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 F	**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 F.xlsx]Case 1		
REF.	**1**		
	2		

ID#	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Tributary - Water El. (ft)	895.99	895.99	896.38	903.5	881.5	**NA**
Diversion - Head Water El. (ft)	893.89	893.89	895.46	903.5	**NA**	**NA**
Diversion - Tail Water El. (ft)	892.57	892.57	893.66	903.5	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	903.5					
Tributary - T.O. Deck L.P. El.(ft)	881.06					
Tributary - T.O. Deck H.P. El.(ft)	883.06					
Diversion - T.O. Mat El. (ft)	878.06					
Tributary - Deck Slab thickness @ L.P. (ft)	2					
Tributary - Deck Slab thickness @ H.P. (ft)	4					
Diversion - Mat Slab thickness (ft)	4					
Tibutary - Water height (ft)	**14.93**	**14.93**	**15.32**	**22.44**	**0.44**	**NA**
Diversion - Head Water height (ft)	**15.83**	**15.83**	**17.4**	**25.44**	**NA**	**NA**
Ice	**NA**	2ft Ice	**NA**	**NA**	2ft Ice	**NA**
Ice Load	**NA**	10 kips/ft	**NA**	**NA**	10 kips/ft	**NA**
Ice Laod El. (ft)	**NA**	**895.99**	**NA**	**NA**	**881.5**	**NA**
Uplift @ HW (ft)	**19.83**	**19.83**	**21.4**	**29.44**	**NA**	**NA**
Uplift @ TW (ft)	**18.51**	**18.51**	**19.6**	**29.44**	**NA**	**NA**
Pile Condition	**Undrained**	**Undrained**	**Undrained**	**Undrained**	**Drained**	**Undrained**
Load Category	**Usual**	**Unusual**	**Unusual**	**Extreme**	**Usual**	**Unusual**
Safety Factors	2	1.5	1.5	1.15	2	1.5
Allwable Lateral Capacity (tons)	**18**	**21**	**21**	**24**	**11.5**	**21**
Allowable Pile Capacity (tons) - Axial	**57.18**	**76.23**	**76.23**	**99.43**	**31.425**	**76.23**
Allowable Pile Capacity (tons) - Uplift	**33.88**	**45.17**	**45.17**	**58.91**	**4.625**	**45.17**

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

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

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	1,424	0	$0
INSTALL HP14x73 WALL PILING		LF	1,424	0	$0
PILE TEST, 42.4 ft	Long	EA	2	0	$0
FOOTING CONCRETE		CY	236	0	$0
	Forming	SF	757		
STEM CONCRETE		CY	253	0	$0
	Forming	SF	3,648		
STEEL REINFORCEMENT		LB	97,083	0	$0
WALL RAILING		LF	67	0	$0
SHEET PILE CUT-OFF WALL		SF	670	0	$0
					$0

Structure Length =	67	ft
No. piles =	44	Each
Length =	32.38	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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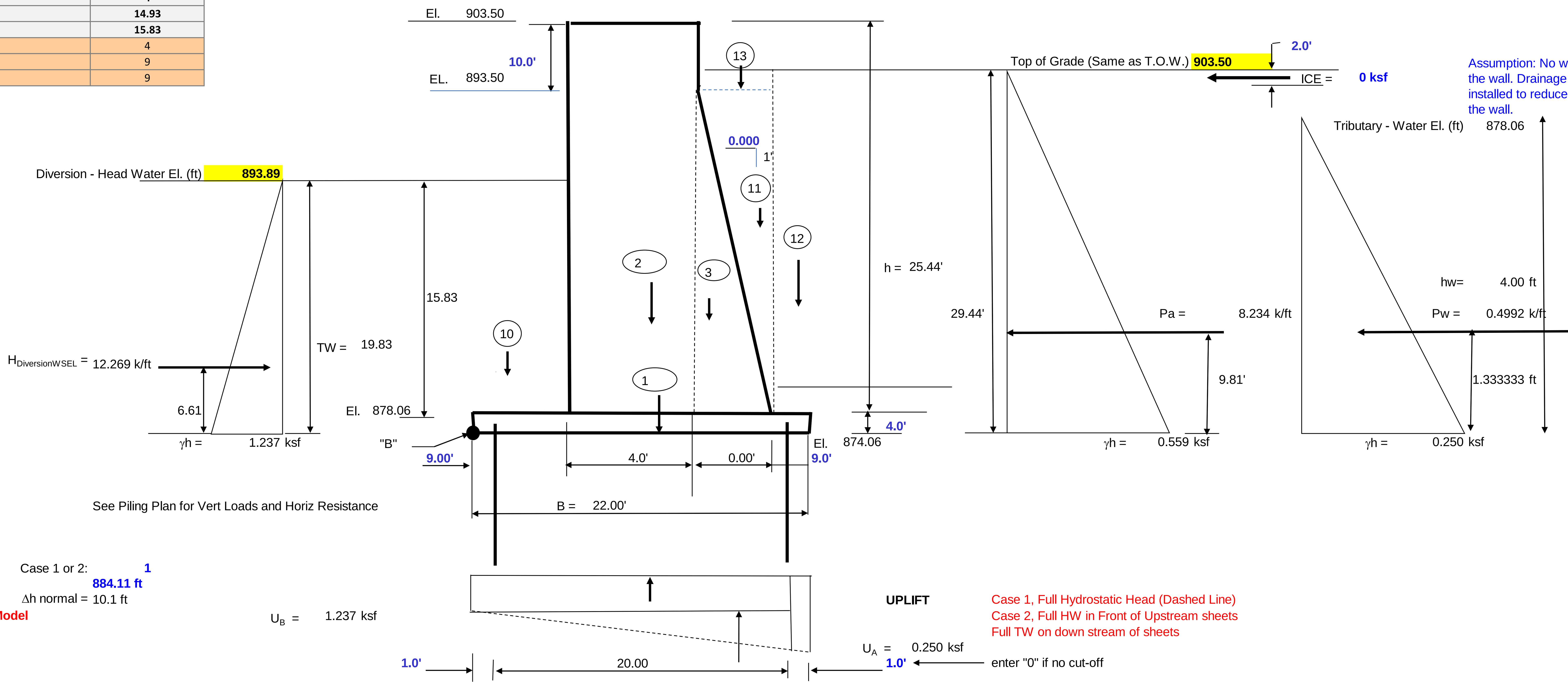
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood	Panel F

ID#	Case 1
Name	100 yr. flood
Load Category	Usual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
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)	15.83
Wall Thickness (ft)	4
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 = 67.0 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.

