April 22, 2020

Mr. Keith A. Cota, PE
Chief Project Manager
New Hampshire Department of Transportation
7 Hazen Drive
P.O. Box 483
Concord, NH 03302

Re: Connector Road over Shields Brook, Exit 4A
Type, Span, and Location Study
Fuss & O'Neill Reference No. 20190127.A10

Dear Mr. Cota:

Fuss & O'Neill is pleased to provide the following TSL Report for the construction of the Exit 4A Connector Road Bridge over Shields Brook. This report summarizes the layout and superstructure type, and evaluates the substructure types for the proposed bridge.

Executive Summary

- The bridge will replace the existing undersized 6-foot diameter corrugated metal pipe structure and will accommodate the widening of the Connector Road.
- A rolled steel girder with a composite concrete deck is recommended.
- Semi-Integral concrete abutments bearing on structural fill is recommended.

Existing Condition

The existing Folsom Road / North High Street consists of two 11-foot lanes with a 3-foot shoulder on either side. The existing structure is a 6-foot diameter corrugated metal pipe with a 22 degree skew. Shields Brook converges with an unnamed stream approximately 90 feet upstream of the existing structure. According to the Folsom Road / North High Street over Shields Brook Hydrologic and Hydraulic report dated November 2018, the pipe is undersized and the road is overtopped for all storms greater than the 2-year event.

Proposed Roadway Alignment and Profile

As part of the Exit 4A Interchange Project, the existing 28-foot wide Folsom Road / North High Street roadway will be replaced with a four-lane connector road on a new alignment with two additional turning lanes at the project location. The proposed curb-to-curb width for the Connector Road will be 83 feet with a sidewalk on both sides and fully encompasses the existing Folsom Road / North High Street with the entirety of the existing road located in the eastbound lanes of the proposed roadway. The proposed structure will be located on a horizontal curve with a radius of 2000 feet and a superelevation of 2.6%.

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The finished grade elevations of the proposed Connector Road will be 7 to 8 feet higher than the existing elevations along the existing Folsom Road / North High Street. The bridge will be located on a sag vertical curve with the low point occurring at station 1057+85, which is well beyond the limits of work for the replacement structure.

Proposed Bridge Layout

Two bridge layout options have been evaluated; a buried structure with a clear-span of 28.5 feet and an at-grade structure with a span of 63 feet. These options are discussed below.

Option 1 – Buried Structure

This layout option consists of a buried 28.5-foot clear-span structure. The buried structure alignment follows the stream alignment and requires an approximate skew of 40 degrees. This was the structure type and width used for the hydraulic model. The hydraulic analysis shows that with a 28.5-foot clear span, a minimum 4.7-foot rise structure is required to pass the 100-year design flood event with the required 1-foot minimum freeboard. Due to the raise in profile at this location, this results in over 10 feet of fill over the top of the buried structure.

A 28.5-foot clear-span was initially estimated for the hydraulic analysis, which assumes 1.2 times bankfull width plus 2 feet with a delineated bankfull width of 22 feet. However, the NHDES Stream Crossing Requirements state that the clear-span should be equal to the bankfull width times a factor based on the "low" side of the entrenchment ratio as specified by "The Key to the Rosgen Classification of Natural Rivers" (Rosgen) chart. The stream survey, conducted after the hydraulic analysis was completed, determined an entrenchment ratio of 3.1 and a bankfull width of 23.5 feet. Based on the Rosgen chart and an entrenchment ratio of 3.1, a factor of 2.2 should be used, which results in a clear-span of 52 feet. Therefore, that the buried structure does not meet NHDES Stream Crossing Requirements.

The proposed Connector Road alignment is shifted north of the existing Folsom Road / North High Street alignment. This shift combined with the substantially increased width of the Connector Road as compared to the existing road encroaches into the Shields Brook upstream channel. This pushes the proposed upstream invert of the buried structure upstream past the convergence of Shields Brook with the unnamed stream, which will require realigning the unnamed stream to shift the convergence further upstream within the delineated wetland. Realignment of the stream will result in significant wetland impacts.

This option is not recommended because the structure will not meet NHDES Stream Crossing Requirements and will result in significant wetland impacts.

Option 2 – At-Grade Structure

This layout option consists of an at-grade structure with a clear-span of 52 feet (perpendicular to the stream) with a skew of 30-degrees, which results in a span length of 63 feet along the alignment from centerline-of-bearing to centerline-of-bearing. The structure meets NHDES Stream Crossing Requirements with a minimum clear-span of 52 feet. The new Connector Road alignment and roadway width will result in encroachment on Shields Brook by the embankment slopes in the front of the upstream wingwall, which will require realignment of a short section of the brook immediately upstream of the bridge. A reduction in skew from 40 degrees to 30 degrees can also be accommodated due to the increased span. This option was not analyzed in the hydraulic analysis, but since the width and height of the opening are greater than for Option 1, this structure will pass the required flows using engineering judgement. Stream banks will be carried through the structure similarly to Option 1, but additional hydraulic capacity is provided by this larger span. A minimum low chord elevation of 275.5 feet based on the buried structure hydraulic analysis would be provided.

