SHEYENE AQUADUCT STRUCTURE

Client Name:	**U.S. ARMY CORPS OF ENGINEERS**	**Design By:**	**MBI**
Project Name:	**FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4**	**Review By:**	
Work Describtion:	**Sheyenne Aquaduct Structure - Retaining Walls**	**Date:**	**2/10/2011**
	Panel D	**Job #:**	**34091004**
File Path:	P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_Phase4\070 Structural\Aqueducts\Sheyene\[34091004 PH4 Sheyene Retaining Walls Panel D.xlsx]Case 6		
REF.	**1**		
	2		

ID#	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Tributary - Water El. (ft)	914.56	914.56	914.67	916	903.24	**NA**
Diversion - Head Water El. (ft)	902.12	902.12	903.32	916	**NA**	**NA**
Diversion - Tail Water El. (ft)	901.91	901.91	903.06	916	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	916					
Tributary - T.O. Deck L.P. El.(ft)	898.7					
Tributary - T.O. Deck H.P. El.(ft)	900.7					
Diversion - T.O. Mat El. (ft)	883.68					
Tributary - Deck Slab thickness @ L.P. (ft)	2					
Tributary - Deck Slab thickness @ H.P. (ft)	4					
Diversion - Mat Slab thickness (ft)	4					
Tibutary - Water height (ft)	**15.86**	**15.86**	**15.97**	**17.3**	**4.54**	**NA**
Diversion - Head Water height (ft)	**18.44**	**18.44**	**19.64**	**32.32**	**NA**	**NA**
Ice	**NA**	2ft Ice	**NA**	**NA**	2ft Ice	**NA**
Ice Load	**NA**	10 kips/ft	**NA**	**NA**	10 kips/ft	**NA**
Ice Laod El. (ft)	**NA**	**914.56**	**NA**	**NA**	**903.24**	**NA**
Uplift @ HW (ft)	**22.44**	**22.44**	**23.64**	**36.32**	**NA**	**NA**
Uplift @ TW (ft)	**22.23**	**22.23**	**23.38**	**36.32**	**NA**	**NA**
Pile Condition	**Undrained**	**Undrained**	**Undrained**	**Undrained**	**Drained**	**Undrained**
Load Category	**Usual**	**Unusual**	**Unusual**	**Extreme**	**Usual**	**Unusual**
Safety Factors	2	1.5	1.5	1.15	2	1.5
Allwable Lateral Capacity (tons)	**18**	**20.5**	**20.5**	**24**	**11.5**	**20.5**
Allowable Pile Capacity (tons) - Axial	**61.95**	**82.60**	**82.60**	**107.74**	**36.525**	**82.60**
Allowable Pile Capacity (tons) - Uplift	**38.65**	**51.53**	**51.53**	**67.22**	**5.9**	**51.53**

Pile Capacity	**Ultimate Axial Capacity (kips)**	**Allowable Lateral Capacity (kips)**		
		0.5" (Usual)	**0.67" (Unusual)**	**0.875" (Extreme)**
Undrained - Axial	247.8	36	41	48
Undrained - Uplift	154.6			
Drained - Axial	146.1	23	29	36
Drained - Uplift	23.6			

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel D		

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	2,660	0	$0
INSTALL HP14x73 WALL PILING		LF	2,660	0	$0
PILE TEST, 48.0 ft	Long	EA	4	0	$0
FOOTING CONCRETE		CY	359	0	$0
	Forming	SF	922		
STEM CONCRETE		CY	385	0	$0
	Forming	SF	5,504		
STEEL REINFORCEMENT		LB	145,219	0	$0
WALL RAILING		LF	81	0	$0
SHEET PILE CUT-OFF WALL		SF	1,610	0	$0
					$0

Structure Length = 80.5 ft

No. piles = 70 Each

Length = 38 ft

Note: HP14x73 pile used for design, use HP14x73 to allow for corrosion

LENGTH

(FRONT & Back FACE) 10 FT

Native Soil has low permeability assume cut-off minimal to prevent scour

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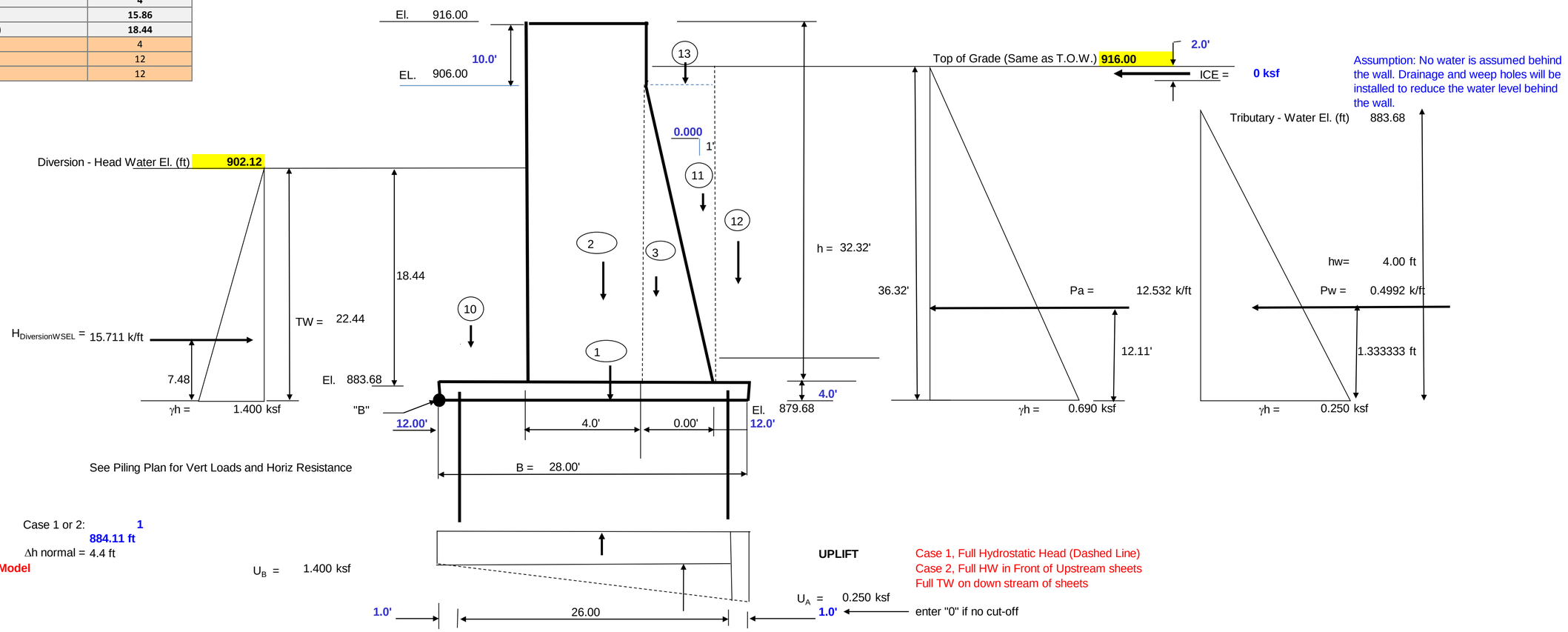
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood Panel D	