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 10.1 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

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	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
				D.L. Concrete		ΣVc =	**1907.1**	ΣM_V =	**20,978.0**

CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	15.83	0.0624	rec	595.6	4.50	2,680.4
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
				D.L. Water		ΣVw =	**1555.9**	ΣM_V =	**19,485.7**

Uplift Loads		L ft	W	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	67	22.00	1.237	rec	-1823.9	11.00	-20,063
	U_A	67	22.00	-0.988	tri	728.0	14.67	10,677
					ΣU =	**-1095.9**	ΣM_U =	**-9,386**

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

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	67	2.00	0.00	rec	0.0	28.44	0.0

	L	Force	H	arm	Mw
	ft	k/ft	K	ft	ft-k
SOIL	67	-8.234	-551.66	9.81	-5413.65

Water Loads

	L	Force			arm	
H_{TW}	67	12.269	tri	822.01	6.61	5433.46
H_{HW}	67	-0.499	tri	-33.45	1.33	-44.60
			ΣWater =	**788.56**	ΣM_W =	**-24.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-9410	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	40464	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**31,053**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,367**	kips
Sum of Horizontal Forces	H = Σhorizontal	**237**	kips

Location of Resultant

Xr = ΣM / P = 13.12 ft from Toe
e = B/2 - Xr = (2.12) ft
B/6 = 3.667 ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	253	cy	3648	sf
Total =	477			

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	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
	b) Skin Reinf. On Monolith								
Vert Face	Vertical	9	6	3.40	24.94	134	11,363	22,725.33	
	Longitudinal:	9	6	3.40	66.5	50	11,305	22,610.00	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	24.9	134	11,363		
	Vertical O.F.	9	6	3.40	24.9	134	11,363		
								cy	**LB/cy**
							48,796	253	193.2411328
						Σ =	**89,467**		
	Lap Splices (long. Bars)		9	3.40	8	280	7,616		
						Σ Bar Wt=	97,083	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face		H	γ	Pbase	V	arm	Mv
		ft	kcf		K	ft	ft-k
Diversion WSEL		15.83	0.0624	0.987792	7.818	5.277	41.25495
Tributary SEL =		25.44	0.019	0.48336	6.148	8.480	52.13792
Tributary WSEL =		0.00	0.0624	0	0.000	0.000	0
	Sum				6.148		52.13792
	Net Forces				-1.670		10.88296

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2/11/11				Load Cases: Case 2 100 yr. flood + ice	Panel F

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
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)	15.83
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

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MN State Building Codes

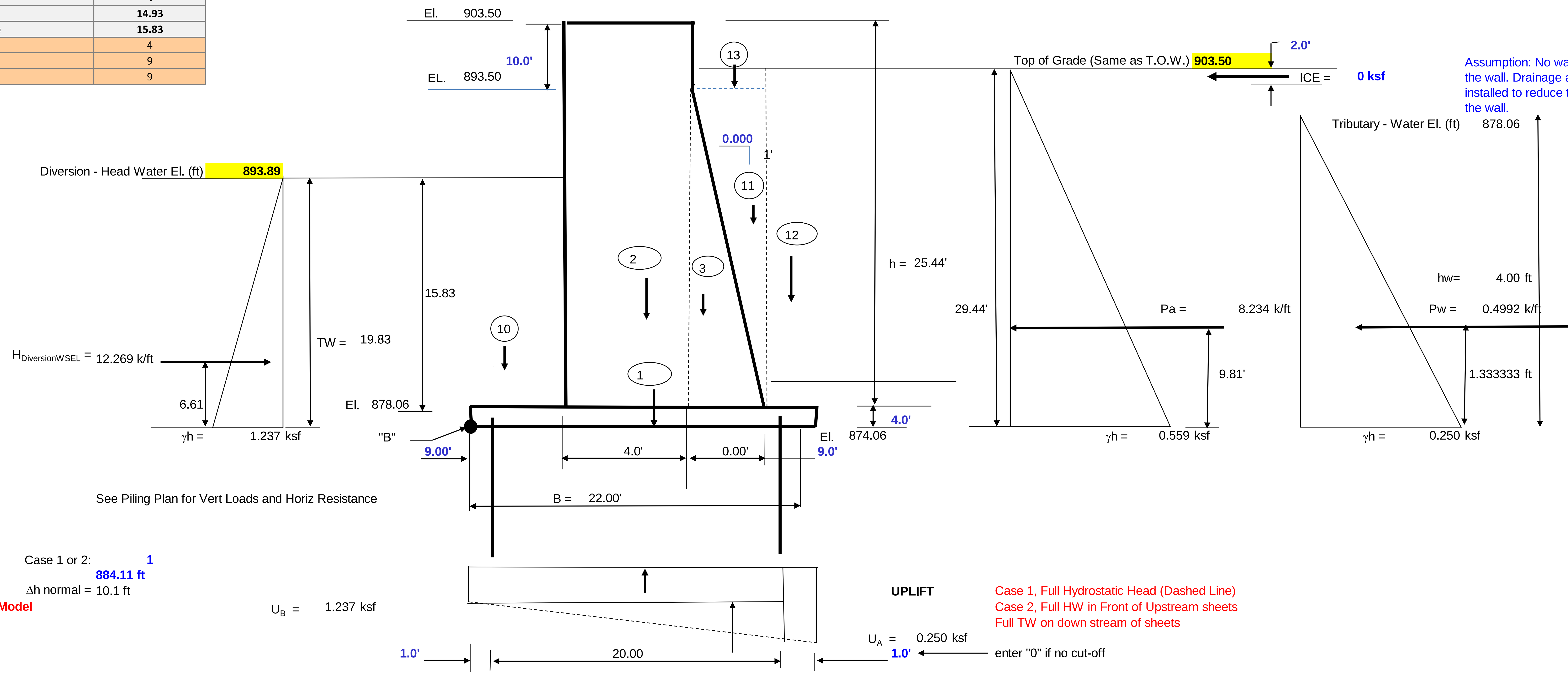
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March

