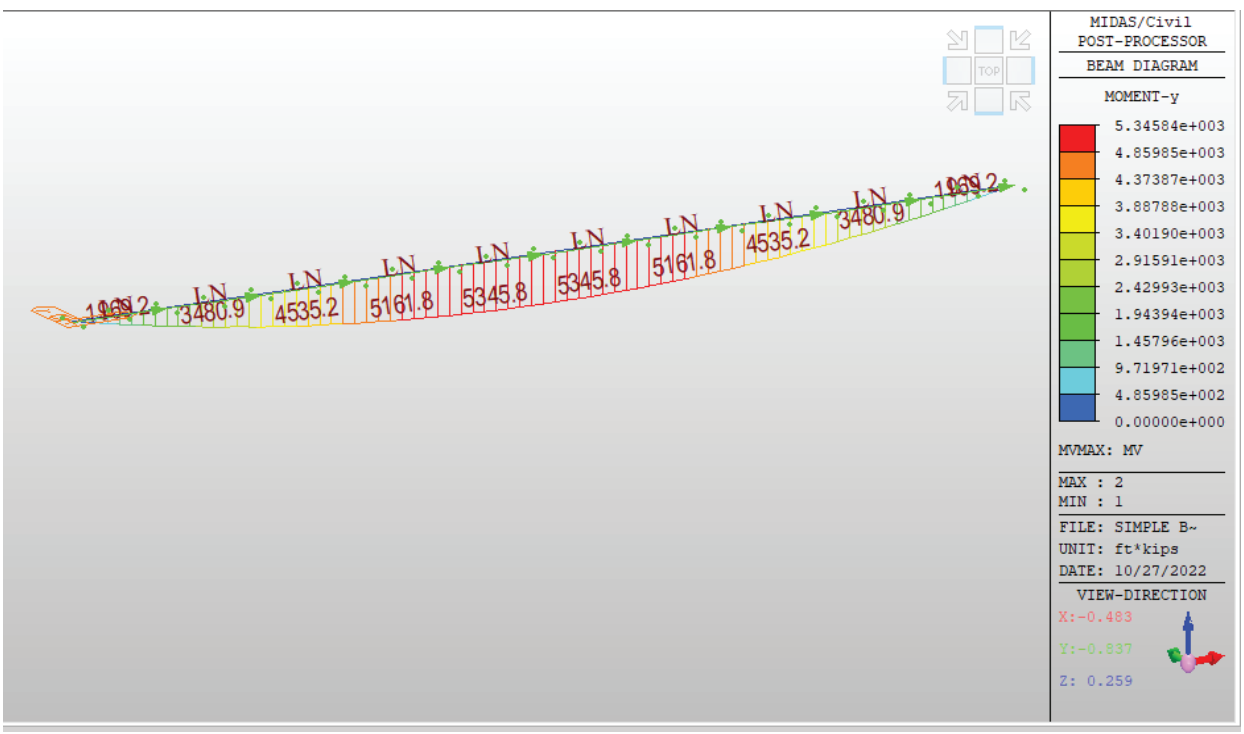
Thus the L5 x 5 x 1/2 section will be adequate to resist the applied forces

Both Cross-frame options results in the same Live Load Moment distribution into girders.
In addition both cross-frame have adequate sections to support the applied forces to them.

Now for validation purposes, let compare the Live load moments obtained from both models to the corresponding live load moment using the AASHTO Live Load Distribution factors (LLDF)

<u>AASTHO Live Load Distribution Factors (LLDF)</u>

Let apply a Line lane load to the Simple Beam model we created ealier in order to obtain the maximum applied Live load, then apply to LLDF obtained from hand calculation



The maximum Live load Moment is 5345.8 k-ft

DESIGNED BY:	C. Kashosi	**DATE:**	10/28/22
CHECKED BY:	H. Wolf	**DATE:**	

AASHTO LLDF

Typical X-section:	k		
L	156.75	ft	Table 4.6.2.2.1-2
Simplified $(Kg/12Lts^3)^{0.1}$	1.09		Table 4.6.2.2.1-3
Simplified $(Kg/12Lts^3)^{0.25}$	1.15		Table 4.6.2.2.1-3
Simplified $(12Lts^3/Kg)^{0.3}$	0.85		Table 4.6.2.2.1-3
Girder spacing (s)	10	ft	
# of girders (Nb)	5		
Deck thicnkess (ts)	8.5	in	
de	3	ft	
e	1.100		

Table 4.6.2.2.1-1

Table 4.6.2.2.2b-1—Live Load Distribution Factor for Moment in Interior Beams

Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	Distribution Factors	Range of Applicability
Wood Deck on Wood or Steel Beams	a, l	See Table 4.6.2.2.2a-1	
Concrete Deck on Wood Beams	l	One Design Lane Loaded: $S/12.0$ Two or More Design Lanes Loaded: $S/10.0$	$S \le 6.0$
Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-beams, T- and Double T-sections	a, e, k and also i, j if sufficiently connected to act as a unit	One Design Lane Loaded: $0.06+\left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$ Two or More Design Lanes Loaded: $0.075+\left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0\,Lt_s^3}\right)^{0.1}$	$3.5 \le S \le 16.0$ $4.5 \le t_s \le 12.0$ $20 \le L \le 240$ $N_b \ge 4$ $10{,}000 \le K_g \le 7{,}000{,}000$
		use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$

n Articles 4.6.2.2.2 and 4.6.2.2.3

Typical Cross-Section

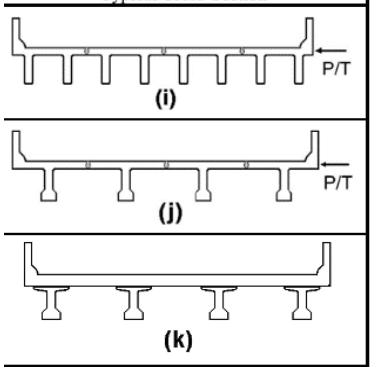


Table 4.6.2.2.2d-1—Live Load Distribution Factor for Moment in Exterior Longitudinal Beams

Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	One Design Lane Loaded	Two or More Design Lanes Loaded	Range of Applicability
Wood Deck on Wood or Steel Beams	a, l	Lever Rule	Lever Rule	N/A
Concrete Deck on Wood Beams	l	Lever Rule	Lever Rule	N/A
Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-beams, T- and Double T-sections	a, e, k and also i, j if sufficiently connected to act as a unit	Lever Rule	$g = e\,g_{interior}$ $e = 0.77 + \frac{d_e}{9.1}$	$-1.0 \le d_e \le 5.5$
			use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$

Therefore the LLDF for both exterior and interrior girders obtained from AASHTO are summarized in the table below:

LLDF for Moment	
Interior Girder	Exterior Girder
2^+ LN	2^+ LN
0.723	**0.795**

$M_{LL\text{-}midas}$ = 5346 k-ft

Now, applying the LLDF to the Maximum Live load moment from the Simple Beam Model, we have

	Exterior Girder	Interior Girder
Moment (k-ft)	4251.78	3866.42

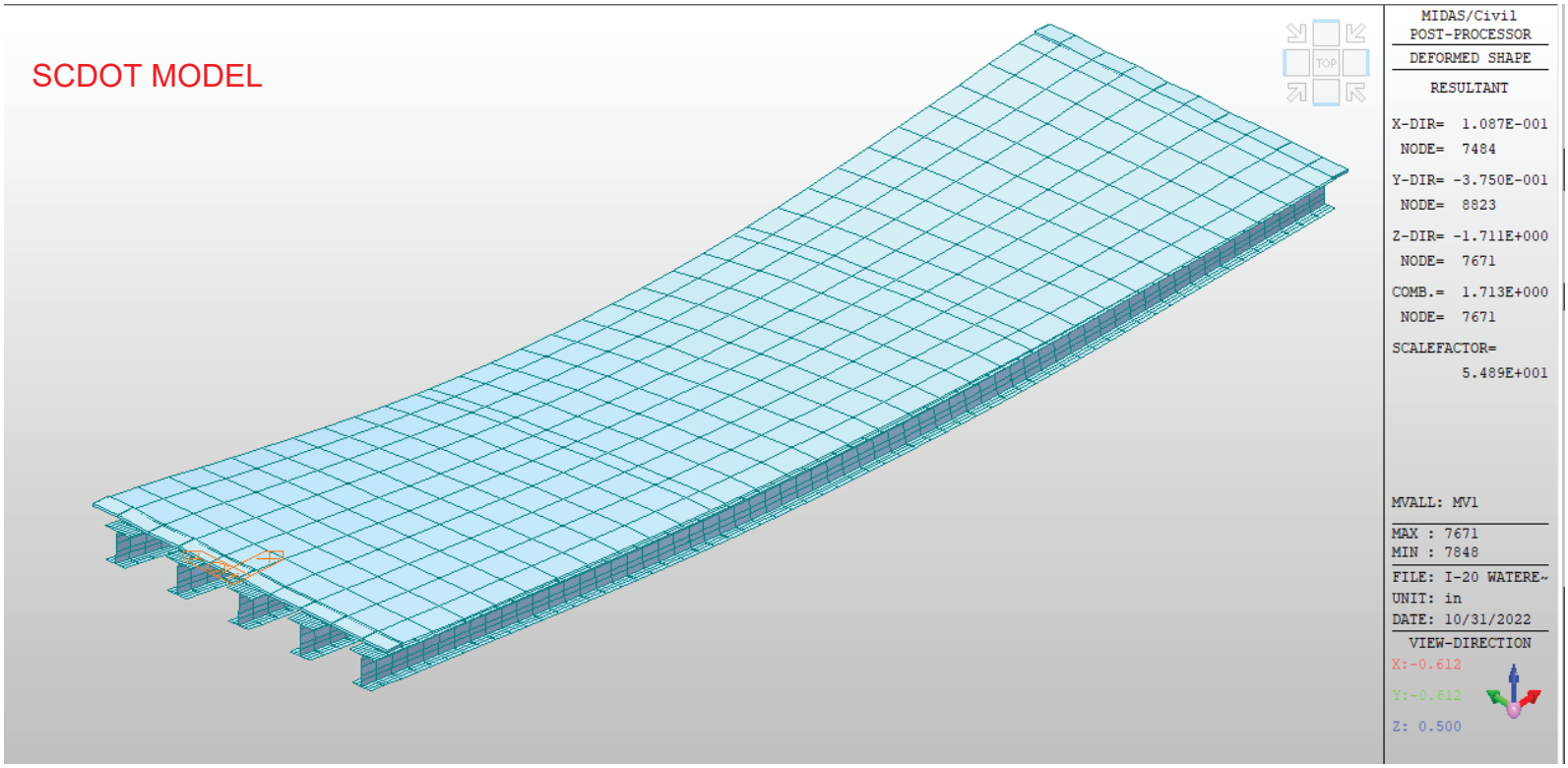
Comparing these values to the ones obtained from both the SCDOT and Kiewit models, we have:

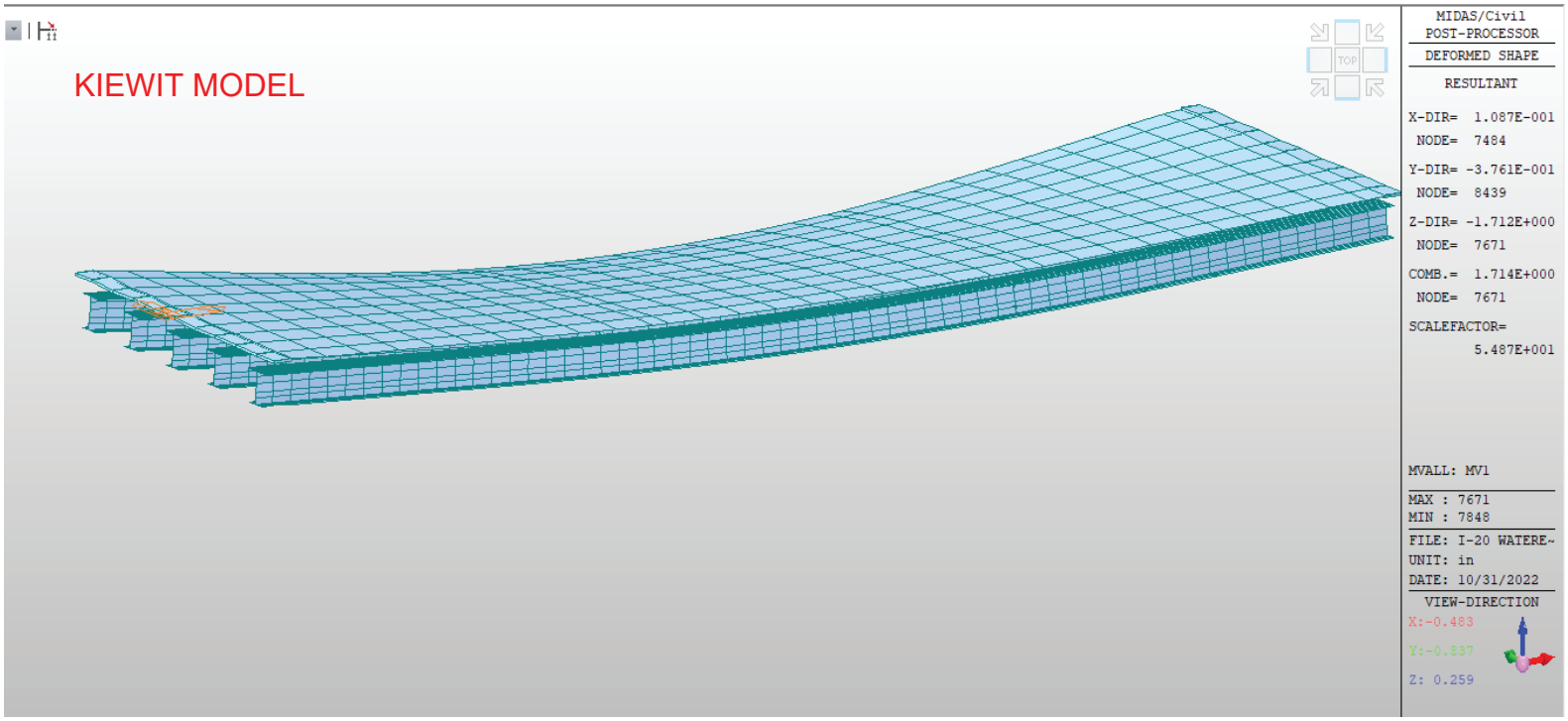
Maximum Live Load Moment		
	Exterior Girder	Interior Girder
ASHTO LLDF	4251.78	3866.42
SCDOT Model	2835.004	2401.261
Kiewit Model	2834.855	2402.224

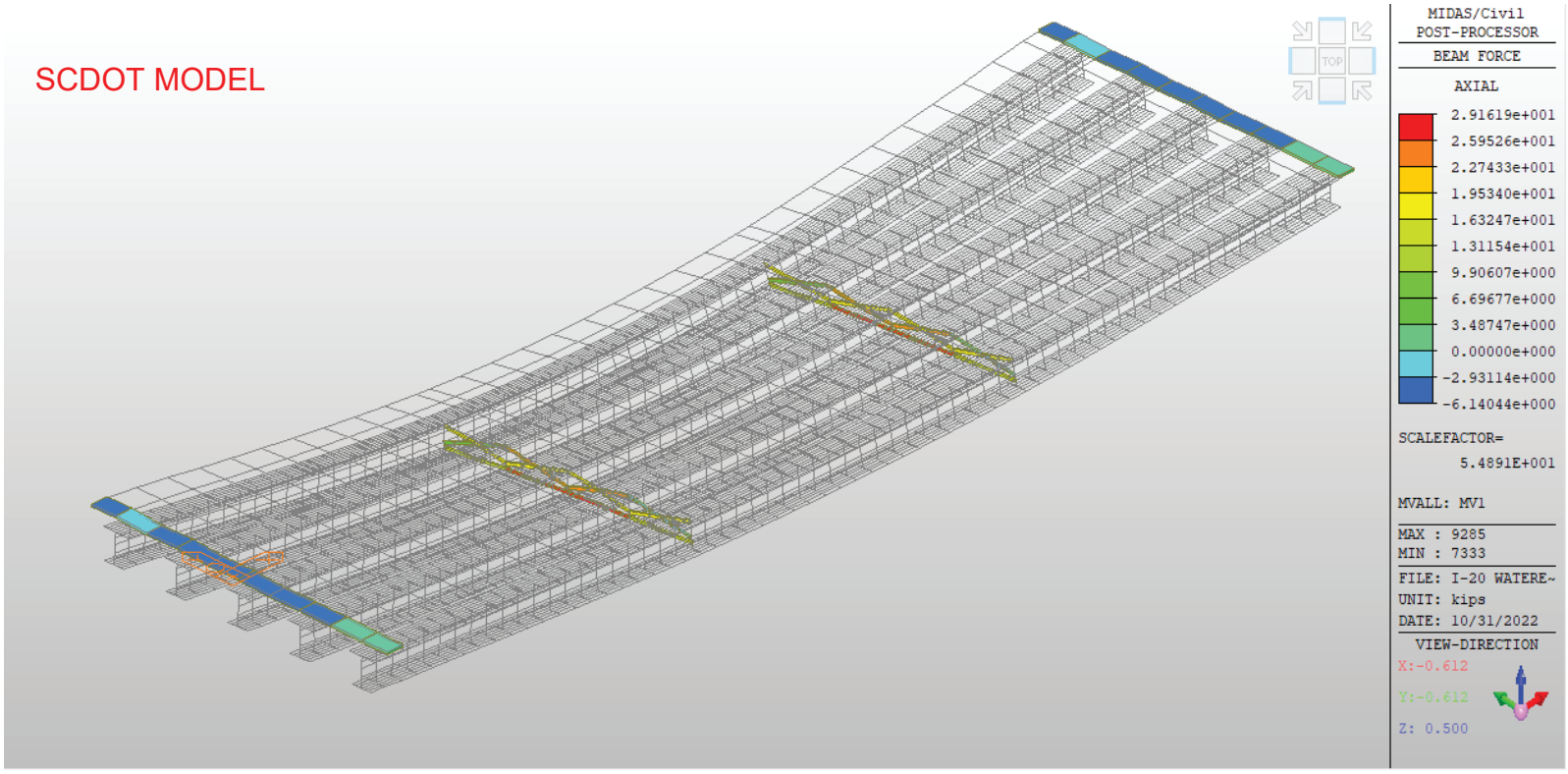
Knowing that AASTHO LLDF is a more conservative approach, and assuming it is these girders are to be designed with based on AASTHO LLDF, they will definitely be over desiged.

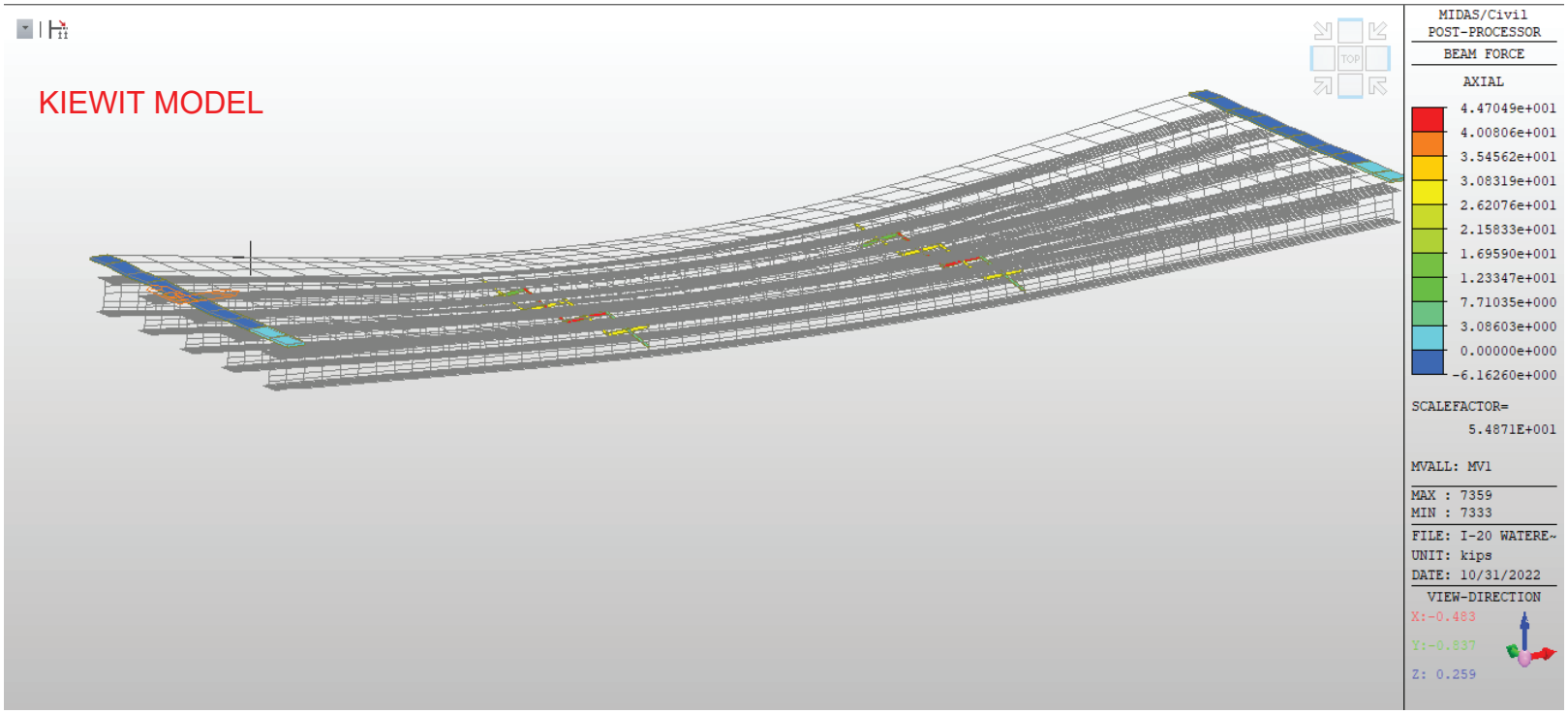
Conclusion

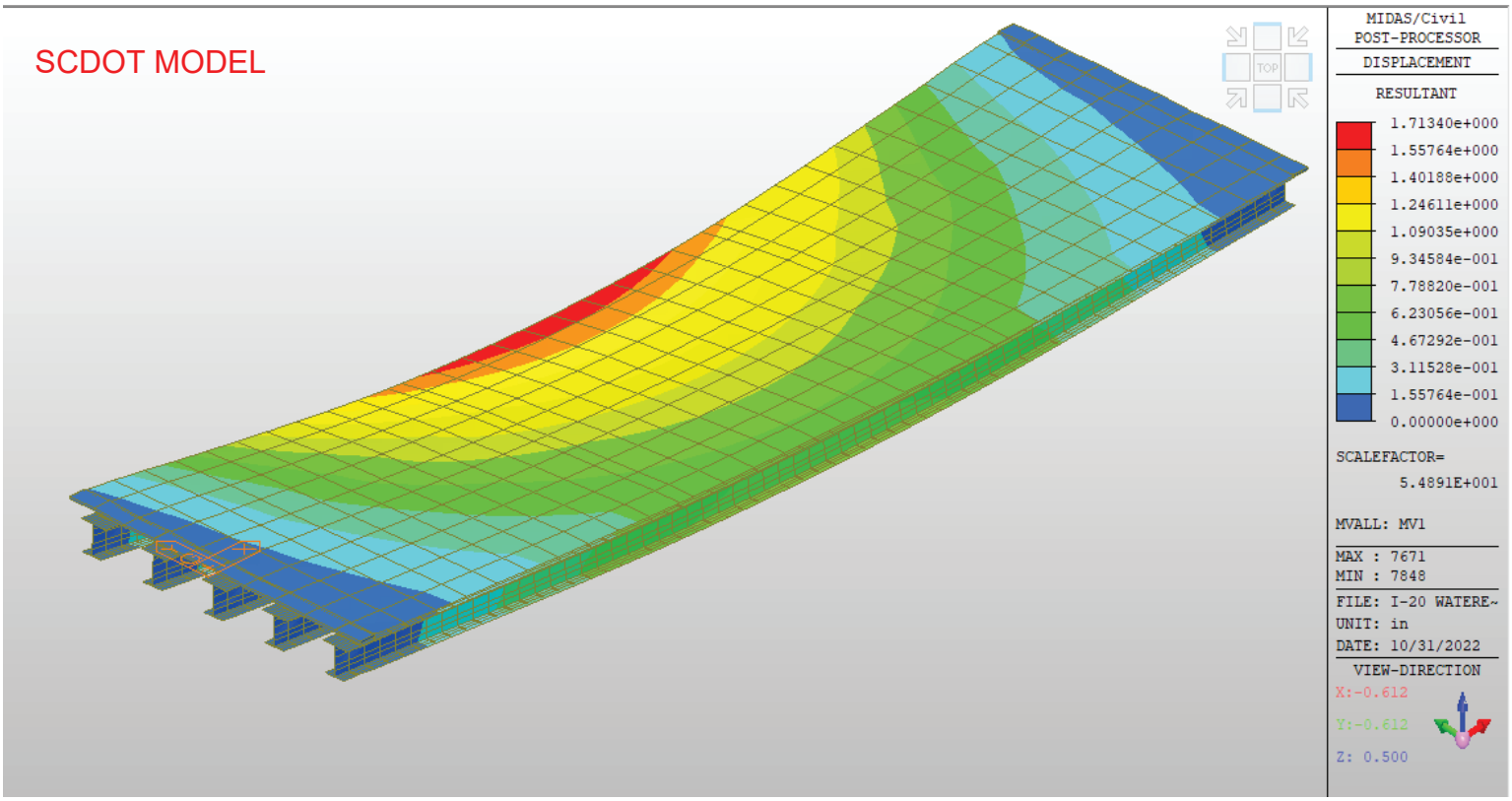
The use of either the SCDOT or Kiewit Cross-frame details would results in the relatively same Live load distribution over the girders. And will not have no detrimental negative effect on the girder service life.


SCDOT MODEL
MIDAS/Civil
POST-PROCESSOR
DEFORMED SHAPE
RESULTANT
X-DIR= 1.087E-001
NODE= 7484
Y-DIR= -3.750E-001
NODE= 8823
Z-DIR= -1.711E+000
NODE= 7671
COMB.= 1.713E+000
NODE= 7671
SCALEFACTOR=
5.489E+001
MVALL: MV1
MAX : 7671
MIN : 7848
FILE: I-20 WATERE~
UNIT: in
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.612
Y:-0.612
Z: 0.500


KIEWIT MODEL
MIDAS/Civil
POST-PROCESSOR
DEFORMED SHAPE
RESULTANT
X-DIR= 1.087E-001
NODE= 7484
Y-DIR= -3.761E-001
NODE= 8439
Z-DIR= -1.712E+000
NODE= 7671
COMB.= 1.714E+000
NODE= 7671
SCALEFACTOR=
5.487E+001
MVALL: MV1
MAX : 7671
MIN : 7848
FILE: I-20 WATERE~
UNIT: in
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.483
Y:-0.837
Z: 0.259


SCDOT MODEL
MIDAS/Civil
POST-PROCESSOR
BEAM FORCE
AXIAL
2.91619e+001
2.59526e+001
2.27433e+001
1.95340e+001
1.63247e+001
1.31154e+001
9.90607e+000
6.69677e+000
3.48747e+000
0.00000e+000
-2.93114e+000
-6.14044e+000
SCALEFACTOR=
5.4891E+001
MVALL: MV1
MAX : 9285
MIN : 7333
FILE: I-20 WATERE~
UNIT: kips
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.612
Y:-0.612
Z: 0.500


KIEWIT MODEL
MIDAS/Civil
POST-PROCESSOR
BEAM FORCE
AXIAL
4.47049e+001
4.00806e+001
3.54562e+001
3.08319e+001
2.62076e+001
2.15833e+001
1.69590e+001
1.23347e+001
7.71035e+000
3.08603e+000
0.00000e+000
-6.16260e+000
SCALEFACTOR=
5.4871E+001
MVALL: MV1
MAX : 7359
MIN : 7333
FILE: I-20 WATERE~
UNIT: kips
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.483
Y:-0.837
Z: 0.259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POST-PROCESSOR
DISPLACEMENT
RESULTANT
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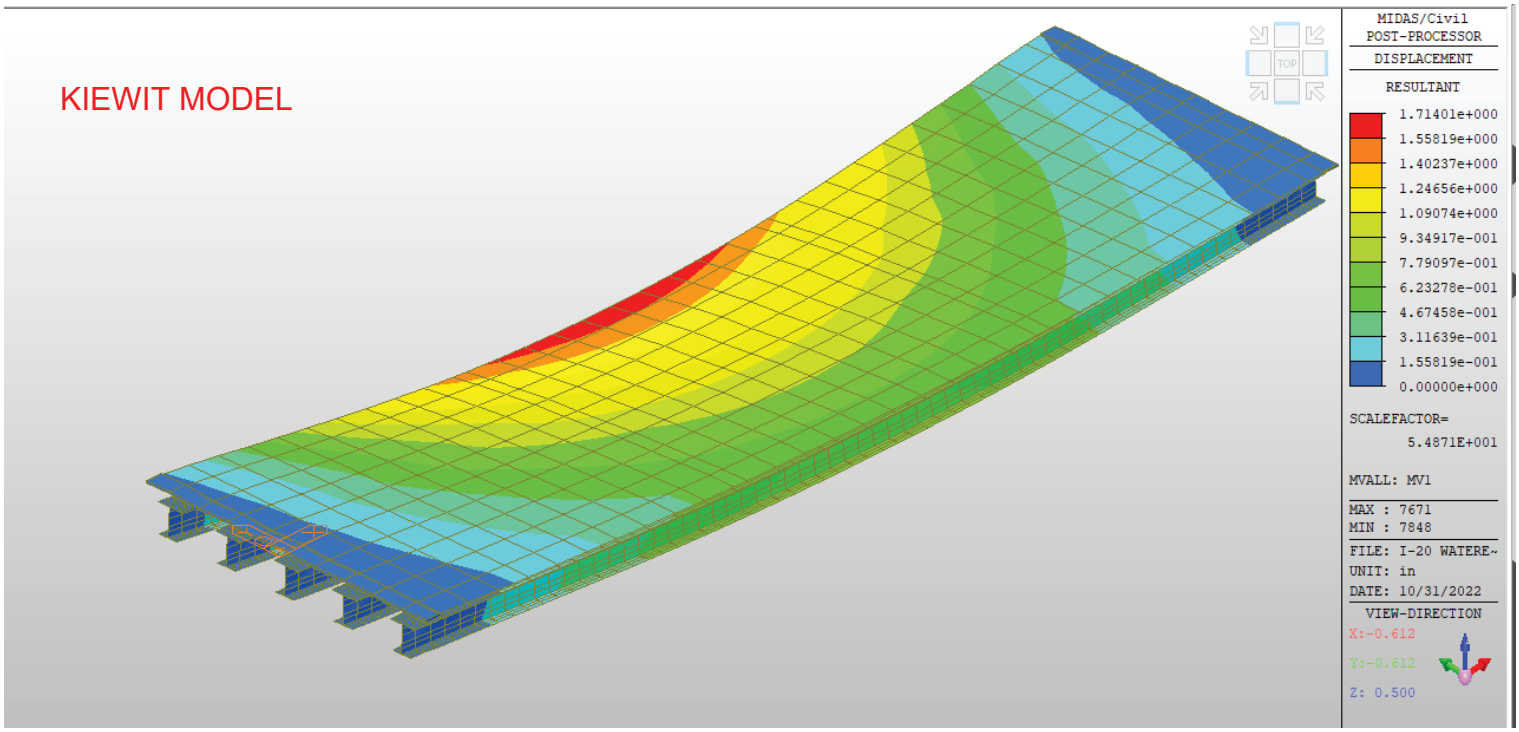
1.55764e+000
1.40188e+000
1.24611e+000
1.09035e+000
9.34584e-001
7.78820e-001
6.23056e-001
4.67292e-001
3.11528e-001
1.55764e-001
0.00000e+000
SCALEFACTOR=
5.4891E+001
MVALL: MV1
MAX : 7671
MIN : 7848
FILE: I-20 WATERE~
UNIT: in
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.612
Y:-0.612
Z: 0.500


KIEWIT MODEL
MIDAS/Civil
POST-PROCESSOR
DISPLACEMENT
RESULTANT
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1.55819e+000
1.40237e+000
1.24656e+000
1.09074e+000
9.34917e-001
7.79097e-001
6.23278e-001
4.67458e-001
3.11639e-001
1.55819e-001
0.00000e+000
SCALEFACTOR=
5.4871E+001
MVALL: MV1
MAX : 7671
MIN : 7848
FILE: I-20 WATERE~
UNIT: in
DATE: 10/31/2022
VIEW-DIRECTION
X:-0.612
Y:-0.612
Z: 0.500

APPENDIX 1: SCDOT MODEL RESULTS

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
1	MV1(n	I	6.42	8.27	2.59	119.4	323.96	745.07
1	MV1(n	J	5.92	9.74	1.44	129.5	798.42	1685.15
2	MV1(n	I	5.92	9.74	1.44	326.3	769.35	814.39
2	MV1(n	J	5.92	9.74	1.44	326.3	2577.04	648.65
3	MV1(n	I	5.92	9.74	1.44	129.5	728.13	1863.66
3	MV1(n	J	5.22	11.96	2.54	131.4	1810.78	1600.84
4	MV1(n	I	5.22	11.96	2.54	468.9	2297.52	892.88
4	MV1(n	J	5.22	11.96	2.54	468.9	5559.37	589.1
5	MV1(n	I	5.22	11.96	2.54	131.4	1595.83	1893.61
5	MV1(n	J	5.22	11.96	2.54	468.9	5559.37	589.1
6	MV1(n	I	5.22	11.96	2.54	131.4	1595.83	1893.61
6	MV1(n	J	3.62	13.54	3.95	119.9	3635.24	1471.82
7	MV1(n	I	3.62	13.54	3.95	479.7	5330.84	861.86
7	MV1(n	J	3.62	13.54	3.95	479.7	8775.78	495.46
8	MV1(n	I	3.62	13.54	3.95	119.9	3171.51	1830.03
8	MV1(n	J	2.35	12.99	6.91	129.7	5998.71	1353.41
9	MV1(n	I	2.35	12.99	6.91	428.7	8739.67	755.97
9	MV1(n	J	2.35	12.99	6.91	428.7	12266.1	409.52
10	MV1(n	I	2.35	12.99	6.91	129.7	5475.06	1703.17
10	MV1(n	J	1.91	11.74	10.49	136.8	8259.4	1249.37
11	MV1(n	I	1.91	11.74	10.49	350.5	12217.3	644.04
11	MV1(n	J	1.91	11.74	10.49	350.5	15735.2	338.79
12	MV1(n	I	1.91	11.74	10.49	136.8	7746.21	1576.58
12	MV1(n	J	1.63	10.56	14.14	140.3	10358.4	1162.2
13	MV1(n	I	1.63	10.56	14.14	280.1	15663.2	565.05
13	MV1(n	J	1.63	10.56	14.14	280.1	19057.9	283.43
14	MV1(n	I	1.63	10.56	14.14	140.3	9857.31	1462.7
14	MV1(n	J	1.36	9.88	18.05	146.2	12426.6	1097.25
15	MV1(n	I	1.36	9.88	18.05	240	18972.1	502.35
15	MV1(n	J	1.36	9.88	18.05	240	22152.9	241.52
16	MV1(n	I	1.36	9.88	18.05	146.2	11843.7	1362.95
16	MV1(n	J	1.1	9.92	21.91	166.7	14649	1065.11
17	MV1(n	I	1.1	9.92	21.91	225.8	22072.8	445.71
17	MV1(n	J	1.1	9.92	21.91	225.8	24950.6	240.31
18	MV1(n	I	1.1	9.92	21.91	166.7	14081.9	1269.89
18	MV1(n	J	0.88	10.5	25.53	203.5	16673.4	1107.02
19	MV1(n	I	0.88	10.5	25.53	218.8	24881.1	355.14
19	MV1(n	J	0.88	10.5	25.53	218.8	27400.7	348.55
20	MV1(n	I	0.88	10.5	25.53	203.5	16157.3	1183.38

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
20	MV1(n	J	0.72	13.07	28.63	253.9	18464.6	1247.53
21	MV1(n	I	0.72	13.07	28.63	215.1	27332.7	261.16
21	MV1(n	J	0.72	13.07	28.63	215.1	29472.7	659.91
22	MV1(n	I	0.72	13.07	28.63	253.9	18023.2	1273.39
22	MV1(n	J	0.63	15.44	29.88	268.4	30250.4	278.69
23	MV1(n	I	0.63	15.44	29.88	268.4	29402.6	487.81
23	MV1(n	J	0.55	11.83	29.87	446.1	20532.1	878.4
24	MV1(n	I	0.55	11.83	29.87	361.8	30199.3	282.06
24	MV1(n	J	0.55	11.83	29.87	361.8	31738.6	81.52
25	MV1(n	I	0.55	11.83	29.87	446.1	20251.4	1000.79
25	MV1(n	J	0.46	8.46	32.58	360.4	21596.7	774.34
26	MV1(n	I	0.46	8.46	32.58	377.1	31673	123.44
26	MV1(n	J	0.46	8.46	32.58	377.1	32820.6	128.58
27	MV1(n	I	0.46	8.46	32.58	360.4	21415.5	873.96
27	MV1(n	J	0.37	7.12	35.79	313.5	22368.2	757.1
28	MV1(n	I	0.37	7.12	35.79	366.8	32772.5	152.31
28	MV1(n	J	0.37	7.12	35.79	366.8	33560.8	149.02
29	MV1(n	I	0.37	7.12	35.79	313.5	22250.3	834.26
29	MV1(n	J	0.3	6.11	39.38	294.7	22849.9	769.5
30	MV1(n	I	0.3	6.11	39.38	357.6	33520.1	166.31
30	MV1(n	J	0.3	6.11	39.38	357.6	33950.7	152.73
31	MV1(n	I	0.3	6.11	39.38	294.7	22785.3	831.12
31	MV1(n	J	0.22	5.44	43.25	323.3	23040.7	793.64
32	MV1(n	I	0.22	5.44	43.25	364.2	33914.6	162.15
32	MV1(n	J	0.22	5.44	43.25	364.2	33994.9	157.54
33	MV1(n	I	0.22	5.44	43.25	323.3	23027.6	809.33
33	MV1(n	J	0.18	5.15	47.29	382.1	22950.4	815.91
34	MV1(n	I	0.18	5.15	47.29	389.5	34020	156.84
34	MV1(n	J	0.18	5.15	47.29	389.5	33784.9	162.3
35	MV1(n	I	0.18	5.15	47.29	382.1	22984.5	786.93
35	MV1(n	J	0.24	5.04	51.39	448.4	22572.4	831.13
36	MV1(n	I	0.24	5.04	51.39	430	33820.1	153.49
36	MV1(n	J	0.24	5.04	51.39	430	33230.5	159.87
37	MV1(n	I	0.24	5.04	51.39	448.4	22657.8	762
37	MV1(n	J	0.3	4.89	55.44	526.3	21893.9	836.77
38	MV1(n	I	0.3	4.89	55.44	483.2	33272.5	145.14
38	MV1(n	J	0.3	4.89	55.44	483.2	32326.9	130.78
39	MV1(n	I	0.3	4.89	55.44	526.3	22034.7	769.68
39	MV1(n	J	0.37	5.04	59.25	625.9	20915.2	907.42

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
40	MV1(n	I	0.37	5.04	59.25	538.9	32368.5	111.45
40	MV1(n	J	0.37	5.04	59.25	538.9	31055.7	162.01
41	MV1(n	I	0.37	5.04	59.25	625.9	21123.2	806.08
41	MV1(n	J	0.45	6.15	62.61	762.6	19608.8	1120.14
42	MV1(n	I	0.45	6.15	62.61	648.7	31118	123.68
42	MV1(n	J	0.45	6.15	62.61	648.7	29410	493.39
43	MV1(n	I	0.45	6.15	62.61	762.6	19915.7	1068.48
43	MV1(n	J	0.52	14.22	67.88	683.5	28517.3	290.28
44	MV1(n	I	0.52	14.22	67.88	683.5	29461.7	557.16
44	MV1(n	J	0.6	12.47	69.07	877.8	17173.4	1220.88
45	MV1(n	I	0.6	12.47	69.07	778.8	28576.3	457.99
45	MV1(n	J	0.6	12.47	69.07	778.8	26269.7	333.85
46	MV1(n	I	0.6	12.47	69.07	877.8	17644.3	1140.76
46	MV1(n	J	0.76	10.08	74.13	830.7	15198.5	1220.3
47	MV1(n	I	0.76	10.08	74.13	758	26338.2	290.11
47	MV1(n	J	0.76	10.08	74.13	758	23646.8	406.53
48	MV1(n	I	0.76	10.08	74.13	830.7	15733.3	1088.45
48	MV1(n	J	0.97	7.93	79.26	799.9	13038.3	1310.72
49	MV1(n	I	0.97	7.93	79.26	774.4	23720.6	237.03
49	MV1(n	J	0.97	7.93	79.26	774.4	20693.7	476.58
50	MV1(n	I	0.97	7.93	79.26	799.9	13616	1078.61
50	MV1(n	J	1.21	7.13	84.41	783.7	10844.8	1407.04
51	MV1(n	I	1.21	7.13	84.41	817.5	20773.9	260.66
51	MV1(n	J	1.21	7.13	84.41	817.5	17480.2	534.92
52	MV1(n	I	1.21	7.13	84.41	783.7	11342.6	1126.3
52	MV1(n	J	1.46	7.71	89.64	792.1	8832.54	1513.75
53	MV1(n	I	1.46	7.71	89.64	865.1	17559.5	309.56
53	MV1(n	J	1.46	7.71	89.64	865.1	14093.3	605.74
54	MV1(n	I	1.46	7.71	89.64	792.1	9362.28	1200.99
54	MV1(n	J	1.74	9.06	94.99	805.5	6641.84	1634.96
55	MV1(n	I	1.74	9.06	94.99	908	14157.1	372.2
55	MV1(n	J	1.74	9.06	94.99	908	10608.9	696.75
56	MV1(n	I	1.74	9.06	94.99	805.5	7196.28	1296.31
56	MV1(n	J	2.45	10.27	100.59	811.7	4315.05	1764.79
57	MV1(n	I	2.45	10.27	100.59	931.3	10668.2	450.45
57	MV1(n	J	2.45	10.27	100.59	931.3	7148.7	810.53
58	MV1(n	I	2.45	10.27	100.59	811.7	4901.88	1408.05
58	MV1(n	J	4.01	10.45	106.52	798	2137.96	1880.32
59	MV1(n	I	4.01	10.45	106.52	904.2	7267.4	542.15

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
59	MV1(n	J	4.01	10.45	106.52	904.2	3895.7	898.5
60	MV1(n	I	4.01	10.45	106.52	798	2627.69	1534.82
60	MV1(n	J	5.27	7.99	112.87	757.2	1149.44	1930.73
61	MV1(n	I	5.27	7.99	112.87	790.5	4210.12	638.84
61	MV1(n	J	5.27	7.99	112.87	790.5	1488.19	914.74
62	MV1(n	I	5.27	7.99	112.87	757.2	1330.25	1670.68
62	MV1(n	J	5.96	3.27	119.6	687	472.01	1885.35
63	MV1(n	I	5.96	3.27	119.6	553.1	1553.58	722.18
63	MV1(n	J	5.96	3.27	119.6	553.1	324.1	813.12
64	MV1(n	I	5.96	3.27	119.6	687	451.01	1779.46
64	MV1(n	J	5.96	3.27	119.6	553.1	324.1	813.12
65	MV1(n	I	0.88	8.56	1.01	727	44.81	172.37
65	MV1(n	J	0.97	11.24	0.74	455.3	601.29	323.93
66	MV1(n	I	0.97	11.24	0.74	684	625.79	544.97
66	MV1(n	J	0.97	11.24	0.74	684	2425.99	366.79
67	MV1(n	I	0.97	11.24	0.74	455.3	458.76	604.06
67	MV1(n	J	1.18	15.06	2.78	420.5	1815.43	511.98
68	MV1(n	I	1.18	15.06	2.78	828.9	2266.6	1016.78
68	MV1(n	J	1.18	15.06	2.78	828.9	5224.17	519.34
69	MV1(n	I	1.18	15.06	2.78	420.5	1534.75	1098.89
69	MV1(n	J	1.18	15.06	2.78	828.9	5224.17	519.34
70	MV1(n	I	1.18	15.06	2.78	420.5	1534.75	1098.89
70	MV1(n	J	0.94	14.82	4.98	422.2	3673.93	629.15
71	MV1(n	I	0.94	14.82	4.98	844.8	5049.12	1227.33
71	MV1(n	J	0.94	14.82	4.98	844.8	8152.62	629.82
72	MV1(n	I	0.94	14.82	4.98	422.2	3163.24	1302.91
72	MV1(n	J	0.73	14.41	8.08	421.4	5782.67	821.2
73	MV1(n	I	0.73	14.41	8.08	798.2	7993.78	1436.11
73	MV1(n	J	0.73	14.41	8.08	798.2	11011.2	830.68
74	MV1(n	I	0.73	14.41	8.08	421.4	5281.73	1493.32
74	MV1(n	J	0.64	13.24	11.65	419.9	7798.07	1048.16
75	MV1(n	I	0.64	13.24	11.65	715.5	10891.5	1615.13
75	MV1(n	J	0.64	13.24	11.65	715.5	13714.5	1058.05
76	MV1(n	I	0.64	13.24	11.65	419.9	7340.42	1663.58
76	MV1(n	J	0.59	12.09	15.13	401.8	9696.6	1281.82
77	MV1(n	I	0.59	12.09	15.13	624.2	13630.3	1774.47
77	MV1(n	J	0.59	12.09	15.13	624.2	16279.6	1290.68
78	MV1(n	I	0.59	12.09	15.13	401.8	9242.88	1813.59
78	MV1(n	J	0.54	11.48	18.62	378.2	11407.6	1509.2

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
79	MV1(n	I	0.54	11.48	18.62	544.8	16245.1	1919.3
79	MV1(n	J	0.54	11.48	18.62	544.8	18760.3	1514.92
80	MV1(n	I	0.54	11.48	18.62	378.2	10971.7	1942.32
80	MV1(n	J	0.49	11.92	21.9	363.5	12923.1	1706.09
81	MV1(n	I	0.49	11.92	21.9	511	18721.9	2036.14
81	MV1(n	J	0.49	11.92	21.9	511	20990.8	1701.6
82	MV1(n	I	0.49	11.92	21.9	363.5	12508.3	2021.15
82	MV1(n	J	0.44	14.15	25.16	407.2	14384.3	1828.17
83	MV1(n	I	0.44	14.15	25.16	488.9	20948.3	2060.01
83	MV1(n	J	0.44	14.15	25.16	488.9	22943.7	1823.32
84	MV1(n	I	0.44	14.15	25.16	407.2	13971.5	1951.68
84	MV1(n	J	0.38	18.11	27.79	610.5	15749.5	1873.55
85	MV1(n	I	0.38	18.11	27.79	458.4	22907.4	1989.68
85	MV1(n	J	0.38	18.11	27.79	458.4	24628.8	1818.49
86	MV1(n	I	0.38	18.11	27.79	610.5	15400.9	1932.27
86	MV1(n	J	0.34	17.24	28.55	666.8	25310.7	1931.55
87	MV1(n	I	0.34	17.24	28.55	666.8	24603.7	1935.82
87	MV1(n	J	0.3	13.33	28.05	807.1	17455.3	2044.68
88	MV1(n	I	0.3	13.33	28.05	623.4	25299.3	2073.31
88	MV1(n	J	0.3	13.33	28.05	623.4	26659.2	2116.82
89	MV1(n	I	0.3	13.33	28.05	807.1	17233.1	2111.27
89	MV1(n	J	0.24	10.04	30.27	555.7	18404.8	2249.58
90	MV1(n	I	0.24	10.04	30.27	571.7	26642.6	2291.32
90	MV1(n	J	0.24	10.04	30.27	571.7	27685	2266.95
91	MV1(n	I	0.24	10.04	30.27	555.7	18269.3	2305.37
91	MV1(n	J	0.18	8.58	33.13	469.6	19133.2	2314.15
92	MV1(n	I	0.18	8.58	33.13	547.6	27665.6	2328.41
92	MV1(n	J	0.18	8.58	33.13	547.6	28381.5	2315.1
93	MV1(n	I	0.18	8.58	33.13	469.6	19047.2	2333.16
93	MV1(n	J	0.13	7.63	36.49	460.5	19603.8	2338.97
94	MV1(n	I	0.13	7.63	36.49	539	28362.2	2342.75
94	MV1(n	J	0.13	7.63	36.49	539	28748.4	2330.75
95	MV1(n	I	0.13	7.63	36.49	460.5	19553.1	2349.51
95	MV1(n	J	0.08	7	40.23	487.8	19795	2345.92
96	MV1(n	I	0.08	7	40.23	544.1	28731.2	2344.79
96	MV1(n	J	0.08	7	40.23	544.1	28811.3	2336.28
97	MV1(n	I	0.08	7	40.23	487.8	19785.9	2354.09
97	MV1(n	J	0.08	6.77	44.19	512.4	19708.5	2344.5
98	MV1(n	I	0.08	6.77	44.19	567.1	28815.1	2341.26

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
98	MV1(n	J	0.08	6.77	44.19	567.1	28605.1	2336.23
99	MV1(n	I	0.08	6.77	44.19	512.4	19737.1	2350.6
99	MV1(n	J	0.12	6.85	48.23	536.4	19341.8	2332
100	MV1(n	I	0.12	6.85	48.23	607.1	28621.6	2330.78
100	MV1(n	J	0.12	6.85	48.23	607.1	28083.5	2327.17
101	MV1(n	I	0.12	6.85	48.23	536.4	19409.8	2336.17
101	MV1(n	J	0.16	7	52.21	588.4	18703.3	2304.88
102	MV1(n	I	0.16	7	52.21	655	28101.9	2303.31
102	MV1(n	J	0.16	7	52.21	655	27235.7	2296.82
103	MV1(n	I	0.16	7	52.21	588.4	18809	2295.42
103	MV1(n	J	0.21	7.15	55.93	714	17800.5	2252.7
104	MV1(n	I	0.21	7.15	55.93	715.2	27255.5	2227.18
104	MV1(n	J	0.21	7.15	55.93	715.2	26067.2	2224.19
105	MV1(n	I	0.21	7.15	55.93	714	17962.5	2196.35
105	MV1(n	J	0.26	9.5	59.23	965	16662	2036.73
106	MV1(n	I	0.26	9.5	59.23	769.2	26086.6	2027.15
106	MV1(n	J	0.26	9.5	59.23	769.2	24594.7	1982.43
107	MV1(n	I	0.26	9.5	59.23	965	16905.6	1946
107	MV1(n	J	0.3	25.91	61.23	659.1	23859.4	1919.32
108	MV1(n	I	0.3	25.91	61.23	659.1	24605.3	1849.57
108	MV1(n	J	0.33	21.61	61.23	744.9	14723.5	1921.91
109	MV1(n	I	0.33	21.61	61.23	801.9	23886.3	1837.46
109	MV1(n	J	0.33	21.61	61.23	801.9	22039	1988.25
110	MV1(n	I	0.33	21.61	61.23	744.9	15091.5	1869.72
110	MV1(n	J	0.38	17.36	64.31	687.3	13217.8	2004.15
111	MV1(n	I	0.38	17.36	64.31	808.9	22073.1	1783.35
111	MV1(n	J	0.38	17.36	64.31	808.9	19950.1	2061.42
112	MV1(n	I	0.38	17.36	64.31	687.3	13643.9	1783.91
112	MV1(n	J	0.41	14.71	67.99	690.3	11757.3	1991.16
113	MV1(n	I	0.41	14.71	67.99	803.9	19991.2	1629.53
113	MV1(n	J	0.41	14.71	67.99	803.9	17597.8	1984.65
114	MV1(n	I	0.41	14.71	67.99	690.3	12177	1629.31
114	MV1(n	J	0.45	14.33	72.25	708.9	10125.3	1879.13
115	MV1(n	I	0.45	14.33	72.25	812.7	17637.2	1420.62
115	MV1(n	J	0.45	14.33	72.25	812.7	15022.4	1847.61
116	MV1(n	I	0.45	14.33	72.25	708.9	10571.6	1412.94
116	MV1(n	J	0.47	15.52	76.92	716	8305.53	1734.02
117	MV1(n	I	0.47	15.52	76.92	860.3	15079.8	1184.21
117	MV1(n	J	0.47	15.52	76.92	860.3	12375.8	1689.94

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
118	MV1(n	I	0.47	15.52	76.92	716	8775.35	1174.78
118	MV1(n	J	0.51	17.41	81.98	696.3	6328.45	1565.65
119	MV1(n	I	0.51	17.41	81.98	905	12475.4	947.52
119	MV1(n	J	0.51	17.41	81.98	905	9562.65	1513.8
120	MV1(n	I	0.51	17.41	81.98	696.3	6839.07	937.92
120	MV1(n	J	0.62	18.87	87.34	648.5	4203.2	1369.08
121	MV1(n	I	0.62	18.87	87.34	910	9696.72	720.99
121	MV1(n	J	0.62	18.87	87.34	910	6621.85	1307.61
122	MV1(n	I	0.62	18.87	87.34	648.5	4757.59	716.03
122	MV1(n	J	0.9	18.76	93.02	581.7	2237.02	1137.47
123	MV1(n	I	0.9	18.76	93.02	857.6	6801.36	556.19
123	MV1(n	J	0.9	18.76	93.02	857.6	3767.2	1051.75
124	MV1(n	I	0.9	18.76	93.02	581.7	2706.54	567.82
124	MV1(n	J	1.05	16.2	99.05	499.6	1000.88	817.75
125	MV1(n	I	1.05	16.2	99.05	720.5	3937.54	461.83
125	MV1(n	J	1.05	16.2	99.05	720.5	1444.12	746.74
126	MV1(n	I	1.05	16.2	99.05	499.6	1262.29	418.78
126	MV1(n	J	0.99	9.02	105.4	479.3	76.71	434.94
127	MV1(n	I	0.99	9.02	105.4	600.4	1481.82	243.11
127	MV1(n	J	0.99	9.02	105.4	600.4	48.97	395.75
128	MV1(n	I	0.99	9.02	105.4	479.3	71.78	210.85
128	MV1(n	J	0.99	9.02	105.4	600.4	48.97	395.75
129	MV1(n	I	1.82	6.78	1.83	620.9	100.54	154.4
129	MV1(n	J	1.38	7.35	0.58	437.5	534.57	261.1
130	MV1(n	I	1.38	7.35	0.58	540.8	556.82	422.05
130	MV1(n	J	1.38	7.35	0.58	540.8	2374.43	312.29
131	MV1(n	I	1.38	7.35	0.58	437.5	412.59	496.13
131	MV1(n	J	1.38	9.27	1.72	434.5	1767.54	391.04
132	MV1(n	I	1.38	9.27	1.72	597.6	2095.5	723.08
132	MV1(n	J	1.38	9.27	1.72	597.6	5003.05	403.55
133	MV1(n	I	1.38	9.27	1.72	434.5	1447.77	785.61
133	MV1(n	J	1.38	9.27	1.72	597.6	5003.05	403.55
134	MV1(n	I	1.38	9.27	1.72	434.5	1447.77	785.61
134	MV1(n	J	1.08	8.78	3.84	450.5	3656.79	527.59
135	MV1(n	I	1.08	8.78	3.84	552.3	4619.74	927.14
135	MV1(n	J	1.08	8.78	3.84	552.3	7520.16	542.93
136	MV1(n	I	1.08	8.78	3.84	450.5	3253.72	960.98
136	MV1(n	J	0.89	7.65	7.16	464	5787.72	766.51
137	MV1(n	I	0.89	7.65	7.16	496.5	7086.66	1116.02

