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 I	**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 I.xlsx]Load Cases		
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	917.5	903.24	**NA**
Diversion - Head Water El. (ft)	902.12	902.12	903.32	917.5	**NA**	**NA**
Diversion - Tail Water El. (ft)	901.91	901.91	903.06	917.5	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	917.5					
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)	898.68					
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**	**18.8**	**4.54**	**NA**
Diversion - Head Water height (ft)	**3.44**	**3.44**	**4.64**	**18.82**	**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)	**7.44**	**7.44**	**8.64**	**22.82**	**NA**	**NA**
Uplift @ TW (ft)	**7.23**	**7.23**	**8.38**	**22.82**	**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 I		

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	3,816	0	$0
INSTALL HP14x73 WALL PILING		LF	3,816	0	$0
PILE TEST, 63.0 ft	Long	EA	10	0	$0
FOOTING CONCRETE		CY	423	0	$0
	Forming	SF	1,870		
STEM CONCRETE		CY	433	0	$0
	Forming	SF	8,048		
STEEL REINFORCEMENT		LB	197,309	0	$0
WALL RAILING		LF	207	0	$0
SHEET PILE CUT-OFF WALL		SF	4,140	0	$0
					$0

Structure Length = 207 ft

No. piles = 72 Each

Length = 53 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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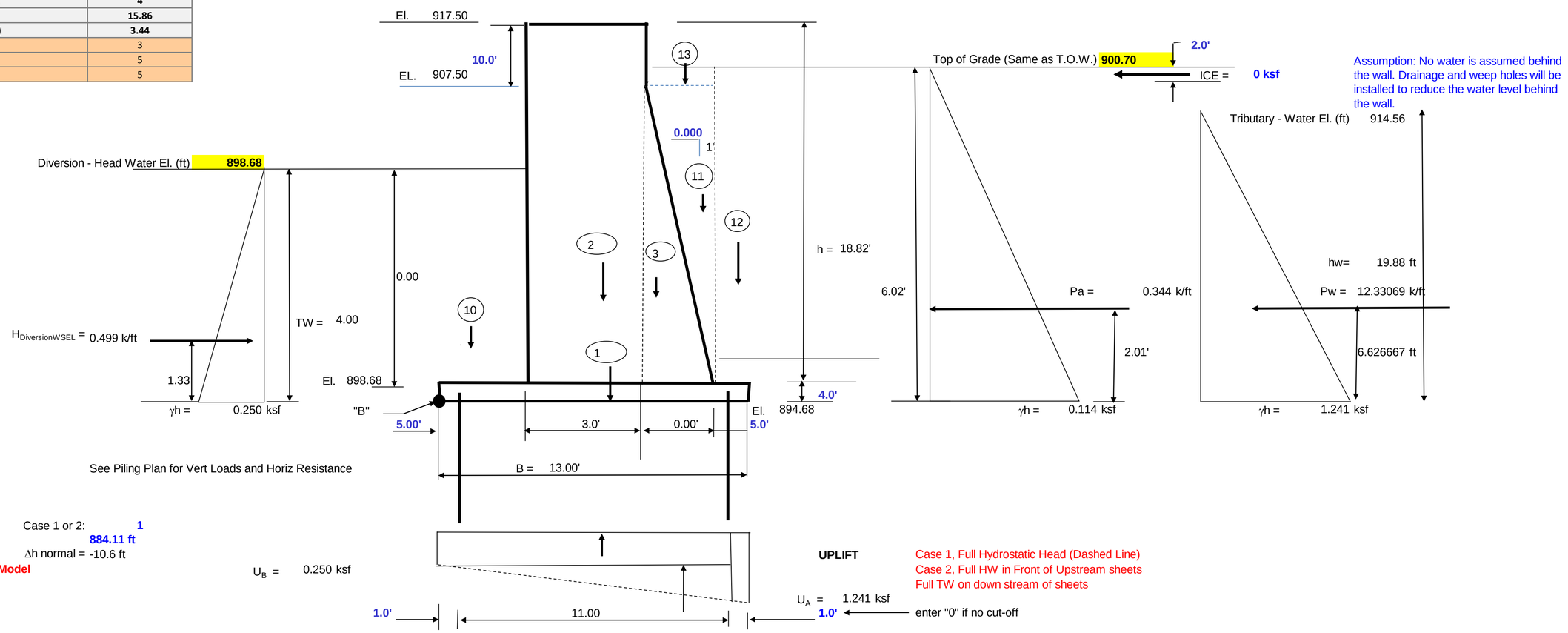
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood Panel I	

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)	917.5
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)	898.68
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)	3.44
Wall Thickness (ft)	3
Toe (Ft)	5
Heel (ft)	5

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 = 207.0 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 = -10.6 ft
See Geotechnical seepage Model

U_B = 0.250 ksf

U_A = 1.241 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
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	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem	2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter	3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
					D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	15.88	0.0624	rec	1025.6	10.50	10,768.7
					D.L. Water	ΣVw =	**2245.0**	ΣM_V =	**23,572.1**

Uplift Loads	L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
U_A	207	13.00	0.991	tri	-1333.3	8.67	-11,555
				ΣU =	**-2004.9**	ΣM_U =	**-15,921**

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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 I	

Horizontal Loads

	L	H	Pressure		**ICE**	arm	**Mu**
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	5.02	0.0

	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.344		-71.27	2.01	-143.01
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		-12.331	tri	-2552.45	6.63	-16914.25
				ΣWater =	**-2449.12**	ΣM_W =	**-16919.5**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-32840	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	45462	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**12,622**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,608**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,520**	kips