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

Non-Overflow Section — **Length = 67.0 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.



Normal Water Level, El. 884.11 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

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	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1907.1**	ΣM_V =	**20,978.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	15.83	0.0624	rec	595.6	4.50	2,680.4
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1555.9**	ΣM_V =	**19,485.7**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	67	22.00	1.237	rec	-1823.9	11.00	-20,063
	U_A	67	22.00	-0.988	tri	728.0	14.67	10,677
					ΣU =	**-1095.9**	ΣM_U =	**-9,386**

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

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

	L		Force		H	arm	Mw
ICE	67	2.00	0.00	rec	0.0	28.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	67		-8.234		-551.66	9.81	-5413.65
Water Loads							
H_{TW}	67		12.269	tri	822.01	6.61	5433.46
H_{HW}	67		-0.499	tri	-33.45	1.33	-44.60
				ΣWater =	**788.56**	ΣM_W =	**-24.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-9410	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	40464	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**31,053**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,367**	kips
Sum of Horizontal Forces	H = Σhorizontal	**237**	kips

Location of Resultant

Xr = ΣM / P = 13.12 ft from Toe
e = B/2 - Xr = (2.12) ft
B/6 = 3.667 ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	15.83	**0.0624**	0.987792	7.818	5.277	41.25495
Tributary SEL =	25.44	**0.019**	0.48336	6.148	8.480	52.13792
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				6.148		52.13792
Net Forces				-1.670		10.88296

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

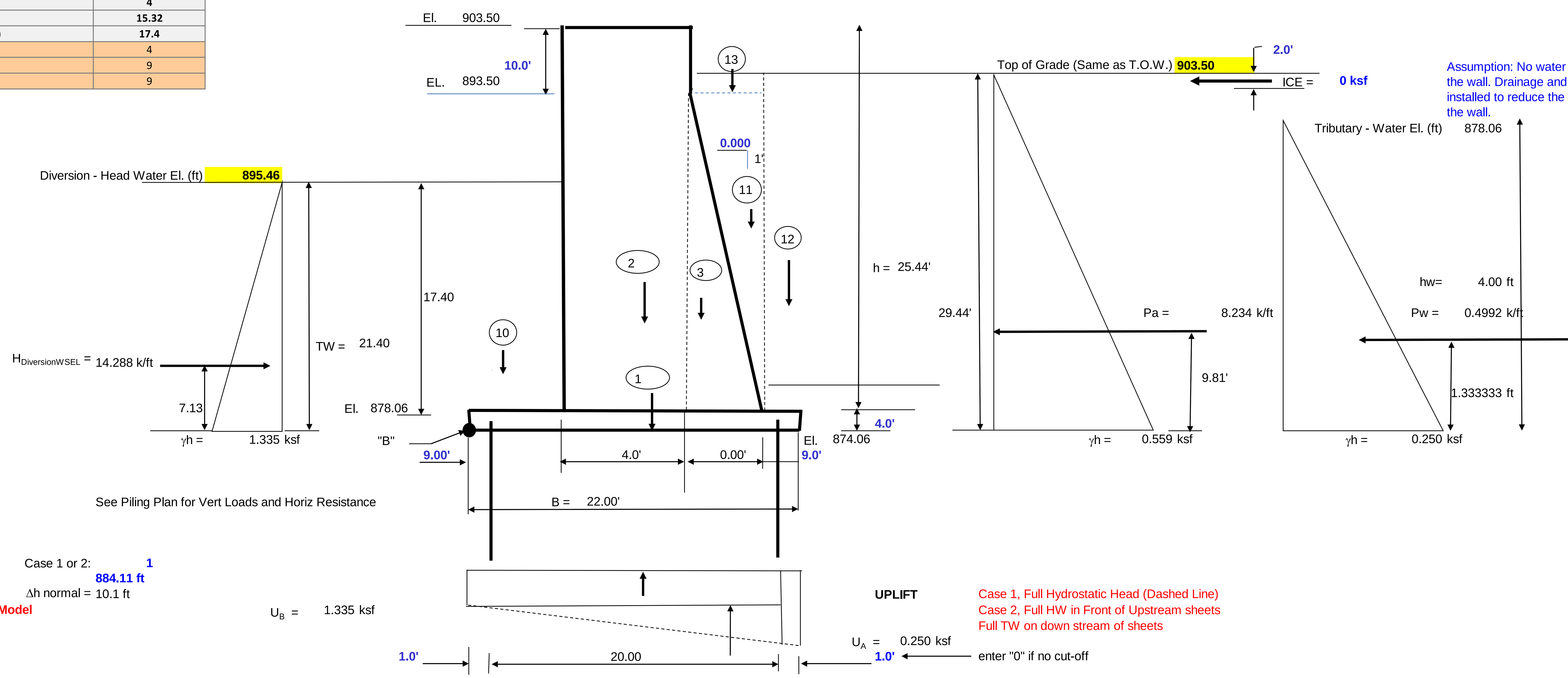
ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	896.38
Diversion - Head Water El. (ft)	895.46
Diversion - Tail Water El. (ft)	893.66
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
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)	17.4
Wall Thickness (ft)	4
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 = 67.0 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.