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
137	MV1(n	J	0.89	7.65	7.16	496.5	9773.69	788.15
138	MV1(n	I	0.89	7.65	7.16	464	5368.2	1148.9
138	MV1(n	J	0.81	6.81	11.16	473.8	7753.19	1023.77
139	MV1(n	I	0.81	6.81	11.16	464.6	9509.21	1309.37
139	MV1(n	J	0.81	6.81	11.16	464.6	11929.8	1046.65
140	MV1(n	I	0.81	6.81	11.16	473.8	7355.24	1345.96
140	MV1(n	J	0.74	6.32	15.33	465.5	9456.88	1270.53
141	MV1(n	I	0.74	6.32	15.33	444.3	11821.3	1504.09
141	MV1(n	J	0.74	6.32	15.33	444.3	14017.6	1289.23
142	MV1(n	I	0.74	6.32	15.33	465.5	9063.28	1538.19
142	MV1(n	J	0.68	6.42	19.7	445	10849.9	1482.98
143	MV1(n	I	0.68	6.42	19.7	434.1	13927.8	1689.3
143	MV1(n	J	0.68	6.42	19.7	434.1	15878.4	1488.42
144	MV1(n	I	0.68	6.42	19.7	445	10466.4	1712.81
144	MV1(n	J	0.61	7.35	23.87	438.6	11953.8	1630.55
145	MV1(n	I	0.61	7.35	23.87	445.9	15800.7	1854.39
145	MV1(n	J	0.61	7.35	23.87	445.9	17504.1	1613.87
146	MV1(n	I	0.61	7.35	23.87	438.6	11582.1	1848.03
146	MV1(n	J	0.54	10.11	27.42	492.1	12813.4	1649.04
147	MV1(n	I	0.54	10.11	27.42	477.9	17429.8	1946.24
147	MV1(n	J	0.54	10.11	27.42	477.9	18907.7	1600.79
148	MV1(n	I	0.54	10.11	27.42	492.1	12495.4	1868.99
148	MV1(n	J	0.46	15.1	29.82	733.5	13677.3	1656.14
149	MV1(n	I	0.46	15.1	29.82	508.1	18843.8	1860.25
149	MV1(n	J	0.46	15.1	29.82	508.1	20138	1800.33
150	MV1(n	I	0.46	15.1	29.82	733.5	13383.2	1745.93
150	MV1(n	J	0.42	16.85	28.79	566.8	20685.2	1757.19
151	MV1(n	I	0.42	16.85	28.79	566.8	20091.1	1834.15
151	MV1(n	J	0.37	12.36	27.76	736.4	15042.2	1845.15
152	MV1(n	I	0.37	12.36	27.76	529.2	20669	1835.41
152	MV1(n	J	0.37	12.36	27.76	529.2	21853.5	2017.44
153	MV1(n	I	0.37	12.36	27.76	736.4	14858.4	1942.23
153	MV1(n	J	0.31	7.77	29.15	529.7	15874	2183.94
154	MV1(n	I	0.31	7.77	29.15	484.8	21822	2199.66
154	MV1(n	J	0.31	7.77	29.15	484.8	22770.7	2247.65
155	MV1(n	I	0.31	7.77	29.15	529.7	15771	2247.85
155	MV1(n	J	0.25	6.36	31.51	467.6	16541.7	2299.73
156	MV1(n	I	0.25	6.36	31.51	449.8	22737.5	2342.69
156	MV1(n	J	0.25	6.36	31.51	449.8	23413.6	2322.78

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
157	MV1(n	I	0.25	6.36	31.51	467.6	16484.9	2367.68
157	MV1(n	J	0.2	5.68	34.63	448.5	17026.3	2355.42
158	MV1(n	I	0.2	5.68	34.63	433.6	23376.8	2396.11
158	MV1(n	J	0.2	5.68	34.63	433.6	23754.9	2360.99
159	MV1(n	I	0.2	5.68	34.63	448.5	16992.6	2409.08
159	MV1(n	J	0.15	5.37	38.28	450.9	17258.3	2386.75
160	MV1(n	I	0.15	5.37	38.28	430.9	23719	2399.75
160	MV1(n	J	0.15	5.37	38.28	430.9	23788.5	2383.43
161	MV1(n	I	0.15	5.37	38.28	450.9	17251.3	2406.39
161	MV1(n	J	0.14	5.37	42.18	449.5	17164.2	2401.69
162	MV1(n	I	0.14	5.37	42.18	431.7	23814	2382.06
162	MV1(n	J	0.14	5.37	42.18	431.7	23599.8	2392.38
163	MV1(n	I	0.14	5.37	42.18	449.5	17185.3	2381.43
163	MV1(n	J	0.18	5.65	46.12	449.6	16753.1	2386.23
164	MV1(n	I	0.18	5.65	46.12	437.5	23636.9	2352.68
164	MV1(n	J	0.18	5.65	46.12	437.5	23117.3	2369.02
165	MV1(n	I	0.18	5.65	46.12	449.6	16797.1	2340.96
165	MV1(n	J	0.23	6.16	49.85	500.3	16160.4	2309.78
166	MV1(n	I	0.23	6.16	49.85	462.8	23153.9	2299.46
166	MV1(n	J	0.23	6.16	49.85	462.8	22346.4	2278.56
167	MV1(n	I	0.23	6.16	49.85	500.3	16232.1	2262.41
167	MV1(n	J	0.28	8.43	52.96	632.2	15339.4	2143.82
168	MV1(n	I	0.28	8.43	52.96	515.6	22375.4	2184.67
168	MV1(n	J	0.28	8.43	52.96	515.6	21309.7	2060.45
169	MV1(n	I	0.28	8.43	52.96	632.2	15465.3	2086.07
169	MV1(n	J	0.34	13.78	54.91	868	14350.6	1802
170	MV1(n	I	0.34	13.78	54.91	584.2	21345.6	1854.28
170	MV1(n	J	0.34	13.78	54.91	584.2	20072.3	1867.49
171	MV1(n	I	0.34	13.78	54.91	868	14555.5	1758.76
171	MV1(n	J	0.38	17.53	54.07	602.4	19521.5	1733.23
172	MV1(n	I	0.38	17.53	54.07	602.4	20097.8	1811.95
172	MV1(n	J	0.42	13.27	52.44	780	12851.3	1766.55
173	MV1(n	I	0.42	13.27	52.44	636.6	19572.4	1625.89
173	MV1(n	J	0.42	13.27	52.44	636.6	18194.5	1925.29
174	MV1(n	I	0.42	13.27	52.44	780	13160.6	1627.16
174	MV1(n	J	0.48	8.81	55.15	613.4	11999.8	1869.99
175	MV1(n	I	0.48	8.81	55.15	621.9	18267.4	1632.3
175	MV1(n	J	0.48	8.81	55.15	621.9	16686.5	1909.29
176	MV1(n	I	0.48	8.81	55.15	613.4	12334.6	1658.66

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
176	MV1(n	J	0.54	6.99	58.71	592.4	10994.5	1787.12
177	MV1(n	I	0.54	6.99	58.71	602.1	16761.1	1574.87
177	MV1(n	J	0.54	6.99	58.71	602.1	14944.1	1776.78
178	MV1(n	I	0.54	6.99	58.71	592.4	11370.1	1580.56
178	MV1(n	J	0.6	6.69	62.94	609.6	9753.11	1627.86
179	MV1(n	I	0.6	6.69	62.94	596.2	15026.8	1408.45
179	MV1(n	J	0.6	6.69	62.94	596.2	12963.7	1597.72
180	MV1(n	I	0.6	6.69	62.94	609.6	10143.6	1394.66
180	MV1(n	J	0.66	7.22	67.71	620.8	8213.53	1439.55
181	MV1(n	I	0.66	7.22	67.71	602.3	13061.7	1183.35
181	MV1(n	J	0.66	7.22	67.71	602.3	10761.7	1403.39
182	MV1(n	I	0.66	7.22	67.71	620.8	8623.09	1161.8
182	MV1(n	J	0.71	8.23	72.89	611	6381.08	1235.55
183	MV1(n	I	0.71	8.23	72.89	616	10875.1	926.22
183	MV1(n	J	0.71	8.23	72.89	616	8369.03	1200.41
184	MV1(n	I	0.71	8.23	72.89	611	6809.82	903.85
184	MV1(n	J	0.82	9.32	79.11	576.5	4299.85	1021.16
185	MV1(n	I	0.82	9.32	79.11	634.8	8754.82	667.09
185	MV1(n	J	0.82	9.32	79.11	634.8	5961.45	993.36
186	MV1(n	I	0.82	9.32	79.11	576.5	4758.98	649.88
186	MV1(n	J	1.13	10.16	85.67	529.4	2208.18	816.56
187	MV1(n	I	1.13	10.16	85.67	629.5	6396.47	442.78
187	MV1(n	J	1.13	10.16	85.67	629.5	3488.25	774.86
188	MV1(n	I	1.13	10.16	85.67	529.4	2656.07	459.35
188	MV1(n	J	1.33	9.57	92.39	482.5	916.57	613.91
189	MV1(n	I	1.33	9.57	92.39	573.5	3819.93	382.27
189	MV1(n	J	1.33	9.57	92.39	573.5	1333.93	547.26
190	MV1(n	I	1.33	9.57	92.39	482.5	1207.54	331.85
190	MV1(n	J	1.45	6.99	99.11	520.8	116.53	367.94
191	MV1(n	I	1.45	6.99	99.11	552.6	1396.86	224.31
191	MV1(n	J	1.45	6.99	99.11	552.6	102.81	311.17
192	MV1(n	I	1.45	6.99	99.11	520.8	99.13	178.29
192	MV1(n	J	1.45	6.99	99.11	552.6	102.81	311.17
193	MV1(n	I	8.16	3.94	1.57	541.3	428.01	103.79
193	MV1(n	J	8.27	13.19	1.41	187.9	909.93	270.16
194	MV1(n	I	8.27	13.19	1.41	341.1	737	619.69
194	MV1(n	J	8.27	13.19	1.41	341.1	1982.97	292.05
195	MV1(n	I	8.27	13.19	1.41	187.9	779.81	690.66
195	MV1(n	J	7.66	19.11	3.35	186.3	1693.32	452.94

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
196	MV1(n	I	7.66	19.11	3.35	310.8	1692.31	1015.68
196	MV1(n	J	7.66	19.11	3.35	310.8	3877.94	477.11
197	MV1(n	I	7.66	19.11	3.35	186.3	1470	1070.83
197	MV1(n	J	7.66	19.11	3.35	310.8	3877.94	477.11
198	MV1(n	I	7.66	19.11	3.35	186.3	1470	1070.83
198	MV1(n	J	6.29	19.96	5.23	223.5	2949.24	606.07
199	MV1(n	I	6.29	19.96	5.23	265.8	3606.66	1136.92
199	MV1(n	J	6.29	19.96	5.23	265.8	5763.33	617.01
200	MV1(n	I	6.29	19.96	5.23	223.5	2608.36	1152.62
200	MV1(n	J	4.55	18.9	8.11	250	4478.31	737.98
201	MV1(n	I	4.55	18.9	8.11	218.1	5593.26	1152.24
201	MV1(n	J	4.55	18.9	8.11	218.1	7694.83	746.72
202	MV1(n	I	4.55	18.9	8.11	250	4147.92	1161.89
202	MV1(n	J	3	16.85	11.69	281.2	5826.58	912.05
203	MV1(n	I	3	16.85	11.69	179	7531.57	1167.54
203	MV1(n	J	3	16.85	11.69	179	9478.67	946.84
204	MV1(n	I	3	16.85	11.69	281.2	5542.7	1209.33
204	MV1(n	J	1.9	14.95	15.19	305.8	6998	1130.73
205	MV1(n	I	1.9	14.95	15.19	152.9	9336.12	1281.21
205	MV1(n	J	1.9	14.95	15.19	152.9	11104.2	1162.78
206	MV1(n	I	1.9	14.95	15.19	305.8	6694.67	1321.56
206	MV1(n	J	1.31	14.2	18.69	340.2	8231.89	1337.11
207	MV1(n	I	1.31	14.2	18.69	201.9	10983.9	1393.03
207	MV1(n	J	1.31	14.2	18.69	201.9	12558.7	1367.82
208	MV1(n	I	1.31	14.2	18.69	340.2	7883.32	1422.44
208	MV1(n	J	0.98	15.52	21.93	409.7	9301.01	1529.85
209	MV1(n	I	0.98	15.52	21.93	268.7	12453	1532.09
209	MV1(n	J	0.98	15.52	21.93	268.7	13834.7	1560.21
210	MV1(n	I	0.98	15.52	21.93	409.7	8966.38	1562.24
210	MV1(n	J	0.75	19.05	24.58	544.6	10192.8	1713.88
211	MV1(n	I	0.75	19.05	24.58	346.4	13731.4	1699.21
211	MV1(n	J	0.75	19.05	24.58	346.4	14934.4	1751.43
212	MV1(n	I	0.75	19.05	24.58	544.6	9894.39	1725.51
212	MV1(n	J	0.57	24.39	26.28	860	10958.9	1988.98
213	MV1(n	I	0.57	24.39	26.28	427.5	14844.7	1841.8
213	MV1(n	J	0.57	24.39	26.28	427.5	15898.2	2226.79
214	MV1(n	I	0.57	24.39	26.28	860	10717.2	1861.85
214	MV1(n	J	0.48	10.69	25.5	378.7	16336	1938.36
215	MV1(n	I	0.48	10.69	25.5	378.7	15837.6	2082.26

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
215	MV1(n	J	0.41	9.62	23.27	203.2	12031.3	2009.06
216	MV1(n	I	0.41	9.62	23.27	290.5	16301.3	1981.8
216	MV1(n	J	0.41	9.62	23.27	290.5	17274.6	2014.66
217	MV1(n	I	0.41	9.62	23.27	203.2	11887.4	1975.44
217	MV1(n	J	0.32	9.73	24.08	181.3	12690	2082.81
218	MV1(n	I	0.32	9.73	24.08	299.9	17234.6	2071.51
218	MV1(n	J	0.32	9.73	24.08	299.9	18007.7	2083.58
219	MV1(n	I	0.32	9.73	24.08	181.3	12616.7	2071.4
219	MV1(n	J	0.26	9.93	25.69	183.1	13218.4	2110.68
220	MV1(n	I	0.26	9.93	25.69	332.4	17974	2103.18
220	MV1(n	J	0.26	9.93	25.69	332.4	18523.2	2108.38
221	MV1(n	I	0.26	9.93	25.69	183.1	13175.6	2105.46
221	MV1(n	J	0.22	9.74	27.95	211.6	13565.2	2128.5
222	MV1(n	I	0.22	9.74	27.95	365.2	18486.2	2127.27
222	MV1(n	J	0.22	9.74	27.95	365.2	18798.9	2126.99
223	MV1(n	I	0.22	9.74	27.95	211.6	13541.8	2131.45
223	MV1(n	J	0.18	9.55	30.72	244.8	13709.8	2136.71
224	MV1(n	I	0.18	9.55	30.72	401.8	18760.5	2138.58
224	MV1(n	J	0.18	9.55	30.72	401.8	18827.5	2133.93
225	MV1(n	I	0.18	9.55	30.72	244.8	13707.4	2142.62
225	MV1(n	J	0.18	9.66	33.71	285.5	13650.4	2132.08
226	MV1(n	I	0.18	9.66	33.71	442.6	18846.4	2138.88
226	MV1(n	J	0.18	9.66	33.71	442.6	18664.3	2127.73
227	MV1(n	I	0.18	9.66	33.71	285.5	13664.5	2140.73
227	MV1(n	J	0.21	10.2	36.75	342.3	13384.2	2113.8
228	MV1(n	I	0.21	10.2	36.75	488.7	18702.5	2125.42
228	MV1(n	J	0.21	10.2	36.75	488.7	18277.9	2110.18
229	MV1(n	I	0.21	10.2	36.75	342.3	13417.4	2126.72
229	MV1(n	J	0.25	11.26	39.59	447	12920.6	2080.7
230	MV1(n	I	0.25	11.26	39.59	540.4	18313.5	2102.01
230	MV1(n	J	0.25	11.26	39.59	540.4	17657.4	2079.72
231	MV1(n	I	0.25	11.26	39.59	447	12976.2	2102.95
231	MV1(n	J	0.31	12.93	41.94	644	12274.1	2043.42
232	MV1(n	I	0.31	12.93	41.94	599	17691.6	2068.88
232	MV1(n	J	0.31	12.93	41.94	599	16822.1	2044
233	MV1(n	I	0.31	12.93	41.94	644	12368.5	2064.99
233	MV1(n	J	0.39	16.15	43.41	971.9	11484.9	1942.37
234	MV1(n	I	0.39	16.15	43.41	685.8	16870.1	1982.7
234	MV1(n	J	0.39	16.15	43.41	685.8	15821.7	2086.79

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
235	MV1(n	I	0.39	16.15	43.41	971.9	11643	2015.61
235	MV1(n	J	0.46	15.95	43.93	366.7	15389.5	1857.67
236	MV1(n	I	0.46	15.95	43.93	366.7	15860.8	2157.86
236	MV1(n	J	0.56	13.74	43.04	477.8	10302.5	1796.31
237	MV1(n	I	0.56	13.74	43.04	470.3	15458.3	1975.99
237	MV1(n	J	0.56	13.74	43.04	470.3	14336.4	1777.25
238	MV1(n	I	0.56	13.74	43.04	477.8	10557.2	1831.07
238	MV1(n	J	0.74	11.24	45.22	393.7	9422.93	1644.93
239	MV1(n	I	0.74	11.24	45.22	503.7	14430.3	1668.42
239	MV1(n	J	0.74	11.24	45.22	503.7	13147.1	1616.44
240	MV1(n	I	0.74	11.24	45.22	393.7	9732.89	1635.54
240	MV1(n	J	0.99	9.76	48.12	391.9	8426.61	1473.23
241	MV1(n	I	0.99	9.76	48.12	516.8	13252.7	1478.17
241	MV1(n	J	0.99	9.76	48.12	516.8	11779.5	1450.36
242	MV1(n	I	0.99	9.76	48.12	391.9	8763.61	1449.13
242	MV1(n	J	1.36	9.13	51.53	420.6	7270	1373.36
243	MV1(n	I	1.36	9.13	51.53	583.4	11891.8	1280.51
243	MV1(n	J	1.36	9.13	51.53	583.4	10226.1	1337.68
244	MV1(n	I	1.36	9.13	51.53	420.6	7616.39	1249.35
244	MV1(n	J	2.09	9.43	55.38	442.1	6111.78	1261.3
245	MV1(n	I	2.09	9.43	55.38	664.1	10356.1	1066.66
245	MV1(n	J	2.09	9.43	55.38	664.1	8506.07	1219.14
246	MV1(n	I	2.09	9.43	55.38	442.1	6393.55	1033.2
246	MV1(n	J	3.38	10.52	59.56	447.1	4848.28	1143.27
247	MV1(n	I	3.38	10.52	59.56	747.2	8658.59	843.87
247	MV1(n	J	3.38	10.52	59.56	747.2	6640.77	1121.63
248	MV1(n	I	3.38	10.52	59.56	447.1	5176.43	811.76
248	MV1(n	J	5	11.6	64.04	432.1	3361.07	1129.62
249	MV1(n	I	5	11.6	64.04	806.1	6807.21	682.86
249	MV1(n	J	5	11.6	64.04	806.1	4660.45	1123.06
250	MV1(n	I	5	11.6	64.04	432.1	3731.4	674.78
250	MV1(n	J	6.48	11.82	68.86	403	1931.13	1063.04
251	MV1(n	I	6.48	11.82	68.86	813.9	4865.56	546.93
251	MV1(n	J	6.48	11.82	68.86	813.9	2707.1	1030.19
252	MV1(n	I	6.48	11.82	68.86	403	2233.13	534.77
252	MV1(n	J	7.6	9.98	74.07	388.3	1106.36	867.86
253	MV1(n	I	7.6	9.98	74.07	739.2	3045.06	393.57
253	MV1(n	J	7.6	9.98	74.07	739.2	1247.55	805.47
254	MV1(n	I	7.6	9.98	74.07	388.3	1324.79	358.12

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
254	MV1(n	J	7.79	5.26	79.8	451.6	618.69	429.54
255	MV1(n	I	7.79	5.26	79.8	508.6	1302.93	216.11
255	MV1(n	J	7.79	5.26	79.8	508.6	408.16	366.24
256	MV1(n	I	7.79	5.26	79.8	451.6	610.72	196.69
256	MV1(n	J	7.79	5.26	79.8	508.6	408.16	366.24
257	MV1(n	I	50.92	0.95	13.51	156.7	2498.47	97.93
257	MV1(n	J	52.41	5.53	12.05	136.2	3338.95	350.2
258	MV1(n	I	52.41	5.53	12.05	170.1	2116.66	397.83
258	MV1(n	J	52.41	5.53	12.05	170.1	1418.46	229.34
259	MV1(n	I	52.41	5.53	12.05	136.2	3459.96	435.88
259	MV1(n	J	55.38	10.53	10.99	136.9	2665.24	421.99
260	MV1(n	I	55.38	10.53	10.99	179.2	1491.95	768.45
260	MV1(n	J	55.38	10.53	10.99	179.2	1312.86	355.07
261	MV1(n	I	55.38	10.53	10.99	136.9	2816.01	717.72
261	MV1(n	J	55.38	10.53	10.99	179.2	1312.86	355.07
262	MV1(n	I	55.38	10.53	10.99	136.9	2816.01	717.72
262	MV1(n	J	59.28	11.28	10.28	140.3	2061.81	525.24
263	MV1(n	I	59.28	11.28	10.28	168.8	1633.48	912.02
263	MV1(n	J	59.28	11.28	10.28	168.8	1864.8	491.64
264	MV1(n	I	59.28	11.28	10.28	140.3	2222.09	817.8
264	MV1(n	J	63.7	10.25	9.81	146.5	1694.69	645.74
265	MV1(n	I	63.7	10.25	9.81	139	2328.41	974.55
265	MV1(n	J	63.7	10.25	9.81	139	3144.58	651.72
266	MV1(n	I	63.7	10.25	9.81	146.5	1793.41	867.1
266	MV1(n	J	68.29	8.62	9.47	156.7	1668.71	770.06
267	MV1(n	I	68.29	8.62	9.47	101.8	3570.67	1010.96
267	MV1(n	J	68.29	8.62	9.47	101.8	4579.71	828.75
268	MV1(n	I	68.29	8.62	9.47	156.7	1708.34	922.04
268	MV1(n	J	72.64	7.34	9.18	174.7	1875.92	896.67
269	MV1(n	I	72.64	7.34	9.18	89.83	4952.1	1107.26
269	MV1(n	J	72.64	7.34	9.18	89.83	6092.47	1003.44
270	MV1(n	I	72.64	7.34	9.18	174.7	1842	996.48
270	MV1(n	J	76.69	7.17	8.81	215.5	2573.86	1031.3
271	MV1(n	I	76.69	7.17	8.81	88.92	6415.49	1230.83
271	MV1(n	J	76.69	7.17	8.81	88.92	7617.71	1155.46
272	MV1(n	I	76.69	7.17	8.81	215.5	2360.71	1073.68
272	MV1(n	J	80.52	8.55	8.24	300.7	3553.94	1185.55
273	MV1(n	I	80.52	8.55	8.24	148.9	7912.11	1343.34
273	MV1(n	J	80.52	8.55	8.24	148.9	9088.1	1270.08

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
274	MV1(n	I	80.52	8.55	8.24	300.7	3324.35	1144.08
274	MV1(n	J	84.25	11.19	7.32	423.2	4512.86	1386.97
275	MV1(n	I	84.25	11.19	7.32	209.5	9362.56	1414.36
275	MV1(n	J	84.25	11.19	7.32	209.5	10435.1	1367.87
276	MV1(n	I	84.25	11.19	7.32	423.2	4291.56	1322.04
276	MV1(n	J	87.15	14.04	5.9	598.2	5373.08	1665.49
277	MV1(n	I	87.15	14.04	5.9	266.6	10658.4	1389.31
277	MV1(n	J	87.15	14.04	5.9	266.6	11554.1	1704.91
278	MV1(n	I	87.15	14.04	5.9	598.2	5183.03	1603.92
278	MV1(n	J	88.85	6.5	4.11	99.17	11866.4	1605.3
279	MV1(n	I	88.85	6.5	4.11	99.17	11670.1	1691.23
279	MV1(n	J	89.66	5.78	3.91	128.2	6087.88	1651.14
280	MV1(n	I	89.66	5.78	3.91	111.2	11925.8	1604.24
280	MV1(n	J	89.66	5.78	3.91	111.2	12248.9	1615.48
281	MV1(n	I	89.66	5.78	3.91	128.2	5981.75	1601.59
281	MV1(n	J	90.06	4.88	4.78	80.16	6295.58	1572.55
282	MV1(n	I	90.06	4.88	4.78	123.4	12288.2	1646.86
282	MV1(n	J	90.06	4.88	4.78	123.4	12451.8	1765.54
283	MV1(n	I	90.06	4.88	4.78	80.16	6233.92	1531.55
283	MV1(n	J	90.25	5.09	5.86	58.9	6378.34	1544.13
284	MV1(n	I	90.25	5.09	5.86	137.3	12464.6	1766.25
284	MV1(n	J	90.25	5.09	5.86	137.3	12550.8	1826.66
285	MV1(n	I	90.25	5.09	5.86	58.9	6342.91	1509.06
285	MV1(n	J	90.46	5.01	6.76	59.96	6399.15	1536.24
286	MV1(n	I	90.46	5.01	6.76	147.8	12563.4	1829.07
286	MV1(n	J	90.46	5.01	6.76	147.8	12599.8	1851.39
287	MV1(n	I	90.46	5.01	6.76	59.96	6383	1517.28
287	MV1(n	J	90.51	4.91	7.48	71.92	6394.03	1537.84
288	MV1(n	I	90.51	4.91	7.48	165.1	12608.5	1855.18
288	MV1(n	J	90.51	4.91	7.48	165.1	12615.3	1856.48
289	MV1(n	I	90.51	4.91	7.48	71.92	6393.13	1536.28
289	MV1(n	J	90.46	5.06	8.25	109.5	6389.4	1525.9
290	MV1(n	I	90.46	5.06	8.25	195.3	12612.3	1857.07
290	MV1(n	J	90.46	5.06	8.25	195.3	12593.5	1843.7
291	MV1(n	I	90.46	5.06	8.25	109.5	6396.82	1540.09
291	MV1(n	J	90.26	5.62	9	163.4	6369.86	1506.4
292	MV1(n	I	90.26	5.62	9	235.3	12581.4	1842.64
292	MV1(n	J	90.26	5.62	9	235.3	12525.5	1800.89
293	MV1(n	I	90.26	5.62	9	163.4	6393.41	1538.96

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293	MV1(n	J	89.96	6.63	9.84	235.8	6303.47	1511.71
294	MV1(n	I	89.96	6.63	9.84	275.1	12512.7	1803.19
294	MV1(n	J	89.96	6.63	9.84	275.1	12398.4	1713.64
295	MV1(n	I	89.96	6.63	9.84	235.8	6348.55	1553.01
295	MV1(n	J	89.69	8.24	10.92	359.4	6148.34	1557.7
296	MV1(n	I	89.69	8.24	10.92	310.4	12375.3	1713.33
296	MV1(n	J	89.69	8.24	10.92	310.4	12156.4	1559.26
297	MV1(n	I	89.69	8.24	10.92	359.4	6222.62	1600.76
297	MV1(n	J	88.84	11.69	12.7	536.4	5824.73	1661.74
298	MV1(n	I	88.84	11.69	12.7	336.8	12088.2	1537.15
298	MV1(n	J	88.84	11.69	12.7	336.8	11679.9	1690.49
299	MV1(n	I	88.84	11.69	12.7	536.4	5945.11	1726.11
299	MV1(n	J	87.54	10.42	16.17	233.5	11241.8	1535.08
300	MV1(n	I	87.54	10.42	16.17	233.5	11593.8	1698.6
300	MV1(n	J	85.37	9.29	19.02	443.8	4809.41	1459.23
301	MV1(n	I	85.37	9.29	19.02	293.5	11087.1	1547.32
301	MV1(n	J	85.37	9.29	19.02	293.5	10107	1406.71
302	MV1(n	I	85.37	9.29	19.02	443.8	5014.24	1535.05
302	MV1(n	J	81.92	7.79	21.64	404.7	3876.19	1221.21
303	MV1(n	I	81.92	7.79	21.64	303.1	9853.29	1310.23
303	MV1(n	J	81.92	7.79	21.64	303.1	8719.62	1386.28
304	MV1(n	I	81.92	7.79	21.64	404.7	4101.83	1286.84
304	MV1(n	J	78	6.59	23.58	387.7	2902.48	1111.33
305	MV1(n	I	78	6.59	23.58	301.8	8436.55	1226.38
305	MV1(n	J	78	6.59	23.58	301.8	7232.63	1292.92
306	MV1(n	I	78	6.59	23.58	387.7	3130.61	1108.93
306	MV1(n	J	73.93	5.97	24.98	378.2	1997.05	1035.16
307	MV1(n	I	73.93	5.97	24.98	318	6926.1	1092.45
307	MV1(n	J	73.93	5.97	24.98	318	5733.85	1171.74
308	MV1(n	I	73.93	5.97	24.98	378.2	2182.72	964.72
308	MV1(n	J	69.68	6.04	25.94	368.9	1717	953.77
309	MV1(n	I	69.68	6.04	25.94	364.3	5391.18	927.57
309	MV1(n	J	69.68	6.04	25.94	364.3	4293.63	1045.18
310	MV1(n	I	69.68	6.04	25.94	368.9	1720.58	833.72
310	MV1(n	J	65.2	6.58	26.58	354.3	1671.71	877.27
311	MV1(n	I	65.2	6.58	26.58	427.1	3902.38	747.45
311	MV1(n	J	65.2	6.58	26.58	427.1	2957.94	981.82
312	MV1(n	I	65.2	6.58	26.58	354.3	1611.96	702.85
312	MV1(n	J	60.65	6.97	27.04	329.9	1843.94	810.11

Kiewit	DESIGNED BY: C. Kashosi	DATE: 10/31/22	
	CHECKED BY: H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
313	MV1(n	I	60.65	6.97	27.04	479.1	2524.54	569.75
313	MV1(n	J	60.65	6.97	27.04	479.1	1830.72	916.28
314	MV1(n	I	60.65	6.97	27.04	329.9	1724.03	577.22
314	MV1(n	J	56.42	6.57	27.37	292.5	2412.72	722.65
315	MV1(n	I	56.42	6.57	27.37	493.6	1472.21	410.76
315	MV1(n	J	56.42	6.57	27.37	493.6	1443.62	800.04
316	MV1(n	I	56.42	6.57	27.37	292.5	2249.51	461.3
316	MV1(n	J	52.77	4.91	27.69	251.8	3028.06	554.21
317	MV1(n	I	52.77	4.91	27.69	432.6	1198.41	274.02
317	MV1(n	J	52.77	4.91	27.69	432.6	1650.11	558.72
318	MV1(n	I	52.77	4.91	27.69	251.8	2873.09	377.23
318	MV1(n	J	50.41	2.17	28.1	248.8	3686.87	287.51
319	MV1(n	I	50.41	2.17	28.1	289.1	1693.91	184.76
319	MV1(n	J	50.41	2.17	28.1	289.1	2432.48	205.43
320	MV1(n	I	50.41	2.17	28.1	248.8	3591.58	311.19
320	MV1(n	J	50.41	2.17	28.1	289.1	2432.48	205.43

APPENDIX 2: KIEWIT MODEL RESULTS

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
1	MV1(a I		-364.76	8.28	-124.09	-49.8	-1498.39	62.11
1	MV1(a J		-363.62	9.77	-116.54	-60.9	-2018.25	140.48
2	MV1(a I		-363.62	9.77	-116.54	-58.9	-1311.04	67.82
2	MV1(a J		-363.62	9.77	-116.54	-58.9	-940.76	54.07
3	MV1(a I		-363.62	9.77	-116.54	-60.9	-2084.79	155.3
3	MV1(a J		-361.36	12.01	-109.98	-65.6	-1644.17	133.45
4	MV1(a I		-361.36	12.01	-109.98	-71	-947.6	74.28
4	MV1(a J		-361.36	12.01	-109.98	-71	-649.53	49.12
5	MV1(a I		-361.36	12.01	-109.98	-65.6	-1722.05	157.63
5	MV1(a J		-361.36	12.01	-109.98	-71	-649.53	49.12
6	MV1(a I		-361.36	12.01	-109.98	-65.6	-1722.05	157.63
6	MV1(a J		-359.35	13.58	-103.9	-67.9	-1322.55	122.71
7	MV1(a I		-359.35	13.58	-103.9	-78	-655.3	-76.05
7	MV1(a J		-359.35	13.58	-103.9	-78	730.99	41.34
8	MV1(a I		-359.35	13.58	-103.9	-67.9	-1399.79	152.19
8	MV1(a J		-357.51	13	-98.18	-68.2	-1045.51	112.84
9	MV1(a I		-357.51	13	-98.18	-77.9	727.84	-80.92
9	MV1(a J		-357.51	13	-98.18	-77.9	1021.8	-41.37
10	MV1(a I		-357.51	13	-98.18	-68.2	-1118.54	141.5
10	MV1(a J		-356.23	11.7	-92.73	-67.2	-810.83	104.14
11	MV1(a I		-356.23	11.7	-92.73	-75	1017.32	-83.63
11	MV1(a J		-356.23	11.7	-92.73	-75	1310.86	-50.51
12	MV1(a I		-356.23	11.7	-92.73	-67.2	-876.02	130.9
12	MV1(a J		-355.94	10.46	-87.45	-65.9	863.98	96.8
13	MV1(a I		-355.94	10.46	-87.45	-71.4	1304.45	-86.76
13	MV1(a J		-355.94	10.46	-87.45	-71.4	1587.95	-59.58
14	MV1(a I		-355.94	10.46	-87.45	-65.9	822.37	121.42
14	MV1(a J		-355.66	9.76	-82.27	-65.5	1036.15	91.27
15	MV1(a I		-355.66	9.76	-82.27	-68.2	1580.46	-90.84
15	MV1(a J		-355.66	9.76	-82.27	-68.2	1846.21	-66.55
16	MV1(a I		-355.66	9.76	-82.27	-65.5	987.31	113.38
16	MV1(a J		-355.52	9.85	-77.15	-67.2	1222.4	88.42
17	MV1(a I		-355.52	9.85	-77.15	-65.8	1839.19	-94.57
17	MV1(a J		-355.52	9.85	-77.15	-65.8	2079.99	-69.45
18	MV1(a I		-355.52	9.85	-77.15	-67.2	1174.59	106.26
18	MV1(a J		-355.5	-11.43	-72	-70	1392.08	91.8
19	MV1(a I		-355.5	-11.43	-72	-64.3	2073.94	-92.71
19	MV1(a J		-355.5	-11.43	-72	-64.3	2285.04	-66.23
20	MV1(a I		-355.5	-11.43	-72	-70	1348.53	99.56

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
20	MV1(a	J	-354.74	-14.66	-66.93	-73.8	1542.19	103.55
21	MV1(a	I	-354.74	-14.66	-66.93	-63.7	2279.26	-72.36
21	MV1(a	J	-354.74	-14.66	-66.93	-63.7	2458.88	-82.58
22	MV1(a	I	-354.74	-14.66	-66.93	-73.8	1505.13	106.07
22	MV1(a	J	-354.41	16.07	-67.7	-45.5	2523.11	-73.72
23	MV1(a	I	-354.41	16.07	-67.7	-45.5	2452.87	-75.48
23	MV1(a	J	-353.54	12.05	-61.86	-55	1713.75	73.33
24	MV1(a	I	-353.54	12.05	-61.86	-48.2	2518.88	-70.19
24	MV1(a	J	-353.54	12.05	-61.86	-48.2	2646.28	-93.76
25	MV1(a	I	-353.54	12.05	-61.86	-55	1690.63	82.96
25	MV1(a	J	-352.06	8.32	-58.08	-46.5	1801.24	65.62
26	MV1(a	I	-352.06	8.32	-58.08	-42.4	2640.77	-89.44
26	MV1(a	J	-352.06	8.32	-58.08	-42.4	2735.52	-106.08
27	MV1(a	I	-352.06	8.32	-58.08	-46.5	1786.69	72.18
27	MV1(a	J	-350.92	6.91	-53.95	-40.1	1864.85	-63.65
28	MV1(a	I	-350.92	6.91	-53.95	-38.9	2731.55	-104.99
28	MV1(a	J	-350.92	6.91	-53.95	-38.9	2796.66	-112.07
29	MV1(a	I	-350.92	6.91	-53.95	-40.1	1855.42	68.64
29	MV1(a	J	-349.55	5.91	-49.73	-34.7	1904.55	-65.23
30	MV1(a	I	-349.55	5.91	-49.73	-35	2793.48	-112.58
30	MV1(a	J	-349.55	5.91	-49.73	-35	2829.04	-114.16
31	MV1(a	I	-349.55	5.91	-49.73	-34.7	1899.35	67.95
31	MV1(a	J	-348.01	5.26	-45.55	-30	1920.34	-65.61
32	MV1(a	I	-348.01	5.26	-45.55	-31.9	2826.14	-114.91
32	MV1(a	J	-348.01	5.26	-45.55	-31.9	2832.81	-114.97
33	MV1(a	I	-348.01	5.26	-45.55	-30	1919.28	65.79
33	MV1(a	J	-348.38	-5.38	47.32	31.82	1913.06	66.45
34	MV1(a	I	-348.38	-5.38	47.32	32.66	2834.86	-114.66
34	MV1(a	J	-348.38	-5.38	47.32	32.66	2815.56	-114.19
35	MV1(a	I	-348.38	-5.38	47.32	31.82	1915.75	-65.49
35	MV1(a	J	-349.68	-6.18	51.52	36.8	1882.12	68.16
36	MV1(a	I	-349.68	-6.18	51.52	36.16	2818.28	-113.26
36	MV1(a	J	-349.68	-6.18	51.52	36.16	2769.78	-109.7
37	MV1(a	I	-349.68	-6.18	51.52	36.8	1888.92	-64.57
37	MV1(a	J	-350.98	-7.38	55.71	42.6	1826.47	69.04
38	MV1(a	I	-350.98	-7.38	55.71	40.23	2773.02	-109.87
38	MV1(a	J	-350.98	-7.38	55.71	40.23	2695.03	-98.32
39	MV1(a	I	-350.98	-7.38	55.71	42.6	1837.61	64.82
39	MV1(a	J	-351.88	-9.27	59.73	49.77	1745.91	75.12

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
40	MV1(a I		-351.88	-9.27	59.73	43.69	2698.52	-99.83
40	MV1(a J		-351.88	-9.27	59.73	43.69	2590.16	-80.27
41	MV1(a I		-351.88	-9.27	59.73	49.77	1762.69	68.28
41	MV1(a J		-353.35	-13.72	63.26	59.83	1638.01	93.06
42	MV1(a I		-353.35	-13.72	63.26	50.54	2595.45	-84.23
42	MV1(a J		-353.35	-13.72	63.26	50.54	2454.02	-77.47
43	MV1(a I		-353.35	-13.72	63.26	59.83	1663.34	88.17
43	MV1(a J		-353.96	-15.46	67.77	55.12	2378.92	-64.18
44	MV1(a I		-353.96	-15.46	67.77	55.12	2458.28	-81.72
44	MV1(a J		-354.18	12.9	69.1	72.01	1434.08	102.35
45	MV1(a I		-354.18	12.9	69.1	65.09	2383.92	-69.91
45	MV1(a J		-354.18	12.9	69.1	65.09	2190.43	-84.12
46	MV1(a I		-354.18	12.9	69.1	72.01	1473.61	94.74
46	MV1(a J		-354.72	10.19	74.23	68.78	1268.27	102.56
47	MV1(a I		-354.72	10.19	74.23	64.24	2196.33	-67.5
47	MV1(a J		-354.72	10.19	74.23	64.24	1970.85	-94.94
48	MV1(a I		-354.72	10.19	74.23	68.78	1313.35	90.31
48	MV1(a J		-354.73	-9.66	79.36	66.42	1087.3	109.31
49	MV1(a I		-354.73	-9.66	79.36	66.52	1977.3	-68.54
49	MV1(a J		-354.73	-9.66	79.36	66.52	1724.14	-93.52
50	MV1(a I		-354.73	-9.66	79.36	66.42	1135.85	89.61
50	MV1(a J		-354.81	-9.96	84.51	65.4	904.64	116.86
51	MV1(a I		-354.81	-9.96	84.51	69.22	1731.22	-63.64
51	MV1(a J		-354.81	-9.96	84.51	69.22	1455.99	-89.22
52	MV1(a I		-354.81	-9.96	84.51	65.4	946	93.69
52	MV1(a J		-355.11	-10.94	89.71	66.18	-748.22	125.64
53	MV1(a I		-355.11	-10.94	89.71	72.68	1463.02	-55.52
53	MV1(a J		-355.11	-10.94	89.71	72.68	1173.66	-85.18
54	MV1(a I		-355.11	-10.94	89.71	66.18	780.95	100.01
54	MV1(a J		-355.82	-12.24	95.04	67.54	-970.07	135.78
55	MV1(a I		-355.82	-12.24	95.04	76.03	1179.34	-46.12
55	MV1(a J		-355.82	-12.24	95.04	76.03	883.54	-81.33
56	MV1(a I		-355.82	-12.24	95.04	67.54	-900.93	108.01
56	MV1(a J		-357.48	-13.29	100.63	67.85	-1231.14	146.7
57	MV1(a I		-357.48	-13.29	100.63	77.88	888.68	37.54
57	MV1(a J		-357.48	-13.29	100.63	77.88	595.36	-76.24
58	MV1(a I		-357.48	-13.29	100.63	67.85	-1154.24	117.34
58	MV1(a J		-359.52	-13.23	106.54	66.62	-1532.14	156.48
59	MV1(a I		-359.52	-13.23	106.54	75.57	606.01	45.19

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
59	MV1(a	J	-359.52	-13.23	106.54	75.57	-771.77	74.7
60	MV1(a	I	-359.52	-13.23	106.54	66.62	-1450.71	127.91
60	MV1(a	J	-361.49	-11.21	112.88	63.18	-1876.2	160.84
61	MV1(a	I	-361.49	-11.21	112.88	66.05	-765.6	53.23
61	MV1(a	J	-361.49	-11.21	112.88	66.05	-1096.74	76.18
62	MV1(a	I	-361.49	-11.21	112.88	63.18	-1792.98	139.26
62	MV1(a	J	-362.9	-6.79	119.61	57.28	-2255.76	157.15
63	MV1(a	I	-362.9	-6.79	119.61	46.19	-1090.57	60.2
63	MV1(a	J	-362.9	-6.79	119.61	46.19	-1495.63	67.77
64	MV1(a	I	-362.9	-6.79	119.61	57.28	-2195.37	148.35
64	MV1(a	J	-362.9	-6.79	119.61	46.19	-1495.63	67.77
65	MV1(a	I	-304.59	8.57	-109.81	60.59	-1281.25	-15.58
65	MV1(a	J	-304.26	-13.28	-102.7	-40.3	-1704.36	27.03
66	MV1(a	I	-304.26	-13.28	-102.7	57.01	-1130.09	-51.71
66	MV1(a	J	-304.26	-13.28	-102.7	57.01	-835.15	30.7
67	MV1(a	I	-304.26	-13.28	-102.7	-40.3	-1754.72	-57.63
67	MV1(a	J	-303.98	-19.13	-96.47	-45.8	-1403.66	42.81
68	MV1(a	I	-303.98	-19.13	-96.47	-71.3	-835.5	84.72
68	MV1(a	J	-303.98	-19.13	-96.47	-71.3	-594.98	43.56
69	MV1(a	I	-303.98	-19.13	-96.47	-45.8	-1463.98	91.48
69	MV1(a	J	-303.98	-19.13	-96.47	-71.3	-594.98	43.56
70	MV1(a	I	-303.98	-19.13	-96.47	-45.8	-1463.98	91.48
70	MV1(a	J	-303.35	-19.95	-90.53	-52	-1143.46	52.43
71	MV1(a	I	-303.35	-19.95	-90.53	-76.8	-595.44	102.1
71	MV1(a	J	-303.35	-19.95	-90.53	-76.8	679.97	52.52
72	MV1(a	I	-303.35	-19.95	-90.53	-52	-1203.44	108.25
72	MV1(a	J	-302.72	-18.85	-84.93	-56.4	-916.75	68.3
73	MV1(a	I	-302.72	-18.85	-84.93	-77.9	666.69	119.21
73	MV1(a	J	-302.72	-18.85	-84.93	-77.9	918.15	69.07
74	MV1(a	I	-302.72	-18.85	-84.93	-56.4	-974.3	123.75
74	MV1(a	J	-302.32	-16.74	-79.63	-59.5	-721.65	87.11
75	MV1(a	I	-302.32	-16.74	-79.63	-75.5	908.41	133.72
75	MV1(a	J	-302.32	-16.74	-79.63	-75.5	1143.41	87.92
76	MV1(a	I	-302.32	-16.74	-79.63	-59.5	-774.19	137.51
76	MV1(a	J	-301.87	-14.78	-74.85	-60.1	808.01	106.48
77	MV1(a	I	-301.87	-14.78	-74.85	-70.9	1136.77	146.63
77	MV1(a	J	-301.87	-14.78	-74.85	-70.9	1357.14	107.2
78	MV1(a	I	-301.87	-14.78	-74.85	-60.1	770.5	149.75
78	MV1(a	J	-301.63	-13.99	-70.33	-59.2	949.68	125.33

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
79	MV1(a I		-301.63	-13.99	-70.33	-68.5	1354.11	158.77
79	MV1(a J		-301.63	-13.99	-70.33	-68.5	1564	125.89
80	MV1(a I		-301.63	-13.99	-70.33	-59.2	913.61	160.99
80	MV1(a J		-301.46	-15.41	-66.08	-58	1074.18	141.81
81	MV1(a I		-301.46	-15.41	-66.08	-68.9	1560.59	169.74
81	MV1(a J		-301.46	-15.41	-66.08	-68.9	1749.64	141.73
82	MV1(a I		-301.46	-15.41	-66.08	-58	1039.79	169.52
82	MV1(a J		-301.29	-19.33	-62.3	-58.6	1199.53	152.52
83	MV1(a I		-301.29	-19.33	-62.3	-70.2	1745.77	174.55
83	MV1(a J		-301.29	-19.33	-62.3	-70.2	1911.74	152.5
84	MV1(a I		-301.29	-19.33	-62.3	-58.6	1164.82	166.78
84	MV1(a J		-301.53	-25.56	-59.41	-65.7	1312.57	156.97
85	MV1(a I		-301.53	-25.56	-59.41	-69.7	1908.4	167.31
85	MV1(a J		-301.53	-25.56	-59.41	-69.7	2051.43	152.55
86	MV1(a I		-301.53	-25.56	-59.41	-65.7	1283.25	162.33
86	MV1(a J		-302.05	18.59	-62.74	-52.7	2108.68	162.64
87	MV1(a I		-302.05	18.59	-62.74	-52.7	2049.31	162.98
87	MV1(a J		-302.67	13.9	-58.37	-65.1	1454.86	172.66
88	MV1(a I		-302.67	13.9	-58.37	-60.2	2107.83	173.87
88	MV1(a J		-302.67	13.9	-58.37	-60.2	2221.95	178.36
89	MV1(a I		-302.67	13.9	-58.37	-65.1	1436.46	176.68
89	MV1(a J		-303.34	10.01	-54.7	-50.4	1534.47	188.62
90	MV1(a I		-303.34	10.01	-54.7	-57.5	2220.9	191.3
90	MV1(a J		-303.34	10.01	-54.7	-57.5	2307.97	189.43
91	MV1(a I		-303.34	10.01	-54.7	-50.4	1523.59	191.97
91	MV1(a J		-303.44	8.48	-50.67	-45.9	1595.45	192.57
92	MV1(a I		-303.44	8.48	-50.67	-53.2	2306.58	193.66
92	MV1(a J		-303.44	8.48	-50.67	-53.2	2366.11	192.22
93	MV1(a I		-303.44	8.48	-50.67	-45.9	1588.75	193.77
93	MV1(a J		-302.88	7.51	-46.5	-43.8	1634.68	193.97
94	MV1(a I		-302.88	7.51	-46.5	-49.5	2364.65	194.46
94	MV1(a J		-302.88	7.51	-46.5	-49.5	2396.7	193.14
95	MV1(a I		-302.88	7.51	-46.5	-43.8	1630.62	194.9
95	MV1(a J		-301.82	6.88	-42.37	-42.1	1650.59	194.44
96	MV1(a I		-301.82	6.88	-42.37	-46.5	2395.37	194.42
96	MV1(a J		-301.82	6.88	-42.37	-46.5	2401.87	193.62
97	MV1(a I		-301.82	6.88	-42.37	-42.1	1649.87	195.18
97	MV1(a J		-302.15	-6.92	44.19	42.81	1643.39	194.4
98	MV1(a I		-302.15	-6.92	44.19	47.21	2402.22	194.02

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
98	MV1(a	J	-302.15	-6.92	44.19	47.21	2384.75	193.78
99	MV1(a	I	-302.15	-6.92	44.19	42.81	1645.7	194.87
99	MV1(a	J	-302.87	-7.65	48.35	44.46	1612.93	193.51
100	MV1(a	I	-302.87	-7.65	48.35	50.47	2386.06	193.29
100	MV1(a	J	-302.87	-7.65	48.35	50.47	2341.23	193.3
101	MV1(a	I	-302.87	-7.65	48.35	44.46	1618.34	193.99
101	MV1(a	J	-303.23	-8.7	52.47	47.55	1559.72	191.57
102	MV1(a	I	-303.23	-8.7	52.47	54.11	2342.61	191.73
102	MV1(a	J	-303.23	-8.7	52.47	54.11	2270.37	191.31
103	MV1(a	I	-303.23	-8.7	52.47	47.55	1568.14	191.63
103	MV1(a	J	-303.13	-11.03	56.36	55.22	1483.91	187.97
104	MV1(a	I	-303.13	-11.03	56.36	58.39	2271.74	186.89
104	MV1(a	J	-303.13	-11.03	56.36	58.39	2172.14	186.11
105	MV1(a	I	-303.13	-11.03	56.36	55.22	1497.1	184.85
105	MV1(a	J	-302.4	-16.81	59.81	75.01	1388.4	170.74
106	MV1(a	I	-302.4	-16.81	59.81	61.53	2173.61	170.9
106	MV1(a	J	-302.4	-16.81	59.81	61.53	2048.33	166.62
107	MV1(a	I	-302.4	-16.81	59.81	75.01	1408.43	163.97
107	MV1(a	J	-301.78	27.48	60.57	56.46	1987.18	161.27
108	MV1(a	I	-301.78	27.48	60.57	56.46	2049.23	155.46
108	MV1(a	J	-301.29	22.38	60.59	60.2	1226.93	161.86
109	MV1(a	I	-301.29	22.38	60.59	69.3	1989.54	154.09
109	MV1(a	J	-301.29	22.38	60.59	69.3	1836.15	170.1
110	MV1(a	I	-301.29	22.38	60.59	60.2	1257.68	156.42
110	MV1(a	J	-301.14	17.43	63.8	58.09	1101.74	169.71
111	MV1(a	I	-301.14	17.43	63.8	69.34	1839.33	148.87
111	MV1(a	J	-301.14	17.43	63.8	69.34	1662.68	173.16
112	MV1(a	I	-301.14	17.43	63.8	58.09	1137.9	148.51
112	MV1(a	J	-301.26	14.57	67.92	58.5	978.13	165.87
113	MV1(a	I	-301.26	14.57	67.92	68.18	1666.39	135.54
113	MV1(a	J	-301.26	14.57	67.92	68.18	1466.85	164.66
114	MV1(a	I	-301.26	14.57	67.92	58.5	1012.93	135.35
114	MV1(a	J	-301.45	14.2	72.27	59.68	843.62	155.34
115	MV1(a	I	-301.45	14.2	72.27	68.34	1470.29	117.98
115	MV1(a	J	-301.45	14.2	72.27	68.34	1252.09	152.66
116	MV1(a	I	-301.45	14.2	72.27	59.68	880.51	117.32
116	MV1(a	J	-301.76	15.44	76.87	59.94	692.62	143.19
117	MV1(a	I	-301.76	15.44	76.87	72.14	1257.02	98.35
117	MV1(a	J	-301.76	15.44	76.87	72.14	1032.18	139.73