ID#	Case 1
Name	100 yr. flood
Load Category	Usual
Tributary - Water El. (ft)	914.56
Diversion - Head Water El. (ft)	902.12
Diversion - Tail Water El. (ft)	901.91
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	883.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.86
Diversion - Head Water height (ft)	18.44
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.4 ft
See Geotechnical seepage Model

U_B = 1.400 ksf

UPLIFT
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets

U_A = 0.250 ksf
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	32.32	0.15	rec	1561.1	14.00	21,854.8
Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**
T.W on ftg Stem	10	80.5	12.00	18.44	0.0624	rec	1111.5	6.00	6,669.2
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3066.0**	ΣM_V =	**49,666.9**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.400	rec	-3156.2	14.00	-44,186
	U_A	80.5	28.00	-1.151	tri	1296.8	18.67	24,207
					ΣU =	**-1859.4**	ΣM_U =	**-19,980**

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 1 100 yr. flood — Panel D	

Horizontal Loads

		L	H	Pressure		**ICE**	arm	**Mu**
		ft	ft	ksf		K	ft	ft-k
ICE		80.5	2.00	0.00	rec	0.0	35.32	0.0
		L		Force		**H**	arm	**Mw**
		ft		k/ft		K	ft	ft-k
SOIL		80.5		-12.532		-1008.81	12.11	-12213.38
Water Loads								
H_{TW}		80.5		15.711	tri	1264.73	7.48	9460.14
H_{HW}		80.5		-0.499	tri	-40.19	1.33	-53.58
					ΣWater =	**1224.54**	ΣM_W =	**-2806.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-22787	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	90455	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**67,669**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,120**	kips
Sum of Horizontal Forces	H = Σhorizontal	**216**	kips

Location of Resultant	Xr = ΣM / P =	16.42	ft from Toe
	e = B/2 - Xr =	(2.42)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

				forming	
Ftg conc:	342	cy (includes stepped)		922	sf
Stem Conc:	385	cy		5504	sf
Total =	728				

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
Bot mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
								cy	**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34,836.54	
	Longitudinal:	9	6	3.40	80	64	17,408	34,816.00	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
	Vertical O.F.	9	6	3.40	31.8	161	17,418		
								cy	**LB/cy**
							73,755	385	191.3490299
						Σ =	**135,835**		
	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	18.44	0.0624	1.150656	10.609	6.147	65.21028
Tributary SEL =	32.32	0.019	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				-0.686		41.69924

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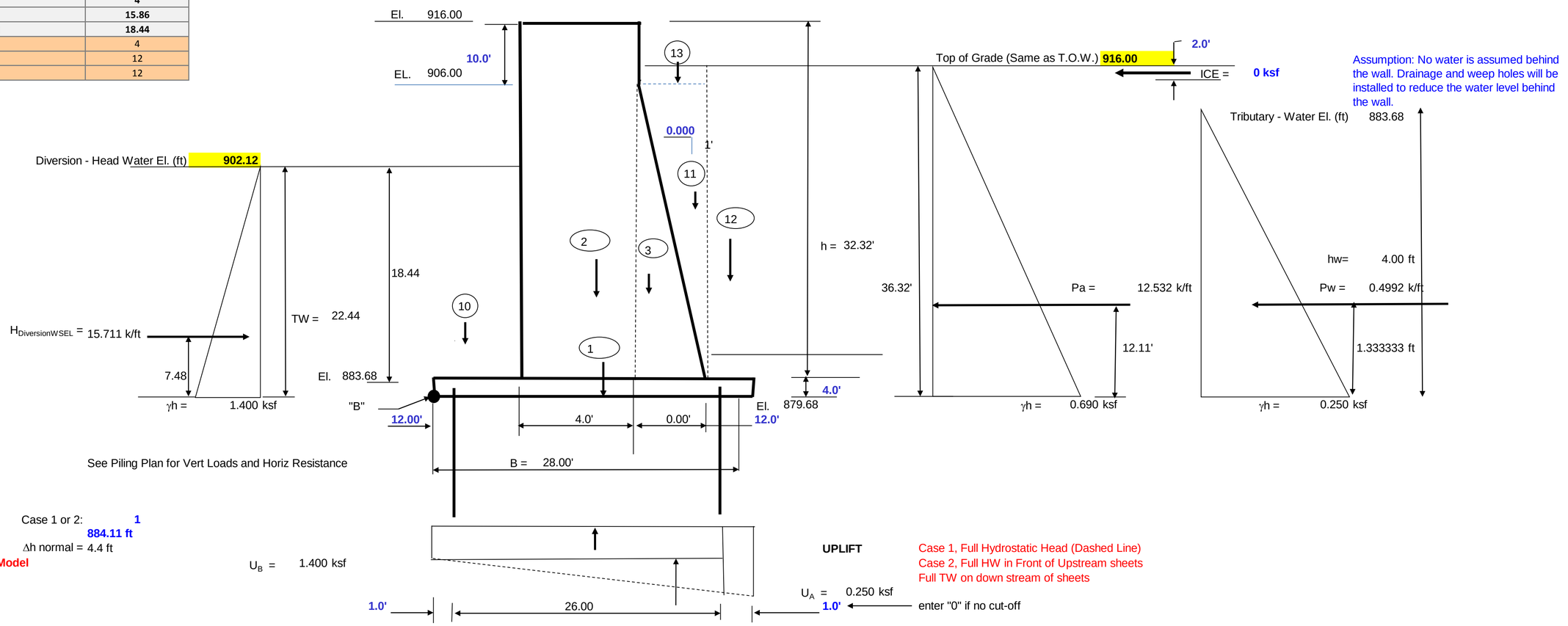
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 2 100 yr. flood + ice Panel D	

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	914.56
Diversion - Head Water El. (ft)	902.12
Diversion - Tail Water El. (ft)	901.91
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	883.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.86
Diversion - Head Water height (ft)	18.44
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 4.4 ft
See Geotechnical seepage Model

U_B = 1.400 ksf

U_A = 0.250 ksf

UPLIFT

Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets

1.0' ← enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	32.32	0.15	rec	1561.1	14.00	21,854.8
Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	12.00	18.44	0.0624	rec	1111.5	6.00	6,669.2
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3066.0**	ΣM_V =	**49,666.9**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.400	rec	-3156.2	14.00	-44,186
	U_A	80.5	28.00	-1.151	tri	1296.8	18.67	24,207
					ΣU =	**-1859.4**	ΣM_U =	**-19,980**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 2 100 yr. flood + ice	Panel D

ICE	80.5	2.00	0.00	rec	0.0	35.32	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-12.532		-1008.81	12.11	-12213.38	
Water Loads								
H_{TW}	80.5		15.711	tri	1264.73	7.48	9460.14	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**1224.54**	ΣM_W =	**-2806.8**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-22787	kip-ft
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Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**67,669**	kip-ft
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Location of Resultant	Xr = ΣM / P =	16.42	ft from Toe
	e = B/2 - Xr =	(2.42)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	385	cy	5504	sf
Total =	728			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
Bot mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
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							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34836.536	
	Longitudinal:	9	6	3.40	80	64	17,408	34816	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
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							73,755	385	191.3490299
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	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	18.44	**0.0624**	1.150656	10.609	6.147	65.21028
Tributary SEL =	32.32	**0.019**	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				-0.686		41.69924

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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel D	

ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	914.67
Diversion - Head Water El. (ft)	903.32
Diversion - Tail Water El. (ft)	903.06
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
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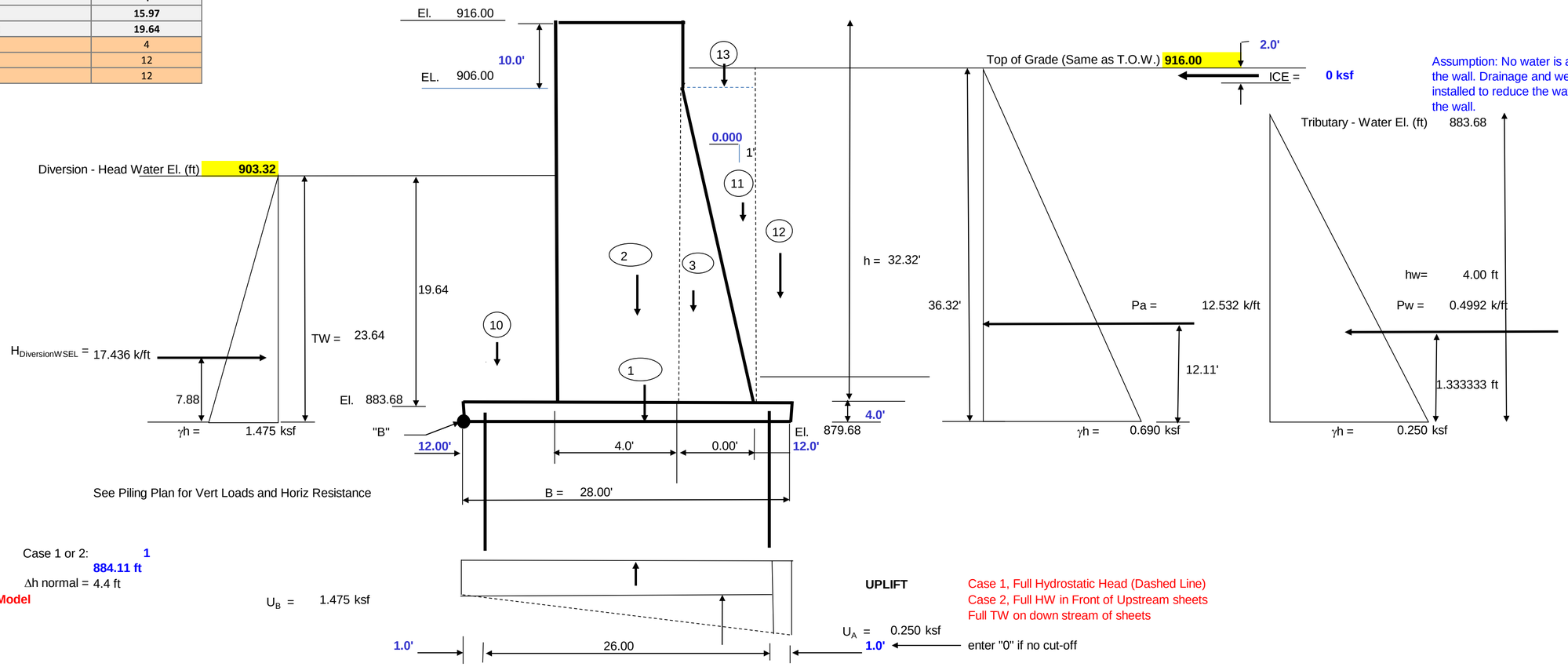
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.97
Diversion - Head Water height (ft)	19.64
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
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Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**
T.W on ftg Stem	10	80.5	12.00	19.64	0.0624	rec	1183.9	6.00	7,103.2
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3138.3**	ΣM_V =	**50,100.9**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.475	rec	-3325.0	14.00	-46,549
	U_A	80.5	28.00	-1.226	tri	1381.2	18.67	25,782
					ΣU =	**-1943.8**	ΣM_U =	**-20,767**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 3 500 yr. flood — Panel D	

ICE	80.5	2.00	0.00	rec	0.0	35.32	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-12.532		-1008.81	12.11'	-12213.38	
Water Loads								
H_{TW}	80.5		17.436	tri	1403.61	7.88	11060.42	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**1363.42**	ΣM_W =	**-1206.5**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-21974	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	90889	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**68,915**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,108**	kips
Sum of Horizontal Forces	H = Σhorizontal	**355**	kips

Location of Resultant	Xr = ΣM / P =	16.78	ft from Toe
	e = B/2 - Xr =	(2.78)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	385	cy	5504	sf
Total =	728			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
Bot mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
								cy	**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34836.536	
	Longitudinal:	9	6	3.40	80	64	17,408	34816	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
	Vertical O.F.	9	6	3.40	31.8	161	17,418		
								cy	**LB/cy**
							73,755	385	191.3490299
						Σ =	**135,835**		
	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	19.64	0.0624	1.225536	12.035	6.547	78.78759
Tributary SEL =	32.32	0.019	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				-2.111		28.12194

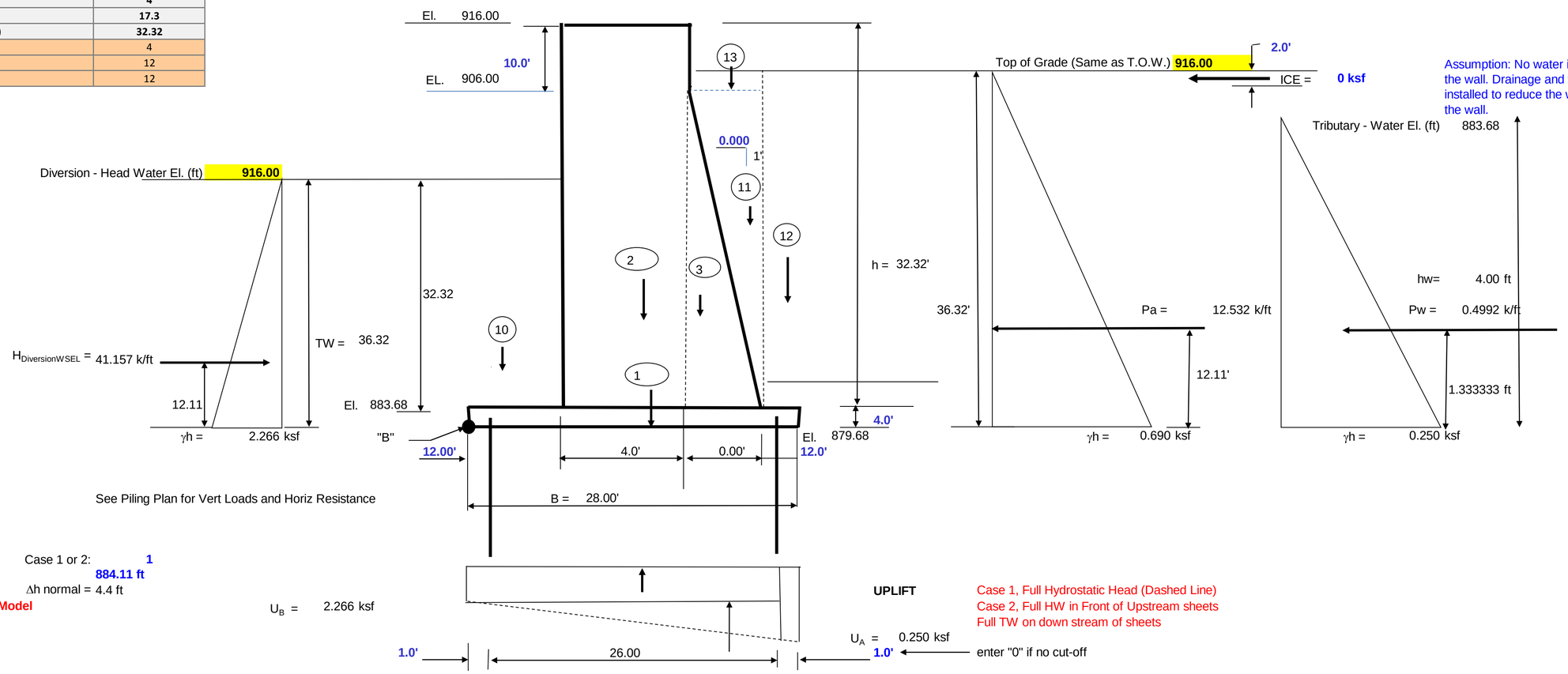
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 4 T.O. Levee Panel D	

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	916
Diversion - Tail Water El. (ft)	916
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	883.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	17.3
Diversion - Head Water height (ft)	32.32
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.4 ft
See Geotechnical seepage Model

Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	32.32	0.15	rec	1561.1	14.00	21,854.8
Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**
T.W on ftg Stem	10	80.5	12.00	32.32	0.0624	rec	1948.2	6.00	11,689.2
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3902.6**	ΣM_V =	**54,686.9**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	2.266	rec	-5108.4	14.00	-71,518
	U_A	80.5	28.00	-2.017	tri	2272.9	18.67	42,427
					ΣU =	**-2835.5**	ΣM_U =	**-29,090**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 4 T.O. Levee Panel D	

ICE	80.5	2.00	0.00		rec	0.0	35.32	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	80.5		-12.532			-1008.81	12.11'	-12213.38
Water Loads								
H_{TW}	80.5		41.157		tri	3313.16	12.11	40111.30
H_{HW}	80.5		-0.499		tri	-40.19	1.33	-53.58
					ΣWater =	**3272.97**	ΣM_W =	**27844.3**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1246	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	95475	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**94,230**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,981**	kips
Sum of Horizontal Forces	H = Σhorizontal	**2,264**	kips

Location of Resultant	Xr = ΣM / P =	23.67	ft from Toe
	e = B/2 - Xr =	(9.67)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	385	cy	5504	sf
Total =	728			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
								cy	**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34836.536	
	Longitudinal:	9	6	3.40	80	64	17,408	34816	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
	Vertical O.F.	9	6	3.40	31.8	161	17,418		
								cy	**LB/cy**
							73,755	385	191.3490299
						Σ =	**135,835**		
	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	32.32	**0.0624**	2.016768	32.591	10.773	351.1134
Tributary SEL =	32.32	**0.019**	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				-22.667		-244.204

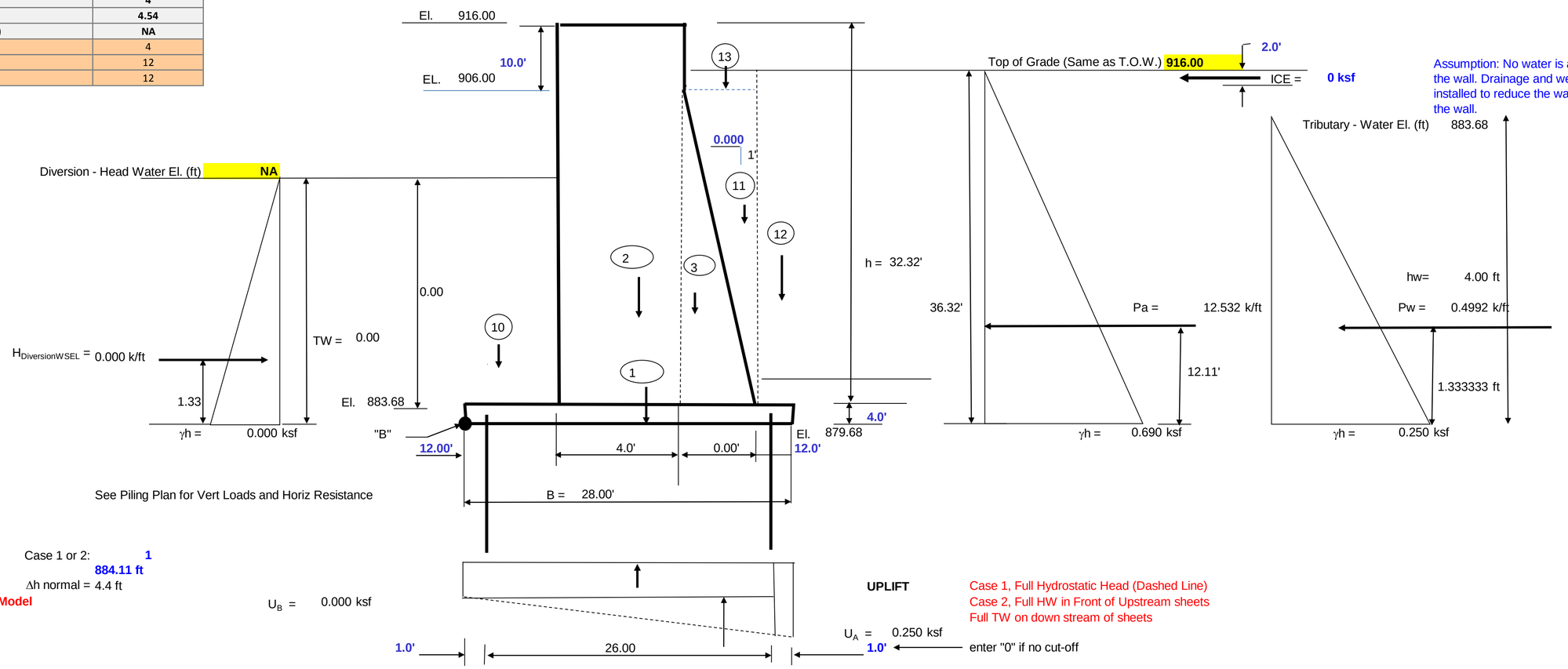
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 5 Normal flow + ice Panel D	

ID#	Case 5
Name	Normal flow + ice
Load Category	Usual
Tributary - Water El. (ft)	903.24
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	883.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	4.54
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 4.4 ft
See Geotechnical seepage Model

Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	32.32	0.15	rec	1561.1	14.00	21,854.8
Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**
T.W on ftg Stem	10	80.5	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**1954.4**	ΣM_V =	**42,997.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	0.000	rec	0.0	14.00	0
	U_A	80.5	28.00	0.250	tri	-281.3	18.67	-5,251
					ΣU =	**-281.3**	ΣM_U =	**-5,251**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 5 Normal flow + ice Panel D	

ICE	80.5	2.00	0.00		rec	0.0	35.32	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	80.5		-12.532			-1008.81	12.11'	-12213.38
Water Loads								
H_{TW}	80.5		0.000		tri	0.00	1.33	0.00
H_{HW}	80.5		-0.499		tri	-40.19	0.00	0.00
					ΣWater =	**-40.19**	ΣM_W =	**-12213.4**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-17464	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	83786	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**66,322**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,587**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-1,049**	kips

Location of Resultant	Xr = ΣM / P =	14.46	ft from Toe
	e = B/2 - Xr =	(0.46)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	385	cy	5504	sf
Total =	728			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
								cy	**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34836.536	
	Longitudinal:	9	6	3.40	80	64	17,408	34816	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
	Vertical O.F.	9	6	3.40	31.8	161	17,418		
								cy	**LB/cy**
							73,755	385	191.3490299
						Σ =	**135,835**		
	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	0.00	0.0624	0	0.000	0.000	0
Tributary SEL =	32.32	0.019	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				9.924		106.9095

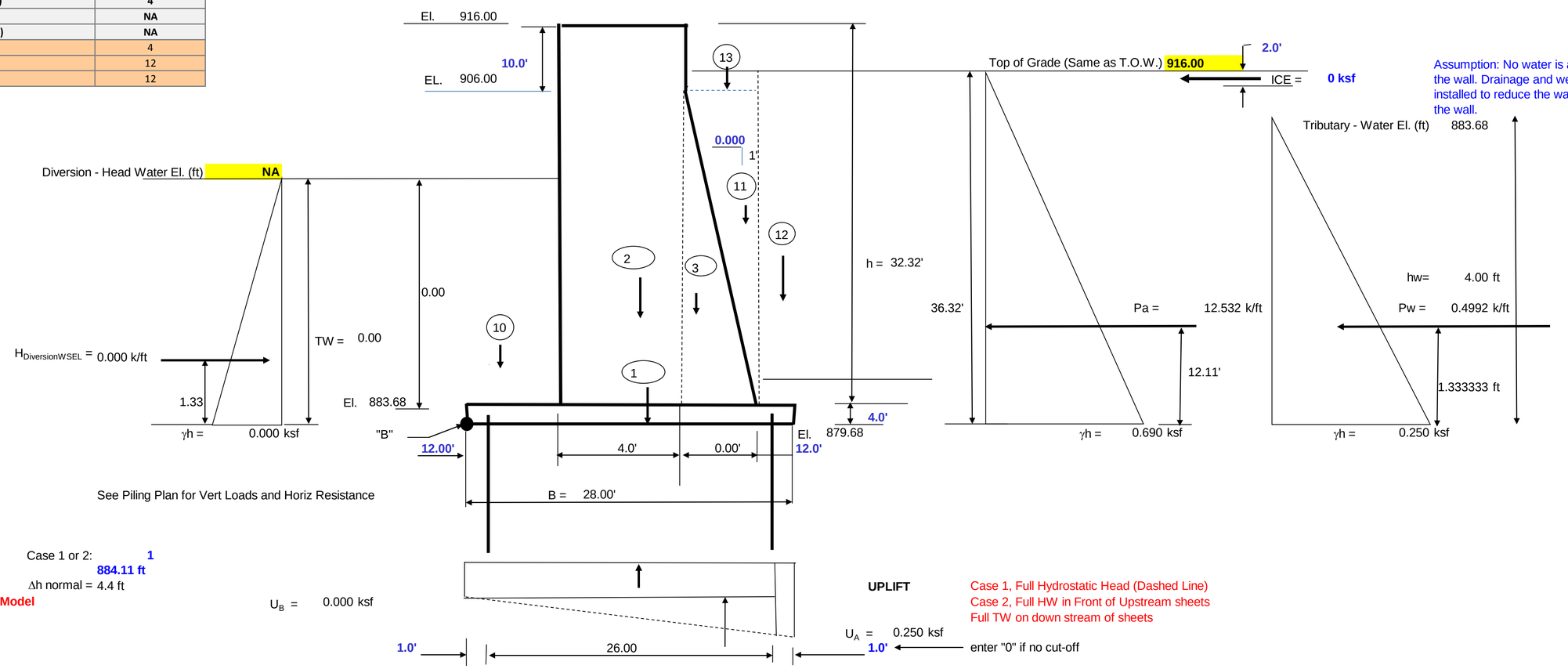
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction Panel D	

ID#	Case 6
Name	Construction
Load Category	Unusual
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	916
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	883.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	NA
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.4 ft
See Geotechnical seepage Model

Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	32.32	0.15	rec	1561.1	14.00	21,854.8
Batter	3	80.5	0.00	22.32	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2913.5**	ΣM_V =	**40,788.4**
T.W on ftg Stem	10	80.5	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	80.5	0.00	22.32	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	32.32	0.0626	rec	1954.4	22.00	42,997.7
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**1954.4**	ΣM_V =	**42,997.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	0.000	rec	0.0	14.00	0
	U_A	80.5	28.00	0.250	tri	-281.3	18.67	-5,251
					ΣU =	**-281.3**	ΣM_U =	**-5,251**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction	Panel D

ICE	80.5	2.00	0.00	rec	0.0	35.32	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-12.532		-1008.81	12.11'	-12213.38	
Water Loads								
H_{TW}	80.5		0.000	tri	0.00	1.33	0.00	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**-40.19**	ΣM_W =	**-12267.0**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-17518	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	83786	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**66,268**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,587**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-1,049**	kips

Location of Resultant	Xr = ΣM / P =	14.45	ft from Toe
	e = B/2 - Xr =	(0.45)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	385	cy	5504	sf
Total =	728			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing in	LB /ft	Length ft	# of bars ea	Total wt lb		
a) Footing									
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
							cy		**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	31.82	161	17,418	34836.536	
	Longitudinal:	9	6	3.40	80	64	17,408	34816	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	31.8	161	17,418		
	Vertical O.F.	9	6	3.40	31.8	161	17,418		
							cy		**LB/cy**
							73,755	385	191.3490299
						Σ =	**135,835**		
	Lap Splices (long. Bars)	9		3.40	8	345	9,384		
						Σ Bar Wt=	145,219	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H ft	γ kcf	Pbase	**V** K	arm ft	**Mv** ft-k
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	32.32	**0.019**	0.61408	9.924	10.773	106.9095
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				9.924		106.9095
Net Forces				9.924		106.9095

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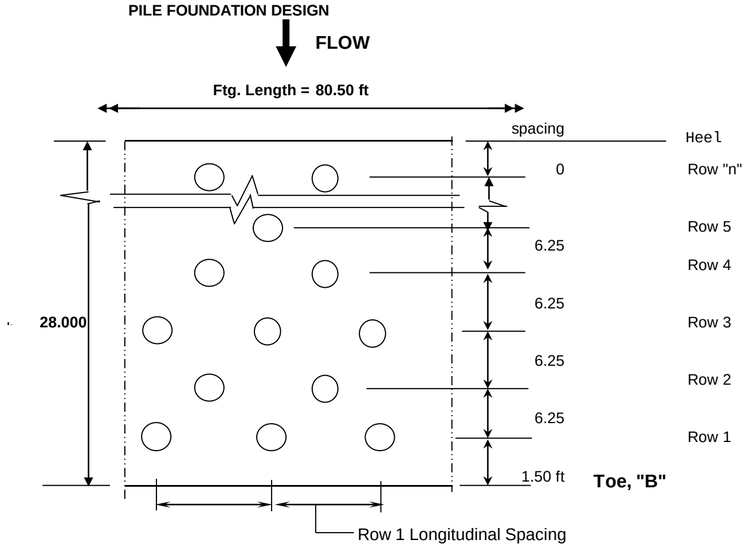
PILE FOUNDATION DESIGN



L = 80.50 ft

PILE PATTERN GEOMETRY

Transverse Spacing		Distance to Toe, d_{toe}	Longitudinal Spacing	Batter	Piles per Row (N)	Edge Dist (ft)		Trial N
Row 1 to Toe	1.50 ft	1.5 ft	2.50 ft	0 "/12"	14	24.00	1	33
Row 1 to Row 2	6.25 ft	7.8 ft	5.00 ft	0 "/12"	14	7.75	2	17
Row 2 to Row 3	6.25 ft	14.0 ft	5.00 ft	0 "/12"	14	7.75	0	17
Row 3 to Row 4	6.25 ft	20.3 ft	5.00 ft	0 "/12"	14	7.75	1	17
Row 4 to Row 5	6.25 ft	26.5 ft	5.00 ft	0 "/12"	14	7.75	2	17
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Last Row to Heel	1.50 ft							
	28.00 ft				ΣN =	70		101

Note: Enter 0 for Longitudinal Spacing for Rows Not Used)

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **38.0 ft**
HP Nominal Depth, h = **14.0 in**
Wt. per ft, plf **73**
Ftg EL. 879.68
Pile Tip El. 842.68
Pile Cap Embed = **1.00 ft**
Total pile Length = 2,660 LF

Pile Group Properties

N.A. of Pile Group to Toe
$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **14.00 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	12.50 ft	14	2187.5
2	Dist. To Row 2	6.25 ft	14	546.9
0	Dist. Row 3	0.00 ft	14	0.0
1	Dist. Row 4	-6.25 ft	14	546.9
2	Dist. Row 5	-12.50 ft	14	2187.5
0	Row 6 (not used)	0.00 ft	0	0.0
0	Row 7 (not used)	0.00 ft	0	0.0
0	Row 8 (not used)	0.00 ft	0	0.0
0	Row 9 (not used)	0.00 ft	0	0.0
0	Row 10 (not used)	0.00 ft	0	0.0
0	Row 11 (not used)	0.00 ft	0	0.0
0	Row 12 (not used)	0.00 ft	0	0.0
0	Row 13 (not used)	0.00 ft	0	0.0
0	Row 14 (not used)	0.00 ft	0	0.0
0	Row 15 (not used)	0.00 ft	0	0.0
			70	$\Sigma I =$ **5468.8**

ALLOWABLE LOADS (from Geotechnical)

	Service	Allowable Pile Loads					
	ID#	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
	Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
	Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Allwable Lateral Capacity (tons)		18.0 tons	20.5 tons	20.5 tons	24.0 tons	11.5 tons	20.5 tons
Allowable Pile Capacity (tons) - Axial		62.0 tons	82.6 tons	82.6 tons	107.7 tons	36.5 tons	82.6 tons
Safety Factors		2.00	1.50	1.50	1.15	2.00	1.50

w/o Group effects

Summary Pile Reactions

Load Combinations	Allowable Pile Capacity (tons) - Axial	Pile Loads (tons/pile) 1	2	3	4	5	6	7	8	9	10	11	12	Max. Vertical Load (Tons)	Horiz Pile Group Capacity (k)	Check
Case 1	**62.0 tons**	18.0	23.7	29.4	35.1	40.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.8	2,520	**OK**
Case 2	**82.6 tons**	18.0	23.7	29.4	35.1	40.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.8	2,870	**OK**
Case 3	**82.6 tons**	16.3	22.8	29.3	35.9	42.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.4	2,870	**OK**
Case 4	**107.7 tons**	-15.6	6.4	28.4	50.4	72.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.4	3,360	**OK**
Case 5	**36.5 tons**	30.4	31.6	32.8	34.0	35.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.2	1,610	**OK**
Case 6	**82.6 tons**	30.4	31.6	32.8	33.9	35.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.1	1,610	**OK**

Max Service : P = **72.4**

Using solid mechanics equations adapted for discrete elements, the forces in the pile rows for different load combinations are determined.
The force in each pile row is found using:

$$\text{Pile Load} = P / N + M_{NA} / I$$

First, the moment about the toe must be translated to get the moment about the neutral axis of the pile group.

$$e_{toe} = M_{toe} / P$$

Then the eccentricity about the neutral axis of the pile group is

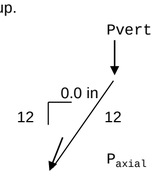
$$e_{NA} = X_{NA} - e_{toe}$$

The moment about the neutral axis of the pile group becomes

$$M_{NA} = P * e_{NA}$$

For battered pile, the Vertical pile load needs to be transformed to the axial load along the pile axis

Paxial = 1.000 Pvert



FORCE RESULTANT (see Stability Analysis)

CASE	Event		Vertical Load P (kips)	Horizontal	ΣM toe (kip-	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$

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Case 1	**100 yr. flood**	**Usual**	4,120	-216	67,669	16.42	-2.42	-9988
Case 2	**100 yr. flood + ice**	**Unusual**	4,120	-216	67,669	16.42	-2.42	-9988
Case 3	**500 yr. flood**	**Unusual**	4,108	-355	68,915	16.78	-2.78	-11404
Case 4	**T.O. Levee**	**Extreme**	3,981	-2,264	94,230	23.67	-9.67	-38501
Case 5	**Normal flow + ice**	**Usual**	4,587	1,049	66,322	14.46	-0.46	-2109
Case 6	**Construction**	**Unusual**	4,587	1,049	66,268	14.45	-0.45	-2056

SERVICE

Case **Case 1**
Flood Event **100 yr. flood**
Usual

Vertical Load, P = 4120 kips
Horizontal Load, H = -216 kips
M_{NA} = -9988 kip-ft

70

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	58.9		-22.8	36.0 kips/pile	18.0 tons/pile	18.0 tons/pile
2	Row 2	58.9		-11.4	47.4 kips/pile	23.7 tons/pile	23.7 tons/pile
3	Row 3	58.9		0.0	58.9 kips/pile	29.4 tons/pile	29.4 tons/pile
4	Row 4	58.9		11.4	70.3 kips/pile	35.1 tons/pile	35.1 tons/pile
5	Row 5	58.9		22.8	81.7 kips/pile	40.8 tons/pile	40.8 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**40.8 tons/pile**	**max: 40.8 tons/pile**

