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 I	**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 I.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)	879.06					
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)	**14.83**	**14.83**	**16.4**	**22.94**	**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)	**18.83**	**18.83**	**20.4**	**26.94**	**NA**	**NA**
Uplift @ TW (ft)	**17.51**	**17.51**	**18.6**	**26.94**	**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**	**20.5**	**20.5**	**24**	**11.5**	**20.5**
Allowable Pile Capacity (tons) - Axial	**61.95**	**82.60**	**82.60**	**107.74**	**36.525**	**82.60**
Allowable Pile Capacity (tons) - Uplift	**38.65**	**51.53**	**51.53**	**67.22**	**5.9**	**51.53**

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

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

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	4,005	0	$0
INSTALL HP14x73 WALL PILING		LF	4,005	0	$0
PILE TEST, 43.4 ft	Long	EA	10	0	$0
FOOTING CONCRETE		CY	683	0	$0
	Forming	SF	1,938		
STEM CONCRETE		CY	528	0	$0
	Forming	SF	9,786		
STEEL REINFORCEMENT		LB	266,835	0	$0
WALL RAILING		LF	207	0	$0
SHEET PILE CUT-OFF WALL		SF	4,140	0	$0
					$0

Structure Length = 207 ft

No. piles = 120 Each
Length = 33.38 ft

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

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

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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 I

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)	879.06
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)	14.83
Wall Thickness (ft)	3
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes

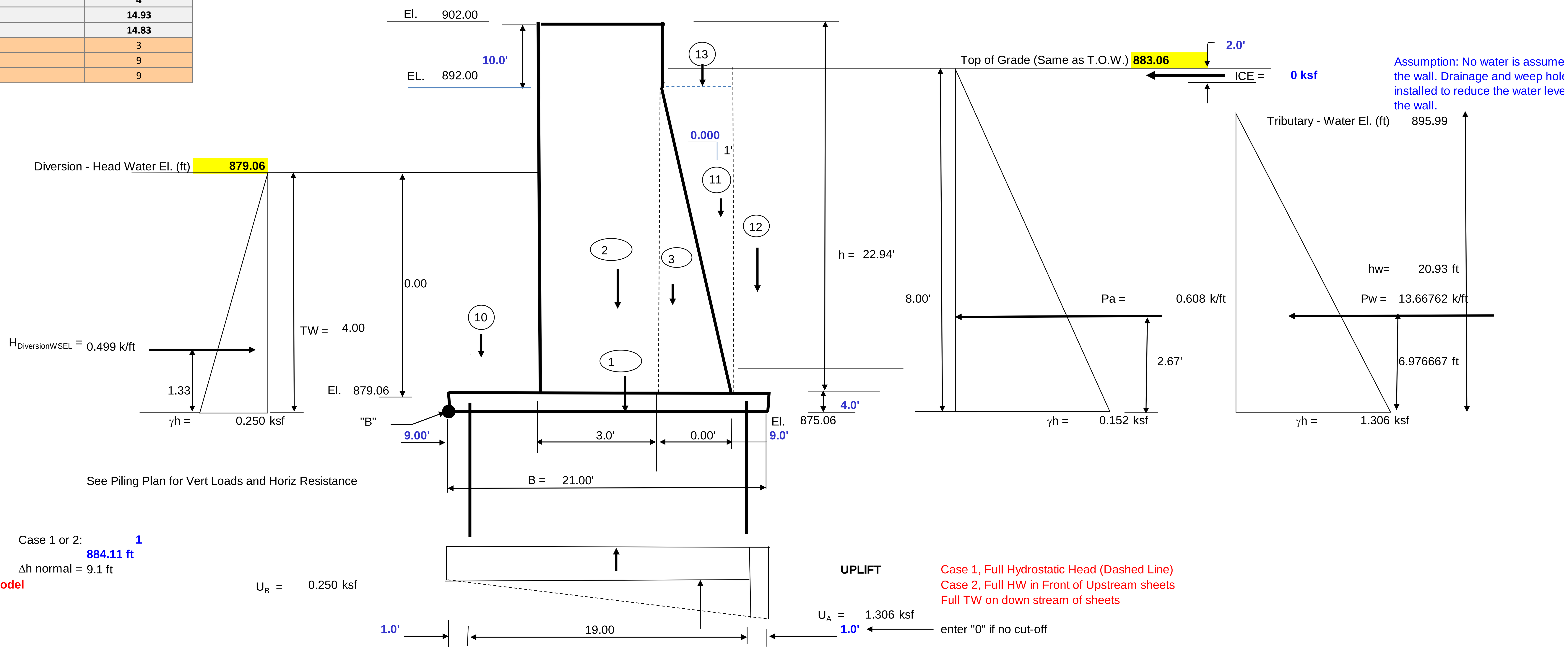
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March

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

Non-Overflow Section

Length = 207.0 ft

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



Case 1 or 2: 1

Normal Water Level, El. 884.11 ft

Δh normal = 9.1 ft

See Geotechnical seepage Model

Vertical Loads	Section	L	W	H	γ	shape	V	arm	Mv
		ft	ft	ft	kcf		K	ft	ft-k
Ftg concrete	1	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
					D.L. Concrete	ΣVc =	**4745.1**	ΣM_V =	**49,823.1**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
H.W. on Footing	12w	207	9.00	16.93	0.0624	rec	1968.1	16.50	32,474.2
					D.L. Water	ΣVw =	**4643.5**	ΣM_V =	**76,617.5**

Uplift Loads		L	W	Pressure	shape	U	arm	Mu
		ft	ft	ksf		K	ft	ft-k
	U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
	U_A	207	21.00	1.056	tri	-2296.2	14.00	-32,146
					ΣU =	**-3381.2**	ΣM_U =	**-43,539**

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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 I

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	7	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	207	-0.608		-125.86	2.67	-335.62

Water Loads						
H_{TW}	207	0.499	tri	103.33	1.33	137.78
H_{HW}	207	-13.668	tri	-2829.20	6.98	-19738.37
			ΣWater =	**-2725.86**	ΣM_W =	**-19936.2**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-63475	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	126441	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**62,966**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,007**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,852**	kips

Location of Resultant
Xr = ΣM / P = 10.48 ft from Toe
e = B/2 - Xr = 0.02 ft
B/6 = 3.500 ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	650	cy (includes stepped)	1938	sf
Stem Conc:	528	cy	9786	sf
Total =	1,178			