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
118	MV1(a I		-301.76	15.44	76.87	59.94	731.47	97.58
118	MV1(a J		-302.22	17.4	81.89	58.1	-854.78	129.54
119	MV1(a I		-302.22	17.4	81.89	75.59	1040.17	78.73
119	MV1(a J		-302.22	17.4	81.89	75.59	797.55	125.47
120	MV1(a I		-302.22	17.4	81.89	58.1	-799.01	77.95
120	MV1(a J		-302.61	18.91	87.29	54.04	-1068.81	113.58
121	MV1(a I		-302.61	18.91	87.29	75.91	808.55	59.99
121	MV1(a J		-302.61	18.91	87.29	75.91	552.39	108.65
122	MV1(a I		-302.61	18.91	87.29	54.04	-1008.45	59.58
122	MV1(a J		-303.09	18.82	92.98	48.43	-1313.3	94.58
123	MV1(a I		-303.09	18.82	92.98	71.52	567.29	46.65
123	MV1(a J		-303.09	18.82	92.98	71.52	-693.98	87.54
124	MV1(a I		-303.09	18.82	92.98	48.43	-1250.31	47.5
124	MV1(a J		-303.56	16.26	99.02	41.58	-1590.25	-72.32
125	MV1(a I		-303.56	16.26	99.02	-61.4	-693.53	38.7
125	MV1(a J		-303.56	16.26	99.02	-61.4	-958.82	-67.17
126	MV1(a I		-303.56	16.26	99.02	41.58	-1527.15	35.01
126	MV1(a J		-303.99	9.04	105.38	-44	-1895.05	-40.88
127	MV1(a I		-303.99	9.04	105.38	-53.7	-958.02	20.33
127	MV1(a J		-303.99	9.04	105.38	-53.7	-1280.04	-34.85
128	MV1(a I		-303.99	9.04	105.38	-44	-1848.44	17.58
128	MV1(a J		-303.99	9.04	105.38	-53.7	-1280.04	-34.85
129	MV1(a I		-255.59	-7.05	-103.94	51.74	-1074.93	12.85
129	MV1(a J		-253.28	-8.48	-96.36	-40.5	-1417.97	21.71
130	MV1(a I		-253.28	-8.48	-96.36	-45.4	-947.23	35.06
130	MV1(a J		-253.28	-8.48	-96.36	-45.4	-694.69	26.01
131	MV1(a I		-253.28	-8.48	-96.36	-40.5	-1463.55	41.2
131	MV1(a J		-249.53	-10.63	-89.67	-42.1	-1162.97	32.56
132	MV1(a I		-249.53	-10.63	-89.67	-54.6	-701.68	60.03
132	MV1(a J		-249.53	-10.63	-89.67	-54.6	-501.55	33.63
133	MV1(a I		-249.53	-10.63	-89.67	-42.1	-1215.55	65.19
133	MV1(a J		-249.53	-10.63	-89.67	-54.6	-501.55	33.63
134	MV1(a I		-249.53	-10.63	-89.67	-42.1	-1215.55	65.19
134	MV1(a J		-245.85	-10.16	-82.98	-46.6	-948.99	43.84
135	MV1(a I		-245.85	-10.16	-82.98	-55.3	-506.64	76.89
135	MV1(a J		-245.85	-10.16	-82.98	-55.3	627.53	45.05
136	MV1(a I		-245.85	-10.16	-82.98	-46.6	-999.47	79.56
136	MV1(a J		-242.71	-8.71	-76.5	-49.8	-766.38	63.58
137	MV1(a I		-242.71	-8.71	-76.5	-53.7	591.3	92.35

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
137	MV1(a J		-242.71	-8.71	-76.5	-53.7	815.84	65.28
138	MV1(a I		-242.71	-8.71	-76.5	-49.8	-813.74	94.97
138	MV1(a J		-240.63	-7.48	-70.57	-51.7	646.92	84.83
139	MV1(a I		-240.63	-7.48	-70.57	-51.2	792.82	108.08
139	MV1(a J		-240.63	-7.48	-70.57	-51.2	994.8	86.62
140	MV1(a I		-240.63	-7.48	-70.57	-51.7	-654.51	111.01
140	MV1(a J		-239.44	-6.55	-65.54	-51.8	788.99	105.28
141	MV1(a I		-239.44	-6.55	-65.54	-50.6	985.75	123.92
141	MV1(a J		-239.44	-6.55	-65.54	-50.6	1168.95	106.83
142	MV1(a I		-239.44	-6.55	-65.54	-51.8	756.37	126.72
142	MV1(a J		-238.16	-6.3	-60.89	-50.6	904.68	123.13
143	MV1(a I		-238.16	-6.3	-60.89	-50.5	1161.49	139.3
143	MV1(a J		-238.16	-6.3	-60.89	-50.5	1323.81	123.88
144	MV1(a I		-238.16	-6.3	-60.89	-50.6	872.8	141.52
144	MV1(a J		-236.66	7.1	-56.81	-49.8	995.15	136.06
145	MV1(a I		-236.66	7.1	-56.81	-51.8	1317.2	153.99
145	MV1(a J		-236.66	7.1	-56.81	-51.8	1458.24	135.37
146	MV1(a I		-236.66	7.1	-56.81	-49.8	964.18	154.3
146	MV1(a J		-234.87	-10.17	-53.47	-53.5	1063.48	138.34
147	MV1(a I		-234.87	-10.17	-53.47	-54.1	1451.6	163.97
147	MV1(a J		-234.87	-10.17	-53.47	-54.1	1573.23	135.08
148	MV1(a I		-234.87	-10.17	-53.47	-53.5	1037.3	158.48
148	MV1(a J		-233.22	-16.57	-51.16	-71	1136.76	138.67
149	MV1(a I		-233.22	-16.57	-51.16	-55	1567.46	158.1
149	MV1(a J		-233.22	-16.57	-51.16	-55	1673.6	151.92
150	MV1(a I		-233.22	-16.57	-51.16	-71	1111.99	146.36
150	MV1(a J		-232.33	18.2	-58.33	-45.6	1719.96	147.59
151	MV1(a I		-232.33	18.2	-58.33	-45.6	1669.45	154.47
151	MV1(a J		-231.33	12.72	-54.96	-58.5	1251.37	157.33
152	MV1(a I		-231.33	12.72	-54.96	-44.2	1718.95	153.62
152	MV1(a J		-231.33	12.72	-54.96	-44.2	1820.05	171.45
153	MV1(a I		-231.33	12.72	-54.96	-58.5	1235.91	163.05
153	MV1(a J		-230.05	7.44	-52.2	-43.4	1322.55	183.62
154	MV1(a I		-230.05	7.44	-52.2	-40.9	1817.9	184.67
154	MV1(a J		-230.05	7.44	-52.2	-40.9	1898.55	187.79
155	MV1(a I		-230.05	7.44	-52.2	-43.4	1314.12	187.67
155	MV1(a J		-228.37	6.21	-48.52	-38.8	1379.51	191.02
156	MV1(a I		-228.37	6.21	-48.52	-37.6	1896.02	195.2
156	MV1(a J		-228.37	6.21	-48.52	-37.6	1953.14	192.21

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
157	MV1(a I		-228.37	6.21	-48.52	-38.8	1375.07	196.67
157	MV1(a J		-226.15	5.55	-44.48	37.59	1423.31	194.71
158	MV1(a I		-226.15	5.55	-44.48	-36.1	1950.13	198.57
158	MV1(a J		-226.15	5.55	-44.48	-36.1	1981.96	194.85
159	MV1(a I		-226.15	5.55	-44.48	37.59	1420.37	199.47
159	MV1(a J		-223.57	5.24	-40.39	-37.9	1443.37	197.21
160	MV1(a I		-223.57	5.24	-40.39	-35.8	1978.99	198.34
160	MV1(a J		-223.57	5.24	-40.39	-35.8	1984.74	196.83
161	MV1(a I		-223.57	5.24	-40.39	-37.9	1442.73	198.92
161	MV1(a J		-224.38	5.26	42.25	37.75	1435.16	198.68
162	MV1(a I		-224.38	5.26	42.25	35.84	1986.91	196.6
162	MV1(a J		-224.38	5.26	42.25	35.84	1968.8	197.96
163	MV1(a I		-224.38	5.26	42.25	37.75	1437.02	196.75
163	MV1(a J		-226.72	-5.63	46.33	37.48	1399.53	197.85
164	MV1(a I		-226.72	-5.63	46.33	36.4	1971.89	194.31
164	MV1(a J		-226.72	-5.63	46.33	36.4	1927.98	196.77
165	MV1(a I		-226.72	-5.63	46.33	37.48	1403.29	193.82
165	MV1(a J		-228.81	-6.39	50.26	40.49	1347.24	192.35
166	MV1(a I		-228.81	-6.39	50.26	38.52	1930.92	190.95
166	MV1(a J		-228.81	-6.39	50.26	38.52	1862.3	190.51
167	MV1(a I		-228.81	-6.39	50.26	40.49	1352.95	188.82
167	MV1(a J		-230.33	-9.21	53.62	49.19	1276.88	179.38
168	MV1(a I		-230.33	-9.21	53.62	41.97	1864.49	183.9
168	MV1(a J		-230.33	-9.21	53.62	41.97	1773.65	173.48
169	MV1(a I		-230.33	-9.21	53.62	49.19	1287.38	176.69
169	MV1(a J		-231.74	-15.96	55.74	67.98	1192.65	150.96
170	MV1(a I		-231.74	-15.96	55.74	45.38	1776.2	157.86
170	MV1(a J		-231.74	-15.96	55.74	45.38	1667.79	157.56
171	MV1(a I		-231.74	-15.96	55.74	67.98	1209.46	147.77
171	MV1(a J		-232.72	18.7	53.38	48.51	1622.38	145.17
172	MV1(a I		-232.72	18.7	53.38	48.51	1669.76	152.62
172	MV1(a J		-233.72	13.59	52.05	62.12	1068.46	150.41
173	MV1(a I		-233.72	13.59	52.05	53.93	1626.95	135.91
173	MV1(a J		-233.72	13.59	52.05	53.93	1514.06	163.44
174	MV1(a I		-233.72	13.59	52.05	62.12	1094.13	136.74
174	MV1(a J		-235.46	8.5	54.85	50.59	997.44	157.39
175	MV1(a I		-235.46	8.5	54.85	52.75	1520.69	137.51
175	MV1(a J		-235.46	8.5	54.85	52.75	1390.31	159.63
176	MV1(a I		-235.46	8.5	54.85	50.59	1025.24	138.86

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
176	MV1(a J		-237.18	6.69	58.53	50	916.02	148.3
177	MV1(a I		-237.18	6.69	58.53	50.77	1396.79	131.59
177	MV1(a J		-237.18	6.69	58.53	50.77	1246	146.89
178	MV1(a I		-237.18	6.69	58.53	50	947.3	131.51
178	MV1(a J		-238.65	6.45	62.86	51.28	813.67	134.18
179	MV1(a I		-238.65	6.45	62.86	49.91	1252.92	116.92
179	MV1(a J		-238.65	6.45	62.86	49.91	1081.06	131.59
180	MV1(a I		-238.65	6.45	62.86	51.28	846.03	115.65
180	MV1(a J		-239.92	7.07	67.69	51.96	685.46	118.6
181	MV1(a I		-239.92	7.07	67.69	50.23	1089.2	97.96
181	MV1(a J		-239.92	7.07	67.69	50.23	897.32	115.68
182	MV1(a I		-239.92	7.07	67.69	51.96	719.45	96.24
182	MV1(a J		-241.4	8.15	72.96	50.96	-719.7	101.98
183	MV1(a I		-241.4	8.15	72.96	51.24	906.74	76.66
183	MV1(a J		-241.4	8.15	72.96	51.24	697.61	99.18
184	MV1(a I		-241.4	8.15	72.96	50.96	-674.35	74.92
184	MV1(a J		-244.09	9.27	79.22	48	-891.52	84.48
185	MV1(a I		-244.09	9.27	79.22	52.75	730.62	55.29
185	MV1(a J		-244.09	9.27	79.22	52.75	497.35	82.27
186	MV1(a I		-244.09	9.27	79.22	48	-841.22	53.94
186	MV1(a J		-247.51	10.14	85.79	44.05	-1091.34	67.65
187	MV1(a I		-247.51	10.14	85.79	52.3	533.59	36.88
187	MV1(a J		-247.51	10.14	85.79	52.3	-587.21	64.29
188	MV1(a I		-247.51	10.14	85.79	44.05	-1037.76	38.26
188	MV1(a J		-251.19	9.55	92.5	40.13	-1324.06	50.94
189	MV1(a I		-251.19	9.55	92.5	47.64	-580.83	31.86
189	MV1(a J		-251.19	9.55	92.5	47.64	-804.32	45.43
190	MV1(a I		-251.19	9.55	92.5	40.13	-1268.13	27.62
190	MV1(a J		-254.38	6.98	99.21	43.34	-1587.22	30.58
191	MV1(a I		-254.38	6.98	99.21	45.97	-797.13	18.69
191	MV1(a J		-254.38	6.98	99.21	45.97	-1077.03	25.87
192	MV1(a I		-254.38	6.98	99.21	43.34	-1543.71	14.83
192	MV1(a J		-254.38	6.98	99.21	45.97	-1077.03	25.87
193	MV1(a I		-201.1	-6.84	-84.8	45.08	-845.86	-9.38
193	MV1(a J		-199.6	13.24	-77.48	-34.4	-1115	22.57
194	MV1(a I		-199.6	13.24	-77.48	-55.4	-743.97	51.7
194	MV1(a J		-199.6	13.24	-77.48	-55.4	-545.87	24.43
195	MV1(a I		-199.6	13.24	-77.48	-34.4	-1150.71	57.54
195	MV1(a J		-197.22	19.18	-71.99	-32.9	-915.46	37.86

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
196	MV1(a I		-197.22	19.18	-71.99	-69.4	-549.84	84.61
196	MV1(a J		-197.22	19.18	-71.99	-69.4	-393.29	39.92
197	MV1(a I		-197.22	19.18	-71.99	-32.9	-956.71	89.09
197	MV1(a J		-197.22	19.18	-71.99	-69.4	-393.29	39.92
198	MV1(a I		-197.22	19.18	-71.99	-32.9	-956.71	89.09
198	MV1(a J		-194.45	20.02	-66.93	-35.2	-747.72	50.67
199	MV1(a I		-194.45	20.02	-66.93	-70.9	-395.83	94.46
199	MV1(a J		-194.45	20.02	-66.93	-70.9	480.53	51.63
200	MV1(a I		-194.45	20.02	-66.93	-35.2	-787.34	95.6
200	MV1(a J		-191.54	18.92	-62.23	-37.1	-604.58	61.7
201	MV1(a I		-191.54	18.92	-62.23	-67.1	466.05	95.32
201	MV1(a J		-191.54	18.92	-62.23	-67.1	641.76	62.48
202	MV1(a I		-191.54	18.92	-62.23	-37.1	-641.65	95.94
202	MV1(a J		-188.82	16.81	-57.82	-37.7	486.42	75.93
203	MV1(a I		-188.82	16.81	-57.82	-60.4	628.04	96.73
203	MV1(a J		-188.82	16.81	-57.82	-60.4	790.92	78.82
204	MV1(a I		-188.82	16.81	-57.82	-37.7	-517.05	100.12
204	MV1(a J		-186.1	14.84	-53.71	-36.8	584	94.02
205	MV1(a I		-186.1	14.84	-53.71	-53.3	778.97	105.9
205	MV1(a J		-186.1	14.84	-53.71	-53.3	926.76	96.65
206	MV1(a I		-186.1	14.84	-53.71	-36.8	558.71	109.3
206	MV1(a J		-183.63	14.05	-49.89	-34.9	687.33	111.08
207	MV1(a I		-183.63	14.05	-49.89	-47.8	916.67	115.19
207	MV1(a J		-183.63	14.05	-49.89	-47.8	1047.91	113.64
208	MV1(a I		-183.63	14.05	-49.89	-34.9	657.95	117.93
208	MV1(a J		-181.13	15.44	-46.53	32.34	776.26	127.16
209	MV1(a I		-181.13	15.44	-46.53	-45.3	1038.87	127.51
209	MV1(a J		-181.13	15.44	-46.53	-45.3	1153.19	129.79
210	MV1(a I		-181.13	15.44	-46.53	32.34	747.88	130.31
210	MV1(a J		-178.46	19.36	-43.7	42.51	849.22	142.85
211	MV1(a I		-178.46	19.36	-43.7	-45.4	1144.01	142.26
211	MV1(a J		-178.46	19.36	-43.7	-45.4	1242.51	146.2
212	MV1(a I		-178.46	19.36	-43.7	42.51	824.06	144.9
212	MV1(a J		-176.14	25.59	-41.64	64.94	910.74	165.3
213	MV1(a I		-176.14	25.59	-41.64	-43.1	1234.4	154.76
213	MV1(a J		-176.14	25.59	-41.64	-43.1	1319.9	186.08
214	MV1(a I		-176.14	25.59	-41.64	64.94	890.16	156.41
214	MV1(a J		-175.26	-18.51	-47.81	-44	1357.8	163.02
215	MV1(a I		-175.26	-18.51	-47.81	-44	1314.67	173.62

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
215	MV1(a	J	-175.18	-14.9	-43.87	-60.9	1001.28	169.22
216	MV1(a	I	-175.18	-14.9	-43.87	-48.5	1355.15	165.97
216	MV1(a	J	-175.18	-14.9	-43.87	-48.5	1439.09	169.35
217	MV1(a	I	-175.18	-14.9	-43.87	-60.9	989.17	165.15
217	MV1(a	J	-175.03	-12.02	-41.61	-40.6	1058.25	174.45
218	MV1(a	I	-175.03	-12.02	-41.61	-46.2	1436.32	172.6
218	MV1(a	J	-175.03	-12.02	-41.61	-46.2	1502.27	173.99
219	MV1(a	I	-175.03	-12.02	-41.61	-40.6	1052.5	172.23
219	MV1(a	J	-174.66	-10.58	-38.69	-30.2	1103.65	175.68
220	MV1(a	I	-174.66	-10.58	-38.69	-42.6	1499.78	174.75
220	MV1(a	J	-174.66	-10.58	-38.69	-42.6	1546.12	175.23
221	MV1(a	I	-174.66	-10.58	-38.69	-30.2	1100.53	174.78
221	MV1(a	J	-173.62	-9.71	-35.51	-25.3	1133.12	176.64
222	MV1(a	I	-173.62	-9.71	-35.51	-39	1543.15	176.56
222	MV1(a	J	-173.62	-9.71	-35.51	-39	1569.4	176.5
223	MV1(a	I	-173.62	-9.71	-35.51	-25.3	1131.28	176.85
223	MV1(a	J	-172.17	9.4	-32.29	-22.3	1145.35	177.22
224	MV1(a	I	-172.17	9.4	-32.29	-35.6	1566.26	177.43
224	MV1(a	J	-172.17	9.4	-32.29	-35.6	1571.74	177.06
225	MV1(a	I	-172.17	9.4	-32.29	-22.3	1145.16	177.71
225	MV1(a	J	-172.62	9.48	33.72	23.5	1140.37	176.91
226	MV1(a	I	-172.62	9.48	33.72	36.7	1573.37	177.43
226	MV1(a	J	-172.62	9.48	33.72	36.7	1558.08	176.6
227	MV1(a	I	-172.62	9.48	33.72	23.5	1141.47	177.55
227	MV1(a	J	-173.9	10.02	36.93	27.14	1117.96	175.44
228	MV1(a	I	-173.9	10.02	36.93	40.17	1561.23	176.43
228	MV1(a	J	-173.9	10.02	36.93	40.17	1525.44	175.23
229	MV1(a	I	-173.9	10.02	36.93	27.14	1120.48	176.64
229	MV1(a	J	-174.67	11.13	40.02	34	1078.63	172.83
230	MV1(a	I	-174.67	11.13	40.02	43.8	1528.23	175
230	MV1(a	J	-174.67	11.13	40.02	43.8	1472.61	172.97
231	MV1(a	I	-174.67	11.13	40.02	34	1082.83	175.48
231	MV1(a	J	-175.03	13.03	42.7	48.26	1022.78	170.23
232	MV1(a	I	-175.03	13.03	42.7	47.3	1474.99	173.29
232	MV1(a	J	-175.03	13.03	42.7	47.3	1400.34	170.63
233	MV1(a	I	-175.03	13.03	42.7	48.26	1030.4	173.49
233	MV1(a	J	-175.35	16.92	44.52	74.23	954.56	162.69
234	MV1(a	I	-175.35	16.92	44.52	50.27	1403.98	166.73
234	MV1(a	J	-175.35	16.92	44.52	50.27	1313.36	174.34

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
235	MV1(a I		-175.35	16.92	44.52	74.23	967.35	167.53
235	MV1(a J		-175.8	-27.5	43.19	-37	1278.27	155.93
236	MV1(a I		-175.8	-27.5	43.19	-37	1316.59	179.66
236	MV1(a J		-176.97	-22.41	42.46	-52.7	856.83	151.1
237	MV1(a I		-176.97	-22.41	42.46	43.68	1284.33	163.86
237	MV1(a J		-176.97	-22.41	42.46	43.68	1193.08	149.27
238	MV1(a I		-176.97	-22.41	42.46	-52.7	878.02	152.97
238	MV1(a J		-179.59	-17.44	44.87	-37.3	785.3	137.69
239	MV1(a I		-179.59	-17.44	44.87	45.3	1201.6	138.99
239	MV1(a J		-179.59	-17.44	44.87	45.3	1096.03	134.92
240	MV1(a I		-179.59	-17.44	44.87	-37.3	811.6	136.06
240	MV1(a J		-182.21	-14.6	47.97	33.37	703.13	122.57
241	MV1(a I		-182.21	-14.6	47.97	45.83	1105.28	122.89
241	MV1(a J		-182.21	-14.6	47.97	45.83	982.94	120.26
242	MV1(a I		-182.21	-14.6	47.97	33.37	731.58	120.42
242	MV1(a J		-184.73	-14.25	51.51	35.59	606.71	113.65
243	MV1(a I		-184.73	-14.25	51.51	49.99	992.43	106.4
243	MV1(a J		-184.73	-14.25	51.51	49.99	853.39	110.53
244	MV1(a I		-184.73	-14.25	51.51	35.59	635.73	103.83
244	MV1(a J		-187.31	-15.5	55.46	37.15	510.38	104.35
245	MV1(a I		-187.31	-15.5	55.46	55.88	864.27	88.72
245	MV1(a J		-187.31	-15.5	55.46	55.88	709.54	100.85
246	MV1(a I		-187.31	-15.5	55.46	37.15	533.46	85.97
246	MV1(a J		-190.09	-17.47	59.69	37.35	-567.67	94.36
247	MV1(a I		-190.09	-17.47	59.69	62.45	722.35	70.29
247	MV1(a J		-190.09	-17.47	59.69	62.45	553.56	92.47
248	MV1(a I		-190.09	-17.47	59.69	37.35	-531.9	67.56
248	MV1(a J		-192.87	-18.97	64.18	36	-702.3	93.47
249	MV1(a I		-192.87	-18.97	64.18	67.26	567.58	57.15
249	MV1(a J		-192.87	-18.97	64.18	67.26	388.32	93.1
250	MV1(a I		-192.87	-18.97	64.18	36	-662.82	56.43
250	MV1(a J		-195.74	-18.86	69.01	33.51	-859.37	88.27
251	MV1(a I		-195.74	-18.86	69.01	67.87	406.29	45.78
251	MV1(a J		-195.74	-18.86	69.01	67.87	-459.47	85.68
252	MV1(a I		-195.74	-18.86	69.01	33.51	-817.19	44.72
252	MV1(a J		-198.27	-16.32	74.21	32.28	-1041.62	72.25
253	MV1(a I		-198.27	-16.32	74.21	61.62	-456.1	32.93
253	MV1(a J		-198.27	-16.32	74.21	61.62	-631.11	67.13
254	MV1(a I		-198.27	-16.32	74.21	32.28	-998.11	29.94

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
254	MV1(a J		-200.27	-8.22	79.94	37.61	-1248.17	35.81
255	MV1(a I		-200.27	-8.22	79.94	42.38	-626.75	18.05
255	MV1(a J		-200.27	-8.22	79.94	42.38	-847.33	30.59
256	MV1(a I		-200.27	-8.22	79.94	37.61	-1213.97	16.42
256	MV1(a J		-200.27	-8.22	79.94	42.38	-847.33	30.59
257	MV1(a I		-137.2	-2.63	-27.73	13.07	-561.14	-23.03
257	MV1(a J		-138.68	5.6	-27.76	-20.7	-793.14	-53.17
258	MV1(a I		-138.68	5.6	-27.76	-31.3	-501.3	33.31
258	MV1(a J		-138.68	5.6	-27.76	-31.3	-382.1	-20.04
259	MV1(a I		-138.68	5.6	-27.76	-20.7	-809.39	-52.43
259	MV1(a J		-141.65	10.62	-27.39	-22.7	-668.71	-51.57
260	MV1(a I		-141.65	10.62	-27.39	-42	-377.83	64.11
260	MV1(a J		-141.65	10.62	-27.39	-42	-270.13	29.58
261	MV1(a I		-141.65	10.62	-27.39	-22.7	-691.25	59.78
261	MV1(a J		-141.65	10.62	-27.39	-42	-270.13	29.58
262	MV1(a I		-141.65	10.62	-27.39	-22.7	-691.25	59.78
262	MV1(a J		-145.72	11.35	-27.13	-26.2	-550.48	-48.13
263	MV1(a I		-145.72	11.35	-27.13	-43.2	-268.63	75.81
263	MV1(a J		-145.72	11.35	-27.13	-43.2	-177.96	40.89
264	MV1(a I		-145.72	11.35	-27.13	-26.2	-575.83	68.01
264	MV1(a J		-150.74	10.27	-26.81	-28.8	-439.55	53.91
265	MV1(a I		-150.74	10.27	-26.81	-39.8	193.13	80.73
265	MV1(a J		-150.74	10.27	-26.81	-39.8	260.5	54.14
266	MV1(a I		-150.74	10.27	-26.81	-28.8	-465.78	72.03
266	MV1(a J		-156.94	8.58	-26.35	-30.3	-338.69	64.22
267	MV1(a I		-156.94	8.58	-26.35	-34.3	295.72	83.47
267	MV1(a J		-156.94	8.58	-26.35	-34.3	379.06	68.75
268	MV1(a I		-156.94	8.58	-26.35	-30.3	-363.72	76.53
268	MV1(a J		-164.81	7.21	-25.67	-31.2	-251.84	74.64
269	MV1(a I		-164.81	7.21	-25.67	-29.4	409.87	91.66
269	MV1(a J		-164.81	7.21	-25.67	-29.4	504.75	83.27
270	MV1(a I		-164.81	7.21	-25.67	-31.2	-273.83	82.67
270	MV1(a J		-173.21	7.01	-24.69	-31.8	214.63	85.61
271	MV1(a I		-173.21	7.01	-24.69	-26.7	531.6	102.03
271	MV1(a J		-173.21	7.01	-24.69	-26.7	632.54	96.09
272	MV1(a I		-173.21	7.01	-24.69	-31.8	-197.16	89.25
272	MV1(a J		-182.04	8.53	-23.26	-32.6	298.58	98.23
273	MV1(a I		-182.04	8.53	-23.26	-26.3	657.44	112.09
273	MV1(a J		-182.04	8.53	-23.26	-26.3	757.61	106.07

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Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
274	MV1(a I		-182.04	8.53	-23.26	-32.6	278.81	95.92
274	MV1(a J		-191.11	11.39	-21.17	-34.3	382.01	115.17
275	MV1(a I		-191.11	11.39	-21.17	-27	781.6	119.39
275	MV1(a J		-191.11	11.39	-21.17	-27	874.62	113.54
276	MV1(a I		-191.11	11.39	-21.17	-34.3	362.86	109.58
276	MV1(a J		-199.05	14.66	-18.33	44.12	458.45	139.26
277	MV1(a I		-199.05	14.66	-18.33	-24.4	894.46	117.98
277	MV1(a J		-199.05	14.66	-18.33	-24.4	973.69	143.35
278	MV1(a I		-199.05	14.66	-18.33	44.12	441.85	133.86
278	MV1(a J		-203.23	-13.83	-12.35	-15.5	997.55	134.19
279	MV1(a I		-203.23	-13.83	-12.35	-15.5	983.78	142.28
279	MV1(a J		-205.05	-10.17	-11.42	-32.7	514.39	137.35
280	MV1(a I		-205.05	-10.17	-11.42	-23.8	1001.85	133.97
280	MV1(a J		-205.05	-10.17	-11.42	-23.8	1023.72	136.87
281	MV1(a I		-205.05	-10.17	-11.42	-32.7	506.29	133.48
281	MV1(a J		-206.78	-7.35	-10.22	-21.6	526.72	130.82
282	MV1(a I		-206.78	-7.35	-10.22	-23.9	1025.66	137.78
282	MV1(a J		-206.78	-7.35	-10.22	-23.9	1035.66	147.85
283	MV1(a I		-206.78	-7.35	-10.22	-21.6	522.29	127.06
283	MV1(a J		-207.85	-5.94	-9.41	-15.4	530.27	128.77
284	MV1(a I		-207.85	-5.94	-9.41	-21.5	1036.04	146.92
284	MV1(a J		-207.85	-5.94	-9.41	-21.5	1041.08	151.62
285	MV1(a I		-207.85	-5.94	-9.41	-15.4	527.92	125.33
285	MV1(a J		-208.66	-5.13	-8.71	-11	530.06	128.08
286	MV1(a I		-208.66	-5.13	-8.71	-18.3	1042.1	151.63
286	MV1(a J		-208.66	-5.13	-8.71	-18.3	1044.15	153.1
287	MV1(a I		-208.66	-5.13	-8.71	-11	529.04	125.98
287	MV1(a J		-209.13	4.78	-8.05	-7.76	528.98	127.43
288	MV1(a I		-209.13	4.78	-8.05	-15.4	1044.93	153.44
288	MV1(a J		-209.13	4.78	-8.05	-15.4	1045.38	153.49
289	MV1(a I		-209.13	4.78	-8.05	-7.76	528.98	127.14
289	MV1(a J		-209.03	4.86	8.28	9.04	529.05	126.36
290	MV1(a I		-209.03	4.86	8.28	16.46	1045.08	153.48
290	MV1(a J		-209.03	4.86	8.28	16.46	1044.13	152.67
291	MV1(a I		-209.03	4.86	8.28	9.04	529.42	127.94
291	MV1(a J		-208.22	5.4	8.95	12.82	528.96	125.3
292	MV1(a I		-208.22	5.4	8.95	19.57	1043.04	152.55
292	MV1(a J		-208.22	5.4	8.95	19.57	1040.01	149.55
293	MV1(a I		-208.22	5.4	8.95	12.82	530.42	128.41

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	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
293	MV1(a	J	-207.38	6.43	9.69	17.81	526.28	125.45
294	MV1(a	I	-207.38	6.43	9.69	22.42	1039.14	150.19
294	MV1(a	J	-207.38	6.43	9.69	22.42	1032.46	142.9
295	MV1(a	I	-207.38	6.43	9.69	17.81	529.31	129.36
295	MV1(a	J	-206.17	8.21	10.65	26.1	517.64	129.38
296	MV1(a	I	-206.17	8.21	10.65	24.43	1031.63	144.3
296	MV1(a	J	-206.17	8.21	10.65	24.43	1017.9	130.88
297	MV1(a	I	-206.17	8.21	10.65	26.1	522.99	133.05
297	MV1(a	J	-203.66	12.33	12.2	39.61	496.19	138.9
298	MV1(a	I	-203.66	12.33	12.2	24.29	1013.22	128.93
298	MV1(a	J	-203.66	12.33	12.2	24.29	984.61	142.09
299	MV1(a	I	-203.66	12.33	12.2	39.61	505.33	144.19
299	MV1(a	J	-200.81	-15.02	16.72	17.97	946.25	128.12
300	MV1(a	I	-200.81	-15.02	16.72	17.97	977.66	142.72
300	MV1(a	J	-195.71	-12.87	19.65	-38	408.54	121.1
301	MV1(a	I	-195.71	-12.87	19.65	24.83	932.51	129.11
301	MV1(a	J	-195.71	-12.87	19.65	24.83	846.51	119.4
302	MV1(a	I	-195.71	-12.87	19.65	-38	426.29	127.89
302	MV1(a	J	-186.86	-10.13	22.18	33.21	326.5	101.3
303	MV1(a	I	-186.86	-10.13	22.18	26.7	823.92	109.65
303	MV1(a	J	-186.86	-10.13	22.18	26.7	726.36	116.34
304	MV1(a	I	-186.86	-10.13	22.18	33.21	345.94	106.65
304	MV1(a	J	-177.76	-7.77	23.96	32.03	242.55	92.73
305	MV1(a	I	-177.76	-7.77	23.96	26	701.99	102.18
305	MV1(a	J	-177.76	-7.77	23.96	26	600.18	107.47
306	MV1(a	I	-177.76	-7.77	23.96	32.03	262.1	91.95
306	MV1(a	J	-169.11	-6.93	25.19	31.37	-227.95	85.91
307	MV1(a	I	-169.11	-6.93	25.19	27.29	574.53	90.74
307	MV1(a	J	-169.11	-6.93	25.19	27.29	474.86	97.01
308	MV1(a	I	-169.11	-6.93	25.19	31.37	-207.74	80.21
308	MV1(a	J	-160.82	-7.6	26.01	30.7	-310.74	79.16
309	MV1(a	I	-160.82	-7.6	26.01	30.75	446.46	76.94
309	MV1(a	J	-160.82	-7.6	26.01	30.75	355.4	86.55
310	MV1(a	I	-160.82	-7.6	26.01	30.7	-287.32	69.34
310	MV1(a	J	-153.8	-9.04	26.57	29.55	-406.86	72.84
311	MV1(a	I	-153.8	-9.04	26.57	35.83	323.36	62.03
311	MV1(a	J	-153.8	-9.04	26.57	35.83	245.14	81.12
312	MV1(a	I	-153.8	-9.04	26.57	29.55	-380.73	58.66
312	MV1(a	J	-148.26	-10.32	26.99	27.55	-513.31	67.28

Kiewit	DESIGNED BY:	C. Kashosi	DATE:	10/31/22
	CHECKED BY:	H. Wolf	DATE:	

Virtual Beam	Load	Part	Axial (kips)	Shear - Y (kips)	Shear - Z (kips)	Torsion (ft-Kips)	Moment-Y (ft-Kips)	Moment-Z (ft-Kips)
313	MV1(a I		-148.26	-10.32	26.99	40.11	209.06	47.35
313	MV1(a J		-148.26	-10.32	26.99	40.11	-215.02	76.03
314	MV1(a I		-148.26	-10.32	26.99	27.55	-486.63	48.2
314	MV1(a J		-143.75	-10.52	27.3	24.45	-626.61	60.14
315	MV1(a I		-143.75	-10.52	27.3	41.31	-215.11	34.19
315	MV1(a J		-143.75	-10.52	27.3	41.31	-314.4	66.61
316	MV1(a I		-143.75	-10.52	27.3	24.45	-601.13	-50.05
316	MV1(a J		-140.25	-8.06	27.61	21.06	-744.53	-51.8
317	MV1(a I		-140.25	-8.06	27.61	36.22	-317.39	22.83
317	MV1(a J		-140.25	-8.06	27.61	36.22	-431.52	46.69
318	MV1(a I		-140.25	-8.06	27.61	21.06	-722.34	-53.29
318	MV1(a J		-137.87	-2.43	28.02	20.78	-863.68	-55.04
319	MV1(a I		-137.87	-2.43	28.02	24.22	-436.5	-22.05
319	MV1(a J		-137.87	-2.43	28.02	24.22	-559.68	-22.53
320	MV1(a I		-137.87	-2.43	28.02	20.78	-850.57	-55.89
320	MV1(a J		-137.87	-2.43	28.02	24.22	-559.68	-22.53

Formal Alternative Technical Concepts Submittal Form

Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 8 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

Description (required):

This ATC proposes the use of a polymer slurry (KB SlurryPro CDP or SlurrySMART) as an alternate material in place of traditional mineral slurry for drilled shaft application to allow the slurry to be recycled. KB SlurryPro CDP and KB SlurrySMART are both polymer products with similar properties that may be ideal for use. Project and environmental requirements along with geotechnical conditions will govern which product is best suited to the Project. Kiewit will work with KB to determine the best polymer application for the Project and clearly communicate the reasoning with SCDOT.

Usage:

Polymer slurry may be substituted for mineral (bentonite) slurry for drilled shaft construction.

Deviations (required):

The SCDOT Standard Specification for Highway Construction 2007 Section 712.4.9 states that only use of mineral (bentonite) slurry is allowed for the wet construction method of drilled shafts.
This ATC proposes to allow the use of polymer slurry for drilled shaft applications.

Justification:

Polymer slurry has been successfully used on SCDOT projects, improves shaft quality due to the elimination of filter cakes, and reduces environmental impact risk. Polymer slurry is preferred for its construction, reuse, and disposal benefits when compared to bentonite.

Schedule:

There are no overall project schedule savings anticipated by this ATC.

Impacts:

Implementing this ATC will not impact vehicular traffic, community, utilities, right-of way, or safety. The ATC will reduce environmental risk and is considered equal or better to the current specified construction method.

History:

Polymer slurry has been successfully used for SCDOT projects SC170 in Beaufort, SC and recently US21 over Harbor River.

Risks:

Use of polymer slurry poses less environmental risk than the use of mineral slurry, which is particularly important given proximity to the Wateree River. Secondary containment shall be used under mixing and storage tanks to prevent accidental spills from entering waterways, sewer systems, or environmentally protected areas.

Costs (required):

Cost Savings: $49,000

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Project: I-20 over Wateree River Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 8 **Priority:** Med **Team:** Kiewit Infrastructure South Co. **Date:** 12/2/22

Quality:

The use of polymer slurry will enhance shaft quality since it does not have the potential to form clayey buildup along the shaft (known to occur with bentonite slurry), which can compromise side resistance. A representative of KB Polymer shall be onsite during the first application to provide guidance and ensure quality during construction. Kiewit will also follow SCDOT Standard Specifications Section 712 requirements and carry out control tests for density, viscosity, sand content, and pH as required. SCDOT projects and load tests have demonstrated the effectiveness of polymer slurry.

Operations & Maintenance:

This ATC does not affect the Operations & Maintenance of the Project.

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Product Data Sheet

SlurrySMART

Physical Data:

Appearance:	Opaque to white free flowing granular solid
Odor:	Odorless
pH:	NA
Freeze Point:	NA
Specific Gravity:	1.00-1.01 (Water = 1.00)

Description:

SlurrySMART forms a synthetic membrane on the sidewalls during excavation that controls loss of fluid to the formation. It also allows for positive pressure to be applied to the formation wall insuring excavation stability. Unlike bentonite, this membrane does not continue to grow on itself over time. SlurrySMART is able to react to field conditions and perform as needed based on system demands. **No pH adjustment** with caustic or soda ash is required when using SlurrySMART unless, extreme water hardness or salt water is encountered.

General Application and Instructions:

KB recommends SlurrySMART initially be mixed at a rate of 1.5 to 2.5 lb/yd^3 of fresh water. For larger projects this should be done in a properly designed mixing tank; please see KB's "Mix Tank Diagram" for specifics. Many contractors find they can start with lower dosages and adjust as required for stability. On smaller projects or highly mobile projects, such as transmission lines, SlurrySMART may be applied at the point of excavation. Typical product consumption rates are suggested to be as follows; although many contractors find less is acceptable:

Formation Type	Suggested SlurrySMART Initial Dosage			Typical Marsh Funnel Visc.
	lbs/yd^3	lbs/1000 gals	kg/m^3	sec/qt
Clay & Shale	1.50-2.20	7.50-11.00	0.70-1.00	60-75±
Silt & Fine to Medium Sand	1.75-2.20	8.75-11.00	0.80-1.00	65-100±
Coarse Sand to Pea Gravel	2.00-2.50	10.00-12.50	0.90-1.15	75-100±
Gravel to Cobbles	2.20-3.00	11.00-15.00	1.0-1.40	85-100+

Formation Type	Suggested SlurrySMART Refreshment Dosage			Typical Marsh Funnel Visc.
	lbs/yd^3	lbs/1000 gals	kg/m^3	sec/qt
Clay & Shale	1.00-1.50	5.00-7.50	0.45-0.70	60-75±
Silt & Fine to Medium Sand	1.10-1.70	5.50-8.50	0.50-0.80	65-100±
Coarse Sand to Pea Gravel	1.25-2.00	6.250-10.00	0.60-1.00	75-100±
Gravel to Cobbles	1.266-2.109	6.259-10.432	0.75-1.25	85-100+

Additional SlurrySMART may be introduced at the point of excavation through a KB Eductor or into the mix tank or agitated slurry storage tanks. The addition of small quantities of SlurrySMART at the hole provides the following benefits: rapid increase in viscosity to stabilize highly permeable soils and immediate intervention in case of emergencies or other atypical situations. When adding at the point of excavation, please pour SlurrySMART slowly into a KB Eductor that feeds into an adequately flowing stream of slurry emptying into the excavation. SlurrySMART may also be added directly into the stream of fluid flowing into a pile while the excavation tool is one meter (3 feet) below the surface of the slurry. The tool rotates to form a vortex within the slurry column. Avoid clumping the dry SlurrySMART into "white gel balls" by slowly sifting product into the fluid stream. Feeding SlurrySMART too quickly, with lack of

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proper agitation, causes balling of the polymer particles into “fish eyes” and larger polymer masses. After adding SlurrySMART to the any excavation, raise and lower the excavation tool from the top of the hole to the bottom to assist in proper distribution of the product throughout the slurry column. The slurry viscosity within the excavation should never be allowed to drop below 55 seconds per quart regardless of what type of soil is being excavated.

At least one sedimentation tank is always recommended for recaptured slurry to pass through prior to the mix tank and the re-addition of SlurrySMART.

The dosage rate of the SlurrySMART synthetic polymer in the initial make-up water should use the higher levels recommended in the dosage chart. Only after the slurry has been established, in a secure dosage and viscosity obtained, should the dosage be reduced.

If unusual site conditions arise during excavation recommendations should be sought from KB technical personnel to resolve the problem.

Special Operational Precautions and Instructions:

It is suggested that the specific gravity of a SlurrySMART fluid should not exceed 1.05 under normal operating conditions. If low hydrostatic conditions are encountered where the water table is less than 3 meters or 10 feet beneath the slurry level, the specific gravity of the slurry should be increased as required.

Due to the unique characteristics of SlurrySMART as compared to bentonite, several key operational procedures are recommended to be modified from bentonite systems. These modifications will have a major impact on the overall effectiveness and successful use of SlurrySMART. For smaller projects, please consult KB International’s “General Operating, Product Addition, and Testing Procedures.” For larger or more complicated projects, please contact KB International for specific project planning.

Packaging:

25 kilo / 55 lb. poly bags

10 kilo / 22 lb. resealable plastic pails

Availability:

SlurrySMART is available out of KB International’s Charleston, SC warehouse and various other regional warehouses. Please check for availability in your area.

KB International LLC
735 Broad St., Suite 209
Chattanooga, TN 37402
Office: 1 423 266 6964
Tech Service: 1 281 216 7440

KB International LLC
20 Batten Bend, Blouberg Sands
Blouberg, Cape Town 7441, South Africa
South Africa 27 76 865 3597

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Formal Alternative Technical Concepts Submittal Form

Project: 1-20 over Wateree Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 11 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 1/19/23

Description (required):

This ATC proposes to use a 60-mph design speed and Method 2 superelevation design as described in the National Cooperative Highway Research Program Report (NCHRP) 581, Design of Construction Work Zones on High-Speed Highways for the temporary crossovers situated at the west end of the Wateree Structures, between the existing Buck Creek Bridge and the Wateree River. Please see attached for the NCHRP 581 report. This approach allows the temporary crossover superelevation transitions to rotate back to normal crown entirely, between the structures, eliminating the need for temporary asphalt to be placed across the existing Buck Creek Bridge as well as the proposed center portion of the permanent six-lane bridge over the Wateree River that Kiewit has proposed in our design. This design is shown in Attachment 1 – 60-mph Method 2 Design and exceeds the minimum radius required by Method 2 calculation for 60-mph.

Using a design speed of 70-mph and the superelevation design defined in the SCDOT Roadway Design Manual section 5.3 (AASHTO Method 5) for the temporary crossovers between the two structures results in the superelevation transitions significantly extending onto the existing Buck Creek Bridge as well as onto the newly constructed center portion of the proposed Wateree structure. Due to the nature of the need for a minimum amount of asphalt on a deck to be viable, the asphalt would need to be run across the entire Buck Creek Bridges and would tie in beyond the west end. Additionally, to prevent running asphalt across the entire Wateree structure, a 1- to 2-inch-tall lip would need to be cast into the first unit of the Wateree Bridge deck to allow a minimum amount of asphalt to be cast into that deck. This design is shown in Attachment 2 – 70-mph Method 5 Design.

Because both structures would require variable asphalt depths, the Buck Creek structures would need to be reviewed to ensure a reduced, temporary load rating is not warranted as well as a taller temporary barrier to sit against the taller asphalt sections. The added loading of variable asphalt on the Wateree structure potentially requires additional superstructure, substructure, and foundations as well as a special temporary barrier able to handle the higher asphalt height.

Additionally, Kiewit has reviewed the use of a temporary design speed reduction to 60-mph and the utilization of the Method 5 superelevation transition design approach for the construction work zone. In the attached schematic and calculations, this method removes the need for asphalt onto the Buck Creek Bridges but would require a runout of asphalt to encroach onto the Wateree Structure including the need for the 1- to 2-inch-tall lip cast into the first unit of the Wateree Bridge deck as noted above.

Alternatively, an allowance of a temporary design speed reduction to 60-mph and utilization of the Method 2 superelevation transition design approach for construction work zones on high-speed roadways, as described in NCHRP 581, will achieve a comfortable superelevation rate (4%) on the crossovers without physically impacting the bridge decks of either structure. Kiewit believes that keeping temporary asphalt from extending over the existing Buck Creek Bridge as well as extending significantly onto the proposed Wateree Bridge is favorable to SCDOT.

Usage:

The use of the reduced, temporary design speed of 60-mph and the Method 2 superelevation transition design approach as described in NCHRP 581 is only proposed between the existing Buck Creek Bridge and the proposed Wateree Bridge for the temporary crossover conditions required for the phased construction of the proposed six-lane Bridge over Wateree.

Deviations (required):

This ATC deviates from superelevation design set forth in the SCDOT Roadway Design Manual (RDM) which applies to the project through the language “SCDOT policies, standards, and procedures” that appears in the Rule on Work Zone

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Project: 1-20 over Wateree Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 11 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:**

Safety and Mobility: Implementation, Maintenance, and Safety Guidelines as required per Exhibit 4d s 2.1. This ATC deviates from the curve radius required for 4% superelevation per the SCDOT Roadway Design Manual (RDM), Figure 5.3-B Superelevation Rate (emax = 8%). The required radius for a 4% superelevation at 60 mph is 3,890 ft to 4,140 ft. The proposed design is a radius of 1,900 ft with a 4% superelevation.
Additionally, this ATC deviates from the Request for Proposals (RFP) – Addendum 2, Exhibit 4d – Traffic Design Criteria – Part 2, Section 2.6 Staging that states, "Design speeds shall meet 70mph throughout the Project except as follows: SCDOT will accept a 60mph design speed for the transition from the existing I-20 mainline travel lanes to the temporary bridge structure only on the west end of the main channel bridge over Wateree River." This ATC requests this section to be revised to state, "Design speeds shall meet 70mph throughout the Project except as follows: SCDOT will accept a 60mph design speed for the transition from the existing I-20 mainline travel lanes to the temporary bridge structure or the temporary center-section of the permanent six-lane structure on the west end of the main channel bridge over Wateree River."

Justification:

This ATC permits the project to provide temporary cross overs without running superelevation transitions onto the newly constructed Wateree center bridge deck or the existing Buck Creek structures. This ATC is only applicable to the crossovers on the west side of the Wateree structures. Application of the AASHTO Method 2 superelevation design approach at a 60-mph design speed will provide a comfortable superelevation rate (4%) in the crossover with a side friction factor (0.09 less than the maximum allowed (0.12) for a 60-mph design per SCDOT RDM Figure 5.2-B. The application of Method 5 superelevation design with a 50%/50% superelevation runoff results in temporary pavement running onto the Wateree bridge. Superelevation design calculations for both Method 2 and Method 5 are included with this ATC. NCHRP 581 (see attached), Section 2.3.2 Superelevation Distribution states, "The Green Book, which is used primarily for the design of permanent roadways, recommends Method 5 for the distribution of e and f on rural highways, urban freeways, and high-speed urban streets. The Green Book recommends Method 2 for the design of horizontal curves on low-speed urban streets. Both methods are used for designing temporary roadways in construction work zones on high-speed highways."

Schedule:

There are no overall project schedule savings anticipated.

Impacts:

This ATC will eliminate the need of a variable depth temporary asphaltic buildup on the new Wateree Structure as well as extending over the existing Buck Creek Bridges that would be required with the 70-mph temporary design speed and the superelevation transition design defined in the SCDOT Roadway Design Manual section 5.3. (AASHTO Method 5) for the temporary crossovers.

History:

This methodology is from NCHRP 581 and is broadly implemented for traffic control measures throughout the country temporarily during construction.

Risks:

There are no additional risks to SCDOT or other persons/entities with implementing this ATC.

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Project: 1-20 over Wateree Bridge Replacement and Swamp Overflow Bridge Rehab **Project ID:** 2847360

ATC No.: 11 **Priority:** High **Team:** Kiewit Infrastructure South Co. **Date:** 1/19/23

Costs (required):

Cost Savings: $197,000

Quality:

This ATC improves the final quality of the project because there will not be a need to place asphalt on the existing or new structures; therefore, there is no need to grind any asphalt or concrete off the structures at the end of the project.

Operations & Maintenance:

This ATC does not affect the Operations & Maintenance of the project.

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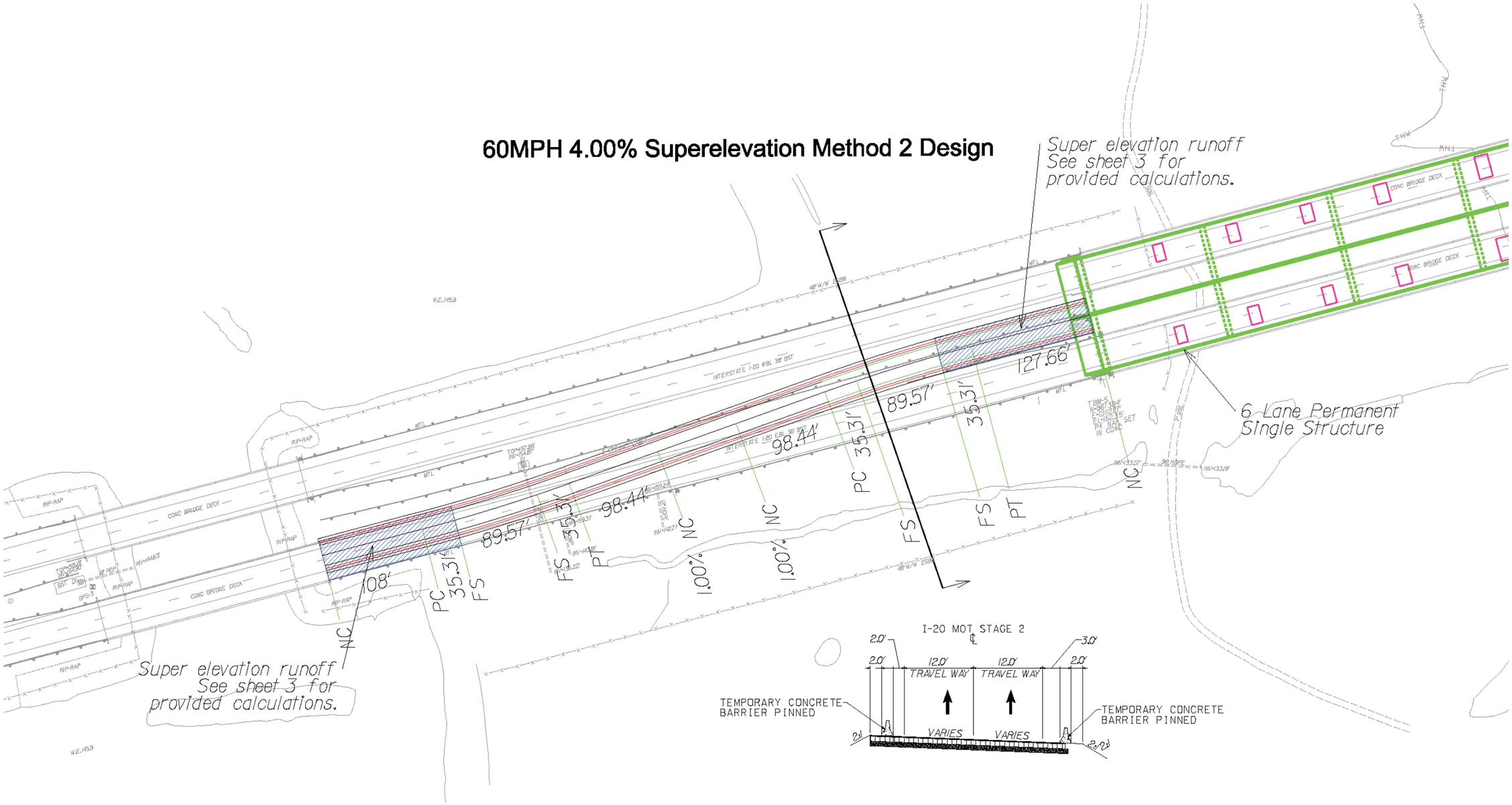
ATC 11 – ATTACHMENT 1 - 60 MPH 4.00% SUPERELEVATION METHOD 2 DESIGN (NCHRP 581)



60 mph Method 2 Superelevation Design Calculations

The minimum radius required, calculated below, uses the maximum side friction factor for a 60mph design speed. The maximum side friction factor for a 60 mph design speed is 0.12 per SCDOT RDM Figure 5.2-B. The minimum radius for a 60 mph design speed at a 4% superelevation is 1,500 ft. The radius used in the crossover design is 1,900 ft.

$$R_{min}=\frac{V^2}{15(e_{max}+f_{max}}$$

$$R_{min}=\frac{60^2}{15(.04+.12)}=1500\text{ft}$$

5.2-4 HORIZONTAL ALIGNMENT March 2017

Design Speed, (V_d) (miles per hour)	f_{max}	Minimum Radii, R_{min}* (feet)
25	0.23	134
30	0.20	214
35	0.18	314
40	0.16	444
45	0.15	587
50	0.14	758
55	0.13	960
60	0.12	1200
65	0.11	1480
70	0.10	1810
75	0.09	2210

$$^*R_{min}=\frac{V_d^{\,2}}{15(e_{max}+f_{max})}$$

MINIMUM RADII (e_{max} = 8.0 Percent)
Figure 5.2-B

Design radius of 1900' provides a side friction factor of .09.

$$f=\frac{60^2}{(15)(1900)}-.04=.09$$

Side Friction

$$f=\frac{V^2}{15R}-e$$

AASHTO EQ 3-7

where:
R = radius of curve, ft;
V = design speed, mph;
e = rate of roadway superelevation, ft/ft;
f = side friction factor.

Superelevation Runoff 60mph, *e*=4% =L_R =107'

AASHTO Table 3-16a provides runoff length of 107' for a 60mph design speed at a 4% superelevation.