This is the recommended option as it will meet NHDES Stream Crossing Requirements, will result in fewer wetland impacts than Option 1, and provides greater hydraulic capacity. It should be noted that the hydraulic analysis will need to be updated for the 52-foot clear-span bridge in order to provide accurate flood flow elevations and/or decrease the minimum low chord elevation if desired. A scour analysis will also be required. As the crossing occurs in a FEMA detailed study area that includes a floodway delineation, a Letter of Map Revision (LOMR) application will be required at the completion of construction and an updated hydraulic analysis utilizing as-built survey will be required to complete the application.

Bridge Superstructure

The bridge out-to-out width will be 98 feet. Eastbound and westbound traffic will be divided by a 4-foot concrete median. Two 11-foot travel lanes, a 5-foot shoulder, and a 2-foot shoulder will be provided in the westbound direction and four 11-foot travel lanes, a 5-foot shoulder, and a 1-foot shoulder will be provided in the eastbound direction. A 6-foot sidewalk with T4 bridge rail will also be provided on both sides of the road. The bridge will be located on a horizontal and vertical curve and have a superelevation of 2.6%.

Option 1 – NEXT Beams

Given the span length of 63 feet, the use of precast, prestressed concrete NEXT beams would normally be viable. However, PCI recommends a maximum skew of 20 degrees for NEXT beams. Therefore, this option was not evaluated further.

Option 2 – Precast, Prestressed Concrete Voided Slabs

Concrete is more durable than steel in close proximity to water; and for shorter spans, concrete is often more economical than steel. However, a preliminary analysis determined that the proposed span and skew could not be accommodated by a voided slab bridge. Therefore, this option was not evaluated further.

Option 3 – Rolled Steel Girder

The preliminary girder layout and design for the rolled steel girder bridge with composite concrete deck provides 11 girders spaced at 9'-3" on center. The girders were designed to be parallel to the bridge chord. Because the bridge is on a horizontal curve with straight girders, the overhang distance will vary. As structure depth is not a concern due to the significant profile grade increase and larger span, an economical beam can be utilized resulting in cost savings. A W36x160 was assumed for the preliminary design, but a similar size plate girder could also be utilized.

The steel girders could be weathering steel, galvanized, or metalized. The NHDOT Bridge Design Manual v1.0 section 630.3.2 states that weathering steel shouldn't be used when the height clearance is less than 10 feet for stagnant water or 8 feet above moving water. Since the area upstream of the structure is a delineated wetland, there will be standing water during low flows, so the stagnant water limit will be used. The calculated low chord elevation of the proposed structure is 282.8 feet. The estimated normal high water elevation (2-year event) from the hydraulic report is 272.85 feet, which gives a height clearance of 9.95 feet. Since the clearance height is below the stagnant water limit, the use of weathering steel is not recommended. Due to the length of the proposed beams and the lack of larger kettle lengths locally, double dipping would be required to galvanize the beam, or the beam would need to be sent out of the region. A splice could be utilized to shorten the beam length, however the beam would not be shortened enough to be accommodated by the local kettles. Double dipping would roughly double the cost of galvanizing per pound of steel, and shipping the beams out of the region to dip them would also be expensive. Due to the high cost of galvanizing, metalizing is recommended.

As the precast options were not viable and the rolled beams required for this option are economical, this option is recommended.

<u>Geotechnical</u>

Borings have been completed at the approximate location of the wingwalls on the south side of the structure. The borings indicate that the approximate bedrock elevations are 264.5 feet and 262.3 feet for Abutment A and B, respectively. Both borings consist of organic silt and fine sand with very low blow counts from existing ground to an elevation of 267.2 feet for Abutment A and 265.3 feet for Abutment B. Below the organic material is a layer of glacial outwash. At Abutment A, the glacial outwash layer sits directly on bedrock. At Abutment B, there is a layer of glacial till beginning at elevation 263.3 feet below the glacial outwash, then bedrock below the glacial till.

Abutment Type

Several abutment types have been evaluated for the recommended bridge layout; integral/semi-integral, cantilever on piles, and cantilever on spread footings. The evaluated abutment types are discussed below.

Cantilever Abutment on Piles

This option consists of a cantilever abutment supported on piles driven into bedrock. An expansion joint should be located at Abutment A because it has the higher finished grade elevation. The joint should also be located behind the backwall to protect the bearings and beam seat from future leaking.

