FORSGREN Associates Inc.

MEMORANDUM

DATE: April 4, 2014

TO: Jim Hamilton, Mammoet

CC: Shanon Murgoitio, ITD

FROM: Christopher M. Atkinson, E.I.T. / Jason W. Wolfe, P.E.

RE: Overweight Load Permit Assistance; For Mammoet Calumet Reactor Configuration T04 Rev 00; Long Bridge over Lake Pend Oreille. (3 Pages)

This memo summarizes the results and recommendations from the load rating analysis of the Long Bridge on US-95 over Lake Pend Oreille (Bridge Key 18715) following ITD Bridge procedures for overweight truck permit application reviews.

Mammoet is currently unable to utilize I-90 for the Calumet Reactor Configuration T04 Rev 00 truck configuration (referred to as "the truck configuration", see Figure 1). Originally the route for the configuration proceeded from the port in Lewiston up US-95 and along I-90 to the Idaho/Montana border. Mammoet requested that Forsgren Associates analyze the Long Bridge which is on the proposed alternate route that uses US-95 from Coeur d'Alene to Sandpoint then SH-200 to the Idaho/Montana border.

Description of 'The Long Bridge'
The Long Bridge (bridge key 18715) across Lake Pend Oreille is a 180-span structure, with four superstructure unit types (see Figure 2):

- **Navigation Span:** One unit is a simple, one-span structure called the navigation span. The navigation span bridges a distance of 81ft and uses adjacent pre-stressed concrete box girders with a 4" reinforced concrete slab.
- **Three-Span Unit:** Two units are three-span continuous superstructures found at either end of the bridge. The span configuration is 34'-7", 35 feet, and 35 feet.
- **Six-span Unit:** On either side of the navigation span is a six-span continuous superstructure unit. Five of the six spans are 35ft. A shorter 17ft span is found three spans away from either side of the navigation span.
- **Seven-Span Unit:** Finally, there are twenty-eight continuous seven-span units. Six of the seven spans are 35ft and the span in the center of each unit is 17ft.

With the exception of the navigation span, the superstructures of each span are made with pre-stressed adjacent five-T-girders topped with a 4" reinforced concrete deck. The deck carries two lanes of traffic, has a roadway width of 39'-2" and an overall deck width of 42'-2".

Initial Analysis
The inspection report for the bridge was reviewed. The report records minor deterioration. After review of the report, it was determined that the noted deterioration is not anticipated to affect the load rating analysis.

The Mammoet configuration was applied to the Long Bridge BrR models supplied by ITD. The results of this initial analysis are summarized in Table 1. Three items in the structure warranted further analysis.

1. The truck configuration resulted in an operating rating less than 1.0 for the six-span units. The controlling rating occurred at piers 14 and 19 (as labeled in Figure 2). The rating is due to positive moment at these supports. Since a positive moment at the supports is not created with standard truck configurations, the ITD load rating model did not include a continuity diaphragm at the supports.

2. In addition to positive moments, uplift is also generated at piers 6, 7, 13, 14, and all similar locations throughout the bridge (see Figure 2). A check of the resistance to uplift was warranted.

3. The simply supported “Navigation Span” of the structure model was initially rated as a line girder in BrR, due to limitations of the program at the time of the original rating. The load rating value shown in Table 1 does not reflect any adjustment in the live load distribution factor to account for the narrow gage of the Mammoet configuration. In lieu of adjusting the LLDF, the load rating model was revised from a line girder to a girder system.

Continuity Diaphragms
The Mammoet truck configuration causes a unique loading case for the Long Bridge with a significant positive moment at piers 14 and 19 (see Figure 2). The low rating was attributed to exceeding the concrete tensile strength of the continuity diaphragm. Noting the significant positive moment it was determined that the continuity diaphragm should be modelled for the given truck configuration.

The design plans and shop drawing of the structure were used to determine the amount of reinforcing steel in the continuity diaphragms at the piers. The capacity of the steel was calculated using the design guidance of the AASHTO Standard Specifications. This reinforcement steel could not be fully developed as detailed in the shop drawings and design plans. The allowable resistance was scaled accordingly and was modeled in BrR. (See the appendix for calculations.)

Results of the analysis with the Calumet Reactor T04 Rev 00 truck configuration, for the girders mentioned, with the update to the model yielded a load rating of 1.039. (Results are detailed in Table 2.)