Table 3-16a. Superelevation Runoff L_r (ft) for Horizontal Curves

U.S. Customary

e (%)	V_d = 15 mph		V_d = 20 mph		V_d = 25 mph		V_d = 30 mph		V_d = 35 mph		V_d = 40 mph		Vd = 45 mph		Vd = 50 mph		V_d = 55 mph		V_d = 60 mph		V_d = 65 mph		V_d = 70 mph		V_d = 75 mph	
	Number of Lanes Rotated. Note that 1 lane rotated is typical for a 2-lane highway, 2 lanes rotated is typical for a 4-lane highway, etc. (See Table 3-15.)																									
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)
1.5	23	35	24	37	26	39	27	41	29	44	31	47	33	50	36	54	38	58	40	60	42	63	45	68	47	71	52	77
2.0	31	46	32	49	34	51	36	55	39	58	41	62	44	67	48	72	51	77	53	80	56	84	60	90	63	95	69	103
2.2	34	51	36	54	38	57	40	60	43	64	46	68	49	73	53	79	56	84	59	88	61	92	66	99	69	104	75	113
2.4	37	55	39	58	41	62	44	65	46	70	50	74	53	80	58	86	61	92	64	96	67	100	72	108	76	114	82	123
2.6	40	60	42	63	45	67	47	71	50	75	54	81	58	87	62	94	66	100	69	104	73	109	78	117	82	123	89	134
2.8	43	65	45	68	48	72	51	76	54	81	58	87	62	93	67	101	71	107	75	112	78	117	84	126	88	133	96	144
3.0	46	69	49	73	51	77	55	82	58	87	62	93	67	100	72	108	77	115	80	120	84	126	90	135	95	142	103	154
3.2	49	74	52	78	55	82	58	87	62	93	66	99	71	107	77	115	82	123	85	128	89	134	96	144	101	152	110	165
3.4	52	78	55	83	58	87	62	93	66	99	70	106	76	113	82	122	87	130	91	136	95	142	102	153	107	161	117	175
3.6	55	83	58	88	62	93	65	98	70	105	74	112	80	120	86	130	92	138	96	144	100	151	108	162	114	171	123	185
3.8	58	88	62	92	65	98	69	104	74	110	79	118	84	127	91	137	97	146	101	152	106	159	114	171	120	180	130	195
4.0	62	92	65	97	69	103	73	109	77	116	83	124	89	133	96	144	102	153	107	160	112	167	120	180	126	189	137	206
4.2	65	97	68	102	72	108	76	115	81	122	87	130	93	140	101	151	107	161	112	168	117	176	126	189	133	199	144	216
4.4	68	102	71	107	75	113	80	120	85	128	91	137	98	147	106	158	112	169	117	176	123	184	132	198	139	208	151	226
4.6	71	106	75	112	79	118	84	125	89	134	95	143	102	153	110	166	117	176	123	184	128	193	138	207	145	218	158	237
4.8	74	111	78	117	82	123	87	131	93	139	99	149	107	160	115	173	123	184	128	192	134	201	144	216	152	227	165	247
5.0	77	115	81	122	86	129	91	136	97	145	103	155	111	167	120	180	128	191	133	200	140	209	150	225	158	237	171	257
5.2	80	120	84	126	89	134	95	142	101	151	108	161	116	173	125	187	133	199	139	208	145	218	156	234	164	246	178	267
5.4	83	125	88	131	93	139	98	147	105	157	112	168	120	180	130	194	138	207	144	216	151	226	162	243	171	256	185	278
5.6	86	129	91	136	96	144	102	153	108	163	116	174	124	187	134	202	143	214	149	224	156	234	168	252	177	265	192	288
5.8	89	134	94	141	99	149	105	158	112	168	120	180	129	193	139	209	148	222	155	232	162	243	174	261	183	275	199	298
6.0	92	138	97	146	103	154	109	164	116	174	124	186	133	200	144	216	153	230	160	240	167	251	180	270	189	284	206	309
6.2	95	143	101	151	106	159	113	169	120	180	128	192	138	207	149	223	158	237	165	248	173	260	186	279	196	294	213	319
6.4	98	148	104	156	110	165	116	175	124	186	132	199	142	213	154	230	163	245	171	256	179	268	192	288	202	303	219	329
6.6	102	152	107	161	113	170	120	180	128	192	137	205	147	220	158	238	169	253	176	264	184	276	198	297	208	313	226	339
6.8	105	157	110	165	117	175	124	185	132	197	141	211	151	227	163	245	174	260	181	272	190	285	204	306	215	322	233	350

Find
3.3.8.2.1
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Tangent Runout

(Per AASHTO Green Book Equation 3-24)

At Buck Creek, existing NC =1%

$$L_t = \frac{e_{NC}}{e_d} * L_R = \frac{1}{4} * 107' = 26.75'$$

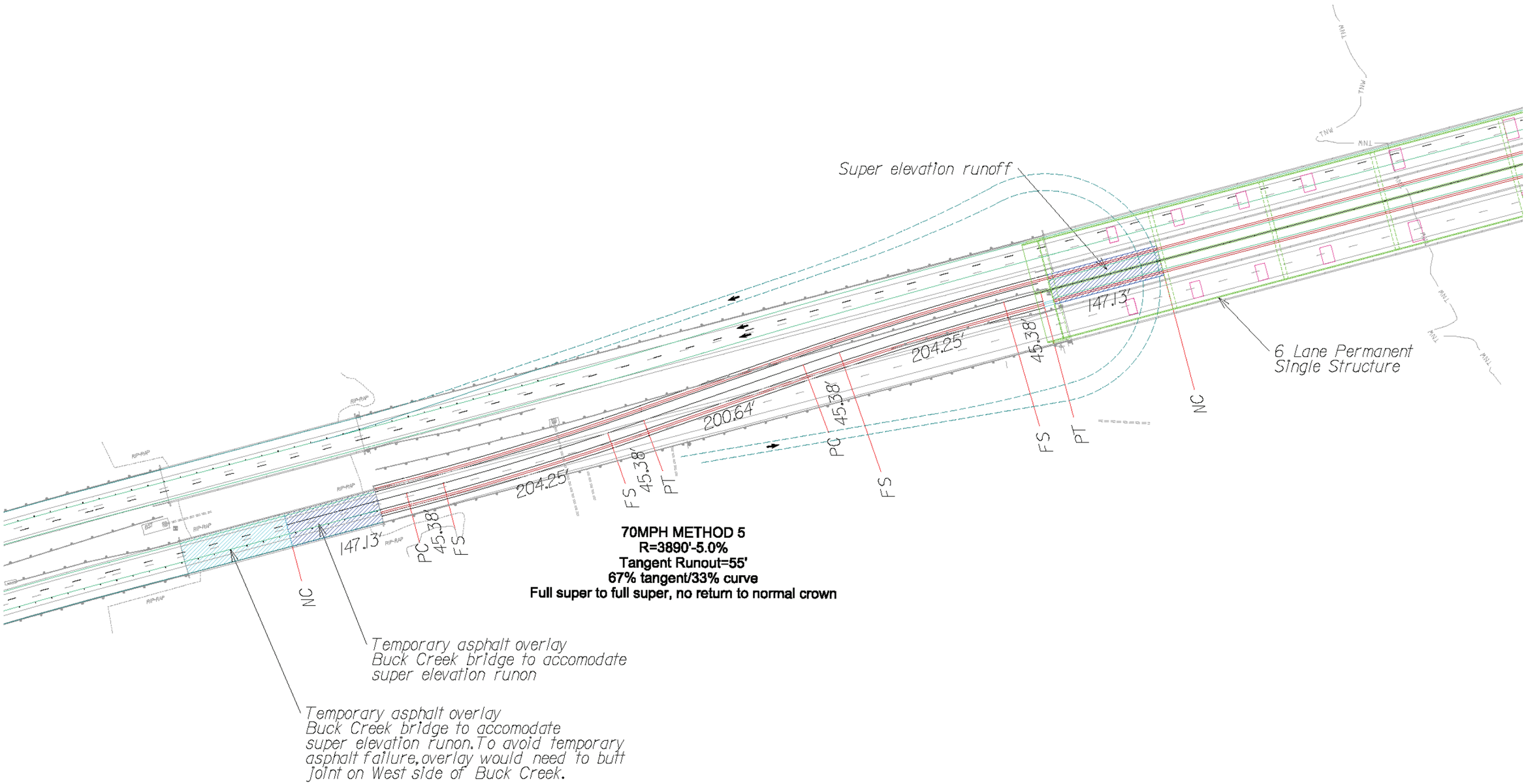
At Wateree, NC =2%

$$L_t = \frac{e_{NC}}{e_d} * L_R = \frac{2}{4} * 107' = 53.50'$$

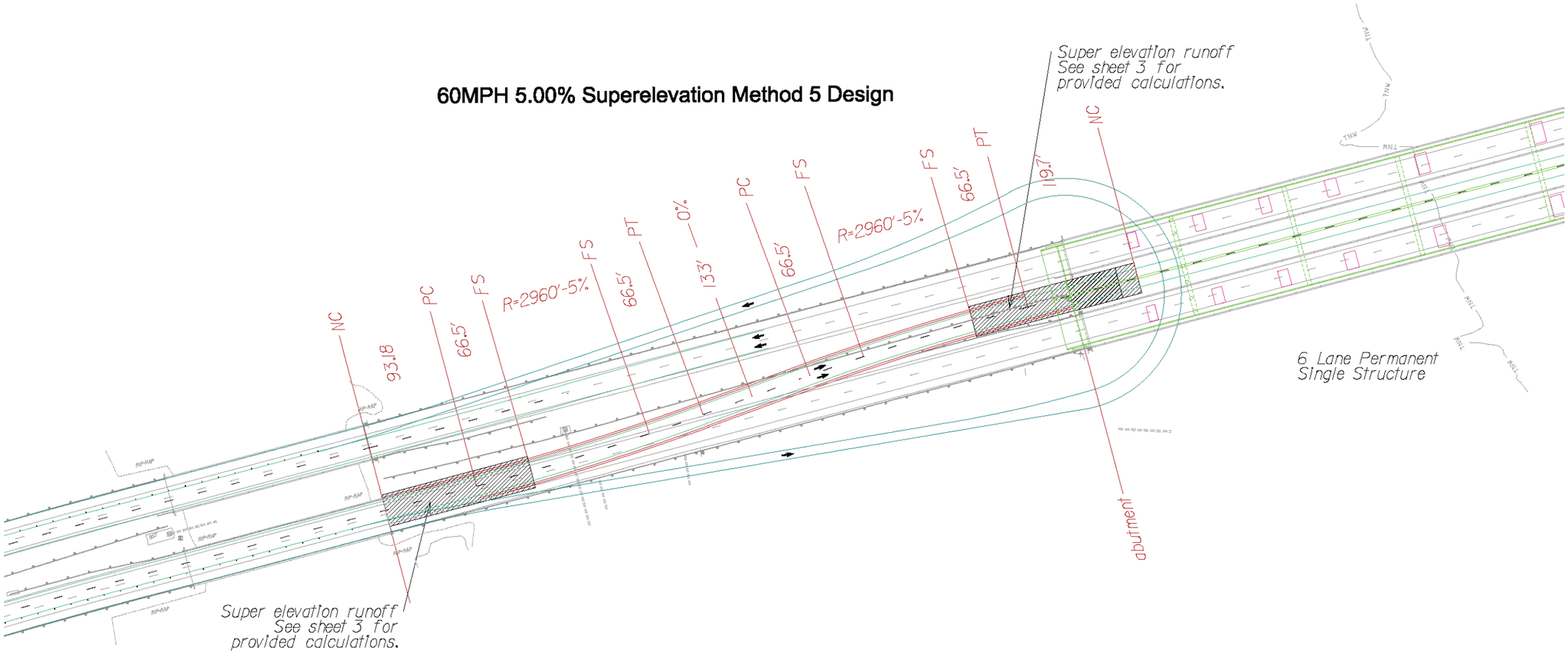
Distances provided in Attachment 1:

1. $L_t + (0.67)L_R = 26.75 + 0.67*107 = 98.44'$
2. $(0.33)L_R = 107'*.33 = 35.31'$
3. $L_t + (0.67)\ L_R = 53.50' + 0.67*107' = 125.2'$

ATC 11 – ATTACHMENT 2 - METHOD 5 SUPERELEVATION WITH 70 MPH DESIGN SPEED APPLIED TO TEMPORARY CONSTRUCTION ZONE



ATC 11 – ATTACHMENT 3 - 60MPH 5.00% SUPERELEVATION METHOD 5 DESIGN (NCHRP 581)



60 mph Method 5 Superelevation Design Calculations

The minimum radius required for a 5% superelevation at 60mph is 2960'.

Table 3-10. Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} = 8%

U.S. Customary														
e (%)	V_d = 15 mph	V_d = 20 mph	V_d = 25 mph	V_d = 30 mph	V_d = 35 mph	V_d = 40 mph	V_d = 45 mph	V_d = 50 mph	V_d = 55 mph	V_d = 60 mph	V_d = 65 mph	V_d = 70 mph	V_d = 75 mph	V_d = 80 mph
	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)
NC	932	1640	2370	3240	4260	5410	6710	8150	9720	11500	12900	14500	16100	17800
RC	676	1190	1720	2370	3120	3970	4930	5990	7150	8440	9510	10700	12000	13300
2.2	605	1070	1550	2130	2800	3570	4440	5400	6450	7620	8600	9660	10800	12000
2.4	546	959	1400	1930	2540	3240	4030	4910	5870	6930	7830	8810	9850	11000
2.6	496	872	1280	1760	2320	2960	3690	4490	5370	6350	7180	8090	9050	10100
2.8	453	796	1170	1610	2130	2720	3390	4130	4950	5850	6630	7470	8370	9340
3.0	415	730	1070	1480	1960	2510	3130	3820	4580	5420	6140	6930	7780	8700
3.2	382	672	985	1370	1820	2330	2900	3550	4250	5040	5720	6460	7260	8130
3.4	352	620	911	1270	1690	2170	2700	3300	3970	4700	5350	6050	6800	7620
3.6	324	572	845	1180	1570	2020	2520	3090	3710	4400	5010	5680	6400	7180
3.8	300	530	784	1100	1470	1890	2360	2890	3480	4140	4710	5350	6030	6780
4.0	277	490	729	1030	1370	1770	2220	2720	3270	3890	4450	5050	5710	6420
4.2	255	453	678	955	1280	1660	2080	2560	3080	3670	4200	4780	5410	6090
4.4	235	418	630	893	1200	1560	1960	2410	2910	3470	3980	4540	5140	5800
4.6	215	384	585	834	1130	1470	1850	2280	2750	3290	3770	4310	4890	5530
4.8	193	349	542	779	1060	1390	1750	2160	2610	3120	3590	4100	4670	5280
5.0	172	314	499	727	991	1310	1650	2040	2470	2960	3410	3910	4460	5050
5.2	154	284	457	676	929	1230	1560	1930	2350	2820	3250	3740	4260	4840
5.4	139	258	420	627	870	1160	1480	1830	2230	2680	3110	3570	4090	4640
5.6	126	236	387	582	813	1090	1390	1740	2120	2550	2970	3420	3920	4460
5.8	115	216	358	542	761	1030	1320	1650	2010	2430	2840	3280	3760	4290
6.0	105	199	332	506	713	965	1250	1560	1920	2320	2710	3150	3620	4140
6.2	97	184	308	472	669	909	1180	1480	1820	2210	2600	3020	3480	3990

Superelevation Runoff 60mph, *e*=5% =L_R =133'

AASHTO Table 3-16a provides runoff length of 133' for a 60mph design speed at a 5% superelevation.

Table 3-16a. Superelevation Runoff L_r (ft) for Horizontal Curves

U.S. Customary																												
e (%)	V_d = 15 mph		V_d = 20 mph		V_d = 25 mph		V_d = 30 mph		V_d = 35 mph		V_d = 40 mph		Vd = 45 mph		Vd = 50 mph		V_d = 55 mph		V_d = 60 mph		V_d = 65 mph		V_d = 70 mph		V_d = 75 mph		V_d = 80 mph	
	Number of Lanes Rotated. Note that 1 lane rotated is typical for a 2-lane highway, 2 lanes rotated is typical for a 4-lane highway, etc. (See Table 3-15.)																											
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)	L_r (ft)
1.5	23	35	24	37	26	39	27	41	29	44	31	47	33	50	36	54	38	58	40	60	42	63	45	68	47	71	52	77
2.0	31	46	32	49	34	51	36	55	39	58	41	62	44	67	48	72	51	77	53	80	56	84	60	90	63	95	69	103
2.2	34	51	36	54	38	57	40	60	43	64	46	68	49	73	53	79	56	84	59	88	61	92	66	99	69	104	75	113
2.4	37	55	39	58	41	62	44	65	46	70	50	74	53	80	58	86	61	92	64	96	67	100	72	108	76	114	82	123
2.6	40	60	42	63	45	67	47	71	50	75	54	81	58	87	62	94	66	100	69	104	73	109	78	117	82	123	89	134
2.8	43	65	45	68	48	72	51	76	54	81	58	87	62	93	67	101	71	107	75	112	78	117	84	126	88	133	96	144
3.0	46	69	49	73	51	77	55	82	58	87	62	93	67	100	72	108	77	115	80	120	84	126	90	135	95	142	103	154
3.2	49	74	52	78	55	82	58	87	62	93	66	99	71	107	77	115	82	123	85	128	89	134	96	144	101	152	110	165
3.4	52	78	55	83	58	87	62	93	66	99	70	106	76	113	82	122	87	130	91	136	95	142	102	153	107	161	117	175
3.6	55	83	58	88	62	93	65	98	70	105	74	112	80	120	86	130	92	138	96	144	100	151	108	162	114	171	123	185
3.8	58	88	62	92	65	98	69	104	74	110	79	118	84	127	91	137	97	146	101	152	106	159	114	171	120	180	130	195
4.0	62	92	65	97	69	103	73	109	77	116	83	124	89	133	96	144	102	153	107	160	112	167	120	180	126	189	137	206
4.2	65	97	68	102	72	108	76	115	81	122	87	130	93	140	101	151	107	161	112	168	117	176	126	189	133	199	144	216
4.4	68	102	71	107	75	113	80	120	85	128	91	137	98	147	106	158	112	169	117	176	123	184	132	198	139	208	151	226
4.6	71	106	75	112	79	118	84	125	89	134	95	143	102	153	110	166	117	176	123	184	128	193	138	207	145	218	158	237
4.8	74	111	78	117	82	123	87	131	93	139	99	149	107	160	115	173	123	184	128	192	134	201	144	216	152	227	165	247
5.0	77	115	81	122	86	129	91	136	97	145	103	155	111	167	120	180	128	191	133	200	140	209	150	225	158	237	171	257
5.2	80	120	84	126	89	134	95	142	101	151	108	161	116	173	125	187	133	199	139	208	145	218	156	234	164	246	178	267
5.4	83	125	88	131	93	139	98	147	105	157	112	168	120	180	130	194	138	207	144	216	151	226	162	243	171	256	185	278
5.6	86	129	91	136	96	144	102	153	108	163	116	174	124	187	134	202	143	214	149	224	156	234	168	252	177	265	192	288
5.8	89	134	94	141	99	149	105	158	112	168	120	180	129	193	139	209	148	222	155	232	162	243	174	261	183	275	199	298
6.0	92	138	97	146	103	154	109	164	116	174	124	186	133	200	144	216	153	230	160	240	167	251	180	270	189	284	206	309
6.2	95	143	101	151	106	159	113	169	120	180	128	192	138	207	149	223	158	237	165	248	173	260	186	279	196	294	213	319
6.4	98	148	104	156	110	165	116	175	124	186	132	199	142	213	154	230	163	245	171	256	179	268	192	288	202	303	219	329
6.6	102	152	107	161	113	170	120	180	128	192	137	205	147	220	158	238	169	253	176	264	184	276	198	297	208	313	226	339
6.8	105	157	110	165	117	175	124	185	132	197	141	211	151	227	163	245	174	260	181	272	190	285	204	306	215	322	233	350

Tangent Runout

At Buck Creek, existing NC =1%

$$L_t = \frac{e_{NC}}{e_d} * L_R = \frac{1}{4} * 133' = 33.25'$$

At Wateree, NC =2%

$$L_t = \frac{e_{NC}}{e_d} * L_R = \frac{2}{4} * 133' = 66.5'$$

Distances provided in Attachment 2:

1. $L_t + (0.67)L_R = 33.25 + 0.50 * 133 = 99.75'$
2. $(0.33)L_R = 133' * .50 = 66.5'$
3. $L_t + (0.67)\ L_R = 66.5' + 0.5 * 133' = 133'$

Kiewit ATC 11 – Attachment 4 - NCHRP Report 581

NCHRP

REPORT 581

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Design of Construction Work Zones on High-Speed Highways

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 581

Design of Construction Work Zones on High-Speed Highways

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Research sponsored by the American Association of State Highway and Transportation Officials
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

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NCHRP REPORT 581

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The authors acknowledge and appreciate the contributions of state DOT personnel who provided valuable input through responses to a survey. Additionally, the Pennsylvania DOT and Texas DOT provided a special contribution by enabling the research team to collect work zone speed data on active construction projects.

FOREWORD

By Charles W. Niessner
Staff Officer
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This report presents the findings of a research project to develop guidance for designing geometric features of construction work zones on high-speed highways. The report will be of particular interest to practitioners responsible for the design of construction work zones.

Work zones require drivers to increase their attention in order to discern situations requiring special care. These special situations include the temporary geometrics that occur on the high-speed facilities that carry much of the nation's traffic. The consequences of errors made at high rates of speed are generally severe. U.S. DOT data show that most fatal work zone crashes for all vehicles and large trucks occurred on roads with speed limits of 55 mph or greater.

Both the American Association of State Highway and Transportation Officials (AASHTO), through its Strategic Highway Safety Plan, and the Federal Highway Administration (FHWA) consider improvement of work zone safety and mobility a high priority. More than 40,000 people are injured each year as a result of motor vehicle crashes in work zones. Recent data for work zone crashes show over 1,000 fatalities each year between 2002 and 2005.

The *AASHTO Policy on Geometric Design of Highways and Streets* (Green Book) provides design criteria for permanent highway and street facilities. It does not provide detailed guidance for design of high-speed highway construction work zones, for topics such as temporary geometrics (e.g., ramps, crossovers, diversions, and superelevation rates). Also, the *Manual on Uniform Traffic Control Devices* (MUTCD) includes a chapter on temporary traffic controls, but there is no direct link with the Green Book or guidance on many of the geometric decisions associated with work zones.

Some state DOTs have comprehensive work zone design guidance; however, no comparable national guideline has been published. Better information and design guidelines are needed to assist designers in making decisions about the safest and most effective work zone design and traffic control treatments.

Under NCHRP Project 3-69, "Design of Construction Work Zones on High-Speed Highways," researchers at the Pennsylvania State University developed guidance for the design of geometric features, including horizontal and vertical alignment, cross-sectional features, and temporary concrete barrier placement. The research team also developed a work zone speed prediction model that estimates free-flow vehicle speeds through two types of construction work zones on four-lane freeways: single-lane closure and median crossovers.

The research team reviewed the literature and ongoing research related to work zone design and safety. A survey of state DOTs was also conducted. Survey responses and a review of state DOT websites provided substantial information on current DOT work zone design

policies and guidelines. The survey also identified priority topics associated with the design of construction work zones, and these priorities guided the research effort. Seventy-five percent of the states responding to the survey ranked improved guidance on traffic barriers and design as the "most important/critical" need. The roadside design and barrier placement guidance includes a discussion of the clear zone concept and its applicability to construction work zones, the identification of work zone hazards that may require treatment or shielding, and the use of benefit-cost analysis for roadside safety treatment decisions.

The subject of speed is inextricably connected to work zones. There is a widely held perception that speed is one of the most significant factors in road crashes. The work zone speed prediction model enables designers to develop a speed profile to detect inconsistencies in construction work zone designs.

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PREFACE

This publication is intended for consideration by state departments of transportation (DOTs) in developing policies and procedures related to work zone safety and mobility. It is also intended for use by transportation agency and consultant personnel involved in the planning, design, and review of construction work zones on high-speed highways. This publication is not a standard.

No document alone can guide a user to the most appropriate design choice for every application. Experience and relevant knowledge are also necessary in rendering work zone design decisions. The guidance provided in many areas reflects consideration of engineering principles, research findings related to work zones and permanent roads, and agency work zone practice. For many design factors, there are no published research findings to indicate the safety or operational consequences of a particular choice. Furthermore, specific practice and criteria used by different agencies sometimes vary substantially. As such, the recommended design approach and values do not necessarily reflect a complete understanding of all work zone factors or a consensus of DOT policies. Therefore, agencies are encouraged to place substantial weight on processes and criteria that have been implemented in an operational environment and carefully evaluated.

CHAPTER 1

Introduction

1.1 Background

After decades of rapid highway system expansion, construction of additional capacity has diminished. Increasingly, capital program resources are being directed to the enhancement and preservation of existing facilities. However, growth in highway travel continues unabated. Exhibit 1-1 illustrates the recent asymmetric growth of travel and basic capacity in the United States.

Many segments of highway infrastructure constructed during the system expansion era are approaching or have exceeded their useful lives. As a result, construction activity on existing facilities is increasing at a time when the facilities are of increasing importance to economic efficiency and social activity. Transportation agencies are challenged with continuous management of highways, assuring their adequate performance in the near term and far into the future. To meet long-term expectations, highway infrastructure renewal and enhancement are needed. The construction work zones required to improve infrastructure are a source of potential disruption that often impede mobility and are widely perceived as locations of elevated crash risk. Management and design strategies can substantially reduce the negative consequences caused by construction work zones.

This publication is intended to directly guide work zone design decisions associated with construction on high-speed highways. High-speed highways are those with free-flow speeds of 80 km/h [50 mph] or more. The guidance was not developed for maintenance and utility work zones or for work zones on low- and intermediate-speed roads and streets.

Historically, plans for highway construction work zones have emphasized temporary traffic control (TTC), which is intended to facilitate travel through a construction work zone by the use of devices that inform, advise, and regulate motorists. Guidance for the development of TTC plans is provided by FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD), which is the national standard for traffic control. While the importance of TTC grows as traffic exposure and public expectations increase, there are additional aspects of construction work zones for which guidance is needed that are not covered by the MUTCD or other publications. In general, this guidance is related to the geometric characteristics and physical infrastructure of roadways within construction work zones on high-speed highways. Consequently, this publication is intended for use in conjunction with the MUTCD, not as a substitute.

This report will be the first of its type: guidance for designing the geometric features of construction work zones, with intended national application. However, other nationally disseminated publications address aspects of roadway and roadside design in work zones. *A Policy on Geometric Design of Highways and Streets* (Green Book) (*1*) and the *Roadside Design Guide* (*2*), both of which are published by American Association of State Highway and Transportation Officials (AASHTO), also provide limited guidance on the design of work zones. The information in this report is intended to enhance that found in the Green Book. Most of the information in Chapter 9 of the 2002 *Roadside Design Guide*—"Traffic Barriers, Traffic Control Devices and Other Safety Features for Work Zones"—relates to the installation details and structural characteristics of particular barrier systems. However, limited roadside design and barrier placement guidance are also provided (Section 9.1). The information provided in Chapters 4 and 5 of this report is intended as an enhancement of the information in Chapter 9 of the *Roadside Design Guide.* Exhibit 1-2 identifies the intended general relationship between this report and the other publications.

This report provides an approach for the selection of an appropriate construction work zone type. Guidance for the design of geometric features, including horizontal and vertical alignment, cross-sectional features, and barrier placement is included. Guidance for a variety of ancillary features (e.g., drainage systems, lighting, and surface type) is also provided.

	Measure	Year		Change (%)
		1980	2000	
Metric	Million Vehicle-Kilometers Traveled	2,458,945	4,427,183	+ 80.0
Metric	Lane-Km	12,754,700	13,239,663	+ 3.8
U.S. Customary	Million Vehicle-Miles Traveled	1,527,295	2,749,803	+ 80.0
U.S. Customary	Lane-Miles	7,922,174	8,223,393	+ 3.8

Source: FHWA, *Highway Statistics.* Washington, DC (various years).

Exhibit 1-1. Changes in U.S. travel and capacity.

1.2 Terminology

Construction and work zone terms are not used consistently across agencies and disciplines (planning, design, enforcement, construction, etc.). To facilitate communication, terms used in this publication are defined here.

50th-percentile speed: the median speed of the observed traffic at a particular point or segment.

85th-percentile speed: the speed at or below which 85 percent of all observed traffic is traveling at a particular point or segment.

Advisory speed: the speed displayed on an advisory speed plaque and determined on the basis of an engineering analysis.

Alternating one-way operation: a construction work zone mitigation strategy used on two-way roadways wherein opposing directions of travel take turns using a single travel lane. Flaggers, with or without pilot vehicles; STOP signs; or signals are normally used to coordinate the two directions of traffic. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as o*ne-lane, two-way operation.*

Annual average daily traffic (AADT): the total volume of traffic passing a point or segment of a highway in both directions for 1 year divided by the number of days in the year.

Anticipated free-flow speed: the speed at which vehicles are expected to travel when roadway conditions (e.g., geometry and traffic control devices), and not other vehicles, control speed.

Average daily traffic (ADT): the total volume of traffic passing a point or segment of a highway in both directions for a period of time (in whole days), greater than 1 day and less than 1 year, divided by the number of days.

Construction work zone: an area occupied for three or more days for the purpose of constructing, reconstructing, rehabilitating, or performing preventive maintenance. A construction work zone extends from the first TTC device to the last TTC device.

Crossover: a construction work zone type for which adjacent traffic lanes that normally carry traffic in the same direction are converted to two-way traffic operation. Also see *median crossover* for a particular type of crossover.

Design consistency: the provision of geometric features and design elements that meet driver expectancies.

Design controls: factors outside the designer's discretion that may affect the design process and designed solution. Examples include traffic volumes, vehicle size and weight, atmospheric conditions, driver, and other human characteristics.

Design criteria: characteristics by which the sufficiency of a design feature may be assessed.

Design features: geometric and dimensional characteristics of the roadway and roadside, including horizontal and vertical alignment and cross-sectional elements.

Design hourly volume (DHV): a two-way hourly volume determined for use in design, representing traffic expected to use a highway.

Publication	Summary of Coverage	Relationship to This Report
AASHTO Green Book	Geometric guidance for all types of roads, primarily permanent facilities	This report supplements the limited guidance in the Green Book specifically related to work zones.
MUTCD	Traffic control devices, including temporary traffic control	This report should be used in conjunction with the MUTCD, which is applicable to work zones.
AASHTO *Roadside Design Guide* (RDG) Chapter 9	Roadside safety, including work zone barriers, traffic control devices and other features	This report supplements RDG Chapter 9 regarding placement of temporary barriers in construction work zones.
NCHRP Report 581	Geometric and physical features common to construction work zones on high-speed highways	This report is *NCHRP Report 581*.

Exhibit 1-2. Relationships between this report and national publications that address work zones.

Detour: a construction work zone mitigation strategy wherein traffic in one or both directions is rerouted onto an existing highway to avoid a construction work zone. Detoured vehicles may travel on permanent roads only or on a combination of permanent and temporary roads. This strategy compensates for the removal of permanent travel lanes from service.

Direction design hourly volume (DDHV): an hourly volume determined for use in design, representing traffic expected to use one direction of travel on a highway.

Diversion: a construction work zone mitigation strategy wherein traffic in one or both directions on a designated route is carried by a temporary roadway around a work area and reconnected with the permanent infrastructure of the designated route. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as a *shoofly* or *runaround.*

Emergency turnouts: segments of wider-than-typical shoulder. May be provided as disabled vehicle refuge at regular intervals or where conditions permit on roadways (perhaps temporary) where it is not practical to provide a continuous full-width shoulder. May also be referred to as intermittent shoulders.

Entrance/exit ramp configurations: geometric attributes of expressway ramps within a construction work zone.

Freeway: an expressway with full access control and no at-grade intersections.

Full road closure: a construction work zone mitigation strategy wherein traffic operations are removed or suspended in either one or two directions on a segment of roadway or ramp.

Half-width construction: a construction strategy wherein half of a symmetrical (or nearly so) roadway is reconstructed (or refurbished) as a phase without encroachment on the other half. For divided highways, a one-way roadway is reconstructed as a phase.

High-speed highway: a road or highway on which traffic operates with an 85th-percentile free-flow speed of 80 km/h [50 mph] or greater.

Intermittent closure: a construction work zone mitigation strategy wherein all traffic in one or both directions is stopped for a relatively short period to allow for construction operations.

Lane closure: a construction work zone mitigation strategy wherein one or more travel lanes and any adjacent shoulders are closed to traffic. As defined here, this term is not limited to closing one lane of a multilane highway. Lane closures are inherent to *median crossovers.*

Lane constriction: a construction work zone mitigation strategy wherein the width of one or more travel lanes is reduced. The number of travel lanes may be retained (possibly through median or shoulder use) or reduced.

Lane construction: a construction work zone mitigation strategy wherein a travel lane is reconstructed (or refurbished) without encroaching into other travel lanes.

Median crossover: a construction work zone mitigation strategy used on expressways (including freeways) to establish *two-way traffic on a normally divided facility.* In this strategy:

- The number of lanes in both directions is reduced;
- At both ends, traffic in one direction is routed across the median to the opposite-direction roadway on a temporary roadway constructed for that purpose; and
- Two-way traffic is maintained on one roadway while the opposite direction roadway is closed.

This strategy involves the inherent use of *median crossovers,* and this strategy may be employed in combination with *use of shoulder.*

One-lane, two-way operation: see *alternating one-way operation*.

Operating speed: the 85th-percentile of the distribution of vehicle speeds observed operating under free-flow conditions.

Part-width construction: a construction strategy wherein roadway elements (travel lane, shoulder, etc.) are reconstructed while traffic is maintained on adjacent elements.

Percent trucks (%T): of the average daily traffic at a particular point or segment, the percentage that is trucks.

Portable concrete safety-shape barrier: see *temporary concrete barrier*

Posted speed: see *regulatory speed*

Regulatory speed: the legally established and designated speed limit. With further modification, the term includes (1) the regulatory speed of a roadway as a driver approaches a work zone, (2) the regulatory speed for a road prior to its inclusion in a work zone, and (3) the regulatory speed within a work zone.

Runaround: see *diversion*.

Shoofly: see *diversion.*

Shoulder closure: a construction work zone mitigation strategy wherein a shoulder is closed to traffic.

Temporary concrete barrier (TCB): a temporary concrete longitudinal traffic barrier. Same as *portable concrete safety-shape barrier.*

Temporary roadway: a roadway constructed to carry highway traffic exclusively during construction. Temporary roadways are used in conjunction with *diversion* and *median crossover* work zone strategies and may be used with a *detour* work zone mitigation strategy.

Temporary traffic control (TTC): a construction work zone mitigation strategy wherein devices and measures are used to facilitate road users through work zones.

Transportation management plan (TMP): a strategy to manage the work zone impacts of a project. Each TMP will include a TTC plan. For some projects, the TMP will also include

additional elements addressing transportation operations and public information.

Two-way traffic on a normally divided facility (TWTNDF): a construction work zone type in which traffic in one direction of a normally divided facility is transferred to two-way operation on one roadway. A *median crossover* is the infrastructure used to implement this work zone type. The terms are sometimes used interchangeably. *Use of shoulder* may also be used to support this work zone type.

Use of shoulder: a construction work zone mitigation strategy involving the use of a right-side or median shoulder as all or part of a temporary traffic lane. This strategy compensates for the removal of permanent travel lanes from service. Employing this strategy may require constructing or upgrading shoulder pavement structures to adequately support traffic loads.

Work zone design speed: a selected speed used to determine specific work zone geometric design features.

CHAPTER 2

Design Controls and Principles

The design of construction work zones involves many of the same factors that pertain to permanent roads, and much of the knowledge used for highway design is also relevant to design of construction work zones on high-speed highways. Yet there are substantive differences between permanent roads and roads in construction work zones that should be reflected in the respective design processes.

Separate design guidance for permanent roads and roadways in construction work zones is appropriate for two major reasons. First, construction work zones have short service lives. Exposure is directly related to service life and is a key consideration in any design decision involving safety. Service life also affects the cost-effectiveness of investments (i.e., costs related to infrastructure and impacts). Second, the design of work zones is far more restricted than the design of permanent roads. The feasibility of work zone alignment and cross-sectional alternatives is often limited by the necessity to tie in existing facilities and to avoid costs and impacts associated with short-term arrangements.

This chapter covers subjects that serve as background to the development of design guidance and to individual design decisions. The chapter is organized in a manner somewhat similar to guidance provided for permanent roads and reflects many of the same considerations and conventions involved in designing permanent roadways.

2.1 Design Controls

Design controls are factors that lie outside the designer's discretion but may affect the design process and the designed solution. Factors can be grouped as outlined below.

2.1.1 Human

Vehicle operators and pedestrians have an expected range of capability and performance with respect to visual acuity, cognition, attentiveness, dexterity, and coordination. Nearly all human and driver characteristics have safety overtones when they affect performance within an operating environment that includes high-mass, high-speed vehicles. The number of licensed drivers in the United States is approaching 200 million, and individual drivers will react to the same conditions differently. Accommodating such a large and diverse set of performance levels and expectations is a major consideration in developing nearly all design criteria.

2.1.2 Material

The engineering and physical properties (e.g., friction, resistance to deformation, and retroreflectivity) of roadway components and appurtenances affect some design criteria.

2.1.3 Vehicles

Vehicle characteristics and performance capabilities affect design criteria. Vehicle factors that directly or indirectly influence design criteria include dimensions, height of operator's seat, weight-to-power ratio, acceleration and deceleration (i.e., braking) capability, body roll angles, and cornering and turning stability. In construction work zones, geometry is often constrained. Several key decisions (e.g., minimum lane width and maximum grades) are strongly influenced by traffic volume and composition (i.e., type of vehicles).

2.1.4 Setting

Highways are woven into communities and natural settings. The characteristics of a project location are referred to as the setting, and they affect design criteria and specific design choices. Examples of setting include area type (e.g., rural or urban), terrain, density and type of adjacent land use, natural and human-made environmental features, and community characteristics.

2.1.5 Traffic

The magnitude and intensity of vehicle usage imposed on a specific facility are generally beyond the control of the design process. These factors (measured by ADT, DHV, and %T) have a substantial influence on design criteria and design choices. Transportation management plans for some projects include activities that will reduce the construction work zone traffic demand and may exclude specific vehicle categories from the traffic stream.

2.1.6 Facility Type

Construction work zones are designed and exist within the context of one or more existing transportation facilities. Traffic routinely using the facilities and traffic approaching the work zone may have expectations based on previous experience with a facility type. These expectations might involve the number and width of lanes, the shoulder width and type, appropriate speeds, the location of decision points, and access arrangements.

2.1.7 Scope of Construction

There may be some latitude in scope (e.g., pavement overlay and reconstruction), but a project's basic purpose generally lies beyond the designer's discretion and has substantial influence on the time and space required for construction. The time and space requirements, in turn, affect work zone design.

2.2 Design Principles

Through research and practice, a set of principles have been developed to guide design decisions. The principles address various aspects of the complex and interdependent vehicle-highway-human system. As an evolving body of knowledge, design principles have been used to develop explicit and narrowly tailored criteria (e.g., travel lane width) and as holistic guidance (e.g., combination of alignment elements) for permanent roads.

Principles exist in a context of objectives and constraints. Although difficult to quantify, all roads, individually and collectively, involve benefits and costs. Highways are constructed and maintained because they provide social benefits that exceed their cost. The principal objectives and direct benefits of highways are mobility and land access. Different highways, roads, and streets provide these functions in different proportions. The differences in emphasis are the basis for the functional classification system. Mobility is critical to an advanced and efficient economy, and it addresses a fundamental human and social desire. By creating access, land can be used for agricultural, commercial, industrial, recreational, and residential purposes. Both the mobility and land access functions are essential to community and personal vitality. Temporary reductions in these basic highway functions are sometimes required in conjunction with construction and reconstruction. A design objective specifically related to work zones is to minimize any reduction in the mobility and access functions.

Highways and mobility are not cost free. In addition to public expenditures for planning, designing, constructing, and reconstructing facilities, there are nonfinancial costs associated with the construction and operation of highways. Direct and indirect impacts are imposed on the natural (i.e., air, land, and water) and human environment. Some of these impacts are incurred at the time and location of construction, while other impacts develop over time and reach far beyond the immediate highway location. These negative consequences, some of which are also attached to construction work zones, are regarded as social costs. Some costs can be reasonably quantified, but others have to be considered on a qualitative basis. Through careful consideration of design alternatives and their respective probable impacts, designers and decision makers attempt to minimize negative impacts during the design development process.

The feasible range of design alternatives is often constrained by cost and setting (e.g., right-of-way and environmental features), including factors identified as controls. Designs for highways in construction work zones are often more restricted than designs for permanent roadways, since work zones must also accommodate construction operations and be closely aligned with the permanent road. The principles used to develop design criteria and to make choices at the project level are discussed below.

2.2.1 Safety

All movement and travel involves some level of risk. Regrettably, property damage, injuries, and death occur in conjunction with highway travel. Negative safety consequences are social costs. A primary objective of design policies and processes, including those used for construction work zones, is to minimize the frequency and severity of crashes. To effectively address safety in construction work zones, design guidance should reflect the growing body of highway safety knowledge. Increasingly, highway safety is treated as an objective and quantitative subject that requires the use of explicit terminology and measures.

However, the term "safe" is subjective and qualitative; in the context of highway travel, it does not have a specific meaning. If a safe highway is one that will never be the site of a crash, then safe highways exist only as conceptual abstractions. In fact, the discrete terms "safe" and "unsafe" are not meaningful in characterizing the likelihood or results of crashes.

Highway safety is a relative characteristic that is best described using quantitative measures. Crashes can occur on

any highway open to traffic; however, the probability of crash occurrence varies. "Substantive safety" is defined as "the expected crash frequency and severity" (*3*). Substantive safety is distinguished from "nominal safety," which is "examined in reference to compliance with standards, warrants, guidelines and sanctioned design procedures" (*3*). Highways with low expected crash frequencies and severity (i.e., with a high level of substantive safety) are a desirable outcome of the design process. The objective of design is to provide maximum benefits at minimum cost on an aggregate basis. Therefore, substantive safety is a principal, but not sole, consideration in developing design guidance for permanent roads and roads in construction work zones.

Substantive safety is a function of exposure. Exposure is the degree to which a highway element is subject to potential crash occurrence and is often measured via traffic volume. Since permanent roads exist for an indefinite period of time, analysis can be performed using a recurring increment of time for all relevant factors (e.g., number of crashes, traffic, and infrastructure costs). ADT is a suitable indicator of exposure for permanent roads, since the estimated rate will be fairly constant for a long period of time, probably indefinitely. Its use is conducive to the development of benefit-cost analysis on an annualized basis. However, work zones exist for a finite period of time, and it is appropriate to think of exposure in different terms. A specific condition may exist for a period ranging from hours to years, but not indefinitely. For construction work zones, exposure can be characterized by accounting for both rate (e.g., ADT) and duration. Conditions that may not be acceptable indefinitely (i.e., as part of a permanent roadway) may be acceptable for a low level of exposure (i.e., for a short duration and low traffic volume). Exposure is explicitly considered in quantitative safety analysis and should also be factored into the development of design policy and individual design decisions.

This design guidance is based on the pursuit of substantive safety, along with other considerations previously discussed. However, it should not be interpreted as outlining the boundaries for "safe" construction work zones. Designs that do not conform to this guidance should not be regarded as unsafe. That term has no practical meaning. Further, no general guidance can provide explicit direction for each and every design decision.

2.2.2 Design Consistency

Drivers continually interpret and respond to the roadway environment. Repeated exposure to, as well as successful experience with, certain roadway configurations creates driver expectancies. These expectancies instill an inclination by drivers to respond to common situations in predictable ways that have been successful in the past. Design consistency calls for the production of designs that reinforce (rather than violate) prevailing expectancies. Design consistency is the use of design elements that meet driver expectancies and that avoid unexpected geometric conditions and features. Work zone designs should conform to the reasonable expectations of drivers based on their previous experience. Information sources, including the roadway and associated traffic control devices, should provide positive guidance and be presented consistent with the principle of primacy. Design consistency is also related to speed management.

2.2.3 Primacy

Primacy refers to how drivers prioritize information they receive from various sources (e.g., traffic control devices, geometry, traffic, and terrain). Construction work zones often present drivers with higher information loads than permanent roads. Under the principle of primacy, safety-critical and other important information should be clearly, conspicuously, and prominently presented to drivers.

2.2.4 Speed Management

There is a widely held perception that speed is one of the most significant factors in road crashes. This perception is especially strong with regard to work zones. Speed reduction measures are a prominent topic in work zone practice and published research. Perceived speed-safety linkages stem, in part, from the relationship between vehicle speed and operator capability. Crash severity is related to the change in speed upon impact. Crash severity increases with speed and substantially so for speeds exceeding 100 km/h [60 mph]. The relationship of vehicle speed to crash probability is less clear. For permanent roadways, there is evidence indicating that crash probability is related to speed deviation above and below the mean speed. Crash rates are lowest for vehicles traveling near the mean speed. The objective of speed management is to elicit appropriate speed selection by drivers.

Many factors can influence the speed at which a motorist drives, including driver age, gender, attitude, and perceived risks of law enforcement or crash. Therefore, different drivers will choose different speeds for the same conditions. Speed choice is also influenced by factors such as weather, road and vehicle characteristics, speed zoning, speed adaptation, and impairment (*4*). The speed management practices discussed below are intended to influence mean speeds and speed variance and are considered appropriate for application to work zones.

2.2.4.1 Establish Reasonable Target Speeds

Target speed is the desirable free-flow operating speed. No single value can represent all vehicle speeds, since different

drivers will choose to operate at different speeds under the same conditions. The 85th-percentile speed is commonly used to characterize operating speed at a location or segment. In this guidance, target speed is the desirable 85th-percentile free-flow speed within a construction work zone.

The general characteristics of certain highways and drivers' previous experience with specific facilities create expectations, including those related to appropriate speed. Target speeds that meet or nearly meet experience-based expectations are desirable. The MUTCD suggests that TTC plans "be designed so that vehicles can reasonably safely travel through the TTC zone with a speed limit reduction of no more than 16 km/h [10 mph]." A speed prediction model developed during this project (NCHRP Project 3-69) may be used to estimate speeds for two common freeway work zone types: median crossovers and travel lane closure adjacent to active lane. Development of the model is summarized in *NCHRP Web-Only Document 105,* Section 4.2, which is available online at www.trb.org/news/blurb_detail.asp?id=7362. The model and user's manual are provided online at the same URL.

For a variety of reasons, experience-based speed expectancies are not always reasonable targets speeds. Operating speeds at particular locations must sometimes be reduced substantially below approach speeds. On high-speed facilities, this is undesirable yet unavoidable. Work zone design features are a potential cause of speed reduction and may preclude a target speed directly related to experience-based speed expectancies. This situation is addressed in the next section.

2.2.4.2 Employ Measures to Attain Significant Speed Reductions

The requirements for construction operations and other factors (e.g., right-of-way restrictions and existing features) may not allow a work zone design resulting in speeds comparable to those on the approaches or that prevailed on the same segment prior to establishing the work zone. Although the MUTCD suggests designing TTC plans that provide for reasonably safe travel with a speed limit reduction of no more than 16 km/h [10 mph], the potential need for greater speed reductions required by restrictive features is also recognized. In such a case, the work zone target speed is based on the restrictive features. A target speed selected in this manner may not be consistent with driver expectancy.

When a restrictive feature implies a speed limit reduction greater than 16 km/h [10 mph], driver notification should be provided through consistent, credible, and complementary information sources. Although static (i.e., advisory and regulatory) signage is a fundamental and important source of information, it should not be presumed as independently sufficient. The array of design, enforcement, legal, and technology strategies should be considered. Specific candidate speed management measures include automated enforcement (if applicable), dedicated enforcement patrols, drone radar, portable changeable message signs, rumble strips, speed trailers, warning devices, and variable speed limits. The selection of speed management measures should also consider the magnitude of speed reduction, exposure (i.e., traffic volume and duration of condition), and experience with comparable situations. Work zone speed management and control strategies are the subject of ongoing development and evaluation. Current information is available through a variety of websites, including the National Work Zone Safety Information Clearinghouse and sites hosted by organizations such as AASHTO and the FHWA.

2.2.5 Work Zone Design Speed

The Green Book and many other design policies employ a design speed approach for the design of permanent roads. With this convention, criteria for some design elements (e.g., sight distance, minimum radii, maximum grade, some cross-sectional dimensions, and superelevation) are directly related to design speed, whereas criteria for other roadway design elements (e.g., some cross-sectional elements and vertical clearance) are not related to design speed. Many, but not all, state transportation agencies use a speed parameter to guide some work zone design decisions. Agencies may use a speed parameter primarily for selected features (e.g., horizontal curvature) and/or for selected work zones types (e.g., median crossover). This report employs the work zone design speed that is defined (in Chapter 1) as "a selected speed used to determine specific work zone geometric design features." A value equal to or slightly greater than the target speed (discussed in Section 2.2.4) is appropriate. In this report, work zone design speed is applicable to radius of curvature and superelevation. When the work zone design speed is less than 60 km/h [40 mph], it is also used to determine appropriate sight distance. Work zone design speed may also be used in computing minimum length of sag vertical curves. Other speed parameters (e.g., speed limit and anticipated 85th-percentile speed) are also referenced in some design guidelines.

The establishment of a target speed and work zone design speed, design of TTC, and potential selection of speed management measures are related. Speed-related decisions within specific domains (i.e., design, regulatory, and speed management) should be consistent with an overall strategy. Exhibit 2-1 illustrates a process for work zone speed-related decisions.

2.2.6 Sight Distance

Drivers acquire most of the information they use to control and navigate their vehicles visually. Therefore, facilitating

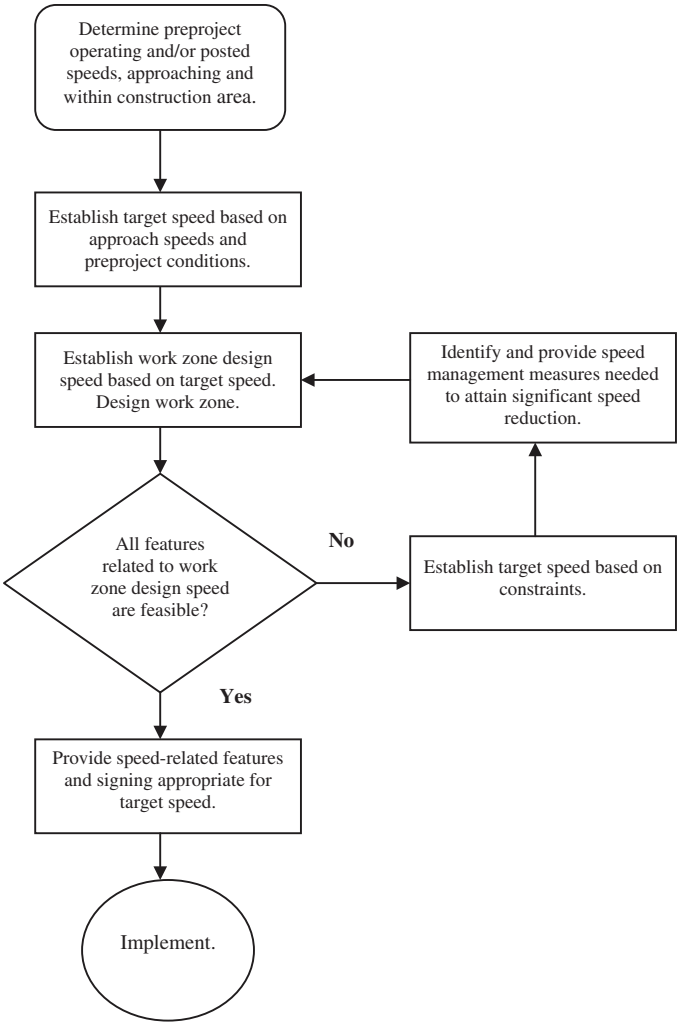


Exhibit 2-1. Work zone speed-related decision process.

driver visibility of the roadway, other traffic (e.g., pedestrians and vehicles), traffic control devices, appurtenances, and other conditions is imperative. The Green Book identifies four types of sight distance:

- Decision,
- Intersection,
- Passing, and
- Stopping.

Each of these sight distance types may be applicable to work zones, although providing for passing opportunities in work zones is not a priority.

Work zone designs that provide extensive visibility of their existence and features are desirable. Decision sight distance is defined as the distance needed by a driver to (a) detect an unexpected or difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, (b) recognize the condition or its potential threat, (c) select an appropriate path, and (d) initiate and complete the maneuver safely and efficiently (*5*). Although extended sight distances throughout work zones are desirable, the underlying need for decision sight distance (because of an unexpected or difficult-to-perceive information source or condition) should be avoided in designing construction work zones. TTC and other driver information strategies should be used in conjunction with extended sight distance to mitigate work zone conditions that are atypical or involve complex driver decisions.

The Green Book provides an approach for determining the minimum sight distance value for permanent roads. Current sight distance criteria for work zones vary among DOTs; some agencies have stopping sight distance criteria and others do not. For DOTs that have work zone stopping sight distance criteria, the typical approach is to use the value associated with the permanent road design criteria and the work zone speed parameter. Typically, Green Book values are used.

Several research studies have investigated a possible relationship between available sight distance and crash rates on permanent roads. These studies were reviewed (*6*) as a group, and no discernable effect of limited sight distance on crash frequencies or rates was found. However, one of the studies (*7*) reported that crash frequencies on crest vertical curves with sight distances less than 90 m [300 ft] were more than 50 percent higher than those on crest vertical curves with very long sight distances. No studies investigating the effects of sight distance on work zone safety have been published.

In conclusion, extended sight distance approaching and within work zones is desirable from an operations perspective. Safety considerations also point to the need for some minimum sight distance. For work zone design speeds less than 60 km/h [40 mph], the stopping sight distance values tabulated in the Green Book and corresponding to work zone design speed are recommended. For work zone design speeds of 60 km/h [40 mph] and greater, the Green Book design-speed-corresponding values do not necessarily represent the minimums that can be accepted, and a minimum sight distance of 90 m [300 ft] is recommended using a driver eye height of 1,080 mm [3.5 ft] and an object height of 600 mm [2.0 ft].

2.2.7 Forgiving Roadside

Vehicles leave the traveled way for a variety of reasons. Regardless of the reason for the departure, a roadside environment free of fixed objects with stable, relatively flat slopes enhances the opportunity for reducing accident severity (*2*). Although a vehicle may depart from any roadway, the roadway itself can influence the probability of a departure; roadside characteristics affect the probable consequences of the departure. The forgiving roadside and risk exposure principles

are the basis for traffic barrier placement and roadside design guidance. Specific guidance related to the forgiving roadside principle is provided in Chapter 5, "Roadside Design and Barrier Placement."

2.2.8 Roadway Surface and Cross Section

Driving surface characteristics, especially roughness and friction, have an influence on motorist comfort and tire-road interaction. As discussed earlier in Section 2.2.1, traffic exposure should be considered in any assessment of how design decisions will affect safety. Several transportation agency work zone policies provide for the use of unpaved surfaces on temporary roadways in construction work zones. In most cases, the guidance establishes exposure as the principal consideration, referring to short durations, low volume, or a combination of duration and volume as factors under which unpaved traveled way surfaces may be used. Some agencies provide quantitative guidance, and others provide qualitative guidance.

Exhibit 2-2 is an adaptation of one agency's guidance. It is objective, easy to apply, and considered reasonable, but it should not be rigidly applied. For example, these guidelines may not be appropriate for locations where heavy precipitation is routine.

No relevant research is available on the safety effects of unpaved traveled way surfaces in work zones. However, many design criteria for high-speed facilities are specifically related to paved driving surfaces. Additionally, unpaved driving surfaces are difficult to maintain. Therefore, some form of speed control may be appropriate when gravel or aggregate driving surfaces are employed. Prevailing environmental conditions and maintenance requirements should also be considered in selecting temporary traveled way surface types and their ongoing compatibility with high-speed traffic.

