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DATE: June 13, 2018, Revised June 25, 2018

SUBJECT: CDOT Project Code 22420 – US 550 S Connection to US 160 D-B
Bridge Foundations

This memo presents a summary of subsurface conditions, geotechnical considerations and preliminary foundation design recommendations for proposed Bridge Structures P-05-AZ (Bridge 1) and P-05-BA (Bridge 2) as shown on preliminary plans provided by CDOT for Project 19378 (Post-FIR dated 12-05-16). The recommendations are intended for use to develop Reference Design Plans for the Design-Build project.

Bridge 1

This proposed bridge will have a total length of approximately 520 feet and will be a four span structure with 2 abutments and 3 piers. The proposed roadway profile will require cuts to depths ranging from approximately 25 feet to 40 at the abutments.

Fifteen (15) borings were drilled to investigate subsurface conditions at Bridge 1. The boring locations and logs are shown on the attached Engineering Geology plan sheet. The conditions encountered in the borings generally consist of 5 to 20 feet of clayey sand soil or clayey sand and gravel over dense alluvial terrace gravel or claystone/shale bedrock. A summary of the conditions encountered in each boring at Bridge 1 is provided in Table 1.

The plan location of Abutment 1 is in an area that has been mapped as a landslide. Borings B1-01 and B1-02 were drilled at the proposed location of the south abutment as shown on the plans. These borings encountered silty sand soil over sandy gravel with cobbles and boulders. Bedrock was encountered at depths of 89 feet and 88 feet respectively. The bedrock surface elevation is, in general, lower in these borings than in other nearby borings.

Table 1 Summary of Bridge 1 Borings

Boring	Station	Offset	Total Depth (ft)	Approx. Cut (ft)	Depth to Gravel (ft)	Depth to Bedrock (ft)
B1-1B	1013+18	36’ LT	79.1	20	16.5	66.5
B1-2A	1013+38	31’ RT	89.2	30	27	79.0
B1-1A	1013+80	17’ RT	122.0	17	18	100.4
B1-01	1013+94	24’ LT	106.0	9	9	89.0
B1-02	1014+08	29’ RT	101.0	7	0	88.0
B1-03	1014+68	24' RT	48.5	n/a	0	35.0
B1-04	1015+09	1' RT	55.0	n/a	0	1.5
B1-05	1015+39	20' LT	45.0	n/a	0	9.0
B1-06	1015+60	24' RT	32.7	n/a	0	10.3
B1-07	1015+72	41' LT	40.0	n/a	0	21.0
B1-08	1016+11	0'	70.0	n/a	0	7.0
B1-09	1016+55	0'	70.0	n/a	0	5.0
B1-10	1017+80	1' LT	70.0	n/a	0	6.7
B1-11	1019+17	21' LT	70.2	n/a	0	15.2
B1-12	1019+20	25' RT	70.4	n/a	0	13.0

We believe irregular erosion of the bedrock near the proposed location of Abutment 1 has resulted in a bedrock surface depression that was subsequently infilled with a mixture of clayey soils and terrace deposits that contains cobbles and boulders (slope wash). The slope wash materials were transported by erosion and gravity from their original alluvial deposit and are expected to be less stable in the long term than the undisturbed alluvium. Boring B1-01A was drilled south of the abutment location to identify the extent of the bedrock depression and slope wash materials. This boring encountered conditions similar to those in Borings B1-01 and B1-02, with bedrock at a depth of approximately 100 feet. Borings B1-01B and B1-02A were drilled approximately 80 feet south of the planned location of Abutment 1. These borings encountered clayey surficial soils overlying terrace alluvium that appears to be unaltered by recent erosion. These in-place alluvial materials are expected to have good foundation support characteristics.

The landslide mapped near Abutment 1, and shown on the Engineering Geology sheet, appears to consist of slope wash materials and possibly underlying weathered and fractured bedrock that are slowly moving down the slope. Inclinometers were installed in Borings B1-03, B1-05, B1-06 and B1-07 to measure the rate, direction and depth of slope movement. Data collection from the instrumentation began in early April 2018 and no significant movement had been observed as of May 26, 2018. The upper portion of the materials that form the landslide is expected to be removed during grading for the roadway. The removal will reduce the potential for landslide activation by decreasing the forces that drive movement.