Check of Uplift Capacity

Uplift of the 17ft spans of the six-span and seven-span continuous units of the Long Bridge was shown to be significant in the software modelling results. BrR is currently unable to assess the strength of structures against uplift forces.

Relying upon the design plans and shop drawings, the capacity of the steel dowels that tie the diaphragms to the piers was evaluated. The strength of the embedment of the steel in the pier and diaphragms was also calculated. Using the results from the updated BrR model of the bridge, the factored uplift and dead load forces at the controlling pier were determined and summed. The load rating result of the uplift capacity with the truck configuration is 2.423. (See calculations in the Appendix.)

Modelling of the Navigation Span

The original BrR model of the Long Bridge navigation span was created using the line girder method. Although the initial rating results were above one, they were based on live load distribution factors for standard gage widths. Adjusting the live load distribution factors to reflect the narrow gage of the Mammoet configuration would have resulted in a rating value below 1.0. Preliminary review of the bridge indicated that the structure is a girder system, and as such could be modelled more accurately in BrR, with the benefit of interacting girders that better distribute the truck loads.

The plans indicated that the girders were similar in strength, keyed together by grout, and tied with rods at the third points. The simple span is also covered with a composite reinforced concrete slab similar to the continuous spans which helps distribute live loads. The design calculations stated clearly that the navigation span was designed as a girder system for purposes of live load distribution. The inspection report did not have any record of longitudinal cracking of the navigation span deck, which would indicate a line girder design behavior.

Consultation with HDR (creators of the original model) also indicates that BrR could only model prestressed box girders as line girders with the versions of VIRTIS being used in 2010. The review and consultation concluded that the line girder method was used due to the limitations of Virtis (now BrR) software at the time, and not for any structural concerns.

Forsgren Associates used the existing model information to create a girder system model of the navigation span. The analysis using the girder system yielded a controlling rating of 1.306 for the navigation span with the Mammoet truck configuration.

Conclusion

Upon reviewing the Long Bridge (bridge key 18715) with the Calumet Reactor T04 Rev 00 Truck Configuration and per ITD policy, an operating rating factor of greater than 1.0 has been computed for each of the bridge units for the Long Bridge. It is recommended that the vehicle proceed down the centerline of the bridge with no other vehicles allowed on the bridge. A reduced speed of 10mph or less is also recommended.

Table - 1: Results of initial load rating analysis

Structural Unit	Operating Rating	Controlling Span	Span Length (ft)	Location (ft)	Controlling Girder	Model Type	Analysis Type	Truck	Limit State	Design Impact (%)	Permit Rating Impact (%)	LLDF (lanes)	Status
Navigation Span	1.063	1	81	40.5	1-9	Girder Line	Line Girder	Half Truck; Standard Gauge	Flexure	24%	10%	0.342	Develop girder system model to analyze non-standard gauge truck .
Three-Span Unit	1.197	1	34.58	34.58	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.29	OK, no further analysis required.
Six-Span Unit	0.748	4	17	17	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.288	Requires Further Analysis. Check uplift at piers.
Seven-Span Unit	1.038	3	35	35	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.29	Rating OK, check uplift at piers.

Table - 2: Results of final load rating analysis

Structural Unit	Operating Rating	Controlling Span	Span Length (ft)	Location (ft)	Controlling Girder	Model Type	Analysis Type	Truck	Limit State	Design Impact (%)	Permit Rating Impact (%)	LLDF	Status
Navigation Span	1.306	1	81	40.5	4	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	24%	10%	0.18	OK, no further analysis required.
Three-Span Unit	1.197	1	34.58	34.58	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.29	OK, no further analysis required.
Six-Span Unit	1.039	4	17	17	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.288	OK, no further analysis required.
Seven-Span Unit	1.038	3	35	35	3	Girder System	Distribution Factor-Line Girder	Full Truck; Non-Standard Gauge	Flexure	30%	10%	0.29	OK, no further analysis required.