Location of Resultant	Xr = ΣM / P =	3.50	ft from Toe
	e = B/2 - Xr =	3.00	ft
	B/6 =	2.167	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	403	cy (includes stepped)	1870	sf
Stem Conc:	433	cy	8048	sf
Total =	835			

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	12.5	418	17,765		
	Longitudinal:	9	6	3.40	208.5	26	18,431		
Bot mat	Transverse:	9	6	3.40	12.5	418	17,765		
	Longitudinal:	9	6	3.40	208.5	26	18,431		
								cy	**LB/cy**
							72,393	403	179.8496135
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	18.32	414	25,787	51,574.46	
	Longitudinal:	9	6	3.40	206.5	37	25,978	51,955.40	
Top Face	Transverse:	9	6	3.40	2.5	414	3,519		
	Longitudinal:	9	6	3.40	206.5	6	4,213		
Dowels	Vertical I.F.	9	6	3.40	18.3	414	25,787		
	Vertical O.F.	9	6	3.40	18.3	414	25,787		
								cy	**LB/cy**
							111,071	433	256.597967
						Σ =	**183,464**		
	Lap Splices (long. Bars)	9		3.40	8	509	13,845		
						Σ Bar Wt=	197,309	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 =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	15.88	**0.0624**	0.990912	7.868	5.293	41.64711
Sum				7.907		41.67321
Net Forces				7.907		41.67321

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

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)	917.5
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)	898.68
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)	3.44
Wall Thickness (ft)	3
Toe (Ft)	5
Heel (ft)	5

File:

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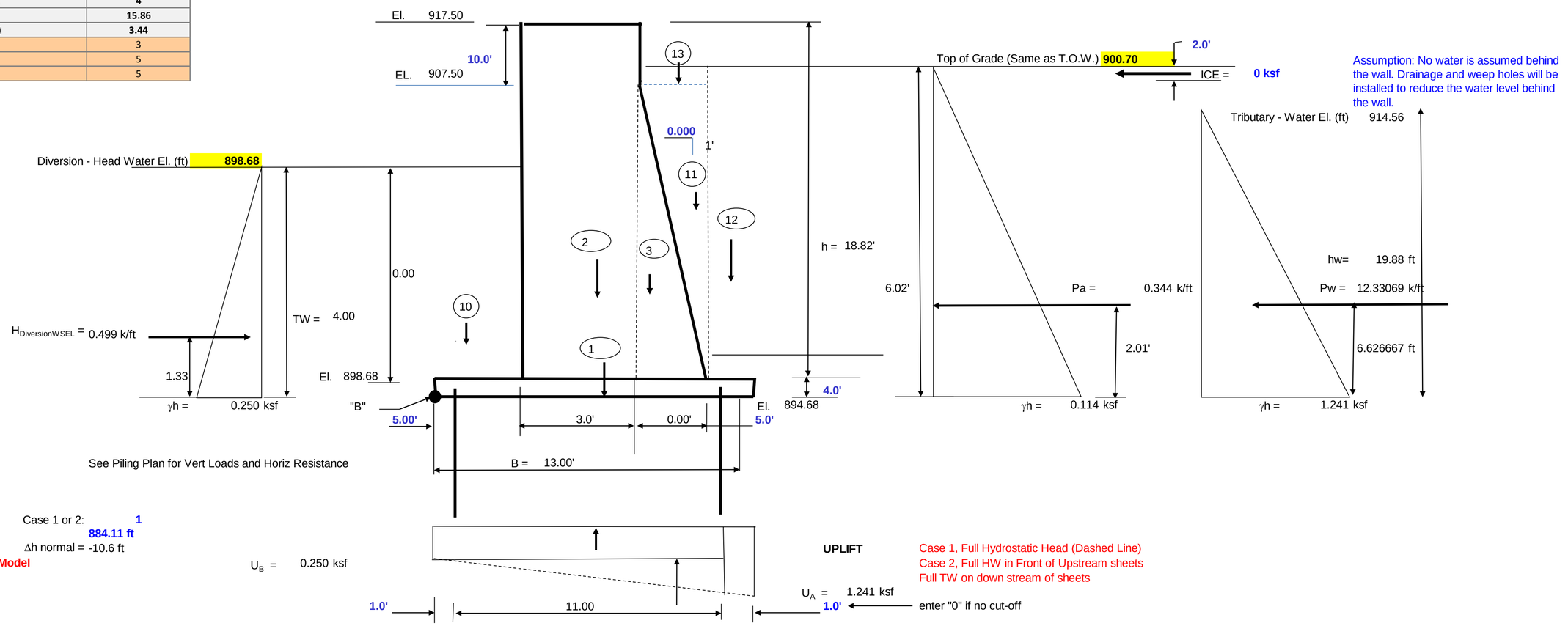
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 207.0 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 = -10.6 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	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem		2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter		3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
						D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	15.88	0.0624	rec	1025.6	10.50	10,768.7
					D.L. Water	ΣVw =	**2245.0**	ΣM_V =	**23,572.1**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
	U_A	207	13.00	0.991	tri	-1333.3	8.67	-11,555
					ΣU =	**-2004.9**	ΣM_U =	**-15,921**

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 I

ICE	207	2.00	0.00	rec	0.0	5.02	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	207		-0.344		-71.27	2.01	-143.01	
Water Loads								
H_{TW}	207		0.499	tri	103.33	1.33	137.78	
H_{HW}	207		-12.331	tri	-2552.45	6.63	-16914.25	
				ΣWater =	**-2449.12**	ΣM_W =	**-16919.5**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-32840	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	45462	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**12,622**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,608**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,520**	kips

Location of Resultant	Xr = ΣM / P =	3.50	ft from Toe
	e = B/2 - Xr =	3.00	ft
	B/6 =	2.167	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	15.88	**0.0624**	0.990912	7.868	5.293	41.64711
Sum				7.907		41.67321
Net Forces				7.907		41.67321

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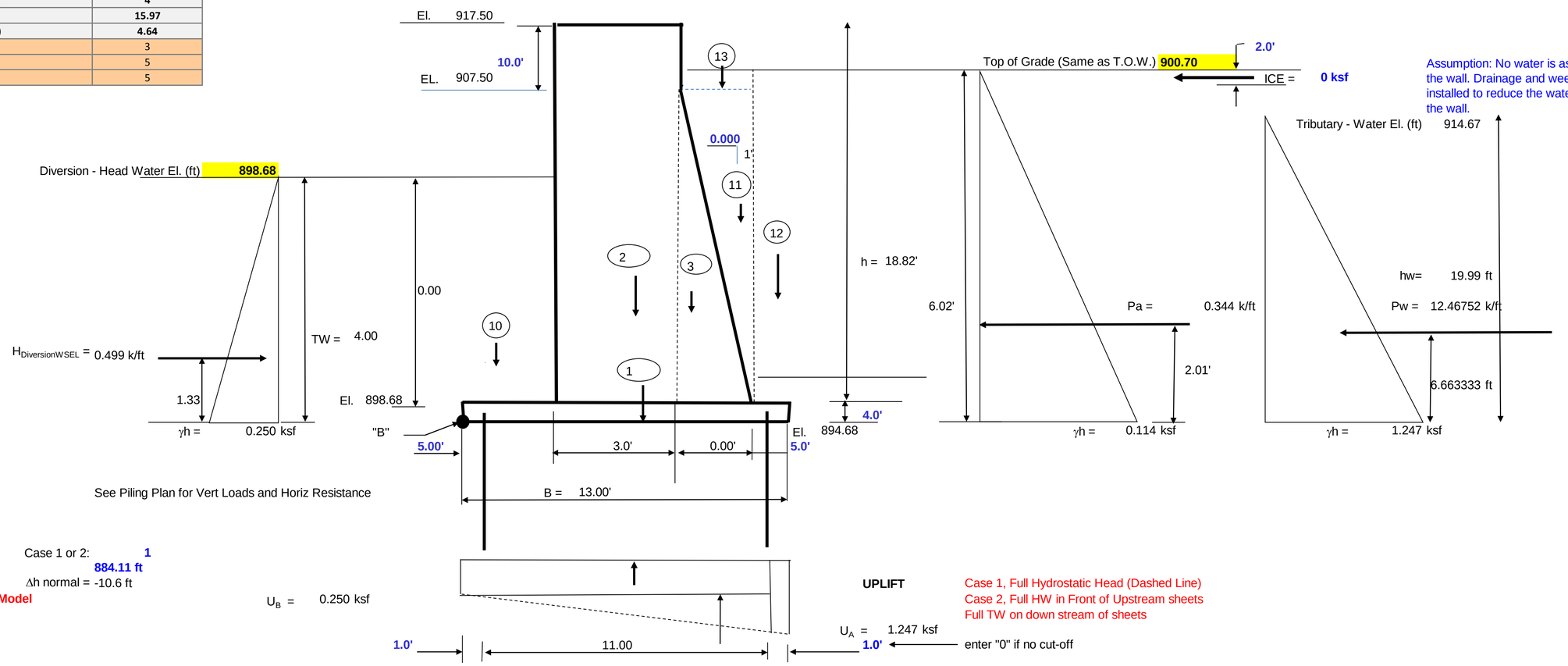
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 3 500 yr. flood	Panel I

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)	917.5
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)	898.68
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)	15.97
Diversion - Head Water height (ft)	4.64
Wall Thickness (ft)	3
Toe (Ft)	5
Heel (ft)	5

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 = 207.0 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 = -10.6 ft
See Geotechnical seepage Model

UPLIFT
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	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem	2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter	3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
					D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	15.99	0.0624	rec	1032.7	10.50	10,843.3
					D.L. Water	ΣVw =	**2252.1**	ΣM_V =	**23,646.7**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
	U_A	207	13.00	0.998	tri	-1342.5	8.67	-11,635
					ΣU =	**-2014.2**	ΣM_U =	**-16,001**

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

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

ICE	207	2.00	0.00	rec	0.0	5.02	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	207		-0.344		-71.27	2.01'	-143.01	
Water Loads								
H_{TW}	207		0.499	tri	103.33	1.33	137.78	
H_{HW}	207		-12.468	tri	-2580.78	6.66	-17196.58	
				ΣWater =	**-2477.44**	ΣM_W =	**-17201.8**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-33203	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	45537	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**12,334**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,606**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,549**	kips

Location of Resultant	Xr = ΣM / P =	3.42	ft from Toe
	e = B/2 - Xr =	3.08	ft
	B/6 =	2.167	ft

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 =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	15.99	**0.0624**	0.997776	7.977	5.330	42.51858
Sum				8.016		42.54468
Net Forces				8.016		42.54468

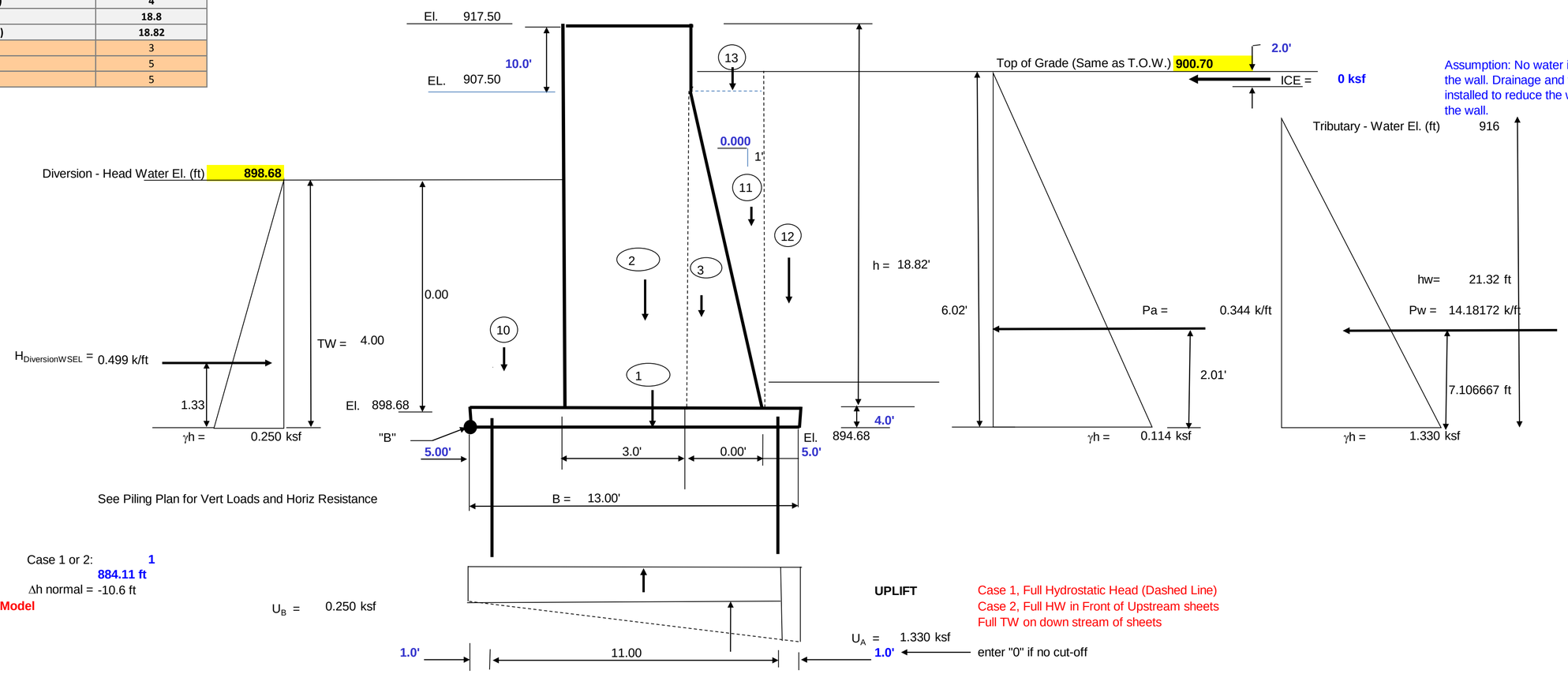
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 4 T.O. Levee Panel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

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	917.5
Diversion - Tail Water El. (ft)	917.5
Tributary - T.O. Wall El. (ft)	917.5
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)	898.68
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)	18.8
Diversion - Head Water height (ft)	18.82
Wall Thickness (ft)	3
Toe (Ft)	5
Heel (ft)	5

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 = 207.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



UPLIFT
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

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -10.6 ft
See Geotechnical seepage Model

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem	2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter	3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
					D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**
T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	17.32	0.0624	rec	1118.6	10.50	11,745.2
					D.L. Water	ΣVw =	**2338.0**	ΣM_V =	**24,548.6**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
	U_A	207	13.00	1.081	tri	-1454.2	8.67	-12,603
					ΣU =	**-2125.8**	ΣM_U =	**-16,969**

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 I

ICE	207	2.00	0.00	rec	0.0	5.02	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.344		-71.27	2.01'	-143.01
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		-14.182	tri	-2935.62	7.11	-20862.45
				ΣWater =	**-2832.28**	ΣM_W =	**-20867.7**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-37836	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	46439	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**8,602**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,580**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,904**	kips

Location of Resultant	Xr = ΣM / P =	2.40	ft from Toe
	e = B/2 - Xr =	4.10	ft
	B/6 =	2.167	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	17.32	**0.0624**	1.080768	9.359	5.773	54.03523
Sum				9.398		54.06133
Net Forces				9.398		54.06133

