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 Describtion:	**Maple Aquaduct Structure - Retaining Walls**	**Date:**	**2/10/2011**
	Panel E	**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 E.xlsx]Piling		
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	903.5	881.5	**NA**
Diversion - Head Water El. (ft)	893.89	893.89	895.46	903.5	**NA**	**NA**
Diversion - Tail Water El. (ft)	892.57	892.57	893.66	903.5	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	903.5					
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)	872.06					
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)	**14.93**	**14.93**	**15.32**	**22.44**	**0.44**	**NA**
Diversion - Head Water height (ft)	**21.83**	**21.83**	**23.4**	**31.44**	**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**	**895.99**	**NA**	**NA**	**881.5**	**NA**
Uplift @ HW (ft)	**25.83**	**25.83**	**27.4**	**35.44**	**NA**	**NA**
Uplift @ TW (ft)	**24.51**	**24.51**	**25.6**	**35.44**	**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**	**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			

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

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	3,297	0	$0
INSTALL HP14x73 WALL PILING		LF	3,297	0	$0
PILE TEST, 36.4 ft	Long	EA	6	0	$0
FOOTING CONCRETE		CY	618	0	$0
	Forming	SF	1,428		
STEM CONCRETE		CY	652	0	$0
	Forming	SF	9,127		
STEEL REINFORCEMENT		LB	244,455	0	$0
WALL RAILING		LF	140	0	$0
SHEET PILE CUT-OFF WALL		SF	1,400	0	$0
					$0

Structure Length = 140 ft

No. piles = 125 Each
Length = 26.38 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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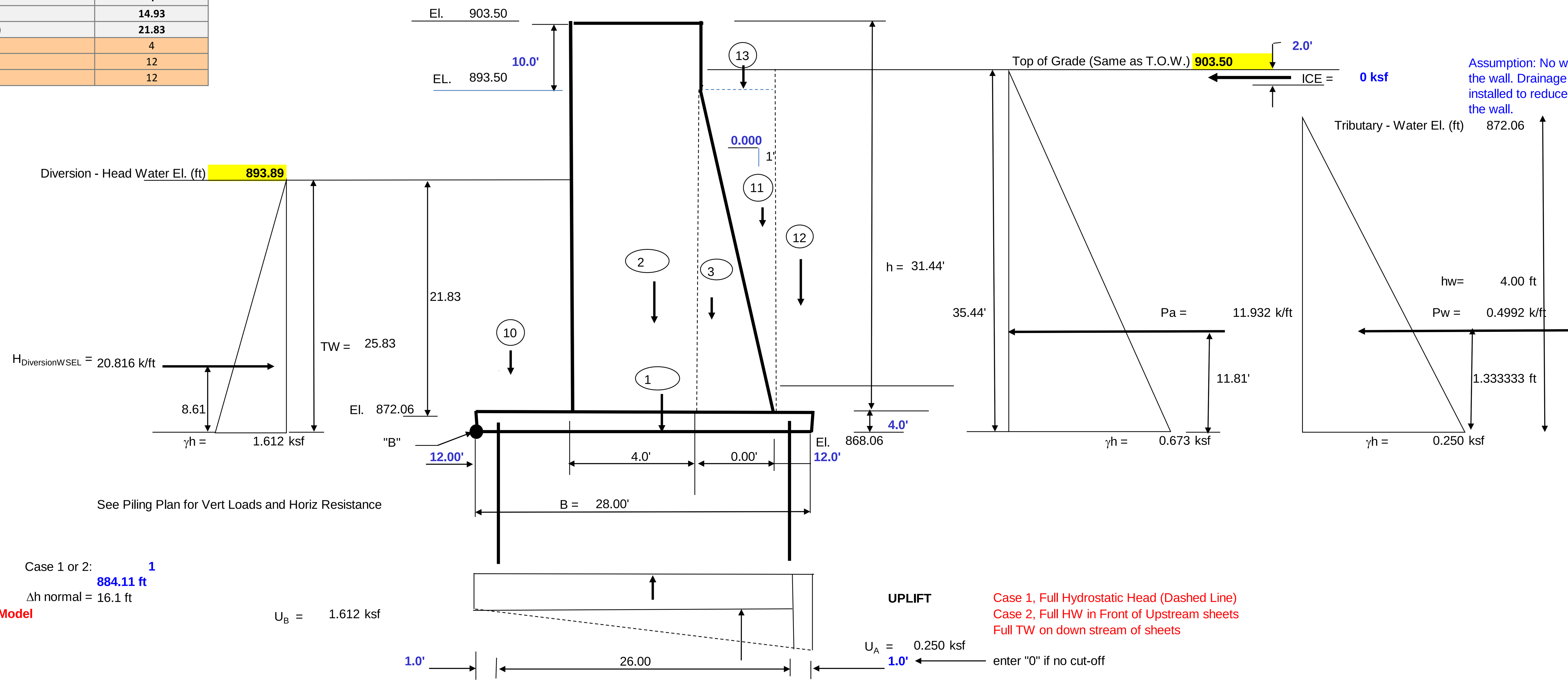
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 1 100 yr. flood	Panel E

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)	903.5
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)	872.06
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)	14.93
Diversion - Head Water height (ft)	21.83
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section — **Length = 140.0 ft**
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



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

See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 16.1 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	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**4993.0**	ΣM$_V$ =	**69,901.4**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	21.83	0.0624	rec	2288.5	6.00	13,730.9
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**5595.0**	ΣM$_V$ =	**86,473.5**

Uplift Loads		L (ft)	W (ft)	Pressure (ksf)	shape	U (K)	arm (ft)	Mu (ft-k)
	U$_B$	140	28.00	1.612	rec	-6318.2	14.00	-88,455
	U$_A$	140	28.00	-1.362	tri	2669.9	18.67	49,838
					ΣU =	**-3648.3**	ΣM$_U$ =	**-38,617**

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

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	140	2.00	0.00	rec	0.0	34.44	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	140	-11.932		-1670.47	11.81	-19733.84

Water Loads

	L				arm	
H_{TW}	140	20.816	tri	2914.28	8.61	25091.96
H_{HW}	140	-0.499	tri	-69.89	1.33	-93.18
			ΣWater =	**2844.39**	ΣM_W =	**5264.9**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-33352	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	156375	kip-ft

Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**123,023**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,940**	kips
Sum of Horizontal Forces	H = Σhorizontal	**1,174**	kips