Temporary roadway cross slopes should generally follow the guidance applicable to permanent roadways, including consideration of surface type, number of lanes, and environmental exposure factors (e.g., rainfall or ice). For paved traveled way surfaces, 1.5 to 2.5 percent is appropriate. For aggregate and treated surfaces, cross slopes should generally be in the range of 0.5 to 1.0 percent higher than percentages used for paved surfaces.

Current ADT (veh/day)	Duration of operation			
	< 5 days	5–30 days	31–90 days	> 90 days
< 500	A	A	B	B
500–1,499	A	B	B	C
1,500–5,999	B	B	C	C
> 6,000	B	C	C	C

A = aggregate or gravel.
B = aggregate or gravel with surface treatment.
C = designed pavement structure.

Exhibit 2-2. Traveled way surface type guideline for temporary roadways.

Temporary roadway shoulder widths vary by volume and type (i.e., crossover and diversion) and are often not paved. Shoulder cross slopes may be difficult to control because of width and material type. Generally, shoulder slopes should be greater than the slopes of the adjacent traveled way, particularly if the shoulder is unpaved. Shoulder slopes of up to 8 percent are appropriate.

For superelevated temporary roadways, the maximum rollover (i.e., the algebraic difference of roadway and high-side shoulder slope) should be limited to approximately 8 percent.

2.3 Alignment Principles

Although there are similarities in the design of permanent road alignments and alignments through work zones, there are also substantial differences. A key difference is that of service life, permanent versus temporary. Costs, impacts, and right-of-way acquisition are more difficult to justify when the corresponding usefulness is short lived. Roads designed in conjunction with construction work zones are typically more constrained by setting than permanent roads. Yet temporary roads must connect to existing roads and provide sufficient space for construction operations. Consequently, there is a strong and appropriate motivation to use and integrate permanent infrastructure elements (e.g., embankments, pavements, structures, and appurtenances) into construction work zone roadway alignments. Constructing and removing temporary infrastructure is warranted when doing so is necessary to provide the desired levels of access, mobility, and safety.

The degree to which a work zone roadway requires temporary infrastructure and imparts impacts is influenced by the horizontal and vertical alignment. The service a roadway provides is also influenced by its horizontal and vertical alignment. The design of construction work zones, including alignments, is an exercise of balancing cost, impacts, and service provided over a finite period of time.

The following information addresses horizontal and vertical alignment design of temporary roadways in construction work zones. Two general approaches to establishing a relationship between horizontal curvature and superelevation are presented, and guidance on the use of both approaches is provided.

2.3.1 Curvature-Superelevation Relationship

Horizontally curved permanent roadways are routinely designed and analyzed using the following basic curve formula.

In metric units:

$$0.01e + f = \frac{V^2}{127R} \qquad (2\text{-}1a)$$

Where

e = rate of superelevation, percent;
f = side friction (demand factor);
V = vehicle speed, km/h; and
R = radius of curve, m.

In U.S. customary units:

$$0.01e + f = \frac{V^2}{15R} \tag{2-1b}$$

Where

e = rate of superelevation, percent;
f = side friction (demand factor);
V = vehicle speed, mph; and
R = radius of curve, ft.

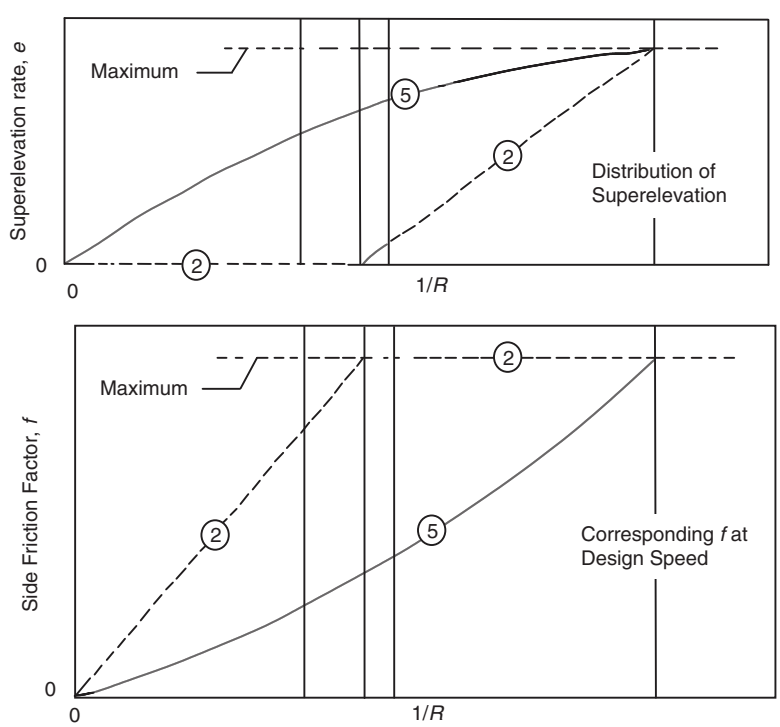
This approach treats a vehicle as a point mass. The simplifying assumptions and derivation of the formula are discussed in many texts and research publications and are omitted here.

2.3.2 Superelevation Distribution

For a specific radius and speed (actual or design), the value of the right side of Equation 2-1 can be calculated explicitly. The equation can be satisfied by an infinite number of $e + f$ combinations on the left side. Both e and f have practical limits (i.e., maximum values) and the Green Book provides guidance on selecting limiting values. The individual limits of e and f impose a limit on the absolute magnitude of the left side of the equation. For speed-radius combinations that require less than a maximum e and f, a method of distributing these values across their ranges is used. The Green Book identifies five distribution methods. Methods 2 and 5 are the most commonly used distributions. Exhibit 2-3 illustrates how e and f vary with curvature (expressed as the inverse of radius) for Methods 2 and 5. Information on other distribution methods can be obtained from the Green Book.

The Green Book, which is used primarily for the design of permanent roadways, recommends Method 5 for the distribution of e and f on rural highways, urban freeways, and high-speed urban streets. The Green Book recommends Method 2 for the design of horizontal curves on low-speed urban streets. Both methods are used for designing temporary roadways in construction work zones on high-speed highways. Typically, a state DOT uses one method or the other exclusively for work zone temporary roadway designs. Several points are worth noting:

- The Green Book–designated limiting friction values are related to driver comfort: "A key consideration in selecting the maximum side friction factors for use in design is the



Source: AASHTO, *A Policy on Geometric Design of Highways and Streets.* Washington, D.C. (2004).

Exhibit 2-3. Method 2 and 5 distributions.

level of centripetal or lateral acceleration that is sufficient to cause drivers to experience a feeling of discomfort and to react instinctively to avoid higher speed."

- The selection of a distribution method (e.g., Method 2 or Method 5) has no effect on the maximum values of *e* and *f*. Although the design rate of superelevation for a specific curve will be different depending on the selected distribution method, no method (if properly applied) will result in limiting values of *e* or *f* being exceeded.
- The use of any distribution method will yield the same maximum curvature (i.e., minimum radius) for a specific speed and limiting values of *e* and *f*.

Maximum superelevation rates are typically selected as a matter of policy rather than for specific projects. Absent other considerations, the e_{max} used for permanent roadways is appropriate for construction work zones.

Superelevating roadway curves necessitates superelevation transitions, which bring alignment and other (e.g., drainage) complications. For these reasons, it is common design practice to provide curves that are sufficiently flat to not require the introduction of superelevation. Since Method 2 relies more on friction (and less on superelevation) than Method 5, its use for establishing superelevation rates on work zone roadway curves has been adopted by some state DOTs. Guidance for designing horizontal curves using Method 2 and Method 5 distributions is provided.

The next two sections provide information and references for the use of Methods 2 and 5. More discussion and design guidance (Exhibit 2-4) are provided for Method 2 than for Method 5. This is not an indication that Method 2 is the preferred or superior approach. Additional information on Method 2 is provided because it is not widely used for designing permanent high-speed roads and many design guides do not include tabulated design values.

2.3.2.1 Design Superelevation Rates Based on Method 2 Distribution

Method 2 distribution is often used to avoid the need for superelevation. Exhibit 2-4 indicates the minimum radii that should be provided for a specified superelevation rate and work zone design speed based on Method 2 distribution.

Along with the values that result from Equation 2-1, there are several other guidelines that apply. Roadway cross slopes should be at least 1.5 percent. Consequently, no minimum radius values are shown for superelevation rates between –1.5 and 1.5 percent.

Negative superelevation is the condition where a driving surface is sloped away from the center of a horizontal curve. Negative superelevation is most common when the normal cross slope of an approach tangent road is retained on a horizontal curve. For example, a roadway curving to the left with a slope of 2 percent from left to right has a superelevation rate of –2 percent. The example below clarifies how Exhibit 2-4 is used, specifically regarding negative superelevation.

In metric units:

Given:

Temporary work zone roadway
Normal cross slope = 2 percent (left to right)
Work zone design speed = 90 km/h

Determine:

Minimum radius for normal cross slope

From Exhibit 2-4

$$\text{Minimum radius } (e = -2.0 \text{ percent}) = \underline{R = 580 \text{ m}} \qquad (2\text{-}2a)$$

In U.S. customary units:

Given:

Temporary work zone roadway
Normal cross slope = 2 percent (left to right)
Work zone design speed = 55 mph

Determine:

Minimum radius for normal cross slope

From Exhibit 2-4

$$\text{Minimum radius } (e = -2.0 \text{ percent}) = \underline{R = 1{,}833 \text{ ft}} \qquad (2\text{-}2b)$$

It is possible to have negative superelevation rates with magnitudes greater than 2.5 percent (i.e., values less than –2.5 percent). For this condition (e.g., –3.5 percent superelevation), Equation 2-1 should be used to determine the minimum radius corresponding to the superelevation and work zone design speed. The friction value (*f*) selected for use in the equation should be the "Maximum *f*" tabulated in Green Book Exhibit 3-15 and corresponding to the design speed.

2.3.2.2 Design Superelevation Rates Based on Method 5 Distribution

The Green Book, which is used primarily for designing permanent roads, recommends Method 5 distribution for rural highways, urban freeways, and high-speed urban streets. Many agencies also use Method 5 for construction work zone temporary roads. For Method 5, the use of e_{max} = 4 percent is recommended only in urban areas and with design speeds of 100 km/h [60 mph] and less. To apply Method 5, Green Book Exhibits 3-25 through 3-29 may be used to determine the minimum radius for a superelevation rate and work zone design speed.

Metric

e (%)	Work zone design speed (km/h)							
	60	70	80	90	100	110	120	130
	R (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)
-2.5	195	309	438	607	829	1121	1744	2419
-2.0	189	297	420	580	787	1059	1620	2218
-1.5	183	286	403	555	750	1003	1512	2047
1.5	153	234	325	440	583	762	1080	1401
2.0	149	227	315	425	562	733	1031	1331
2.1	148	226	313	422	558	727	1021	1318
2.2	148	224	311	420	555	722	1012	1305
2.3	147	223	309	417	551	716	1003	1292
2.4	146	222	307	414	547	711	995	1280
2.5	145	220	305	411	543	706	986	1267
2.6	145	219	304	409	539	701	977	1255
2.7	144	218	302	406	536	695	969	1244
2.8	143	217	300	404	532	690	961	1232
2.9	142	216	298	401	528	685	953	1221
3.0	142	214	296	399	525	681	945	1210
3.1	141	213	295	396	521	676	937	1199
3.2	140	212	293	394	518	671	929	1188
3.3	140	211	291	391	515	666	922	1178
3.4	139	210	290	389	511	662	914	1167
3.5	138	209	288	387	508	657	907	1157
3.6	138	207	286	384	505	653	900	1147
3.7	137	206	285	382	502	648	893	1137
3.8	136	205	283	380	498	644	886	1128
3.9	136	204	282	377	495	639	879	1118
4.0	135	203	280	375	492	635	872	1109
4.1	134	202	278	373	489	631	866	1100
4.2	134	201	277	371	486	627	859	1091
4.3	133	200	275	369	483	623	853	1082
4.4	132	199	274	367	480	619	846	1073
4.5	132	198	272	364	477	615	840	1065
4.6	131	197	271	362	474	611	834	1056
4.7	131	196	269	360	471	607	828	1048
4.8	130	195	268	358	469	603	822	1040
4.9	129	194	267	356	466	599	816	1032
5.0	129	193	265	354	463	595	810	1024
5.1	128	192	264	352	460	592	804	1016
5.2	128	191	262	350	458	588	798	1008
5.3	127	190	261	349	455	585	793	1001
5.4	127	189	260	347	453	581	787	993
5.5	126	188	258	345	450	577	782	986
5.6	125	187	257	343	447	574	777	978
5.7	125	186	256	341	445	571	771	971
5.8	124	185	255	339	442	567	766	964
5.9	124	185	253	337	440	564	761	957
6.0	123	184	252	336	437	560	756	951
6.1	123	183	251	334	435	557	751	944
6.2	122	182	249	332	433	554	746	937
6.3	122	181	248	330	430	551	741	931
6.4	121	180	247	329	428	548	736	924
6.5	121	179	246	327	426	544	732	918
6.6	120	179	245	325	423	541	727	911
6.7	120	178	243	324	421	538	722	905
6.8	119	177	242	322	419	535	718	899
6.9	119	176	241	321	417	532	713	893
7.0	118	175	240	319	414	529	709	887

Metric

e (%)	Work zone design speed (km/h)							
	60	70	80	90	100	110	120	130
	R (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)
7.1	118	175	239	317	412	526	704	881
7.2	117	174	238	316	410	523	700	875
7.3	117	173	237	314	408	521	696	870
7.4	116	172	235	313	406	518	691	864
7.5	116	171	234	311	404	515	687	859
7.6	115	171	233	310	402	512	683	853
7.7	115	170	232	308	400	509	679	848
7.8	114	169	231	307	398	507	675	842
7.9	114	168	230	305	396	504	671	837
8.0	113	168	229	304	394	501	667	832
8.1	113	167	228	302	392	499	663	827
8.2	112	166	227	301	390	496	659	821
8.3	112	166	226	299	388	494	655	816
8.4	112	165	225	298	386	491	652	811
8.5	111	164	224	297	384	489	648	806
8.6	111	163	223	295	382	486	644	802
8.7	110	163	222	294	380	484	641	797
8.8	110	162	221	293	379	481	637	792
8.9	109	161	220	291	377	479	633	787
9.0	109	161	219	290	375	476	630	783
9.1	109	160	218	289	373	474	626	778
9.2	108	159	217	287	371	472	623	774
9.3	108	159	216	286	370	469	620	769
9.4	107	158	215	285	368	467	616	765
9.5	107	157	214	283	366	465	613	760
9.6	107	157	214	282	365	463	610	756
9.7	106	156	213	281	363	460	606	752
9.8	106	156	212	280	361	458	603	748
9.9	105	155	211	279	360	456	600	743
10.0	105	154	210	277	358	454	597	739
10.1	105	154	209	276	356	452	594	735
10.2	104	153	208	275	355	449	591	731
10.3	104	153	207	274	353	447	587	727
10.4	103	152	207	273	352	445	584	723
10.5	103	151	206	271	350	443	581	719
10.6	103	151	205	270	348	441	578	715
10.7	102	150	204	269	347	439	576	712
10.8	102	150	203	268	345	437	573	708
10.9	102	149	202	267	344	435	570	704
11.0	101	148	202	266	342	433	567	700
11.1	101	148	201	265	341	431	564	697
11.2	101	147	200	264	339	429	561	693
11.3	100	147	199	262	338	427	559	689
11.4	100	146	198	261	336	425	556	686
11.5	99	146	198	260	335	423	553	682
11.6	99	145	197	259	334	422	550	679
11.7	99	145	196	258	332	420	548	675
11.8	98	144	195	257	331	418	545	672
11.9	98	143	195	256	329	416	543	669
12.0	98	143	194	255	328	414	540	665

Exhibit 2-4. Minimum radii for superelevation rates and work zone design speed based on Method 2 superelevation distribution.

U.S. Customary

e (%)	Work zone design speed (mph)							
	40	45	50	55	60	65	70	75
	R (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)
-2.5	790	1080	1449	1921	2526	3314	4356	5769
-2.0	762	1038	1389	1833	2400	3130	4083	5357
-1.5	736	1000	1333	1754	2286	2965	3843	5000
1.5	610	818	1075	1391	1778	2253	2841	3571
2.0	593	794	1042	1344	1714	2167	2722	3409
2.1	589	789	1035	1336	1702	2150	2700	3378
2.2	586	785	1029	1327	1690	2134	2678	3348
2.3	583	780	1022	1318	1678	2118	2656	3319
2.4	580	776	1016	1310	1667	2102	2634	3289
2.5	577	771	1010	1301	1655	2086	2613	3261
2.6	573	767	1004	1293	1644	2071	2593	3233
2.7	570	763	998	1285	1633	2056	2572	3205
2.8	567	758	992	1276	1622	2041	2552	3178
2.9	564	754	986	1268	1611	2026	2532	3151
3.0	561	750	980	1260	1600	2012	2513	3125
3.1	558	746	975	1253	1589	1998	2494	3099
3.2	556	742	969	1245	1579	1984	2475	3074
3.3	553	738	963	1237	1569	1970	2456	3049
3.4	550	734	958	1230	1558	1956	2438	3024
3.5	547	730	952	1222	1548	1943	2420	3000
3.6	544	726	947	1215	1538	1929	2402	2976
3.7	541	722	942	1208	1529	1916	2384	2953
3.8	539	718	936	1200	1519	1903	2367	2930
3.9	536	714	931	1193	1509	1890	2350	2907
4.0	533	711	926	1186	1500	1878	2333	2885
4.1	531	707	921	1179	1491	1865	2317	2863
4.2	528	703	916	1172	1481	1853	2300	2841
4.3	525	699	911	1166	1472	1841	2284	2820
4.4	523	696	906	1159	1463	1829	2269	2799
4.5	520	692	901	1152	1455	1817	2253	2778
4.6	518	689	896	1146	1446	1806	2237	2757
4.7	515	685	891	1139	1437	1794	2222	2737
4.8	513	682	887	1133	1429	1783	2207	2717
4.9	510	678	882	1127	1420	1771	2192	2698
5.0	508	675	877	1120	1412	1760	2178	2679
5.1	506	672	873	1114	1404	1749	2163	2660
5.2	503	668	868	1108	1395	1739	2149	2641
5.3	501	665	864	1102	1387	1728	2135	2622
5.4	498	662	859	1096	1379	1717	2121	2604
5.5	496	659	855	1090	1371	1707	2108	2586
5.6	494	655	850	1084	1364	1697	2094	2568
5.7	492	652	846	1078	1356	1687	2081	2551
5.8	489	649	842	1073	1348	1677	2068	2534
5.9	487	646	838	1067	1341	1667	2055	2517
6.0	485	643	833	1061	1333	1657	2042	2500
6.1	483	640	829	1056	1326	1647	2029	2483
6.2	480	637	825	1050	1319	1638	2016	2467
6.3	478	634	821	1045	1311	1628	2004	2451
6.4	476	631	817	1040	1304	1619	1992	2435
6.5	474	628	813	1034	1297	1610	1980	2419
6.6	472	625	809	1029	1290	1600	1968	2404
6.7	470	622	805	1024	1283	1591	1956	2389
6.8	468	619	801	1019	1277	1582	1944	2373
6.9	466	616	797	1013	1270	1574	1933	2358
7.0	464	614	794	1008	1263	1565	1922	2344

U.S. Customary

e (%)	Work zone design speed (mph)							
	40	45	50	55	60	65	70	75
	R (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)	*R* (ft)
7.1	462	611	790	1003	1257	1556	1910	2329
7.2	460	608	786	998	1250	1548	1899	2315
7.3	458	605	782	993	1244	1539	1888	2301
7.4	456	603	779	989	1237	1531	1877	2287
7.5	454	600	775	984	1231	1523	1867	2273
7.6	452	597	772	979	1224	1514	1856	2259
7.7	450	595	768	974	1218	1506	1846	2246
7.8	448	592	765	970	1212	1498	1835	2232
7.9	446	590	761	965	1206	1490	1825	2219
8.0	444	587	758	960	1200	1482	1815	2206
8.1	443	584	754	956	1194	1475	1805	2193
8.2	441	582	751	951	1188	1467	1795	2180
8.3	439	579	747	947	1182	1459	1785	2168
8.4	437	577	744	942	1176	1452	1775	2155
8.5	435	574	741	938	1171	1444	1766	2143
8.6	434	572	737	934	1165	1437	1756	2131
8.7	432	570	734	929	1159	1430	1747	2119
8.8	430	567	731	925	1154	1423	1738	2107
8.9	428	565	728	921	1148	1415	1728	2095
9.0	427	563	725	917	1143	1408	1719	2083
9.1	425	560	722	913	1137	1401	1710	2072
9.2	423	558	718	908	1132	1394	1701	2060
9.3	422	556	715	904	1127	1388	1693	2049
9.4	420	553	712	900	1121	1381	1684	2038
9.5	418	551	709	896	1116	1374	1675	2027
9.6	417	549	706	892	1111	1367	1667	2016
9.7	415	547	703	888	1106	1361	1658	2005
9.8	413	544	700	885	1101	1354	1650	1995
9.9	412	542	697	881	1096	1348	1642	1984
10.0	410	540	694	877	1091	1341	1633	1974
10.1	409	538	692	873	1086	1335	1625	1963
10.2	407	536	689	869	1081	1329	1617	1953
10.3	406	534	686	866	1076	1322	1609	1943
10.4	404	531	683	862	1071	1316	1601	1933
10.5	403	529	680	858	1067	1310	1593	1923
10.6	401	527	678	855	1062	1304	1586	1913
10.7	400	525	675	851	1057	1298	1578	1904
10.8	398	523	672	847	1053	1292	1571	1894
10.9	397	521	669	844	1048	1286	1563	1884
11.0	395	519	667	840	1043	1280	1556	1875
11.1	394	517	664	837	1039	1275	1548	1866
11.2	392	515	661	833	1034	1269	1541	1856
11.3	391	513	659	830	1030	1263	1534	1847
11.4	389	511	656	827	1026	1257	1526	1838
11.5	388	509	654	823	1021	1252	1519	1829
11.6	386	508	651	820	1017	1246	1512	1820
11.7	385	506	649	816	1013	1241	1505	1812
11.8	384	504	646	813	1008	1235	1498	1803
11.9	382	502	644	810	1004	1230	1492	1794
12.0	381	500	641	807	1000	1225	1485	1786

Exhibit 2-4. (Continued)

2.3.3 Other Horizontal Alignment Considerations

A variety of techniques are used by agencies to attain superelevation along an alignment for various types of permanent roads. The superelevation transition techniques used for high-speed permanent roads should be applied to roadways within construction work zones on high-speed highways.

In addition to cross slope and superelevation, sight distance is a consideration in designing horizontal alignments. Cross-sectional and other features common to construction projects (e.g., barriers, material stock piles, and equipment) may limit sight distance on the inside of horizontal curves. Refer to Section 2.2.6 for sight distance guidance.

2.3.4 Vertical Alignment Considerations

Generally, the same maximum grade criteria applicable to the highway under construction should be applied to work zone roads. However, marginally exceeding these criteria is often justified in consideration of all factors. Grades below the maximum are desirable. When designing work zone temporary roadways, the potential effect of grades on operations and capacity should be considered. When speeds are substantially reduced in advance of a temporary roadway (e.g., in conjunction with a reduction in the number of lanes), the work zone capacity may be controlled by heavy vehicles attempting to accelerate on grade. Capacity, in turn, influences queue formation.

The minimum length of vertical curves for permanent roads is typically established on the basis of sight distance considerations. Sight distance information and considerations relative to safety and operating speed are outlined in Section 2.2.6. When minimum sight distance design criteria are adopted for work zones, minimum vertical curve length criteria on that basis are appropriate. The most common basis for agency work zone sight distance design criteria is the Green Book stopping sight distance values. For this case, minimum crest and sag vertical curve lengths are determined from Green Book Exhibits 3-71 and 3-74, respectively.

Some agencies have adopted a policy of determining the minimum sag vertical curve length on the basis of comfort. For this case, minimum lengths are determined from a Green Book formula, which is adapted here as Equation 2-3.

In metric units:

$$L = \frac{AV^2}{395} \tag{2-3a}$$

Where

L = length of sag vertical curve, m;
A = algebraic difference in grades, percent; and
V = work zone design speed, km/h.

In U.S. customary units:

$$L = \frac{AV^2}{46.5} \tag{2-3b}$$

Where

L = length of sag vertical curve, ft;
A = algebraic difference in grades, percent; and
V = work zone design speed, mph.

CHAPTER 3

Conceptual Design and Planning of Work Zones

Agency policies and procedures directly and indirectly impact work zone design. Directly, agency policies and guidance are sources of information that guide decisions. Indirectly, these same policies define the conditions that designers of subsequent projects will face. For example, suppose the design policy for a particular road indicates that a minimum of 22 feet of pavement is needed, so the designer provides 22 feet of pavement. Fifteen years later, the road has to be resurfaced. To maintain traffic, it would be nice if there were a 32-foot-wide road so that traffic could pass around the paving operation. Thus, the guidance on 22 feet of pavement essentially led to one decision and created the conditions encountered for the work zone designer.

Work zone design decisions should be integrated into project development. Alternative work zone types, along with their impacts, mitigation, and costs should be evaluated at the same time as, and in conjunction with, other design factors. The level of detail to which work zone issues are evaluated should be proportional to the potential work zone consequences. Some project categories (e.g., resurfacing and deck repair) pose a limited number of design alternatives and perhaps even fewer feasible work zone alternatives. However, substantial impacts can occur in connection with routine projects, and the impacts may extend far beyond the limits of the work zone. Impacts may take the form of traffic congestion, interruption of commercial and industrial activity, cost overruns, decreased constructability, adverse safety experience, disturbance of local travel patterns (including nonmotorized modes), and citizen complaints.

3.1 Project-Level Work Zone Strategies

All projects require a strategy or set of strategies that will accommodate needed construction operations while maintaining acceptable transportation service. These strategies are outlined in transportation management plans (TMPs), which are prepared for specific projects. When potential impacts are substantial, a comprehensive, integrated and proactive work zone management and design effort is needed. Impacts may be mitigated through strategies such as traffic demand reduction measures, public involvement and information, provision of permanent facilities with wider cross sections to accommodate temporary traffic use during construction, innovative construction techniques, incident management, and advanced traveler information systems. In all cases, a strategy is needed to carry traffic through or around the facility under construction through a system of infrastructure and temporary traffic control (TTC). This section identifies common work zone strategies and factors that should be considered in the selection process.

The following strategies have been widely and successfully employed for construction work zones on high-speed highways:

- Alternating one-way operation,
- Detour,
- Diversion,
- Full road closure,
- Intermittent closure,
- Lane closure,
- Lane constriction,
- Median crossover, and
- Use of shoulder.

These strategies are not necessarily separate, individual choices. In fact, several of them do not provide a complete and workable solution. Use of a full road closure requires one or more additional strategies (e.g., detour or diversion). Some of the strategies are identified as mitigation strategies, meaning that they can be used to offset negative consequences (e.g., reduced capacity and access limitations) for one or more other strategies.

The basic characteristics of individual work zone design strategies result in general advantages and disadvantages, as summarized in Exhibit 3-1 and outlined in successive sections.

Strategy	Summary	Advantages	Disadvantages
Alternating one-way operation	Mitigates for full or intermittent closure of lanes. Used primarily with two-lane facilities.	Low agency cost and low non-transportation impacts; flexible, several variations available.	Requires stopping of traffic; reduces capacity.
Detour	Reroutes traffic onto other existing facilities.	Flexible; cost varies depending on improvements to detour route; in some cases, only TTC needed.	Usually reduces capacity; service and infrastructure on existing roads may be degraded; may need agreement of another agency.
Diversion	Provides a temporary roadway adjacent to construction.	Separates traffic from construction; reduced impact on traffic.	Cost may be substantial, especially if temporary grade separation of hydraulic structure involved; right-of-way often required.
Full road closure	Closes the facility to traffic for a specified (limited) duration.	Generally also involves expedited construction; separates traffic from construction.	Some form of mitigation is needed (detour, diversion, etc.); potentially significant traffic impacts.
Intermittent closure	Stops traffic for a short period.	Flexible and low agency cost.	Useful only for activities that can be completed in short time; requires stopping traffic.
Lane closure	Closes one or more travel lanes.	Maintains service; fairly low agency cost if temporary barriers are omitted.	Reduces capacity; may involve traffic close to active work.
Lane constriction	Reduces traveled way width.	Maximizes number of travel lanes.	Traveled way width is less than desirable; may involve traffic close to active work.
Median crossover	Maintains two-way traffic on one roadway of a normally divided highway.	Separates traffic from construction; right-of-way not required.	Reduced capacity; not consistent with approach roadway; relatively costly; interchanges need special attention.
Use of shoulder	Uses shoulder as a travel lane.	Fairly low cost, depending on shoulder preparation.	Displaces traditional refuge for disabled vehicles; debilitates shoulder pavement structure; cross slopes may be problematic.

Exhibit 3-1. Summary of work zone strategies.

3.1.1 Alternating One-Way Operation

Alternating one-way operation: a construction work zone mitigation strategy used on two-way roadways wherein opposing directions of travel take turns using a single travel lane. Flaggers, with or without pilot vehicles; STOP signs; or signals are normally used to coordinate the two directions of traffic. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as o*ne-lane, two-way operation.*

There are several variations of this strategy related to the type of control employed (e.g., STOP sign, temporary signal control, or pilot car), as outlined in the MUTCD. Design and TTC provisions are also required to facilitate transition from high-speed approaches to stop conditions for the spectrum of operational conditions (e.g., day-night and weather). The agency cost and nontransportation impacts of this strategy are generally low.

This strategy has a significant impact on capacity. As the length of the one-way segment increases, capacity is reduced. Also, construction operations take place in close proximity to traffic operations. Application of this strategy is generally limited to low-volume, two-lane, two-way roads.

3.1.2 Detour

Detour: a construction work zone mitigation strategy wherein traffic in one or both directions is rerouted onto an existing highway to avoid a construction work zone. Detoured vehicles may travel on permanent roads only or on a combination of permanent and temporary roads. This strategy compensates for the removal of permanent travel lanes from service.

When traffic is directed from a facility under construction to an alternative traffic route, construction operations can be prosecuted with little restraint. This can improve construction efficiency (i.e., reduce cost) and quality. Agency costs to implement detours may involve only TTC or temporary infrastructure and TTC.

Generally, a detour is applicable to all approaching traffic, but some detours reroute a portion of the traffic from the affected facility and accommodate all other traffic through the work zone. Selective detours may apply to vehicles that carry certain

categories of cargo or exceed specified dimensions or gross vehicle weights. In these cases, special attention to TTC is needed.

Detouring traffic imposes additional capacity and load demands on an alternative route and may result in congestion and infrastructure deterioration on the detour (i.e., alternate route). Detours should be carefully evaluated to ensure that they are capable of accommodating the volume and types (configuration, size, and weight) of detoured vehicles. Mitigation may include temporary changes to traffic control (e.g., signal timing and signs) and remedial pavement and bridge work. When detours are being considered, the access normally provided to various land uses (e.g., residents and businesses) by the closed facility should also be considered. The added length of trips using the detour is a cost to motorists and should be evaluated.

Ownership or owner agreement is usually needed to use a facility as a detour. If the agency detouring traffic from a facility does not own the roadway onto which traffic is detoured, coordination with the other agency is needed. In some jurisdictions, interagency agreements are needed and may provide for improvements to the detour route in preparation for the detour or as redress for damage induced by the detour traffic.

3.1.3 Diversion

Diversion: a construction work zone mitigation strategy wherein traffic in one or both directions on a designated route is carried by a temporary roadway around a work area and reconnected with the permanent infrastructure of the designated route. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as a *shoofly* or *runaround.*

This strategy provides substantial separation of construction from traffic, although generally not as much as detours. Diversions are often used for bridge projects, including bridge replacements, but are also used for other types of work. When used in conjunction with bridge projects, a temporary bridge or culvert may also be needed.

Unless a detour is also established to carry a portion of the traffic, the diversion will accommodate the entire approach volume, including large and oversized vehicles. Selection of a work zone design speed, as outlined in Section 2.2.5, is recommended. The capacity of the diversion should generally be close to or equal to that of the approach roadway to avoid substantial delay, queue formation, or trip-length extension. The geometry of the diversion and associated TTC should consider traffic characteristics on the approach roadway. Construction of temporary roads can be costly. Major variables affecting cost include the length and design features (e.g., barriers, earthwork, hydraulic structures, and surface/pavement). The design and cost of these elements vary based on traffic volume and duration of use.

Diversions involve construction of new, temporary roads. Therefore, some of the institutional processes associated with road construction may apply to provision of a diversion. The need to acquire property interests (e.g., right-of-way or easements), impose impacts on protected resources (e.g., historic sites), or acquire permits generally affect project schedules and should be considered.

Detailed design guidance for this strategy is provided in Section 4.1.

3.1.4 Full Road Closure

Full road closure: a construction work zone mitigation strategy wherein traffic operations are removed or suspended in either one or two directions on a segment of roadway or ramp.

When roadway traffic is completely eliminated, construction efficiency and the resultant quality of permanent features (i.e., bridge and pavements) are maximized, while the time required for completion is minimized. Contract provisions (i.e., liquidated damages) should reflect the degree of disruption that this strategy involves.

The cost of the full road closure itself is very low; however, this work zone strategy does not provide for maintenance of traffic. Therefore, one or more supplemental strategies are needed, with detours being the most common. The supplemental strategies may have impacts, as outlined in this report, and should be considered. Full road closures have been used successfully on low-, medium- and high-volume facilities. When full road closures are used with high-volume facilities, alternative strategies (e.g., detours) usually cannot fully compensate for the capacity reduction. TMPs are needed, including an aggressive public information component.

3.1.5 Intermittent Closure

Intermittent closure: a construction work zone mitigation strategy wherein all traffic in one or both directions is stopped for a relatively short period to allow for construction operations.

This work zone strategy alone is generally not adequate for an entire construction project. It is often employed during specific operations (e.g., setting bridge beams, conducting blast detonation, and moving equipment) for which project personnel can select the beginning point and reasonably predict the duration. In nonemergency cases, intermittent closure should be used only if the duration of closure and period of traffic impact will be short (less than 20 minutes).

3.1.6 Lane Closure

Lane closure: a construction work zone mitigation strategy wherein one or more travel lanes and any adjacent shoulders are closed to traffic. As defined here, this term is not limited to closing one lane of a multilane highway. Lane closures are inherent to *median crossovers.*

Reducing existing capacity increases the probability of queue formation and delays. Depending on traffic density, the

ability of drivers to individually select their speeds is reduced or lost. Traffic impacts (e.g., speeds, queue formation, and delay) should be assessed, and lane-closure length, roadway grades, traffic volumes, and percent trucks should be considered. The agency cost to implement this work zone strategy varies depending on the supporting infrastructure employed. Many common TTC devices (e.g., drums, signs, and arrow panels) can be transported using medium-duty vehicles. When lane closures are used for invasive construction operations (e.g., pavement reconstruction), temporary concrete barriers are often used and can substantially increase the cost of implementation. When barriers are omitted, this work zone strategy can be installed and removed over short periods (i.e., hours). Because of its flexibility, this work zone strategy can be used on high-volume facilities during periods when traffic impacts are deemed acceptable (e.g., weekends, mid-day, and nighttime).

This work zone type is often used in conjunction with lane construction involving operations adjacent to an active traffic lane. This creates the possibility of conflict among construction equipment operations (e.g., compaction, demolition, deliveries, and material placements), workers, and roadway traffic. In addition to safety concerns, the proximity may interfere with construction quality objectives.

3.1.7 Lane Constriction

Lane constriction: a construction work zone mitigation strategy wherein the width of one or more travel lanes is reduced. The number of travel lanes may be retained (possibly through median or shoulder use) or reduced.

The use of this work zone strategy is often associated with traffic in close proximity to construction operations. This also creates the possibility of conflict among construction equipment operations, workers, and roadway traffic. In addition to raising safety concerns, the proximity may interfere with construction quality.

This work zone strategy is employed when maintaining traffic with less-than-desirable travel lane widths is preferable to other candidate alternatives. At some level of expenditure and impact, constricted lanes can almost always be avoided. The decision to use this strategy is made in consideration of the magnitude of the constriction (i.e., actual traveled way width), the service conditions (e.g., duration, length, and traffic), and the cost associated with avoiding the constriction. In making these decisions, agencies often draw on their considerable accumulated experience.

This work zone strategy can directly impact the ability of the facility to accommodate large vehicles. In some cases, agency coordination involving permits for oversized vehicles is needed.

Detailed design guidance for this strategy is provided in Section 4.2.

3.1.8 Median Crossover

Median crossover: a construction work zone mitigation strategy used on expressways (including freeways) to establish *two-way traffic on a normally divided facility*. In this strategy:

- The number of lanes in both directions is reduced;
- At both ends, traffic in one direction is routed across the median to the opposite-direction roadway on a temporary roadway constructed for that purpose; and
- Two-way traffic is maintained on one roadway while the opposite direction roadway is closed.

Substantial separation of construction from traffic is provided by this work zone strategy. Generally, this strategy allows construction of an entire one-way roadway (e.g., travel lanes, shoulders, structures, and appurtenances) with little conflict between roadway traffic and equipment, workers, or onsite material movement. The work is generally more expedient and results in higher construction quality than would be produced with a lane-constriction approach. This work zone type is typically employed with full (i.e., pavements or bridges) or extensive reconstruction.

Median crossovers involve a reduction in the number of travel lanes and capacity. Depending on traffic density, the ability for drivers to individually select their speeds is lost or reduced. Traffic impacts (e.g., speeds, queue formation, and delay) should be assessed, and overall median crossover length, roadway grades, traffic volumes, and percent trucks should be considered. The overall median crossover length is defined by the distance between the temporary crossover roadways. Locating termini (and thus establishing the overall median crossover length) requires system and site considerations. Decisions to close or maintain existing access points (i.e., interchanges and intersections for expressways) may influence the crossover locations. Additionally, substantial grade differences between one-way roadways or within median topography can influence the feasibility and cost of a temporary crossover roadway. Even under favorable conditions, temporary crossover roadways are a significant cost consideration.

Detailed design guidance for this strategy is provided in Section 4.3.

3.1.9 Use of Shoulder

Use of shoulder: a construction work zone mitigation strategy involving the use of a right-side or median shoulder as all or part of a temporary traffic lane. This strategy compensates for the removal of permanent travel lanes from service. Employing this strategy may require constructing or upgrading shoulder pavement structures to adequately support traffic loads.

This strategy uses existing roadway width to compensate for the capacity lost by closing a permanent travel lane and is viable on many facility types (e.g., divided multilane, undi-

vided multilane, and two-lane). Many shoulders are narrower than the closed travel lane. Additionally, many shoulders do not have the same pavement structure as the adjacent travel lanes. Depending on the traffic service requirements (e.g., duration, traffic volumes and types, and speed), considerable work and expense may be required to provide a suitable surface or pavement structure. Full-width shoulders with the same pavement structure as the adjoining travel lane can generally be used as a travel lane at low agency cost. Some bridges have narrower shoulders than the approach roadways, which may determine or limit the feasibility of this strategy.

Invariably, when a shoulder is used to carry traffic, the roadside hazards on that side will be closer to traffic. The existence, proximity, and nature of roadside features (e.g., bridge piers) should be considered in assessing this strategy.

Detailed design guidance for this strategy is provided in Section 4.4.

3.2 Contracting Strategies and Considerations

Traditionally, highway construction was undertaken during daylight hours by contractors procured through the conventional contract model. Under the conventional contract model, the transportation agency prepares a set of contract documents (i.e., plans and specifications), which describe the responsibilities and duties of the parties. Bids are solicited, and a contract is awarded to the responsible bidder submitting the lowest responsive bid. Under the conventional approach, the contract documents include an agency-prepared work zone design. Most agencies allow the contractor to propose an alternative work zone design, which will be adopted if approved by the agency. The conventional contract model remains the dominant approach to contracting, but a number of contracting strategies are being employed to reduce the impacts of construction on traffic. These strategies include alternative procurement techniques and contract provisions requiring that construction be performed during off-peak traffic periods (including at night). This section addresses three contract issues that are closely related to work zones: (1) alternative contracting techniques (including A+B bidding, design-build contracting, incentive-disincentive provisions, and lane rental), (2) night construction, and (3) evaluation of work zone designs proposed by contractors.

3.2.1 Alternative Contracting Techniques

Avoiding and reducing work zone impacts are an impetus for alternative contracting techniques and for specifying that work be undertaken at night (although no alternative contracting technique is necessarily associated with the specification of night work). Other reasons for using alternative contracting techniques are to centralize accountability (in one organization rather than several), improve quality, and reduce project delivery time. The alternative contracting processes with the closest relationship to work zone design are

- A+B bidding,
- Design-build contracting,
- Incentive-disincentive provisions, and
- Lane rental.

These contracting techniques are not work zone strategies, per se, but are sometimes regarded as a means to reduce work zone impacts. In general, the transportation agency uses competitive market-based incentives to attain its objectives. Each of these techniques and night work will be discussed separately.

Contracts are legal documents. Agencies are governed by a body of law, including procurement statutes. Therefore, project personnel should be aware of potential limitations and requirements as contracts are awarded and administered. Special Experimental Project No. 14 (SEP-14—Innovative Contracting) is an ongoing FHWA activity to encourage and evaluate promising contracting processes. Approval is needed under this program before any contracting technique that deviates from federal competitive bidding provisions can be used. Some of the techniques have already been classified as operational (e.g., A+B bidding and lane rental), and of the contracting techniques listed above, only design-build contracting requires SEP-14 approval.

Some agencies have combined two strategies in a single contract. For example, lane rental could be combined with A+B bidding or incentive-disincentive provisions. The strategies should be consistent with each other and with agency goals. For example, a lane rental fee structure designed to discourage peak-hour traffic interference may not have its intended effect if the contract also includes an early completion incentive provision that is large enough to economically justify occupying lanes during peak-hour periods.

Coordination with agency construction contracting offices to obtain current information is recommended prior to applying any of the four listed contracting techniques.

The role and responsibilities of contractors varies substantially with contracting type. This variation is intended. Contracting strategies and some of the associated opportunities and implications are described below.

3.2.1.1 A+B Bidding

A+B bidding is also known as cost-plus-time bidding, and each "bid" is computed using Equation 3-1.

In metric units and U.S. customary units:

$$\text{Bid} = A + Bx \tag{3-1}$$

Where

A = the dollar amount to perform all work identified in the contract, as submitted by the bidder;
B = the total number of calendar days required to complete the project, as estimated by the bidder;
x = Road user cost per day as designated by the agency.

Equation 3-1 is used to determine the lowest bid. Contractor payments are based on the schedule of bid items (A portion of bid).

Additionally, for each day in excess of B used by the contractor to actually complete the work, an assessment is made for road user costs. Frequently, there is a reciprocal incentive provision when the actual number of days to complete construction is less than the number of days bid (B).

Typically, the agency's cost-plus-time contract documents include a work zone design in the same or similar manner as if the contract were a conventional one. Contractors, as bidders and in contract performance, have a strong business incentive to minimize the number of days needed to complete the specified work. Therefore, the contract documents must clearly indicate contractor duties and limitations with regard to traffic control and work zone design. This strategy is generally applied to projects with a high potential for mobility and/or safety impacts, generally on high-volume facilities that do not have reasonable detour routes.

3.2.1.2 Design-Build Contracting

Under this contracting method, an agency-owner procures a single contract providing for both design and construction. This avoids questions of responsibility and coordination between a contract designer and contract constructor. It has been employed on a wide variety of project scales, including the reconstruction of I-15 in Salt Lake City, Utah.

Benefits attributed to design-build contracting include time savings, contractor innovation, and administration efficiencies.

Design-build practices are emerging and varied due to the merging of these traditionally separate functions. In many jurisdictions, design service and construction contract procurements are governed by distinct laws and traditions. Federal and state laws may be relevant to contracts that include both categories of service.

FHWA recommends that this technique be used only for projects that fit the design-build process, including adequate scope definition by the agency prior to requesting proposals. A design-build project should have a strong creative design component. Relatively simple projects, such as roadway resurfacing or minor roadway widening, do not provide significant design components and are not the ideal type of projects for design-build (*8*).

Under design-build contracting, work zone design is generally the responsibility of the contractor. In some cases, the agency may provide a schematic or conceptual plan, and in other cases, the development of the entire TMP may be assigned to the design-build contractor. The agency should always specify its high-level requirements and acceptable criteria and processes. Examples of high-level requirements may include: minimum number of lanes by day and time (e.g., holidays and peak periods), access requirements and allowances (e.g., to abutters and interchange ramps), noise restrictions, and public information programs. Criteria and process requirements include definition of applicable TTC and design criteria.

3.2.1.3 Incentive-Disincentive Provisions

Incentive-disincentive contract provisions provide for specified financial consequences to contractors based on actual completion of identified work (considered critical by the agency owner) relative to scheduled completion. The schedule (calendar days or completion date) for critical work items is established by the owner agency and identified in the bid documents. A daily incentive-disincentive amount is also established by the owner agency in the procurement documents. Additional contractor payment (i.e., incentive payment) is made for each day that the identified critical work is completed ahead of schedule, and contractor payment is reduced for each day that the contractor overruns the scheduled completion.

Incentive-disincentive provisions are intended primarily to minimize work zone impacts on critical projects. The determination of incentive-disincentive daily amounts includes consideration of traffic safety, road user delay, and maintenance of traffic costs (*9*).

As it relates to work zone design and traffic control, the use of an incentive-disincentive provision is somewhat similar to A+B (cost-plus-time) bidding. The contract documents must clearly indicate contractor duties and limitations with regard to traffic control and work zone design.

3.2.1.4 Lane Rental

Lane rental involves assessing the contractor a preestablished fee to occupy a travel lane or shoulder as part of the contract. Rental rates are established by the agency in the procurement documents and are typically stated in dollars per travel lane or shoulder per time period (e.g., day, hour, or faction of hour), with peak periods carrying higher rates. The anticipated times or durations of occupation are not stated in the agency procurement or bid. The contract is awarded to the low bidder on the basis of pay items.

During execution of the contract, rental fees are computed by the agency based on the agency's rental rates and actual times that the contractor occupies travel lanes and shoulders. The rental fees reduce the net amount paid to the contractor and provide a financial incentive to minimize the duration of contractor occupations and hasten return of the facility to service.

The lane rental approach allows some flexibility in the distribution of work zone design assignments between agency and contractor. The conventional approach of providing a work zone design with the contract documents is workable and common. When a TTC and/or construction phasing plan are provided, the competitive and innovative forces are focused on minimizing the time that travel lanes are occupied while completing the identified work. Alternatively, an agency may identify the high-level requirements and lane rental fee schedule. This more open approach allows the contractor greater flexibility and more areas of potential innovation. This approach has been used for several freeway paving projects.

3.2.2 Night Construction

Conducting construction operations and implementing the associated capacity-reducing measures during periods of reduced demand is a method of bringing available capacity more closely into balance with demand. Night traffic volumes are generally lower than daylight volumes. Consequently, agency interest in night work as a means of reducing impacts is growing. Generally, there are no or few legal and contracting limits on an agency's authority to specify day and time restrictions. However, schedule restrictions (i.e., days, dates, or times when activities are not permitted) or requirements (i.e., days, dates, or times when activities must be performed) carry many potential consequences. Although some research has been conducted into the consequences of night construction (*10, 11*) and more is being conducted, a rigorous evaluation of all its implications has not been undertaken. Exhibit 3-2 summarizes commonly perceived advantages and disadvantages of night work.

When commercial land uses abut facilities being constructed (or reconstructed), access by customers and suppliers may be impaired. Restoring access and capacity during nonwork periods (i.e., business day and time) reduces impacts. This consideration is more important in commercial areas, where speeds tend to be lower than on high-speed highways.

There are many costs involved in highway construction, including those related to safety, user delay, and possible economic disruption. Agency costs are those paid by the transportation agency to employees, contracting constructors, and engineers. These direct costs tend to be higher for night construction because of additional devices, wage differential, and producer costs. Additionally, agencies and personnel experienced in administering night construction often refer to elevated risk factors (e.g., higher speeds, impaired drivers, and reduced visibility). Prevailing commercial, personal, family, and social patterns are the very reasons that traffic volumes are reduced at night; therefore, working at night may be very disruptive to a person's quality of life. This may affect the ability of the transportation agency and contractor to attract qualified personnel. Also, construction often creates sound, and the noise levels that may be tolerable and conform to ordinances during day hours may not be at night. Also, nearly all construction operations (e.g., materials placement and compaction) are vision dependent. Although lighting systems can mitigate for the absence of sunlight, there remains a concern that some work is compromised by limited visibility.

Specifying night work is a contracting strategy that is increasingly attractive to many agencies. However, a careful evaluation of potential ramifications should be conducted before selecting this alternative (*11*). Paving high-volume facilities is a common project type for this strategy.

Advantages	Disadvantages
• Lower traffic volumes and lower traffic impacts • Lower impacts to commercial activity	• Higher agency cost • Higher safety risks • Disrupts normal social patterns of work force • Noise • Possible compromise in construction quality

Exhibit 3-2. Perceived advantages and disadvantages of night construction.

3.2.3 Evaluation of Work Zone Designs Proposed by Contractors

As outlined in Sections 3.2 and 3.2.1.2, there are situations under which contractors develop work zone designs and submit them for agency approval or concurrence. There should be a basis for the review. Exhibit 3-3 is a general framework for conducting a comparative evaluation between an agency-prepared design and a proposed alternative. Some of the factors are quantifiable, and others have to be assessed qualitatively. An agency could elaborate on this general approach by adding additional factors and assigning weights to factors.

3.3 Identifying and Evaluating Alternative Work Zone Strategies

The identification of candidate strategies begins after the project scope is defined and other preliminary information (e.g., typical sections, traffic volumes, right-of-way, and context) is available. Based on experience and guidance, such as the guidance in Exhibits 3-4 and 3-5, a set of preliminary alternatives is identified. Exhibits 3-4 and 3-5 identify candidate work zone strategies for combinations of six generic facility types and two generic construction methods. Lane construction refers to an operation where a single lane (i.e., travel or auxiliary) is constructed or reconstructed while an adjacent lane carries traffic. Resurfacing, pavement reconstruction, and

Evaluation categories and factors		Agency (base) design	Contractor-proposed design
Road user factors	Safety (queue formation, exposure to roadside hazards, speed reductions, etc.)		
	Mobility (capacity, delay, interruption of commercial and industrial flow, etc.)		
	Access (abutters, intersections, interchanges, etc.)		
	Nonmotorized traffic		
	Special groups (oversized vehicles, modal connections, etc.)		
Agency factors	Worker safety		
	Emergency services implications		
	Community impacts (local events, noise, etc.)		
	Contract administration and inspection		
	Coordination with other project schedules		
	Quality of completed construction (traffic interference, time of day and seasonal effects, etc.)		
	Cost		
Other factors (for project)			

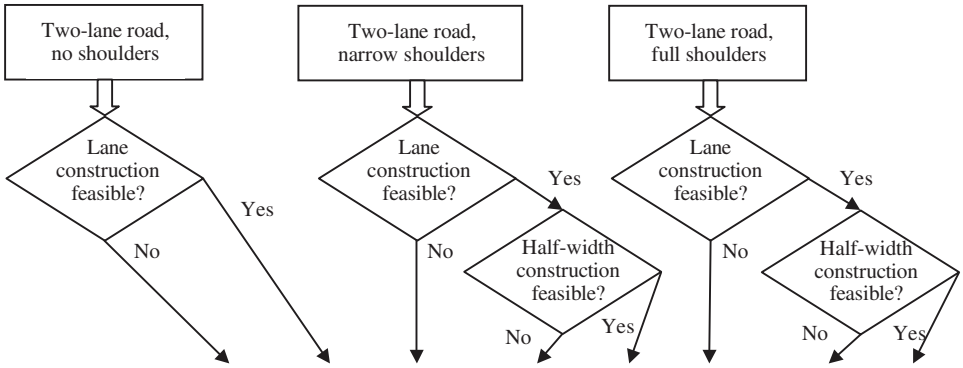
Exhibit 3-3. Framework for evaluating alternative work zone design.

some types of bridge work are routinely accomplished using lane construction. Half-width construction refers to constructing or reconstructing one-half of the typical template as a single phase. Reconstruction of some bridges on divided highways is an example of this category.

The following guidance applies to Exhibits 3-4 and 3-5:

- *Lane construction feasible* means that the basic roadway construction activity (e.g., resurfacing or reconstruction) can be accomplished in basic lane-by-lane phases. During each phase, a single permanent travel lane or shoulder is occupied for construction, and the other cross-sectional elements (roadway and roadside) are available for traffic management and control.
- *Half-width construction feasible* means that the roadway construction activity (e.g., resurfacing or reconstruction) can be accomplished in two basic phases. During each phase, half of the permanent roadway cross section is occupied for construction, and the other half of the cross section and roadsides are available for traffic management and control.
- From a traffic control standpoint, *lane construction* is considered to be a subset of *half-width construction*. Generally, any traffic control strategy that is feasible for half-width construction is also feasible for lane construction, although the strategy may not be desirable because of the wider range of choices available for lane construction. However, in some cases, half-width construction may be feasible when lane construction is not. Some bridge deck replacements are in this category.
- The numerical rankings in the matrix cells represent the general ranking and feasibility of various zone design strategies for various construction work requirements and facility types. The lower-numbered strategies are generally more preferred and feasible than higher-numbered strategies, although no general characterization is true for all cases. The selection of an appropriate strategy always requires project-specific information. The exhibits recommend strategies for consideration. The numerical rankings do not imply that lower-numbered strategies are superior, but rather suggest that lower-numbered strategies be considered before final selection of a higher-numbered alternative. As an example, before selecting the #3 strategy, the #1 and #2 strategies should be considered. Further, in using these exhibits, the designer is not restricted to considering only strategies that are ranked, nor must the designer consider all of the strategies that are ranked.

