

MAPLE 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 Description:	Maple Aquaduct Structure - Retaining Walls	Date:	2/10/2011
	Panel B	Job #:	34091004
File Path:	P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_Phase4\070 Structural\Aqueducts\Maple\[34091004 PH4 Maple Retaining Walls Panel B.xlsx]Stem		

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)	895.99	895.99	896.38	902	881.5	NA
Diversion - Head Water El. (ft)	893.89	893.89	895.46	902	NA	NA
Diversion - Tail Water El. (ft)	892.57	892.57	893.66	902	NA	NA
Tributary - T.O. Wall El. (ft)	902					
Tributary - T.O. Deck L.P. El.(ft)	881.06					
Tributary - T.O. Deck H.P. El.(ft)	883.06					
Diversion - T.O. Mat El. (ft)	884.06					
Tributary - Deck Slab thickness @ L.P. (ft)	2					
Tributary - Deck Slab thickness @ H.P. (ft)	4					
Diversion - Mat Slab thickness (ft)	4					
Tributary - Water height (ft)	14.93	14.93	15.32	20.94	0.44	NA
Diversion - Head Water height (ft)	9.83	9.83	11.4	17.94	NA	NA
Ice	NA	2ft Ice	NA	NA	2ft Ice	NA
Ice Load	NA	10 kips/ft	NA	NA	10 kips/ft	NA
Ice Load El. (ft)	NA	895.99	NA	NA	881.5	NA
Uplift @ HW (ft)	13.83	13.83	15.4	21.94	NA	NA
Uplift @ TW (ft)	12.51	12.51	13.6	21.94	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
Allowable Lateral Capacity (tons)	18	21	21	24	11.5	21
Allowable Pile Capacity (tons) - Axial	57.18	76.23	76.23	99.43	31.425	76.23
Allowable Pile Capacity (tons) - Uplift	33.88	45.17	45.17	58.91	4.625	45.17

Pile Capacity	Ultimate Axial Capacity (kips)	Allowable Lateral Capacity (kips)		
		0.5" (Usual)	0.67" (Unusual)	0.875" (Extreme)
Undrained - Axial	228.7	36	42	48
Undrained - Uplift	135.5			
Drained - Axial	125.7	23	29	33
Drained - Uplift	18.5			

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	Maple Aquaduct Structure - Retaining Walls		
2/11/11				Panel B		

Monolith Structure			UNIT	QUANTITY	UNIT COST	TOTAL Cost
ITEM						
FURNISH HP14x73 WALL PILING			LF	1,381	0	\$0
INSTALL HP14x73 WALL PILING			LF	1,381	0	\$0
PILE TEST, 48.4 ft Long			EA	4	0	\$0
FOOTING CONCRETE			CY	205	0	\$0
	Forming		SF	820		
STEM CONCRETE			CY	214	0	\$0
	Forming		SF	3,074		
STEEL REINFORCEMENT			LB	42,699	0	\$0
WALL RAILING			LF	81	0	\$0
SHEET PILE CUT-OFF WALL			SF	805	0	\$0
						\$0

Structure Length = 80.5 ft

No. piles = 36 Each

Length = 38.38 ft

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

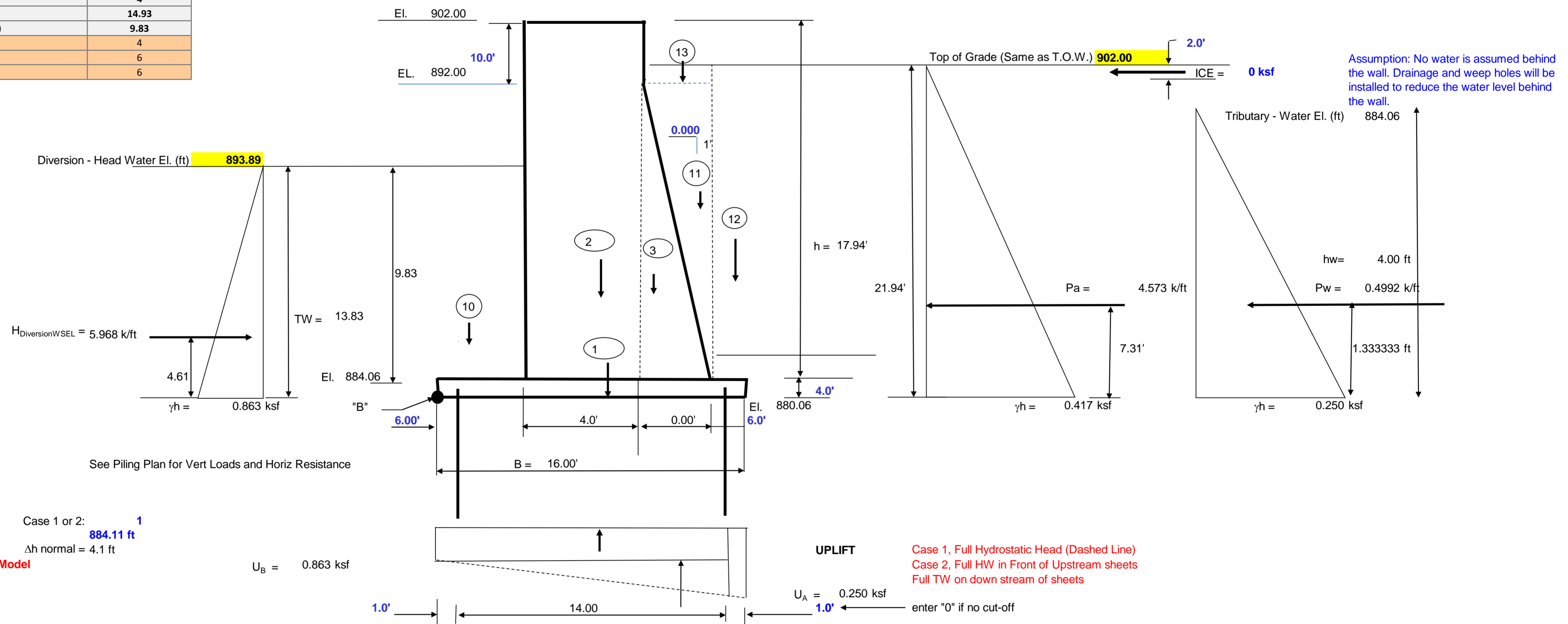
LENGTH
(FRONT FACE) 10 FT
Native Soil has low permeability assume cut-off minimal to prevent scour

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MBI	CHECKED	PROJECT NUMBER	34091004		
2/11/11	MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
		Load Cases: Case 1	100 yr. flood	Panel B	

ID#	Case 1
Name	100 yr. flood
Load Category	Usual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	14.93
Diversion - Head Water height (ft)	9.83
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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 = 4.1 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	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0
D.L. Concrete							ΣVc = 1639.3	ΣMv = 13,114.4	CONSTANT FOR ALL LOAD CASES

T.W. on ftg Stem	10	80.5	6.00	9.83	0.0624	rec	296.3	3.00	888.8
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0
D.L. Water							ΣVw = 838.7	ΣMv = 7,940.4	

Uplift Loads		L ft	W ft	Pressure ksf	U K	arm ft	Mu ft-k
Ub		80.5	16.00	0.863	-1111.5	8.00	-8,892
Ua		80.5	16.00	-0.613	395.0	10.67	4,214
					ΣU = -716.5	ΣMu = -4,679	

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COMPUTED			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4		
MBI	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
				Load Cases: Case 1 100 yr. flood Panel B		