Borings B1-05, B1-06, B1-09 and B1-10 were drilled at proposed pier locations for Bridge 1. These borings encountered approximately 5 to 10 feet of sandy gravel slope wash deposits over highly weathered to unweathered bedrock. The bedrock consists of claystone, sandstone and interbedded claystone/sandstone/shale. Generally, the upper 20 to 30 feet of the bedrock is weathered or weak and should be considered an Intermediate Geo Material (IGM) as defined in

the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications (AASHTO Specifications). Below the IGM, bedrock consists of hard sandstone and shale. Unconfined compressive strengths of samples from the IGM ranged from 1,072 psi to 1,405 psi. The unconfined compressive strength of samples from the hard sandstone and shale ranged from 2,843 psi to 5,496 psi.

Subsurface conditions at the proposed location of Abutment 5 were investigated by drilling Borings B1-11 and B1-12. The conditions encountered below about 5 feet of slope wash deposit (gravel in a sandy clay matrix, cobbles and boulders) consist of medium dense to dense terrace alluvium (gravel in a silty sand matrix, cobbles and scattered boulders). Interbedded sandstone and claystone bedrock was encountered below the terrace alluvium at depths ranging from 13 to 15 feet.

Bridge 2

The proposed Bridge 2 is a two-span structure with a total length of 264 feet. The bridge will have 2 abutments and a single center pier. The roadway profile shows the cut depths below existing ground at the approaches ranges from approximately 30 to 40 feet.

The subsurface conditions at Bridge 2 were investigated by drilling 4 borings: Boring B2-01 at Abutment 1, Boring B2-03 at Pier 2, Boring B2-04 at Abutment 3 and Boring B2-02 on the slope below Abutment 1. The subsurface conditions encountered in the borings generally consisted of about 4 to 8 feet of slope wash deposits of sandy clay soil or sand and gravel, overlying moderately weathered to hard claystone, sandstone and shale of the Animas Formation. A summary of the conditions encountered in each boring at Bridge 2 is provided in Table 2. The boring locations and logs are shown on the attached Engineering Geology plan sheet. A potential landslide was identified at the location of Abutment 1. The landslide consists of the slope wash deposits encountered at Abutment 1 and in Boring B2-02. The proposed cut for the roadway at this location will effectively remove most of the upper portion of this landslide feature, thereby reducing forces that drive movement and improving the long term stability of this slope.

Table 2 Summary of Bridge 2 Borings

Boring	Station	Offset	Total Depth (ft)	Approx. Cut (ft)	Depth to Gravel (ft)	Depth to Bedrock (ft)
B2-01	1029+55	3' RT	58.8	n/a	n/a	5.0
B2-02	1030+32	0'	70.2	n/a	n/a	7.8
B2-03	1030+88	3' LT	69.0	n/a	n/a	4.0
B2-04	1032+19	2' RT	69.9	n/a	n/a	7.2

The upper 13 to 26 feet of the bedrock should be considered an IGM for foundation design purposes. Below the IGM, the bedrock encountered consists of interlayered sandstone and claystone that is slightly weathered to hard.

Foundations

Spread footing and drilled caisson foundations may be appropriate for support of the abutments and piers of Bridges 1 and 2, depending on the foundation location. Placement of foundations on the slope wash materials should be avoided because of the potential for long term differential settlement. The landslide soils identified near Abutment 1 of Bridge 1 and Abutment 1 of Bridge 2 are unsuitable for support of foundations.

Spread Footings: Based on the conditions encountered at Abutment 1 of Bridge 1, it is assumed that a spread footing foundation bearing on the alluvial terrace deposit will be designed for this location. Spread footings bearing on the alluvial terrace deposit can be designed for a nominal bearing resistance of 75 ksf for an assumed footing width of 8 feet. A bearing resistance factor of 0.45 should be used in the design. Nominal sliding resistance should be calculated using equation 10.6.3.4-2 in AASHTO (2017) for an internal friction angle of drained soil of 38 degrees. A sliding resistance factor of 0.80 should be used for cast-in-place concrete.

The weathered claystone bedrock encountered immediately beneath the slope wash deposits at pier locations of Bridge 1 and at abutment and pier locations of Bridge 2 is suitable for support of spread footings. The claystone will degrade over time and is expected to have strength properties similar to a clay soil over the long term. Spread footings placed on the weathered claystone can be designed for a nominal bearing resistance of 18 ksf. A bearing resistance factor of 0.50 should be used in the design. Nominal sliding resistance should be calculated using a Coefficient of Friction of 0.45. A sliding resistance factor of 0.85 should be used for cast-in-place concrete.

Settlement of spread footings placed on alluvial terrace deposits or weathered claystone bedrock is expected to be less than 1 inch. The settlement will occur during or soon after construction. Long term consolidation settlement of spread footings placed on these materials is not anticipated.