Assumed lateral Capacity: 36.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance
1	Row 1	0	14	0.0	504	1.000	504 kips
2	Row 2	0	14	0.0	504	1.000	504 kips
3	Row 3	0	14	0.0	504	1.000	504 kips
4	Row 4	0	14	0.0	504	1.000	504 kips
5	Row 5	0	14	0.0	504	1.000	504 kips
6	Row 6	0	0	0.0	0	1.000	0 kips
7	Row 7	0	0	0.0	0	1.000	0 kips
8	Row 8	0	0	0.0	0	1.000	0 kips
9	Row 9	0	0	0.0	0	1.000	0 kips
10	Row 10	0	0	0.0	0	1.000	0 kips
11	Row 11	0	0	0.0	0	1.000	0 kips
12	Row 12	0	0	0.0	0	1.000	0 kips
13	Row 13	0	0	0.0	0	1.000	0 kips
14	Row 14	0	0	0.0	0	1.000	0 kips
15	Row 15	0	0	0.0	0	1.000	0 kips
			70		2520		**2520 kips**

OK

Case **Case 2**
Flood Event **100 yr. flood + ice**
Unusual

Vertical Load, P = 4120 kips
Horizontal Load, H = -216 kips
M_{NA} = -9988 kip-ft

70

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	58.9		-22.8	36.0 kips/pile	18.0 tons/pile	18.0 tons/pile
2	Row 2	58.9		-11.4	47.4 kips/pile	23.7 tons/pile	23.7 tons/pile
3	Row 3	58.9		0.0	58.9 kips/pile	29.4 tons/pile	29.4 tons/pile
4	Row 4	58.9		11.4	70.3 kips/pile	35.1 tons/pile	35.1 tons/pile
5	Row 5	58.9		22.8	81.7 kips/pile	40.8 tons/pile	40.8 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**40.8 tons/pile**	**max: 40.8 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance
1	Row 1	0	14	0.0	574	1.000	574 kips
2	Row 2	0	14	0.0	574	1.000	574 kips
3	Row 3	0	14	0.0	574	1.000	574 kips

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4	Row 4	0	14	0.0	574	1.000	574 kips	
5	Row 5	0	14	0.0	574	1.000	574 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		2870		**2870 kips**	**OK**

Case **Case 3**
Flood Event **500 yr. flood**
Unusual

Vertical Load, P = 4108 kips
Horizontal Load, H = -355 kips
M_{NA} = -11404 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	58.7		-26.1	32.6 kips/pile	16.3 tons/pile	16.3 tons/pile
2	Row 2	58.7		-13.0	45.7 kips/pile	22.8 tons/pile	22.8 tons/pile
3	Row 3	58.7		0.0	58.7 kips/pile	29.3 tons/pile	29.3 tons/pile
4	Row 4	58.7		13.0	71.7 kips/pile	35.9 tons/pile	35.9 tons/pile
5	Row 5	58.7		26.1	84.8 kips/pile	42.4 tons/pile	42.4 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
						max: **42.4 tons/pile**	**max:** **42.4 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	14	0.0	574	1.000	574 kips	
2	Row 2	0	14	0.0	574	1.000	574 kips	
3	Row 3	0	14	0.0	574	1.000	574 kips	
4	Row 4	0	14	0.0	574	1.000	574 kips	
5	Row 5	0	14	0.0	574	1.000	574 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		2870		**2870 kips**	**OK**

Case **Case 4**
Flood Event **T.O. Levee**
Extreme

Vertical Load, P = 3981 kips
Horizontal Load, H = -2264 kips
M_{NA} = -38501 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	56.9		-88.0	-31.1 kips/pile	-15.6 tons/pile	-15.6 tons/pile
2	Row 2	56.9		-44.0	12.9 kips/pile	6.4 tons/pile	6.4 tons/pile
3	Row 3	56.9		0.0	56.9 kips/pile	28.4 tons/pile	28.4 tons/pile
4	Row 4	56.9		44.0	100.9 kips/pile	50.4 tons/pile	50.4 tons/pile
5	Row 5	56.9		88.0	144.9 kips/pile	72.4 tons/pile	72.4 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
						max: **72.4 tons/pile**	**max:** **72.4 tons/pile**

Assumed lateral Capacity: 48.0 kips/pile

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	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	14	0.0	672	1.000	672 kips	
2	Row 2	0	14	0.0	672	1.000	672 kips	
3	Row 3	0	14	0.0	672	1.000	672 kips	
4	Row 4	0	14	0.0	672	1.000	672 kips	
5	Row 5	0	14	0.0	672	1.000	672 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		3360		**3360 kips**	**OK**

Case **Case 5**
Flood Event **Normal flow + ice**
Usual

Vertical Load, P = 4587 kips
Horizontal Load, H = 1049 kips
M_{NA} = -2109 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	65.5		-4.8	60.7 kips/pile	30.4 tons/pile	30.4 tons/pile
2	Row 2	65.5		-2.4	63.1 kips/pile	31.6 tons/pile	31.6 tons/pile
3	Row 3	65.5		0.0	65.5 kips/pile	32.8 tons/pile	32.8 tons/pile
4	Row 4	65.5		2.4	67.9 kips/pile	34.0 tons/pile	34.0 tons/pile
5	Row 5	65.5		4.8	70.3 kips/pile	35.2 tons/pile	35.2 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**35.2 tons/pile**	**max: 35.2 tons/pile**

Assumed lateral Capacity: 23.0 kips/pile

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	14	0.0	322	1.000	322 kips	
2	Row 2	0	14	0.0	322	1.000	322 kips	
3	Row 3	0	14	0.0	322	1.000	322 kips	
4	Row 4	0	14	0.0	322	1.000	322 kips	
5	Row 5	0	14	0.0	322	1.000	322 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		1610		**1610 kips**	**OK**

Case **Case 6**
Flood Event **Construction**
Unusual

Vertical Load, P = 4587 kips
Horizontal Load, H = 1049 kips
M_{NA} = -2056 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	65.5		-4.7	60.8 kips/pile	30.4 tons/pile	30.4 tons/pile
2	Row 2	65.5		-2.3	63.2 kips/pile	31.6 tons/pile	31.6 tons/pile
3	Row 3	65.5		0.0	65.5 kips/pile	32.8 tons/pile	32.8 tons/pile
4	Row 4	65.5		2.3	67.9 kips/pile	33.9 tons/pile	33.9 tons/pile
5	Row 5	65.5		4.7	70.2 kips/pile	35.1 tons/pile	35.1 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Panel D 0	

11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
					max:	**35.1 tons/pile**	**max:**	**35.1 tons/pile**	

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	14	0.0	322	1.000	322 kips	
2	Row 2	0	14	0.0	322	1.000	322 kips	
3	Row 3	0	14	0.0	322	1.000	322 kips	
4	Row 4	0	14	0.0	322	1.000	322 kips	
5	Row 5	0	14	0.0	322	1.000	322 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		1610		**1610 kips**	**OK**

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
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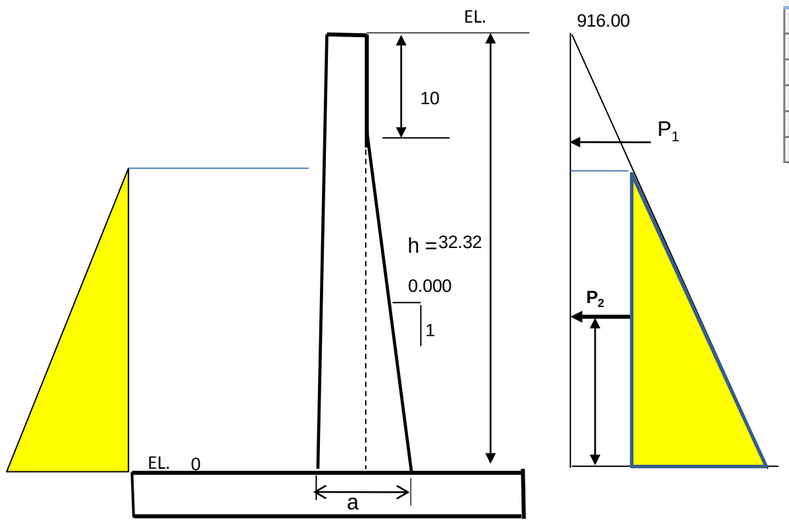
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel D 0	