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	20.94	0.0
		L		Force		H	arm	Mw
		ft		k/ft		K	ft	ft-k
	SOIL	80.5		-4.573		-368.12	7.31	-2692.20
	Water Loads							
	H _{TW}	80.5		5.968	tri	480.39	4.61	2214.60
	H _{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58
						ΣWater = 440.21		ΣM _W = -531.2

Overturning Moments ΣM_{OT} = M_U + M_W + M_{ICE} = -5210 kip-ft
Resisting Moments ΣM_R = M_V = 21055 kip-ft

Sum of Moments	ΣMnet = M _R + M _{OT} =	15,845	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	1,761	kips
Sum of Horizontal Forces	H = Σhorizontal	72	kips

Location of Resultant X_r = ΣM / P = 9.00 ft from Toe
e = B/2 - X_r = (1.00) ft
B/6 = 2.667 ft

CONCRETE QUANTITIES

Ftg conc:	196 cy (includes stepped)	forming	820	sf
Stem Conc:	214 cy		3074	sf
Total =	410			

STEEL REINFORCEMENT: (assumed)

	Bar #	Spacing in	LB/ft	Length ft	# of bars ea	Total wt lb		
a) Footing								
Top mat Transverse:	9	12	3.40	15.5	83	4,374		
Longitudinal:	9	12	3.40	82	16	4,461		
Bot mat Transverse:	9	12	3.40	15.5	83	4,374		
Longitudinal:	9	12	3.40	82	16	4,461		
						17,670	cy	LB/cy
								196 90.35693182
b) Skin Reinf. On Monolith								
Vert Face Vertical:	9	12	3.40	17.44	81	4,803	9,605.95	
Longitudinal:	9	12	3.40	80	18	4,896	9,792.00	
Top Face Transverse:	9	12	3.40	3.5	81	964		
Longitudinal:	9	12	3.40	80	4	1,088		
Dowels Vertical I.F.:	9	12	3.40	17.4	81	4,803		
Vertical O.F.:	9	12	3.40	17.4	81	4,803		
						21,357	cy	LB/cy
						39,027		214 99.82106608
						Σ =		
Lap Splices (long. Bars)	9		3.40	8	135	3,672		
						Σ Bar Wt =		42,699 lb

FORCES AT THE BOTTOM OF THE STEM

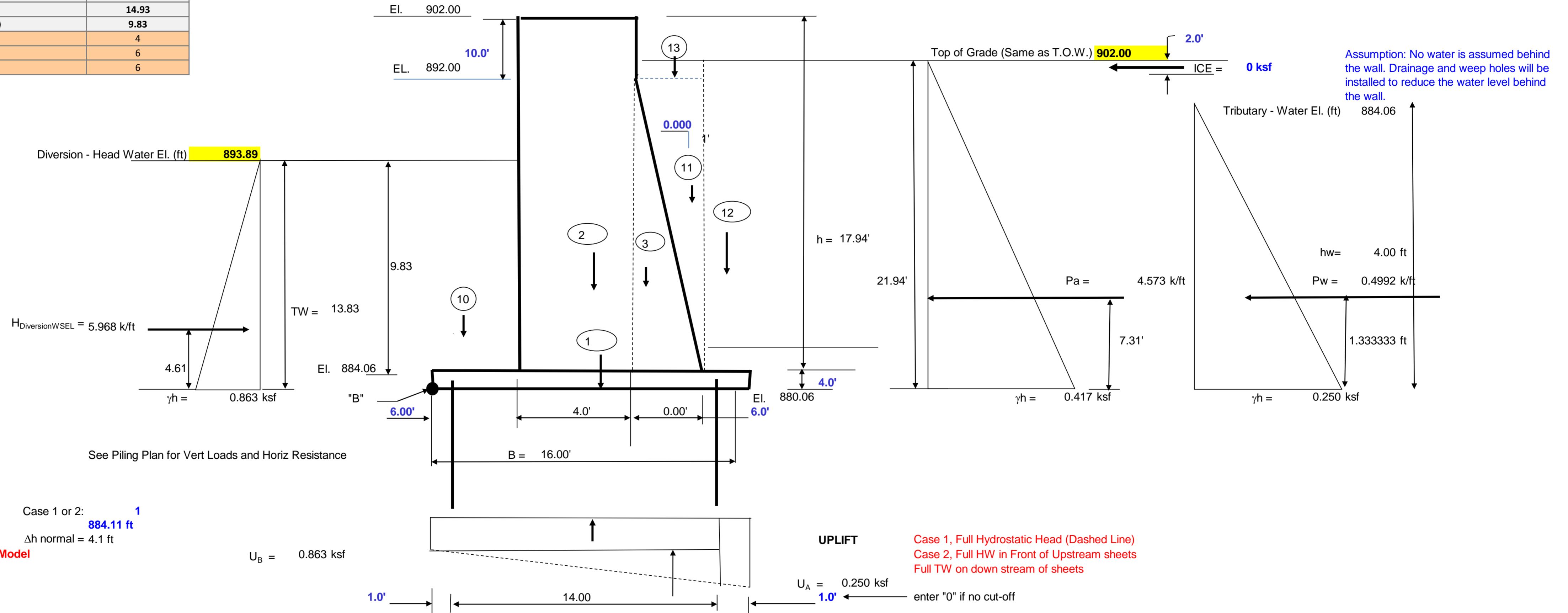
Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	9.83	0.0624	0.613392	3.015	3.277	9.878566
Tributary SEL =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				0.043		8.405369

BARR ENGINEERING		DATE	2/11/2011	SHEET NO.	
COMPUTED		CHECKED		PROJECT NAME	
MBI				FARGO - MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
2/11/11		SUBMITTED	MBI	PROJECT NUMBER	
				34091004	
		SUBJECT		Maple Aquaduct Structure - Retaining Walls	
		SUBJECT		Load Cases: Case 2 100 yr. flood + ice	
				Panel B	

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	14.93
Diversion - Head Water height (ft)	9.83
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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 = 4.1 ft
 See Geotechnical seepage Model

Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv
		ft	ft	ft	kcf		K	ft	ft-k
Ftg concrete	1	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0
D.L. Concrete							ΣVc = 1639.3		ΣMv = 13,114.4

T.W. on ftg Stem	10	80.5	6.00	9.83	0.0624	rec	296.3	3.00	888.8
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0
D.L. Water							ΣVw = 838.7		ΣMv = 7,940.4

Uplift Loads		L	W	Pressure		U	arm	Mu
		ft	ft	ksf		K	ft	ft-k
U _B		80.5	16.00	0.863	rec	-1111.5	8.00	-8,892
U _A		80.5	16.00	-0.613	tri	395.0	10.67	4,214
ΣU =						-716.5		ΣMu = -4,679

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

CONSTANT FOR ALL LOAD CASES

BARR ENGINEERING		DATE	2/11/2011		SHEET NO.	
COMPUTED		PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4			
MBI	CHECKED	PROJECT NUMBER	34091004			
2/11/11	SUBMITTED	SUBJECT	Maple Aquaduct Structure - Retaining Walls			
			Load Cases: Case 2 100 yr. flood + ice Panel B			

ICE	80.5	2.00	0.00	rec	0.0	20.94	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	80.5		-4.573		-368.12	7.31	-2692.20
Water Loads							
H _{TW}	80.5		5.968	tri	480.39	4.61	2214.60
H _{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58
					ΣWater = 440.21		ΣM _W = -531.2

Overturning Moments $\Sigma M_{OT} = M_U + M_W + M_{ICE} = -5210$ kip-ft
Resisting Moments $\Sigma M_R = M_V = 21055$ kip-ft