According to the NHDOT Bridge Design Manual section 6.2.2.B, the bottom of a footing founded on piles should be 4 feet below finished grade. The proposed minimum finished grades in front of the abutments are 276 feet and 275 feet for Abutments A and B, respectively, which leaves a bottom of footing elevation of 272 feet and 271 feet. This results in proposed pile lengths of 7.5 feet for Abutment A and 8.7 feet for Abutment B. Due to these short pile lengths, it is not cost effective to mobilize pile driving for such short piles. Therefore, this option is not recommended.

Cantilever Abutment on Spread Footings

This option consists of a cantilever abutment on structural fill or rock and will have the same geometry as the cantilever abutment on piles option.

According to the NHDOT Bridge Design Manual section 6.2.2.B, the bottom of a footing founded on soil should be 5 feet below grade. This results in bottom of footing elevations of 271 feet and 270 feet for Abutments A and B. Based on the boring logs, the soils at these elevations are not suitable to support spread footings. Therefore, the unsuitable material will need to be excavated to competent bearing surface. This will likely be to bedrock at elevation 264.5 feet for Abutment A and possibly to glacial till at an elevation of 263.3 feet for Abutment B, but should be confirmed by a geotechnical engineer. Any material removed below the proposed bottom of footing elevations will be replaced with structural fill or a tremie seal/subfooting. Additionally, the competency of the bedrock for bearing will need to be evaluated by a geotechnical engineer. The cost to do this work would be less than driving short piles, therefore spread footings are recommended. However, it should be noted that a scour analysis has not yet been performed and may dictate the bottom of footing elevations and/or subgrade materials below the footings.

Integral/Semi-Integral Abutments

According to the NHDOT Bridge Design Manual sec. 6.4.2.B, integral abutments with skews greater than or equal to 20 degrees cannot be designed utilizing the simplified method documented in the VTrans Integral Abutment Bridge Design Guidelines. Although a more advanced method could be utilized to design integral abutments at a 30 degree skew, it is not a feasible option due to the short pile lengths.

Semi-integral abutments on spread footings would be a reasonable alternative to integral abutments and would be preferable to cantilever abutments because it moves the joint off the bridge to the end of the approach slab. The approach slabs will be supported by sleeper slabs, with the sidewalk and bridge rail constructed on top of the approach slab. In the south east corner, the end of the approach slab and the sleeper slab will be located within the intersection with Ferland Drive. In this corner it is recommended to construct the sidewalk on the approach slab, but drive the bridge approach rail beyond the slab instead of mounting it to the approach slab. This will allow the rail splice to be located only at the end of the bridge, which avoids the curved section of the rail needing to expand and contract with the bridge. Semi-integral abutment details will conform to the current NHDOT bridge design manual, which have been included at the end of this report.

Maintenance of Traffic

Two lanes of traffic will be maintained throughout construction, one lane in each direction, and the construction will be completed in two phases. This structure is located in close proximity to the proposed rail trail structure; therefore, the phases in which they are constructed will need to be coordinated to avoid impacting the other structure.

For the first phase of construction, two lanes of traffic will remain on the existing roadway while the northern portion of the proposed structure is built. The two westbound lanes, shoulders, and sidewalk will be constructed. Excavation support will be needed to support the existing roadway before excavating for the proposed footings, but because of the shallow depth to bedrock, tie back anchors may be required. During phase 1 construction, enough of the rail trail structure will need to be completed to support phase 2 traffic before moving on to phase 2.

During the first phase of construction, a portion of Abutment B will be located where the existing inlet for the 6-foot diameter corrugated pipe is located, which prevents the existing pipe from being utilized during construction to maintain stream flow. However, it may be possible to cut the existing pipe at the phase 1 excavation support and divert the water through the shortened existing pipe. Alternatively, a new temporary pipe could be installed through the existing roadway embankment to maintain stream flow during construction. This work will require multiple days of one-way alternating traffic or a temporary closure to excavate and install the pipe. Jacking the pipe through the embankment could be done, but would likely not be cost effective. Pumping the water and utilizing a temporary pipe bypassed just beneath the roadway surface to the east of Abutment B could also be an option.

To support phase 1 backfilling of the abutments, excavation support is required to support the new road while phase 2 excavation operations commence to construct the rest of each abutment. Traffic will be shifted onto the newly constructed westbound lanes for phase 2 construction while the four eastbound lanes, shoulders, and sidewalk are constructed.