Drilled Caissons: The relatively shallow depth to bedrock makes drilled caisson foundations an attractive alternate for all of the proposed bridge foundation elements except Abutment 1 of Bridge 1. Drilling caissons through the slope wash deposits that overlie the bedrock may encounter large cobbles or boulders. Penetration of the slope wash soils with small diameter drilled caissons may be difficult and drilled caissons should have a minimum diameter of 30 inches.

Drilled caissons embedded in weathered to unweathered or hard claystone/sandstone/shale bedrock can be designed for a nominal base resistance of 90 ksf and a nominal side resistance of 9.0 ksf. We recommend a tip resistance factor of 0.50 and a side resistance factor of 0.60. Caissons should penetrate a minimum shaft length of 2 shaft diameters into bedrock. The upper 5 feet of side resistance should be neglected when calculating caisson axial capacity.

For lateral loading analysis using LPILE, the parameters in Table 3 may be used:

Table 3. LPILE Parameters for Drilled Shafts

Soil Type	LPILE Soil Criteria	Effective Unit Weight (pcf)	Friction Angle, ϕ (degrees)	Undrained Cohesion (psf)	Strain Factor, ε50	p-y Modulus, k (pci)
Slope Wash	Sand (Reese)	130	30	----	----	25
Weathered Bedrock (IGM) to Unweathered/Hard bedrock	Stiff Clay w/o Free Water (Welch & Reese)	135		8000	0.005	

The minimum spacing requirements between drilled shafts should be three diameters from center to center. For lateral loading, recommended P multipliers are 0.5 for tangent shafts, increasing linearly to 1.0 for shafts placed at 3 diameters or greater. Additional capacity reduction factors can be provided if required for conditions other than those anticipated.

Lateral earth pressures on abutment walls and wingwalls can be calculated in accordance with Article 3.11.5.1 of the AASHTO LRFD Specifications. A soil unit weight of 135 pcf and an angle of internal friction of 34 degrees should be used for backfill consisting of CDOT Structure Backfill (Class 1). Drilled caissons in landslide areas should be designed to resist additional lateral loads due to potential movement of the slope wash materials that make up the landslides. Lateral loads should due to sliding slope wash soils should be estimated with slope stability analysis after caisson dimensions are available.

Seismicity

The site of Bridges 1 and 2 is classified as Site Class C, Soft Rock in accordance with Table 3.10.3.1-1 of the 2017 AASHTO Guide Specifications for LRFD Bridge Design. The Peak Ground Acceleration (PGA), and the short- and long-period response spectral acceleration coefficients (SS and S1 respectively) for the reference site (Table 4) were obtained using the USGS Design Maps tool for an event with a 7% Probability of Exceedance (PE) in 75 years and a Site Class B (reference site). An event with the above probability of exceedance has a return period of about 1,000 years. Because the bridge sites classification (Class C) is different from the reference site (Class B), site specific value adjustments are necessary. The seismic design parameters for the site are shown on Tables 4 and 5. These values may be used to construct the Design Response Spectrum for use in the seismic design of bridge structures.

Table 4. Seismic Parameters for Reference Site Class B

Site Class	PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
B	0.061 g	0.134g	0.041 g

Table 5. Seismic Design Parameters for Bridges 1 and 2

Site Class	A_S (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)	Seismic zone
C	0.073 g	0.161 g	0.069 g	1

Attachment: Engineering Geology Plans Sheets (Bridge 1 and Bridge 2)