Once identified, the preliminary alternatives are evaluated at two levels. The first is to determine if an alternative has a "fatal flaw," some factor that renders the alternative categorically infeasible. If a fatal flaw is found, the alternative is dismissed



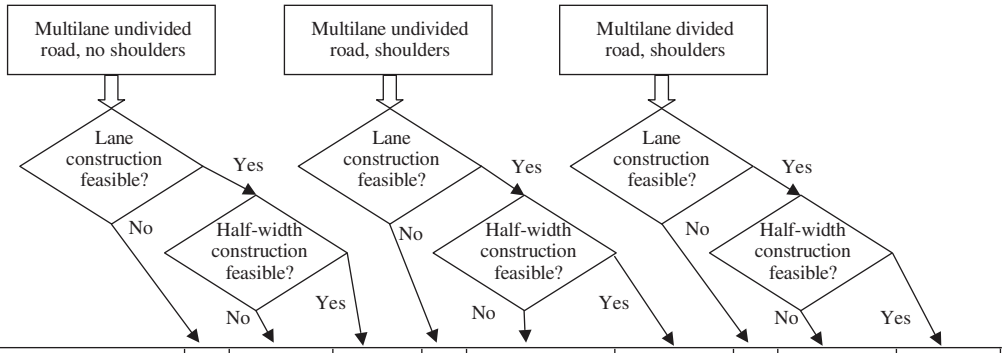
Alternating, one-way operation (mitigation)		2s		2s	2s		6s	5s
Crossover (mitigation)				3s, 4s	3s, 4s		3s	2s
Detour (mitigation)	2s	3s, 5s	2s	5s, 6s	5s, 6s	2s	4s. 7s	3s, 6s
Diversion (mitigation)	3s	4s, 6s	3s	3s, 4s, 7s	3s, 4s, 7s	3s	5s, 8s	4s, 7s
Full road closure	2, 3	5, 6	2, 3	6, 7	6, 7	2, 3	7, 8	6, 7
Intermittent closure	1	1	1	1	1	1	1	1
Lane closure		2, 3, 4		2, 3, 4, 5	2, 3, 4, 5		2, 3, 4, 5, 6	2, 3, 4, 5
Lane constriction (mitigation)				4s	4s			
Use of shoulders (mitigation)				3s, 4s	3s, 4s		2s, 3s	2s, 3s

Notes: Numbers indicate general ranking and feasibility, with lower numbers being generally more preferred and feasible than higher numbers. An "s" next to a number indicates a supporting element of the strategy(ies) with the same number (e.g., one or more "3s" strategies support "3"). A complete strategy includes all of the primary and supporting elements with the same number in a particular column. Multiple numbers in the same cell indicate different rankings for a strategy (as either a base or support) used in a different combination with others.

Exhibit 3-4. Preliminary work zone strategy screening, two-lane roads.

from further consideration. The remaining alternatives are retained for the second level of consideration, which is comparative analysis. At this level, each alternative is rated against a set of criteria.

The fatal flaw and comparative analysis typically use most of the same evaluation factors. The purpose of the first-level analysis is to eliminate any alternative that does not meet predetermined threshold criteria. Exhibit 3-1 summarizes general information about several common work zone design strategies. The exhibits in this report may be used to perform a general screening. However, detailed project-level analysis should be conducted with a multidisciplinary team. Personnel with experience and knowledge in construction operations and contract administration, geometric and structure design, high-



Alternating, one way operation (mitigation)		8s	7s						
Crossover (mitigation)			2s		5s, 6s, 7s	2s, 3s, 4s, 5s		Not applicable	2s, 3s, 4s, 5s
Detour (mitigation)	2s	4s, 6s	3s, 5s	2s	8s, 10s	6s, 8s	2s	5s	6s
Diversion (mitigation)	3s	5s, 7s	4s, 6s	3s	9s, 11s	7s, 9s	3s	6s	7s
Full road closure	2, 3	6, 7	5, 6	2, 3	10, 11	8, 9	2, 3	5, 6	6, 7
Intermittent closure	1	1	1	1	1	1	1	1	1
Lane closure(s)		2, 3, 4, 5, 8	2, 3, 4, 7		2, 3, 4, 5, 6, 7, 8, 9	2, 3, 4, 5, 6, 7		2, 3, 4	2, 3, 4, 5
Lane constriction					4s, 6s	4s		3s	5s
Reversible lane (mitigation)		3s			7s	5s			
Use of shoulder(s) (mitigation)					3s, 4s, 5s, 6s, 7s	3s, 4s, 5s		2s, 3s	3s, 4s, 5s

Notes: Numbers indicate general ranking and feasibility, with lower numbers being generally more preferred and feasible than higher numbers. An "s" next to a number indicates a supporting element of the strategy(ies) with the same number (e.g., one or more "3s" support "3"). A complete strategy includes all of the primary and supporting elements with the same number in a particular column. Multiple numbers in the same cell indicate different rankings for a strategy (as either a base or support) used in a different combination with others.

Exhibit 3-5. Preliminary work zone strategy screening, multilane roads.

way and worker safety, and traffic engineering provide a valuable perspective. Evaluation of work zone strategies should consider the factors in the following sections.

3.3.1 Access

All roads are accessible, but not to the same degree. The functional classification system is based on the proportional distribution of access and mobility functions. Exhibit 3-6 depicts the relative functionality of various facility types. Potential work zone impacts are directly related to the functionality of a highway in its permanent state (i.e., prior to construction work zone). Temporary denial or impedance of access to commercial, industrial, recreational, and residential property can be very disruptive. Additionally, freeway interchanges are sometimes closed or substantially altered during construction. In designing the work zone, the access function should be inventoried and well understood.

Access to highways is provided through the following mechanisms:

- Abutting land use (i.e., driveways and private roads),
- At-grade intersections,
- Interchange ramps, and
- Temporary occupancy (i.e., work zones).

Each of these mechanisms is a work zone design variable, meaning that the design process can affect the status quo. However, designers rarely exercise unconstrained flexibility on any aspect. Although excluding all other access to a highway work zone may result in the greatest construction efficiency, that option is rarely available (and is generally used in the interest of rapid completion). Normally, existing access mechanisms are sustained as part of work zone design, but often at a diminished level.

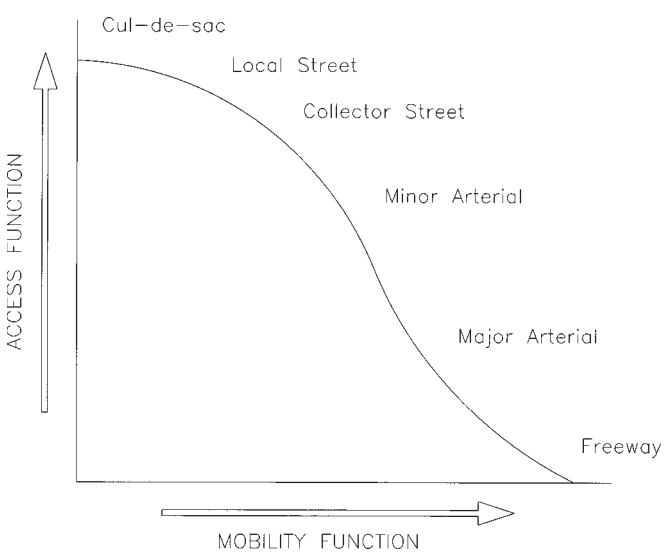


Exhibit 3-6. Conceptual access-mobility functions of various facility types.

3.3.2 Basic Traffic Functionality and Operation

Construction necessarily alters the preproject roadway configuration. The ramifications of the alterations are sometimes overlooked until project implementation. Tabulating the following information for each alternative will show the probable effects on basic traffic and highway operations:

- Bridge deck width available compared with approach road;
- Freeway entrance ramps closed;
- Freeway entrance ramp acceleration lane length reductions;
- Freeway exit ramps closed;
- Freeway exit ramp deceleration lane length reductions;
- Horizontal clearance to bridge piers, above-ground lighting hardware, signs, and other roadside appurtenances;
- Impact on existing drainage systems;
- Location and control of affected intersections;
- Number of lanes per direction;
- Railroad crossings affected;
- Roadway lighting affected;
- Travel lane widths for each affected road; and
- Vertical clearance (based on temporary roads and including construction appurtenances).

Physical alteration and occupation by construction operations can affect traffic operations in many ways. Example impacts include increasing the response time of emergency services and rendering facilities unsuitable for oversized vehicles. The identification of undesirable features may be used to mitigate the condition or, if the condition is unmitigated, to serve as an evaluation factor.

3.3.3 Capacity and Queues

Construction work zones often reduce the capacity of a facility below its preproject capacity level and below the capacity level of the approach roadways. Capacity is related to the number of travel lanes and free-flow speeds; thus, construction-related factors that reduce either will reduce capacity. Although the number of travel lanes is a substantive control on capacity, many additional factors can also influence traffic flow and capacity, including access, lane width, lateral clearance, and activities that result in speed reduction (i.e., enforcement and construction-related activities).

When demand exceeds capacity, two undesirable consequences follow: delay and queue formation. Delay results in user costs. Queues are considered a safety risk. Although a

number of measures have been developed to warn drivers approaching queues (e.g., a moving vehicle with strobes and technology-based measures), avoidance is preferable. Some agencies have developed policies limiting the projected queue length for work zone strategies involving a reduction in the number of travel lanes. Various techniques have been employed to estimate work zone capacity and traffic impacts. The QuickZone software was developed by FHWA (*12*) to assess various project strategies and phases within strategies. QuickZone can estimate the length of total mainline queue, the total mainline delay in vehicle hours, the total passenger car costs, the total travel time in minutes, and the detour delay costs. Some agencies have conducted analyses of their highway networks and predetermined facility segments for which work zone capacity reductions are prohibited or permitted within defined time frames (i.e., time and day).

3.3.4 Constructability

The ability to "bid and build" proposed work is a fundamental necessity of every project. When the feasibility of constructing as-designed work comes into question, then delays, disruption, and additional costs often follow. To prevent this situation and in consideration of increasing project complexity, a growing number of state DOTs routinely conduct constructability reviews. In some cases, the reviews are conducted entirely with internal agency staff; however, more often external people or organizations are engaged. A body of guidance based on research and experience is available to guide these reviews. AASHTO's *Constructability Review Best Practices Guide* (*13*) outlines processes and procedures used by several state DOTs, including consideration of work zones (e.g., maintenance and protection of traffic and detours), for conducting these reviews.

Rudimentary evaluation factors include the following:

- Traffic movement through the work zone during all construction phases and the geometric constraints of temporary construction features (e.g. shoring and bracing);
- Separation of through (i.e., nonconstruction) traffic from construction operations, workers, and construction traffic (equipment and vehicles) and stationary construction roadside hazards; and
- Access by construction forces to storage areas (equipment and materials) and to all necessary operations.

Whether a documented constructability review or a less structured constructability review is conducted, design plans and work zone strategies should be reviewed by personnel experienced in construction operations to evaluate the feasibility and possible cost implications of the design.

3.3.5 Cost

Work zone strategies have both agency and user cost consequences. Agency costs associated with maintenance and protection of traffic are always estimated for the selected strategy. Typically, the costs of TTC items are explicitly associated with maintenance and protection of traffic. Bidders submit prices as an element of their cost proposal, and this bid history is typically used to estimate the cost. However, the actual agency cost of a work zone type can be considerably different from the cost of TTC. Work zone strategies often influence the general method and efficiency of construction operations and the bid prices for major cost items (e.g., earthwork, pavement, and structures). Such differences may not be recognized by design teams. This point emphasizes the benefit of a multidisciplinary approach to work zone strategy evaluation and selection. The safety risk specifically associated with queue formation has not been quantified, but is widely considered to exist. As a result, many agencies endeavor to prevent or mitigate for queue formation. Quantitative estimates of user cost associated with delay are possible. Time-distributed traffic demand (i.e., volume by time of day and day of week) is needed. The values that an agency uses for delay in its life cycle cost analysis policy may be appropriate for a user cost estimate.

3.3.6 Human Environment and Other Modes

The category of "human environment and other modes" covers a myriad of factors that may arise at the intersection of construction operations and transportation facilities and that may not be specifically identified under another category. Disruption of pedestrian and social patterns, noise, natural resource impacts, and displacements are matters of public concern, and the impacts often vary with work zone strategy.

The potential effects of work zones on disabled populations, transit users, intermodal connections, and nonmotorized travel should be evaluated.

3.3.7 Summary

The strategy that is most responsive to the evaluation factors, on an overall basis, is selected. Only rarely is the same strategy optimal for all factors. Usually, the various strategies will exhibit offsetting considerations (e.g., cost or disruption of commerce) that cannot easily be converted to a common measure. In such cases, agency policy, preferences, and discretion prevail.

At the conclusion of the identification and evaluation phase, a work zone strategy and supporting strategies should be selected. The level of information assembled and the evaluation process should be sufficiently detailed to ensure feasibility of the selected strategies.

CHAPTER 4

Roadway Design

Chapter 3 identifies common work zone strategies. Several of these, including alternating one-way operation, full road closure, intermittent closure, and lane closure, are normally implemented exclusively or primarily through temporary traffic control (TTC). Exhibit 4-1 identifies work zone strategies for which the MUTCD Part 6 provides direct and illustrated guidance (in the form of typical applications). The MUTCD in its entirety, with specific emphasis on the Part 6 "General and Fundamental Principles" chapters, should be relied upon. As stated in Chapter 1, this report is intended for use in conjunction with the MUTCD, not as a substitute.

Implementation of a detour may or may not require temporary roadway infrastructure. When temporary roadways are needed, the guidance provided for diversions (see Section 4.1) is generally applicable. Other work zone types generally involve the design of roadways, including geometric design and the provision of supporting appurtenances. This chapter addresses the work zone roadway design elements of specific work zone strategies, including temporary roadway infrastructure and existing roadways that are geometrically altered within work zones.

4.1 Diversions

Diversions, sometimes referred to as runarounds or shooflies, are a specific type of temporary roadway. This strategy offsets the effect of removing the permanent roadway from service. When the number of diversion travel lanes is the same as the affected roadway and speeds are comparable, the mitigation is nearly complete. General considerations and common applications are identified in Section 3.1.3. Diversions can carry one-way or two-way roadways. Two-lane, two-way diversions, such as the one illustrated in Exhibit 4-2, are the most common type.

The diversion design must reflect the service requirements and site constraints. Diversions are often used in conjunction with bridge construction and may involve grade separation or hydraulic structures (temporary bridges, culverts, etc.), which strongly influence the overall geometric design. Selection of the work zone design speed for the diversion should follow the Section 2.2 guidance.

Sight distance guidance is provided in Section 2.2.6. Diversion alignments commonly consist of a series of horizontal and vertical curves. Lateral sight obstructions and crest vertical curves should be reviewed.

Diversions are most common on two-lane roads, and the TTC for that condition is the subject of a Typical Application in the MUTCD. Diversions are sometimes used on other facilities types, as well. Appropriate TTC should be based on general direction and guidance in the MUTCD and with reference to the Typical Application for a two-lane road diversion.

4.1.1 Horizontal Alignment and Superelevation

The cost and impacts of a diversion may be directly related to the length of the alignment between tie-in points on the permanent roadway. This suggests that the best curve radii to use are the smallest curve radii that satisfy all design considerations (e.g., work zone design speed, safety, and project-specific features). A common diversion design (see Exhibit 4-2) includes pairs of opposing-direction horizontal curves. For reasons indicated in Section 2.3.2, it is common design practice to provide curves that are sufficiently flat to not require superelevation. Where superelevation is needed, the agency-adopted policy of superelevation distribution (as discussed in Section 2.3.2) should be applied and the alignment-superelevation criteria met. Where superelevation is provided, the alignment should provide for adequate transitions. In the case of superelevated reverse curves, a tangent between the curves is needed. Normal crown and superelevated cross sections are depicted in Exhibits 4-3 and 4-4, respectively.

4.1.2 Vertical Alignment

Section 2.3.4 is applicable to diversions.

Work zone strategy	MUTCD guidance		
	Freeway	Multilane nonfreeway	Two-lane
Alternating one-way operation	NA	NA	√
At-grade intersections	NA	√	√
Detour			√
Diversion			√
Full road closure	(1)	(1)	(1)
Interchange ramp	√		NA
Intermittent closure			√
Lane closure	√	√	√
Lane constriction			√ (2)
Median crossover	√	√	NA
Use of shoulder	√ (3)		

√ Explicitly addressed by MUTCD Part 6.
NA Not applicable.
1 Full road closure requires a detour.
2 MUTCD typical application provided for one category of lane constriction (Shoulder Work with Minor Encroachment) pertains to minor roads with low speeds.
3 Covered in conjunction with Lane Shift.

Exhibit 4-1. Coverage of MUTCD Part 6 TTC guidance for various work zone strategies.

4.1.3 Cross Section and Surface

From a traffic operations and safety perspective, the diversion cross section should be the same as the approach roadway. However, this expectation is often not reasonable or practical. The duration of service, traffic volume, vehicle mix, construction cost, and impacts of the diversion are relevant considerations. Recommended two-lane diversion travel way and roadway (i.e., combined traveled way and shoulder) widths are shown in Exhibit 4-5. Values above those shown in Exhibit 4-5, up to those used for permanent roads of the same functional class, provide desirable service, but the additional cost is not necessarily justified.

The Section 2.2.8 discussion on traveled way surface type is applicable to diversions. Shoulders are often unpaved. The guidance in Section 2.2.8 applies to traveled way and shoulder cross slopes.

The pavement structure provided with higher-volume diversions should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. For this condition, providing a highly durable pavement structure should be considered.

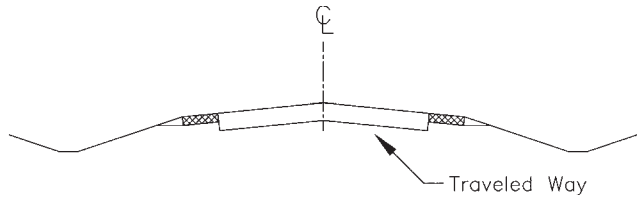


Exhibit 4-3. Diversion typical section with normal crown.

4.1.4 Roadside Design and Barrier Placement

For a discussion of the principles guiding roadside design and safety for construction work zones, see Chapter 5. For a specific discussion of barrier use for a temporary bridge that is part of a diversion on a two-lane, two-way highway, refer to Section 5.5.4.

4.2 Lane Constriction

General considerations are outlined in Section 3.1.7. It is desirable to maintain the approach road travel lane width through construction work zones. However, "lane constriction" implies a width reduction, and desirable dimensions are generally not attainable. Therefore, this strategy inherently involves providing a design feature that is less than desirable. Research indicates that reducing lane widths though work zones may increase crash rates. Relationships between the magnitude of the reduction and the corresponding safety effect were not reported.

It is common practice to reference "travel lane width" as the key lane constriction decision variable. However, operations in one travel lane are influenced by operations in adjacent lanes. Additionally, adjoining travel lanes occasionally have different widths. Therefore, it may be more appropriate for design guidance to address traveled way width. For example, a 3.0-m [10-ft]-wide travel lane adjacent to a 3.6-m [12-ft] travel lane is generally more desirable than a 3.0-m [10-ft]-wide travel lane adjacent to a travel lane of the same width.

A number of factors should be considered in determining the minimum acceptable traveled way width, including the presence and proximity of roadside features. As indicated by the *Roadside Design Guide* (see Section 5.6.1 of this report),

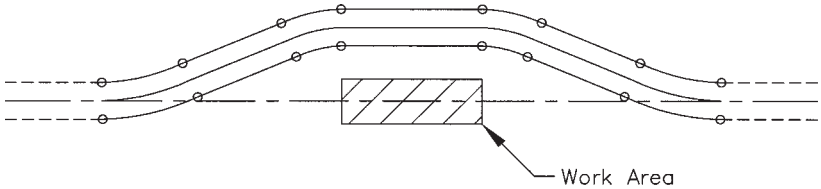


Exhibit 4-2. Example plan of diversion.

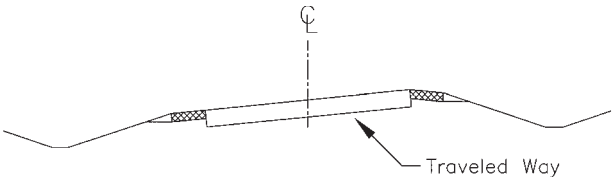


Exhibit 4-4. Diversion typical section with superelevation.

vehicle speeds and position (i.e., lateral vehicle location) may be affected by roadside features. Section 9.2.1.1.2 of the *Roadside Design Guide* indicates that the minimum desirable offset from the edge of the travel lane to the temporary concrete barrier (TCB) is 0.6 m [2 ft]. While the 0.6-m [2-ft] offset is desirable, a number of agencies use lower minimum values.

Traveled way widths that result in 3.6-m [12-ft]-wide travel lanes and provide offsets to constraining features (e.g., barriers) are desirable. However, lane constrictions are less-than-ideal conditions that must sometimes be provided as a matter of practicality. Factors that are sometimes considered in determining acceptable traveled way lane width include

- Traffic volumes,
- Heavy-vehicle (i.e., truck) volumes,
- Lateral constraint,
- Speed,
- Horizontal curvature,
- Duration of lane constriction,
- One-way or two-way roadway (i.e., if all other factors are equal, the minimum traveled way width for an undivided two-way roadway should be greater than for the one-way roadway), and
- Number of lanes.

Traveled ways that result in travel lane widths of 3.3 m [11 ft] are fairly common in work zones; those that result in travel lanes less than 3.0 m [10 ft] are generally not used for construction work zones on high-speed roads.

Exhibit 4-6 and the accompanying notes are an example framework that uses a number of factors to determine minimum traveled way width. For traveled ways with constraint, the distances indicated are measured to the face of the constraining features (i.e., the offset is included in the tabulated dimension).

Current ADT (veh/day)	Metric		U.S. Customary	
	Traveled way width (m)	Roadway width (m)	Traveled way width (ft)	Roadway width (ft)
< 1,000	6.6	7.8	22	26
1,000–3,000	6.6	9.0	22	30
> 3,000	7.2	10.8	24	36

Exhibit 4-5. Recommended two-lane diversion travel way and roadway widths.

Lateral constraint may also restrict sight distance, which should be reviewed in light of Section 2.2.6.

Lane constrictions are often used in conjunction with lane shifts, lane closures, and shoulder closures. Guidance on TTC for each of these is provided in the MUTCD. With the use of a constricted lane, the use of a W5-1 (Road Narrows) sign should be considered in coordination with other applicable TTC devices.

4.2.1 Barrier Placement and Traffic Separation

For a discussion of the principles guiding roadside design and safety for construction work zones, see Chapter 5 of this report. For a specific discussion of barrier use for lane and shoulder closures with minor encroachments onto the remaining travel lanes, refer to Sections 5.5.1 through 5.5.3. In these conditions, a design decision that must be made is how to distribute the remaining paved roadway for temporary lanes and shoulders. A number of combinations can often exist. For the tools used to develop barrier placement guidance, different combinations of lane and shoulder widths did not affect the resulting guidance in the referenced subsections.

4.3 Median Crossover

A *median crossover,* as defined in this document, is the infrastructure used to support the *two-way traffic on a normally divided facility.* In practice, the two terms are often used interchangeably. General considerations and common applications are identified in Section 3.1.8. The core requirement in establishing the length and limits of a median crossover is to remove traffic from the portions of the infrastructure that are to be reconstructed. Although a specific absolute maximum length cannot be established and agency practice in this area varies, crossover lengths should be limited. Crossovers impose more constraint on drivers than the approach roadway. There is usually only one one-way lane, which limits driver lane and speed choice. Additionally, cross-sectional arrangements often involve operation near barriers and provide reduced refuge opportunity for disabled vehicles. These factors increase driver anxiety and may require heightened vigilance. In recognition of these considerations, crossovers longer than 15 km [10 mi] are used infrequently, and some agencies prefer lengths of 8 km [5 mi] and less. The temporary roadways should be sited to avoid unnecessary proximity to bridge structures; substantial grade differences between one-way roadways; complex, sensitive, or formidable geologic features (e.g., rock outcrops or wetlands); and other attributes that require extensive roadbed

		Metric				U.S. Customary			
		Traveled way width (m)				Traveled way width (ft)			
	Facility type	Undivided highway		Divided highway		Undivided highway		Divided highway	
	Lanes per direction	One	Two	One	Two	One	Two	One	Two
Traveled way edge conditions	Constraint along neither traveled way edge	3.0 [1]	6.0 [2,3]	3.3	6.6 [3]	10 [1]	20 [2,3]	11	22 [3]
	Constraint along one traveled way edge	3.3 [1]	6.3 [2,3]	3.6	6.9 [3]	11 [1]	21 [2,3]	12	23 [3]
	Constraint along both traveled way edges	3.6 [1]	6.6 [2,3]	3.9	7.2 [3]	12 [1]	22 [2,3]	13	24 [3]

Notes:

1. Values apply only when all of the following conditions are met: low truck volumes, all curve radii equal or exceed 555 m (1,820 ft); and anticipated 85th-percentile speeds are less than or equal to 80 km/h (50 mph). If any of the three conditions is not met, add 0.3 m (1 ft) to the base value.
2. Values apply only to roadways carrying moderate truck volumes where all curve radii equal or exceed 555 m (1,820 ft). If either condition is not met, add 0.3 m (1 ft) to the base value.
3. Values shown apply to two-lane, one-way traveled ways. For constricted two-way traveled ways, consider separation of opposing directions using (a) additional traveled way width, (b) channelizing devices, or (c) a traffic barrier.

To use this exhibit, first determine the traveled way edge conditions. "Constraint" refers to the presence of an imposing feature, such as a feature that results in "shying away" at the edge of the traveled way. Temporary barriers are a common constraint feature. Next, identify the type of facility (undivided or divided) approaching the work zone. Using this information and the number of travel lanes through the work zone, determine the base (i.e., unadjusted) value within the appropriate cell. Superscripted numerals indicate the note numbers that should be referenced to determine appropriate adjustments, if any, to the base value.

For traveled ways with edge constraint, the distances indicated are measured to the face of the constraining features (i.e., the offset is included in the tabulated or adjusted dimension).

Values lower that those obtained from this method may be appropriate for very low exposure (i.e., traffic volume, constricted lane segment length, and duration of operation).

Exhibit 4-6. Example framework for selecting one-way traveled way widths.

preparation. Interchange ramps are another potential location control.

Selection of the work zone design speed for the median crossover should follow the guidance in Section 2.2. Horizontal curves and grades, particularly those on the temporary median roadways, should be designed in recognition of their potential effect on speed. Sight distance guidance is provided in Section 2.2.6. Median crossovers often include a series of horizontal and vertical curves in combination with a TCB. The effect of crest vertical curves and lateral sight obstructions should be reviewed.

Exhibit 4-7 schematically depicts a median crossover. The distance from the downstream end of the lane-closure taper to the beginning of the curve ("d" in Exhibit 4-7) varies by agency from one-half to twice the lane-closure taper length. Higher values (i.e., longer distances) are desirable to provide separation between locations of driver decisions and associated maneuvering.

Median crossovers are the subject of Typical Applications in the MUTCD, which should be referenced in establishing TTC.

4.3.1 Temporary Roadways Connecting the Permanent Roadways

Median crossovers are a common work zone type (and therefore familiar to drivers) in some regions and not in others. Additionally, the temporary roadways used to connect normally divided highways represent a departure from the default path, the permanent alignment through travel lanes. Hence, driver familiarity and expectancies are not uniform. From the driver's perspective, these temporary roadways are a nondiscretionary exit ramp from a mainline alignment. Although the movement is required for drivers, the combined and complementary use of geometry and TTC is needed to provide positive guidance for a distinctive departure from the perma-

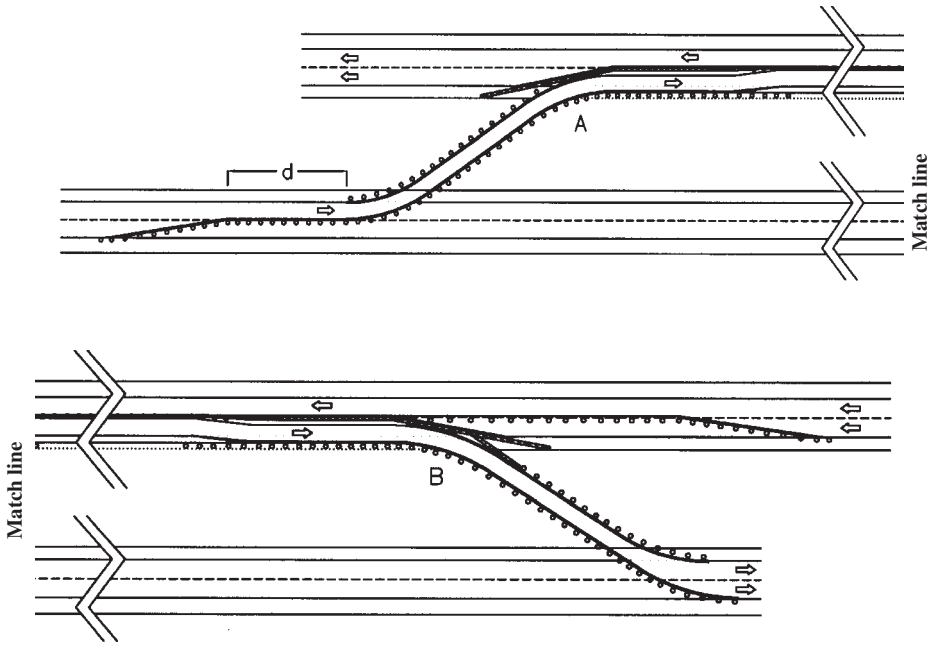


Exhibit 4-7. Example plan view of median crossover.

nent road alignment. The geometry should provide extended sight distance, a well-aligned and -delineated path, and a forgiving cross section.

TCBs in conjunction with other TTC (channelizing devices, pavement markings, etc.) are frequently used to delineate travel paths and to separate opposing directions of travel in the areas where the permanent roadway carrying two-way traffic and temporary connecting roadway converge and diverge (in Exhibit 4-7, locations A and B). The option of providing a TCB to separate traffic throughout the length of two-way roadway is discussed in Section 4.3.3. In cases where a TCB is used at the convergence and/or divergence points and terminated within the limits of the two-way roadway, a crashworthy end treatment is required.

4.3.1.1 Horizontal Alignment and Superelevation

The agency-adopted policy of superelevation distribution (as discussed in Section 2.3.2) should be applied and the alignment-superelevation criteria met. When practicable, the horizontal alignment should be flat enough to avoid the need for superelevation. This goal is often attainable outside urban areas.

4.3.1.2 Vertical Alignment

Section 2.3.4 is applicable to temporary roadways connecting the permanent roadways of a normally divided highway. The discussion on the potential effect of grades on heavy-vehicle performance and capacity is especially relevant to crossovers.

4.3.1.3 Cross Section and Surface

In some cases, median crossovers provide more than one travel lane in the same direction. However, the most common case is a single travel lane per direction. For that case, a number of alternative roadway cross-sectional configurations may be used, including

- Crowned in center, with equal-width shoulders;
- Crowned at center of traveled way, with wide right shoulders;
- Uniform traveled way cross slope, with equal-width shoulders; and
- Uniform traveled way cross slope, with wide right shoulders.

The appropriate selection depends on several factors. Some agencies leave crossovers in place for future use, rather than remove them at the conclusion of a project. Under a subsequent project, the same temporary roadway might carry traffic in the opposite direction (e.g., eastbound in one case and westbound in another). For this situation, both shoulders are a left and right shoulder at various points in their service lives. Additionally, curves may or may not be superelevated, depending on policy and specific design features (e.g., radius and work zone design speed).

The factors discussed above affect cross-sectional design, and agencies have developed a variety of cross-sectional design

practices. Travel lane widths for a single lane range from 3.6 to 4.8 m [12 to 16 ft], with 4.8 m [16 ft] being more common and recommended. The high overall- and truck-traffic volumes and speeds normally associated with freeways and temporary road curvature favor a wide cross section, including the traveled way. Equal-width shoulders are more common than the alternative and are appropriate when the same temporary roadway will be used for opposite-direction traffic at different times. Shoulders range in width from 0.6 to 2.1 m [2 to 7 ft]. For temporary roadways that will carry traffic only in one direction, consideration should be given to a wide right shoulder to reinforce the customary role and driver expectancy of the right shoulder as the location for emergency stopping and refuge. Additionally, emergency stops on the right side reduce potential conflicts with temporary barriers that are often located on the left side in the areas where temporary crossovers converge with and diverge from the one-way roadway carrying two-way traffic.

For multilane temporary roadways serving as median crossovers on high-speed highways, the travel lane should be at least 3.6 m [12 ft] wide. Shoulders 1.5 to 2.4 m [5 to 8 ft] wide on both sides are desirable.

Cross-sectional arrangements different from those stated above are appropriate when supported by agency experience.

A traveled way cross slope transition may be needed between the permanent one-way roadway and the temporary roadway. The direction and magnitude of temporary roadway superelevation are principal considerations.

The median crossover, temporary roadway pavement structure should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. Except for very low volumes and short durations, which are rarely the case with divided highways, a full-depth pavement structure is appropriate for the traveled way. Shoulders may be stabilized aggregate, paved, or paved part-width.

4.3.2 One-Way Roadway Used for Two-Way Traffic

One-way roadways are not specifically designed to carry two-way traffic. Yet this strategy has proven to be highly effective and is commonly employed in many regions. Using a one-way roadway for two-way traffic requires reapportioning the cross section and other adjustments.

A common freeway one-way roadway is shown in Exhibit 4-8. In locations where a TCB is placed, the permanent traveled way width available for use is 6.6 m [22 ft]. A common arrangement is shown in Exhibit 4-9. This asymmetrical configuration provides a much wider shoulder on the outside than the median side. Additionally, the useful traveled way width is reduced by the barrier width footprint and its shy effect. The arrangement shown in Exhibit 4-10 is sometimes used to allocate the roadway width (i.e., traveled way and shoulders) more evenly. When all or part of a shoulder is temporarily used as a travel lane, certain complications follow. Shoulder pavement structures may not be capable of supporting heavy and sustained traffic. Shoulder slopes may not be compatible with high-speed travel because of superelevation requirements on horizontal curves. For these reasons, when a two-lane, one-way roadway is used for two-way traffic, the separation (TCB or channelizing device) is usually centered on the line between the two permanent travel lanes. Separation by vertical panels is depicted in Exhibit 4-11. Although the separation device may result in a shy effect, experience with these conditions indicates that operations are acceptable.

The median shoulder in Exhibits 4-9 and 4-11 does not provide for a paved shoulder width comparable to permanent freeway conditions. Vehicle malfunctions and crashes are possible within work zones. This particular work zone inherently reduces capacity by a reduction in the number of travel lanes (i.e., two instead of four); therefore, further impediments are unwanted. Emergency turnouts (i.e., intermittent shoulders) are responsive to these conditions and are discussed in Section 6.3.

Many freeway shoulders have rumble strips. Depending on their location in relation to temporarily designated travel lanes, the rumble strips may interfere with two-way operations on the one-way roadway. This condition is further discussed in Section 6.9.

When a one-way roadway is used for two-way operation, the probability of an errant vehicle striking certain median hazards may increase substantially. For example, what is normally the departure end of a bridge becomes the approach end. Median roadside hazards should be evaluated. Guidance for common situations is provided in Sections 4.3.3, 5.5.5, and 5.5.6.

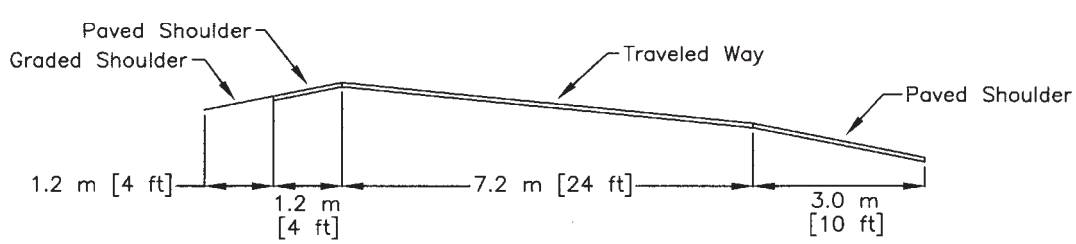


Exhibit 4-8. Typical section of freeway to be used for median crossover.

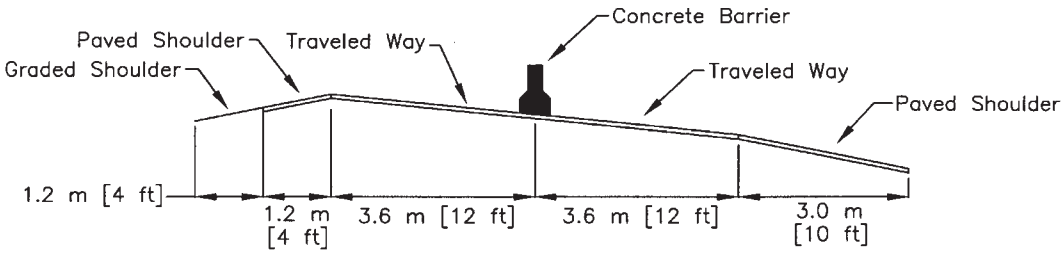


Exhibit 4-9. Typical section of two-way traffic on normally divided facility with barrier centered on existing traveled way.

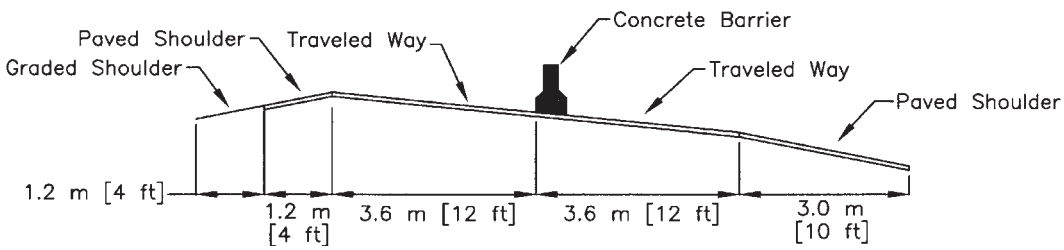


Exhibit 4-10. Typical section of two-way traffic on normally divided facility with barrier offset from center of existing traveled way.

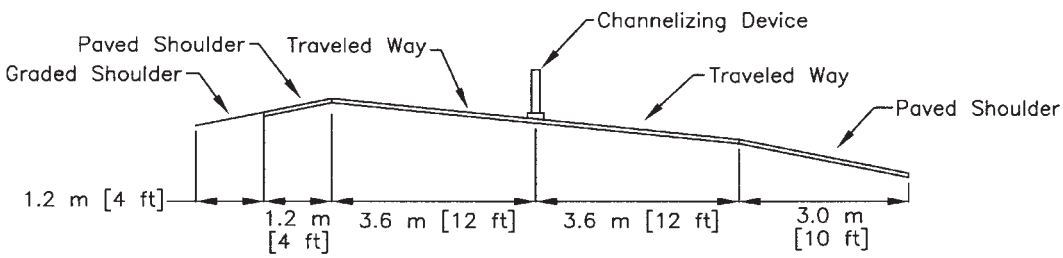


Exhibit 4-11. Typical section of two-way traffic on normally divided facility with vertical panel centered on existing traveled way.

4.3.3 Barrier Placement and Traffic Separation

For a discussion of the principles guiding roadside design and safety for construction work zones, see Chapter 5. For a specific discussion on temporary barrier use for two-lane, two-way traffic on a normally divided facility, refer to Sections 5.5.5 and 5.5.6.

4.4 Use of Shoulder

General considerations are outlined in Section 3.1.9. As indicated in that section, there are numerous variations of this strategy for different facility types and work requirements. A common freeway example is shown in Exhibit 4-12.

This use of shoulder involves limited design decisions and is implemented primarily through TTC. The transitional path of traffic from the permanent travel lane approaching the work zone to the shoulder (as a temporary travel lane) is delineated by shifting traffic. Adoption of a work zone design speed may be appropriate for the evaluation of superelevation (see Section 4.4.1) and sight distance. Because the shoulders will be part of a permanent high-speed roadway, no horizontal or vertical alignment decisions are generally needed. Temporary work zone features can affect sight distance, and the design should be developed and evaluated from that perspective, as discussed in Section 2.2.6.

The use of shoulder in conjunction with a lane shift is the subject of Typical Applications in the MUTCD, which should be referenced in establishing TTC.

4.4.1 Cross Section and Surface

The adequacy of the existing shoulder pavement for use as a travel lane may be assessed in terms of cross slope, structure, and surface characteristics. In some cases, pavement rehabilitation or reconstruction may be needed.

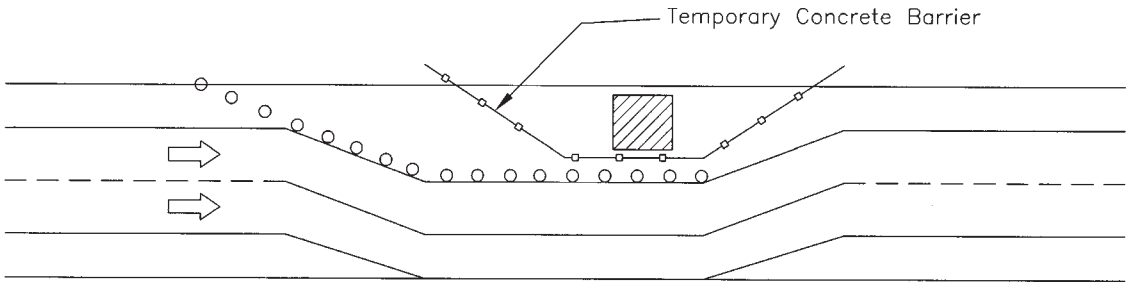


Exhibit 4-12. Use of shoulder in conjunction with a shift.

If the shoulder being used to carry traffic is on a horizontal curve, the magnitude and direction of its cross slope should be compared with the superelevation requirement. The agency's work zone policy for superelevation, using the Method 2 or 5 distributions outlined in Section 2.3.2, should be applied. If the actual curve radius is equal to or greater than the tabulated minimum radius for the work zone design speed and existing cross slope (accounting for direction and magnitude), the evaluation is complete. As sometimes occurs, the travel lane adjacent to a shoulder will be adequately superelevated but the shoulder will not.

Several measures have been employed when the shoulder cross slope does not meet the applicable work zone design criteria. The most comprehensive measure is to extend the cross slope of the adjacent travel lane to the shoulder through pavement reconstruction or surfacing. Other potential mitigation measures include speed advisories and speed-dampening measures (e.g., lane rumble strips). Detouring trucks and buses or prohibiting these vehicles from the shoulder that is temporarily in use for traffic and restricting them to the adjacent lane is an option used in some jurisdictions. An enabling regulation and the corresponding administrative procedures are needed.

Some shoulders have the same pavement structure as the adjoining travel lane; others do not. Travel lanes are subject to more intense service loads than shoulders. These factors, the age of the existing pavement, and the expected temporary pavement service requirements (e.g., traffic volumes, composition, and duration of use) should be considered in evaluating the potential use of existing shoulder pavements as travel lanes. The decision to reconstruct, rehabilitate, or retain an existing pavement structure should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. Providing a highly durable pavement structure should be considered.

Roadway design is based on the assumed availability of certain minimum friction between vehicle tires and the roadway surface. A shoulder being considered for use as a travel lane should meet or exceed the assumed values. Motorist surveys have revealed that rough-riding surfaces and work zones are independently two of the most dissatisfying aspects of highway travel. From a customer satisfaction standpoint, it is undesirable that these be combined in a single experience.

Before using an existing shoulder as a travel lane without modification, it should be considered adequate in each category: cross slope, structure, and surface conditions (i.e., friction and smoothness).

Many shoulders have rumble strips that may be within the wheel-path band. A situation where drivers are preoccupied with steering to avoid contact with rumble strips may induce unwanted distraction and tendencies. If this condition is anticipated, temporary rumble strip eradication and subsequent restoration should be considered. The feasibility and cost of these treatments (eradication and restoration) depend on the rumple strip configuration and shoulder pavement structure.

4.4.2 Barrier Placement and Traffic Separation

When a shoulder is used as a travel lane, the probability of an errant vehicle striking certain existing, permanent roadside hazards may increase. However, for most common construction work zone conditions, providing roadside barriers that shield existing hazards is not cost-effective. The previous statement refers to permanent (preproject) features and does not refer to construction-related work zone roadside hazards. Further, even permanent features with very high levels of exposure justify individual assessment.

4.5 Interchange Ramps

Access provisions are a significant factor for any construction involving interchanges. Maintaining existing access points and associated traffic movements reduces the negative impacts of interrupting established traffic patterns. However, avoidance of these impacts should be weighed against the feasibility of providing adequate infrastructure for traffic to enter and exit the mainline facility. The decision on interchange access during construction progresses in the following manner: temporary connections are provided when adequate arrangements

are feasible, and access points are closed when adequate arrangements are not feasible. The determination of adequacy is often related to speed change (i.e., acceleration or deceleration), lane length, and the associated traffic control.

A temporary single-lane interchange ramp should have a travel lane of approximately 4.5 m [15 ft], with a 1.8-m [6-ft] right shoulder and minimum 0.6-m [2-ft] left shoulder. However, different cross-sectional arrangements are appropriate when supported by agency experience and in consideration of project-specific factors (e.g., traffic volume, mix, and duration of service).

The MUTCD provides considerable guidance and illustrated examples of TTC provisions and schematic geometry for accommodating interchange ramps within work zones. The MUTCD does not provide specific geometric criteria for speed change lanes. These elements are discussed in Sections 4.5.1 and 4.5.2

4.5.1 Entrance Ramps

Maintaining service on existing entrance ramps is often feasible, regardless of work zone strategy (e.g., median crossovers, lane closure, or use of shoulder). Exhibit 4-13 illustrates a temporary entrance ramp for a median crossover.

The feasibility of maintaining an entrance during construction often hinges on providing an adequate combination of roadway geometry and traffic control to facilitate merging. Acceleration lanes enable entering traffic to increase speed while simultaneously selecting a gap in through-lane traffic. The basic principles and considerations associated with permanent entrance ramps pertain to temporary arrangements. Therefore, acceleration lanes in work zones that meet the design criteria for permanent facilities are desirable. However, attaining these lane lengths is often not practical. State DOTs have generally not published explicit minimum acceptable criteria. However, several "rules of thumb" are in use and provided here. One suggestion is to provide at least 90 m [300 ft] of acceleration lane. A second suggestion is to provide at least 70 percent of the permanent roadway criteria length. Traffic volumes (mainline and entrance ramp) and sight distance are sometimes considered in determining the minimally acceptable acceleration lane length for a specific location.

Traffic control measures may be employed to mitigate less-than-desirable acceleration lane lengths. STOP, YIELD, and other signs are often used to mitigate less-than-desirable acceleration lane lengths and conditions. A variety of practices are employed by agencies in establishing appropriate traffic control for interchange entrance ramps. Exhibit 4-14 summarizes the process used by the Maryland State Highway Administration (Standard MD 104.01.31) to install a YIELD sign on entrance ramps merging with expressways/freeways.

When the combination of traffic, geometric, and traffic control factors indicate an adequate entrance is not feasible, the entrance ramp should be closed. Advance coordination with the affected community, public information, and implementation of TTC measures are needed.

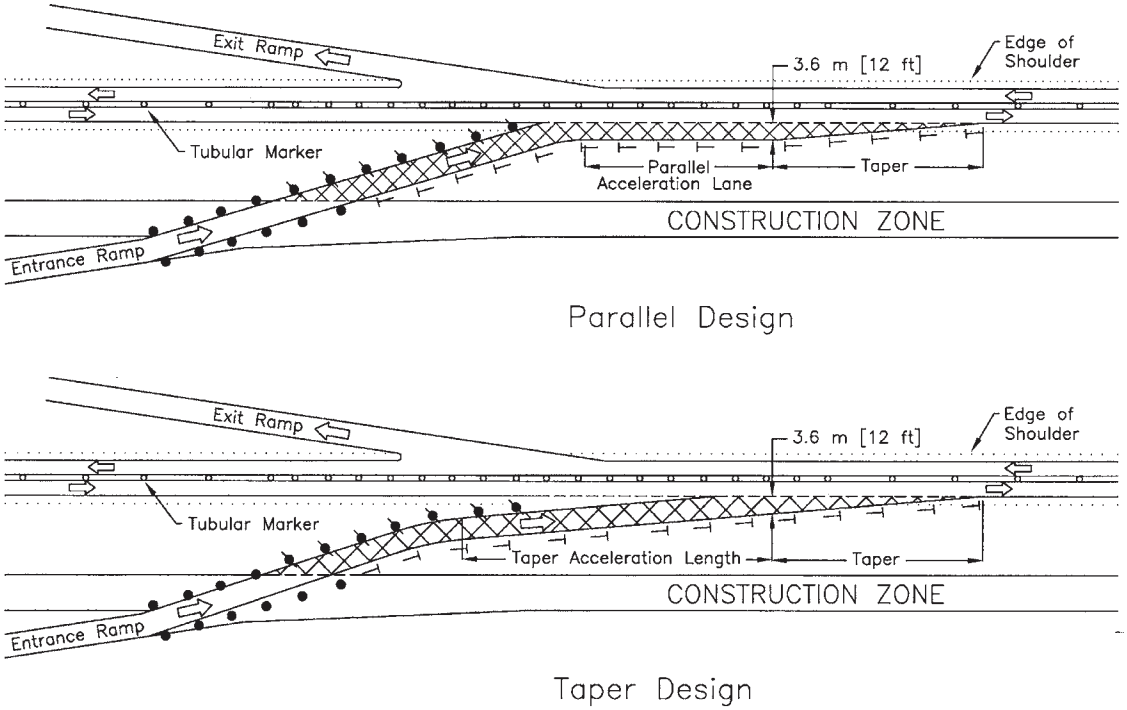
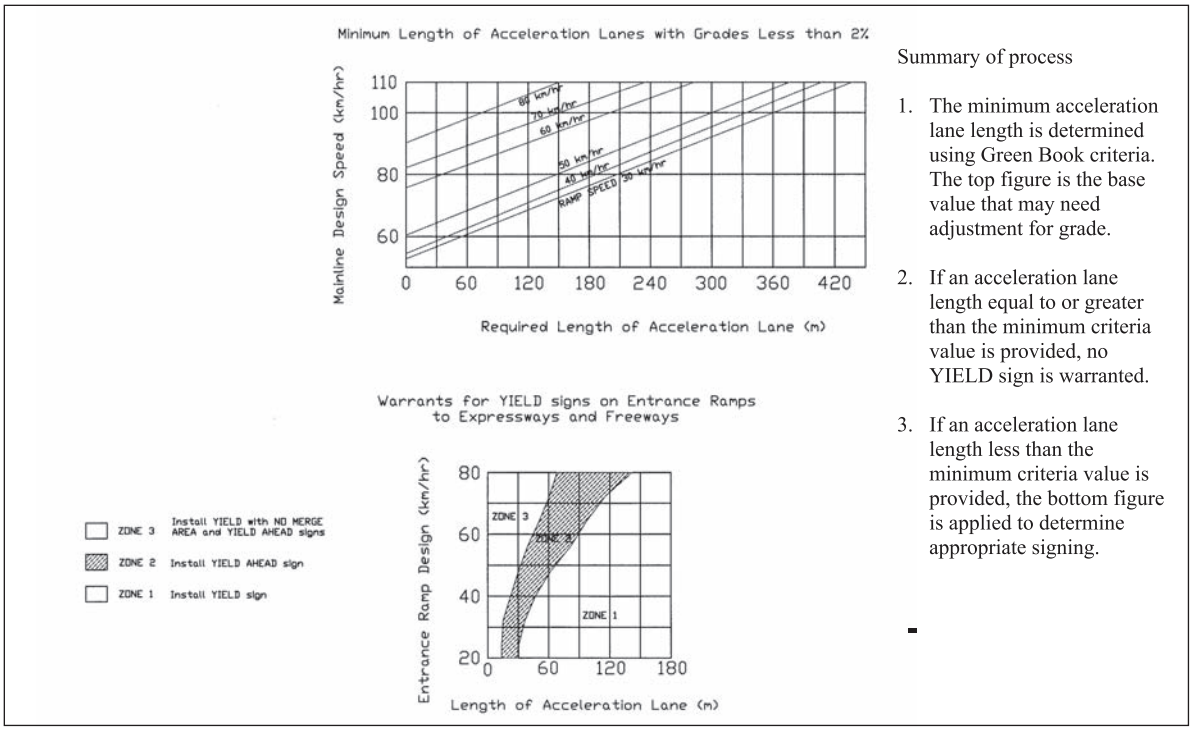
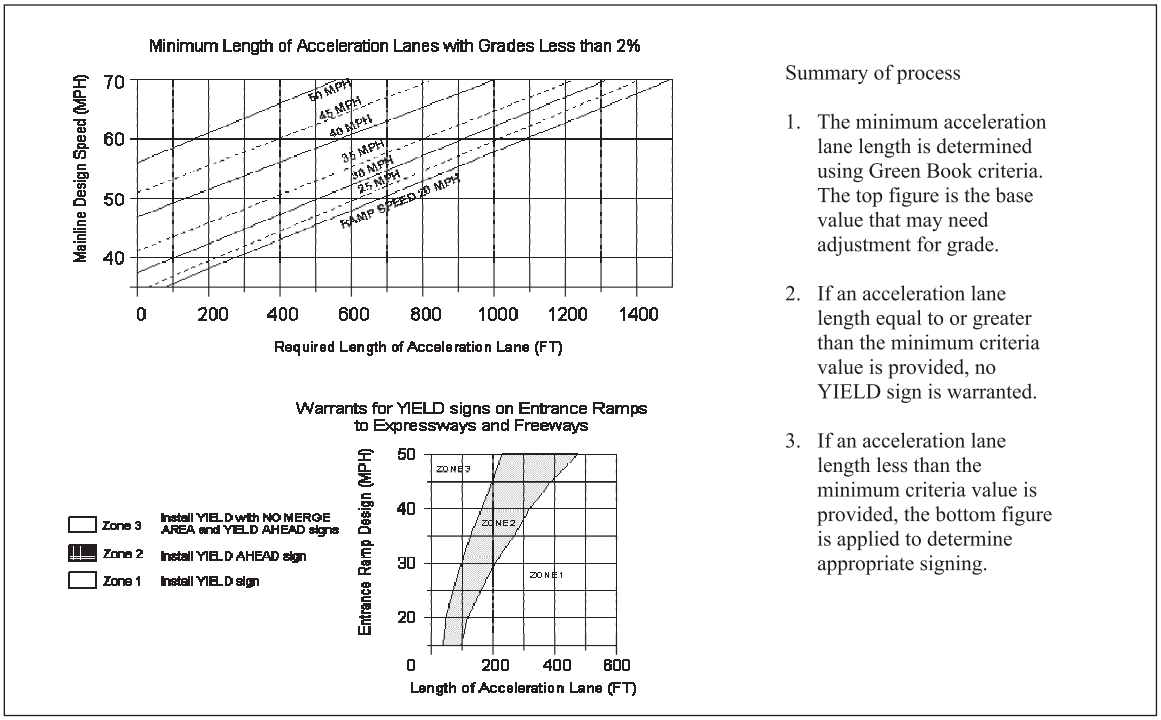


Exhibit 4-13. Temporary interchange entrance ramp for median crossover.



(a) Metric conversion



(b) Original U.S. customary units

Exhibit 4-14. Sample method of determining signing for entrance ramps (Standard MD 104.01.31, used by the Maryland State Highway Administration).

4.5.2 Exit Ramps

Maintaining service on existing exit ramps is usually feasible for all work zone types. An adequate combination of roadway geometry and traffic control is needed to facilitate diverging from the mainline, negotiating the ramp, and meeting the operational requirements at the intersecting roadway (stop, yield, and turn). Deceleration lanes enable exiting traffic to reduce speed after departing the mainline through lane and prior to encountering features that require lower speeds or stopping. The basic principles and considerations associated with permanent exit ramps pertain to temporary arrangements. Therefore, deceleration lanes in work zones that meet the design criteria for permanent facilities are desirable. It is desirable for exiting traffic to depart the through lanes at mainline speed and not reduce speed while occupying the mainline through lane. When this is not practical, the geometry of the ramp should be reviewed to determine if the ramp's length, horizontal alignment, and grade allow for gradual deceleration before reaching speed-critical features.