Location of Resultant
Xr = ΣM / P = 17.73 ft from Toe
e = B/2 - Xr = (3.73) ft
B/6 = 4.667 ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	589	cy (includes stepped)	1428	sf
Stem Conc:	652	cy	9127	sf
Total =	1,241			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing	LB /ft	Length	# of bars	Total wt		
	a) Footing		in		ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	284	26,554		
	Longitudinal:	9	6	3.40	141.5	56	26,942		
Bot mat	Transverse:	9	6	3.40	27.5	284	26,554		
	Longitudinal:	9	6	3.40	141.5	56	26,942		
								cy	**LB/cy**
							106,991	589	181.6374748
	b) Skin Reinf. On Monolith								
Vert Face	Vertical	9	6	3.40	30.94	280	29,455	58,909.76	
	Longitudinal:	9	6	3.40	139.5	62	29,407	58,813.20	
Top Face	Transverse:	9	6	3.40	3.5	280	3,332		
	Longitudinal:	9	6	3.40	139.5	8	3,794		
Dowels	Vertical I.F.	9	6	3.40	30.9	280	29,455		
	Vertical O.F.	9	6	3.40	30.9	280	29,455		
								cy	**LB/cy**
							124,898	652	191.5346851
						Σ =	**231,889**		

Lap Splices (long. Bars)	9	3.40	8	462	12,566	
				Σ Bar Wt=	244,455	lb

FORCES AT THE BOTTOM OF THE STEM

Diversion Face		H	γ	Pbase	V	arm	Mv
		ft	kcf		K	ft	ft-k
Diversion WSEL		21.83	0.0624	1.362192	14.868	7.277	108.1918
Tributary SEL =		31.44	0.019	0.59736	9.390	10.480	98.41243
Tributary WSEL =		0.00	0.0624	0	0.000	0.000	0
	Sum				9.390		98.41243
	Net Forces				-5.478		-9.77942

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

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)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
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Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
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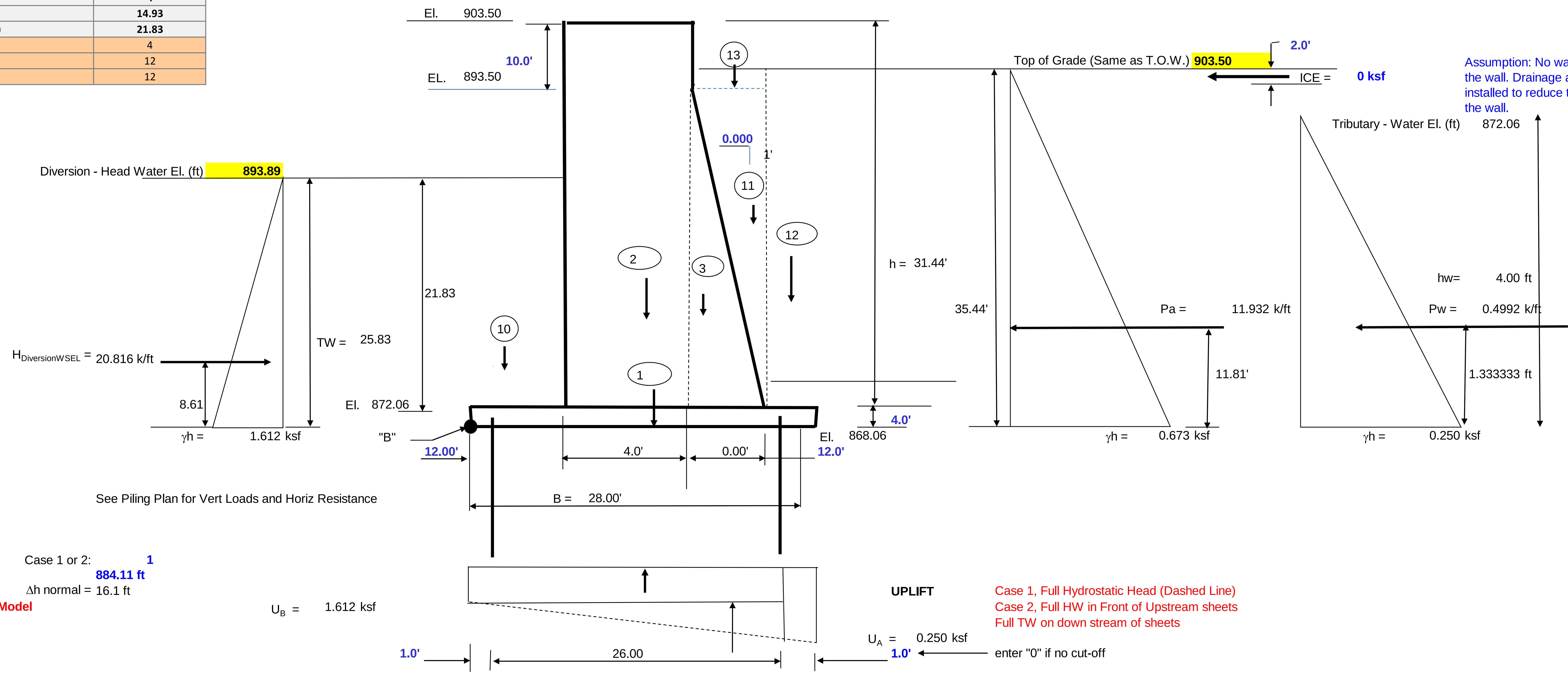
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length =** 140.0 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 = 16.1 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	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**4993.0**	ΣM_V =	**69,901.4**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	21.83	0.0624	rec	2288.5	6.00	13,730.9
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**5595.0**	ΣM_V =	**86,473.5**

Uplift Loads		L (ft)	W (ft)	Pressure (ksf)	shape	U (K)	arm (ft)	Mu (ft-k)
	U_B	140	28.00	1.612	rec	-6318.2	14.00	-88,455
	U_A	140	28.00	-1.362	tri	2669.9	18.67	49,838
					ΣU =	**-3648.3**	ΣM_U =	**-38,617**

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 2 100 yr. flood + ice	Panel E

	L		Force		H	arm	Mw
ICE	140	2.00	0.00	rec	0.0	34.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	140		-11.932		-1670.47	11.81	-19733.84
Water Loads							
H_{TW}	140		20.816	tri	2914.28	8.61	25091.96
H_{HW}	140		-0.499	tri	-69.89	1.33	-93.18
				ΣWater =	**2844.39**	ΣM_W =	**5264.9**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-33352	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	156375	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**123,023**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,940**	kips
Sum of Horizontal Forces	H = Σhorizontal	**1,174**	kips