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 10.1 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	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1907.1**	ΣM_V =	**20,978.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	17.40	0.0624	rec	654.7	4.50	2,946.2
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1615.0**	ΣM_V =	**19,751.5**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	1.335	rec	-1968.3	11.00	-21,652
	U_A	67	22.00	-1.086	tri	800.2	14.67	11,736
					ΣU =	**-1168.1**	ΣM_U =	**-9,915**

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

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

	L		Force		H	arm	Mw
ICE	67	2.00	0.00	rec	0.0	28.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	67		-8.234		-551.66	9.81'	-5413.65
Water Loads							
H_{TW}	67		14.288	tri	957.32	7.13	6828.88
H_{HW}	67		-0.499	tri	-33.45	1.33	-44.60
				ΣWater =	**923.87**	ΣM_W =	**1370.6**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-8545	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	40729	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**32,185**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,354**	kips
Sum of Horizontal Forces	H = Σhorizontal	**372**	kips

Location of Resultant	Xr = ΣM / P =	13.67	ft from Toe
	e = B/2 - Xr =	(2.67)	ft
	B/6 =	3.667	ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face		H	γ	Pbase	V	arm	Mv
		ft	kcf		K	ft	ft-k
Diversion WSEL		17.40	0.0624	1.08576	9.446	5.800	54.78745
Tributary SEL =		25.44	0.019	0.48336	6.148	8.480	52.13792
Tributary WSEL =		0.00	0.0624	0	0.000	0.000	0
	Sum				6.148		52.13792
	Net Forces				-3.298		-2.64953

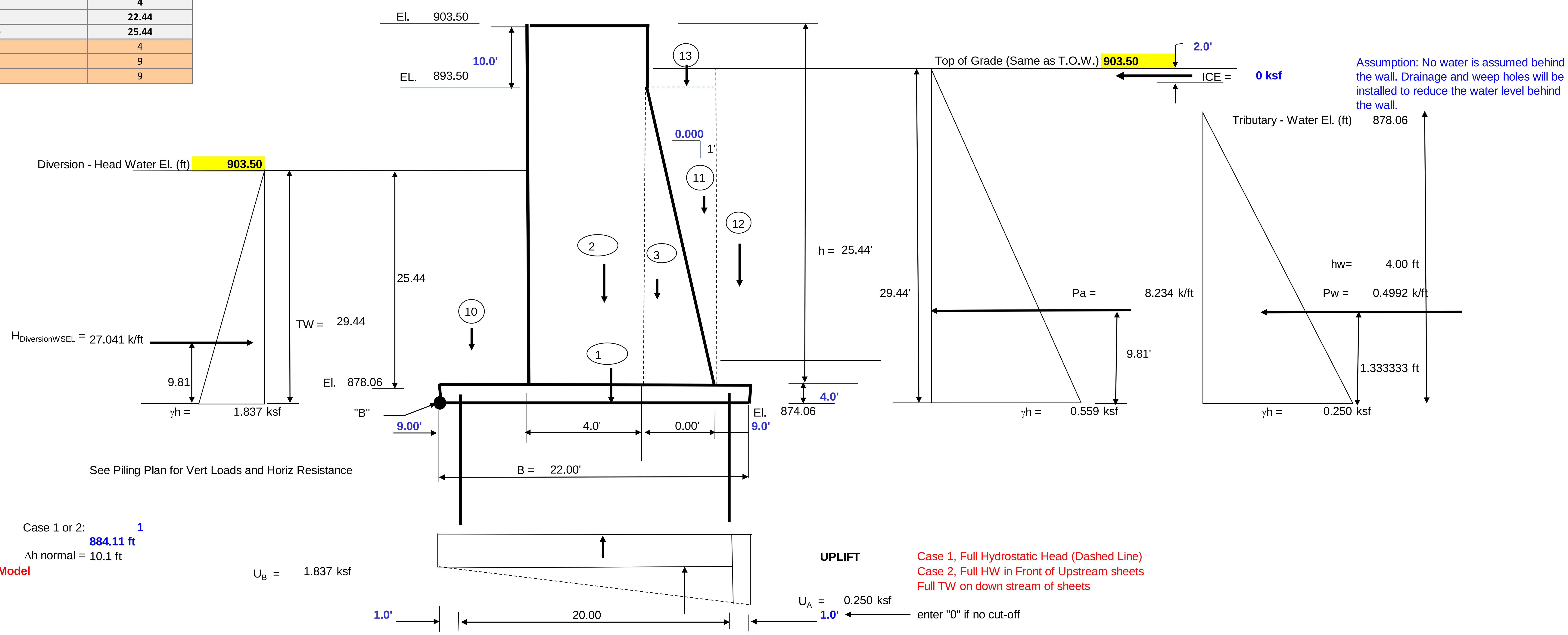
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 4 T.O. Levee	Panel F

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	903.5
Diversion - Tail Water El. (ft)	903.5
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	22.44
Diversion - Head Water height (ft)	25.44
Wall Thickness (ft)	4
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 = 67.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 10.1 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	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1907.1**	ΣM_V =	**20,978.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	25.44	0.0624	rec	957.2	4.50	4,307.6
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1917.5**	ΣM_V =	**21,112.9**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	67	22.00	1.837	rec	-2707.8	11.00	-29,786
	U_A	67	22.00	-1.587	tri	1170.0	14.67	17,159
					ΣU =	**-1537.9**	ΣM_U =	**-12,627**