Access to and from Ferland Drive, which is located just to the west of Abutment A, will be maintained during phase 1 construction. However, due to the 7- to 8-foot increase in grade for the newly constructed phase 1 portion of the road as compared to existing, access to and from Ferland Drive will only be maintained from the west during phase 2 construction. Traffic leaving Ferland Drive will be detoured west onto the existing Folsom Road / North High Street, onto the proposed High Street and then north to the proposed High Street and the Connector Road intersection. Traffic will then be detoured east onto the completed phase 1 section of the Connector Road and over the new phase 1 portion of the Shield Brook bridge. Traffic trying to turn left onto Ferland Road will travel the reverse of this same detour. For this detour to be feasible, a temporary intersection will need to be created to connect the existing Folsom Road / North High Street with the proposed High Street. The proposed intersection between the proposed High Street and the Connector Road will also need to be completed prior to phase 2 construction. It should be noted that traffic control for the Connector Road construction has not yet been determined. The above traffic control concept depends on a specific timeline. Changes to the Connector Road traffic control timeline will affect the phasing for the Shields Brook Bridge and access to and from Ferland Drive.

It should be noted that the turning radius for traffic traveling onto and off of Ferland Drive during phase 2 construction will need to be examined due to its proximity to the west structure approach. The intersection may need to be widened to maintain traffic without impacting the construction of the west approach and to provide construction access to the west side of the bridge.

Cost Estimate

A preliminary cost estimate, for the bridge only, has been prepared using the slope intercept method. The cost for the base bridge items was calculated using a square foot cost of $190.00 for the rolled steel girder option. This price was based on recently bid, similar type, projects.

63-Foot Span Steel Structure

Base Bridge Items:	$ 2,080,000
Cofferdams:	$ 290,000
Culvert Removal:	$ 20,000
Mobilization (10%):	$ 240,000
Engineering & Permitting (10%)	$ 270,000
Construction Engineering (15%)	$ 400,000
GRAND TOTAL	$ 3,300,000

Recommendations

The recommended bridge type is a 63-foot, simple-span, steel girder bridge with composite concrete deck supported on semi-integral abutments with spread footings. This option meets both NHDOT hydraulic requirements and NHDES Stream Crossing Guidelines and has the least amount of wetland impacts.

Please contact me if you have questions, comments, or require any additional information.