Location of Resultant

Xr = ΣM / P = 17.73 ft from Toe
e = B/2 - Xr = (3.73) ft
B/6 = 4.667 ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	21.83	0.0624	1.362192	14.868	7.277	108.1918
Tributary SEL =	31.44	0.019	0.59736	9.390	10.480	98.41243
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				9.390		98.41243
Net Forces				-5.478		-9.77942

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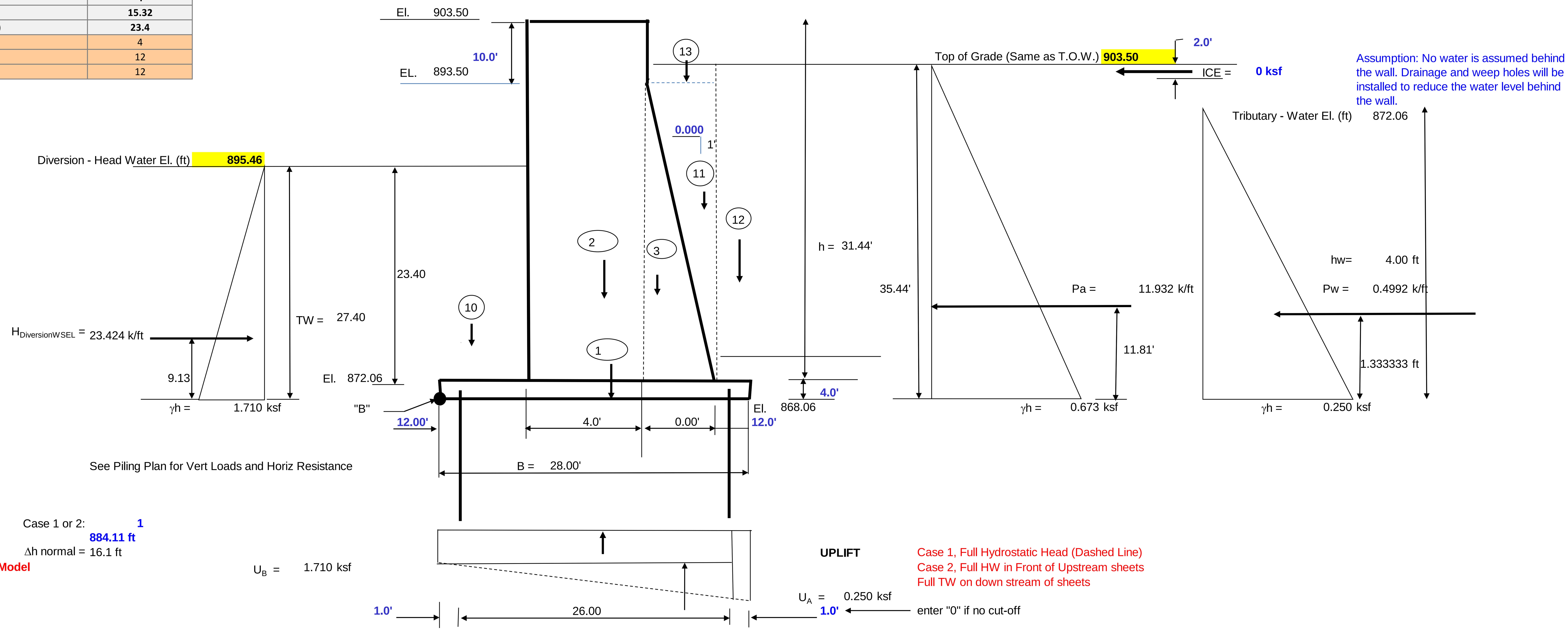
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel E	

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)	903.5
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)	872.06
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)	15.32
Diversion - Head Water height (ft)	23.4
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section Length = 140.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	4993.0	ΣM$_V$ =	69,901.4

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	23.40	0.0624	rec	2453.1	6.00	14,718.4
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	5759.6	ΣM$_V$ =	87,461.0

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	140	28.00	1.710	rec	-6702.3	14.00	-93,832
	U_A	140	28.00	-1.460	tri	2861.9	18.67	53,422
					ΣU =	-3840.3	ΣM$_U$ =	-40,409

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

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2/11/11				Load Cases: Case 3 500 yr. flood	Panel E

	L		Force		H	arm	Mw
ICE	140	2.00	0.00	rec	0.0	34.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	140		-11.932		-1670.47	11.81'	-19733.84
Water Loads							
H_{TW}	140		23.424	tri	3279.32	9.13	29951.12
H_{HW}	140		-0.499	tri	-69.89	1.33	-93.18
				ΣWater =	**3209.43**	ΣM_W =	**10124.1**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-30285	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	157362	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**127,077**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,912**	kips
Sum of Horizontal Forces	H = Σhorizontal	**1,539**	kips

Location of Resultant	Xr = ΣM / P =	18.38	ft from Toe
	e = B/2 - Xr =	(4.38)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	23.40	**0.0624**	1.46016	17.084	7.800	133.2542
Tributary SEL =	31.44	**0.019**	0.59736	9.390	10.480	98.41243
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				9.390		98.41243
Net Forces				-7.693		-34.8418