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

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

	L					H	arm	Mw
ICE	67	2.00	0.00		rec	0.0	28.44	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	67		-8.234			-551.66	9.81'	-5413.65
Water Loads								
H_{TW}	67		27.041		tri	1811.78	9.81	17779.58
H_{HW}	67		-0.499		tri	-33.45	1.33	-44.60
					ΣWater =	**1778.33**	ΣM_W =	**12321.3**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-305	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	42091	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**41,785**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,287**	kips
Sum of Horizontal Forces	H = Σhorizontal	**1,227**	kips

Location of Resultant	Xr = ΣM / P =	18.27 ft from Toe
	e = B/2 - Xr =	(7.27) ft
	B/6 =	3.667 ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	25.44	**0.0624**	1.587456	20.192	8.480	171.2319
Tributary SEL =	25.44	**0.019**	0.48336	6.148	8.480	52.13792
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				6.148		52.13792
Net Forces				-14.044		-119.094

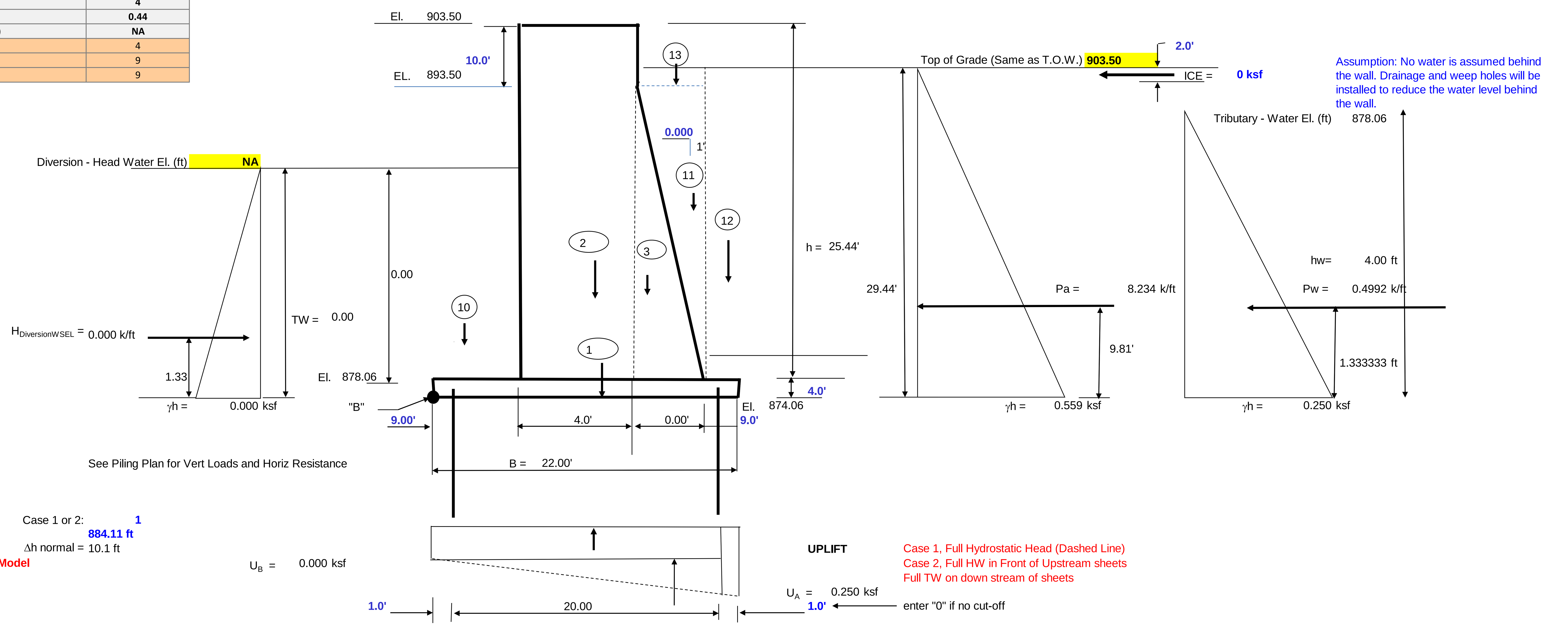
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
COMPUTED	CHECKED	SUBMITTED	PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
MBI		MBI	PROJECT NUMBER	34091004	
2/11/11			SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 5 Normal flow + ice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

ID#	Case 5
Name	Normal flow + ice
Load Category	Usual
Tributary - Water El. (ft)	881.5
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
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)	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 = 67.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
				D.L. Concrete		ΣVc =	1907.1	ΣMV =	20,978.0

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
				D.L. Water		ΣVw =	960.3	ΣMV =	16,805.3

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	0.000	rec	0.0	11.00	0
	U_A	67	22.00	0.250	tri	-184.0	14.67	-2,698
					ΣU =	-184.0	ΣMU =	-2,698

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 F

	L		Force		H	arm	Mw
ICE	67	2.00	0.00	rec	0.0	28.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	67		-8.234		-551.66	9.81'	-5413.65
Water Loads							
H_{TW}	67		0.000	tri	0.00	1.33	0.00
H_{HW}	67		-0.499	tri	-33.45	0.00	0.00
				ΣWater =	**-33.45**	ΣM_W =	**-5413.7**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-8112	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	37783	kip-ft
Sum of Moments	ΣMnet = $M_R + M_{OT}$ =	**29,672**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,683**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-585**	kips