LEGEND

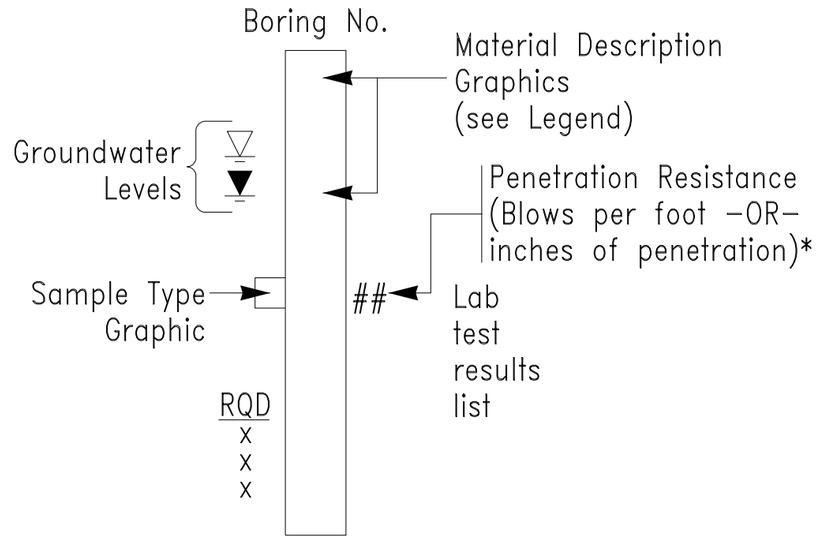
Soil Lithology

- Asphalt
- Fill with Gravel as major soil
- USCS Low Plasticity Sandy Clay
- USCS Clayey Sand
- USCS Clayey Gravel
- USCS Low Plasticity Sandy Clay
- USCS Poorly-graded Sandy Gravel
- USCS Silty Sand
- USCS Low Plasticity Silty Clay
- USCS Clayey Sand
- USCS Poorly-graded Gravelly Sand
- USCS Low Plasticity Clay

Rock Lithology

- Alternating layers of sandstone and shale

TYPICAL BOREHOLE LOG



*e.g. A value of 50/3 or 50:3 indicates that 50 blows were applied to the sampler, with a penetration of 3 inches.

For additional information, refer to Geotechnical Report, DATE, prepared by Yeh and Associates, Inc.

Print Date: 4/10/2018		Sheet Revisions			Colorado Department of Transportation	As Constructed	US 160/550 PLAN CONNECTION SO. ENGINEERING GEOLOGY	Project No./Code
File Name: 017_22420_Engineering Geology Legend and Typical Sheet.dgn		Date:	Comments	Init.	3803 North Main Avenue, Suite 200, Durango, CO 81301	No Revisions:		NHPP 5501-029
Horiz. Scale: 1:50 Vert. Scale: As Noted					Phone: 970-385-1440 FAX: 970-385-8365	Revised:	Designer: TA / Structure Numbers	22420
Unit Information Unit Leader Initials					Region 5 DRV	Void:	Detailer: LR / Sheet Subset: / Subset Sheets:	Sheet Number
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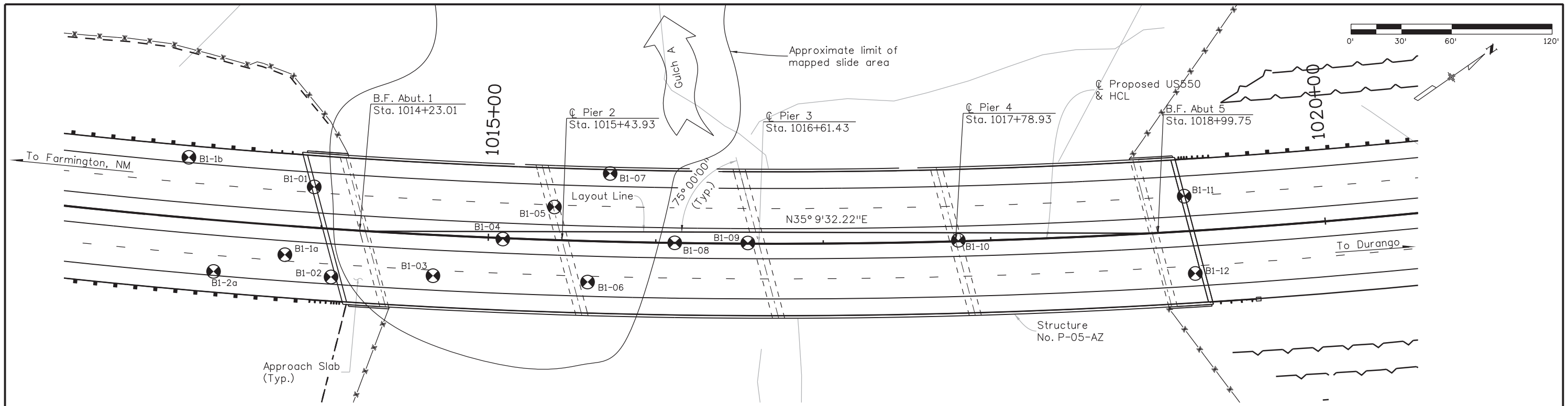

Print Date: 6/6/2018	Sheet Revisions		
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US 160/550
CONNECTION SO.
ENGINEERING GEOLOGY BRIDGE 1

Designer:
Detailer:
Sheet Subset: EG-BRIDGES
Structure Numbers: P-05-AZ
Subset Sheets: 1 OF 2