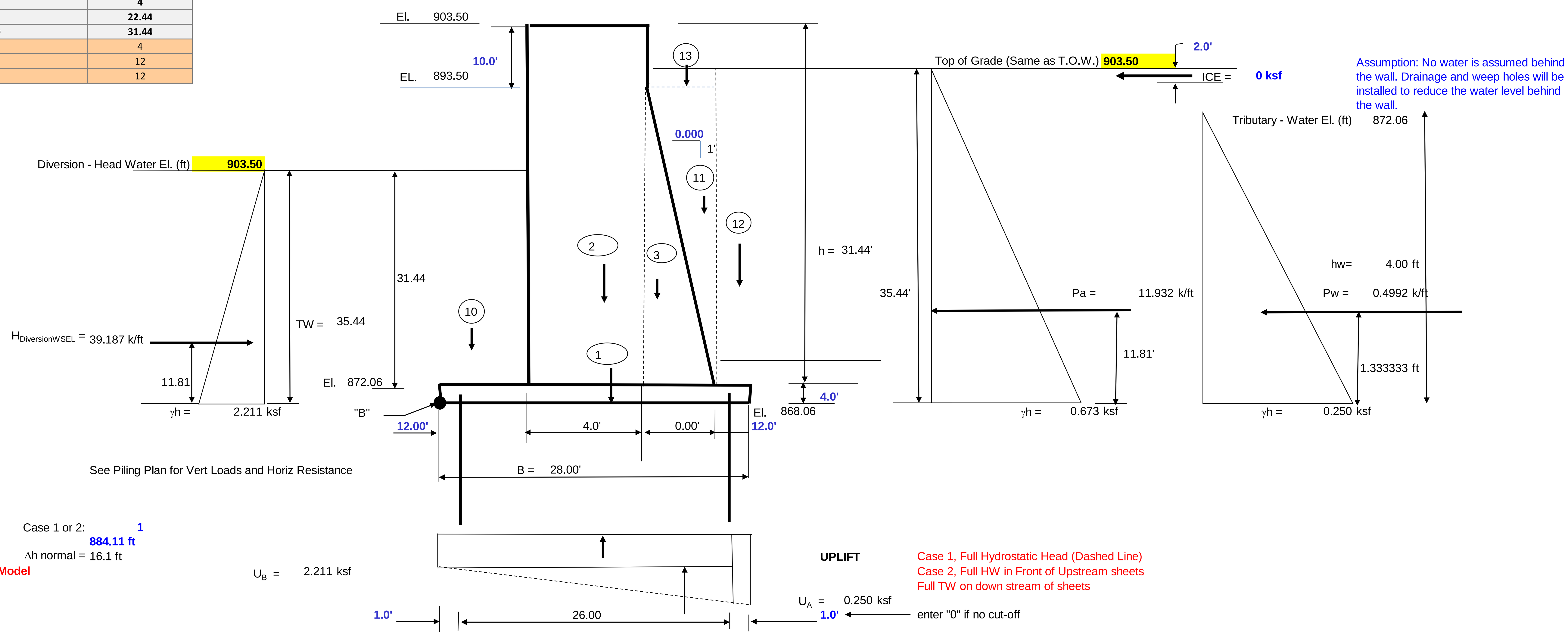
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 4 T.O. Levee Panel E	

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	903.5
Diversion - Tail Water El. (ft)	903.5
Tributary - T.O. Wall El. (ft)	903.5
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)	872.06
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)	22.44
Diversion - Head Water height (ft)	31.44
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section Length = 140.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**4993.0**	ΣM_V =	**69,901.4**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	31.44	0.0624	rec	3295.9	6.00	19,775.5
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**6602.4**	ΣM_V =	**92,518.1**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	140	28.00	2.211	rec	-8668.9	14.00	-121,365
	U_A	140	28.00	-1.962	tri	3845.2	18.67	71,778
					ΣU =	**-4823.7**	ΣM_U =	**-49,587**

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 4 T.O. Levee	Panel E

	L		Force		H	arm	Mw
ICE	140	2.00	0.00	rec	0.0	34.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	140		-11.932		-1670.47	11.81'	-19733.84
Water Loads							
H_{TW}	140		39.187	tri	5486.18	11.81	64810.07
H_{HW}	140		-0.499	tri	-69.89	1.33	-93.18
				ΣWater =	**5416.29**	ΣM_W =	**44983.1**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-4604	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	162420	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**157,816**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,772**	kips
Sum of Horizontal Forces	H = Σhorizontal	**3,746**	kips

Location of Resultant	Xr = ΣM / P =	23.31	ft from Toe
	e = B/2 - Xr =	(9.31)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	31.44	**0.0624**	1.961856	30.840	10.480	323.2071
Tributary SEL =	31.44	**0.019**	0.59736	9.390	10.480	98.41243
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				9.390		98.41243
Net Forces				-21.450		-224.795

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	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice Panel E	

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)	903.5
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)	872.06
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)	0.44
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

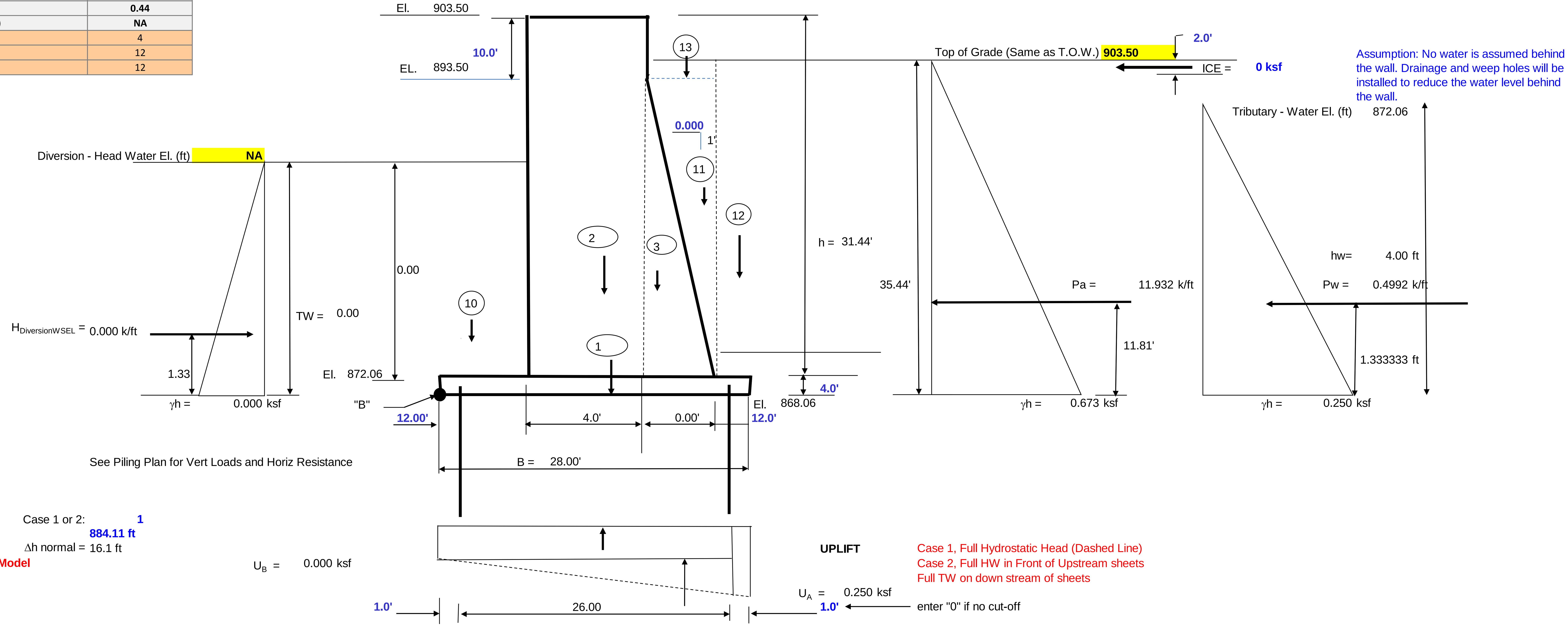
MN State Building Codes

Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March

Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section — Length = 140.0 ft

Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
				D.L. Concrete		ΣVc =	4993.0	ΣM_V =	69,901.4