Location of Resultant	Xr = ΣM / P =	11.06	ft from Toe
	e = B/2 - Xr =	(0.06)	ft
	B/6 =	3.667	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 =	25.44	**0.019**	0.48336	6.148	8.480	52.13792
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				6.148		52.13792
Net Forces				6.148		52.13792

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 F	

ID#	Case 6
Name	Construction
Load Category	Unusual
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	878.06
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)	9
Heel (ft)	9

File:

MN State Building Codes

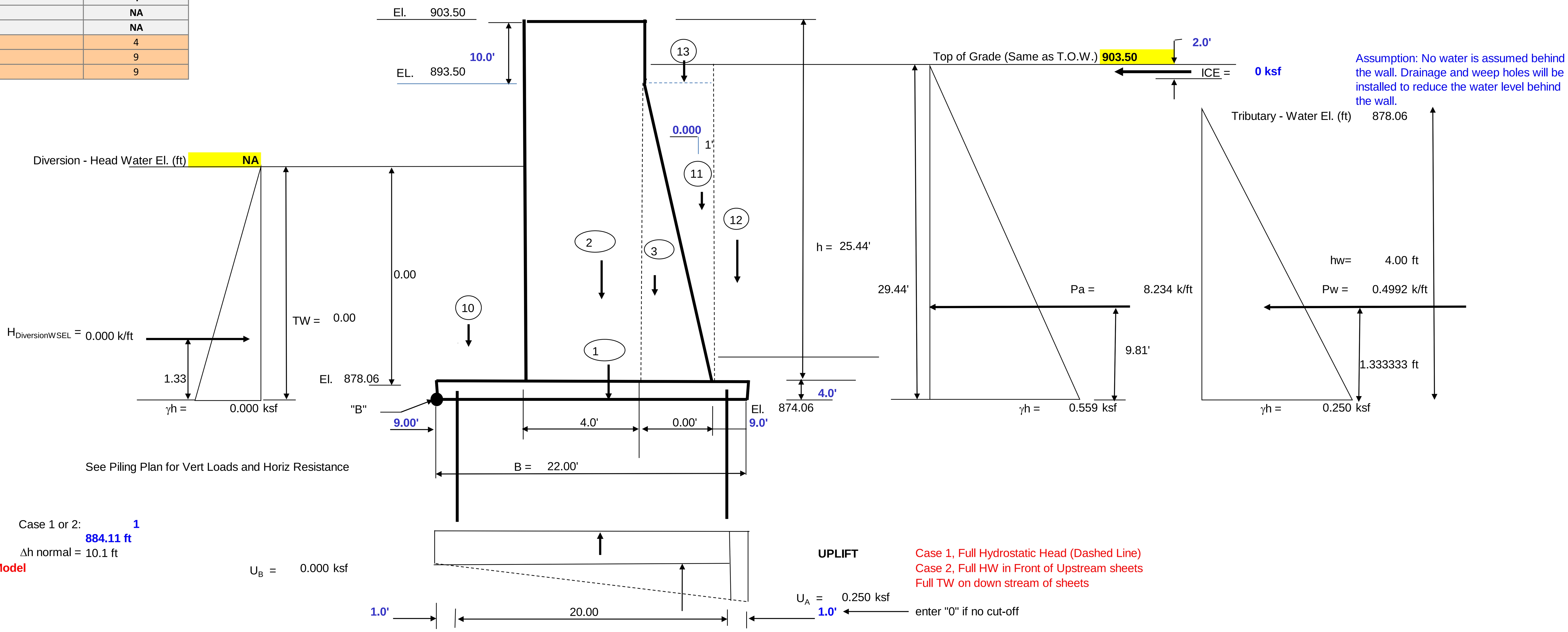
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March

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

Non-Overflow Section — **Length =** 67.0 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.



Case 1 or 2: 1

Normal Water Level, El. 884.11 ft

Δh normal = 10.1 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	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	25.44	0.15	rec	1022.7	11.00	11,249.6
Batter	3	67	0.00	15.44	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1907.1**	ΣM_V =	**20,978.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	67	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	67	0.00	15.44	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	25.44	0.0626	rec	960.3	17.50	16,805.3
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**960.3**	ΣM_V =	**16,805.3**

Uplift Loads

	L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
U_B	67	22.00	0.000	rec	0.0	11.00	0
U_A	67	22.00	0.250	tri	-184.0	14.67	-2,698
				ΣU =	**-184.0**	ΣM_U =	**-2,698**

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 F

	L		Force		H	arm	Mw
ICE	67	2.00	0.00	**rec**	0.0	28.44	0.0
	ft		k/ft		K	ft	ft-k
SOIL	67		-8.234		-551.66	9.81'	-5413.65
Water Loads							
H_{TW}	67		0.000	**tri**	0.00	1.33	0.00
H_{HW}	67		-0.499	**tri**	-33.45	1.33	-44.60
				ΣWater =	**-33.45**	ΣM_W =	**-5458.3**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-8156	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	37783	kip-ft
Sum of Moments	ΣMnet = $M_R + M_{OT}$ =	**29,627**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,683**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-585**	kips