REACTOR

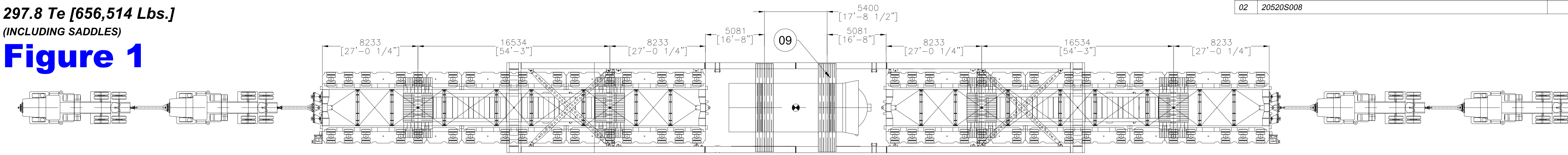
297.8 Te [656,514 Lbs.]

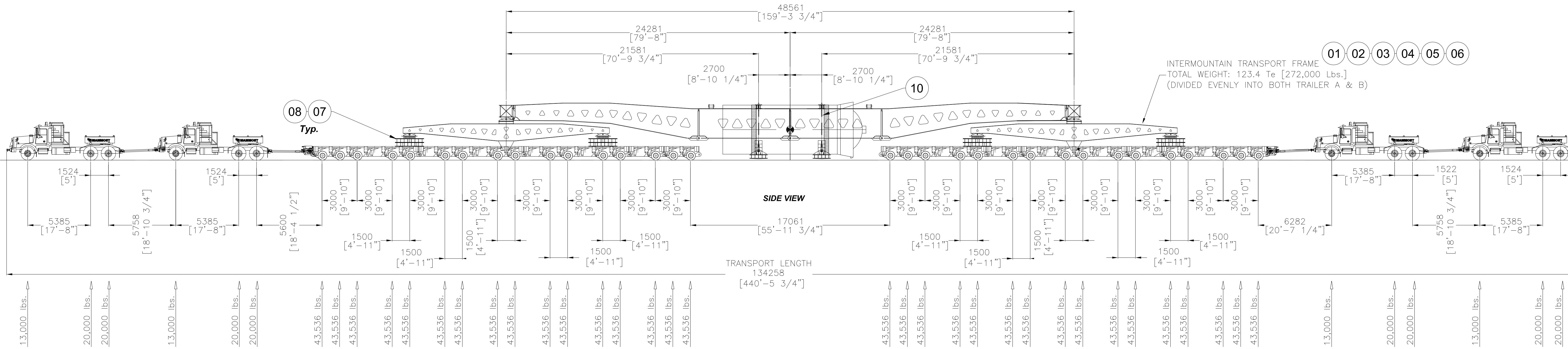
(INCLUDING SADDLES)