Exhibit 4-15 illustrates a temporary interchange exit ramp for a median crossover. This example has a parallel deceleration lane. This arrangement has some operational benefit, since a segment dedicated to deceleration is clearly visible to drivers on the freeway approaching the decision point and may reduce a tendency toward decelerating in the through travel lane. When using this arrangement, a 60-m [200-ft] taper length is adequate, and length of the parallel portion should be in the 60- to 90-m [200- to 300-ft] range. Although the parallel arrangement depicted has the noted benefits, tapered configurations (i.e., no lane parallel and adjacent to the through travel lane) are also used.

4.6 At-Grade Intersections

The general approaches to designing construction work zones that encompass at-grade intersections on high-speed highways can be grouped into the categories described below.

In each case, coordination with the affected community and development of appropriate TTC measures are keys to successful performance. Flaggers are often useful in providing positive guidance in a potentially complex and dynamic setting.

4.6.1 Intersection Closure

The feasibility of intersection closure depends on the availability of a reasonable detour. If a detour is feasible, access to the main road is temporarily terminated. If coordinated with affected parties (local officials, residents, and businesses), then short-duration closures that interrupt access to a limited number of land uses are sometimes possible. When intersections are closed, the facility and associated work zone function as a continuation of the approach segments.

4.6.2 Intersection Relocation

Intersection relocation should be considered when there is no suitable detour and when extensive work will take place

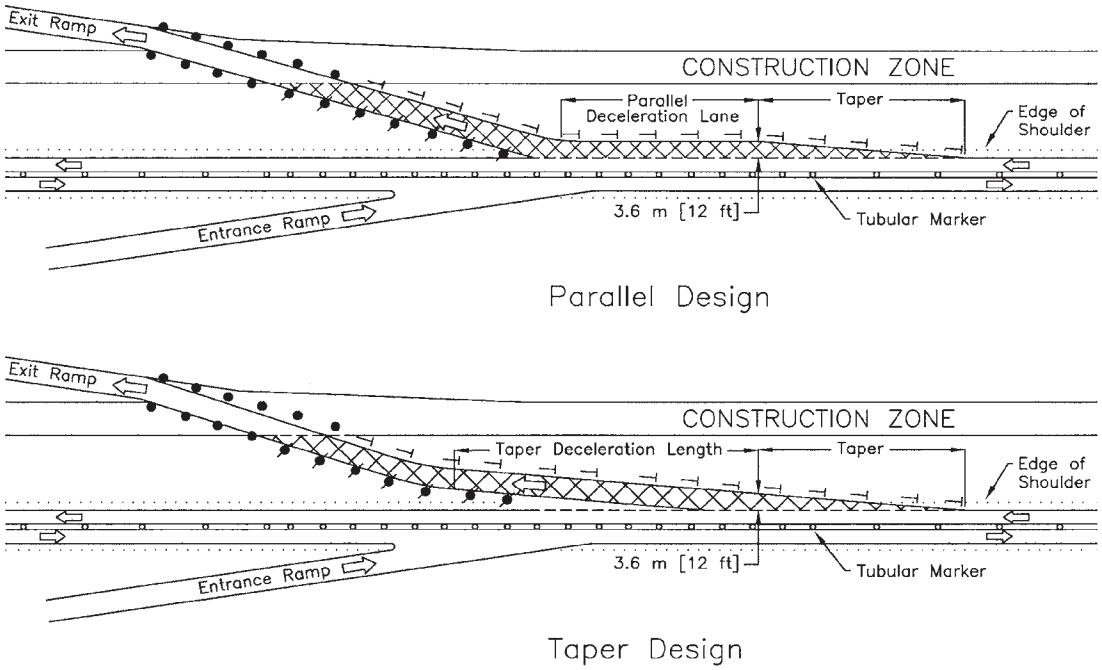


Exhibit 4-15. Temporary interchange exit ramp for a median crossover.

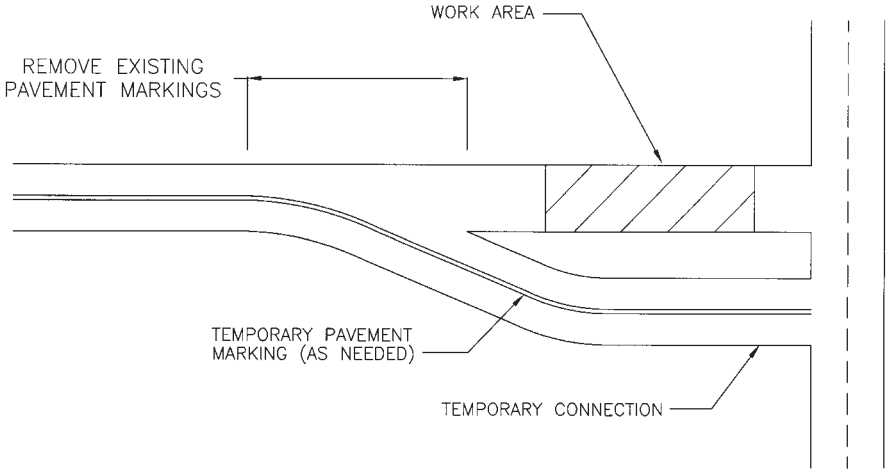


Exhibit 4-16. Temporary intersection relocation.

within the intersection. An example is shown in Exhibit 4-16. The feasibility of this option is tied to having or acquiring property interests (e.g., easement or right-of-way) for the temporary facility. This option is rarely practical unless undeveloped land exists in one or more quadrants.

4.6.3 Maintain Movements with TTC

Maintaining movements with TTC is the most commonly used option when other options are less desirable or not feasible.

Intersections are inherently points of conflict. Even in cases where intersections are closed or relocated, drivers face choices and uncertainty. Therefore, positive guidance should be applied to the high-speed facilities approaching and going through intersections within work zones. Additionally, at the intersection proper, the design features and TTC devices should be developed with consideration given to use of temporary channelizing features that

- Separate conflicts,
- Control the angle of conflict,
- Regulate traffic and indicate proper usage,
- Provide preferential treatment of predominant turning movements, and
- Protect stored and turning vehicles.

These options are not always needed or practical in the context of a construction work zone. However, their applicability should be considered.

Additional traffic control measures—including changes in intersection control type, warnings, portable changeable message signs, and pavement markings and restrictions—are often used at intersections within construction work zones.

CHAPTER 5

Roadside Design and Barrier Placement

5.1 Introduction to Roadside Safety in Construction Work Zones

Adoption of the roadside safety principles and procedures outlined in the *Roadside Design Guide* has significantly enhanced highway safety. Foremost of the *Roadside Design Guide* principles is the forgiving roadside concept, which holds that "Regardless of the reason for a vehicle leaving the roadway, a roadside environment free of fixed objects with stable, flattened slopes enhances the opportunity for reducing crash severity."

A critical step in translating the forgiving roadside concept to practical guidance was the establishment of a clear zone, a traversable and unobstructed roadside area. When the clear zone was introduced in AASHTO's 1974 *Highway Design and Operational Practices Related to Highway Safety* (Yellow Book), the dimension of the desired clear zone, 9 m [30 ft], was based on studies that indicated that 80 percent of the vehicles leaving the roadway could recover within this distance. A single value was perceived to be impractical and not necessarily appropriate for facilities with widely differing volumes, speeds, and roadside slopes. In response, AASHTO's 1977 *Guide for Selecting, Locating and Designing Traffic Barriers* introduced a variable clear zone width based on design speed, volume, and roadside slopes, with adjustments based on the horizontal alignment. The current edition of the *Roadside Design Guide* retains this approach.

If objects are located on the roadside, and especially within the desired clear zone, a series of alternative actions should be considered to reduce the risk to errant vehicles. The order of preference for addressing roadside obstacles follows:

1. Remove the obstacle;
2. Redesign the obstacle so it can be safely traversed;
3. Relocate the obstacle to a point where it is less likely to be struck;
4. Reduce impact severity by using an appropriate breakaway device;
5. Shield the obstacle with a longitudinal barrier designed for redirection, or use a crash cushion;
6. Delineate the obstacle if the above options are not appropriate.

Options 4 and 5 introduce the concept of crashworthiness. Where conditions require the presence of an obstacle or barrier near the traveled way, the obstacle or barrier should be designed to perform appropriately (i.e., with minimized probable motorist harm) if struck. Signs, signals, luminaire supports, and utility poles should use breakaway supports. Guidance for these objects is contained in AASHTO's *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals; A Policy on the Accommodation of Utilities within Highway Right-of-Way;* and *A Policy on the Accommodation of Utilities within Freeway Right-of-Way.* Roadside barriers and end treatments are deemed crashworthy by passing the crash test criteria of *NCHRP Report 350: Recommended Procedures for Safety Performance Evaluation of Highway Features* (*14*).

Roadside safety concepts (i.e., forgiving roadside, clear zone, prioritized treatment of hazards, and crashworthiness) apply to construction work zones on high-speed highways and permanent roadways. While the principles governing roadside design are generally the same, the work zone environment and permanent road environment are very different. Equipment, materials, and workers are inherent to construction work zones but are not normally present for permanent roadway conditions. Depending on the setting, several of the prioritized roadside hazard treatments (e.g., removal or relocation) may not be a practical option.

The assessment of roadside risk involves two factors, the probability of an errant vehicle encountering a roadside feature and the probable harm that will result from an encounter. The amount of traffic on the roadway is a key indicator of the probability of an encounter. Unlike permanent roadway

conditions, which may exist for an indefinite time period, the duration of a construction work zone is definite. The shorter the duration of an observation period, the less likely it would be for 1, 2, or *n* vehicles to strike a roadside feature. Therefore, undesirable conditions that would warrant intervention on a permanent roadway may not justify an investment for a safety treatment in a construction work zone. These considerations were important in the development of the following roadside safety and barrier placement guidance.

5.2 Clear Zones

The clear zone approach has been used in roadside safety and design since the 1960s. The clear zone is a traversable and unobstructed roadside area extending from the edge of the traveled way. The use of clear zones as a design convention has been widely accepted, partly because of its perceived simplicity. In general, the idea is to provide a hazard-free roadside border that is desirably at least as wide as the design clear zone. If attaining this condition is not practical, alternative mitigation actions are evaluated. Given the relative ease of application, some state DOTs have developed desirable clear zone dimensions for construction work zones. As discussed, work zones exist for a finite period and therefore will experience lower total levels of vehicle exposure than a permanent roadway segment with the same daily traffic volume. On this basis, some agencies have developed desirable work zone clear zone dimensions that are less than those applied to permanent roadways. Dimensions representative of current DOT guidance regarding work zone clear zones are shown in Exhibit 5-1.

The state guidance on which Exhibit 5-1 is based includes a statement for use of these dimensions (*15*): "The potentially hazardous conditions typically found within work zones warrant the use of considerable judgment when applying these clear zone distances."

Metric

Approach posted speed limit	ADT (veh/day)	Front slopes			Back slopes		
		1:6 or flatter	1:5 to 1:4	1:3	1:3	1:5 to 1:4	1:6 or flatter
		Work zone clear zone distances (m)					
35 mph or less	Under 750	1.5–2.0	1.5–2.0	**	1.5–2.0	1.5–2.0	1.5–2.0
	750–1,500	2.0–2.5	2.5–3.0		2.0–2.5	2.0–2.5	2.0–2.5
	1,500–6,000	2.5–3.0	3.0		2.5–3.0	2.5–3.0	2.5–3.0
	Over 6,000	3.0	3.0–3.5		3.0	3.0	3.0
35–50 mph	Under 750	2.0–2.5	2.5–3.0		1.5–2.0	1.5–2.0	2.0–2.5
	750–1,500	3.0	3.0–4.0		2.0–2.5	2.5–3.0	3.0
	1,500–6,000	3.0–3.5	4.0–5.0		2.5–3.0	3.0	3.0–3.5
	Over 6,000	4.0	4.5–5.5		3.0	3.5–4.0	4.0
55 mph	Under 750	2.5–3.0	3.0–3.5		1.5–2.0	2.0–2.5	2.0–2.5
	750–1,500	3.0–3.5	4.0–4.5		2.0–2.5	3.0	3.0–3.5
	1,500–6,000	4.0	4.5–5.5		3.0	3.0–3.5	4.0
	Over 6,000	4.0–4.5	5.0–6.0*		3.0–3.5	4.0	4.0–4.5
60 mph	Under 750	3.0–3.5	4.0–4.5		2.0–2.5	2.5–3.0	3.0
	750–1,500	4.0–4.5	5.0–6.0*		2.5–3.0	3.0–3.5	4.0
	1,500–6,000	5.0–5.5	6.0–7.5*		3.0–3.5	3.5–4.0	4.5–5.0
	Over 6,000	5.5–6.0*	7.0–8.5*		4.0	4.5–5.0	5.0–5.5
65 mph	Under 750	3.5–4.0	4.0–5.0		2.0–2.5	3.0	3.0
	750–1,500	4.5–5.0	5.5–7.0*		2.5–3.0	3.5–4.0	4.0
	1,500–6,000	5.5–6.0*	6.5–8.0*		3.0–4.0	4.0–4.5	5.0–5.5
	Over 6,000	5.5–6.5*	7.0–8.5*		4.0–4.5	5.0–5.5	5.5

* Clear zones may be limited to 5.5 m for practicality.
** Use guidance for permanent roadways.

Notes:
- All distances are measured from edge of traveled way.
- For clear zones, the ADT will be the total ADT on two-way roadways and the one-way ADT on one-way roadways. Traffic volumes will be expected traffic volumes through the work zone.
- The values for back slopes apply only to a section where the toe of the back slope is adjacent to the shoulder. For roadside ditches, use permanent roadway guidance.
- The approach posted speed is the approach posted speed prior to the work zone.

Exhibit 5-1. Example of work zone clear zone distances (15).

(continued on next page)

U.S. Customary

Approach posted speed limit	ADT (veh/day)	Front slopes			Back slopes		
		1:6 or flatter	1:5 to 1:4	1:3	1:3	1:5 to 1:4	1:6 or flatter
		Work zone clear zone distances (ft)					
35 mph or less	Under 750	4–6	4–6	**	4–6	4–6	4–6
	750–1,500	6–8	8–10		6–8	6–8	6–8
	1,500–6,000	6–8	10		8–10	8–10	8–10
	Over 6,000	10	10–12		10	10	10
35–50 mph	Under 750	6–8	6–10		4–6	4–6	6–8
	750–1,500	10	10–14		6–8	8–10	10
	1,500–6,000	10–12	12–16		8–10	10	10–12
	Over 6,000	12–14	16–18		10	12	12–14
55 mph	Under 750	6–8	10–12		6	6–8	6–8
	750–1,500	10–12	12–16		6–8	10	10–12
	1,500–6,000	12–14	16–18		10	10–12	12–14
	Over 6,000	14–16	16–20*		10–12	12–14	14–16
60 mph	Under 750	10–12	12–16		6–8	8–10	10
	750–1,500	12–16	16–20*		8–10	10–12	12–14
	1,500–6,000	16–18	20–24*		10–12	12–14	16
	Over 6,000	18–20*	22–28*		12–14	16	16–18
65 mph	Under 750	12	12–16		6–8	10	10
	750–1,500	16	18–22*		8–10	12	12–14
	1,500–6,000	18–20*	22–26*		10–12	14–16	16–18
	Over 6,000	18–22*	24–28*		14–16	16–18	18

* Clear zones may be limited to 18 ft for practicality.
** Use guidance for permanent roadways.

Notes:

- All distances are measured from edge of traveled way.
- For clear zones, the ADT will be the total ADT on two-way roadways and the one-way ADT on one-way roadways. Traffic volumes will be expected traffic volumes through the work zone.
- The values for back slopes apply only to a section where the toe of the back slope is adjacent to the shoulder. For roadside ditches, use permanent roadway guidance.
- The approach posted speed is the approach posted speed prior to the work zone.

Exhibit 5-1. (Continued).

The *Roadside Design Guide* provides similar language regarding the use of clear zone dimensions for permanent roadways:

> A basic understanding of the clear zone concept is critical to its proper application. The numbers obtained . . . imply a degree of accuracy that does not exist. . . . In some cases, it is reasonable to leave a fixed object within the clear zone; in other instances, an object beyond the clear zone distance may require removal or shielding.

In summary, the clear zone convention alone cannot be used to make all roadside design decisions, and the clear border that is provided along any specific roadway segment must consider numerous factors, including the applicable design clear zone dimension. When a potentially hazardous roadside obstruction or nontraversable slope is located on the roadside, an analysis should be conducted that assesses the risk of vehicle collisions with the obstruction, estimates the severity of collisions with the obstruction, and determines the cost-effectiveness of one of the six prioritized treatments of the hazard. This process, as it relates to construction work zones, is discussed in Sections 5.3 through 5.5.

5.3 Identification and Treatment of Construction Work Zone Hazards

There are limited data available on the frequency that various work zone objects are struck by errant vehicles and the corresponding severity of those crashes. Therefore, experience and judgment are used to identify hazardous features. In addition to considering the potential severity for an encroaching vehicle driver and occupant, in construction work zones, the designer must also consider the severity of crashes involving workers. The probability of a fatality for a pedestrian being struck by a vehicle traveling at 60 km/h [40 mph] is approximately 85 percent (*16*). Besides workers, other roadside

hazards that may be present in construction work zone roadsides include

- Construction equipment and materials;
- Edge drop-offs;
- Severe roadside slopes;
- Existing permanent guardrail/concrete barriers;
- Exposed ends of temporary concrete barriers;
- Bridge piers;
- Bridge rail or parapet ends;
- Structure foundations;
- Excavations and rock cuts;
- A gap in the median between dual bridges; and
- Untreated guardrail ends in two-lane, two-way operations.

This list is not exhaustive, and designer experience and judgment should be used to identify other potential hazards introduced by construction activities, work zone plan, and traffic control. In assessing potential work zone hazards, it is important to keep in mind that traffic may be rerouted via diversion or median crossover. Such a change may alter the relationship (i.e., separation) between traffic and fixed features and different traffic streams (i.e., opposing traffic).

5.4 Roadside Safety and Economics

Once an obstruction or potential hazard in the work zone roadside has been identified, the question then becomes selecting the most appropriate treatment (if any) to mitigate the obstruction or hazard. Transportation agencies operate with finite resources, and roadside safety decisions should be both practical and cost-effective.

Benefit-cost analysis is "a method by which the estimated benefits to be derived from a specific course of action are compared to the costs of implementing that action" (*2*). The benefits usually refer to the reduced crash or societal costs as a result of decreases in the number and/or severity of crashes. The costs of implementing the action are the direct costs to the highway agency for initial installation, maintenance, and repair. If the ratio of the benefits to costs, determined by Equation 5-1 below, exceeds 1, then the benefits derived will be worth the investment over the analysis period. The benefit-cost ratio can be used to compare several different actions against each other and against the no-action option.

$$\text{B/C Ratio}_{j-i} = \frac{CC_i - CC_j}{DC_j - DC_i} \tag{5-1}$$

Where

B/C Ratio_{j-i} = incremental benefit-cost ratio of alternative *j* to alternative *i;*

CC_i, CC_j = crash or societal costs resulting from crashes under alternatives *i* and *j* (annualized over the analysis period); and

DC_j, DC_i = direct costs for alternatives *j* and *i* (annualized over the analysis period).

Having a benefit-cost ratio greater than 1 does not alone justify the implementation of a particular alternative. Conversely, a ratio less than 1 does not imply that no action should be taken. However, observing the ratios provides designers or other decision makers with quantitative information to help in making the best investment for safety and mobility needs. To perform a benefit-cost analysis based on safety, several tools must be available for the analyst:

- A method to predict crash frequencies under all proposed options,
- A method to predict crash severities under all proposed options,
- Crash cost estimates by severity,
- Repair cost estimates by crash type,
- Installation and maintenance costs for specified safety treatments, and
- A discount rate over the analysis period.

If the appropriate information is attainable, benefit-cost analysis is a preferred method. Similar analysis has been used to revisit the median barrier warrants in the *Roadside Design Guide* (*17*). In addition, a computerized cost-effectiveness analysis procedure that is capable of evaluating alternative roadside safety treatments at spot locations over sections of roadway or is applicable to development of warrants and guidelines for safety features with different performance levels is available. The Roadside Safety Analysis Program (RSAP) was developed under NCHRP Project 22-9 (*18*). RSAP is intended for use in evaluating roadside safety options associated with permanent roadways. However, with adaptation of the analysis periods, an encroachment model, and roadside features to construction activities, RSAP can also be used to analyze construction work zone scenarios (see *NCHRP Web-Only Document 105,* Section 4.1.5.2, which is available online at www.trb.org/news/blurb_detail.asp?id=7362). This was done in order to develop the temporary barrier guidelines presented in Section 5.5.

5.5 Barrier Placement Guidance for Construction Work Zones

As discussed in Section 5.1, because of the presence of construction activities and the roadside hazards inherent within, it is often not practical to remove, redesign, or relocate potential work zone roadside hazards. Therefore, designers are

often faced with decisions regarding which hazards to shield and which device (e.g., barrier type or crash cushion) is most appropriate. State DOT work zone guidance documents devote considerable attention to these subjects. Factors and situations that are normally considered in making this decision include

- Duration of construction activity,
- Traffic volumes,
- Nature of hazard,
- Length and depth of drop-offs,
- Work zone design speed,
- Highway functional class,
- Length of hazard,
- Proximity of traffic to construction workers and equipment,
- Adverse geometrics,
- Two-way traffic on one roadway of a divided highway,
- Transition areas at crossovers, and
- Lane closures or lane transitions.

RSAP was used to develop a benefit-cost analysis for a set of generic scenarios representing commonly occurring instances where a designer must choose whether to provide a temporary barrier to separate traffic from the work area and/or other hazards. The scenarios were based on the MUTCD Part 6H Typical Applications, as well as practitioner input. The following sections provide a short description, a graphic representation of a work zone plan and cross sections, and the benefit-cost design aid resulting from the RSAP runs for each scenario.

The design aids illustrate benefit-cost regions resulting from simulated crash analyses of the general scenarios presented. Some assumptions were made regarding crash severities, costs, and encroachment rates (see *NCHRP Web-Only Document 105* Section 4.1.5.2, available online at www.trb.org/news/blurb_detail.asp?id=7362). Given these assumptions and the assumptions inherent in RSAP, the probabilistic nature of motor vehicle crashes, and the range of conditions for work zones of specific types, the results should not be used in place of more current (or site-specific) data. The following boundaries were selected for the benefit-cost regions:

- (B/C ratio > 1.25),
- (0.75 < B/C ratio ≤ 1.25),
- (0.5 < B/C ratio ≤ 0.75), and
- (B/C ratio ≤ 0.5).

RSAP is based on a probabilistic approach to roadside safety. Further, numerous assumptions have been made in the development of RSAP and its application to work zone scenarios (e.g., construction costs and work zone configurations). Consequently, the results of RSAP (including benefit-cost ratios) should be regarded as estimates of what would occur over many repetitions of the same conditions. Real-world scenarios would rarely conform to the exact conditions modeled. Therefore, the results shown should not be regarded as precise or always-accurate indications of the cost-effectiveness of a specific barrier placement.

The benefits computed by RSAP are the reduced safety costs resulting from the placement of TCBs. There may be other benefits associated with work zone TCB installations, such as control of aggressive driving and more orderly contractor operations. These benefits and others that may result from TCB placement are not quantified in the RSAP-based analysis, nor are they reflected in the graphic design aids in this chapter. These potential added benefits may also be considered in barrier placement decisions.

5.5.1 Outside Lane and Shoulder Closure for Part-Width Construction on a Four-Lane Divided Highway

The scenario of a part-width construction that requires an outside lane and shoulder closure on a four-lane divided highway is depicted in MUTCD Figure 6H-33. Possible vehicle encroachments from the opposite traveled way (i.e., cross-median encroachments) are not considered. This reconstruction project scenario assumes 0.3-m [1-ft] pavement edge drop-off at the joint between travel lanes, a worker area, and one piece of heavy construction equipment. The segment analyzed is approximately 4.2 km [2.6 mi] long. For the no-barrier work zone alternative, the right edge of the travel lane was 0.9 m [3 ft] away from the pavement edge drop-off. For the barrier alternative, the edge of the barrier was placed 0.3 m [1 ft] from the pavement drop-off and was 0.6 m [2 ft] wide. Therefore, traffic on the inside lane used part of the median shoulder as a travel lane.

Exhibits 5-2 and 5-3 illustrate a plan and cross sections, respectively, for the right lane closure. The scenario was run with average daily traffic (ADT) values ranging from 10,000 to 43,500 veh/day; durations of 2 months, 4 months, and 6 months; and speed limits ranging from 50 to 120 km/h [35 to 70 mph]. The results are illustrated in Exhibit 5-4.

The benefit-cost ratios for the scenarios outlined in Sections 5.5.1, 5.5.2, and 5.5.3 are slightly different. However, from a practical standpoint, the figures illustrating the benefit-cost regions would look the same. Therefore, Exhibit 5-4 is used for all three scenarios.

5.5.2 Outside Shoulder Closure on a Four-Lane Divided Highway with Minor Encroachment

An outside shoulder closure with minor encroachment into the traveled way on a four-lane divided highway is depicted in

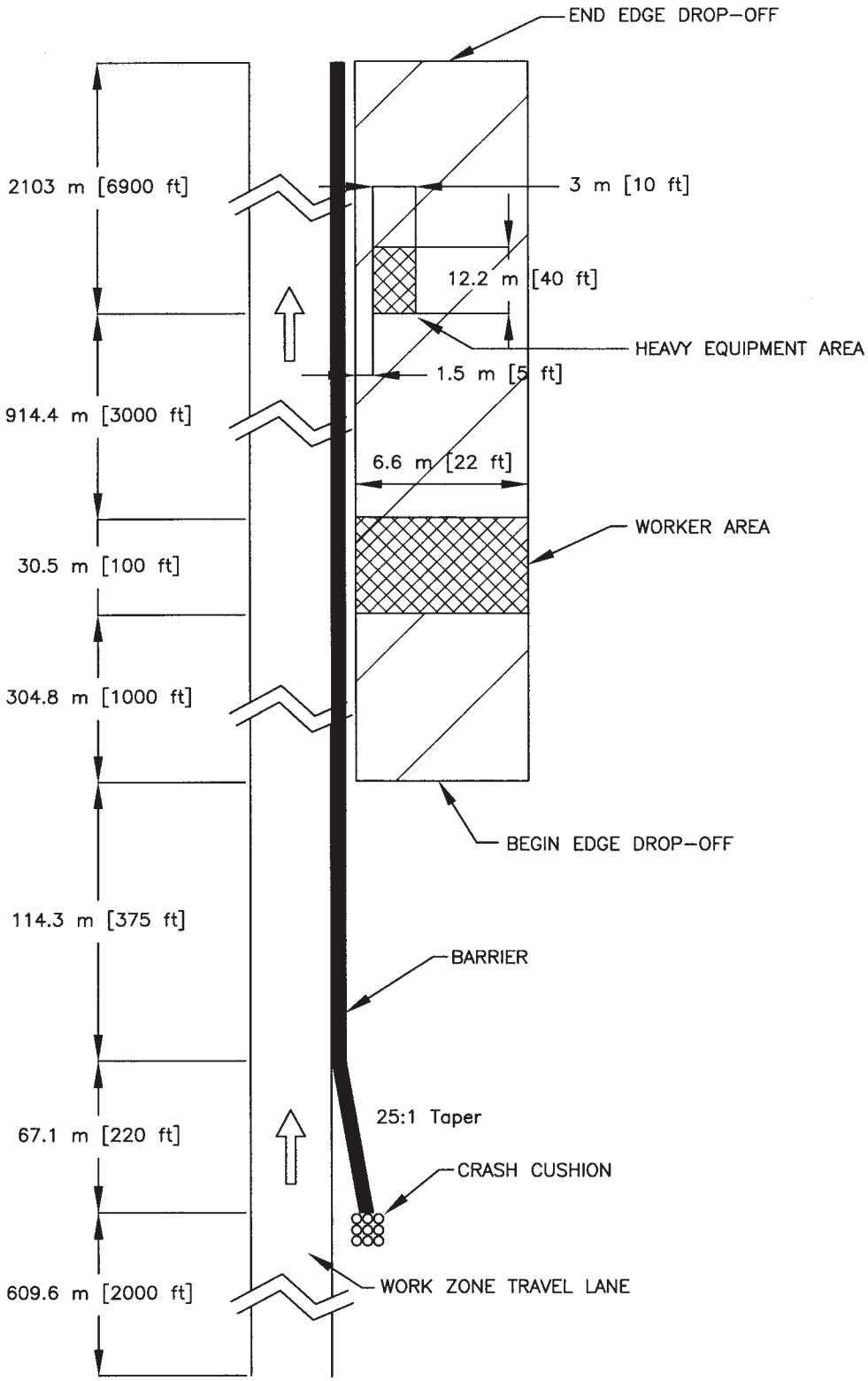


Exhibit 5-2. Plan for outside lane and shoulder closure for part-width construction on a four-lane divided highway.

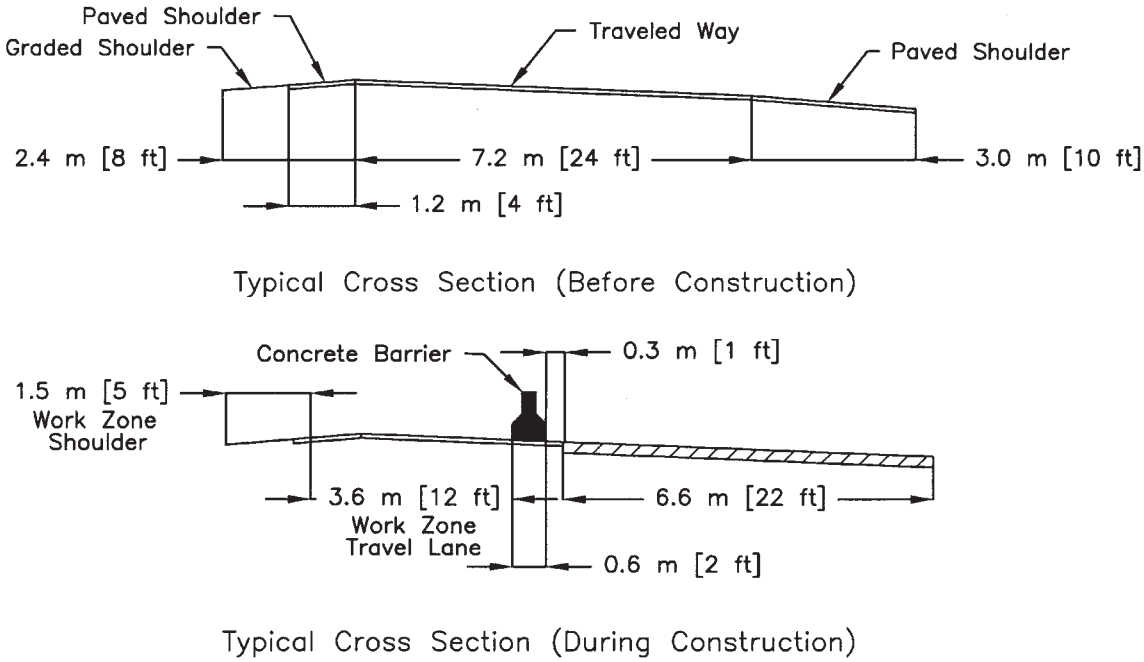


Exhibit 5-3. Cross sections for outside lane and shoulder closure for part-width construction on a four-lane divided highway.

MUTCD Figure 6H-6. Possible types of work for this set-up are shoulder/roadside work or roadway widening (i.e., expansion from a four-lane to a six-lane highway). The scenario is different from the one in Section 5.5.1 in that the traffic is distributed over two travel lanes instead of one and the volumes observed are slightly higher.

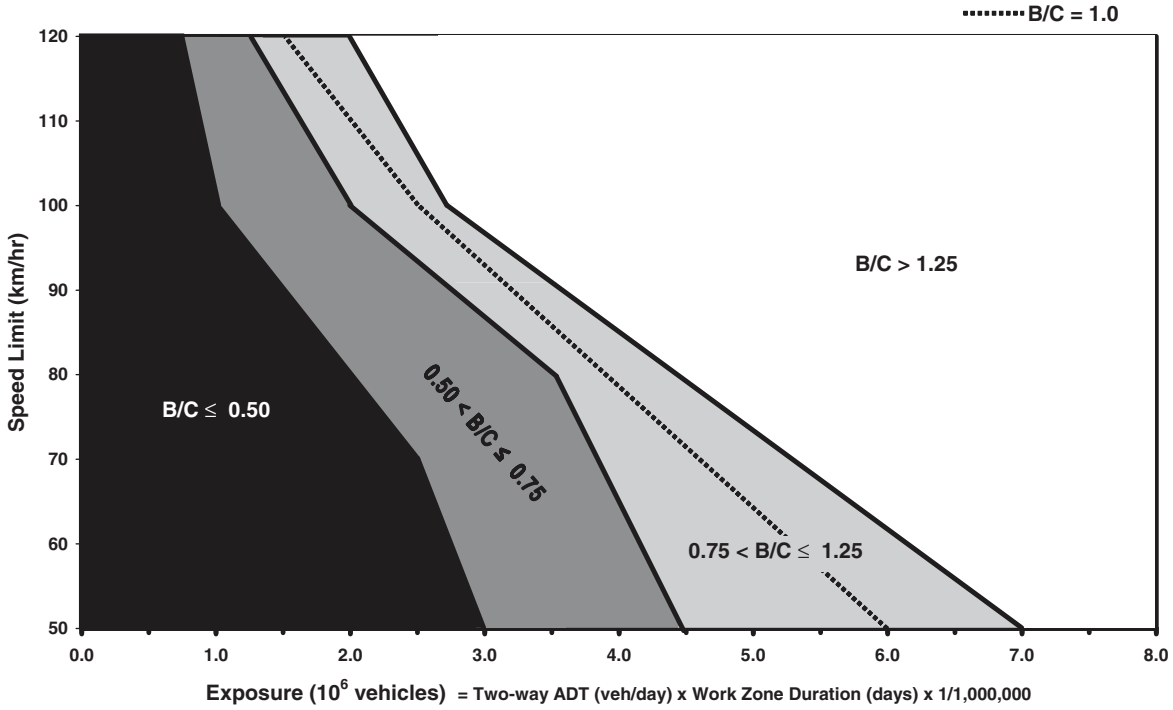
Possible vehicle encroachments from the opposite traveled way (i.e., cross-median encroachments) are not considered. There is an assumed 0.3-m [1-ft] pavement edge drop-off at the joint between the outside travel lane and shoulder, a worker area, and two pieces of heavy construction equipment. The segment analyzed is approximately 4.0 km [2.5 mi] long. For the no-barrier work zone alternative, the right edge of the right travel lane was 0.9 m [3 ft] away from the pavement edge drop-off. For the barrier alternative, the edge of the barrier was placed 0.3 m [1 ft] from the pavement drop-off and was 0.6 m [2 ft] wide. Therefore, to maintain two 3.6-m [12-ft] travel lanes, there was a slight lane shift, and traffic on the inside lane used part of the median shoulder as a travel lane.

Exhibits 5-5 and 5-6 illustrate a plan and cross sections, respectively, for the outside shoulder closure. The scenario was run with ADT values ranging from 10,000 to 80,000 veh/day; durations of 2 months, 4 months, and 6 months; and speed limits ranging from 50 to 120 km/h [35 to 70 mph]. The results are illustrated in Exhibit 5-4.

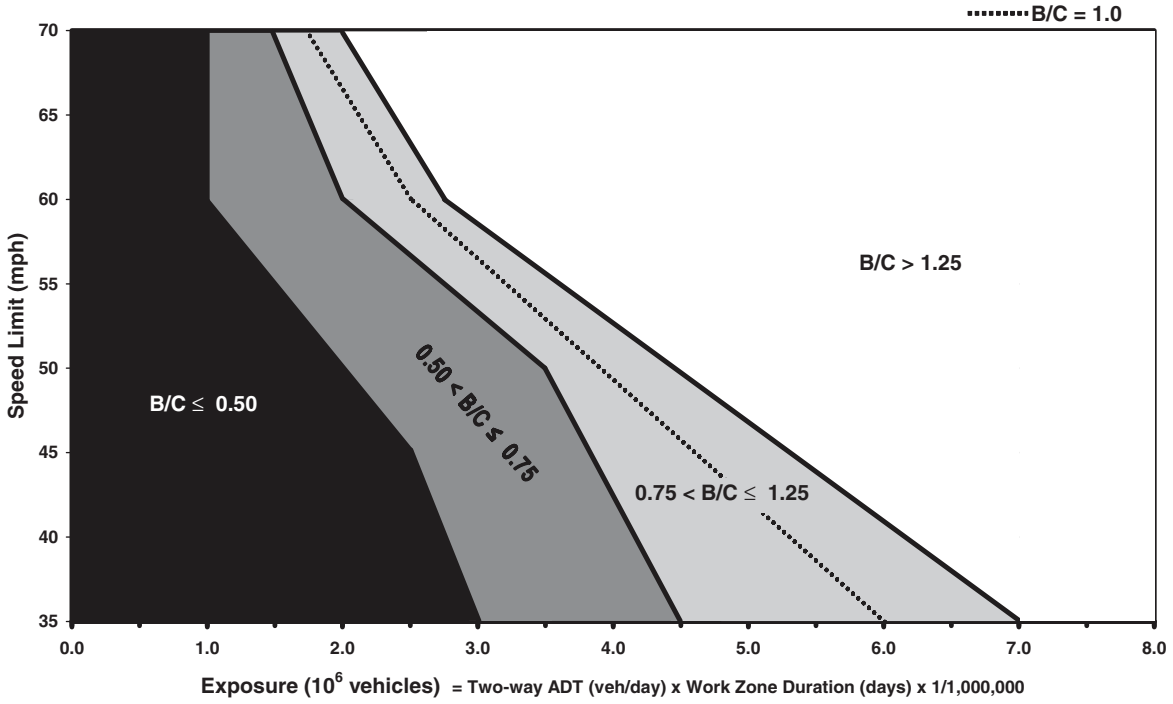
5.5.3 Median Shoulder Closure on a Four-Lane Divided Highway with Minor Encroachment

For a four-lane divided highway requiring closure of the median shoulder with minor encroachment into the traveled way, possible types of work are shoulder/median work or roadway widening (i.e., expansion from a four-lane to a six-lane highway). This scenario is different from those in Sections 5.5.1 and 5.5.2 in that the traffic is distributed over two travel lanes instead of one and the work is adjacent to the inside (i.e., left) travel lane, which usually carries a smaller percentage of the total traffic.

Possible vehicle encroachments from the opposite traveled way (i.e., cross-median encroachments) are not considered. There is an assumed 0.3-m [1-ft] pavement edge drop-off at the joint between the inside travel lane and median shoulder, a worker area, and two pieces of heavy construction equipment. The segment analyzed is approximately 4.0 km [2.5 mi] long. For the no-barrier work zone alternative, the left edge of the inside travel lane was 0.9 m [3 ft] away from the pavement edge drop-off. For the barrier alternative, the edge of the barrier was placed 0.3 m [1 ft] from the pavement drop-off and was 0.6 m [2 ft] wide. Therefore, to maintain two 3.6-m [12-ft] travel lanes, there was a slight lane shift and traffic on the outside lane used part of the outside shoulder as a travel lane.



(metric)



(U.S. customary)

Exhibit 5-4. Barrier guidelines for (1) outside lane and shoulder closure for part-width construction, (2) outside shoulder closure with minor encroachment, or (3) median shoulder closure with minor encroachment on a four-lane divided highway.

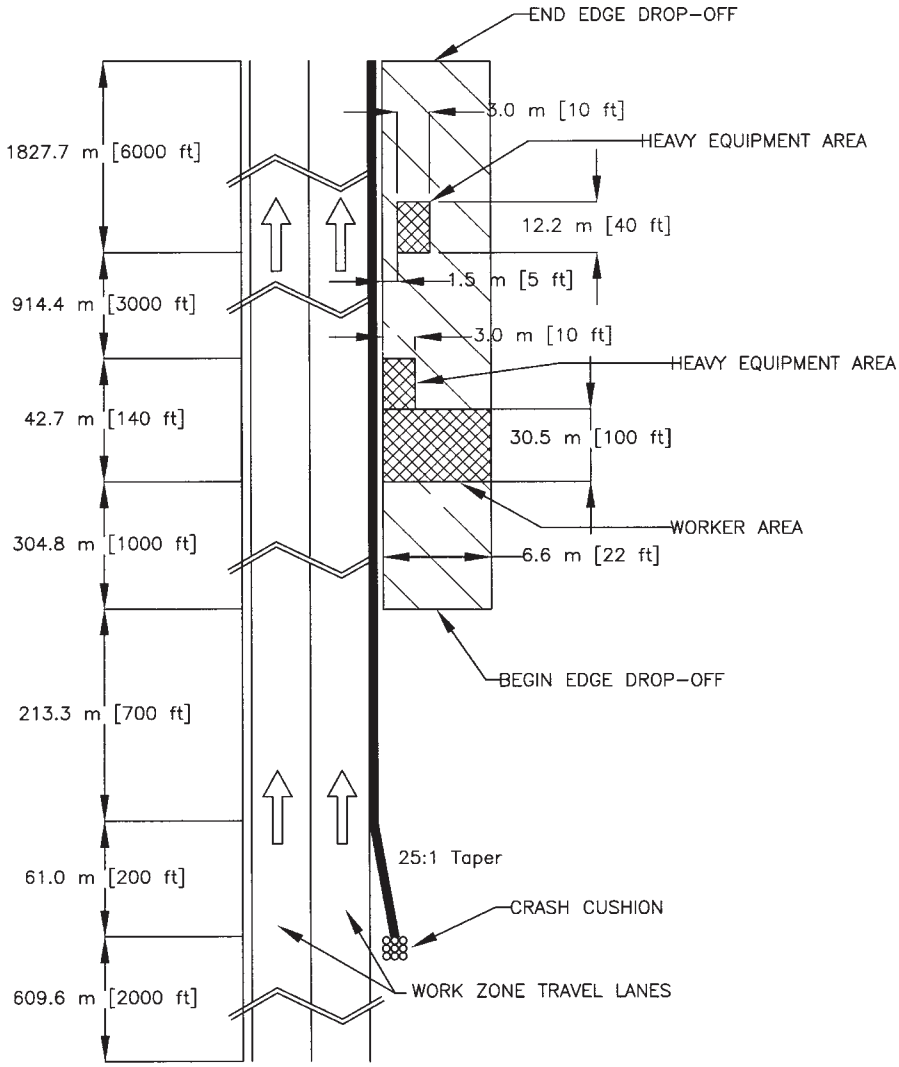


Exhibit 5-5. Plan for outside shoulder closure on a four-lane divided highway with minor encroachment.

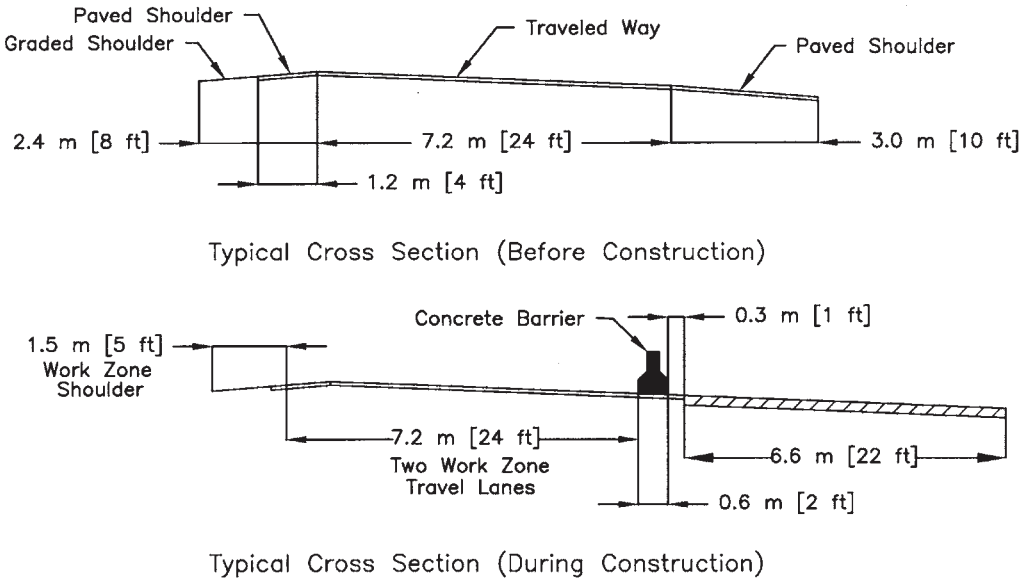


Exhibit 5-6. Cross sections for outside shoulder closure on a four-lane divided highway with minor encroachment.

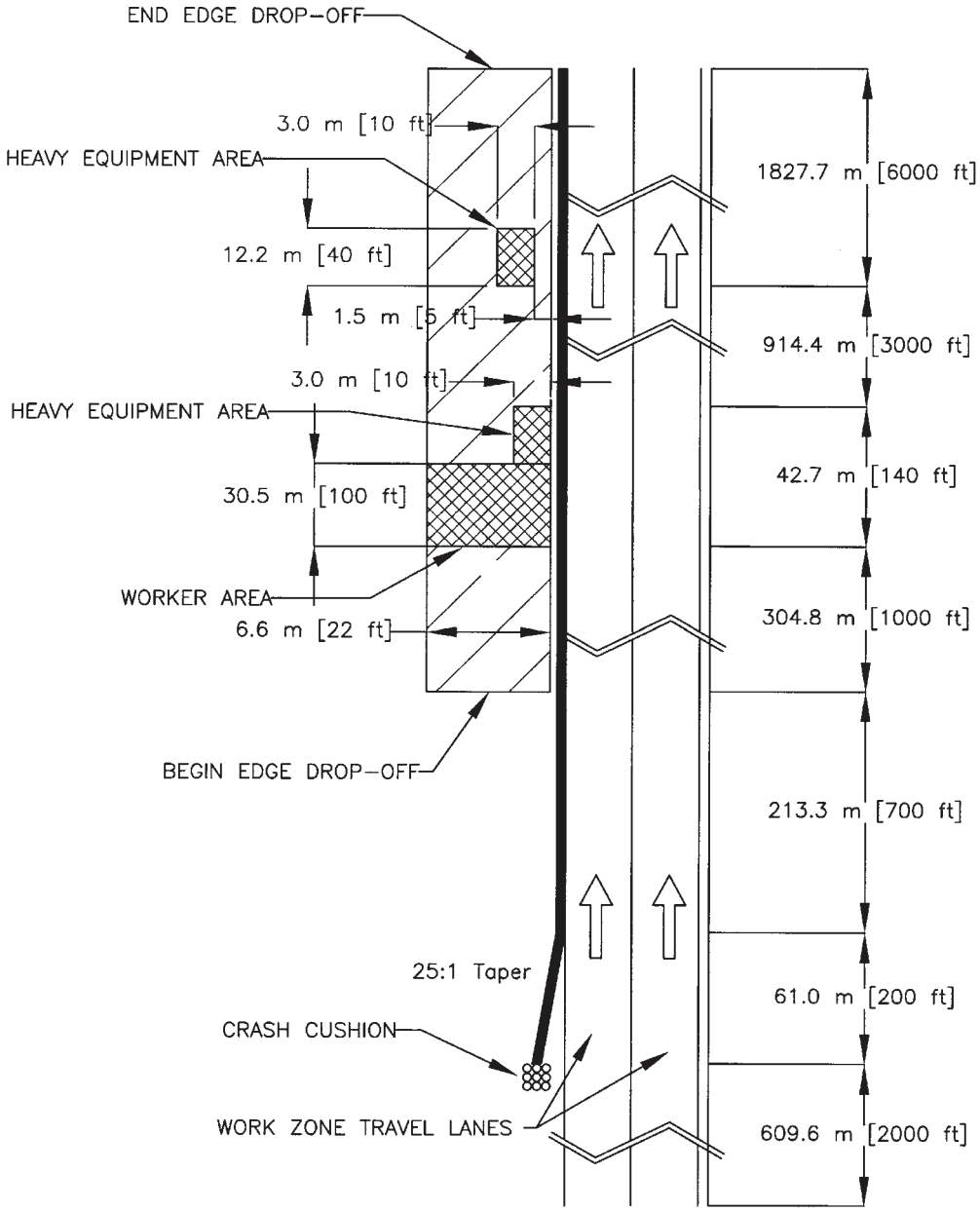


Exhibit 5-7. Plan for median shoulder closure on a four-lane divided highway with minor encroachment.

Exhibits 5-7 and 5-8 illustrate a plan and cross sections, respectively, for the median shoulder closure. The scenario was run with ADT values ranging from 10,000 to 80,000 veh/day; durations of 2 months, 4 months, and 6 months; and speed limits ranging from 50 to 120 km/h [35 to 70 mph]. The results are illustrated in Exhibit 5-4.

5.5.4 Bridge Reconstruction with a Temporary Diversion/Runaround on a Two-Lane, Two-Way Highway

A bridge reconstruction project on a two-lane highway involves the construction of a two-lane diversion, or runaround, with a temporary bridge to accommodate traffic during the bridge reconstruction. It is assumed that the bridge crosses a drop-off that is 90 m [300 ft] wide and 8.0 m [26 ft] deep. Other roadside hazards include construction equipment and workers. Travel in both directions is considered.

The base condition assumes that a concrete barrier will be installed on the temporary bridge and will therefore introduce four barrier blunt ends to traffic exposure (see MUTCD Figure 6H-7). For the base condition, no additional barrier is installed to shield the blunt ends or worker and equipment areas, or to stop encroachments that may reach the drop-off. In Alternative 1, a guardrail starting at each blunt

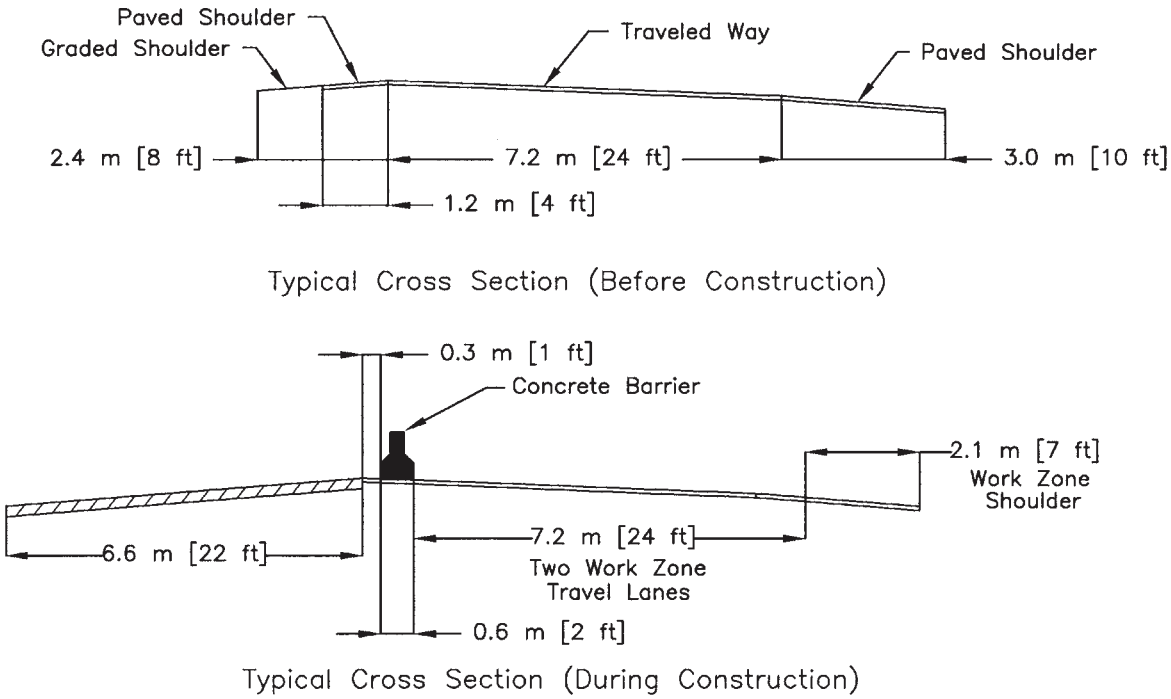


Exhibit 5-8. Cross sections for median shoulder closure on a four-lane divided highway with minor encroachment.

end runs 15 m [50 ft] parallel to the roadway and then tapers for 43 m [140 ft] at a rate of 15:1. The multiple purposes of the guardrail are to (1) shield the barrier blunt end by providing a guardrail-concrete barrier transition (see the *Roadside Design Guide* Section 7.8), (2) shield the equipment and worker areas, and (3) stop an encroaching vehicle from possibly reaching the 8.0-m [26-ft] drop-off. For Alternative 2, the same length of guardrail is provided, but only on the upstream barrier blunt ends for each direction of travel. Exhibits 5-9 and 5-10 illustrate a plan and cross sections, respectively, of the bridge reconstruction with a temporary diversion.

Because of the encroachment curve for two-lane undivided highways in RSAP, an ADT of 5,000 veh/day was used for all analyses, with different durations (ranging from 1 month to 12 months) used to obtain the range of exposure. For a more detailed explanation, see *NCHRP Web-Only Document 105,* Section 4.1.5.2, which is available online at www.trb.org/news/blurb_detail.asp?id=7362. Speed limits ranged from 50 to 90 km/h [35 to 55 mph]. The results are illustrated in Exhibits 5-11 and 5-12.

5.5.5 Separation of Two-Lane, Two-Way Traffic on a Normally Divided Facility

When a one-way roadway on a normally divided facility is used to accommodate two-way operation, a median crossover is the infrastructure used. This scenario involves a substantial decrease in the separation of opposing traffic on higher-volume facilities, and an important design decision is whether to provide a temporary concrete barrier between the opposing directions of travel. Section 6G.15 of the MUTCD states:

> When two-lane, two-way traffic control must be maintained on one roadway of a normally divided highway, opposing vehicular traffic shall be separated with either temporary traffic barriers (concrete safety-shape or approved alternate) or with channelizing devices throughout the length of the two-way operation. The use of markings and complementary signing, by themselves, shall not be used.

A discussion of this strategy, along with an example plan and cross sections, can be found in Section 4.3 of this report. State practice varies. Some states always provide a temporary barrier between opposing directions of travel. Other states provide a barrier depending on the length of the two-lane, two-way segment. Important factors in the decision should include anticipated operating speed, volume, and the presence of restrictive cross-sectional conditions. Ross and Sicking (*19*) developed a roadside analysis program similar to RSAP for construction work zones. Unlike RSAP, Ross and Sicking's program had the ability to model encroachments and head-on collisions for two-lane, two-way traffic on normally divided facilities. The guidelines from their analysis are shown in Exhibit 5-13. Regions to the right of the three line types represent benefit-cost ratios greater than or equal to 1.0.