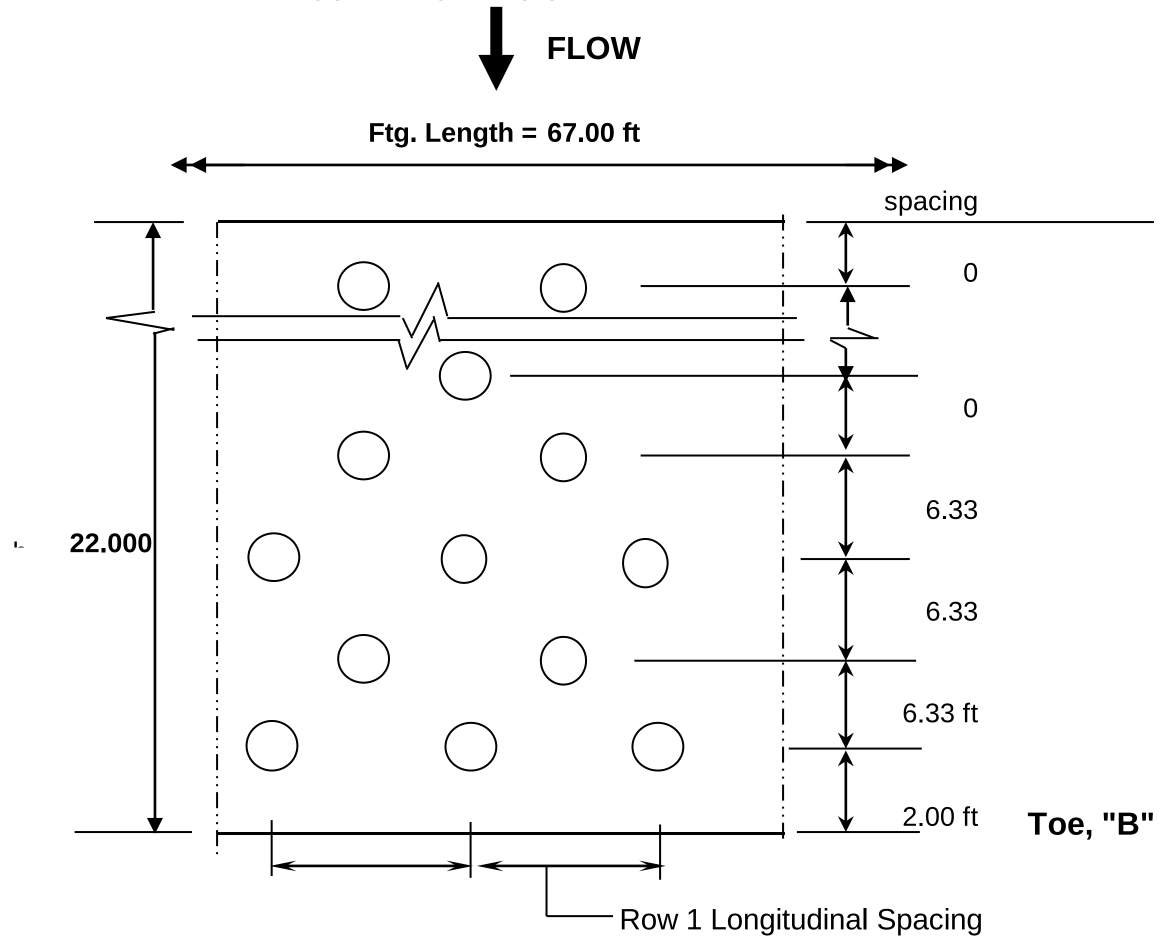
Location of Resultant	Xr = ΣM / P =	11.04	ft from Toe
	e = B/2 - Xr =	(0.04)	ft
	B/6 =	3.667	ft

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 =	25.44	**0.019**	0.48336	6.148	8.480	52.13792
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				6.148		52.13792
Net Forces				6.148		52.13792

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 F	

PILE FOUNDATION DESIGN



L = 67.00 ft

PILE PATTERN GEOMETRY

Transverse Spacing		Distance to Toe, d_{toe}	Longitudinal Spacing	Batter		Piles per Row (N)	Edge Dist (ft)		Trial N
Row 1 to Toe	2.00 ft	2.0 ft	2.50 ft	0	"/12"	12	19.75	1	27
Row 1 to Row 2	6.33 ft	8.3 ft	5.00 ft	0	"/12"	11	8.50	2	14
Row 2 to Row 3	6.33 ft	14.7 ft	5.00 ft	0	"/12"	11	8.50	3	14
Row 3 to Row 4	6.33 ft	21.0 ft	5.00 ft	0	"/12"	10	11.00	4	14
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	33.50	0	0
Last Row to Heel	1.01 ft								
	22.00 ft		Note: Enter 0 for Longitudinal Spacing for Rows Not Used)			ΣN = 44			69

Pile Properties:				
Pile Type: HP	(C.I.P or HP)	Pile Length = 32.4 ft	Ftg EL.	874.06
HP Nominal Depth, h = 14.0 in			Pile Tip El.	842.68
Wt. per ft, plf 73			Pile Cap Embed =	1.00 ft
	Total pile Length =	1,425 LF		

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **11.06 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	9.06 ft	12	985.7
2	Dist. To Row 2	2.73 ft	11	82.2
3	Dist. Row 3	-3.60 ft	11	142.3
4	Dist. Row 4	-9.93 ft	10	985.4
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
			44	Σ I = **2195.6**

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**	16.9	23.9	30.9	37.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.9	1,584	**OK**
Case 2	**76.2 tons**	16.9	23.9	30.9	37.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.9	1,848	**OK**
Case 3	**76.2 tons**	14.1	22.9	31.8	40.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.6	1,848	**OK**
Case 4	**99.4 tons**	-8.0	15.7	39.5	63.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.3	2,112	**OK**
Case 5	**31.4 tons**	30.5	30.5	30.5	30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.5	1,012	**OK**
Case 6	**76.2 tons**	30.6	30.5	30.4	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.6	1,012	**OK**
														Max Service : P =	**63.3**	

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

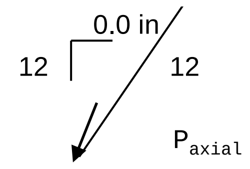
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel F	