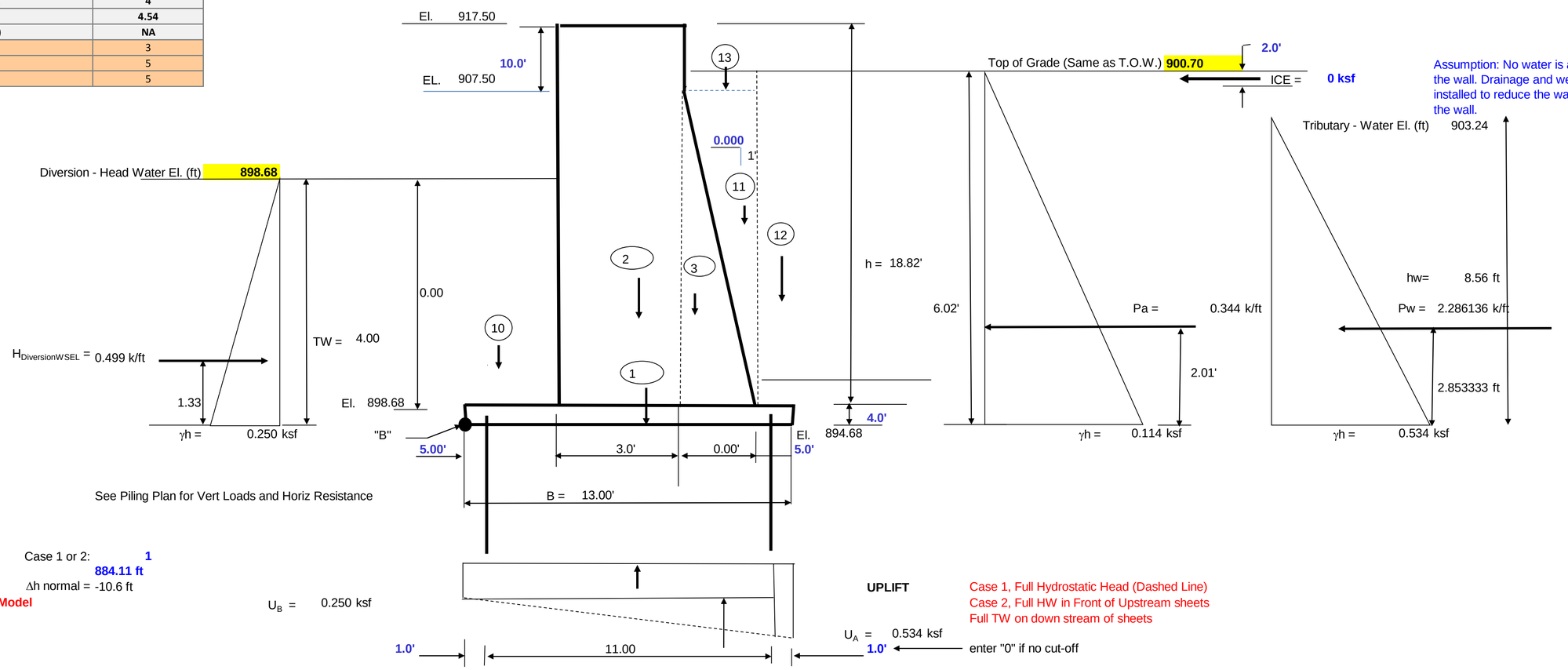
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice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

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)	917.5
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)	898.68
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)	3
Toe (Ft)	5
Heel (ft)	5

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 = 207.0 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 = -10.6 ft
See Geotechnical seepage Model

U_B = 0.250 ksf

U_A = 0.534 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
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	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem	2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter	3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
					D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	4.56	0.0624	rec	294.5	10.50	3,092.3
					D.L. Water	ΣVw =	**1513.9**	ΣM_V =	**15,895.6**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
	U_A	207	13.00	0.285	tri	-382.9	8.67	-3,318
					ΣU =	**-1054.5**	ΣM_U =	**-7,684**

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 I	

ICE	207	2.00	0.00		rec	0.0	5.02	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	207		-0.344			-71.27	2.01'	-143.01
Water Loads								
H_{TW}	207		0.499		tri	103.33	1.33	137.78
H_{HW}	207		-2.286		tri	-473.23	0.00	0.00
					ΣWater =	**-369.90**	ΣM_W =	**-5.2**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-7689	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	37786	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**30,096**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,827**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-441**	kips

Location of Resultant	Xr = ΣM / P =	7.86	ft from Toe
	e = B/2 - Xr =	(1.36)	ft
	B/6 =	2.167	ft

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 =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	4.56	**0.0624**	0.284544	0.649	1.520	0.986116
Sum				0.688		1.012217
Net Forces				0.688		1.012217

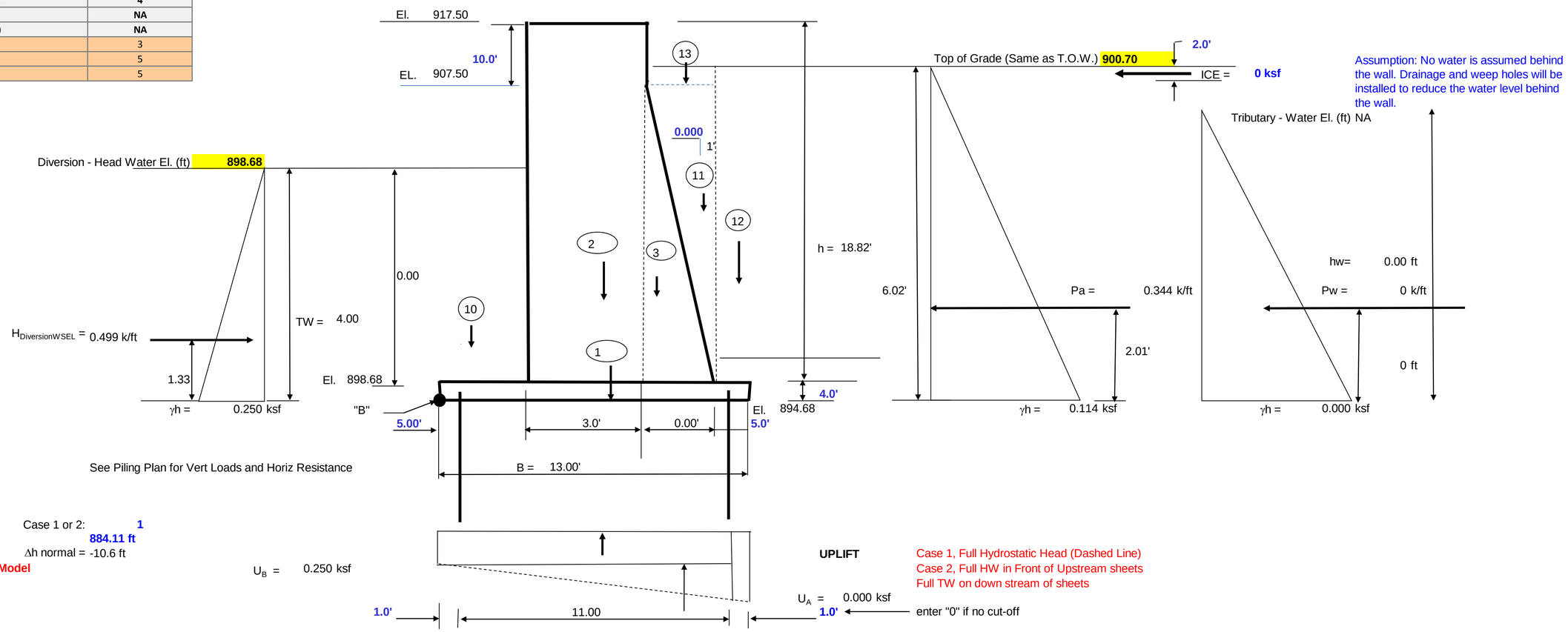
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 6 Construction Panel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

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)	917.5
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)	898.68
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)	3
Toe (Ft)	5
Heel (ft)	5

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 = 207.0 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 = -10.6 ft
See Geotechnical seepage Model

UPLIFT
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	207	13.00	4.00	0.15	rec	1614.6	6.50	10,494.9
Stem	2	207	3.00	18.82	0.15	rec	1753.1	6.50	11,395.0
Batter	3	207	0.00	8.82	0.15	tri	0.0	8.00	0.0
					D.L. Concrete	ΣVc =	**3367.7**	ΣM_V =	**21,889.9**
T.W on ftg Stem	10	207	5.00	0.00	0.0624	rec	0.0	2.50	0.0
H.W. on Stem Slope	11	207	0.00	2.02	0.12	tri	0.0	8.00	0.0
H.W. Above Slope	13	207	0.00	-6.80	0.12	rec	0.0	8.00	0.0
Soil on Footing	12s	207	5.00	18.82	0.0626	rec	1219.4	10.50	12,803.3
H.W. on Footing	12w	207	5.00	-4.00	0.0624	rec	-258.3	10.50	-2,712.5
					D.L. Water	ΣVw =	**961.0**	ΣM_V =	**10,090.8**

CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
	U_B	207	13.00	0.250	rec	-671.7	6.50	-4,366
	U_A	207	13.00	-0.250	tri	335.8	8.67	2,911
					ΣU =	**-335.8**	ΣM_U =	**-1,455**

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 I

ICE	207	2.00	0.00		rec	0.0	5.02	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	207		-0.344			-71.27	2.01'	-143.01
Water Loads								
H_{TW}	207		0.499		tri	103.33	1.33	137.78
H_{HW}	207		0.000		tri	0.00	0.00	0.00
					ΣWater =	**103.33**	ΣM_W =	**-5.2**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1461	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	31981	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**30,520**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,993**	kips
Sum of Horizontal Forces	H = Σhorizontal	**32**	kips

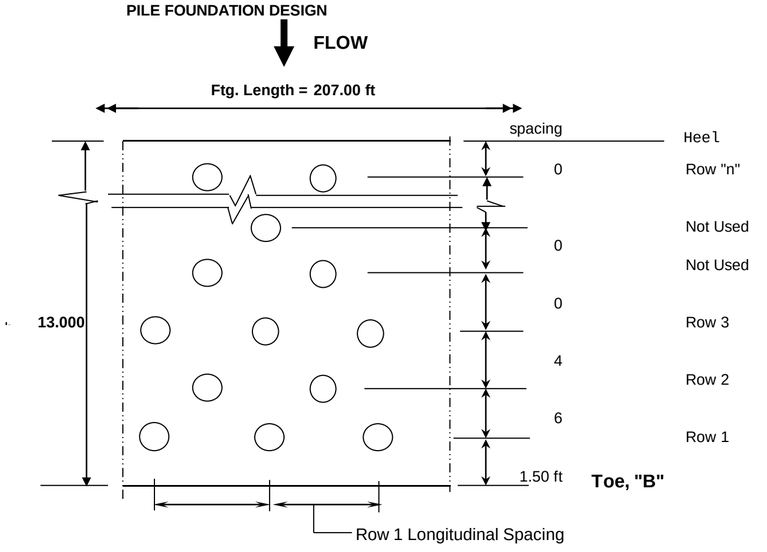
Location of Resultant	Xr = ΣM / P =	7.64	ft from Toe
	e = B/2 - Xr =	(1.14)	ft
	B/6 =	2.167	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	2.02	**0.019**	0.03838	0.039	0.673	0.026101
Tributary WSEL =	-4.00	**0.0624**	-0.2496	0.499	-1.333	-0.6656
Sum				0.538		-0.6395
Net Forces				0.538		-0.6395

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	
				Panel I	

PILE FOUNDATION DESIGN



L = 207.00 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"	24	74.75	1	83
Row 1 to Row 2	6.00 ft	7.5 ft	5.00 ft	0 "/12"	24	46.00	2	42
Row 2 to Row 3	4.00 ft	11.5 ft	0.00 ft	0 "/12"	24	103.50	3	#DIV/0!
Row 3 to Row 4	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	103.50	0	0
Last Row to Heel	1.50 ft							
	13.00 ft				ΣN =	72		#DIV/0!

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

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **53.0 ft**
HP Nominal Depth, h = **14.0 in**
Wt. per ft, plf **73**

Ftg EL. 894.68
Pile Tip El. 842.68
Pile Cap Embed = **1.00 ft**

Total pile Length = 3,816 LF

Pile Group Properties

N.A. of Pile Group to Toe
$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **6.83 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	5.33 ft	24	682.7
2	Dist. To Row 2	-0.67 ft	24	10.7
3	Dist. Row 3	-4.67 ft	24	522.7
0	Row 4 (not used)	0.00 ft	0	0.0
0	Row 5 (not used)	0.00 ft	0	0.0
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
			72	$\Sigma I =$ **1216.0**

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**	51.4	21.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.4	2,592	**OK**
Case 2	**82.6 tons**	51.4	21.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.4	2,952	**OK**
Case 3	**82.6 tons**	52.0	21.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0	2,952	**OK**
Case 4	**107.7 tons**	59.6	20.5	-5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.6	3,456	**OK**
Case 5	**36.5 tons**	17.9	27.7	34.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.1	1,656	**OK**
Case 6	**82.6 tons**	20.6	28.6	33.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.9	1,656	**OK**

Max Service : P = **59.6**

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

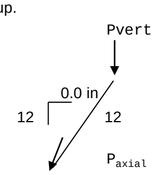
$$e_{NA} = X_{NA} - e_{toe}$$

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-	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$

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 I**	

Case 1	**100 yr. flood**	**Usual**	3,608	2,520	12,622	3.50	3.33	12031
Case 2	**100 yr. flood + ice**	**Unusual**	3,608	2,520	12,622	3.50	3.33	12031
Case 3	**500 yr. flood**	**Unusual**	3,606	2,549	12,334	3.42	3.41	12304
Case 4	**T.O. Levee**	**Extreme**	3,580	2,904	8,602	2.40	4.43	15860
Case 5	**Normal flow + ice**	**Usual**	3,827	441	30,096	7.86	-1.03	-3945
Case 6	**Construction**	**Unusual**	3,993	-32	30,520	7.64	-0.81	-3236

SERVICE

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

Vertical Load, P = 3608 kips
Horizontal Load, H = 2520 kips
M_{NA} = 12031 kip-ft

72

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	50.1		52.8	102.9 kips/pile	51.4 tons/pile	51.4 tons/pile
2	Row 2	50.1		-6.6	43.5 kips/pile	21.8 tons/pile	21.8 tons/pile
3	Row 3	50.1		-46.2	3.9 kips/pile	2.0 tons/pile	2.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**51.4 tons/pile**	**max: 51.4 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	24	0.0	864	1.000	864 kips
2	Row 2	0	24	0.0	864	1.000	864 kips
3	Row 3	0	24	0.0	864	1.000	864 kips
4	Row 4	0	0	0.0	0	1.000	0 kips
5	Row 5	0	0	0.0	0	1.000	0 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
			72		2592		**2592 kips**

OK

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

Vertical Load, P = 3608 kips
Horizontal Load, H = 2520 kips
M_{NA} = 12031 kip-ft

72

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	50.1		52.8	102.9 kips/pile	51.4 tons/pile	51.4 tons/pile
2	Row 2	50.1		-6.6	43.5 kips/pile	21.8 tons/pile	21.8 tons/pile
3	Row 3	50.1		-46.2	3.9 kips/pile	2.0 tons/pile	2.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**51.4 tons/pile**	**max: 51.4 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	24	0.0	984	1.000	984 kips
2	Row 2	0	24	0.0	984	1.000	984 kips
3	Row 3	0	24	0.0	984	1.000	984 kips

4	Row 4	0	0	0.0	0	1.000	0 kips	
5	Row 5	0	0	0.0	0	1.000	0 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	
			72		2952		**2952 kips**	**OK**

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

Vertical Load, P = 3606 kips
Horizontal Load, H = 2549 kips
M_{NA} = 12304 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	50.1		54.0	104.0 kips/pile	52.0 tons/pile	52.0 tons/pile
2	Row 2	50.1		-6.7	43.3 kips/pile	21.7 tons/pile	21.7 tons/pile
3	Row 3	50.1		-47.2	2.9 kips/pile	1.4 tons/pile	1.4 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**52.0 tons/pile**	**max: 52.0 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	24	0.0	984	1.000	984 kips	
2	Row 2	0	24	0.0	984	1.000	984 kips	
3	Row 3	0	24	0.0	984	1.000	984 kips	
4	Row 4	0	0	0.0	0	1.000	0 kips	
5	Row 5	0	0	0.0	0	1.000	0 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	
			72		2952		**2952 kips**	**OK**

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

Vertical Load, P = 3580 kips
Horizontal Load, H = 2904 kips
M_{NA} = 15860 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	49.7		69.6	119.3 kips/pile	59.6 tons/pile	59.6 tons/pile
2	Row 2	49.7		-8.7	41.0 kips/pile	20.5 tons/pile	20.5 tons/pile
3	Row 3	49.7		-60.9	-11.1 kips/pile	-5.6 tons/pile	-5.6 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**59.6 tons/pile**	**max: 59.6 tons/pile**

Assumed lateral Capacity: 48.0 kips/pile

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			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls **Panel I**	

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	24	0.0	1152	1.000	1152 kips	
2	Row 2	0	24	0.0	1152	1.000	1152 kips	
3	Row 3	0	24	0.0	1152	1.000	1152 kips	
4	Row 4	0	0	0.0	0	1.000	0 kips	
5	Row 5	0	0	0.0	0	1.000	0 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	
			72		3456		**3456 kips**	**OK**

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

Vertical Load, P = 3827 kips
Horizontal Load, H = 441 kips
M_{NA} = -3945 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	53.2		-17.3	35.9 kips/pile	17.9 tons/pile	17.9 tons/pile
2	Row 2	53.2		2.2	55.3 kips/pile	27.7 tons/pile	27.7 tons/pile
3	Row 3	53.2		15.1	68.3 kips/pile	34.1 tons/pile	34.1 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**34.1 tons/pile**	**max: 34.1 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	24	0.0	552	1.000	552 kips	
2	Row 2	0	24	0.0	552	1.000	552 kips	
3	Row 3	0	24	0.0	552	1.000	552 kips	
4	Row 4	0	0	0.0	0	1.000	0 kips	
5	Row 5	0	0	0.0	0	1.000	0 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	
			72		1656		**1656 kips**	**OK**

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

Vertical Load, P = 3993 kips
Horizontal Load, H = -32 kips
M_{NA} = -3236 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	55.5		-14.2	41.3 kips/pile	20.6 tons/pile	20.6 tons/pile
2	Row 2	55.5		1.8	57.2 kips/pile	28.6 tons/pile	28.6 tons/pile
3	Row 3	55.5		12.4	67.9 kips/pile	33.9 tons/pile	33.9 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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

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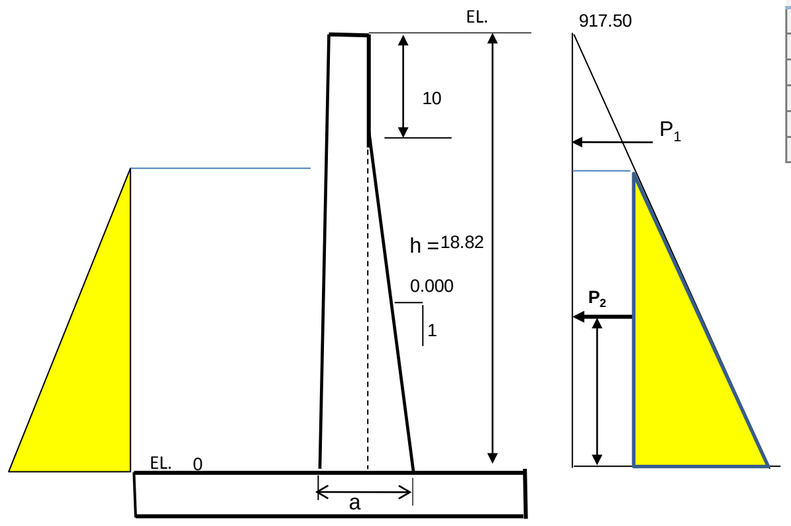
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile
					max:	**33.9 tons/pile**	**max:**	**33.9 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	24	0.0	552	1.000	552 kips	
2	Row 2	0	24	0.0	552	1.000	552 kips	
3	Row 3	0	24	0.0	552	1.000	552 kips	
4	Row 4	0	0	0.0	0	1.000	0 kips	
5	Row 5	0	0	0.0	0	1.000	0 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	
			72		1656		**1656 kips**	**OK**

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 Panel I 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	917.500	917.50	0.00	917.50
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	7.91	41.673	17.47	92.10
Case 2	100 yr. flood + ice	Unusual	0.75	7.91	41.673	13.11	69.07
Case 3	500 yr. flood	Unusual	0.75	8.02	42.545	13.29	70.52
Case 4	T.O. Levee	Extreme	0.75	9.40	54.061	15.58	89.61
Case 5	Normal flow + ice	Usual	1	0.69	1.012	1.52	2.24
Case 6	Construction	Unusual	0.75	0.54	-0.639	0.89	-1.06

STEM DESIGN VALUES

MU, k-ft/ft	92.10	k-ft/ft
VU, k/ft	17.47	k/ft

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Panel I 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 =	92	k-ft /ft	Includes: hf = 1.3
Vuh=	17.47	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 = 54.079

REQ'D p= 0.0009 **O.K.**

p= 0.0012

As (REQ'D)= 0.81 in^2

ACI 10.5.1

p(min)= 3*SQRT(Fc')/fy 0.00316

200* / fy 0.00333

ACI 10.5.3

4/3*p 0.0012

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 =	313.1	**a**	4) p = >**0.5** pb but ≤ 0.375 pb permitted only if detailed serviceability analysis incl. deflect. Calc.
a= T/C =	0.383	in	
Mn= T(d - a/2)/12 =	432.2	ft-k	b) Use of compression reinf. shall be per ACI 318
ϕ Mn=	389.0	ft-k	**> Mu O.K.**

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

Vuh =	17.5	k		NO SHEAR REINF. REQUIRED
Vn = Vuh / ϕ =	23.3	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=		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=	**10.86**	in		
Vs = (Av * Fy * d) / s =	0.0	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 = 0.33 * s

but not less than 50bw*s/ fy = 10.83333333 * 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