Sincerely,

Jaime French

Jaime French, PE
Bridge Team Lead | Project Manager

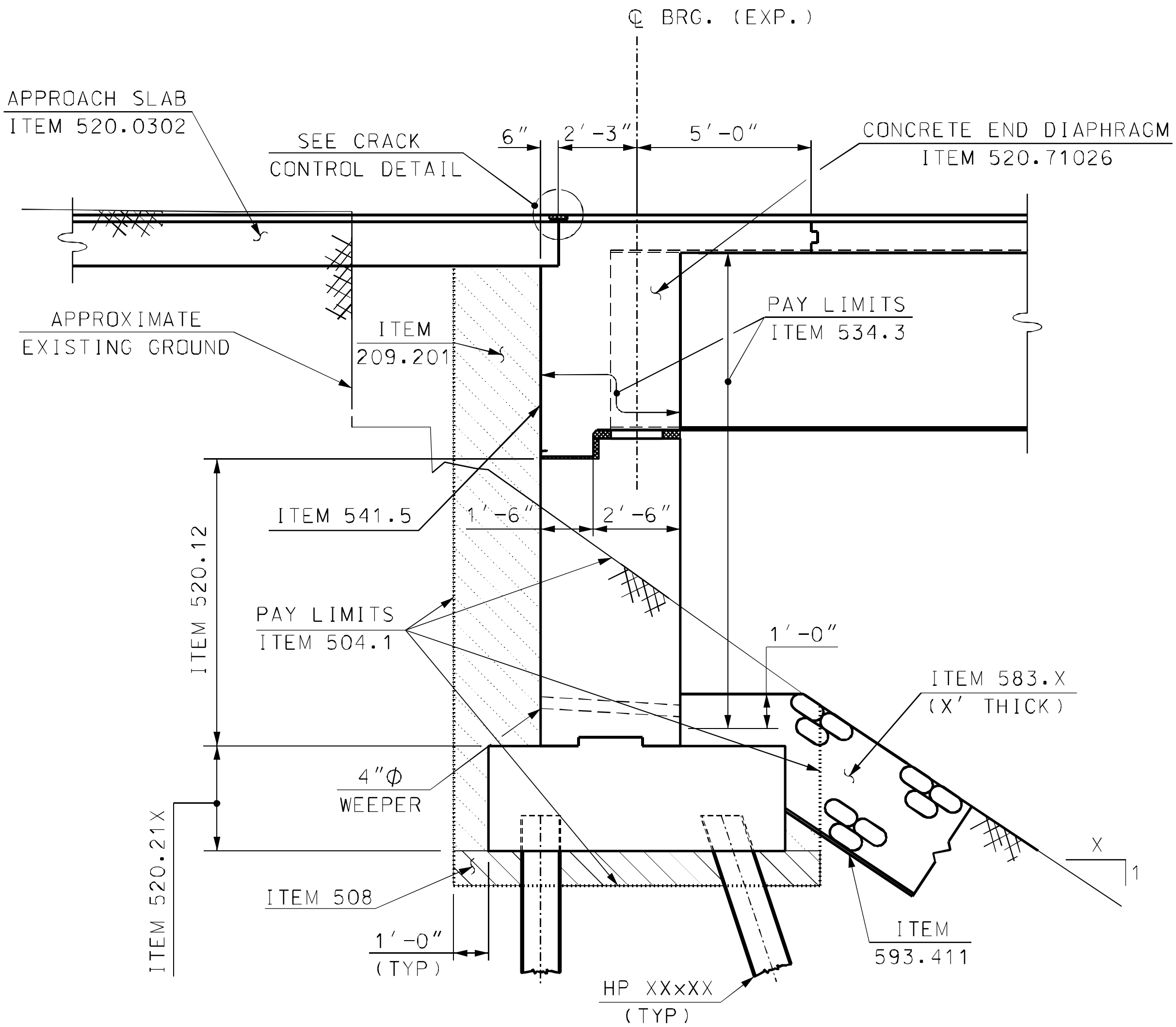
Enclosures

NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

BUREAU OF BRIDGE DESIGN

DESCRIPTION: SUBSTRUCTURE DETAILS - TYP. SEMI-INTEGRAL ABUTMENT SECTION

DATE REVISED: 2/8/2016



TYPICAL SEMI-INTEGRAL ABUTMENT SECTION

MODIFY TO FIT PROJECT

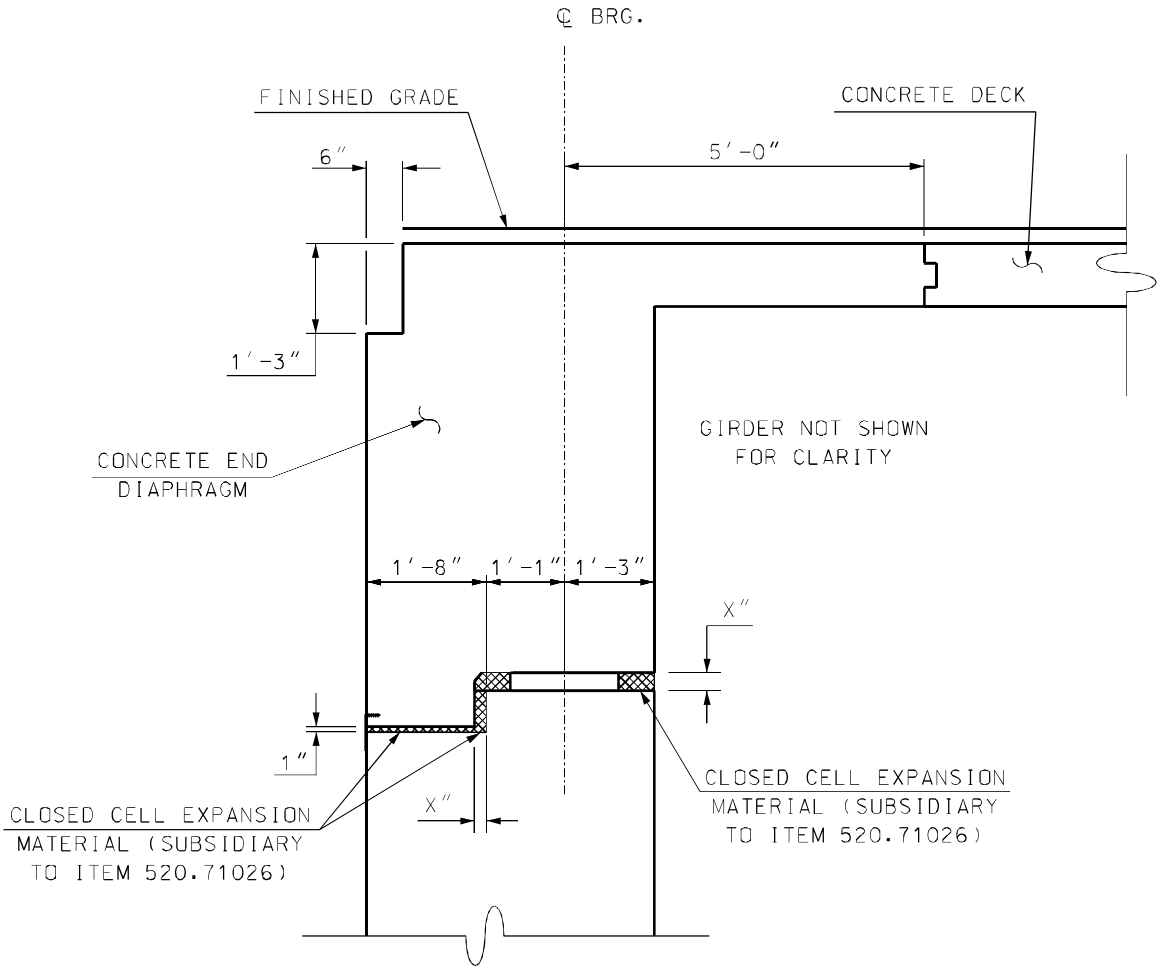
NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