Project No./Code
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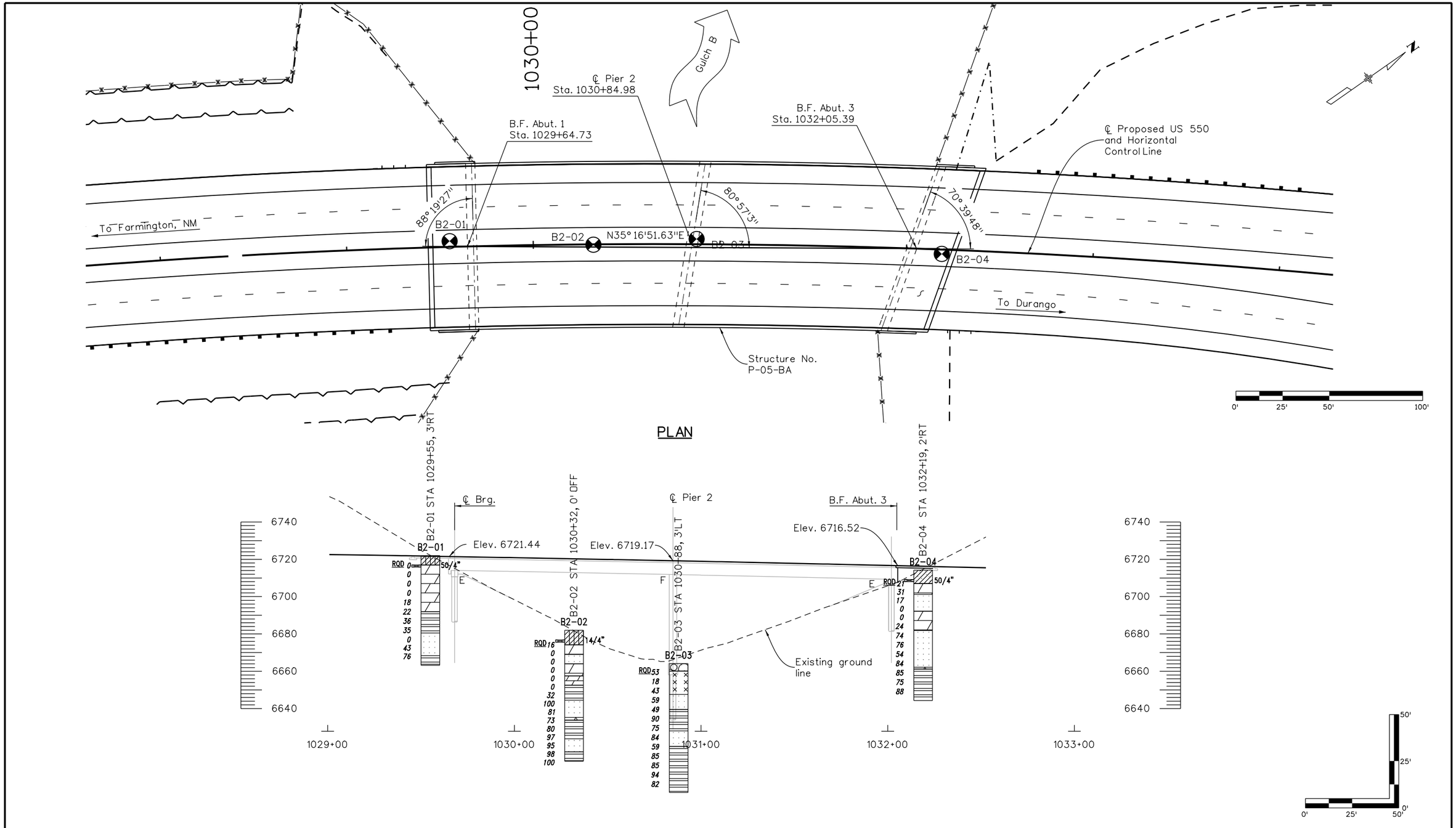

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File Name: 020_22420_Bridge B_PnP (Eng Geol).DGN		Date:	Comments	Init.	3803 North Main Avenue Suite 200 Durango, CO 81301 Phone: 970-385-1440 FAX: 970-385-8365	No Revisions:		NHPP 5501-029
Horiz. Scale: 1:50 Vert. Scale: As Noted						Revised:	Designer:	Structure Numbers: P-05-BA
Unit Information Unit Leader Initials						Void:	Detailer:	22420
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