CASE	Event		HW	TW	Dh	TW -ftg
Case 1	100 yr. flood	Usual	902.12	901.91	0.21	901.91
Case 2	100 yr. flood + ice	Unusual	902.12	901.91	0.21	901.91
Case 3	500 yr. flood	Unusual	914.670	903.06	11.61	903.06
Case 4	T.O. Levee	Extreme	916.000	916.00	0.00	916.00
Case 5	Normal flow + ice	Usual	0.000	0.000	0.00	0.00
Case 6	Construction	Unusual	0.000	0.000	0.00	0.00

LOAD FACTORS

Hf =	1.30	hydraulic Factor
LF =	1.70	
Unsual & Extreme =	0.75	
TOP THICK =	4.0 ft	48.0 in
Batter at Base =	0.00 ft	0.0 in
a =	4.00 ft	48.0 in

Load Factors - Hydraulic Structures	
live load, LL =	1.7
dead load, DL =	1.4
flood level , FL =	1
Fluid, F =	1.7
hydraulic, Hf =	1.3
direct tension hydraulic, Hf =	1.65
ICE =	1.7

WALL DESIGN:

Horizontal Load Components and Moments about Bottom of Stem (Service)

CASE	Event	Condition	Load Factor	H (kips/ft)	Moment (kip-ft/ ft)	Vu (kips/ft)	Mu (kip-ft/ ft)
Case 1	100 yr. flood	Usual	1	-0.69	41.699	-1.51	92.16
Case 2	100 yr. flood + ice	Unusual	0.75	-0.69	41.699	-1.14	69.12
Case 3	500 yr. flood	Unusual	0.75	-2.11	28.122	-3.50	46.61
Case 4	T.O. Levee	Extreme	0.75	-22.67	-244.204	37.57	404.77
Case 5	Normal flow + ice	Usual	1	9.92	106.910	21.93	236.27
Case 6	Construction	Unusual	0.75	9.92	106.910	16.45	177.20

STEM DESIGN VALUES

MU, k-ft/ft	404.77	k-ft/ft
VU, k/ft	37.57	k/ft

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel D 0	

ACI 318-05 w/ Modifications per EM 1110-2-2104 ref. EM 110-2-2104

9.3 - Design Strength

ϕ = **0.9** 9.3.2.1 - Tension Controlled sections

0.75 9.3.2.3 - Shear and torsion

FLEXURAL STEEL FOR RECTANGULAR CONCRETE SECTIONS

fy=	60	ksi	
Fc'=	4	ksi	
B1=	0.85		
Muh =	405	k-ft /ft	Includes: hf = 1.3
Vuh=	37.57	k / ft	
bw=	12	in.	
h=	48	in	
cover=	4	in (include correct stirrup bar dia.)	
d=	43.50	in	
pb=	0.0285		pb=0.85*B1*Fc'/ fy*(87 / (87+fy))
.75*pb=	0.0214		
m=fy / 0.85*Fc'=	17.647		

TRIAL

Ru=Mn/bd^2 =	237.676		**ACI 10.5.1**		**ACI 10.5.3**
REQ'D p=	0.0041	**O.K.**	p(min)= 3*SQRT(Fc')/fy	200* / fy	4/3*p
p=	FALSE	N.G.	0.00316	0.00333	0.0055
As (REQ'D)=	0.81	in^2	**EM 110-2-2104 2-8 c. (not less than Temp & Shrinkage, half in each face)**		
			p(min)= 0.0028 /2	► As =0.5*$p_{T\&S}$bh = 0.8064	in^2
				As = #9 @ 12 = 1.00	in^2

SELECT STEEL

bar #=	9		
spacing, s=	6	in	
# OF BAR=	1	(ENTER 1 IF PER FT, b=12")	a
As=	1.999	in^2	
d=	43.4375	in	
p = As/bd =	0.0038	**O.K. < 0.375pb**	**EM 110-2-2104**
p =	**0.135**	**pb**	**MAXIMUM TENSILE REINFORCEMENT**
			a) For singly reinforced flexural members
			1) p = **0.25** pb Recommended limit
			2) p = **0.375** pb Max. permitted upper limit not requiring special study
T= As*fy =	119.9	k	3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
C= B1*Fc' *b*a =	1376.2	**a**	4) p = >**0.5** pb but ≤ 0.375 pb permitted only if detailed serviceability analysis incl. deflect. Calc.
a= T/C =	0.087	in	b) Use of compression reinf. shall be per ACI 318
Mn= T(d - a/2)/12 =	433.6	ft-k	
ϕ Mn=	390.3	ft-k	**< Mu N.G.**

CHECK SHEAR REINFORCEMENT (ACI 11.3 & EM 110-2-2104 3-3a)

Vuh =	37.6	k		NO SHEAR REINF. REQUIRED
Vn = Vuh / ϕ =	50.1	k		
Vc = 2*sqrt(Fc') bw * d =	65.9	k	**11.3.1.1**	
Vs =Vuh / f - 1.3Vc =	No Shear Reinf. Req.	k	NG	Vs(max) ≤ 8*sqrt(fc')bd = 263.7 k

Trial Stirrup Sizes:

# of stirrup legs =	2	(single stirrup = 2, Dbl stirrup = 4……..)
Stirrup bar size =	4	
Av=	0.393	in^2
s=	0.000	in s = Av * fy * d / (Vu / f - Vc)

11.5.5 - Spacing limits for shear reinforcement

s = d/2 =	21.719	in	OR 24	in
s(max)=	10.859	in		
4*sqrt(Fc')*bw*d=	131.9	k	< Vs Reduce Spacing	
USE s=	**0.00**	in		
Vs = (Av * Fy * d) / s =	#DIV/0!	k		

11.5.6 - MINIMUM SHEAR REINFORCEMENT

A minimum area of shear reinforcement, Av,min shall be provided in all reinforced concrete flexural members where **Vu** exceeds **0.5 f Vc**

NOT REQUIRED IF:

a) SLAB OR FOOTING, vc>vn **O.K.**

b) CONCRETE JOIST ACI 8.11

c) BEAMS W/ h <= 10"

h <= 2.5*Bf

h <= 0.5*tw

d) WALLS (SEE ACI 11.10.1); vc>vn **O.K.**

11.5.6.3

Av,min = 0.75 sqrt(fc') bw*s/fy =	0.70	* s
but not less than 50bw*s/ fy =	23.33333333	* s
s max = Av fy / 0.75 sqrt(fc') bw =	0.00	in
s max = Av fy /50 bw =	0.00	in

11.5.5.3

Where Vs exceeds 4*sqrt(Fc')*bw*d maximum spacings shall be reduced by one-half