New Hampshire DOT Department of Transportation

BUREAU OF BRIDGE DESIGN

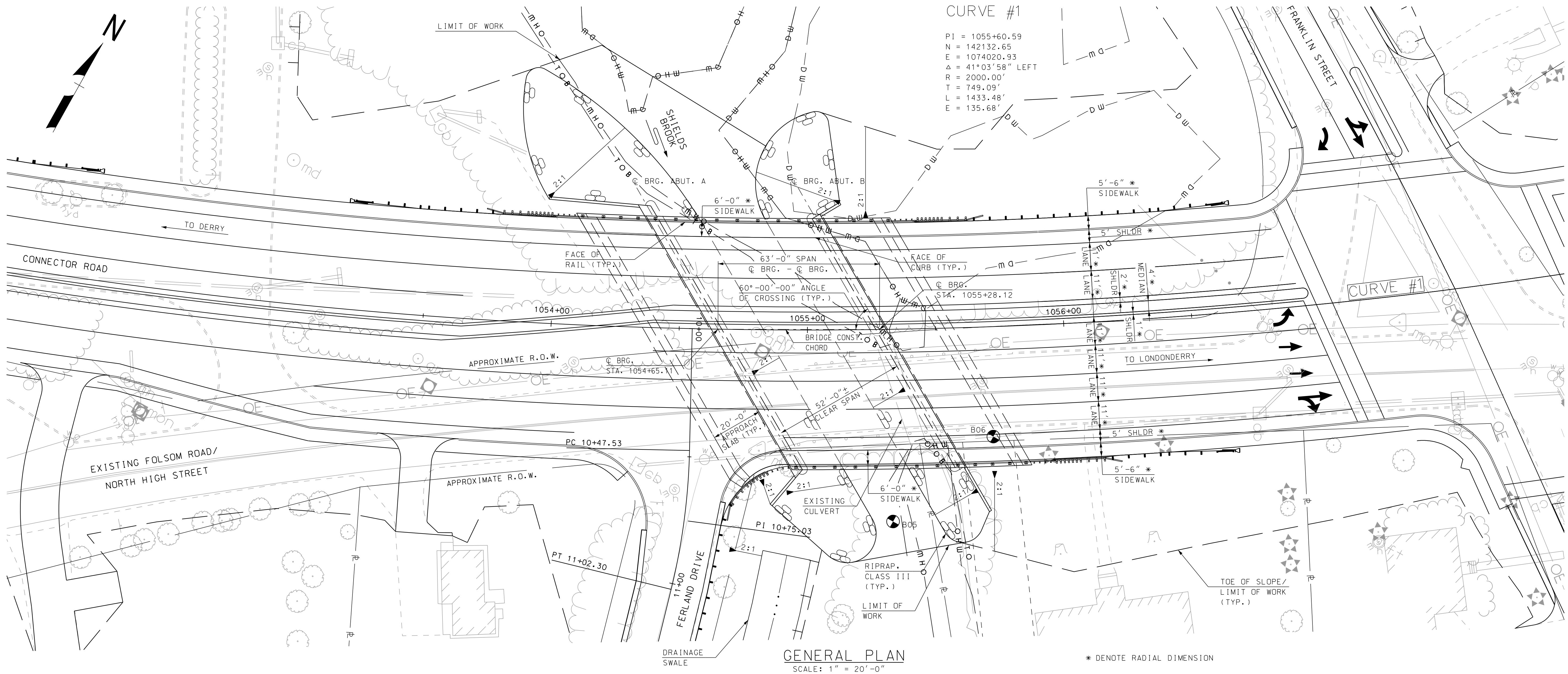
DESCRIPTION: SUBSTRUCTURE DETAILS - TYPICAL SEMI-INTEGRAL DIAPHRAGM SECTION

DATE REVISED: 2/8/2016



TYPICAL SEMI-INTEGRAL DIAPHRAGM SECTION

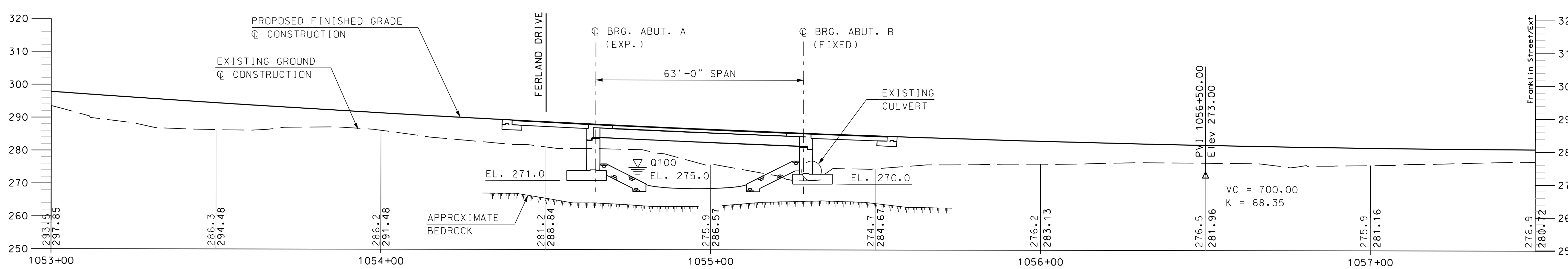
MODIFY TO FIT PROJECT



GENERAL PLAN

SCALE: 1" = 20'-0"

* DENOTE RADIAL DIMENSION



PROFILE

SCALE: 1" = 20'-0"

FUSS & O'NEILL

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN DERRY AND LONDONDERRY | BRIDGE NO. 053\110 | STATE PROJECT 13065