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	20.5	418	29,135		
	Longitudinal:	9	6	3.40	208.5	42	29,774		
Bot mat	Transverse:	9	6	3.40	20.5	418	29,135		
	Longitudinal:	9	6	3.40	208.5	42	29,774		
								cy	**LB/cy**
							117,817	650	181.1946685
	b) Skin Reinf. On Monolith								
Vert Face	Vertical	9	6	3.40	22.44	414	31,587	63,173.09	
	Longitudinal:	9	6	3.40	206.5	45	31,595	63,189.00	
Top Face	Transverse:	9	6	3.40	2.5	414	3,519		
	Longitudinal:	9	6	3.40	206.5	6	4,213		
Dowels	Vertical I.F.	9	6	3.40	22.4	414	31,587		
	Vertical O.F.	9	6	3.40	22.4	414	31,587		
								cy	**LB/cy**
							134,086	528	254.1331489
						Σ =	**251,903**		
	Lap Splices (long. Bars)	9		3.40	8	549	14,933		
						Σ Bar Wt=	266,835	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	0.00	0.0624	0	0.000	0.000	0
Tributary SEL =	4.00	0.019	0.076	0.152	1.333	0.202667
Tributary WSEL =	16.93	0.0624	1.056432	8.943	5.643	50.46662
Sum				9.095		50.66929
Net Forces				9.095		50.66929

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

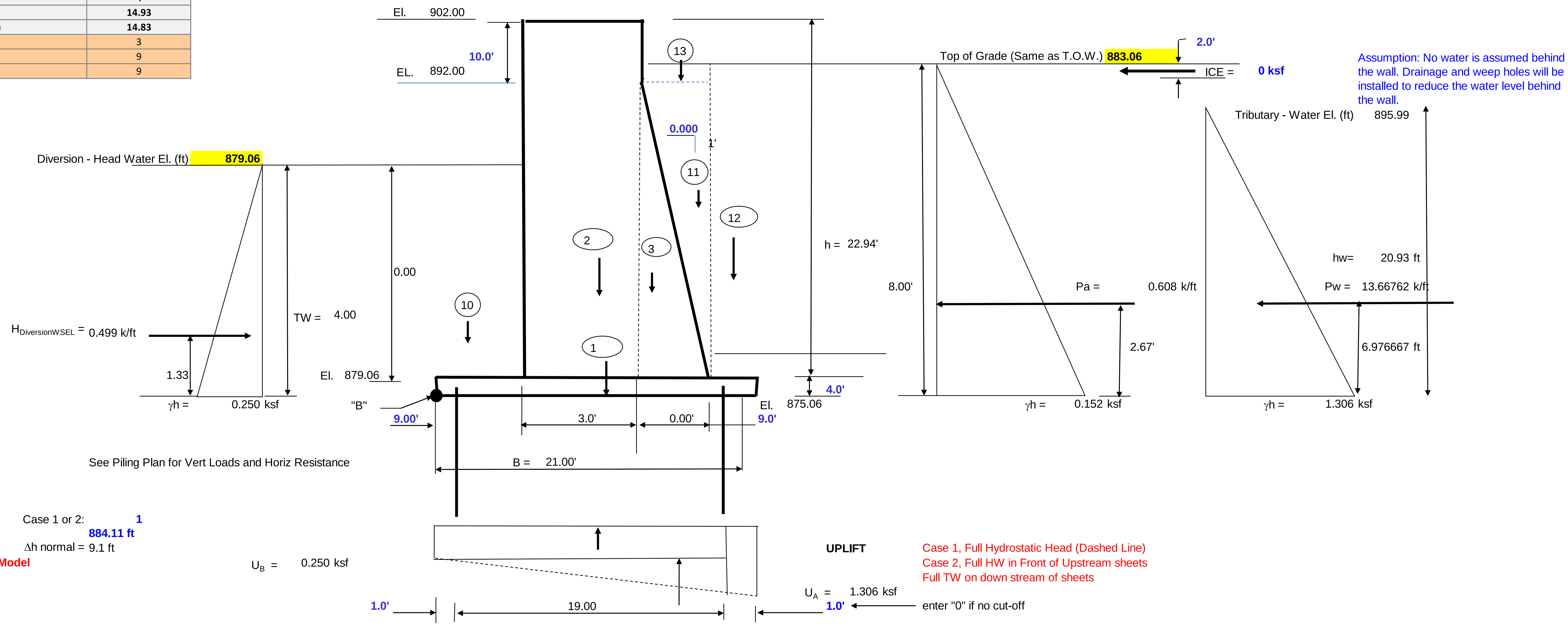
ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	879.06
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)	14.83
Wall Thickness (ft)	3
Toe (Ft)	9
Heel (ft)	9

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 = 207.0 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.



Vertical Loads

	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
					D.L. Concrete	ΣVc =	**4745.1**	ΣM_V =	**49,823.1**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
H.W. on Footing	12w	207	9.00	16.93	0.0624	rec	1968.1	16.50	32,474.2
					D.L. Water	ΣVw =	**4643.5**	ΣM_V =	**76,617.5**

Uplift Loads

	L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
U_A	207	21.00	1.056	tri	-2296.2	14.00	-32,146
				ΣU =	**-3381.2**	ΣM_U =	**-43,539**

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 2 100 yr. flood + ice	Panel I

ICE	207	2.00	0.00	**rec**	0.0	7	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.608		-125.86	2.67	-335.62
Water Loads							
H_{TW}	207		0.499	**tri**	103.33	1.33	137.78
H_{HW}	207		-13.668	**tri**	-2829.20	6.98	-19738.37
				ΣWater =	**-2725.86**	ΣM_W =	**-19936.2**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-63475	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	126441	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**62,966**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,007**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,852**	kips

Location of Resultant	Xr = ΣM / P =	10.48	ft from Toe
	e = B/2 - Xr =	0.02	ft
	B/6 =	3.500	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 =	4.00	**0.019**	0.076	0.152	1.333	0.202667
Tributary WSEL =	16.93	**0.0624**	1.056432	8.943	5.643	50.46662
Sum				9.095		50.66929
Net Forces				9.095		50.66929

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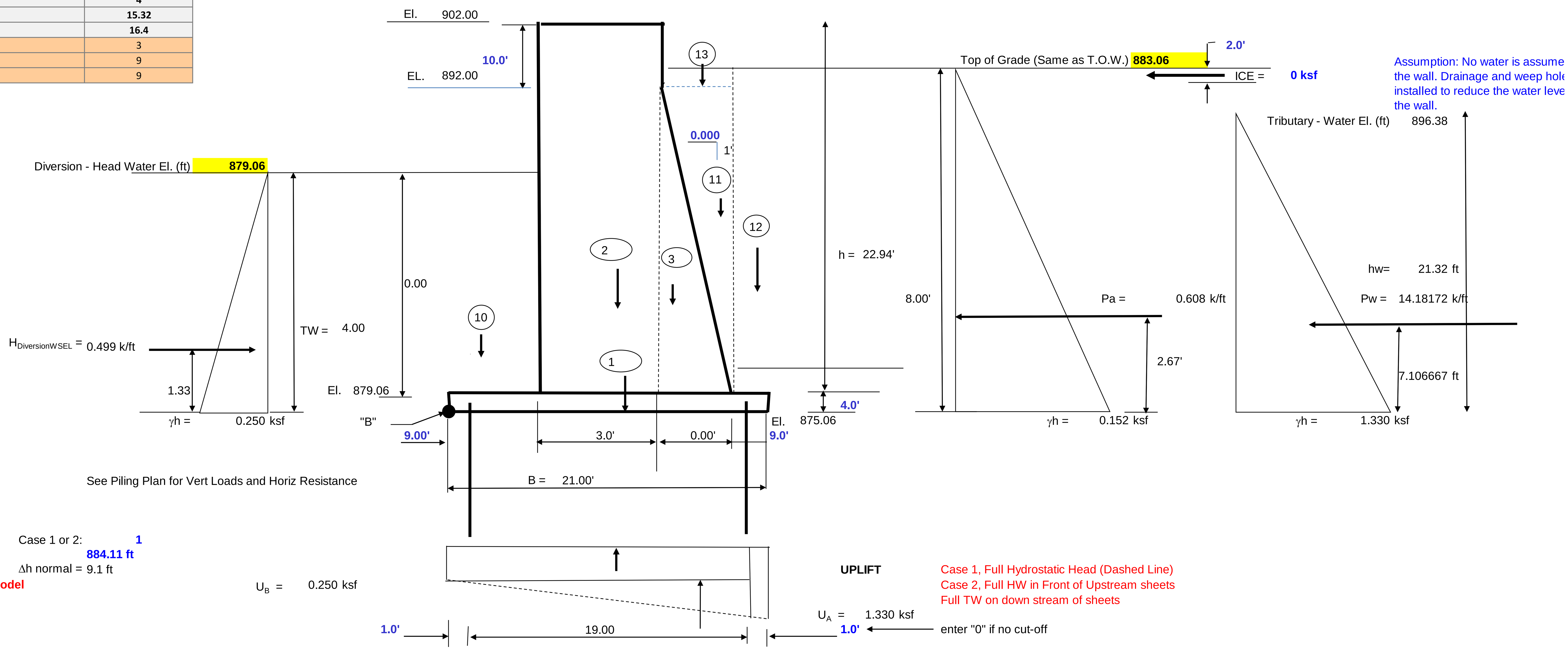
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 3 500 yr. flood	Panel I

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)	879.06
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)	16.4
Wall Thickness (ft)	3
Toe (Ft)	9
Heel (ft)	9

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



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 9.1 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	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
	Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
	Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
						D.L. Concrete	ΣVc =	4745.1	ΣM_V =	49,823.1

← CONSTANT FOR ALL LOAD CASES

		Section	L	W	H	γ	shape	V	arm	Mv
	T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
	H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
	H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
	Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
	H.W. on Footing	12w	207	9.00	17.32	0.0624	rec	2013.5	16.50	33,222.3
						D.L. Water	ΣVw =	4688.8	ΣM_V =	77,365.5

Uplift Loads		L (ft)	W (ft)	Pressure (ksf)		U (K)	arm (ft)	Mu (ft-k)
	U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
	U_A	207	21.00	1.081	tri	-2349.0	14.00	-32,887
					ΣU =	-3434.1	ΣM_U =	-44,279

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

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	7	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.608		-125.86	2.67'	-335.62
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		-14.182	tri	-2935.62	7.11	-20862.45
				ΣWater =	**-2832.28**	ΣM_W =	**-21060.3**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-65340	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	127189	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**61,849**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,000**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-2,958**	kips

Location of Resultant	Xr = ΣM / P =	10.31	ft from Toe
	e = B/2 - Xr =	0.19	ft
	B/6 =	3.500	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 =	4.00	**0.019**	0.076	0.152	1.333	0.202667
Tributary WSEL =	17.32	**0.0624**	1.080768	9.359	5.773	54.03523
Sum				9.511		54.2379
Net Forces				9.511		54.2379

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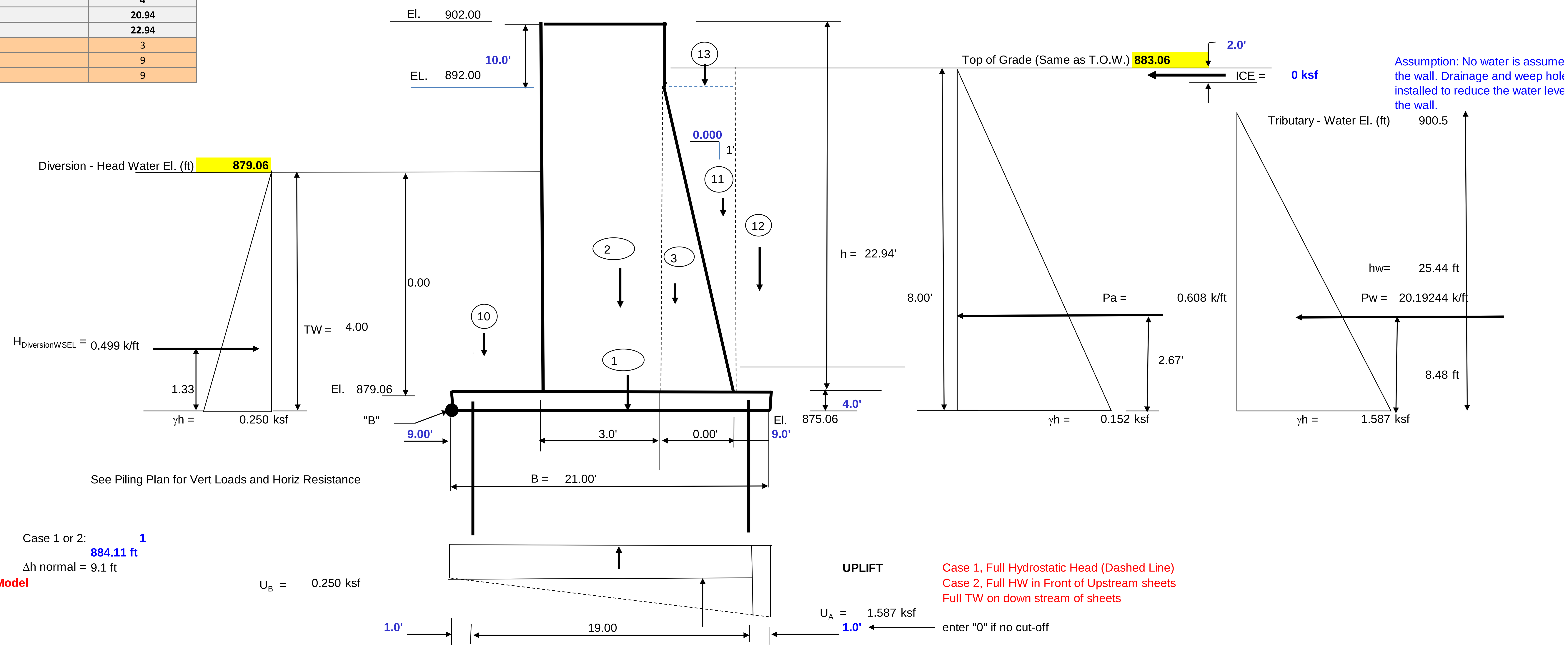
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 4 T.O. Levee	Panel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

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)	879.06
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)	22.94
Wall Thickness (ft)	3
Toe (Ft)	9
Heel (ft)	9

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



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 9.1 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	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
					D.L. Concrete	ΣVc =	**4745.1**	ΣM_V =	**49,823.1**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
H.W. on Footing	12w	207	9.00	21.44	0.0624	rec	2492.4	16.50	41,125.0
					D.L. Water	ΣVw =	**5167.8**	ΣM_V =	**85,268.3**

Uplift Loads		L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
	U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
	U_A	207	21.00	1.338	tri	-2907.8	14.00	-40,710
					ΣU =	**-3992.8**	ΣM_U =	**-52,102**

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 I

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	7	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.608		-125.86	2.67'	-335.62
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		-20.192	tri	-4179.84	8.48	-35445.00
				ΣWater =	**-4076.50**	ΣM_W =	**-35642.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-87745	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	135091	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**47,346**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**5,920**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-4,202**	kips

Location of Resultant	Xr = ΣM / P =	8.00	ft from Toe
	e = B/2 - Xr =	2.50	ft
	B/6 =	3.500	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 =	4.00	0.019	0.076	0.152	1.333	0.202667
Tributary WSEL =	21.44	0.0624	1.337856	14.342	7.147	102.4962
Sum				14.494		102.6988
Net Forces				14.494		102.6988

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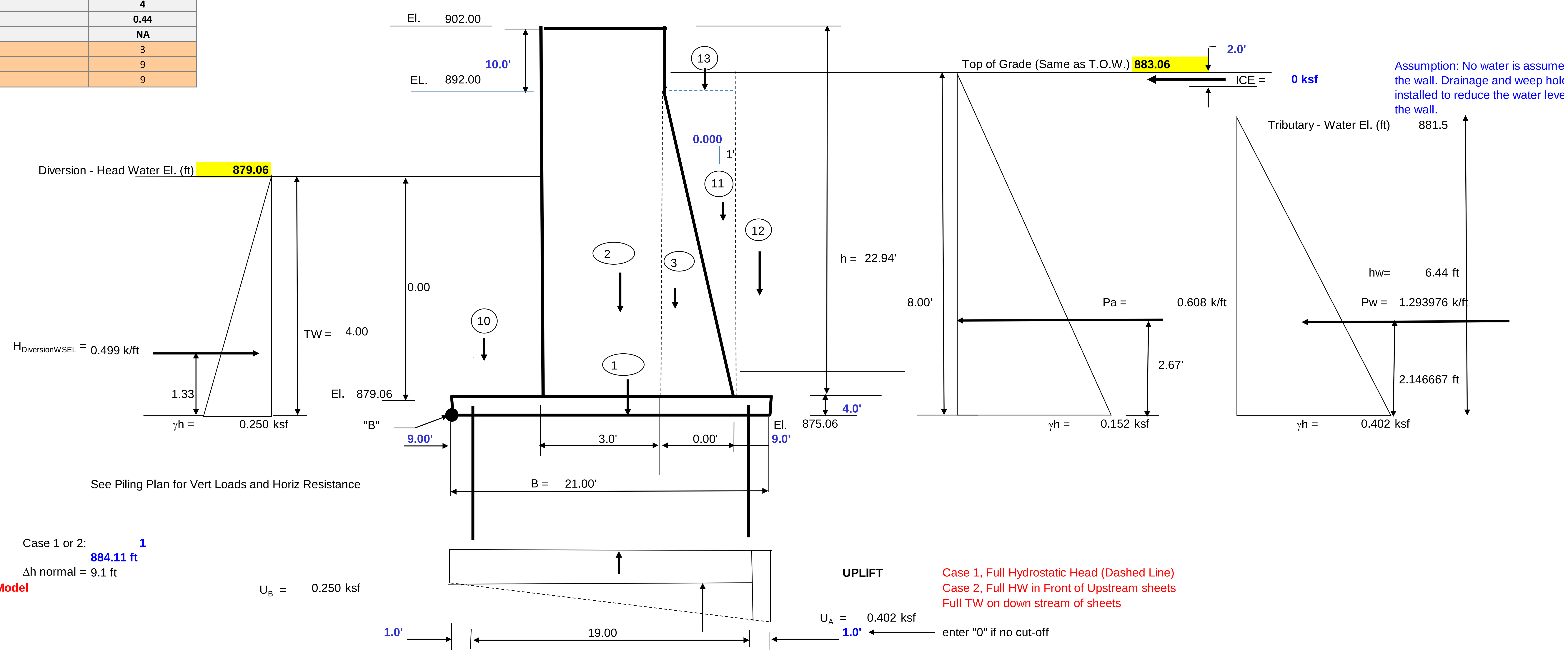
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 5 Normal flow + ice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

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)	879.06
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)	3
Toe (Ft)	9
Heel (ft)	9

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



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 9.1 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	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
					D.L. Concrete	ΣVc =	4745.1	ΣM_V =	49,823.1

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
H.W. on Footing	12w	207	9.00	2.44	0.0624	rec	283.7	16.50	4,680.3
					D.L. Water	ΣVw =	2959.0	ΣM_V =	48,823.5

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
	U_A	207	21.00	0.152	tri	-330.9	14.00	-4,633
					ΣU =	-1415.9	ΣM_U =	-16,026

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 I

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	7	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.608		-125.86	2.67'	-335.62
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		-1.294	tri	-267.85	0.00	0.00
				ΣWater =	**-164.52**	ΣM_W =	**-197.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-16223	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	98647	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**82,423**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,288**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-290**	kips

Location of Resultant	Xr = ΣM / P =	13.11 ft from Toe
	e = B/2 - Xr =	(2.61) ft
	B/6 =	3.500 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 =		4.00	**0.019**	0.076	0.152	1.333	0.202667
Tributary WSEL =		2.44	**0.0624**	0.152256	0.186	0.813	0.151079
	Sum				0.338		0.353745
	Net Forces				0.338		0.353745

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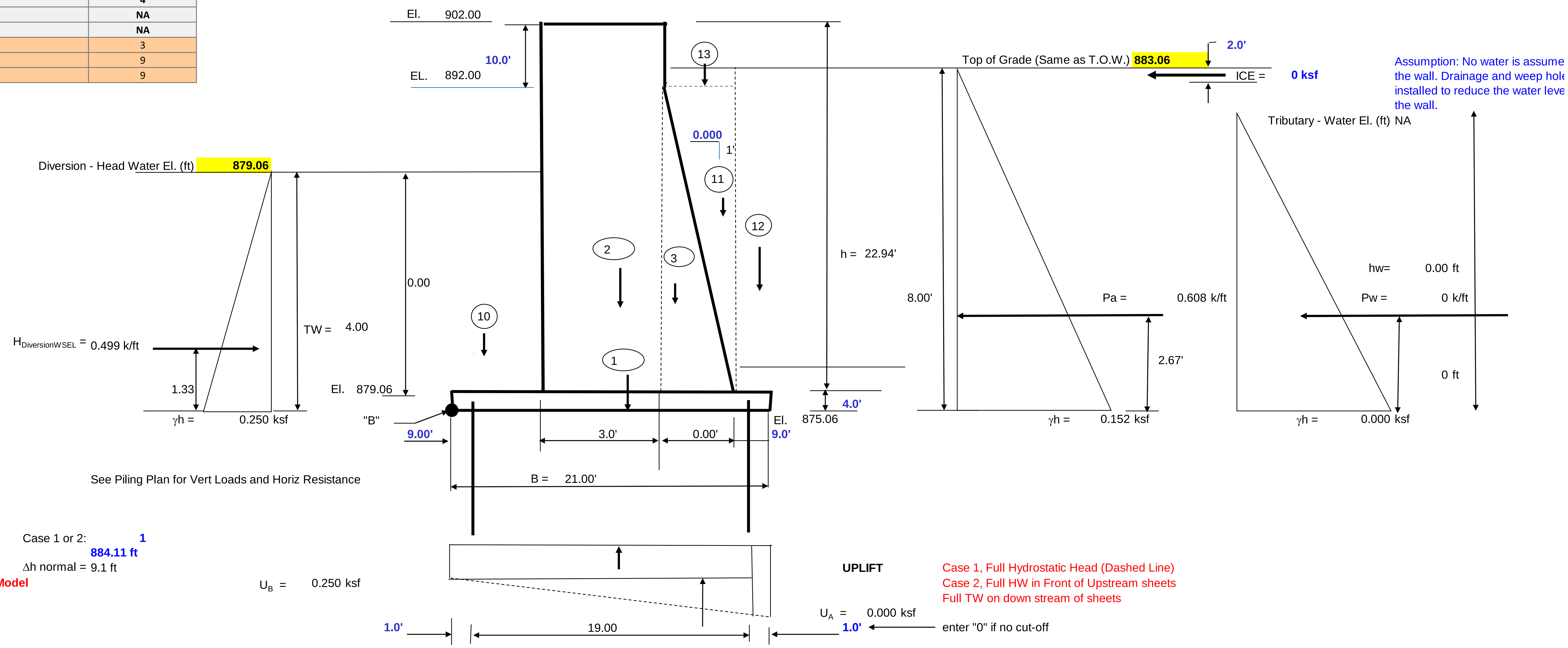
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 6 Construction	Panel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

ID#	Case 6
Name	Construction
Load Category	Unusual
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	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)	879.06
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)	3
Toe (Ft)	9
Heel (ft)	9

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



Normal Water Level, El.

See Geotechnical seepage Model

Vertical Loads		Section	L	W	H	γ	shape	V	arm	Mv
			ft	ft	ft	kcf		K	ft	ft-k
	Ftg concrete	1	207	21.00	4.00	0.15	rec	2608.2	10.50	27,386.1
	Stem	2	207	3.00	22.94	0.15	rec	2136.9	10.50	22,437.0
	Batter	3	207	0.00	12.94	0.15	tri	0.0	12.00	0.0
						D.L. Concrete	ΣVc =	4745.1	ΣM_V =	49,823.1

← CONSTANT FOR ALL LOAD CASES

		Section	L	W	H	γ	shape	V	arm	Mv
	T.W on ftg Stem	10	207	9.00	0.00	0.0624	rec	0.0	4.50	0.0
	H.W. on Stem Slope	11	207	0.00	4.00	0.12	tri	0.0	12.00	0.0
	H.W. Above Slope	13	207	0.00	-8.94	0.12	rec	0.0	12.00	0.0
	Soil on Footing	12s	207	9.00	22.94	0.0626	rec	2675.3	16.50	44,143.3
	H.W. on Footing	12w	207	9.00	-4.00	0.0624	rec	-465.0	16.50	-7,672.6
						D.L. Water	ΣVw =	2210.3	ΣM_V =	36,470.7

Uplift Loads		L	W	Pressure		U	arm	Mu
		ft	ft	ksf		K	ft	ft-k
	U_B	207	21.00	0.250	rec	-1085.0	10.50	-11,393
	U_A	207	21.00	-0.250	tri	542.5	14.00	7,595
					ΣU =	-542.5	ΣM_U =	-3,798

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 I

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	207	2.00	0.00	rec	0.0	7	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	207		-0.608		-125.86	2.67'	-335.62
Water Loads							
H_{TW}	207		0.499	tri	103.33	1.33	137.78
H_{HW}	207		0.000	tri	0.00	0.00	0.00
				ΣWater =	**103.33**	ΣM_W =	**-197.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-3995	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	86294	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**82,298**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**6,413**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-23**	kips
Location of Resultant	Xr = ΣM / P =	12.83	ft from Toe
	e = B/2 - Xr =	(2.33)	ft
	B/6 =	3.500	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 =	4.00	**0.019**	0.076	0.152	1.333	0.202667
Tributary WSEL =	-4.00	**0.0624**	-0.2496	0.499	-1.333	-0.6656
Sum				0.651		-0.46293
Net Forces				0.651		-0.46293

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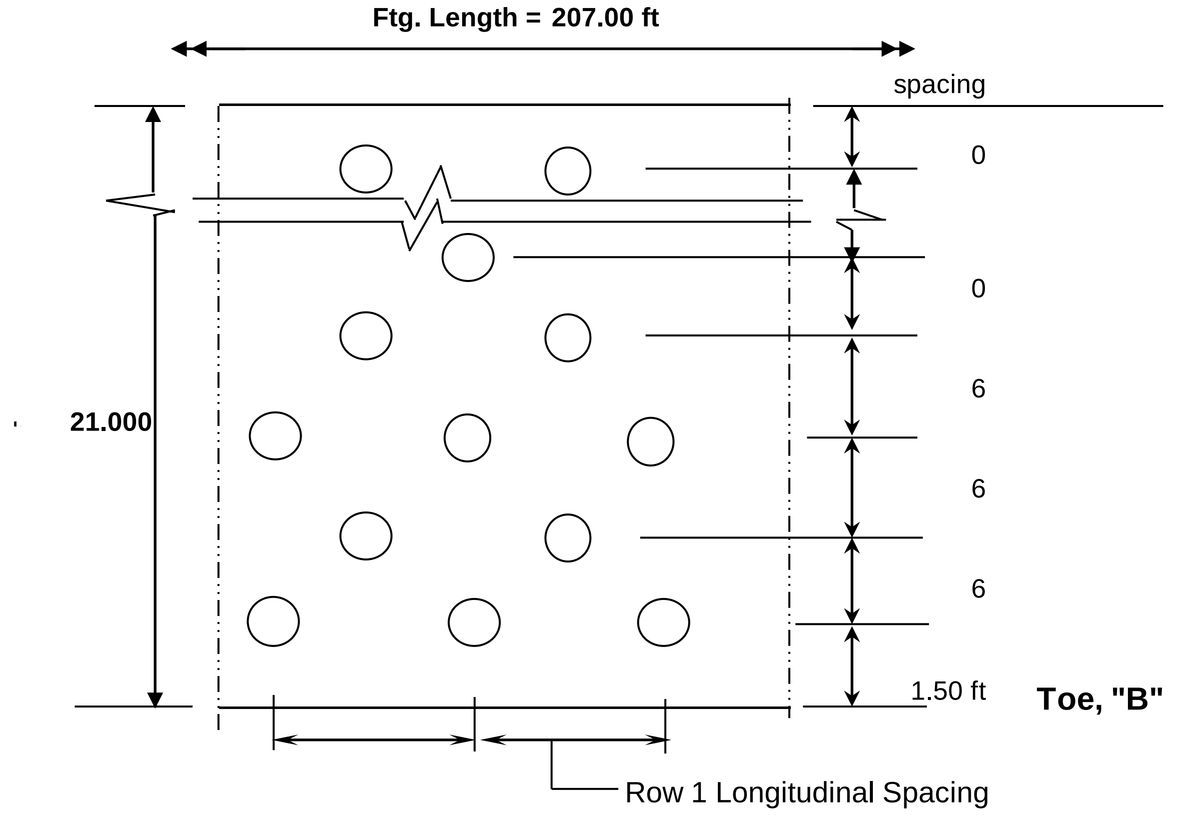
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.	
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4		
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
2/11/11				Panel I		

PILE FOUNDATION DESIGN

FLOW

L = 207.00 ft



PILE PATTERN GEOMETRY

Transverse Spacing		Distance to Toe, d_{toe}	Longitudinal Spacing	Batter		Piles per Row (N)	Edge Dist (ft)		Trial N
Row 1 to Toe	1.50 ft	1.5 ft	2.50 ft	0	"/12"	26	72.25	1	83
Row 1 to Row 2	6.00 ft	7.5 ft	5.00 ft	0	"/12"	30	31.00	2	42
Row 2 to Row 3	6.00 ft	13.5 ft	0.00 ft	0	"/12"	30	103.50	3	#DIV/0!
Row 3 to Row 4	6.00 ft	19.5 ft	0.00 ft	0	"/12"	34	103.50	4	#DIV/0!
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	103.50	0	0
Last Row to Heel	1.50 ft								
	21.00 ft		Note: Enter 0 for Longitudinal Spacing for Rows Not Used)		ΣN =	120			#DIV/0!

Pile Properties:	Pile Type: HP	(C.I.P or HP)	Pile Length = 33.4 ft	Ftg EL. 875.06
	HP Nominal Depth, h = 14.0 in			Pile Tip El. 842.68
	Wt. per ft, plf 73		**Total pile Length =** 4,006 LF	Pile Cap Embed = 1.00 ft

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **11.10 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	9.60 ft	26	2396.2
2	Dist. To Row 2	3.60 ft	30	388.8
3	Dist. Row 3	-2.40 ft	30	172.8
4	Dist. Row 4	-8.40 ft	34	2399.0
0	Row 5 (not used)	0.00 ft	0	0.0
0	Row 6 (not used)	0.00 ft	0	0.0
0	Row 7 (not used)	0.00 ft	0	0.0
0	Row 8 (not used)	0.00 ft	0	0.0
0	Row 9 (not used)	0.00 ft	0	0.0
0	Row 10 (not used)	0.00 ft	0	0.0
0	Row 11 (not used)	0.00 ft	0	0.0
0	Row 12 (not used)	0.00 ft	0	0.0
0	Row 13 (not used)	0.00 ft	0	0.0
0	Row 14 (not used)	0.00 ft	0	0.0
0	Row 15 (not used)	0.00 ft	0	0.0
			120	Σ I = **5356.8**

ALLOWABLE LOADS (from Geotechnical)

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

w/o Group effects

Summary Pile Reactions

Load Combinations	Allowable Pile Capacity (tons) - Axial	Pile Loads (tons/pile) 1	2	3	4	5	6	7	8	9	10	11	12	Max. Vertical Load (Tons)	Horiz Pile Group Capacity (k)	Check
Case 1	**62.0 tons**	28.4	26.3	24.2	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.4	4,320	**OK**
Case 2	**82.6 tons**	28.4	26.3	24.2	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.4	4,920	**OK**
Case 3	**82.6 tons**	29.3	26.6	23.9	21.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3	4,920	**OK**
Case 4	**107.7 tons**	41.1	30.8	20.6	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.1	5,760	**OK**
Case 5	**36.5 tons**	14.9	22.0	29.0	36.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.1	2,760	**OK**
Case 6	**82.6 tons**	16.8	23.0	29.2	35.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.4	2,760	**OK**

Max Service : P = **41.1**

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

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

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

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

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

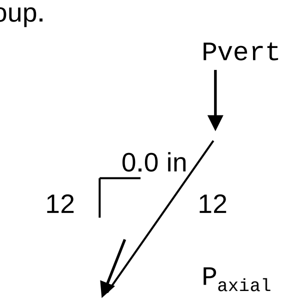
$$e_{NA} = X_{NA} - e_{toe}$$

The moment about the neutral axis of the pile group becomes

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

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

Paxial = 1.000 Pvert



FORCE RESULTANT (see Stability Analysis)