Sum of Moments	$\Sigma M_{net} = M_R + M_{OT} =$	15,845	kip-ft
Sum of Vertical Forces	$P = \text{Conc} + \text{Water} + \text{Uplift} =$	1,761	kips
Sum of Horizontal Forces	$H = \Sigma \text{horizontal} =$	72	kips

Location of Resultant $X_r = \Sigma M / P = 9.00$ ft from Toe
 $e = B/2 - X_r = (1.00)$ ft
 $B/6 = 2.667$ ft

FORCES AT THE BOTTOM OF THE STEM

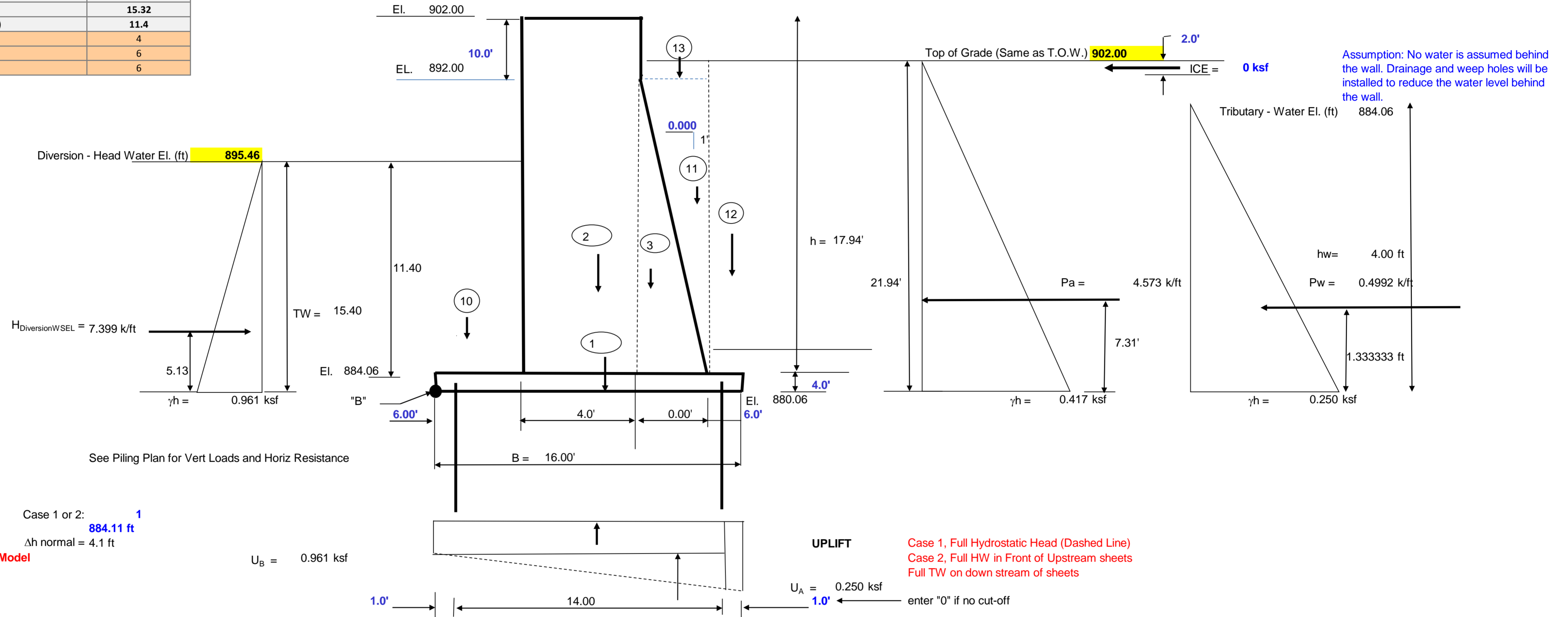
Diversion Face	H ft	γ kcf	Pbase	V K	arm ft	Mv ft-k
Diversion WSEL	9.83	0.0624	0.613392	3.015	3.277	9.878566
Tributary SEL =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				0.043		8.405369

BARR ENGINEERING		DATE	2/11/2011	SHEET NO.	
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MBI	CHECKED	PROJECT NUMBER	34091004		
2/11/11	MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
		Load Cases: Case 3	500 yr. flood	Panel B	

ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	896.38
Diversion - Head Water El. (ft)	895.46
Diversion - Tail Water El. (ft)	893.66
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	15.32
Diversion - Head Water height (ft)	11.4
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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



Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv	
		ft	ft	ft	kcf		K	ft	ft-k	
Ftg concrete	1	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4	
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0	
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0	
D.L. Concrete							$\Sigma V_c =$	1639.3	$\Sigma M_v =$	13,114.4

T.W. on ftg Stem	10	80.5	6.00	11.40	0.0624	rec	343.6	3.00	1,030.8	
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0	
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0	
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6	
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0	
D.L. Water							$\Sigma V_w =$	886.0	$\Sigma M_v =$	8,082.4

Uplift Loads	L	W	Pressure	U	arm	Mu
	ft	ft	ksf	K	ft	ft-k
U_B	80.5	16.00	0.961	-1237.7	8.00	-9,902
U_A	80.5	16.00	-0.711	458.1	10.67	4,887
$\Sigma U =$				-779.6	$\Sigma M_U =$	-5,015

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

CONSTANT FOR ALL LOAD CASES

BARR ENGINEERING			DATE	2/11/2011			SHEET NO.	
COMPUTED			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4				
MBI 2/11/11			CHECKED	PROJECT NUMBER	34091004			
			SUBMITTED	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel B			
			ICE	80.5	2.00	0.00	rec	0.0 20.94 0.0

	L ft	Force k/ft		H K	arm ft	Mw ft-k
SOIL	80.5	-4.573		-368.12	7.31'	-2692.20
Water Loads						
H _{TW}	80.5	7.399	tri	595.65	5.13	3057.68
H _{HW}	80.5	-0.499	tri	-40.19	1.33	-53.58
				ΣWater =	555.47	ΣM _W = 311.9

Overturning Moments $\Sigma M_{OT} = M_U + M_W + M_{ICE} = -4703$ kip-ft
Resisting Moments $\Sigma M_R = M_V = 21197$ kip-ft

Sum of Moments	$\Sigma M_{net} = M_R + M_{OT} =$	16,493	kip-ft
Sum of Vertical Forces	$P = \text{Conc} + \text{Water} + \text{Uplift} =$	1,746	kips
Sum of Horizontal Forces	$H = \Sigma \text{horizontal} =$	187	kips

Location of Resultant $X_r = \Sigma M / P = 9.45$ ft from Toe
 $e = B/2 - X_r = (1.45)$ ft
 $B/6 = 2.667$ ft