LOCATION THE CONNECTOR ROAD OVER SHIELDS BROOK

GENERAL PLAN AND PROFILE

BRIDGE SHEET 1 OF 3

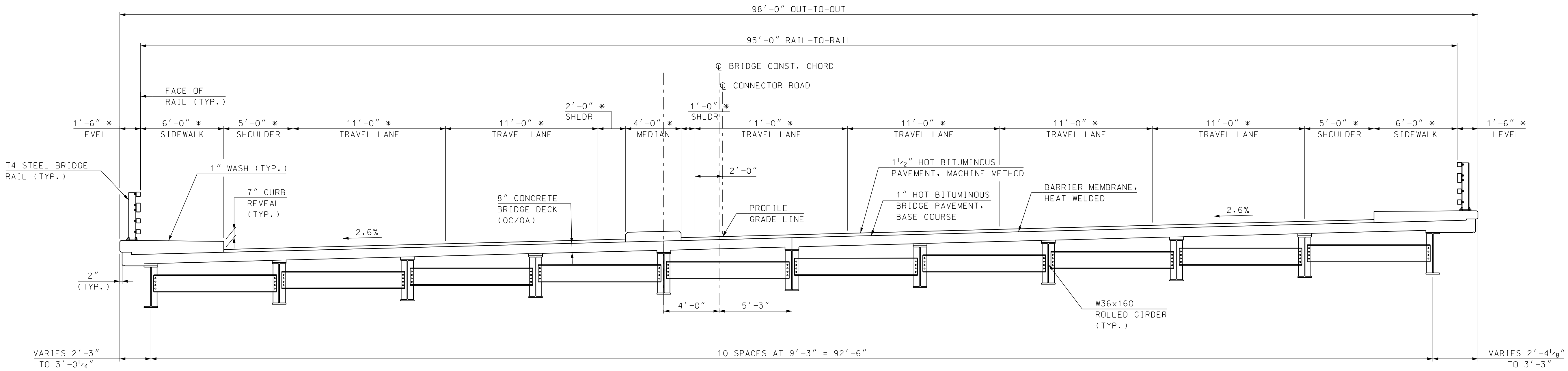
REVISIONS AFTER PROPOSAL

	BY	DATE		BY	DATE
DESIGNED	ETC	1/20	CHECKED	SRB	1/20
DRAWN	MWS	1/20	CHECKED	ETC	1/20
QUANTITIES			CHECKED		

FILE NUMBER

ISSUE DATE	FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE	------------	1	3

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
XX	13065PreGen	AS NOTED



* DENOTES RADIAL DIMENSION

TYPICAL DECK SECTION - STEEL BEAM OPTION

SCALE: ¼" = 1'-0"

FUSS & O'NEILL

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
XX	13065DeckSect	AS NOTED

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN DERRY AND LONDONDERRY BRIDGE NO. 053\110 STATE PROJECT 13065

LOCATION THE CONNECTOR ROAD OVER SHIELDS BROOK

TYPICAL BRIDGE SECTIONS

BRIDGE SHEET 2 OF 3

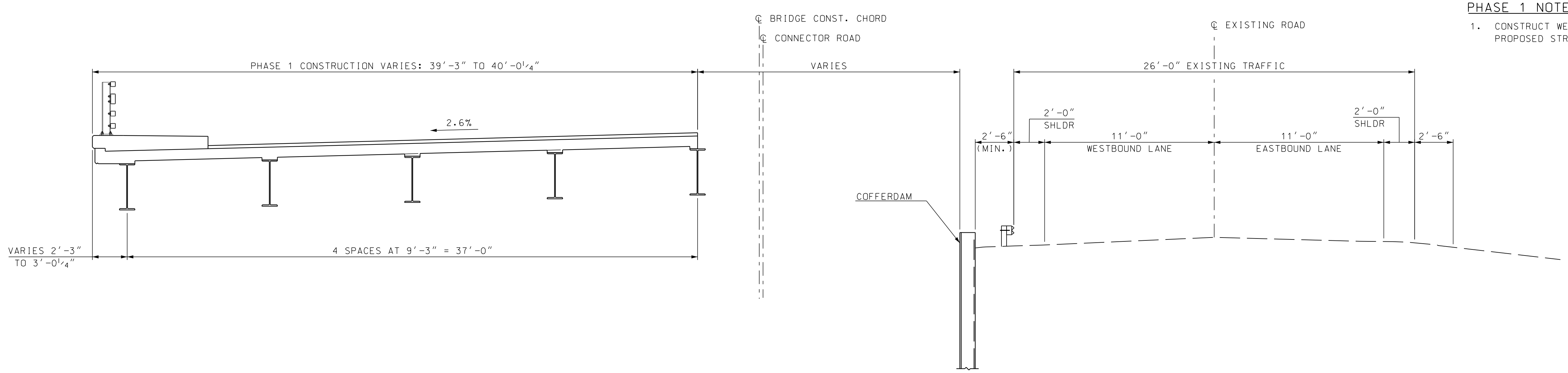
FILE NUMBER

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	ETC	1/20	CHECKED	SRB	1/20
	DRAWN	MWS	1/20	CHECKED	ETC	1/20
	QUANTITIES			CHECKED		

ISSUE DATE		FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE		------------	2	3

PHASE 1 NOTES:

1. CONSTRUCT WESTBOUND LANES OF PROPOSED STRUCTURE

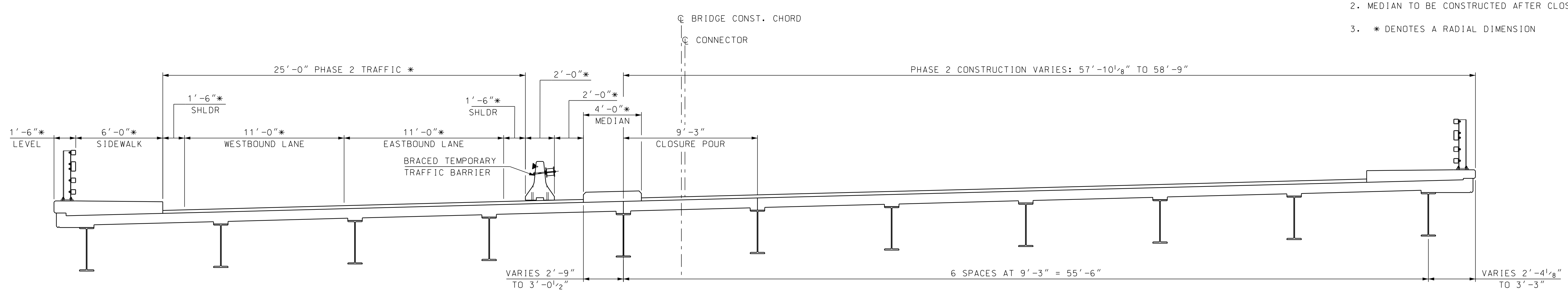


PHASE 1 CONSTRUCTION

SCALE: 1/4" = 1'-0"

PHASE 2 NOTES:

1. MOVE TRAFFIC ONTO WESTBOUND LANES AND CONSTRUCT EASTBOUND LANES.
2. MEDIAN TO BE CONSTRUCTED AFTER CLOSURE POUR.
3. * DENOTES A RADIAL DIMENSION



PHASE 2 CONSTRUCTION

SCALE: 1/4" = 1'-0"

FUSS & O'NEILL

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
XX	13065Phasing	AS NOTED

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN DERRY AND LONDONDERRY — BRIDGE NO. 053\110 — STATE PROJECT 13065

LOCATION THE CONNECTOR ROAD OVER SHIELDS BROOK

CONSTRUCTION PHASING - STEEL OPTION

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	ETC	1/20	CHECKED	SRB	1/20
	DRAWN	MWS	1/20	CHECKED	ETC	1/20
	QUANTITIES			CHECKED		

ISSUE DATE	FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE	------------	3	3

BRIDGE SHEET 3 OF 3

FILE NUMBER