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
				D.L. Water		ΣVw =	3306.5	ΣM_V =	72,742.6

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	140	28.00	0.000	rec	0.0	14.00	0
	U_A	140	28.00	0.250	tri	-489.2	18.67	-9,132
					ΣU =	-489.2	ΣM_U =	-9,132

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 5 Normal flow + ice	Panel E

ICE	140	2.00	0.00	rec	0.0	34.44	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	140		-11.932		-1670.47	11.81'	-19733.84
Water Loads							
H_{TW}	140		0.000	tri	0.00	1.33	0.00
H_{HW}	140		-0.499	tri	-69.89	0.00	0.00
				ΣWater =	**-69.89**	ΣM_W =	**-19733.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-28866	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	142644	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**113,778**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**7,810**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-1,740**	kips

Location of Resultant	Xr = ΣM / P =	14.57	ft from Toe
	e = B/2 - Xr =	(0.57)	ft
	B/6 =	4.667	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 =		31.44	**0.019**	0.59736	9.390	10.480	98.41243
Tributary WSEL =		0.00	**0.0624**	0	0.000	0.000	0
	Sum				9.390		98.41243
	Net Forces				9.390		98.41243

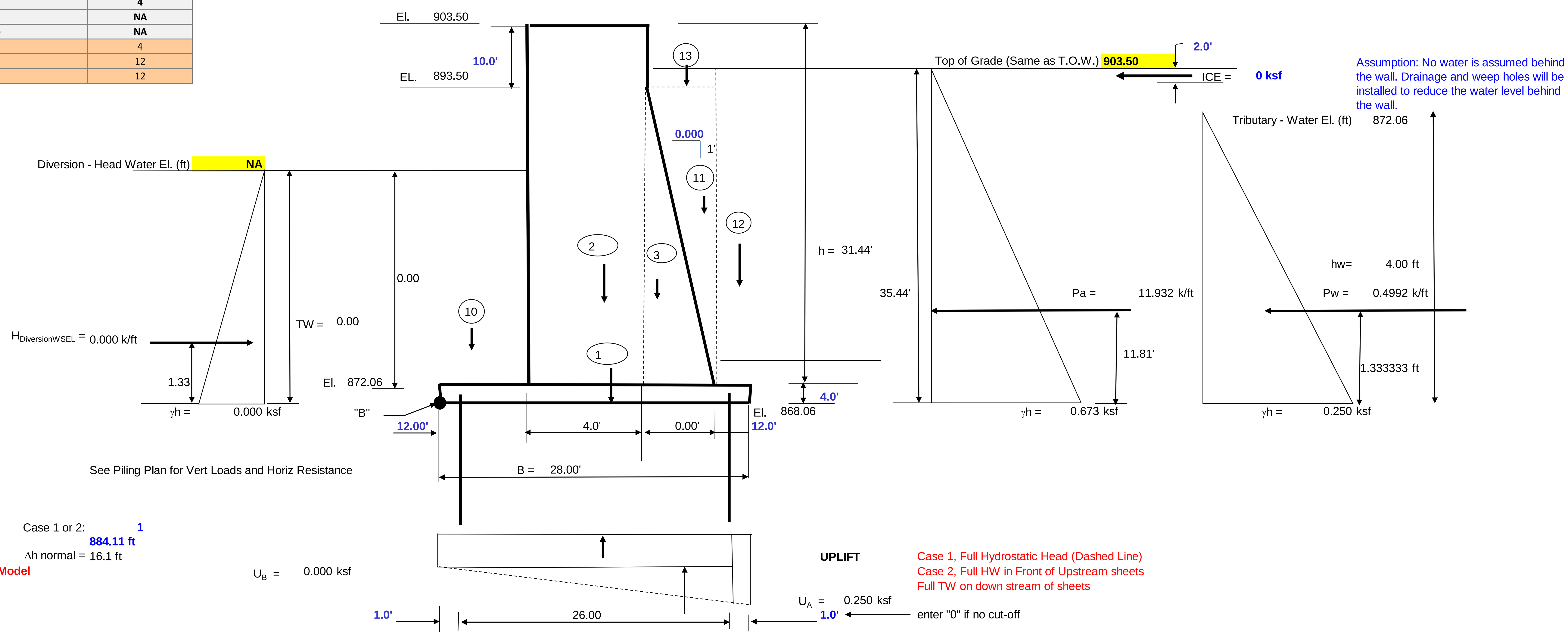
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 6 Construction Panel E	

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)	903.5
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)	872.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	NA
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	12
Heel (ft)	12

File:

MN State Building Codes
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section Length = 140.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	140	28.00	4.00	0.15	rec	2352.0	14.00	32,928.0
Stem	2	140	4.00	31.44	0.15	rec	2641.0	14.00	36,973.4
Batter	3	140	0.00	21.44	0.15	tri	0.0	16.00	0.0
				D.L. Concrete		ΣVc =	**4993.0**	ΣMv =	**69,901.4**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	140	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	140	0.00	21.44	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	140	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	140	12.00	31.44	0.0626	rec	3306.5	22.00	72,742.6
H.W. on Footing	12w	140	12.00	0.00	0.0624	rec	0.0	22.00	0.0
				D.L. Water		ΣVw =	**3306.5**	ΣMv =	**72,742.6**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	140	28.00	0.000	rec	0.0	14.00	0
	U_A	140	28.00	0.250	tri	-489.2	18.67	-9,132
					ΣU =	**-489.2**	ΣMu =	**-9,132**

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	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 6 Construction	Panel E

	L		Force		H	arm	Mw
ICE	140	2.00	0.00	rec	0.0	34.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	140		-11.932		-1670.47	11.81'	-19733.84
Water Loads							
H_{TW}	140		0.000	tri	0.00	1.33	0.00
H_{HW}	140		-0.499	tri	-69.89	1.33	-93.18
				ΣWater =	**-69.89**	ΣM_W =	**-19827.0**