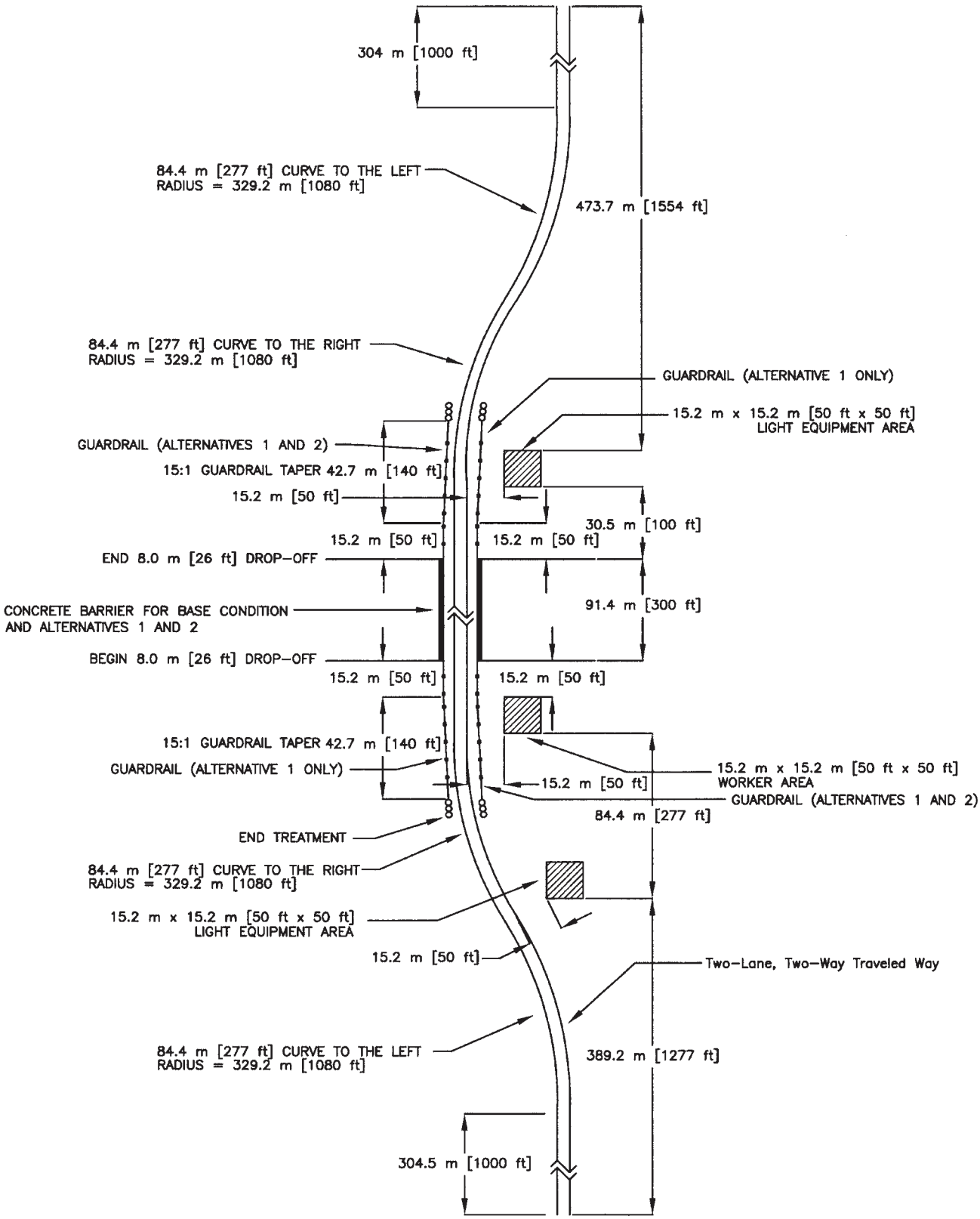


Exhibit 5-9. Plan for bridge reconstruction with a temporary diversion/runaround on a two-lane, two-way highway.

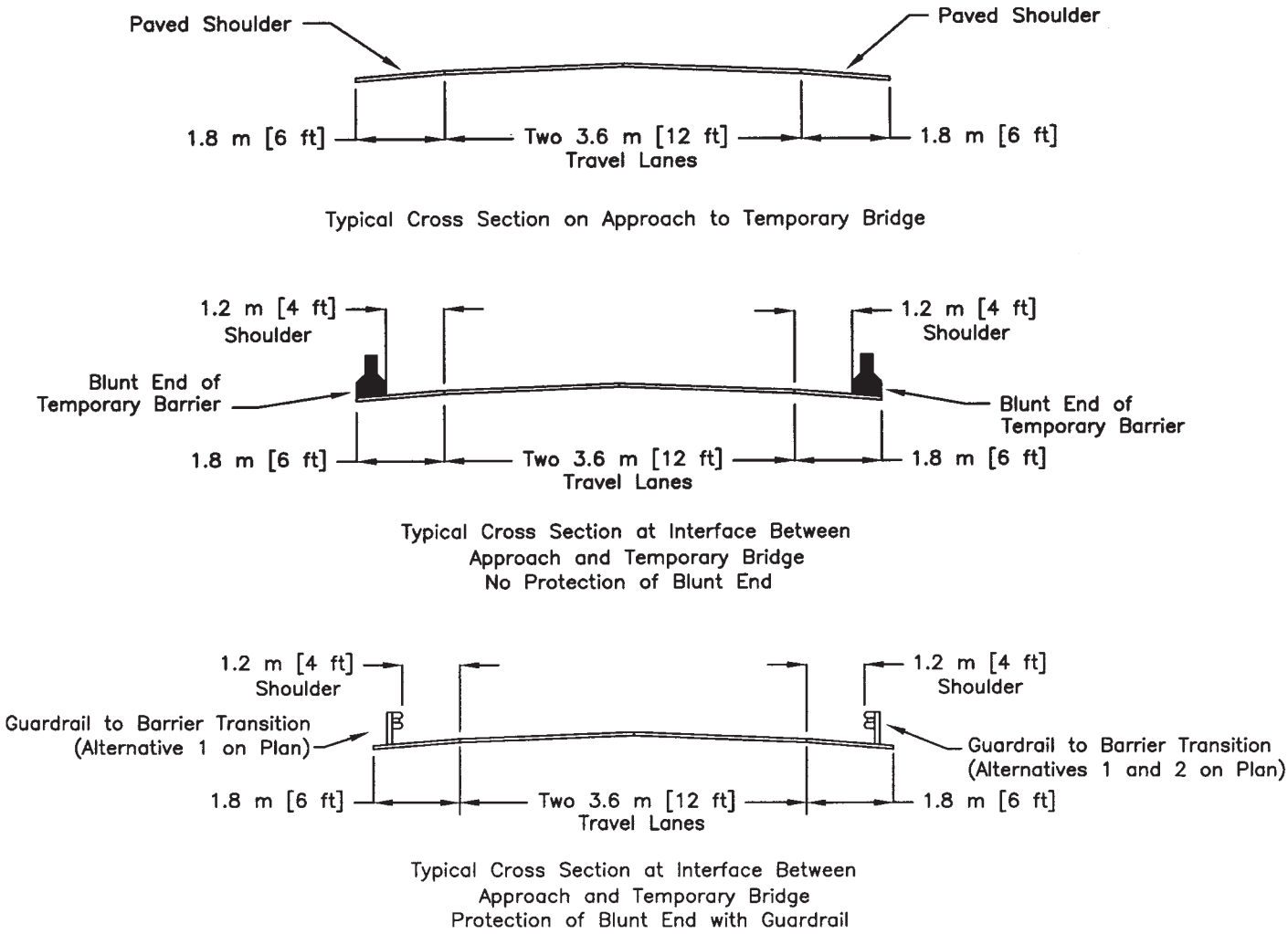
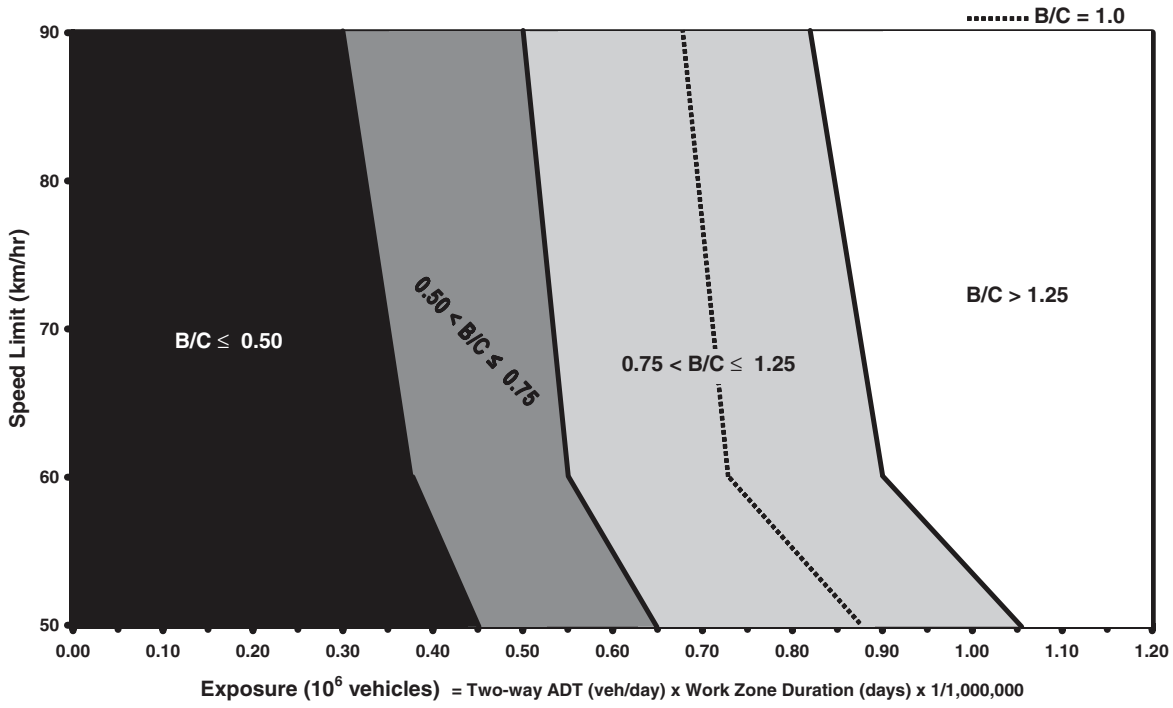


Exhibit 5-10. Cross sections for bridge reconstruction with a temporary diversion/runaround on a two-lane, two-way highway.

5.5.6 Protection of a Normally Downstream Barrier End for Two-Lane, Two-Way Traffic on a Normally Divided Facility

For two-lane, two-way traffic on a normally divided facility, blunt barrier ends on bridges that are normally downstream to traffic become upstream blunt ends for traffic that has been rerouted onto the opposite roadway by a median crossover. When the opposing traffic is separated by a temporary concrete barrier, only one blunt end is exposed to traffic. Exhibits 5-14 and 5-15 illustrate a plan and cross sections, respectively, for this condition. RSAP was used to analyze the decision to shield this blunt end with a guardrail. The guardrail starts at the blunt end, runs 15.25 m [50 ft] parallel to the roadway, and then tapers for 42.70 m [140 ft] at a rate of 15:1. The purposes of the guardrail are (1) to protect the barrier blunt end by providing a guardrail-concrete barrier transition (see the *Roadside Design Guide,* Section 7.8) and (2) to stop an encroaching vehicle from possibly reaching the 7.9-m [26-ft] drop-off. For speed limits between 50 and 120 km/h [35 and 70 mph] (inclusive), the benefit-cost ratio exceeds 1.0 for exposure greater than 1.0×10^6 vehicle-days and exceeds 1.25 for exposure greater than 1.5×10^6 vehicle-days.

When the opposing traffic stream is not separated by a temporary concrete barrier, two blunt ends are exposed to traffic. Exhibits 5-16 and 5-17 illustrate a plan and cross sections, respectively, for this condition. Similar to the previous analysis, RSAP was used to analyze the decision to shield one (the nearest to traffic) or both blunt ends with guardrail. For the decision to shield one blunt end (the nearest to traffic), the results are similar to the condition discussed above: for speed limits between 50 and 120 km/h [35 and 70 mph] (inclusive), the benefit-cost ratio exceeds 1.0 for exposure greater than 1.0×10^6 vehicle-days and exceeds 1.25 for exposure greater than 1.5×10^6 vehicle-days. For the decision to shield both barrier ends at speed limits between 50 and



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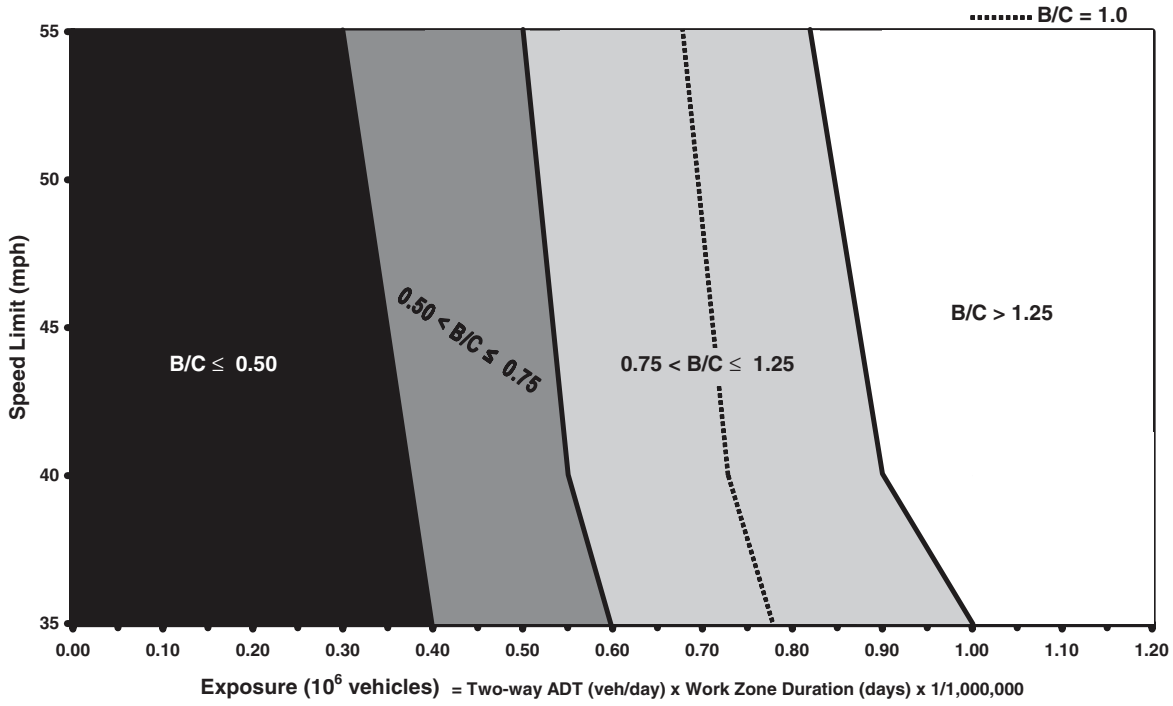
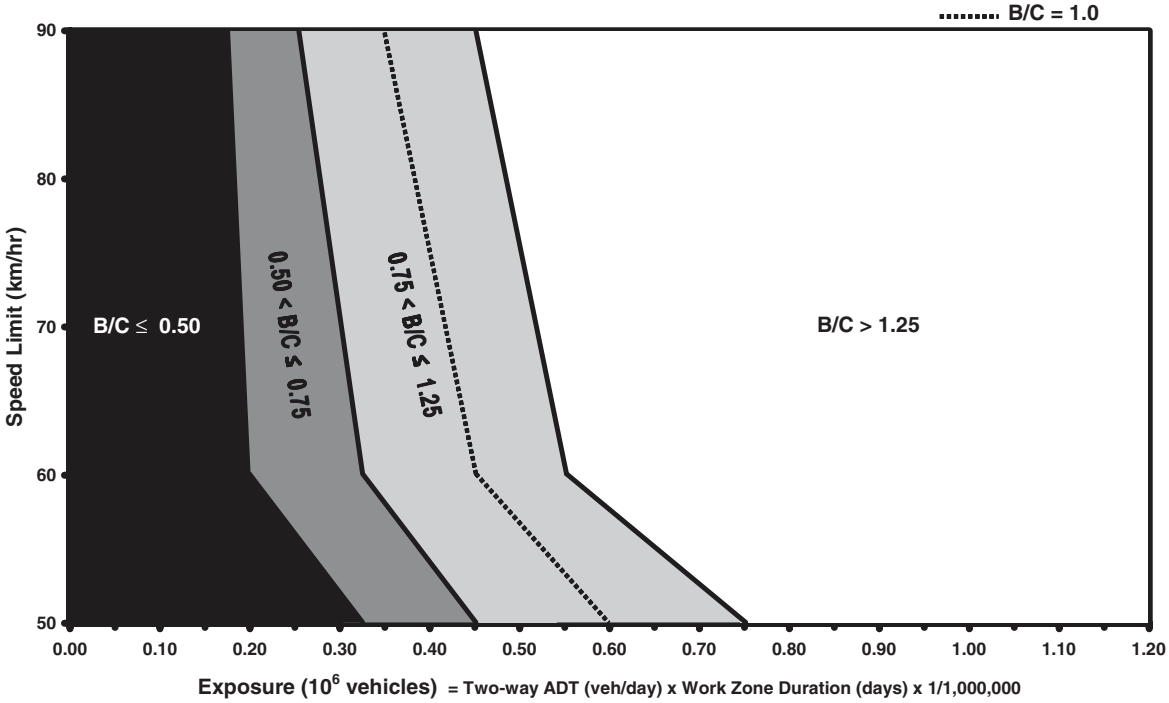


(U.S. Customary)

Exhibit 5-11. Barrier guidelines for bridge reconstruction with a temporary diversion/runaround on a two-lane, two-way highway—Alternative 1.



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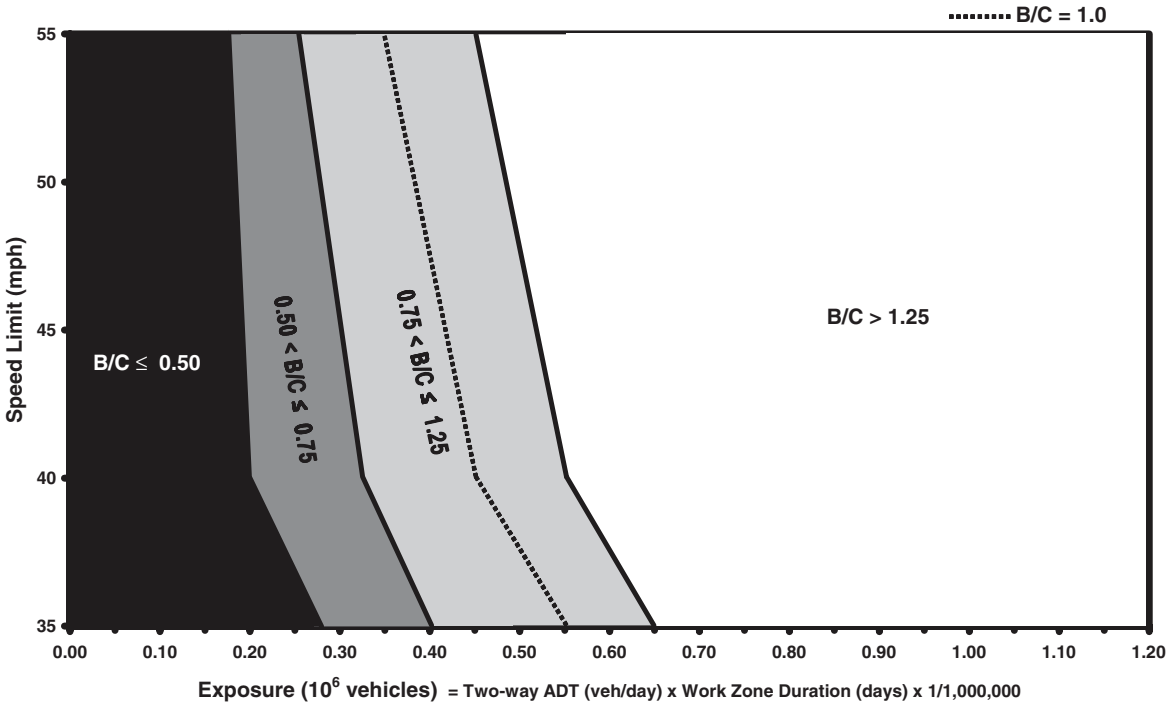
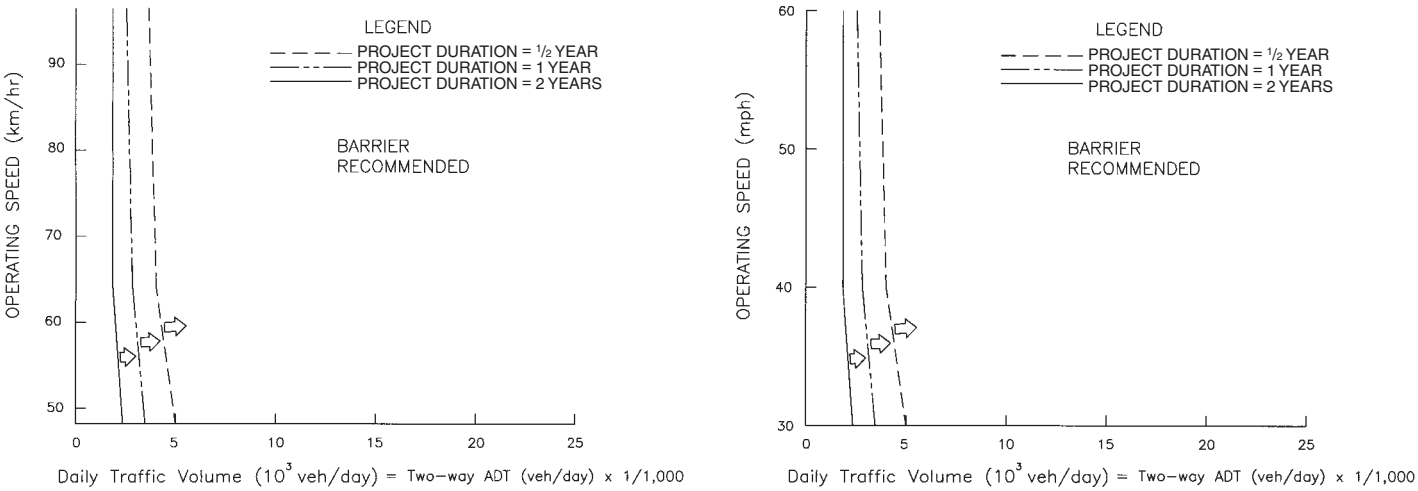


(U.S. Customary)

Exhibit 5-12. Barrier guidelines for bridge reconstruction with a temporary diversion/runaround on a two-lane, two-way highway—Alternative 2.



(Metric conversion of Ross and Sicking [*19*])

(U.S. Customary) (Ross and Sicking [*19*])

Exhibit 5-13. Barrier guidelines for separation of two-lane, two-way traffic on a normally divided facility.

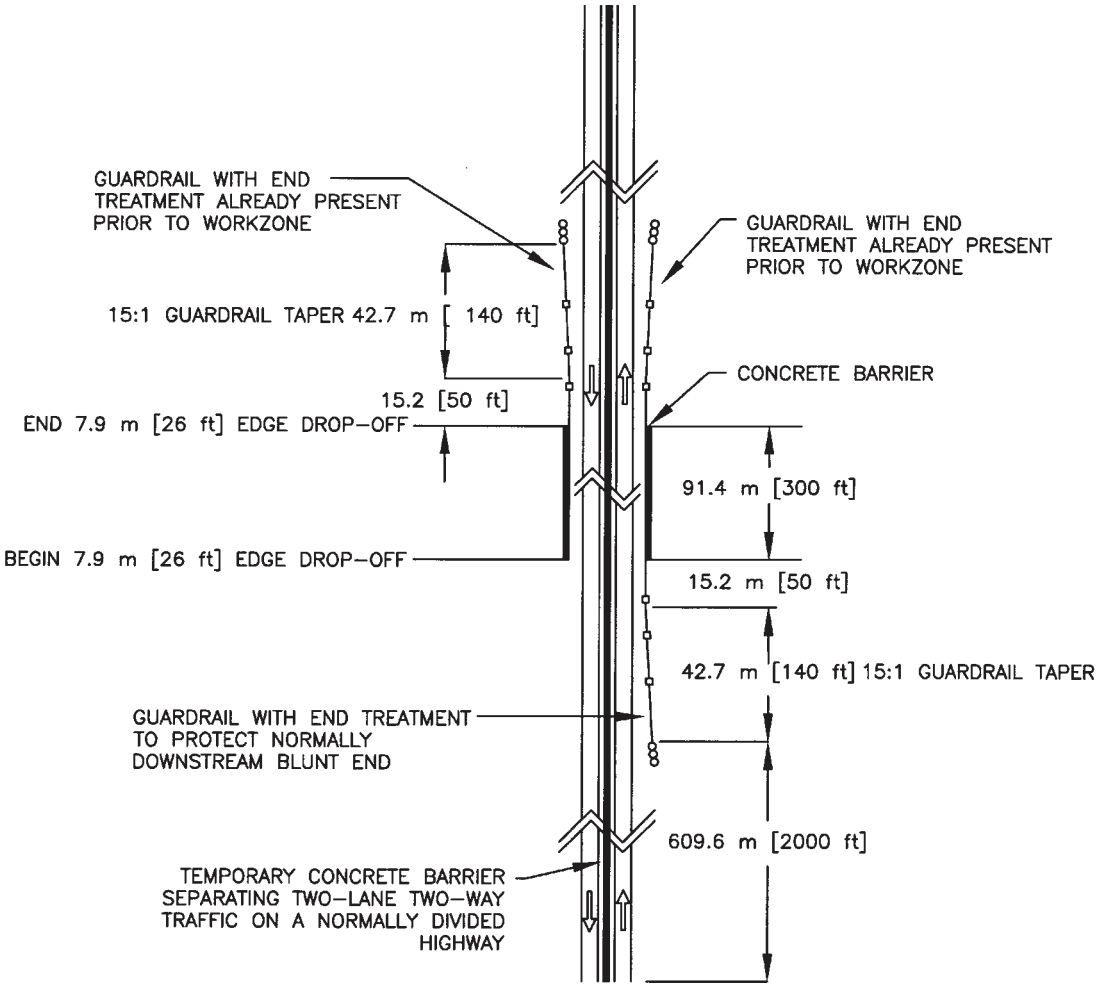
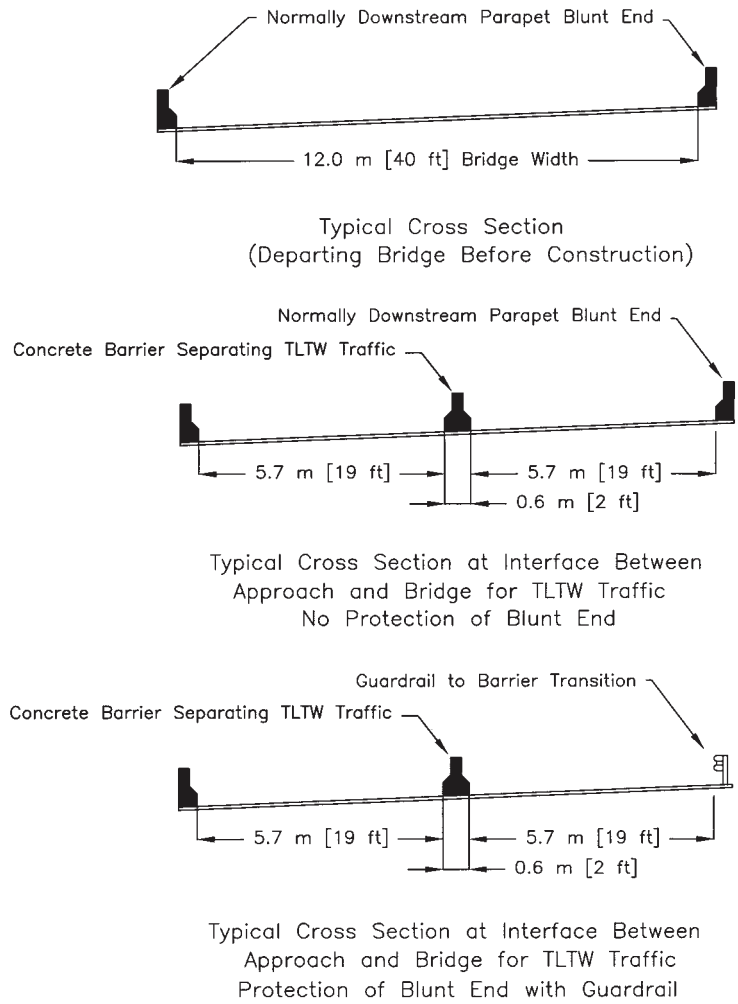


Exhibit 5-14. Plan for protection of a normally downstream barrier end for two-lane, two-way traffic on a normally divided facility (with a temporary barrier separating opposing traffic).



TLTW = two-lane, two-way

Exhibit 5-15. Cross sections for protection of a normally downstream barrier end for two-lane, two-way traffic on a normally divided facility (with a temporary barrier separating opposing traffic).

120 km/h [35 and 70 mph] (inclusive), the benefit-cost ratio exceeds 1.0 for exposure greater than 1.0×10^6 vehicle-days and exceeds 1.25 for exposure greater than 2.0×10^6 vehicle-days.

5.6 Other Considerations

Various other considerations are associated with traffic barriers and roadside safety features in construction work zones. Some of the following sections reference parts of the *Roadside Design Guide,* mainly Chapter 9, which, as stated in the first paragraph of the *Roadside Design Guide* Chapter 9, "describes the safety, functional, and structural aspects of traffic barriers; traffic control devices; and safety features used in work zones; and provides guidance on their application." Information contained in the *Roadside Design Guide* is not repeated or summarized here, because the *Roadside Design Guide* is updated periodically. Reliance should be placed on the current edition in its complete form.

5.6.1 Traffic Barriers

Section 5.5 of this report provides estimated benefit-cost ratios for the use of temporary concrete barriers. This type of barrier is the option most commonly used by state transportation agencies in construction work zones. Several other temporary traffic barrier designs are available that may be appropriate for work zone applications. Section 9.2 of the *Roadside Design Guide* discusses types of temporary concrete barrier systems as well as other types of barriers.

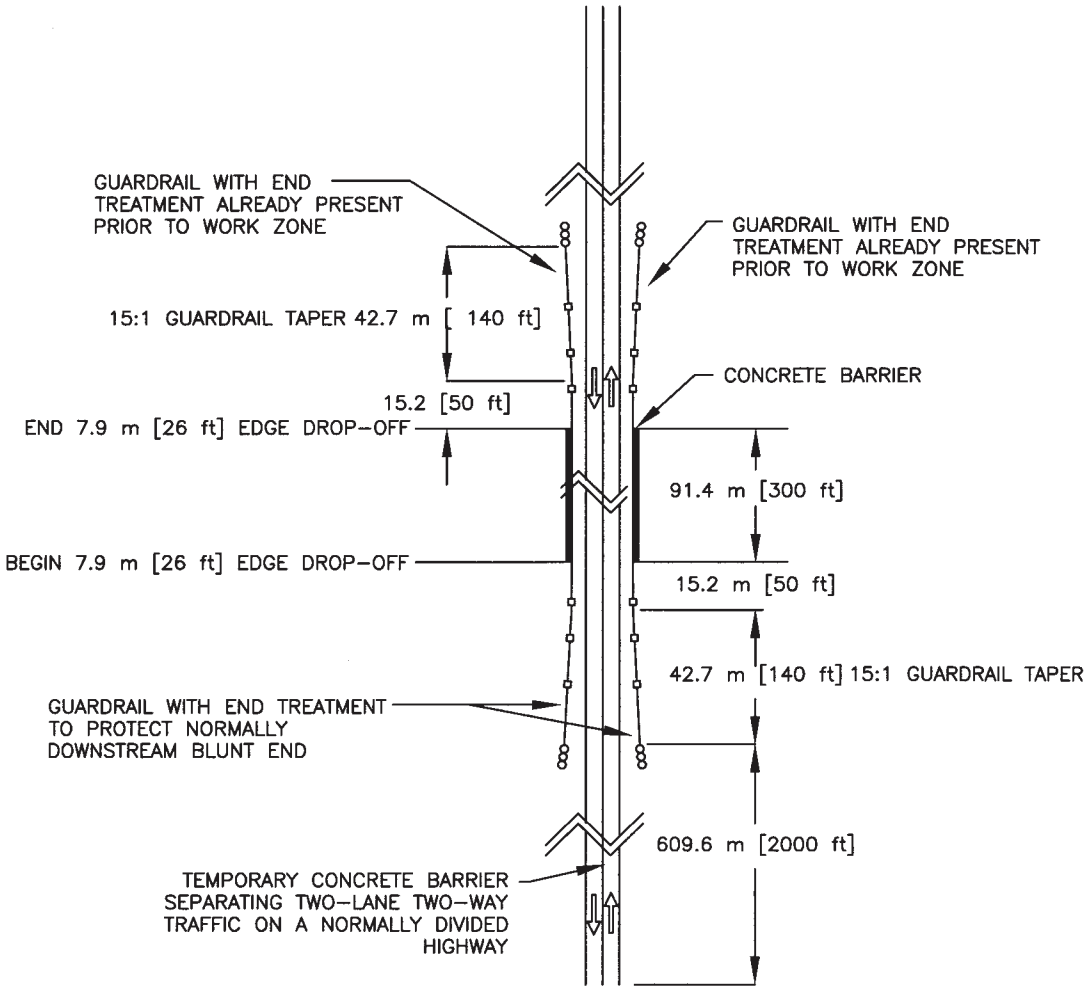
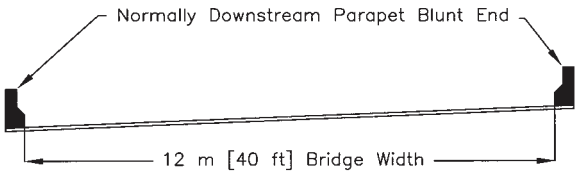
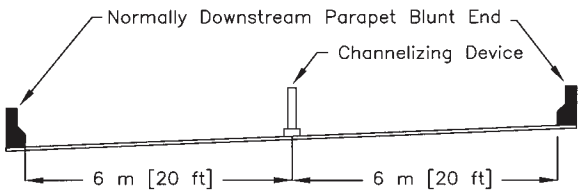


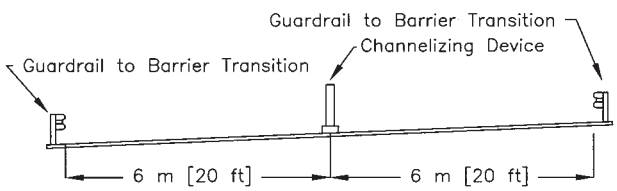
Exhibit 5-16. Plan for protection of a normally downstream barrier end for two-lane, two-way traffic on a normally divided facility (without a temporary barrier separating opposing traffic).



Typical Cross Section
(Departing Bridge Before Construction)



Typical Cross Section at Interface Between
Approach and Bridge for TLTW Traffic
No Protection of Blunt End



Typical Cross Section at Interface Between
Approach and Bridge for TLTW Traffic
Protection of Blunt End with Guardrail

TLTW = two-lane, two-way

Exhibit 5-17. Cross sections for protection of a normally downstream barrier end for two-lane, two-way traffic on a normally divided facility (without a temporary barrier separating opposing traffic).

5.6.2 Length of Need

A sufficient distance of full-strength barrier upstream of the hazard will reduce the possibility that a vehicle will run behind the barrier and impact the hazard. For a discussion of length of need, see Section 5.6 of the *Roadside Design Guide.*

5.6.3 Flare Rates

Flare rates for temporary concrete barriers should be selected to provide the most cost-beneficial safety treatments possible. Section 9.2 of the *Roadside Design Guide* discusses flare rates ranging from 4:1 to 8:1 for temporary concrete barriers. These rates were developed for restricted work zones (*20*). Observed state practice is to use flare rates closer to those for permanent concrete barriers from Table 5.7 of the *Roadside Design Guide.*

5.6.4 End Treatments

Desirable end treatments for a temporary barrier are discussed in Section 9.2 of the *Roadside Design Guide.*

5.6.5 Crash Cushions

Crash cushions are protective systems that prevent errant vehicles from impacting obstacles by either smoothly decelerating the vehicle to a stop or redirecting it away from the obstacle. Two types of crash cushions used in work zones are stationary and mobile. For a discussion of each type, see Section 9.3 of the *Roadside Design Guide.*

CHAPTER 6

Ancillary Design Information

This chapter covers a variety of work zone topics other than geometric design. Some of the sections cross-reference other publications, particularly the MUTCD and the *Roadside Design Guide.* Information in those two publications is not repeated or summarized here, because both publications are updated periodically and reliance should be placed on the current editions in their complete form. For subjects covered by the MUTCD or the *Roadside Design Guide,* limited supplemental information is selectively provided in this publication. The supplemental information does not supersede any information in either of the cited publications.

6.1 Drainage

Drainage for construction work zones has several purposes, including rapid evacuation of moisture from the driving surface, prevention of pavement structure saturation, prevention of damage to properties, and maintenance of the hydrologic systems traversed by the roadway. Provision of construction-phase erosion and sediment control, bank protection, and storm water management are important elements of work zone design. However, the associated design techniques and provisions vary substantially by geographic location, and jurisdictional requirements (e.g., permits) and are not covered in this report.

6.1.1 Basics

A well-drained driving surface, during and after construction, is needed for continued and safe operations during adverse weather conditions. The measures used to provide for drainage of permanent roadways also apply to construction work zones; however, the relatively short life span of temporary roadways in construction work zones is cause for some modification.

The Rational Equation (also known as the Rational Formula) is used in generally the same manner and with the same limitations as it is for permanent drainage structures. One difference relates to the selection of a design event (i.e., design storm), and there are differences among agency practices. Several state DOTs use the same criteria for temporary drainage structures as they would for similar structures in a permanent roadway (e.g., 25-year event for cross drain); many other agencies use different recurrence intervals for permanent and temporary installations. The AASHTO *Model Drainage Manual* (*21*) suggests using a 2-year design frequency for temporary drainage facilities (e.g., channels, culverts, and bridges) if the temporary roadway is required for a year or less, and a 5-year frequency if the roadway is required for more than a year. However, these recommendations may not be consistent with relevant jurisdictional regulations and permitting requirements. Longer recurrence intervals (e.g., 10 years) may be used for temporary bridges than for other temporary hydraulic structures.

6.1.2 Considerations Unique to Work Zones

Often, the placement of devices and infrastructure for each phase of a construction work zone is not detailed to the same level of specificity as for permanent roads. At any given point in the construction of a roadway, the driving surface and adjacent area may be a quilt-like combination of preproject, new permanent, and temporary pavements. Drainage systems are needed to accommodate each phase. The placement of inlets and connecting pipes is a principal means of capturing surface flow from roadway and roadside surfaces. The patterns, locations, and types of temporary inlets may differ from those of permanent roads. Inlets may be needed within and between travel lanes. Some agencies use longitudinal, slotted inlets, such as the one illustrated in Exhibit 6-1, for complex work zone conditions that would not exist within permanent roads. Slotted drains have several advantages that make them particularly useful in work zone application. Slotted inlets can accommodate heavy vehicular traffic in addition to bicycles. Also important, they can intercept sheet drainage and do not

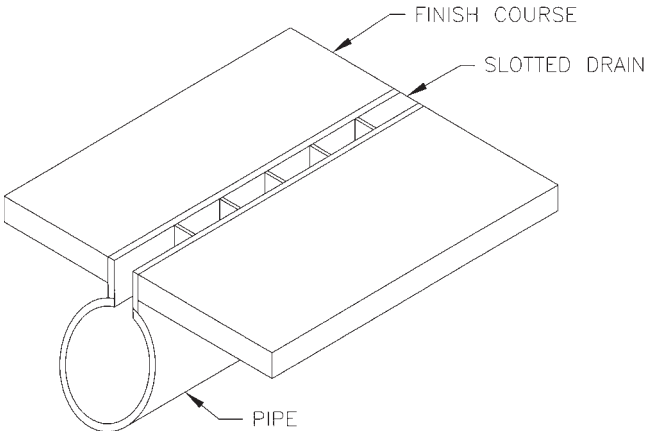


Exhibit 6-1. Longitudinal, slotted inlet.

require a defined depression to capture surface flow. The installation of slotted drains is relatively simple and fast. Some applications of slotted drains also pose some unique maintenance requirements, such as more frequent removal of accumulated debris.

Designers should be mindful that many roadway features (e.g., shoulders, swales, and medians) are part of highway drainage conveyance systems. Several work zone types inherently alter the design of the existing drainage system. For example, when the outside shoulder of a highway is used as a traveled lane, the potential for surface water encroachment into the temporary travel lane is elevated. The following work zone drainage issues are common:

- Temporary infrastructure (e.g., temporary concrete barrier, temporary curbs, and sandbags) may affect roadway drainage patterns, including spread into traveled lanes.
- Existing culverts may require extension to accommodate temporary roadways.
- Positive drainage for emergency turnouts (see Section 6.3) should be provided.
- When a highway with two or more lanes sloped in the same direction is milled, surface water can be trapped, as indicated in Exhibit 6-2.

The analysis and design techniques provided in state DOT drainage manuals and supplementary information sources provide the tools needed for providing work zone drainage.

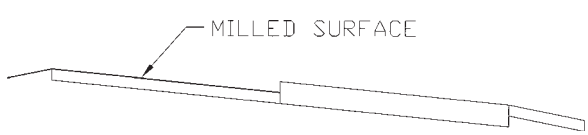


Exhibit 6-2. Water trapped by milling.

Anticipation of construction phase conditions and adaptation to dynamic construction and weather conditions are central to successful execution.

6.2 Temporary Bridges

Temporary bridges are sometimes needed as part of temporary roadways. The functional design (i.e., structural capacity, cross section, and clearances) is generally determined by the agency. The agency may perform the detailed design or include this function as part of the construction contract. In the latter case, the functional requirements and criteria are specified in the contract along with the design criteria and other requirements. Typically, temporary bridges designed though construction contracts require approval of the transportation agency prior to their construction.

Guidance related to the hydraulic design of temporary bridges over watercourses is provided in Section 6.1.1.

6.3 Emergency Turnouts

Cross-sectional width is often reapportioned in work zones, resulting in the reduction or elimination of shoulders and travel lanes. Since shoulders are the traditional refuge for disabled vehicles, operators of disabled vehicles may be faced with unfamiliar conditions and a set of poor choices. The provision of emergency turnouts or intermittent shoulders mitigates cross-sectional reductions.

Agency use of emergency turnouts is mixed. Some agencies do not use them, while others do so for projects where they are considered necessary and feasible. Factors considered in determining necessity are facility type, traffic volume, vehicle mix, and length of road without a shoulder (e.g., less than 0.8 km [0.5 mi] is acceptable).

When provided, sight distance is an important consideration in emergency turnout location selection and design. Extended sight distance aids driver performance in resolving potential conflicts between traffic in the through lanes and traffic that is entering or exiting an emergency turnout. Sight distance approaching the emergency turnout facilitates a smooth departure of traffic entering the emergency turnout. Traffic departing the emergency turnout and merging into a travel lane also benefits from extended sight distance. With extended sight distance, drivers operating in the travel lanes may be able to increase gaps for entering vehicles by changing lanes or speed.

Locating emergency turnouts on flat, tangent sections of the roadway to maximize available sight distance is desirable but not always feasible. When emergency turnouts must be located near crest vertical curves, locating them in advance of the curve will maximize available sight distance for approaching traffic.

When emergency turnouts are provided, typical spacing ranges from 0.8 to 1.6 km [0.5 to 1 mi]. Terrain and other

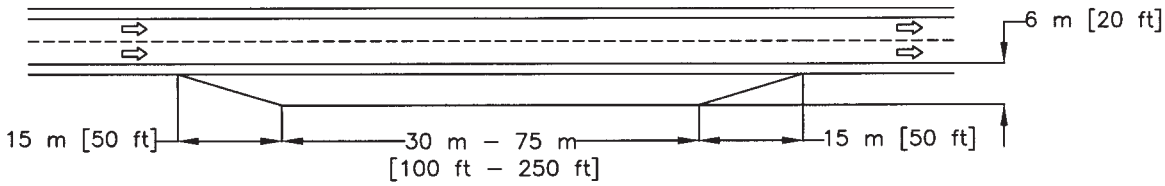


Exhibit 6-3. Example emergency turnout.

context considerations (e.g., structures and slopes) often determine feasible locations and spacing. Emergency turnouts should be located on the right side of the travel lanes. Left-side pullout areas violate driver expectancy and should be avoided. An example emergency turnout configuration is shown in Exhibit 6-3.

Advance construction guide signing improves the use and safety of emergency turnouts. By knowing the distance to a refuge, drivers experiencing emergencies can make informed decisions on the approach and exiting maneuvers. Signing also provides other drivers with notice of potential exiting and merging traffic. Signing should indicate the distance to the emergency turnout.

6.4 Enforcement Pullout Areas

Visible work zone law enforcement presence encourages motorist compliance with warning and regulatory signs and overall safe driver behavior. However, effective enforcement is hindered by the absence of paved shoulders or other locations where officers can safely position themselves and/or pull violators over. Including provisions for temporary enforcement pullout areas in the construction and traffic control plans may be beneficial.

6.4.1 Evaluating the Need for Enforcement Pullout Areas

One or more enforcement pullout areas may be appropriate when the following conditions exist:

- Significant enforcement is needed to achieve compliance with reduced regulatory speeds or other safety-related work zone traffic regulations, and
- There is no left or right shoulder for a distance of more than 5 km [3 mi].

Enforcement pullout areas should be a supporting feature of an enforcement plan; the enforcement areas alone will yield no compliance benefits. Assurances are needed from the jurisdictional enforcement agencies that if enforcement pullout areas are provided, they will be used.

6.4.2 Enforcement Pullout Area Design

To be both safe and effective, enforcement pullout areas should be

- Wide enough to allow the performance of enforcement activities,
- Long enough to afford safe entry to and exit from the normal traffic stream, and
- Spaced so as to be effectively used by both motorists and enforcement vehicles.

Guidance in these three areas is provided below, and an example design is provided in Exhibit 6-4.

Enforcement pullout areas should be wide enough to allow an officer to stand next to a vehicle to issue a citation. Experiences with enforcement areas for high-occupancy vehicle (HOV) lanes on high-speed roadways indicate that a minimum

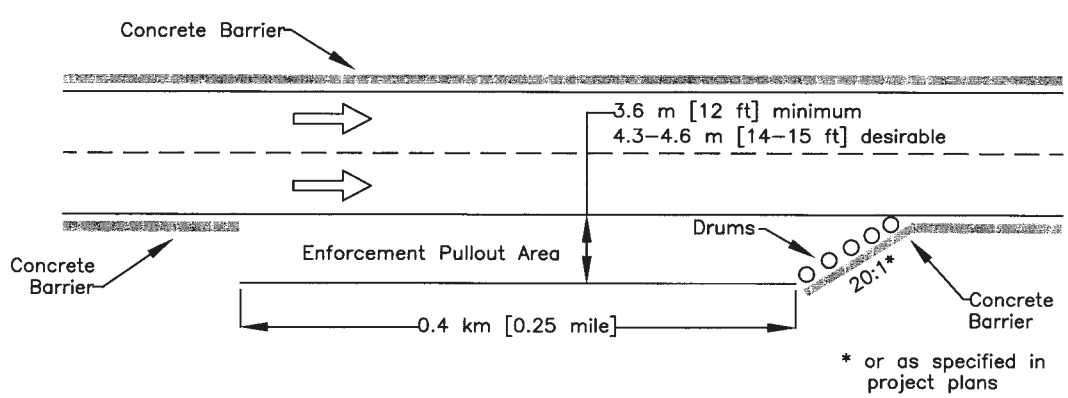


Exhibit 6-4. Example work zone enforcement pullout area.

of 3.6 m [12 ft] in width is required and that 4.3- to 4.6-m [14- to 15-ft] widths are desirable. A minimum width of 3.6 m [12 ft] for work zone enforcement pullouts is recommended.

Pullout areas should be long enough to provide space for the violator and the enforcement vehicle, as well as long enough to provide the opportunity for departing vehicles to accelerate slightly prior to reentering the traffic stream. Based on limited field data from enforcement activities, existing roadway design criteria for vehicle accelerations, experiences with HOV lane enforcement areas, and the preferences of law enforcement personnel, an enforcement pullout length of at least 0.4 km [0.25 mi] is recommended for high-speed roadways. Enforcement pullout areas should be located on the right side of the travel lanes. Left-side pullout areas violate driver expectancy and should be avoided.

Spacing of enforcement pullout areas should reflect a balance between enforcement and construction considerations. Excessive separation of enforcement pullouts reduces the opportunities for enforcement personnel to take action near the point of observed infractions. Conversely, closely spaced enforcement pullout areas may significantly disrupt the effectiveness and efficiency of construction operations. A spacing of approximately 5 km [3 mi] is a reasonable compromise between enforcement and contractor needs.

Sight distance considerations for enforcement pullout areas are similar to those associated with emergency turnouts (see Section 6.3).

6.4.3 Other Implementation Considerations

Enforcement pullout areas are not the only means of facilitating work zone enforcement. Project sequencing and use of other infrastructure (e.g., rest areas and weigh stations) can also be used to implement enforcement efforts. For example, a long project can be divided into segments that are 5 km [3 mi] long or shorter, and a special contract provision can be added specifying that emergency shoulders in adjacent segments must not be eliminated at the same time during the project.

One of the primary concerns of enforcement personnel in work zones is driver unpredictability once enforcement vehicle warning lights are activated to pull the driver over. The lack of a clear choice as to where to go and/or where the next opportunity to pull over is located can lead to potentially unsafe driving decisions and behaviors (e.g., slowing down excessively or even stopping in the travel lanes, or focusing attention on the enforcement vehicle behind rather than on traffic conditions ahead).

Advance construction guide signing to notify motorists of the presence of an enforcement pullout area ahead (and the distance to that area) can be helpful in reducing driver indecision and unsafe behaviors. Signing should be placed at a location to allow drivers adequate time to decide to use the enforcement pullout area and make appropriate driving adjustments.

6.5 Screens

The MUTCD Part 6 identifies and describes screens and provides guidance on their use. The *Roadside Design Guide* Chapter 9 also provides guidance, and both publications should be referenced.

6.5.1 Glare Screens

Glare screens are the most common category of screens and are installed between opposing-direction travel lanes to prevent high-mounted headlights from impairing the night vision of oncoming motorists and to prevent motorist distraction. Factors that are considered in providing for glare screens include traffic volume and composition (i.e., percent trucks), horizontal and vertical curvature, ambient light sources, and lateral separation between the opposing-direction travel lanes.

Glare screen types in use include vertical extension of temporary concrete barrier, commercially available paddles mounted atop temporary concrete barrier, and chain link fence with woven fabric.

6.5.2 Construction Activity Visual Barriers

Screens installed on the outside of the traveled way are less common in construction work zones. However, much of the construction activity in work zones may be an attractive distraction to motorists and interfere with their ability to successfully perform driving functions (e.g., speed, headway, and path maintenance). Visual barriers are devices that shield construction activity from driver visibility. Use of these devices, sometimes referred to as "gawk screening," is not widespread.

6.6 Portable Changeable Message Signs

The MUTCD Part 6 and *Roadside Design Guide* Chapter 9 provide guidance on the use of portable changeable message signs.

6.7 Arrow Panels

The MUTCD Part 6 and *Roadside Design Guide* Chapter 9 provide guidance on the use of arrow panels, which are also known as flashing arrow boards and flashing arrow signs.

6.8 Lighting

Lighting for construction work zones includes units that are part of temporary traffic control devices (e.g., beacons, warning lights, and steady burn lights). Work zone guidance and specifications are included in the MUTCD Part 6.

Flood lighting and conventional highway lighting are sometimes provided in construction work zones. The provision of floodlights to illuminate nighttime construction activity (e.g., paving operations and flaggers) may be specified by the agency or identified as a contractor responsibility. Factors that must be considered in this decision are the vision and comfort of drivers and the ability of the workers to perform different types of tasks. Guidelines for illumination criteria are identified in *NCHRP Report 498* (*22*). Examples that use these guidelines and that illustrate important procedures and considerations of temporary lighting for the purpose of night work can be found in *NCHRP Report 476 (23)*.

Conventional highway lighting that is present in pre-work zone conditions should normally be maintained during construction projects. If individual lighting units are removed from service during construction, temporary units should be considered.

The provision of temporary highway lighting generally considers the same warrants and criteria used for permanent lighting to address issues such as high night-to-day crash ratios, high traffic volumes, high traffic speeds, substantial queuing, complex maneuver areas, restrictive roadway geometry, and high pedestrian volumes. Warrants for highway lighting have been developed for permanent roadways, but because of the complexity of the warrants, they have not been put into widespread use. Experience and judgment have historically been relied upon to determine whether the resulting safety benefits justify the cost of lighting.

The most commonly used lighting design criteria have been based on a set magnitude and uniformity of illuminance, a measure of the amount of light falling on a surface, and on luminance, a measure of the amount of light reflecting from the surface. Guidelines for these criteria have been published by AASHTO and the Illuminating Engineering Society of North America (IESNA).

6.9 Rumble Strips

The MUTCD Part 6 provides guidance on the use of rumble strips.

Several temporary transverse rumble strip configurations are in use. One configuration is sawed or milled into existing asphalt pavement. Another configuration is raised above existing (i.e., preproject) travel lane pavements. Within this configuration, individual strips may consist of basic pavement material (e.g., asphalt) or manufactured materials (e.g., removable neoprene or multiple layers of traffic tape) fastened to the road surface. The depth (i.e., thickness) of typical installations is approximately 0.64 cm [0.25 in.]. Several clusters of temporary rumble strips are generally placed in advance of a segment or feature where reduced speed or elevated driver awareness is desirable. A number of patterns have been evaluated. A common cluster configuration consists of six individual rumble strips, each separated by distances ranging from 0.5 to 3.0 m [1.5 to 10.0 ft]. Within a cluster, spacing between individual strips may be uniform or irregular (*24*).

Research on the effectiveness of transverse rumble strips on reducing work zone speeds is inconclusive (*25*).

Several work zone strategies (e.g., median crossover or use of shoulder) reallocate the roadway cross section, which changes the relationship between wheel paths and the existing edge or shoulder rumble strips. Depending on the pavement material, type of rumble strips, location of wheel paths relative to rumble strips, and duration of temporary reallocation, the rumble strips may be modified, such as by paving over portions of the rumble strips.

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Supplemental Materials

The following materials are available for free online at www.trb.org/news/blurb_detail.asp?id=7362:

- The research team's final report for this project (a PDF listed as *NCHRP Web-Only Document 105*)
- The work zone speed prediction model (an Excel file)
- A user's manual (a PDF)

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation