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 D	**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 D.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	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)	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**	**20.94**	**0.44**	**NA**
Diversion - Head Water height (ft)	**21.83**	**21.83**	**23.4**	**29.94**	**NA**	**NA**
Ice	**NA**	2ft Ice	**NA**	**NA**	2ft Ice	**NA**
Ice Load	**NA**	10 kips/ft	**NA**	**NA**	10 kips/ft	**NA**
Ice Laod El. (ft)	**NA**	**895.99**	**NA**	**NA**	**881.5**	**NA**
Uplift @ HW (ft)	**25.83**	**25.83**	**27.4**	**33.94**	**NA**	**NA**
Uplift @ TW (ft)	**24.51**	**24.51**	**25.6**	**33.94**	**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
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 D		

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	1,846	0	$0
INSTALL HP14x73 WALL PILING		LF	1,846	0	$0
PILE TEST, 36.4 ft	Long	EA	4	0	$0
FOOTING CONCRETE		CY	359	0	$0
	Forming	SF	922		
STEM CONCRETE		CY	357	0	$0
	Forming	SF	5,102		
STEEL REINFORCEMENT		LB	139,815	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 = 70 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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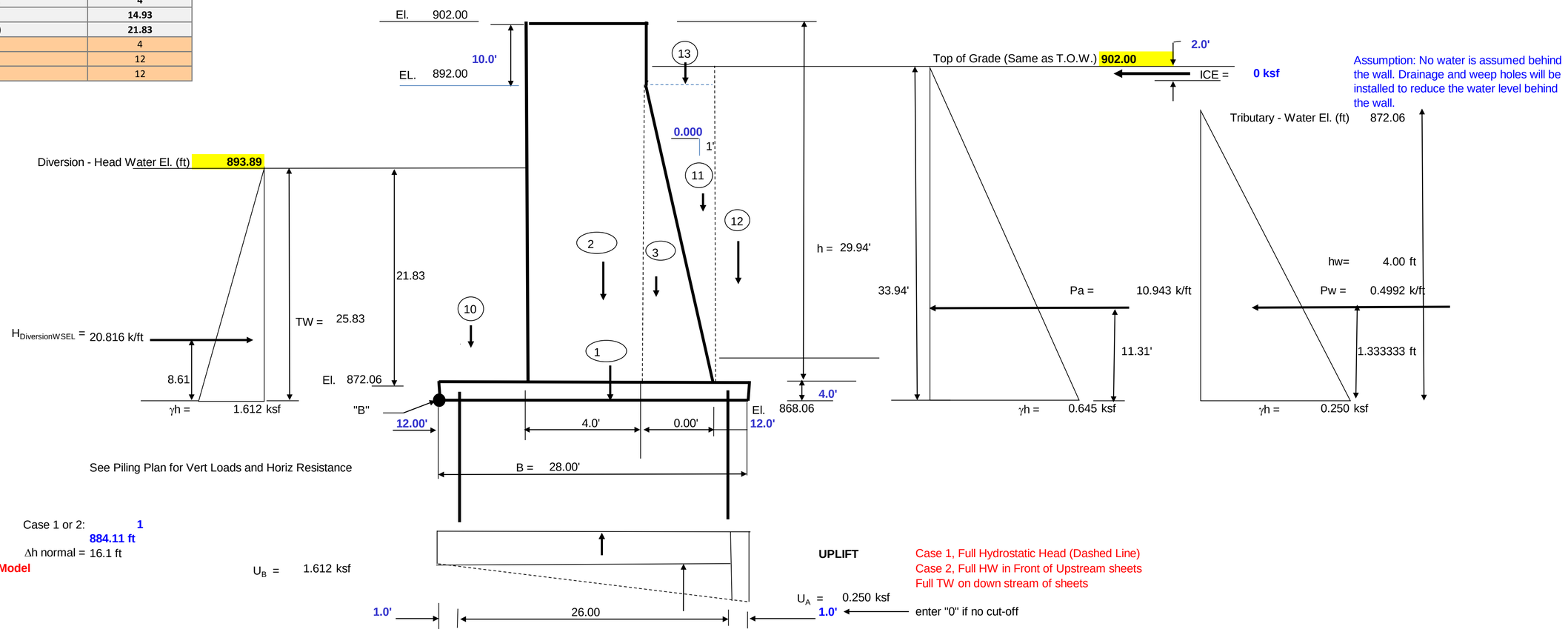
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood Panel D	

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)	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 = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 16.1 ft
See Geotechnical seepage Model

UPLIFT
U A = 0.250 ksf
1.0' ← enter "0" if no cut-off

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

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**
T.W on ftg Stem	10	80.5	12.00	21.83	0.0624	rec	1315.9	6.00	7,895.3
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3126.4**	ΣM_V =	**47,726.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.612	rec	-3633.0	14.00	-50,862
	U_A	80.5	28.00	-1.362	tri	1535.2	18.67	28,657
					ΣU =	**-2097.8**	ΣM_U =	**-22,205**

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

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	80.5	2.00	0.00	rec	0.0	32.94	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	80.5	-10.943		-880.93	11.31	-9966.30

Water Loads

H_{TW}	80.5	20.816	tri	1675.71	8.61	14427.88
H_{HW}	80.5	-0.499	tri	-40.19	1.33	-53.58
			ΣWater =	**1635.53**	ΣM_W =	**4408.0**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-17797	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	86906	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**69,109**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,827**	kips
Sum of Horizontal Forces	H = Σhorizontal	**755**	kips

Location of Resultant	Xr = ΣM / P =	18.06	ft from Toe
	e = B/2 - Xr =	(4.06)	ft
	B/6 =	4.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	342	cy (includes stepped)	922	sf
Stem Conc:	357	cy	5102	sf
Total =	699			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
Bot mat	Transverse:	9	6	3.40	27.5	165	15,428		
	Longitudinal:	9	6	3.40	82	56	15,613		
								cy	**LB/cy**
							62,081	342	181.4043506
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	29.44	161	16,115	32,230.91	
	Longitudinal:	9	6	3.40	80	59	16,048	32,096.00	
Top Face	Transverse:	9	6	3.40	3.5	161	1,916		
	Longitudinal:	9	6	3.40	80	8	2,176		
Dowels	Vertical I.F.	9	6	3.40	29.4	161	16,115		
	Vertical O.F.	9	6	3.40	29.4	161	16,115		
								cy	**LB/cy**
							68,486	357	191.8048557
						Σ =	**130,567**		
	Lap Splices (long. Bars)	9		3.40	8	340	9,248		
						Σ Bar Wt=	139,815	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 =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				-6.352		-23.2038

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

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	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)	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

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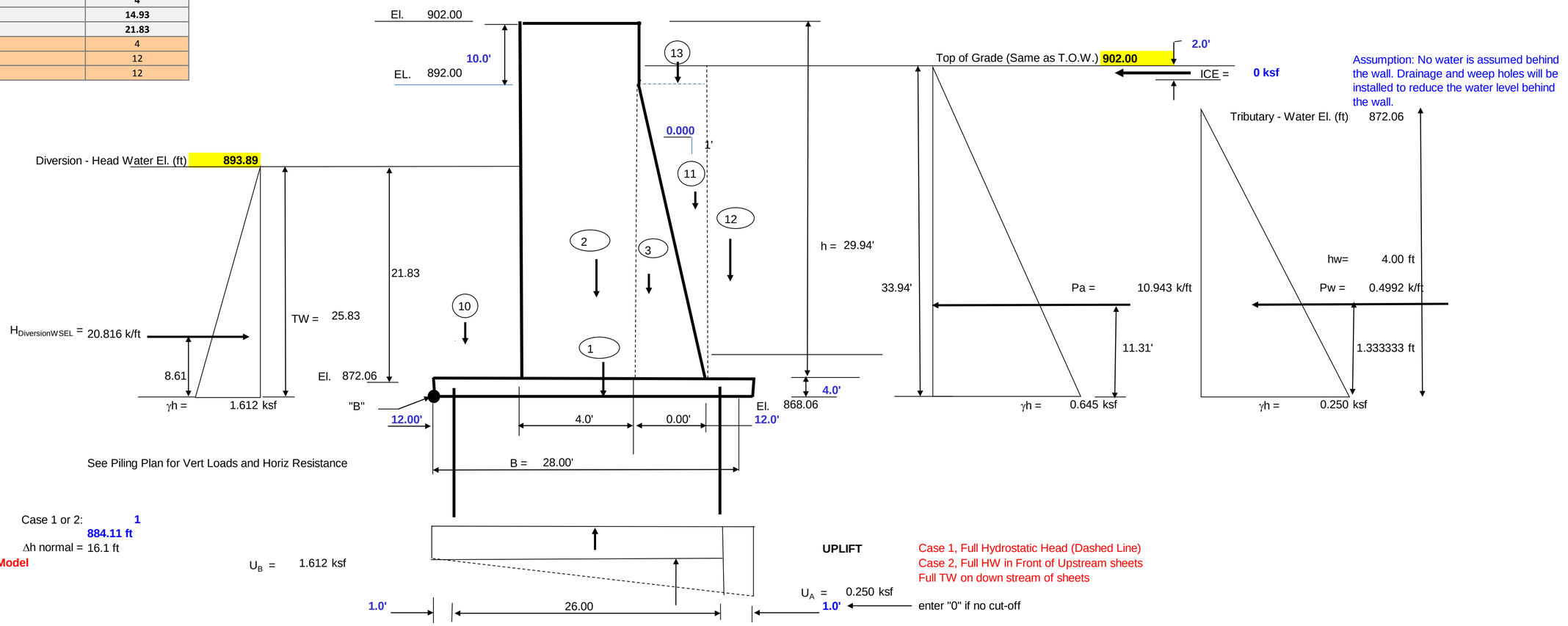
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft DEC, JAN, FEB Mean Water Elevation

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



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 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	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**
T.W on ftg Stem	10	80.5	12.00	21.83	0.0624	rec	1315.9	6.00	7,895.3
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3126.4**	ΣM_V =	**47,726.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.612	rec	-3633.0	14.00	-50,862
	U_A	80.5	28.00	-1.362	tri	1535.2	18.67	28,657
					ΣU =	**-2097.8**	ΣM_U =	**-22,205**

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 D

ICE	80.5	2.00	0.00	rec	0.0	32.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-10.943		-880.93	11.31	-9966.30	
Water Loads								
H_{TW}	80.5		20.816	tri	1675.71	8.61	14427.88	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**1635.53**	ΣM_W =	**4408.0**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-17797	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	86906	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**69,109**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,827**	kips
Sum of Horizontal Forces	H = Σhorizontal	**755**	kips

Location of Resultant	Xr = ΣM / P =	18.06	ft from Toe
	e = B/2 - Xr =	(4.06)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	21.83	**0.0624**	1.362192	14.868	7.277	108.1918
Tributary SEL =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				-6.352		-23.2038

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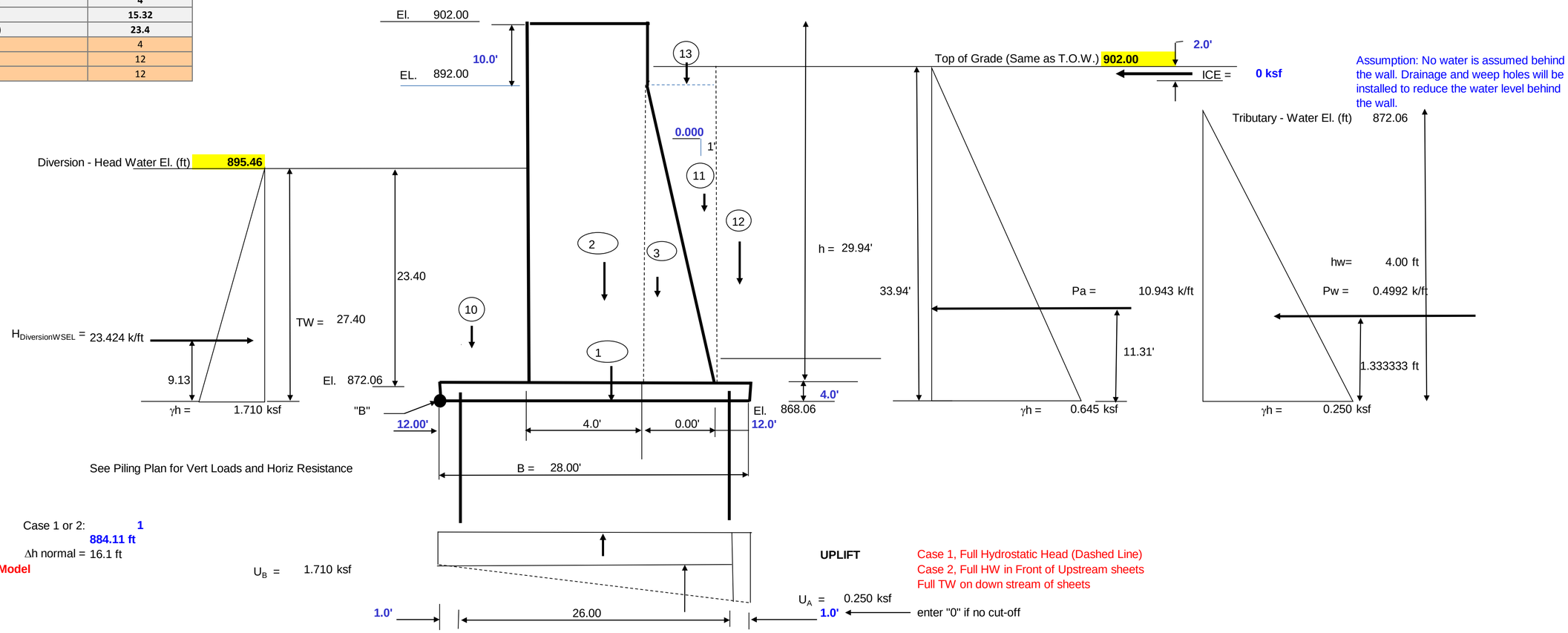
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 3 500 yr. flood Panel D	

ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	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)	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 = 80.5 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 16.1 ft
See Geotechnical seepage Model

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

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	12.00	23.40	0.0624	rec	1410.5	6.00	8,463.1
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3221.0**	ΣM_V =	**48,294.5**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	1.710	rec	-3853.8	14.00	-53,953
	U_A	80.5	28.00	-1.460	tri	1645.6	18.67	30,718
					ΣU =	**-2208.2**	ΣM_U =	**-23,235**

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 D	

ICE	80.5	2.00	0.00		rec	0.0	32.94	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	80.5		-10.943			-880.93	11.31'	-9966.30
Water Loads								
H_{TW}	80.5		23.424		tri	1885.61	9.13	17221.89
H_{HW}	80.5		-0.499		tri	-40.19	1.33	-53.58
					ΣWater =	**1845.42**	ΣM_W =	**7202.0**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-16033	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	87474	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**71,440**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,811**	kips
Sum of Horizontal Forces	H = Σhorizontal	**964**	kips

Location of Resultant	Xr = ΣM / P =	18.74	ft from Toe
	e = B/2 - Xr =	(4.74)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	23.40	**0.0624**	1.46016	17.084	7.800	133.2542
Tributary SEL =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				-8.568		-48.2662