Figure 1

REF	DRAWING NUMBER	REVISION
01	200000520-D-009	03
02	20520S008	00

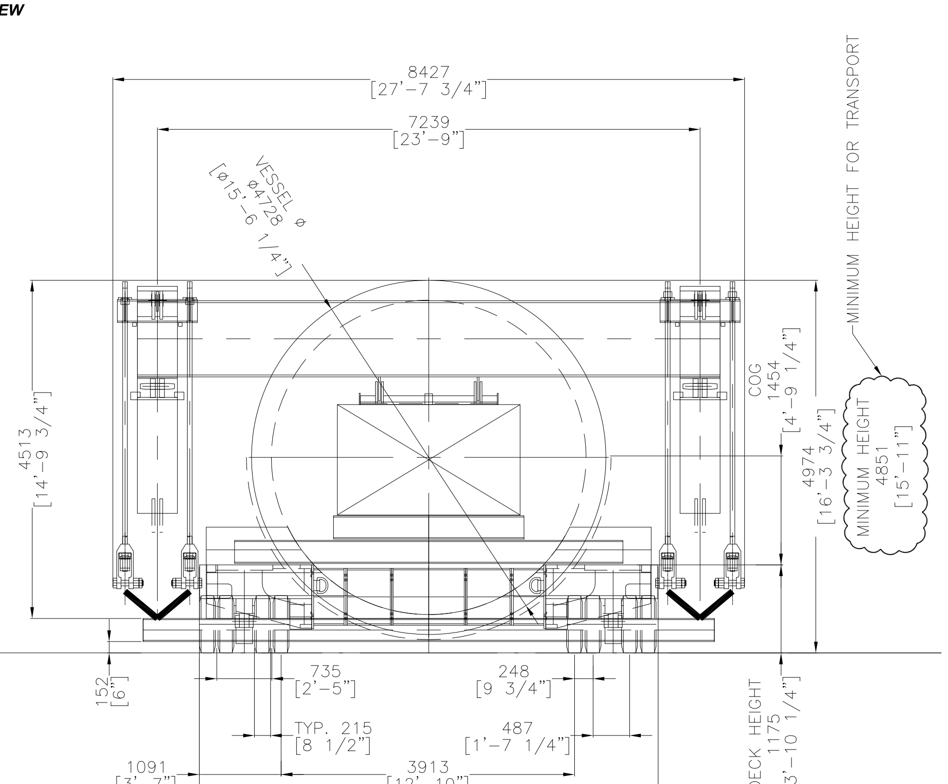
PLAN VIEW





GROSS WEIGHT OF TRANSPORT = 728.1 Te [1,605,152 LBS.]

END VIEW



LOAD DESCRIPTION: Reactor

VEHICLE DESCRIPTION: [2x] 20' 16 L Road Style Goldhofer w_Frame

UNITS:	METRIC		ENGLISH	
LOAD WEIGHT:	297.8	Te	656,514	lbs
SADDLE WEIGHT:	0.0	Te	0.0	lbs
FRAME WEIGHT:	153.7	Te	338,828	lbs
TURNTABLE WEIGHT:	0.0	Te	0.0	lbs
TRUCK WEIGHT:	96.2	Te	212,000	lbs
TRAILER WEIGHT:	180.4	Te	397,810	lbs
TOTAL WEIGHT:	728.1	Te	1,605,152	lbs
LOAD/LINE	19.7	Te	43,536	lbs
LOAD/ AXLE	9.9	Te	21,768	lbs
LOAD/WHEEL	2.5	Te	5,442	lbs
LOAD/LAT. INCH	0.3	Te	640	lbs

FOR PERMIT

MATERIALS LIST

POS	QTY	DESCRIPTION	MATERIAL/ CAPACITY	DIMENSIONS	WEIGHT (lbs / ea)
01	*4*	*Intermountain Frame Necks*		*52'-0"*	
02	*6*	*Intermountain Mid. Sections*		*25'-8"*	
03	*2*	*Intermountain Header Beams*		*25'-6"*	
04	*2*	*Intermountain Loadspreaders*		*57'-11"*	
05	*8*	*Intermountain Long Cross Bracing*		*30'-4"*	
06	*4*	*Intermountain Short Cross Bracing*		*21'-4"*	
			Intermountain Frame Total Weight:		*272000*
07	*2*	*Steel mats 8'*		*8'-4" x 8'-1" x 1'*	*4520*
08	*8*	*Steel mats 17'*		*17' x 4'-1" x 1'*	*4610*
09	*2*	*Hanger Steel Mats 25'*		*25' x 4' x 1*	*6454*
10	*4*	*Auxilary Hanger Equipment*			*2000*
				Grand Total:	*338828*

GENERAL NOTES

1	FIELD VERIFY ALL DIMENSIONS
2	THE CLIENT IS RESPONSIBLE FOR THE STRUCTURAL INTEGRITY OF THE LOAD TO BE TRANSPORTED.
3	THE CLIENT IS TO IDENTIFY AND CONFIRM THE SUITABILITY OF THE SUPPORT POINTS TO BE UTILIZED DURING THE TRANSPORT OF THE LOAD.
4	SECURE CARGO ONTO THE TRAILER USING LASHING MATERIAL TO PREVENT SLIDING AND/OR TIPPING OFF THE LOAD.
5	ALL CHAINS GRADE 70, 1/2"" 11,300 lbs. CAPACITY (SINGLE) AND TIGHTENED WITH BINDERS (NOT SHOWN) 13,000 lbs. CAPACITY.
6	3/4"" PLYWOOD OR ANTI SLIP MATERIAL TO BE USED BETWEEN ALL STEEL CONTACT AREAS TO PROMOTE FRICTION.
7	MAXIMUM WEIGHT AND DIMENSIONS SHOWN FOR REACTOR TRANSPORT
8	SUBJECT TO FINAL ENGINEERING

REV.	DESCRIPTION:	DATE:	DRAWN:	CHECKED:
00	*First Issue*	07/10/13	RLam 940443	JLaw 940062

Without authorized signatures this document is uncontrolled, not binding and for indicative purposes only.

CLIENT: ***CH2M HILL / Calumet Montana Refining***

PROJECT: ***Great Falls, Montana***

TITLE: ***Permit Transport of Reactor with [2x] 20' 16 L Road Style Goldhofer w_Frame***

MAMMOET
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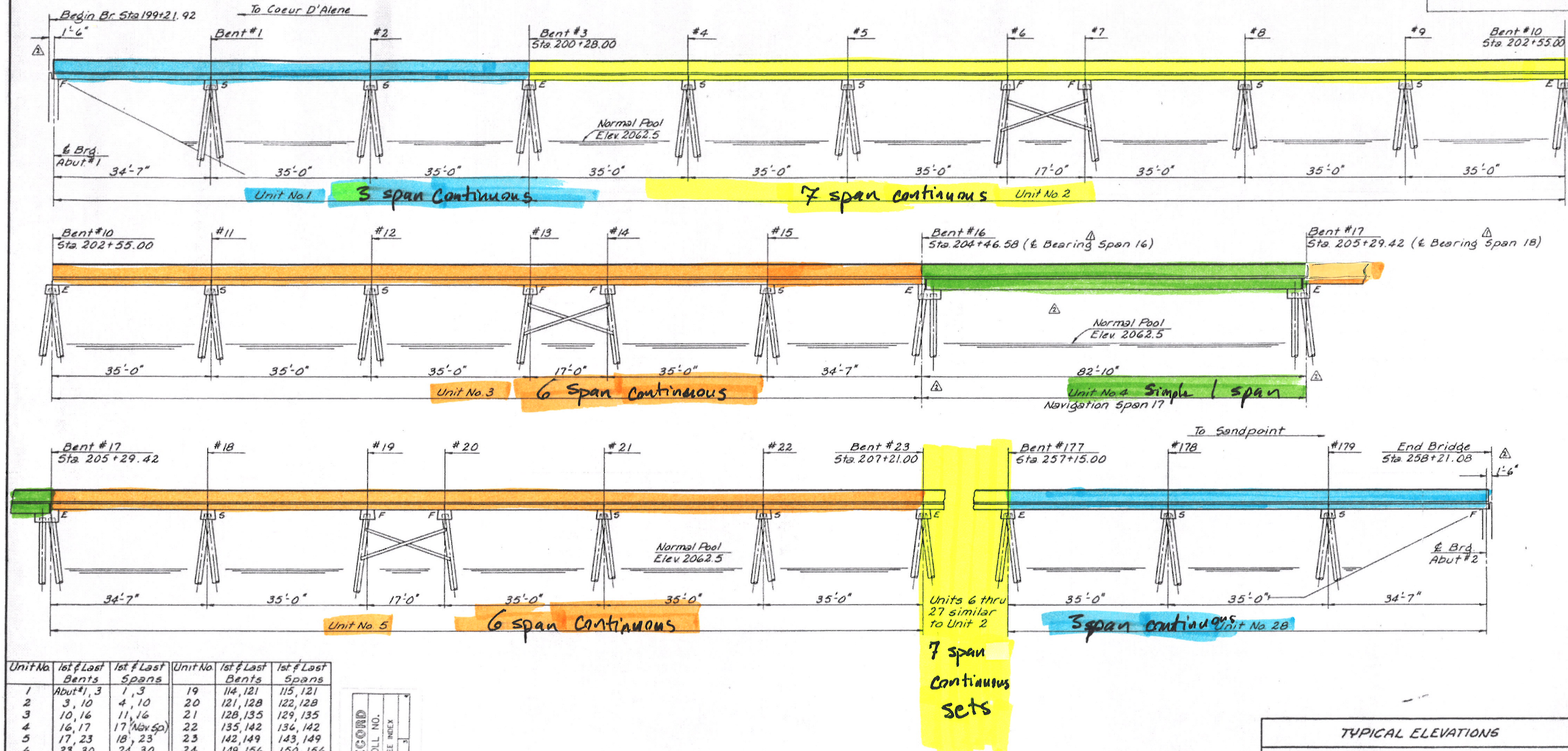
SCALE: *NTS* SIZE: *D*

DRAWING NUMBER

SAP No:	PROJECT No:	SUB:	DOC:	PART:	SHT.	REV.
7000108105	*15010242*	*-P188*	*- D-*	*T04*	*- 1/1*	*-00*

Figure 2

BR-F-5116(39)



Unit No.	1st & Last Bents	1st & Last Spans	Unit No.	1st & Last Bents	1st & Last Spans
1	Abut#1, 3	1, 3	19	114, 121	115, 121
2	3, 10	4, 10	20	121, 128	122, 128
3	10, 16	11, 16	21	128, 135	129, 135
4	16, 17	17 (Nav. Sp.)	22	135, 142	136, 142
5	17, 23	18, 23	23	142, 149	143, 149
6	23, 30	24, 30	24	149, 156	150, 156
7	30, 37	31, 37	25	156, 163	157, 163
8	37, 44	38, 44	26	163, 170	164, 170
9	44, 51	45, 51	27	170, 177	171, 177
10	51, 58	52, 58	28	177, Abut#2	178, 180
11	58, 65	59, 65			
12	65, 72	66, 72			
13	72, 79	73, 79			
14	79, 86	80, 86			
15	86, 93	87, 93			
16	93, 100	94, 100			
17	100, 107	101, 107			
18	107, 114	108, 114			

MICROFILM RECORD
DATE FILMED
ROLL NO.
SEE INDEX

TYPICAL ELEVATIONS

SANDPOINT BRIDGE REPLACEMENT
OVER LAKE PEND OREILLE
STA. 228+71.5

SCALE 1" = 10'-0"
SCALES SHOWN ARE FOR 22" x 36" PRINTS ONLY

STATE OF IDAHO
TRANSPORTATION DEPARTMENT
DIVISION OF HIGHWAYS
BOISE IDAHO

NO.	BY	DATE
2	H.E.H.	7-11-79
1	M.R.P.	29 May 79

REVISIONS

DESIGNED — DATE APR 5 1979
DESIGN CHECKED L. Arnold — DATE 4/79
DRAWN M. K. Peterson — DATE 8 Mar. 79
DWG. CHECKED A. J. Larson — DATE 4 Apr. 79
BRIDGE ENGINEER — DATE APR 5 1979

COUNTY: BONNER
FILE NO.: 1213A
DWG. NO.: 15066
SHEET 2 OF 28

Appendix

FORSGREN Associates Inc.

OWNER-PROJECT	BY	DATE	PROJECT NO.
Mammoet Permit Assistance	CMA	4/3/14	
FEATURE	**CHK'D BY**	**DATE**	
18715 "THE LONG BRIDGE"	[initials]	4/3/14	SHT 1 OF 3

CONTINUITY DIAPHRAGM POSITIVE MOMENT REBAR

Given: 5 Web-T Girders
1 - #5 Bar per web ⇒ 5-#5 Bars per Girder

Development length in Girder: AASHTO STD SPEC 8.25

max of
$$\begin{cases} 12'' \\ l_d = \dfrac{0.04\,A_b\,f_y}{\sqrt{f'_c}} = \dfrac{0.04\,(0.31\,in^2)\,60{,}000\,psi}{\sqrt{5{,}500\,psi}} = 10.03'' \\ 0.0004\,d_b\,f_y = 0.0004\,(0.625\,in)\,60{,}000\,psi = 15'' \end{cases}$$

Given Embedment 24-½" > 15" ∴ OK ←

Development length in Diaphragm: AASHTO STD SPEC 8.29

l_{dh}: $l_{dh} = (\text{factors}) \times l_{hb}$

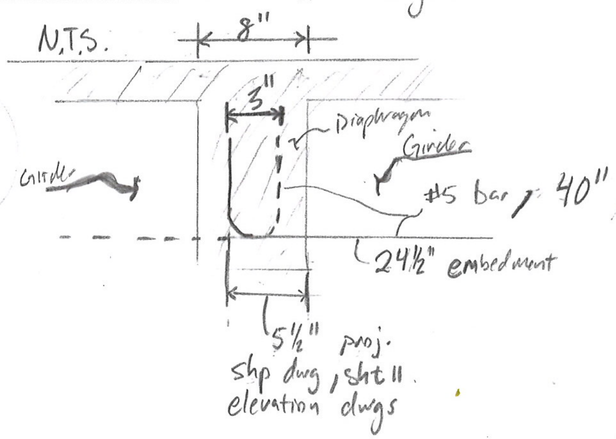
$l_{hb} = 1200\,d_b/\sqrt{f'_c} = 1200\,(0.625'')/\sqrt{4000\,psi} = 11.86''$

Apply 0.7 factor 8.29.3.2 ⇒ $l_{dh} = 0.7\,(11.86\,in) = 8.30''$

Req'd Hook Length: $12\,d_b = 7.5''$

GIVEN EMBEDMENT: Hook length = 40" − 20½" − 5½" − 2½ = 7.5" ∴ OK ←
(↑ for bend radius)

Note: SEE SHOP Drawings SEC (B/11)



Actual l_{dh}
3" of bar development resisting max moment on center line,

Bars are overlapping. Splices require a 1.3 factor (AASHTO 8.32.3.2) or reduce available by 1/1.3 = 0.7692

3" · 0.7692 = 2.308"
2.308" < 8.30" ∴ USE RATIO

∴ USE RATIO OF STEEL ⇒ 2.31"/8.30" = 27.8% ⇒ 0.278 × 5 bars = 1.39

ENTER 1.39 #5 BARS PER GIRDER IN THE CONTINUITY DIAPHRAGM

FORSGREN Associates Inc.

OWNER-PROJECT	BY	DATE	PROJECT NO.
Mammoet Permit Assistance	CMA	4/3/14	
FEATURE 18715 "THE LONG BRIDGE"	CHK'D BY [initials]	DATE 4/3/14	SHT 2 OF 3

UPLIFT FORCES & REBAR DOWEL STRENGTH

Unfactored Loads and Reactions from Virtis @ controlling location Pier 14 (or 4th Pier in 6-span unit).

Maximum Vertical Reaction Due to Non-Standard Gauge Live Load = -19.817^k

factored = $1.3 \cdot 2.2\,(-19.817) = -56.677$

Dead Loads

	Left side of Pier	Right side of Pier	Total
SELF LOAD	5.233^k	10.775^k	16.008^k
CONCRETE DECK	2.541^k	5.232^k	7.773^k
PARAPET	2.873^k		2.873^k
		TOTAL	26.654^k

$0.9(26.654^k) = 23.988^k$

RESULTANT LOAD = $-56.677 + 23.988^k$

$= -32.689^k$

GIVEN REINFORCEMENT: 4-#6, 40" (Grade 60) bars embedded 20" in Pier Cap

FULL CAPACITY OF 4-#6 BARS (60 ksi) = $4(0.44\,in^2) \times 60\text{ ksi} = 105.6^k$

factored ⇒ $0.9 \times 105.6^k = 95.04^k$

CHECK DEVELOPMENT IN PIER CAP

Max
$$\frac{0.04 A_b f_y}{\sqrt{f'_c}} = \frac{0.04(0.44)(60000)}{\sqrt{4000}} = 16.696''$$
$$0.0004 (d_b)(f_y) = 0.0004(0.75)(60{,}000) = 18''$$
$$12''$$

$20'' > 18''$ ∴ OK

ALL STEEL FULLY DEVELOPED $95.04^k > -32.689^k$ ∴ OK

FORSGREN Associates Inc.

OWNER-PROJECT	BY	DATE	PROJECT NO.
Mamgeet Permit Assistance	CMA	4/3/14	
FEATURE 18715 "THE LONG BRIDGE"	CHK'D BY TW	DATE 4/3/14	SHT 3 OF 3

CHECK DEVELOPMENT IN DIAPHRAGM

Design Plans drawings show #6 bar bent @ center line of girder top flange.

Available steel length in diaphragm = 40" − 20" − ½" (bearing pad) = 19½

EMBEDMENT HOOK LENGTH IS 19½" − 15" (to top flange center) − 3" (hook bend) = 1½"

ignoring hook use 15"/18" of development.

$$15''/18'' \, (95.04^k) = 79.2^k > 32.69^k \therefore OK \leftarrow$$

RATING FACTOR: STRENGTH II ; Uplift Rebar

LOADS ARE Positive if they cause tension in rebar

$$RF = \frac{C - A_1 D}{A_2 L (1+I)}$$

$C = 105.6\,(15/18) = 88^k$ $\quad I = 0.1$ $\quad D = (-26.654^k)$

$A_2 = 1.3$ $\quad L = 19.817$

Considering that the dead load helps in this case A_1 is taken to be (0.9)

$$RF = \frac{88^k - (0.9)(-26.654)}{1.3\,(19.817)(1.1)} = \frac{111.989}{28.34} = \underline{\underline{3.95}} \leftarrow$$