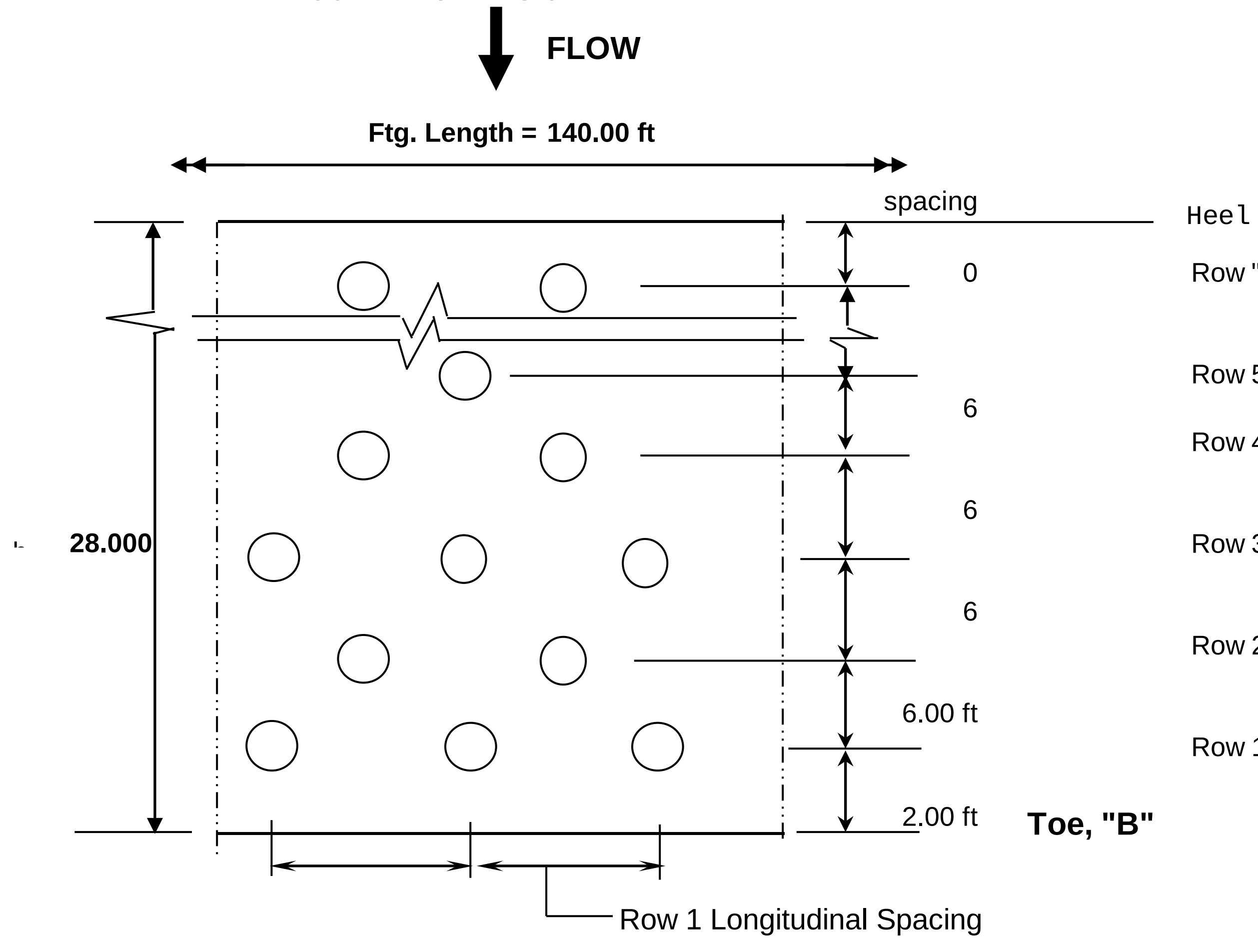
Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-28959	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	142644	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**113,685**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**7,810**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-1,740**	kips

Location of Resultant	Xr = ΣM / P =	14.56	ft from Toe
	e = B/2 - Xr =	(0.56)	ft
	B/6 =	4.667	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 =		31.44	**0.019**	0.59736	9.390	10.480	98.41243
Tributary WSEL =		0.00	**0.0624**	0	0.000	0.000	0
	Sum				9.390		98.41243
	Net Forces				9.390		98.41243

PILE FOUNDATION DESIGN



L = 140.00 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	2.00 ft	2.0 ft	2.50 ft	0	"/12"	23	42.50	1	57
Row 1 to Row 2	6.00 ft	8.0 ft	5.00 ft	0	"/12"	24	12.50	2	29
Row 2 to Row 3	6.00 ft	14.0 ft	5.00 ft	0	"/12"	24	12.50	3	29
Row 3 to Row 4	6.00 ft	20.0 ft	5.00 ft	0	"/12"	26	7.50	4	29
Row 4 to Row 5	6.00 ft	26.0 ft	0.00 ft	0	"/12"	28	70.00	5	#DIV/0!
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	70.00	0	0
Last Row to Heel	2.00 ft								
	28.00 ft		Note: Enter 0 for Longitudinal Spacing for Rows Not Used)		ΣN =	125			#DIV/0!

Pile Properties:				
Pile Type: HP	(C.I.P or HP)	Pile Length = **26.4 ft**	Ftg EL.	868.06
			Pile Tip El.	842.68
HP Nominal Depth, h = **14.0 in**			Pile Cap Embed =	**1.00 ft**
Wt. per ft, plf **73**		**Total pile Length =**	**3,298**	**LF**

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **14.58 ft**

	Dist. From N.A. to Pile Row	d	N	I = N * d²
1	Dist. To Row 1	12.58 ft	23	3637.6
2	Dist. To Row 2	6.58 ft	24	1037.9
3	Dist. Row 3	0.58 ft	24	8.0
4	Dist. Row 4	-5.42 ft	26	764.9
5	Dist. Row 5	-11.42 ft	28	3654.2
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
			125	Σ I = **9102.5**

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	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) 1	2	3	4	5	6	7	8	9	10	11	12	Max. Vertical Load (Tons)	Horiz Pile Group Capacity (k)	Check
Case 1	**57.2 tons**	12.6	19.9	27.1	34.3	41.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5	4,500	**OK**
Case 2	**76.2 tons**	12.6	19.9	27.1	34.3	41.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5	5,250	**OK**
Case 3	**76.2 tons**	9.5	18.1	26.8	35.5	44.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.2	5,250	**OK**
Case 4	**99.4 tons**	-13.7	5.7	25.2	44.7	64.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.2	6,000	**OK**
Case 5	**31.4 tons**	31.3	31.3	31.2	31.2	31.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.3	2,875	**OK**
Case 6	**76.2 tons**	31.3	31.3	31.2	31.2	31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.3	2,875	**OK**
													Max Service : P =	**64.2**		

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.

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

Pvert

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

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

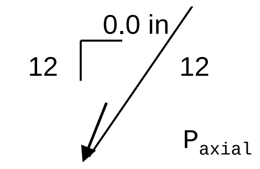
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel E	

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-	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$
Case 1	**100 yr. flood**	**Usual**	6,940	-1,174	123,023	17.73	-3.15	-21871
Case 2	**100 yr. flood + ice**	**Unusual**	6,940	-1,174	123,023	17.73	-3.15	-21871
Case 3	**500 yr. flood**	**Unusual**	6,912	-1,539	127,077	18.38	-3.81	-26326
Case 4	**T.O. Levee**	**Extreme**	6,772	-3,746	157,816	23.31	-8.73	-59112
Case 5	**Normal flow + ice**	**Usual**	7,810	1,740	113,778	14.57	0.01	64
Case 6	**Construction**	**Unusual**	7,810	1,740	113,685	14.56	0.02	157

SERVICE

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

Vertical Load, P = 6940 kips
Horizontal Load, H = -1174 kips
M_{NA} = -21871 kip-ft   125

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	55.5	-30.2	25.3 kips/pile	12.6 tons/pile	12.6 tons/pile
2	Row 2	55.5	-15.8	39.7 kips/pile	19.9 tons/pile	19.9 tons/pile
3	Row 3	55.5	-1.4	54.1 kips/pile	27.1 tons/pile	27.1 tons/pile
4	Row 4	55.5	13.0	68.5 kips/pile	34.3 tons/pile	34.3 tons/pile
5	Row 5	55.5	27.4	83.0 kips/pile	41.5 tons/pile	41.5 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:	**41.5 tons/pile**	**max: 41.5 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	23	0.0	828	1.000	828 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	26	0.0	936	1.000	936 kips	
5	Row 5	0	28	0.0	1008	1.000	1008 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	
			125		4500		**4500 kips**	**OK**

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

Vertical Load, P = 6940 kips
Horizontal Load, H = -1174 kips
M_{NA} = -21871 kip-ft   125

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	55.5	-30.2	25.3 kips/pile	12.6 tons/pile	12.6 tons/pile
2	Row 2	55.5	-15.8	39.7 kips/pile	19.9 tons/pile	19.9 tons/pile
3	Row 3	55.5	-1.4	54.1 kips/pile	27.1 tons/pile	27.1 tons/pile
4	Row 4	55.5	13.0	68.5 kips/pile	34.3 tons/pile	34.3 tons/pile

5	Row 5	55.5	27.4	83.0 kips/pile	41.5 tons/pile	41.5 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:	**41.5 tons/pile**	**max: 41.5 tons/pile**

Assumed lateral Capacity: 42.0 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	23	0.0	966	1.000	966 kips	
2	Row 2	0	24	0.0	1008	1.000	1008 kips	
3	Row 3	0	24	0.0	1008	1.000	1008 kips	
4	Row 4	0	26	0.0	1092	1.000	1092 kips	
5	Row 5	0	28	0.0	1176	1.000	1176 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	
			125		5250		**5250 kips**	**OK**

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

Vertical Load, P = 6912 kips
Horizontal Load, H = -1539 kips
M_{NA} = -26326 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	55.3	-36.4	18.9 kips/pile	9.5 tons/pile	9.5 tons/pile
2	Row 2	55.3	-19.0	36.3 kips/pile	18.1 tons/pile	18.1 tons/pile
3	Row 3	55.3	-1.7	53.6 kips/pile	26.8 tons/pile	26.8 tons/pile
4	Row 4	55.3	15.7	71.0 kips/pile	35.5 tons/pile	35.5 tons/pile
5	Row 5	55.3	33.0	88.3 kips/pile	44.2 tons/pile	44.2 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
				max:	**44.2 tons/pile**	**max: 44.2 tons/pile**

Assumed lateral Capacity: 42.0 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	23	0.0	966	1.000	966 kips	
2	Row 2	0	24	0.0	1008	1.000	1008 kips	
3	Row 3	0	24	0.0	1008	1.000	1008 kips	
4	Row 4	0	26	0.0	1092	1.000	1092 kips	
5	Row 5	0	28	0.0	1176	1.000	1176 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	
			125		5250		**5250 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		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel E	

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

Vertical Load, P = 6772 kips
Horizontal Load, H = -3746 kips
M_{NA} = -59112 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	54.2	-81.7	-27.5 kips/pile	-13.7 tons/pile	-13.7 tons/pile
2	Row 2	54.2	-42.7	11.5 kips/pile	5.7 tons/pile	5.7 tons/pile
3	Row 3	54.2	-3.7	50.4 kips/pile	25.2 tons/pile	25.2 tons/pile
4	Row 4	54.2	35.2	89.4 kips/pile	44.7 tons/pile	44.7 tons/pile
5	Row 5	54.2	74.2	128.4 kips/pile	64.2 tons/pile	64.2 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
				max:	**64.2 tons/pile**	**max: 64.2 tons/pile**

Assumed lateral Capacity: 48.0 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	23	0.0	1104	1.000	1104 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	26	0.0	1248	1.000	1248 kips	
5	Row 5	0	28	0.0	1344	1.000	1344 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	
			125		6000		**6000 kips**	**OK**

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

Vertical Load, P = 7810 kips
Horizontal Load, H = 1740 kips
M_{NA} = 64 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	62.5	0.1	62.6 kips/pile	31.3 tons/pile	31.3 tons/pile
2	Row 2	62.5	0.0	62.5 kips/pile	31.3 tons/pile	31.3 tons/pile
3	Row 3	62.5	0.0	62.5 kips/pile	31.2 tons/pile	31.2 tons/pile
4	Row 4	62.5	0.0	62.4 kips/pile	31.2 tons/pile	31.2 tons/pile
5	Row 5	62.5	-0.1	62.4 kips/pile	31.2 tons/pile	31.2 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
				max:	**31.3 tons/pile**	**max: 31.3 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	23	0.0	529	1.000	529 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	26	0.0	598	1.000	598 kips	
5	Row 5	0	28	0.0	644	1.000	644 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	
			125		2875		**2875 kips**	**OK**

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

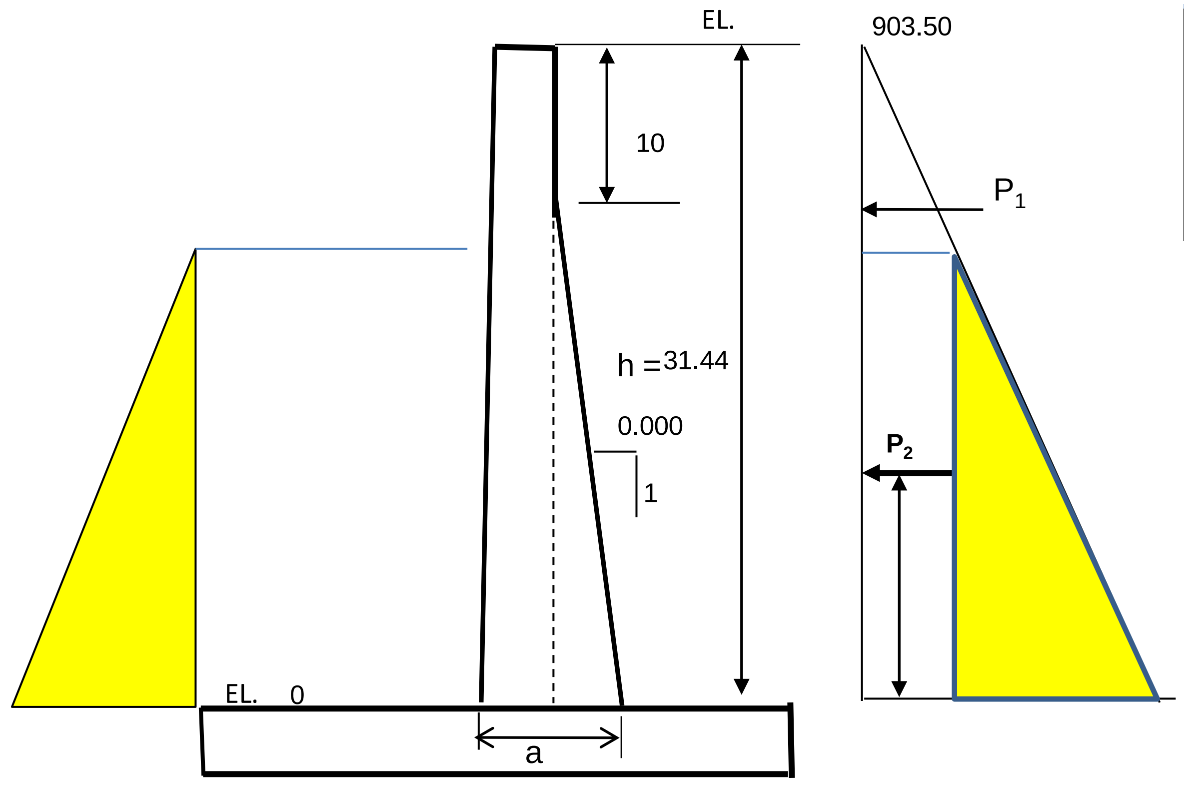
Vertical Load, P = 7810 kips
Horizontal Load, H = 1740 kips
M_{NA} = 157 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	62.5	0.2	62.7 kips/pile	31.3 tons/pile		31.3 tons/pile
2	Row 2	62.5	0.1	62.6 kips/pile	31.3 tons/pile		31.3 tons/pile
3	Row 3	62.5	0.0	62.5 kips/pile	31.2 tons/pile		31.2 tons/pile
4	Row 4	62.5	-0.1	62.4 kips/pile	31.2 tons/pile		31.2 tons/pile
5	Row 5	62.5	-0.2	62.3 kips/pile	31.1 tons/pile		31.1 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
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:	**31.3 tons/pile**	**max:**	**31.3 tons/pile**

Assumed lateral Capacity: 42.0 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	23	0.0	529	1.000	529 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	26	0.0	598	1.000	598 kips	
5	Row 5	0	28	0.0	644	1.000	644 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	
			125		2875		**2875 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		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel E 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	903.500	903.50	0.00	903.50
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	-5.48	-9.779	-12.11	-21.61
Case 2	100 yr. flood + ice	Unusual	0.75	-5.48	-9.779	-9.08	-16.21
Case 3	500 yr. flood	Unusual	0.75	-7.69	-34.842	-12.75	-57.75
Case 4	T.O. Levee	Extreme	0.75	-21.45	-224.795	35.55	372.60
Case 5	Normal flow + ice	Usual	1	9.39	98.412	20.75	217.49
Case 6	Construction	Unusual	0.75	9.39	98.412	15.56	163.12

	STEM DESIGN VALUES	
MU, k-ft/ft	372.60	k-ft/ft
VU, k/ft	35.55	k/ft

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 = 373 k-ft /ft **Includes: hf = 1.3**
Vuh= 35.55 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 = 218.786 **ACI 10.5.1** **ACI 10.5.3**
REQ'D p= 0.0038 **O.K.** p(min)= 3*SQRT(Fc')/fy 200* / fy 4/3*p
p= FALSE N.G. 0.00316 0.00333 0.0050

EM 110-2-2104 2-8 c. (not less than Temp & Shrinkage, half in each face)

As (REQ'D)= 0.81 in^2 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
3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
4) 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

T= As*fy = 119.9 k
C= B1*Fc' *b*a = 1266.8 **a**
a= T/C = 0.095 in
Mn= T(d - a/2)/12 = 433.6 ft-k
ϕ Mn= 390.2 ft-k **> Mu O.K.**

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

Vuh = 35.6 k **NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ = 47.4 k
Vc = 2*sqrt(Fc') bw * d = 65.9 k **11.3.1.1**
Vs =Vuh / f - 1.3Vc = No Shear Reinf. Req. k NG Vs(max) ≤ 8*sqrt(fc')bd = 263.7 k

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

11.5.5 - Spacing limits for shear reinforcement
s = d/2 = 21.719 in OR 24 in
s(max)= 10.859 in
4*sqrt(Fc')*bw*d= 131.9 k < Vs Reduce Spacing

USE s= 0.00 in

Vs = (Av * Fy * d) / s = #DIV/0! k

11.5.6 - MINIMUM SHEAR REINFORCEMENT
A minimum area of shear reinforcement, Av,min shall be provided in all reinforced concrete flexural members where **Vu** exceeds **0.5 f Vc**
NOT REQUIRED IF:
a) SLAB OR FOOTING, vc>vn **O.K.**
b) CONCRETE JOIST ACI 8.11
c) BEAMS W/ h <= 10"
h <= 2.5*Bf
h <= 0.5*tw
d) WALLS (SEE ACI 11.10.1); vc>vn **O.K.**

11.5.6.3
Av,min = 0.75 sqrt(fc') bw*s/fy = 0.70 * s
but not less than 50bw*s/ fy = 23.33333333 * s
s max = Av fy / 0.75 sqrt(fc') bw = 0.00 in
s max = Av fy /50 bw = 0.00 in

11.5.5.3
Where Vs exceeds 4*sqrt(Fc')*bw*d maximum spacings shall be reduced by one-half