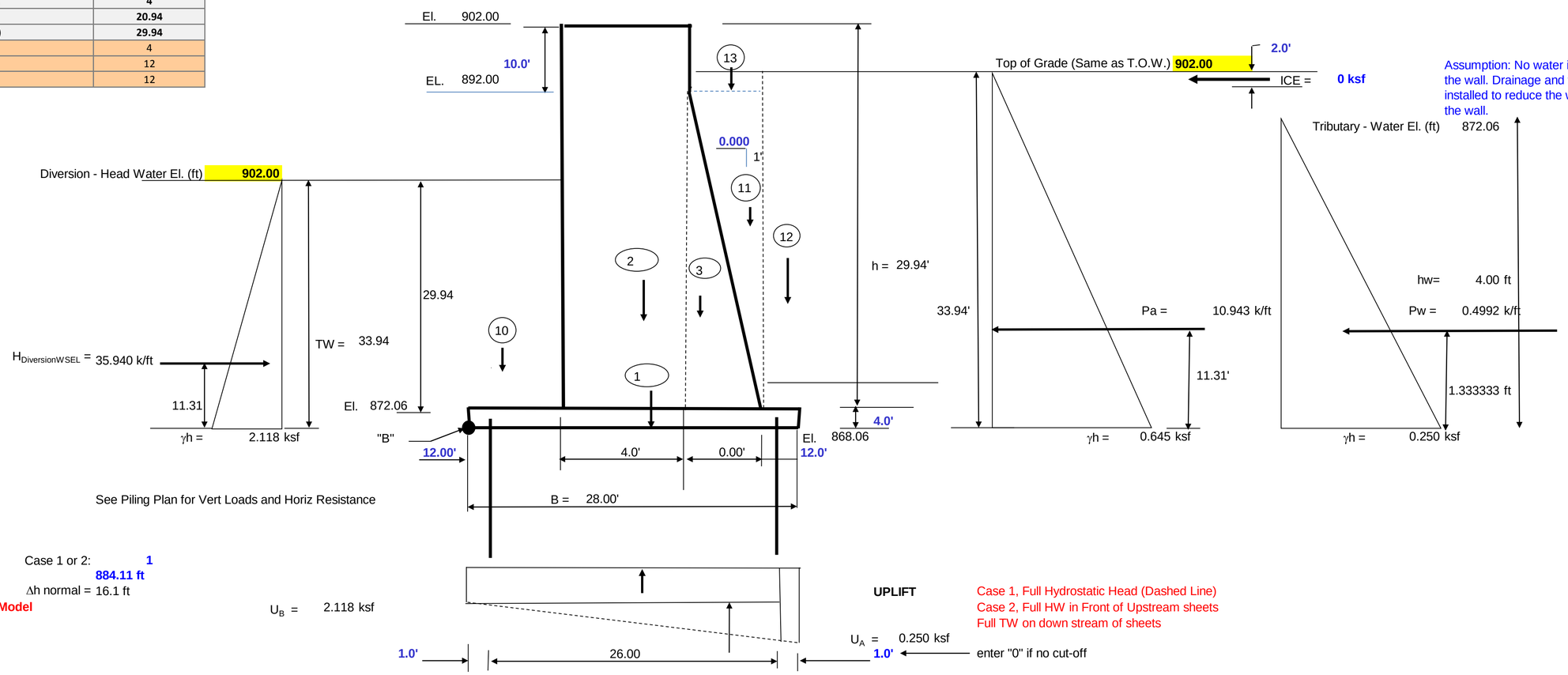
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 4 T.O. Levee Panel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

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)	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)	20.94
Diversion - Head Water height (ft)	29.94
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 = 80.5 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 16.1 ft
See Geotechnical seepage Model

U_B = 2.118 ksf

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

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

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	12.00	29.94	0.0624	rec	1804.7	6.00	10,828.4
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**3615.3**	ΣM_V =	**50,659.8**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	28.00	2.118	rec	-4773.6	14.00	-66,831
	U_A	80.5	28.00	-1.868	tri	2105.5	18.67	39,303
					ΣU =	**-2668.1**	ΣM_U =	**-27,528**

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 D

ICE	80.5	2.00	0.00		rec	0.0	32.94	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	80.5		-10.943			-880.93	11.31'	-9966.30
Water Loads								
H_{TW}	80.5		35.940		tri	2893.17	11.31	32731.41
H_{HW}	80.5		-0.499		tri	-40.19	1.33	-53.58
					ΣWater =	**2852.99**	ΣM_W =	**22711.5**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-4816	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	89839	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**85,022**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**3,746**	kips
Sum of Horizontal Forces	H = Σhorizontal	**1,972**	kips

Location of Resultant	Xr = ΣM / P =	22.70	ft from Toe
	e = B/2 - Xr =	(8.70)	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	29.94	**0.0624**	1.868256	27.968	9.980	279.1186
Tributary SEL =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				-19.452		-194.131

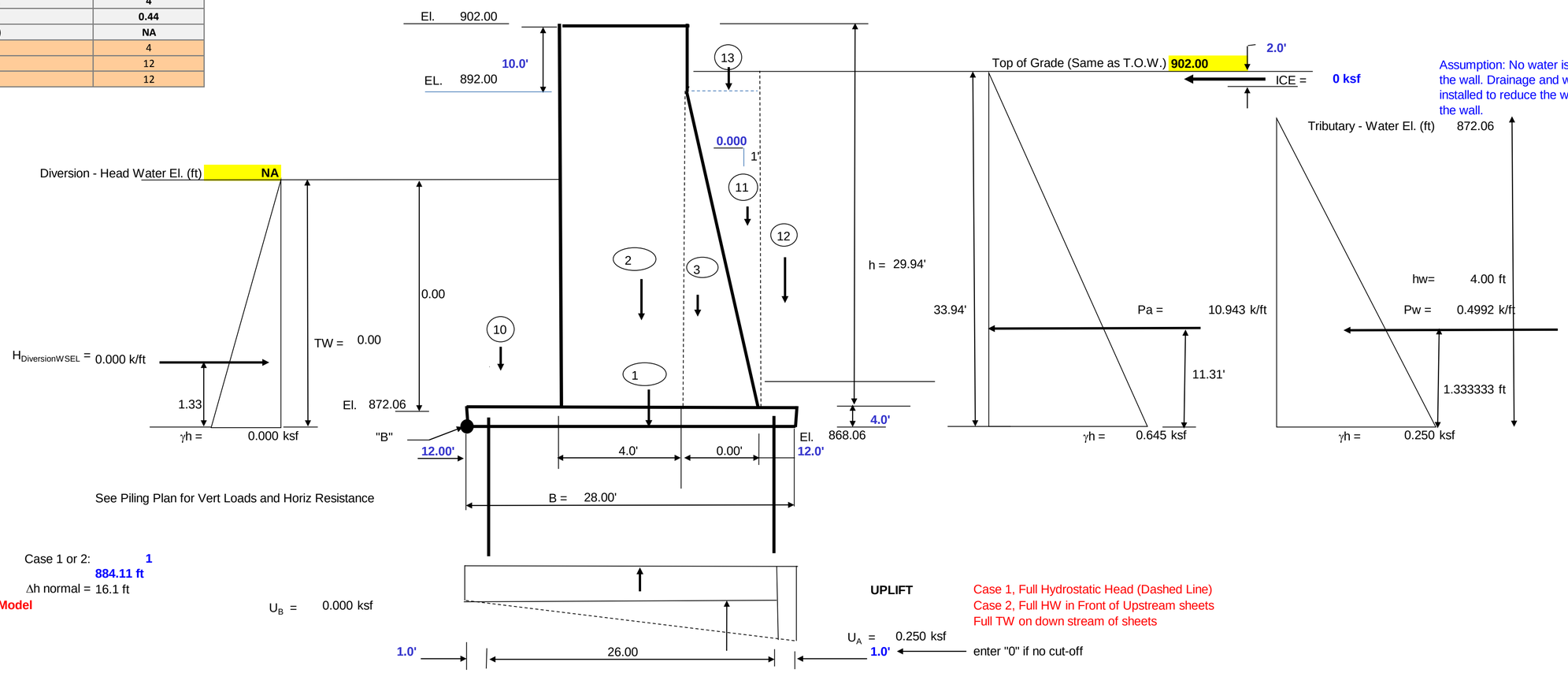
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice Panel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

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)	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 = 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 = 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	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**
T.W on ftg Stem	10	80.5	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**1810.5**	ΣM_V =	**39,831.4**

← CONSTANT FOR ALL LOAD CASES

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

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

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

ICE	80.5	2.00	0.00	rec	0.0	32.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-10.943		-880.93	11.31'	-9966.30	
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 =	**-9966.3**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-15217	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	79010	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**63,793**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,328**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-921**	kips

Location of Resultant	Xr = ΣM / P =	14.74	ft from Toe
	e = B/2 - Xr =	(0.74)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				8.516		84.98803

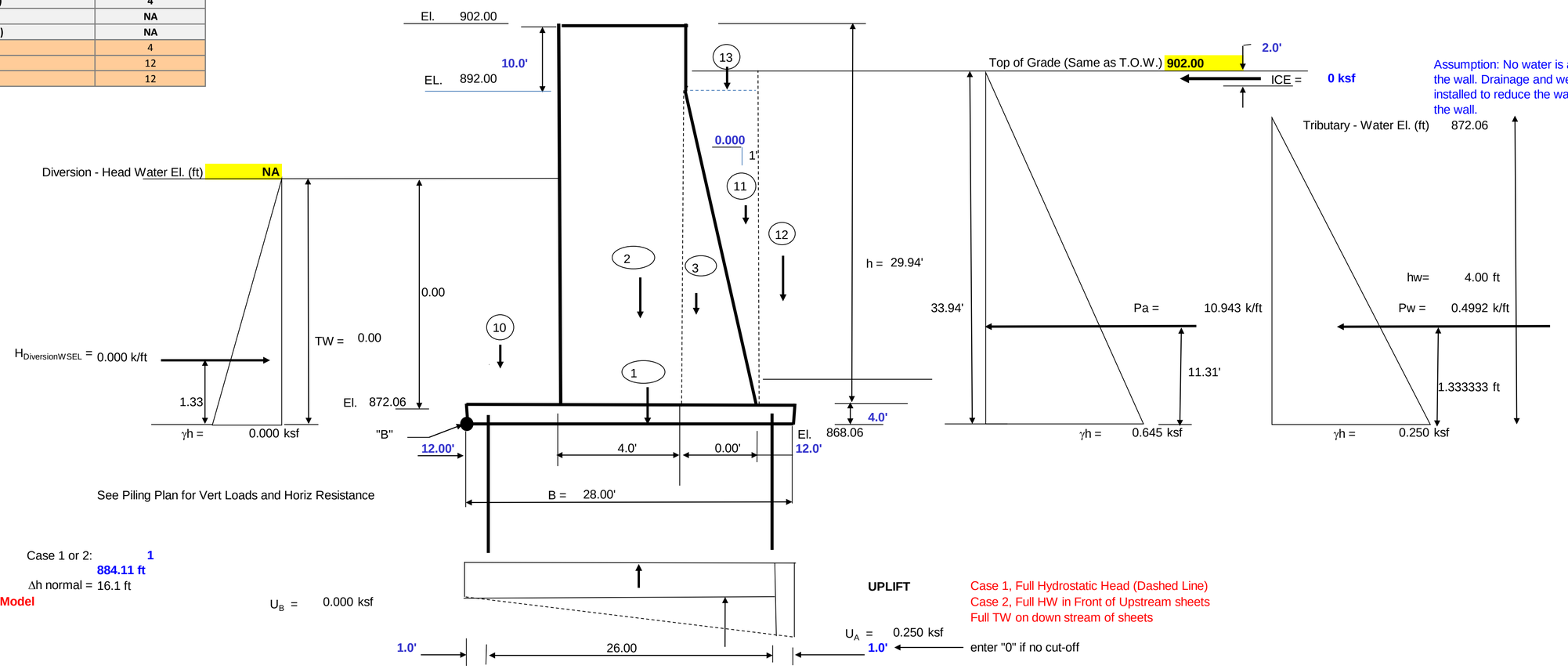
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction Panel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

ID#	Case 6
Name	Construction
Load Category	Unusual
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	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)	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 = 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 = 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	80.5	28.00	4.00	0.15	rec	1352.4	14.00	18,933.6
Stem	2	80.5	4.00	29.94	0.15	rec	1446.1	14.00	20,245.4
Batter	3	80.5	0.00	19.94	0.15	tri	0.0	16.00	0.0
					D.L. Concrete	ΣVc =	**2798.5**	ΣM_V =	**39,179.0**
T.W on ftg Stem	10	80.5	12.00	0.00	0.0624	rec	0.0	6.00	0.0
H.W. on Stem Slope	11	80.5	0.00	19.94	0.12	tri	0.0	16.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	16.00	0.0
Soil on Footing	12s	80.5	12.00	29.94	0.0626	rec	1810.5	22.00	39,831.4
H.W. on Footing	12w	80.5	12.00	0.00	0.0624	rec	0.0	22.00	0.0
					D.L. Water	ΣVw =	**1810.5**	ΣM_V =	**39,831.4**

← CONSTANT FOR ALL LOAD CASES

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

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

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

ICE	80.5	2.00	0.00	rec	0.0	32.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-10.943		-880.93	11.31'	-9966.30	
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 =	**-10019.9**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-15271	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	79010	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**63,740**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**4,328**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-921**	kips

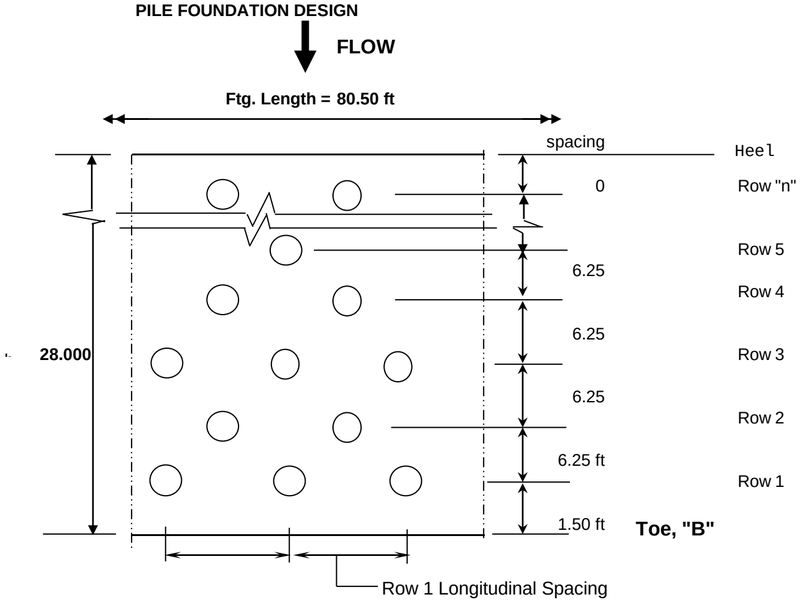
Location of Resultant	Xr = ΣM / P =	14.73	ft from Toe
	e = B/2 - Xr =	(0.73)	ft
	B/6 =	4.667	ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	29.94	**0.019**	0.56886	8.516	9.980	84.98803
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				8.516		84.98803
Net Forces				8.516		84.98803

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 Panel D	

PILE FOUNDATION DESIGN



L = 80.50 ft

PILE PATTERN GEOMETRY

Transverse Spacing		Distance to Toe, d_{toe}	Longitudinal Spacing	Batter	Piles per Row (**N**)	Edge Dist (ft)		Trial N
Row 1 to Toe	1.50 ft	1.5 ft	2.50 ft	0 "/12"	12	26.50	1	33
Row 1 to Row 2	6.25 ft	7.8 ft	5.00 ft	0 "/12"	14	7.75	2	17
Row 2 to Row 3	6.25 ft	14.0 ft	5.00 ft	0 "/12"	14	7.75	3	17
Row 3 to Row 4	6.25 ft	20.3 ft	5.00 ft	0 "/12"	14	7.75	4	17
Row 4 to Row 5	6.25 ft	26.5 ft	0.00 ft	0 "/12"	16	40.25	5	#DIV/0!
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	40.25	0	0
Last Row to Heel	1.50 ft							
	28.00 ft				**ΣN =**	**70**		#DIV/0!

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

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **26.4 ft**
HP Nominal Depth, h = **14.0 in**
Wt. per ft, plf **73**
Total pile Length = 1,847 LF

Ftg EL. 868.06
Pile Tip El. 842.68
Pile Cap Embed = **1.00 ft**

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **14.71 ft**

	Dist. From N.A. to Pile Row	d	N	I = N * d²
1	Dist. To Row 1	13.21 ft	12	2095.4
2	Dist. To Row 2	6.96 ft	14	679.0
3	Dist. Row 3	0.71 ft	14	7.1
4	Dist. Row 4	-5.54 ft	14	429.0
5	Dist. Row 5	-11.79 ft	16	2222.4
0	Row 6 (not used)	0.00 ft	0	0.0
0	Row 7 (not used)	0.00 ft	0	0.0
0	Row 8 (not used)	0.00 ft	0	0.0
0	Row 9 (not used)	0.00 ft	0	0.0
0	Row 10 (not used)	0.00 ft	0	0.0
0	Row 11 (not used)	0.00 ft	0	0.0
0	Row 12 (not used)	0.00 ft	0	0.0
0	Row 13 (not used)	0.00 ft	0	0.0
0	Row 14 (not used)	0.00 ft	0	0.0
0	Row 15 (not used)	0.00 ft	0	0.0
			70	Σ I = **5433.0**

ALLOWABLE LOADS (from Geotechnical)

Service	**Allowable Pile Loads**					
ID#	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Allwable Lateral Capacity (tons)	18.0 tons	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**	11.8	19.1	26.5	33.9	41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.2	2,520	**OK**
Case 2	**76.2 tons**	11.8	19.1	26.5	33.9	41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.2	2,940	**OK**
Case 3	**76.2 tons**	8.5	17.4	26.2	35.0	43.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.9	2,940	**OK**
Case 4	**99.4 tons**	-9.6	7.6	24.8	42.0	59.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.2	3,360	**OK**
Case 5	**31.4 tons**	30.8	30.8	30.9	31.0	31.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	1,610	**OK**
Case 6	**76.2 tons**	30.8	30.9	30.9	30.9	31.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	1,610	**OK**

Max Service : P = **59.2**

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.

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

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

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

Pvert

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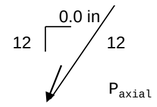
The moment about the neutral axis of the pile group becomes

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

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**	3,827	-755	69,109	18.06	-3.34	-12796
Case 2	**100 yr. flood + ice**	**Unusual**	3,827	-755	69,109	18.06	-3.34	-12796
Case 3	**500 yr. flood**	**Unusual**	3,811	-964	71,440	18.74	-4.03	-15359
Case 4	**T.O. Levee**	**Extreme**	3,746	-1,972	85,022	22.70	-7.98	-29908
Case 5	**Normal flow + ice**	**Usual**	4,328	921	63,793	14.74	-0.03	-114
Case 6	**Construction**	**Unusual**	4,328	921	63,740	14.73	-0.01	-60

SERVICE

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

Vertical Load, P = 3827 kips
Horizontal Load, H = -755 kips
M_{NA} = -12796 kip-ft

70

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	54.7		-31.1	23.6 kips/pile	11.8 tons/pile	11.8 tons/pile
2	Row 2	54.7		-16.4	38.3 kips/pile	19.1 tons/pile	19.1 tons/pile
3	Row 3	54.7		-1.7	53.0 kips/pile	26.5 tons/pile	26.5 tons/pile
4	Row 4	54.7		13.0	67.7 kips/pile	33.9 tons/pile	33.9 tons/pile
5	Row 5	54.7		27.8	82.4 kips/pile	41.2 tons/pile	41.2 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:	**41.2 tons/pile**	**max:** **41.2 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	12	0.0	432	1.000	432 kips
2	Row 2	0	14	0.0	504	1.000	504 kips
3	Row 3	0	14	0.0	504	1.000	504 kips
4	Row 4	0	14	0.0	504	1.000	504 kips
5	Row 5	0	16	0.0	576	1.000	576 kips
6	Row 6	0	0	0.0	0	1.000	0 kips
7	Row 7	0	0	0.0	0	1.000	0 kips
8	Row 8	0	0	0.0	0	1.000	0 kips
9	Row 9	0	0	0.0	0	1.000	0 kips
10	Row 10	0	0	0.0	0	1.000	0 kips
11	Row 11	0	0	0.0	0	1.000	0 kips
12	Row 12	0	0	0.0	0	1.000	0 kips
13	Row 13	0	0	0.0	0	1.000	0 kips
14	Row 14	0	0	0.0	0	1.000	0 kips
15	Row 15	0	0	0.0	0	1.000	0 kips
			70		2520		**2520 kips** **OK**

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

Vertical Load, P = 3827 kips
Horizontal Load, H = -755 kips
M_{NA} = -12796 kip-ft

70

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	54.7		-31.1	23.6 kips/pile	11.8 tons/pile	11.8 tons/pile
2	Row 2	54.7		-16.4	38.3 kips/pile	19.1 tons/pile	19.1 tons/pile
3	Row 3	54.7		-1.7	53.0 kips/pile	26.5 tons/pile	26.5 tons/pile
4	Row 4	54.7		13.0	67.7 kips/pile	33.9 tons/pile	33.9 tons/pile

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5	Row 5	54.7	27.8	82.4 kips/pile		41.2 tons/pile		41.2 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:	**41.2 tons/pile**	**max:**	**41.2 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	12	0.0	504	1.000	504 kips	
2	Row 2	0	14	0.0	588	1.000	588 kips	
3	Row 3	0	14	0.0	588	1.000	588 kips	
4	Row 4	0	14	0.0	588	1.000	588 kips	
5	Row 5	0	16	0.0	672	1.000	672 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		2940		**2940 kips**	**OK**

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

Vertical Load, P = 3811 kips
Horizontal Load, H = -964 kips
M_{NA} = -15359 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads				**Axial Pile Load**
1	Row 1	54.4	-37.4	17.1 kips/pile		8.5 tons/pile		8.5 tons/pile
2	Row 2	54.4	-19.7	34.8 kips/pile		17.4 tons/pile		17.4 tons/pile
3	Row 3	54.4	-2.0	52.4 kips/pile		26.2 tons/pile		26.2 tons/pile
4	Row 4	54.4	15.6	70.1 kips/pile		35.0 tons/pile		35.0 tons/pile
5	Row 5	54.4	33.3	87.8 kips/pile		43.9 tons/pile		43.9 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:	**43.9 tons/pile**	**max:**	**43.9 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	12	0.0	504	1.000	504 kips	
2	Row 2	0	14	0.0	588	1.000	588 kips	
3	Row 3	0	14	0.0	588	1.000	588 kips	
4	Row 4	0	14	0.0	588	1.000	588 kips	
5	Row 5	0	16	0.0	672	1.000	672 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		2940		**2940 kips**	**OK**

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

Vertical Load, P = 3746 kips
Horizontal Load, H = -1972 kips
M_{NA} = -29908 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	53.5		-72.7	-19.2 kips/pile	-9.6 tons/pile	-9.6 tons/pile
2	Row 2	53.5		-38.3	15.2 kips/pile	7.6 tons/pile	7.6 tons/pile
3	Row 3	53.5		-3.9	49.6 kips/pile	24.8 tons/pile	24.8 tons/pile
4	Row 4	53.5		30.5	84.0 kips/pile	42.0 tons/pile	42.0 tons/pile
5	Row 5	53.5		64.9	118.4 kips/pile	59.2 tons/pile	59.2 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:	**59.2 tons/pile**	**max: 59.2 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	12	0.0	576	1.000	576 kips	
2	Row 2	0	14	0.0	672	1.000	672 kips	
3	Row 3	0	14	0.0	672	1.000	672 kips	
4	Row 4	0	14	0.0	672	1.000	672 kips	
5	Row 5	0	16	0.0	768	1.000	768 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		3360		**3360 kips**	**OK**

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

Vertical Load, P = 4328 kips
Horizontal Load, H = 921 kips
M_{NA} = -114 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	61.8		-0.3	61.5 kips/pile	30.8 tons/pile	30.8 tons/pile
2	Row 2	61.8		-0.1	61.7 kips/pile	30.8 tons/pile	30.8 tons/pile
3	Row 3	61.8		0.0	61.8 kips/pile	30.9 tons/pile	30.9 tons/pile
4	Row 4	61.8		0.1	61.9 kips/pile	31.0 tons/pile	31.0 tons/pile
5	Row 5	61.8		0.2	62.1 kips/pile	31.0 tons/pile	31.0 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:	**31.0 tons/pile**	**max: 31.0 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	12	0.0	276	1.000	276 kips
2	Row 2	0	14	0.0	322	1.000	322 kips

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3	Row 3	0	14	0.0	322	1.000	322 kips	
4	Row 4	0	14	0.0	322	1.000	322 kips	
5	Row 5	0	16	0.0	368	1.000	368 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		1610		**1610 kips**	**OK**

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

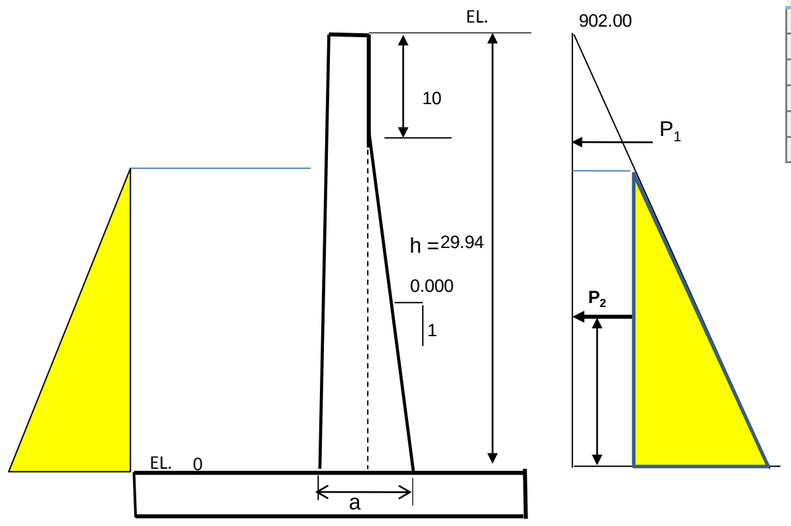
Vertical Load, P = 4328 kips
Horizontal Load, H = 921 kips
M_{NA} = -60 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	61.8		-0.1	61.7 kips/pile	30.8 tons/pile	30.8 tons/pile
2	Row 2	61.8		-0.1	61.7 kips/pile	30.9 tons/pile	30.9 tons/pile
3	Row 3	61.8		0.0	61.8 kips/pile	30.9 tons/pile	30.9 tons/pile
4	Row 4	61.8		0.1	61.9 kips/pile	30.9 tons/pile	30.9 tons/pile
5	Row 5	61.8		0.1	62.0 kips/pile	31.0 tons/pile	31.0 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:	**31.0 tons/pile**	**max:** **31.0 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	12	0.0	276	1.000	276 kips	
2	Row 2	0	14	0.0	322	1.000	322 kips	
3	Row 3	0	14	0.0	322	1.000	322 kips	
4	Row 4	0	14	0.0	322	1.000	322 kips	
5	Row 5	0	16	0.0	368	1.000	368 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			70		1610		**1610 kips**	**OK**

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			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	
				Panel D 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	
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	-6.35	-23.204	-14.04	-51.28
Case 2	100 yr. flood + ice	Unusual	0.75	-6.35	-23.204	-10.53	-38.46
Case 3	500 yr. flood	Unusual	0.75	-8.57	-48.266	-14.20	-80.00
Case 4	T.O. Levee	Extreme	0.75	-19.45	-194.131	32.24	321.77
Case 5	Normal flow + ice	Usual	1	8.52	84.988	18.82	187.82
Case 6	Construction	Unusual	0.75	8.52	84.988	14.11	140.87

STEM DESIGN VALUES

MU, k-ft/ft	321.77	k-ft/ft
VU, k/ft	32.24	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 =	322	k-ft /ft **Includes: hf = 1.3**
Vuh=	32.24	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 = 188.941

REQ'D p= 0.0032 **O.K.**

p= 0.0033

As (REQ'D)= 1.74 in^2

ACI 10.5.1

p(min)= 3*SQRT(Fc')/fy 200* / fy

0.00316 0.00333

ACI 10.5.3

4/3*p

0.0043

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

p(min)= 0.0028 /2 ➔ As =0.5*$p_{T\&S}$bh = 0.8064 in^2

As = #9 @ 12 = 1.00 in^2

SELECT STEEL

bar #=	9	
spacing, s=	6	in
# OF BAR=	1	(ENTER 1 IF PER FT, b=12") a
As=	1.999	in^2
d=	43.4375	in
p = As/bd =	0.0038	**O.K. < 0.375pb**
p =	**0.135**	**pb**
T= As*fy =	119.9	k
C= B1*Fc' *b*a =	1094.0	**a**
a= T/C =	0.110	in
Mn= T(d - a/2)/12 =	433.5	ft-k
ϕ Mn=	390.2	ft-k

EM 110-2-2104

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

> Mu O.K.

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

Vuh =	32.2	k	**NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ =	43.0	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