FORCES AT THE BOTTOM OF THE STEM

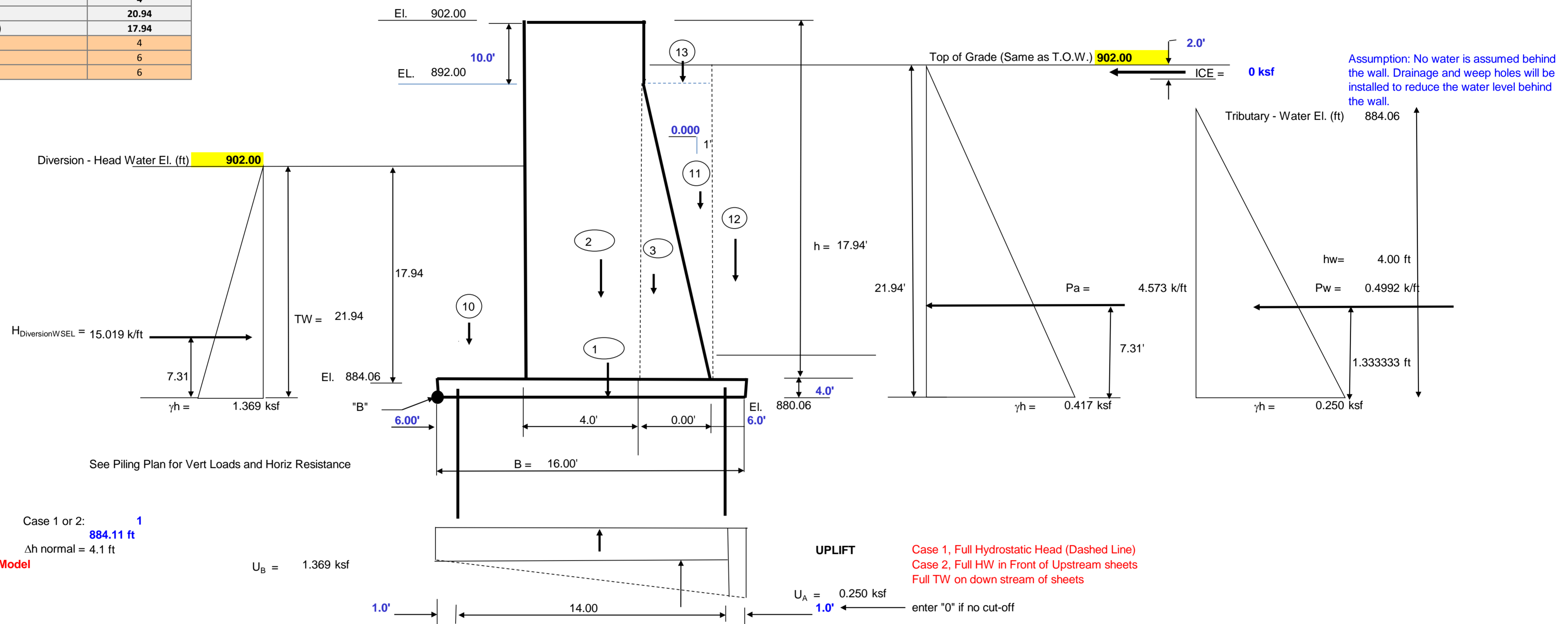
Diversion Face	H ft	γ kcf	Pbase	V K	arm ft	Mv ft-k
Diversion WSEL	11.40	0.0624	0.71136	4.055	3.800	15.40806
Tributary SEL =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				-0.997		2.875877

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		SUBMITTED	MBI	PROJECT NUMBER	
				34091004	
		SUBJECT		Maple Aquaduct Structure - Retaining Walls	
		Load Cases: Case 4 T.O. Levee		Panel B	

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	902
Diversion - Tail Water El. (ft)	902
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	20.94
Diversion - Head Water height (ft)	17.94
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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 = 4.1 ft
 See Geotechnical seepage Model

Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv
		ft	ft	ft	kcf		K	ft	ft-k
Ftg concrete	1	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0
D.L. Concrete							ΣVc = 1639.3		ΣMv = 13,114.4

T.W. on ftg Stem	10	80.5	6.00	17.94	0.0624	rec	540.7	3.00	1,622.1
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0
D.L. Water							ΣVw = 1083.1		ΣMv = 8,673.7

Uplift Loads		L	W	Pressure		U	arm	Mu
		ft	ft	ksf		K	ft	ft-k
UB		80.5	16.00	1.369	rec	-1763.3	8.00	-14,107
UA		80.5	16.00	-1.119	tri	720.9	10.67	7,690
ΣU =						-1042.4		ΣMu = -6,417

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

CONSTANT FOR ALL LOAD CASES

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

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

ICE	80.5	2.00	0.00	rec	0.0	20.94	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	80.5		-4.573		-368.12	7.31'	-2692.20
Water Loads							
H _{TW}	80.5		15.019	tri	1208.99	7.31	8841.77
H _{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58
				ΣWater =	1168.81	ΣM _W =	6096.0

Overturning Moments $\Sigma M_{OT} = M_U + M_W + M_{ICE} = -321$ kip-ft
Resisting Moments $\Sigma M_R = M_V = 21788$ kip-ft

Sum of Moments	$\Sigma M_{net} = M_R + M_{OT} =$	21,467	kip-ft
Sum of Vertical Forces	$P = \text{Conc} + \text{Water} + \text{Uplift} =$	1,680	kips
Sum of Horizontal Forces	$H = \Sigma \text{horizontal} =$	801	kips

Location of Resultant $X_r = \Sigma M / P = 12.78$ ft from Toe
 $e = B/2 - X_r = (4.78)$ ft
 $B/6 = 2.667$ ft

FORCES AT THE BOTTOM OF THE STEM

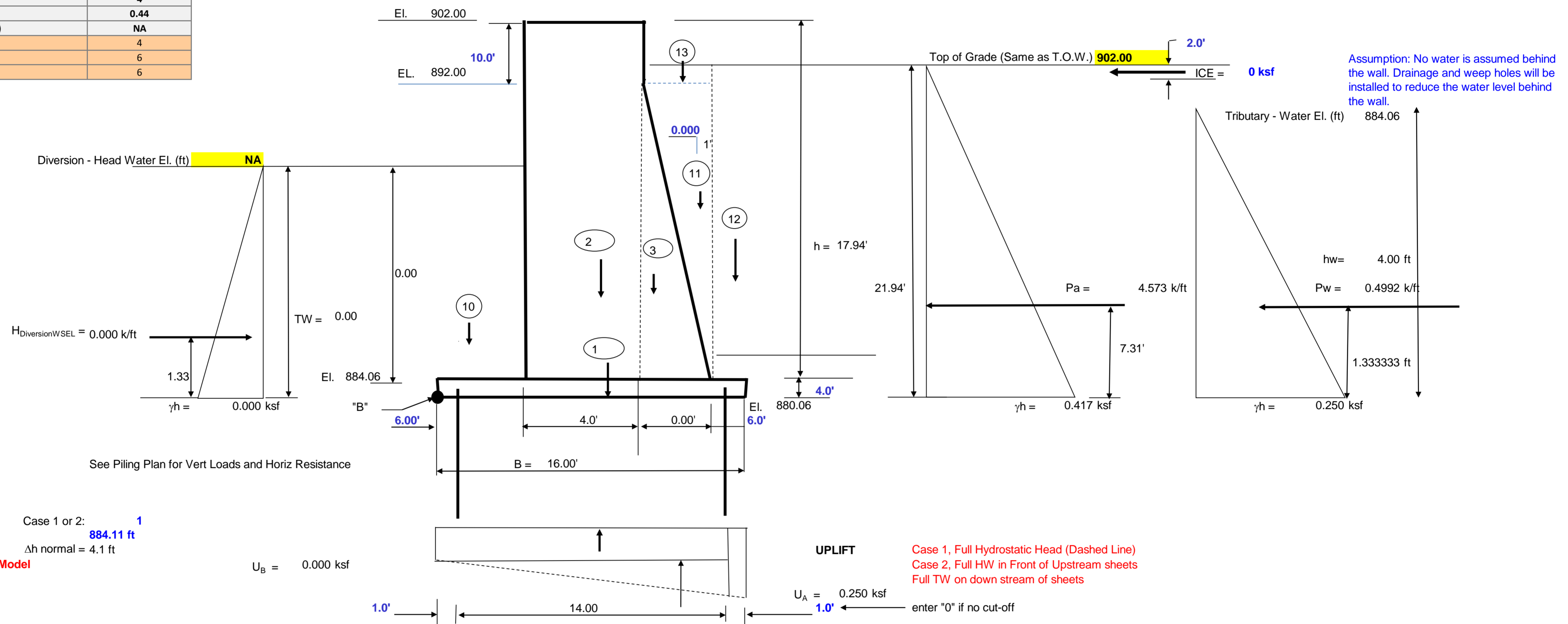
Diversion Face	H ft	γ kcf	Pbase	V K	arm ft	Mv ft-k
Diversion WSEL	17.94	0.0624	1.119456	10.042	5.980	60.04829
Tributary SEL =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				-6.984		-41.7644

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

ID#	Case 5
Name	Normal flow + ice
Load Category	Usual
Tributary - Water El. (ft)	881.5
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	0.44
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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 = 4.1 ft
 See Geotechnical seepage Model

Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv
		ft	ft	ft	kcf		K	ft	ft-k
Ftg concrete	1	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0
D.L. Concrete							ΣVc = 1639.3		ΣMv = 13,114.4

T.W. on ftg Stem	10	80.5	6.00	0.00	0.0624	rec	0.0	3.00	0.0
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0
D.L. Water							ΣVw = 542.4		ΣMv = 7,051.6

Uplift Loads	L	W	Pressure	U	arm	Mu
	ft	ft	ksf	K	ft	ft-k
UB	80.5	16.00	0.000	0.0	8.00	0
UA	80.5	16.00	0.250	-160.7	10.67	-1,715
ΣU =				-160.7		ΣMu = -1,715

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

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

CONSTANT FOR ALL LOAD CASES

Assumption: No water is assumed behind the wall. Drainage and weep holes will be installed to reduce the water level behind the wall.

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

ICE	80.5	2.00	0.00	rec	0.0	20.94	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	80.5		-4.573		-368.12	7.31'	-2692.20
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 =	-2692.2

Overturning Moments $\Sigma M_{OT} = M_U + M_W + M_{ICE} = -4407$ kip-ft
Resisting Moments $\Sigma M_R = M_V = 20166$ kip-ft

Sum of Moments	$\Sigma M_{net} = M_R + M_{OT} =$	15,759	kip-ft
Sum of Vertical Forces	$P = \text{Conc} + \text{Water} + \text{Uplift} =$	2,021	kips
Sum of Horizontal Forces	$H = \Sigma \text{horizontal} =$	-408	kips

Location of Resultant $X_r = \Sigma M / P = 7.80$ ft from Toe
 $e = B/2 - X_r = 0.20$ ft
 $B/6 = 2.667$ ft

FORCES AT THE BOTTOM OF THE STEM

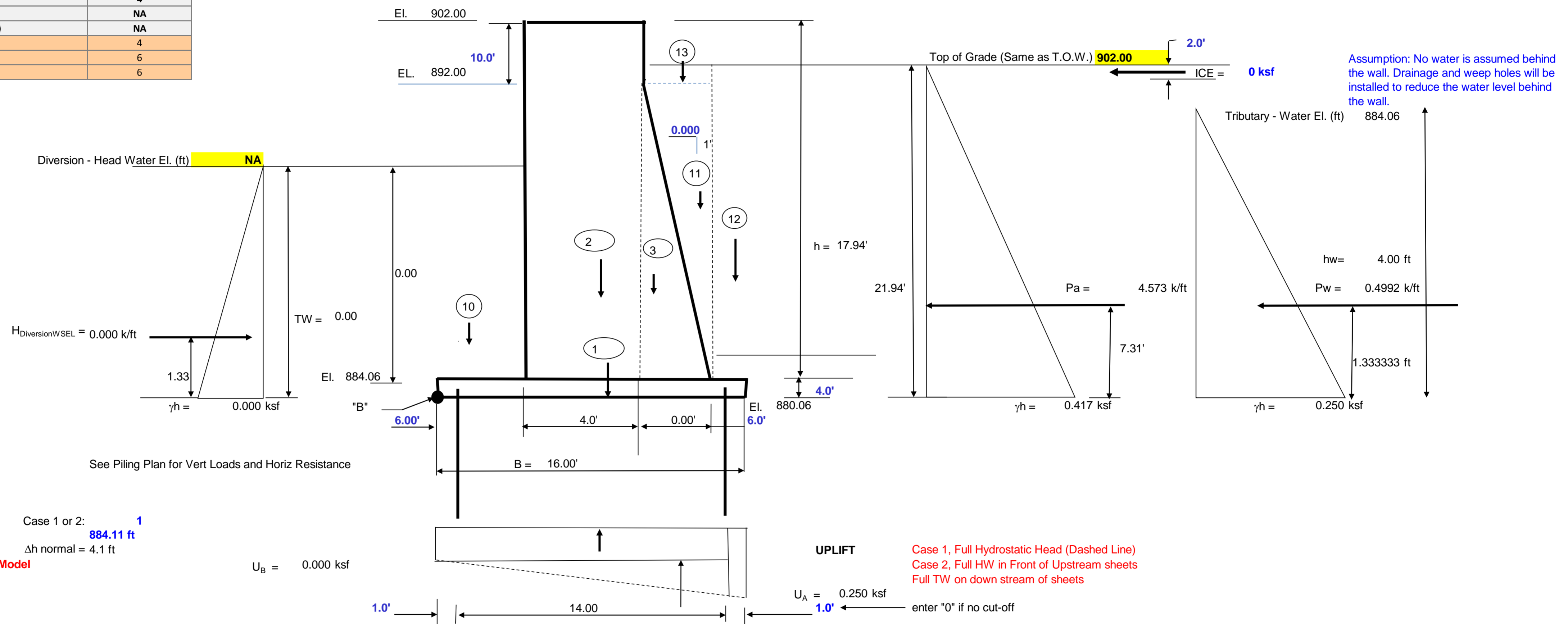
Diversion Face	H ft	γ kcf	Pbase	V K	arm ft	Mv ft-k
Diversion WSEL	0.00	0.0624	0	0.000	0.000	0
Tributary SEL =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				3.058		18.28393

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

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)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	884.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tributary - Water height (ft)	NA
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (ft)	6
Heel (ft)	6

File:
 MN State Building Codes
 Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
 Water El. = 881.50 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 = 4.1 ft
 See Geotechnical seepage Model

Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv
		ft	ft	ft	kcf		K	ft	ft-k
Ftg concrete	1	80.5	16.00	4.00	0.15	rec	772.8	8.00	6,182.4
Stem	2	80.5	4.00	17.94	0.15	rec	866.5	8.00	6,932.0
Batter	3	80.5	0.00	7.94	0.15	tri	0.0	10.00	0.0
D.L. Concrete							ΣVc = 1639.3		ΣMv = 13,114.4

T.W. on ftg Stem	10	80.5	6.00	0.00	0.0624	rec	0.0	3.00	0.0
H.W. on Stem Slope	11	80.5	0.00	7.94	0.12	tri	0.0	10.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	10.00	0.0
Soil on Footing	12s	80.5	6.00	17.94	0.0624	rec	542.4	13.00	7,051.6
H.W. on Footing	12w	80.5	6.00	0.00	0.0624	rec	0.0	13.00	0.0
D.L. Water							ΣVw = 542.4		ΣMv = 7,051.6

Uplift Loads	L	W	Pressure	U	arm	Mu
	ft	ft	kcf	K	ft	ft-k
Ub	80.5	16.00	0.000	0.0	8.00	0
Ua	80.5	16.00	0.250	-160.7	10.67	-1,715
ΣU =				-160.7		ΣMu = -1,715

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

CONSTANT FOR ALL LOAD CASES

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

ICE	80.5	2.00	0.00	rec	0.0	20.94	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	80.5		-4.573		-368.12	7.31'	-2692.20
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 =	-2745.8

Overturning Moments $\Sigma M_{OT} = M_U + M_W + M_{ICE} = -4460$ kip-ft
Resisting Moments $\Sigma M_R = M_V = 20166$ kip-ft

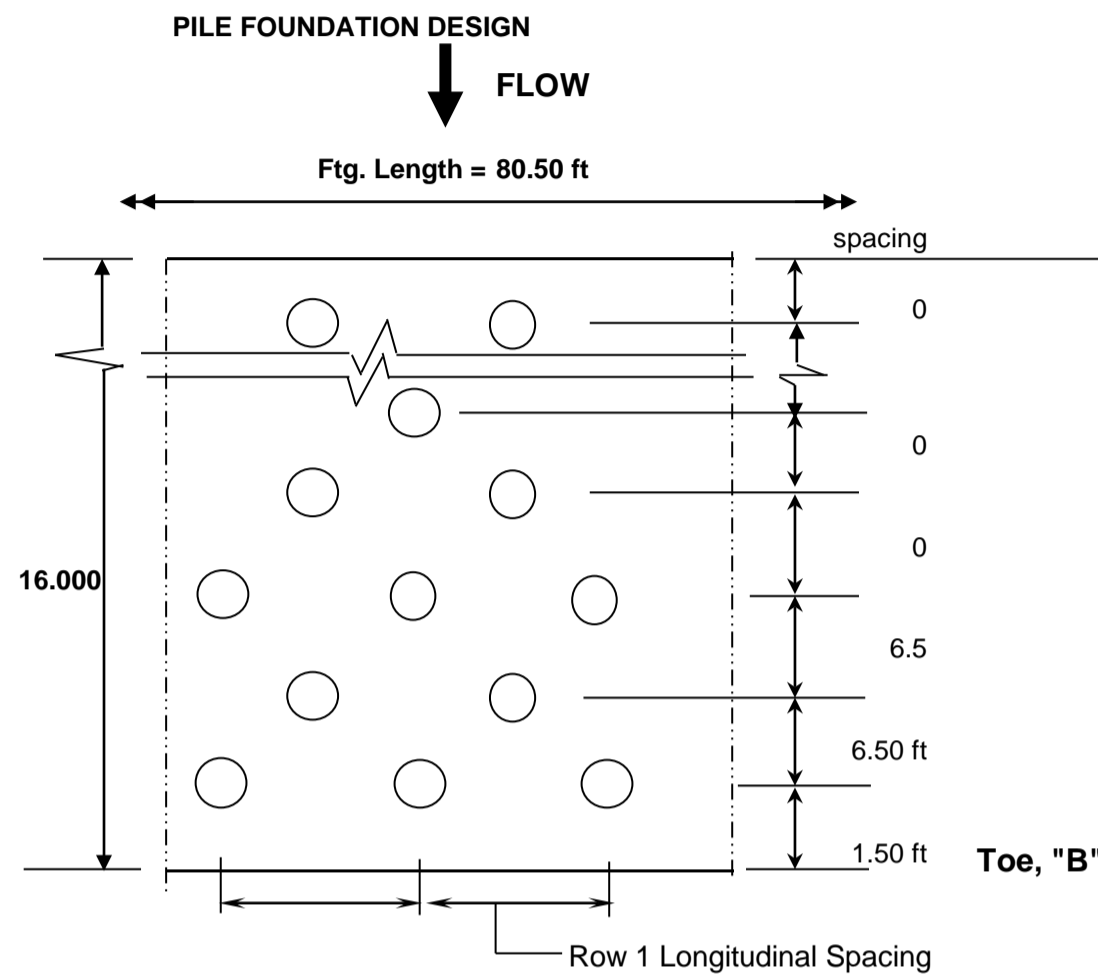
Sum of Moments	$\Sigma M_{net} = M_R + M_{OT} =$	15,706	kip-ft
Sum of Vertical Forces	$P = \text{Conc} + \text{Water} + \text{Uplift} =$	2,021	kips
Sum of Horizontal Forces	$H = \Sigma \text{horizontal} =$	-408	kips

Location of Resultant $X_r = \Sigma M / P = 7.77$ ft from Toe
 $e = B/2 - X_r = 0.23$ ft
 $B/6 = 2.667$ ft

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 =	17.94	0.019	0.34086	3.058	5.980	18.28393
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				3.058		18.28393
Net Forces				3.058		18.28393

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



PILE PATTERN GEOMETRY

Row	Transverse Spacing	Distance to Toe, d _{toe}	Longitudinal Spacing	Batter	Piles per Row (N)	Edge Dist (ft)	Trial N
Heel1	Row 1 to Toe	1.50 ft	2.50 ft	0 "/12"	12	26.50	33
Row "n"	Row 1 to Row 2	6.50 ft	5.00 ft	0 "/12"	12	12.75	17
	Row 2 to Row 3	6.50 ft	5.00 ft	0 "/12"	12	12.75	17
	Row 3 to Row 4	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
Not Used	Row 4 to Row 5	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
Not Used	Row 5 to Row 6	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 6 to Row 7	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 7 to Row 8	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 8 to Row 9	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
Row 3	Row 9 to Row 10	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 10 to Row 11	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 11 to Row 12	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
Row 2	Row 12 to Row 13	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Row 13 to Row 14	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
Row 1	Row 14 to Row 15	0.00 ft	0.00 ft	0 "/12"	0	40.25	0
	Last Row to Heel	1.50 ft					
		16.00 ft					

Note: Enter 0 for Longitudinal Spacing for Rows Not Used

ΣN = 36

67

PILE GROUP PROPERTIES

N.A. of Pile Group to Toe
 $X_{NA} = (\sum N * d_{toe}) / \sum N = 8.00 \text{ ft}$

Dist. From N.A. to Pile Row	d	N	I = N * d ²
1 Dist. To Row 1	6.50 ft	12	507.0
0 Dist. To Row 2	0.00 ft	12	0.0
1 Dist. Row 3	-6.50 ft	12	507.0
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
		36	Σ I = 1014.0

Pile Properties:	Pile Type: HP	(C.I.P or HP)	Pile Length = 38.4 ft	Ftg EL. 880.06
	HP Nominal Depth, h = 14.0 in			Pile Tip El. 842.68
	Wt. per ft, plf 73		Total pile Length = 1,382 LF	Pile Cap Embed = 1.00 ft

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
Allowable Lateral Capacity (tons)	18.0 tons	21.0 tons	21.0 tons	24.0 tons	11.5 tons	21.0 tons
Allowable Pile Capacity (tons) - Axial	57.2 tons	76.2 tons	76.2 tons	99.4 tons	31.4 tons	76.2 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)												Max. Vertical Load (Tons)	Horiz Pile Group Capacity (k)	Check	
		1	2	3	4	5	6	7	8	9	10	11	12				
Case 1	57.2 tons	18.8	24.5	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	1,296	OK
Case 2	76.2 tons	18.8	24.5	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	1,512	OK
Case 3	76.2 tons	16.1	24.2	32.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.3	1,512	OK
Case 4	99.4 tons	-2.4	23.3	49.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.1	1,728	OK
Case 5	31.4 tons	29.4	28.1	26.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.4	828	OK
Case 6	76.2 tons	29.6	28.1	26.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.6	828	OK

Max Service : P = 49.1

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:

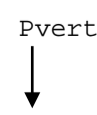
$$\text{Pile Load} = P / N + M_{NA} / I$$

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

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



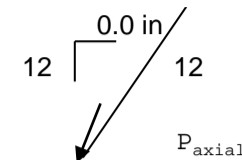
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.	
COMPUTED	CHECKED	SUBMITTED	PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4		
MBI		MBI	PROJECT NUMBER	34091004		
2/11/11			SUBJECT	Maple Aquaduct Structure - Retaining Walls Panel B		

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

$$P_{axial} = 1.000 P_{vert}$$



FORCE RESULTANT (see Stability Analysis)

CASE	Event		Vertical Load P (kips)	Horizontal	ΣM_{toe} (kip-ft)	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$
Case 1	100 yr. flood	Usual	1,761	-72	15,845	9.00	-1.00	-1753
Case 2	100 yr. flood + ice	Unusual	1,761	-72	15,845	9.00	-1.00	-1753
Case 3	500 yr. flood	Unusual	1,746	-187	16,493	9.45	-1.45	-2528
Case 4	T.O. Levee	Extreme	1,680	-801	21,467	12.78	-4.78	-8027
Case 5	Normal flow + ice	Usual	2,021	408	15,759	7.80	0.20	409
Case 6	Construction	Unusual	2,021	408	15,706	7.77	0.23	462

SERVICE

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

Vertical Load, P = 1761 kips
Horizontal Load, H = -72 kips
 $M_{NA} = -1753$ kip-ft

36

Vertical Pile Loading	P / N	+ $M_{NA} * d / \Sigma I$	= Pile Loads		Axial Pile Load
1 Row 1	48.9	-11.2	37.7 kips/pile	18.8 tons/pile	18.8 tons/pile
2 Row 2	48.9	0.0	48.9 kips/pile	24.5 tons/pile	24.5 tons/pile
3 Row 3	48.9	11.2	60.2 kips/pile	30.1 tons/pile	30.1 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: 30.1 tons/pile

max: 30.1 tons/pile

Assumed lateral Capacity: 36.0 kips/pile

Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	12	0.0	432	1.000	432 kips
2 Row 2	0	12	0.0	432	1.000	432 kips
3 Row 3	0	12	0.0	432	1.000	432 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
		36		1296		1296 kips

OK

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

Vertical Load, P = 1761 kips
Horizontal Load, H = -72 kips
 $M_{NA} = -1753$ kip-ft

36

Vertical Pile Loading	P / N	+ $M_{NA} * d / \Sigma I$	= Pile Loads		Axial Pile Load
1 Row 1	48.9	-11.2	37.7 kips/pile	18.8 tons/pile	18.8 tons/pile
2 Row 2	48.9	0.0	48.9 kips/pile	24.5 tons/pile	24.5 tons/pile
3 Row 3	48.9	11.2	60.2 kips/pile	30.1 tons/pile	30.1 tons/pile
4 Row 4	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile

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

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:	30.1 tons/pile

Assumed lateral Capacity: 42.0 kips/pile

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	0	12	0.0	504	1.000	504 kips
2 Row 2	0	0	12	0.0	504	1.000	504 kips
3 Row 3	0	0	12	0.0	504	1.000	504 kips
4 Row 4	0	0	0	0.0	0	1.000	0 kips
5 Row 5	0	0	0	0.0	0	1.000	0 kips
6 Row 6	0	0	0	0.0	0	1.000	0 kips
7 Row 7	0	0	0	0.0	0	1.000	0 kips
8 Row 8	0	0	0	0.0	0	1.000	0 kips
9 Row 9	0	0	0	0.0	0	1.000	0 kips
10 Row 10	0	0	0	0.0	0	1.000	0 kips
11 Row 11	0	0	0	0.0	0	1.000	0 kips
12 Row 12	0	0	0	0.0	0	1.000	0 kips
13 Row 13	0	0	0	0.0	0	1.000	0 kips
14 Row 14	0	0	0	0.0	0	1.000	0 kips
15 Row 15	0	0	0	0.0	0	1.000	0 kips
			36	0.0	1512		1512 kips

OK

Case Case 3
Flood Event 500 yr. flood
Unusual

Vertical Load, P = 1746 kips
Horizontal Load, H = -187 kips
M_{NA} = -2528 kip-ft

	Vertical Pile Loading	P / N +	M _{NA} * d / Σ I	= Pile Loads	Axial Pile Load
1 Row 1	48.5		-16.2	32.3 kips/pile	16.1 tons/pile
2 Row 2	48.5		0.0	48.5 kips/pile	24.2 tons/pile
3 Row 3	48.5		16.2	64.7 kips/pile	32.3 tons/pile
4 Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile
5 Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile
6 Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile
7 Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile
8 Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile
9 Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile
10 Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile
11 Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile
12 Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile
13 Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile
14 Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile
15 Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile
				max:	32.3 tons/pile

Assumed lateral Capacity: 42.0 kips/pile

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	0	12	0.0	504	1.000	504 kips
2 Row 2	0	0	12	0.0	504	1.000	504 kips
3 Row 3	0	0	12	0.0	504	1.000	504 kips
4 Row 4	0	0	0	0.0	0	1.000	0 kips
5 Row 5	0	0	0	0.0	0	1.000	0 kips
6 Row 6	0	0	0	0.0	0	1.000	0 kips
7 Row 7	0	0	0	0.0	0	1.000	0 kips
8 Row 8	0	0	0	0.0	0	1.000	0 kips
9 Row 9	0	0	0	0.0	0	1.000	0 kips
10 Row 10	0	0	0	0.0	0	1.000	0 kips
11 Row 11	0	0	0	0.0	0	1.000	0 kips
12 Row 12	0	0	0	0.0	0	1.000	0 kips
13 Row 13	0	0	0	0.0	0	1.000	0 kips
14 Row 14	0	0	0	0.0	0	1.000	0 kips
15 Row 15	0	0	0	0.0	0	1.000	0 kips
			36	0.0	1512		1512 kips

OK

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MBI		MBI	PROJECT NUMBER	34091004		
2/11/11			SUBJECT	Maple Aquaduct Structure - Retaining Walls Panel B		

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

Vertical Load, P = 1680 kips
Horizontal Load, H = -801 kips
 $M_{NA} = -8027$ kip-ft

Vertical Pile Loading	P / N	+ $M_{NA} \cdot d / \Sigma I$	= Pile Loads		Axial Pile Load
1 Row 1	46.7	-51.5	-4.8 kips/pile	-2.4 tons/pile	-2.4 tons/pile
2 Row 2	46.7	0.0	46.7 kips/pile	23.3 tons/pile	23.3 tons/pile
3 Row 3	46.7	51.5	98.1 kips/pile	49.1 tons/pile	49.1 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: 49.1 tons/pile	max: 49.1 tons/pile

Assumed lateral Capacity: 48.0 kips/pile

Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	12	0.0	576	1.000	576 kips
2 Row 2	0	12	0.0	576	1.000	576 kips
3 Row 3	0	12	0.0	576	1.000	576 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
		36		1728		1728 kips

OK

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

Vertical Load, P = 2021 kips
Horizontal Load, H = 408 kips
 $M_{NA} = 409$ kip-ft

Vertical Pile Loading	P / N	+ $M_{NA} \cdot d / \Sigma I$	= Pile Loads		Axial Pile Load
1 Row 1	56.1	2.6	58.8 kips/pile	29.4 tons/pile	29.4 tons/pile
2 Row 2	56.1	0.0	56.1 kips/pile	28.1 tons/pile	28.1 tons/pile
3 Row 3	56.1	-2.6	53.5 kips/pile	26.8 tons/pile	26.8 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: 29.4 tons/pile	max: 29.4 tons/pile

Assumed lateral Capacity: 23.0 kips/pile

Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	12	0.0	276	1.000	276 kips
2 Row 2	0	12	0.0	276	1.000	276 kips

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3 Row 3	0	12	0.0	276	1.000	276 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
		<u>36</u>		<u>828</u>		<u>828 kips</u>

OK

Case Case 6
Flood Event Construction
Unusual

Vertical Load, P = 2021 kips
Horizontal Load, H = 408 kips
M_{NA} = 462 kip-ft

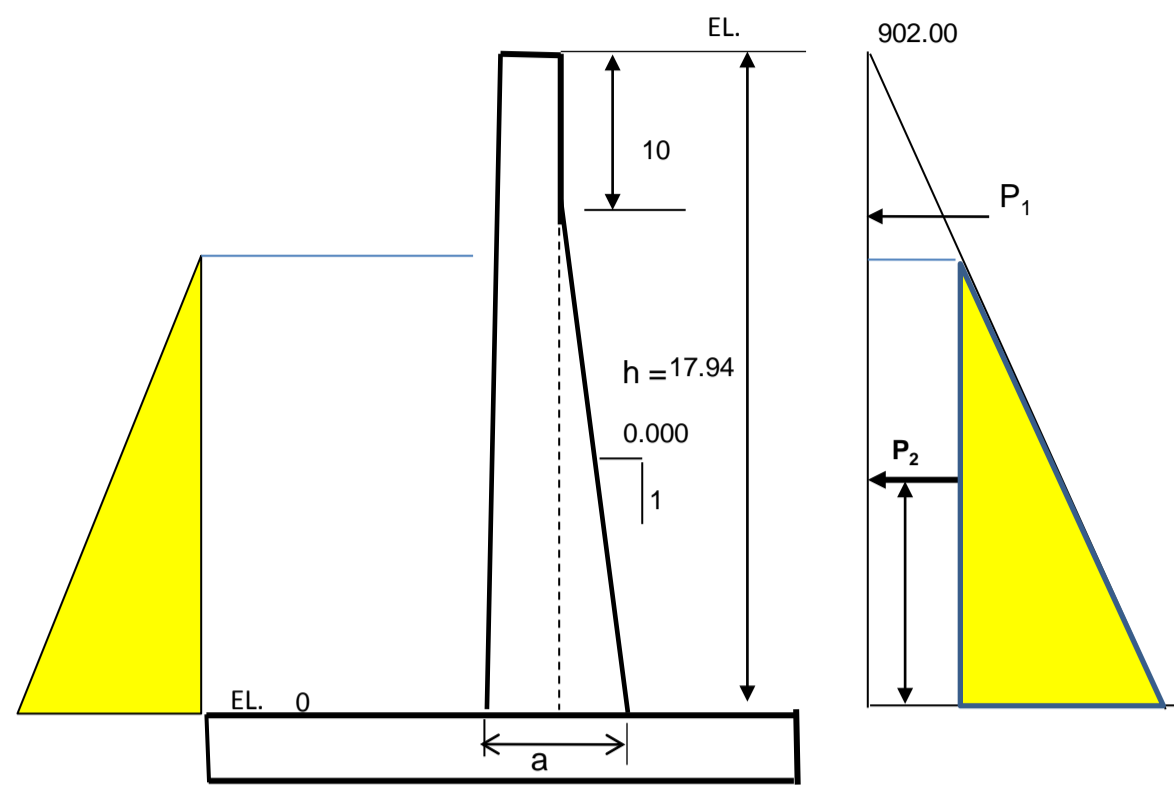
Vertical Pile Loading	P / N	+	M _{NA} * d / Σ I	= Pile Loads		Axial Pile Load
1 Row 1	56.1		3.0	59.1 kips/pile	29.6 tons/pile	29.6 tons/pile
2 Row 2	56.1		0.0	56.1 kips/pile	28.1 tons/pile	28.1 tons/pile
3 Row 3	56.1		-3.0	53.2 kips/pile	26.6 tons/pile	26.6 tons/pile
4 Row 4	0.0		0.0	0.0 kips/pile	0.0 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: 29.6 tons/pile	max: 29.6 tons/pile

Assumed lateral Capacity: 42.0 kips/pile

Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resistance due to Bending, kips	Group Efficiency	Lateral Resistance
1 Row 1	0	12	0.0	276	1.000	276 kips
2 Row 2	0	12	0.0	276	1.000	276 kips
3 Row 3	0	12	0.0	276	1.000	276 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
		<u>36</u>		<u>828</u>		<u>828 kips</u>

OK

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			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4		
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
2/11/11				Panel B 0		



CASE	Event		HW	TW	Dh	TW -ftg
Case 1	100 yr. flood	Usual	893.89	892.57	1.32	892.57
Case 2	100 yr. flood + ice	Unusual	893.89	892.57	1.32	892.57
Case 3	500 yr. flood	Unusual	896.380	893.66	2.72	893.66
Case 4	T.O. Levee	Extreme	902.000	902.00	0.00	902.00
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	
Unusual & 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	0.04	8.405	0.09	18.58
Case 2	100 yr. flood + ice	Unusual	0.75	0.04	8.405	0.07	13.93
Case 3	500 yr. flood	Unusual	0.75	-1.00	2.876	-1.65	4.77
Case 4	T.O. Levee	Extreme	0.75	-6.98	-41.764	11.58	69.22
Case 5	Normal flow + ice	Usual	1	3.06	18.284	6.76	40.41
Case 6	Construction	Unusual	0.75	3.06	18.284	5.07	30.31

STEM DESIGN VALUES

MU, k-ft/ft	69.22	k-ft/ft
VU, k/ft	11.58	k/ft

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

ref. EM 110-2-2104

9.3 - Design Strength

$\phi =$	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 =	69	k-ft / ft
Vuh =	11.58	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 =	40.648	ACI 10.5.1	ACI 10.5.3
REQ'D p =	0.0007 O.K.	p(min) = 3 * SQRT(Fc') / fy	200' / fy
p =	0.0009	0.00316	0.00333
As (REQ'D) =	0.81	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 * Tr * s * bh = 0.8064 in ²
			As = #9 @ 12 = 1.00 in ²

SELECT STEEL

bar # =	9
spacing, s =	12
# OF BAR =	1 (ENTER 1 IF PER FT, b=12")
As =	0.999
d =	43.4375
p = As / bd =	0.0019 O.K. < 0.375pb
p =	0.067 pb

MAXIMUM TENSILE REINFORCEMENT

- a) For singly reinforced flexural members
- p = 0.25 pb Recommended limit
 - p = 0.375 pb Max. permitted upper limit not requiring special study
 - p = 0.5 pb Max. permitted upper limit when excessive deflections are not predicted in ACI 318
 - p = > 0.5 pb but ≤ 0.375 pb permitted only if detailed serviceability analysis incl. deflect. Calc.
- b) Use of compression reinf. shall be per ACI 318
- > Mu O.K.

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

Vuh =	11.6	k	NO SHEAR REINF. REQUIRED
Vn = Vuh / ϕ =	15.4	k	
Vc = 2 * sqrt(Fc') * bw * d =	65.9	k	11.3.1.1
Vs = Vuh / ϕ - 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 / ϕ - 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:
- SLAB OR FOOTING, vc > vn
 - CONCRETE JOIST ACI 8.11
 - BEAMS W/ h ≤ 10"
 - h ≤ 2.5 * Bf
 - h ≤ 0.5 * tw
 - WALLS (SEE ACI 11.10.1); vc > vn

11.5.6.3

Av,min = 0.75 sqrt(Fc') * bw * s / fy =	0.40	* s
but not less than 50bw * s / fy =	13.33333333	* 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