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

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

Case 1	**100 yr. flood**	**Usual**	6,007	2,852	62,966	10.48	0.62	3716
Case 2	**100 yr. flood + ice**	**Unusual**	6,007	2,852	62,966	10.48	0.62	3716
Case 3	**500 yr. flood**	**Unusual**	6,000	2,958	61,849	10.31	0.79	4749
Case 4	**T.O. Levee**	**Extreme**	5,920	4,202	47,346	8.00	3.10	18366
Case 5	**Normal flow + ice**	**Usual**	6,288	290	82,423	13.11	-2.01	-12625
Case 6	**Construction**	**Unusual**	6,413	23	82,298	12.83	-1.73	-11115

SERVICE

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

Vertical Load, P = 6007 kips
Horizontal Load, H = 2852 kips
M_{NA} = 3716 kip-ft   120

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			Axial Pile Load
1	Row 1	50.1	6.7	56.7 kips/pile		28.4 tons/pile	28.4 tons/pile
2	Row 2	50.1	2.5	52.6 kips/pile		26.3 tons/pile	26.3 tons/pile
3	Row 3	50.1	-1.7	48.4 kips/pile		24.2 tons/pile	24.2 tons/pile
4	Row 4	50.1	-5.8	44.2 kips/pile		22.1 tons/pile	22.1 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
					max:	**28.4 tons/pile**	**max: 28.4 tons/pile**

Assumed lateral Capacity: 36.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	26	0.0	936	1.000	936 kips	
2	Row 2	0	30	0.0	1080	1.000	1080 kips	
3	Row 3	0	30	0.0	1080	1.000	1080 kips	
4	Row 4	0	34	0.0	1224	1.000	1224 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			120		4320		**4320 kips**	**OK**

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

Vertical Load, P = 6007 kips
Horizontal Load, H = 2852 kips
M_{NA} = 3716 kip-ft   120

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			Axial Pile Load
1	Row 1	50.1	6.7	56.7 kips/pile		28.4 tons/pile	28.4 tons/pile
2	Row 2	50.1	2.5	52.6 kips/pile		26.3 tons/pile	26.3 tons/pile
3	Row 3	50.1	-1.7	48.4 kips/pile		24.2 tons/pile	24.2 tons/pile
4	Row 4	50.1	-5.8	44.2 kips/pile		22.1 tons/pile	22.1 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
					max:	**28.4 tons/pile**	**max: 28.4 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance
1	Row 1	0	26	0.0	1066	1.000	1066 kips
2	Row 2	0	30	0.0	1230	1.000	1230 kips
3	Row 3	0	30	0.0	1230	1.000	1230 kips

4	Row 4	0	34	0.0	1394	1.000	1394 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			120		4920		**4920 kips**	**OK**

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

Vertical Load, P = 6000 kips
Horizontal Load, H = 2958 kips
M_{NA} = 4749 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	50.0	8.5	58.5 kips/pile		29.3 tons/pile	29.3 tons/pile
2	Row 2	50.0	3.2	53.2 kips/pile		26.6 tons/pile	26.6 tons/pile
3	Row 3	50.0	-2.1	47.9 kips/pile		23.9 tons/pile	23.9 tons/pile
4	Row 4	50.0	-7.4	42.6 kips/pile		21.3 tons/pile	21.3 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
					max:	**29.3 tons/pile**	**max: 29.3 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	26	0.0	1066	1.000	1066 kips	
2	Row 2	0	30	0.0	1230	1.000	1230 kips	
3	Row 3	0	30	0.0	1230	1.000	1230 kips	
4	Row 4	0	34	0.0	1394	1.000	1394 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			120		4920		**4920 kips**	**OK**

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

Vertical Load, P = 5920 kips
Horizontal Load, H = 4202 kips
M_{NA} = 18366 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	49.3	32.9	82.2 kips/pile		41.1 tons/pile	41.1 tons/pile
2	Row 2	49.3	12.3	61.7 kips/pile		30.8 tons/pile	30.8 tons/pile
3	Row 3	49.3	-8.2	41.1 kips/pile		20.6 tons/pile	20.6 tons/pile
4	Row 4	49.3	-28.8	20.5 kips/pile		10.3 tons/pile	10.3 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
					max:	**41.1 tons/pile**	**max: 41.1 tons/pile**

Assumed lateral Capacity: 48.0 kips/pile

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	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	26	0.0	1248	1.000	1248 kips	
2	Row 2	0	30	0.0	1440	1.000	1440 kips	
3	Row 3	0	30	0.0	1440	1.000	1440 kips	
4	Row 4	0	34	0.0	1632	1.000	1632 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			120		5760		**5760 kips**	**OK**

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

Vertical Load, P = 6288 kips
Horizontal Load, H = 290 kips
M_{NA} = -12625 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	52.4	-22.6	29.8 kips/pile	14.9 tons/pile	14.9 tons/pile
2	Row 2	52.4	-8.5	43.9 kips/pile	22.0 tons/pile	22.0 tons/pile
3	Row 3	52.4	5.7	58.1 kips/pile	29.0 tons/pile	29.0 tons/pile
4	Row 4	52.4	19.8	72.2 kips/pile	36.1 tons/pile	36.1 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
				max:	**36.1 tons/pile**	**max: 36.1 tons/pile**

Assumed lateral Capacity: 23.0 kips/pile

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	26	0.0	598	1.000	598 kips	
2	Row 2	0	30	0.0	690	1.000	690 kips	
3	Row 3	0	30	0.0	690	1.000	690 kips	
4	Row 4	0	34	0.0	782	1.000	782 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			120		2760		**2760 kips**	**OK**

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

Vertical Load, P = 6413 kips
Horizontal Load, H = 23 kips
M_{NA} = -11115 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	53.4	-19.9	33.5 kips/pile	16.8 tons/pile	16.8 tons/pile
2	Row 2	53.4	-7.5	46.0 kips/pile	23.0 tons/pile	23.0 tons/pile
3	Row 3	53.4	5.0	58.4 kips/pile	29.2 tons/pile	29.2 tons/pile
4	Row 4	53.4	17.4	70.9 kips/pile	35.4 tons/pile	35.4 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile

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11 Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12 Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13 Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14 Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15 Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
				max:	**35.4 tons/pile**	**max:** **35.4 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1 Row 1	0	26	0.0	598	1.000	598 kips	
2 Row 2	0	30	0.0	690	1.000	690 kips	
3 Row 3	0	30	0.0	690	1.000	690 kips	
4 Row 4	0	34	0.0	782	1.000	782 kips	
5 Row 5	0	0	0.0	0	1.000	0 kips	
6 Row 6	0	0	0.0	0	1.000	0 kips	
7 Row 7	0	0	0.0	0	1.000	0 kips	
8 Row 8	0	0	0.0	0	1.000	0 kips	
9 Row 9	0	0	0.0	0	1.000	0 kips	
10 Row 10	0	0	0.0	0	1.000	0 kips	
11 Row 11	0	0	0.0	0	1.000	0 kips	
12 Row 12	0	0	0.0	0	1.000	0 kips	
13 Row 13	0	0	0.0	0	1.000	0 kips	
14 Row 14	0	0	0.0	0	1.000	0 kips	
15 Row 15	0	0	0.0	0	1.000	0 kips	
		120		2760		**2760 kips**	**OK**

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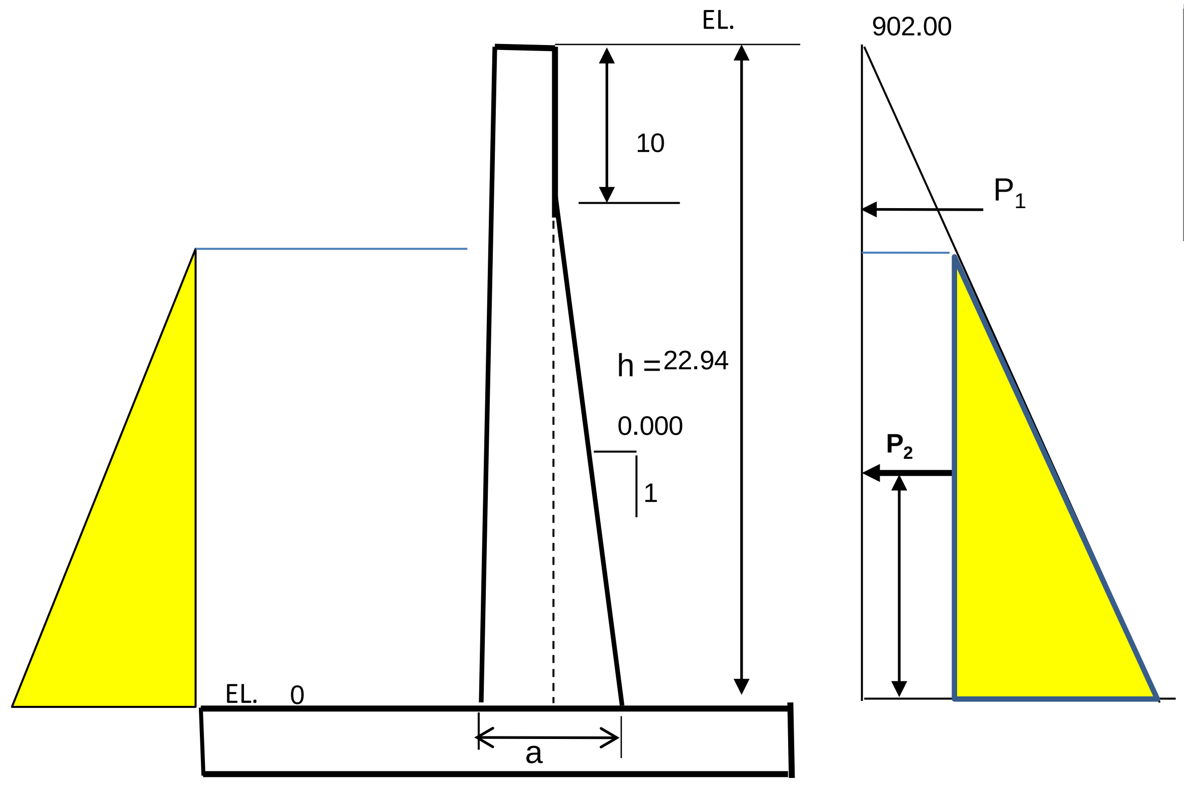
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Panel I 0	



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 =	3.0 ft	36.0 in	
Batter at Base =	0.00 ft	0.0 in	
a =	3.00 ft	36.0 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	9.09	50.669	20.10	111.98
Case 2	100 yr. flood + ice	Unusual	0.75	9.09	50.669	15.07	83.98
Case 3	500 yr. flood	Unusual	0.75	9.51	54.238	15.77	89.90
Case 4	T.O. Levee	Extreme	0.75	14.49	102.699	24.02	170.22
Case 5	Normal flow + ice	Usual	1	0.34	0.354	0.75	0.78
Case 6	Construction	Unusual	0.75	0.65	-0.463	1.08	-0.77

STEM DESIGN VALUES

MU, k-ft/ft	170.22	k-ft/ft
VU, k/ft	24.02	k/ft

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 I 0	

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

9.3 - Design Strength

ϕ = **0.9** 9.3.2.1 - Tension Controlled sections
0.75 9.3.2.3 - Shear and torsion

FLEXURAL STEEL FOR RECTANGULAR CONCRETE SECTIONS

fy= **60** ksi
Fc'= **4** ksi
B1= 0.85

Muh = 170 k-ft /ft **Includes: hf = 1.3**
Vuh= 24.02 k / ft

bw= 12 in.
h= 36 in
cover= **4** in (include correct stirrup bar dia.)
d= **31.50** 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

$Ru=Mn/bd^2$ = 190.614 **ACI 10.5.1** **ACI 10.5.3**
REQ'D p= 0.0033 **O.K.** p(min)= 3*SQRT(Fc')/fy 200* / fy 4/3*p
p= 0.0033 0.00316 0.00333 0.0044

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

As (REQ'D)= 1.26 in^2 p(min)= 0.0028 /2 → As =0.5*$p_{T\&S}$bh = 0.6048 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= 31.4375 in
p = As/bd = 0.0053 **O.K. < 0.375pb** **EM 110-2-2104**
p = 0.186 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 = 578.8 **a**
a= T/C = 0.207 in
Mn= T(d - a/2)/12 = 313.1 ft-k
ϕ Mn= 281.8 ft-k **> Mu O.K.**

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

Vuh = 24.0 k **NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ = 32.0 k
Vc = 2*sqrt(Fc') bw * d = 47.7 k **11.3.1.1**
Vs =Vuh / f - 1.3Vc = No Shear Reinf. Req. k NG Vs(max) ≤ 8*sqrt(fc')bd = 190.9 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 = 15.719 in OR 24 in
s(max)= 7.859 in
4*sqrt(Fc')*bw*d= 95.4 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 = 0.53 * s
but not less than 50bw*s/ fy = 17.5 * 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