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-ft)	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$
Case 1	**100 yr. flood**	**Usual**	2,367	-237	31,053	13.12	-2.06	-4865
Case 2	**100 yr. flood + ice**	**Unusual**	2,367	-237	31,053	13.12	-2.06	-4865
Case 3	**500 yr. flood**	**Unusual**	2,354	-372	32,185	13.67	-2.61	-6142
Case 4	**T.O. Levee**	**Extreme**	2,287	-1,227	41,785	18.27	-7.21	-16486
Case 5	**Normal flow + ice**	**Usual**	2,683	585	29,672	11.06	0.01	16
Case 6	**Construction**	**Unusual**	2,683	585	29,627	11.04	0.02	61

SERVICE

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

Vertical Load, P = 2367 kips
Horizontal Load, H = -237 kips
M_{NA} = -4865 kip-ft 44

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	53.8	-20.1	33.7 kips/pile	16.9 tons/pile	16.9 tons/pile
2	Row 2	53.8	-6.1	47.7 kips/pile	23.9 tons/pile	23.9 tons/pile
3	Row 3	53.8	8.0	61.8 kips/pile	30.9 tons/pile	30.9 tons/pile
4	Row 4	53.8	22.0	75.8 kips/pile	37.9 tons/pile	37.9 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:	**37.9 tons/pile**	**max: 37.9 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	11	0.0	396	1.000	396 kips	
3	Row 3	0	11	0.0	396	1.000	396 kips	
4	Row 4	0	10	0.0	360	1.000	360 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	
			44		1584		**1584 kips**	**OK**

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

Vertical Load, P = 2367 kips
Horizontal Load, H = -237 kips
M_{NA} = -4865 kip-ft 44

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	53.8	-20.1	33.7 kips/pile	16.9 tons/pile	16.9 tons/pile
2	Row 2	53.8	-6.1	47.7 kips/pile	23.9 tons/pile	23.9 tons/pile
3	Row 3	53.8	8.0	61.8 kips/pile	30.9 tons/pile	30.9 tons/pile
4	Row 4	53.8	22.0	75.8 kips/pile	37.9 tons/pile	37.9 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:	**37.9 tons/pile**	**max: 37.9 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	11	0.0	462	1.000	462 kips	
3	Row 3	0	11	0.0	462	1.000	462 kips	
4	Row 4	0	10	0.0	420	1.000	420 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	
			44		1848		**1848 kips**	**OK**

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

Vertical Load, P = 2354 kips
Horizontal Load, H = -372 kips
M_{NA} = -6142 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	53.5	-25.4	28.1 kips/pile		14.1 tons/pile	14.1 tons/pile
2	Row 2	53.5	-7.6	45.9 kips/pile		22.9 tons/pile	22.9 tons/pile
3	Row 3	53.5	10.1	63.6 kips/pile		31.8 tons/pile	31.8 tons/pile
4	Row 4	53.5	27.8	81.3 kips/pile		40.6 tons/pile	40.6 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:	**40.6 tons/pile**	**max: 40.6 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	11	0.0	462	1.000	462 kips	
3	Row 3	0	11	0.0	462	1.000	462 kips	
4	Row 4	0	10	0.0	420	1.000	420 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	
			44		1848		**1848 kips**	**OK**

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

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

Vertical Load, P = 2287 kips
Horizontal Load, H = -1227 kips
M_{NA} = -16486 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	52.0	-68.1	-16.1 kips/pile	-8.0 tons/pile	-8.0 tons/pile
2	Row 2	52.0	-20.5	31.4 kips/pile	15.7 tons/pile	15.7 tons/pile
3	Row 3	52.0	27.0	79.0 kips/pile	39.5 tons/pile	39.5 tons/pile
4	Row 4	52.0	74.5	126.5 kips/pile	63.3 tons/pile	63.3 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:	**63.3 tons/pile**	**max: 63.3 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	11	0.0	528	1.000	528 kips
3	Row 3	0	11	0.0	528	1.000	528 kips
4	Row 4	0	10	0.0	480	1.000	480 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
			44		2112		**2112 kips** **OK**

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

Vertical Load, P = 2683 kips
Horizontal Load, H = 585 kips
M_{NA} = 16 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	61.0	0.1	61.1 kips/pile	30.5 tons/pile	30.5 tons/pile
2	Row 2	61.0	0.0	61.0 kips/pile	30.5 tons/pile	30.5 tons/pile
3	Row 3	61.0	0.0	61.0 kips/pile	30.5 tons/pile	30.5 tons/pile
4	Row 4	61.0	-0.1	60.9 kips/pile	30.5 tons/pile	30.5 tons/pile
5	Row 5	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0	0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
				max:	**30.5 tons/pile**	**max: 30.5 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	11	0.0	253	1.000	253 kips

3 Row 3	0	11	0.0	253	1.000	253 kips	
4 Row 4	0	10	0.0	230	1.000	230 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	
		44		1012		**1012 kips**	**OK**

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

Vertical Load, P = 2683 kips
Horizontal Load, H = 585 kips
M_{NA} = 61 kip-ft

Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1 Row 1	61.0	0.3	61.2 kips/pile		30.6 tons/pile	30.6 tons/pile
2 Row 2	61.0	0.1	61.1 kips/pile		30.5 tons/pile	30.5 tons/pile
3 Row 3	61.0	-0.1	60.9 kips/pile		30.4 tons/pile	30.4 tons/pile
4 Row 4	61.0	-0.3	60.7 kips/pile		30.4 tons/pile	30.4 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
11 Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
12 Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
13 Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
14 Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
15 Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile	0.0 tons/pile
				max:	**30.6 tons/pile**	**max:** **30.6 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	11	0.0	253	1.000	253 kips	
3 Row 3	0	11	0.0	253	1.000	253 kips	
4 Row 4	0	10	0.0	230	1.000	230 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	
		44		1012		**1012 kips**	**OK**

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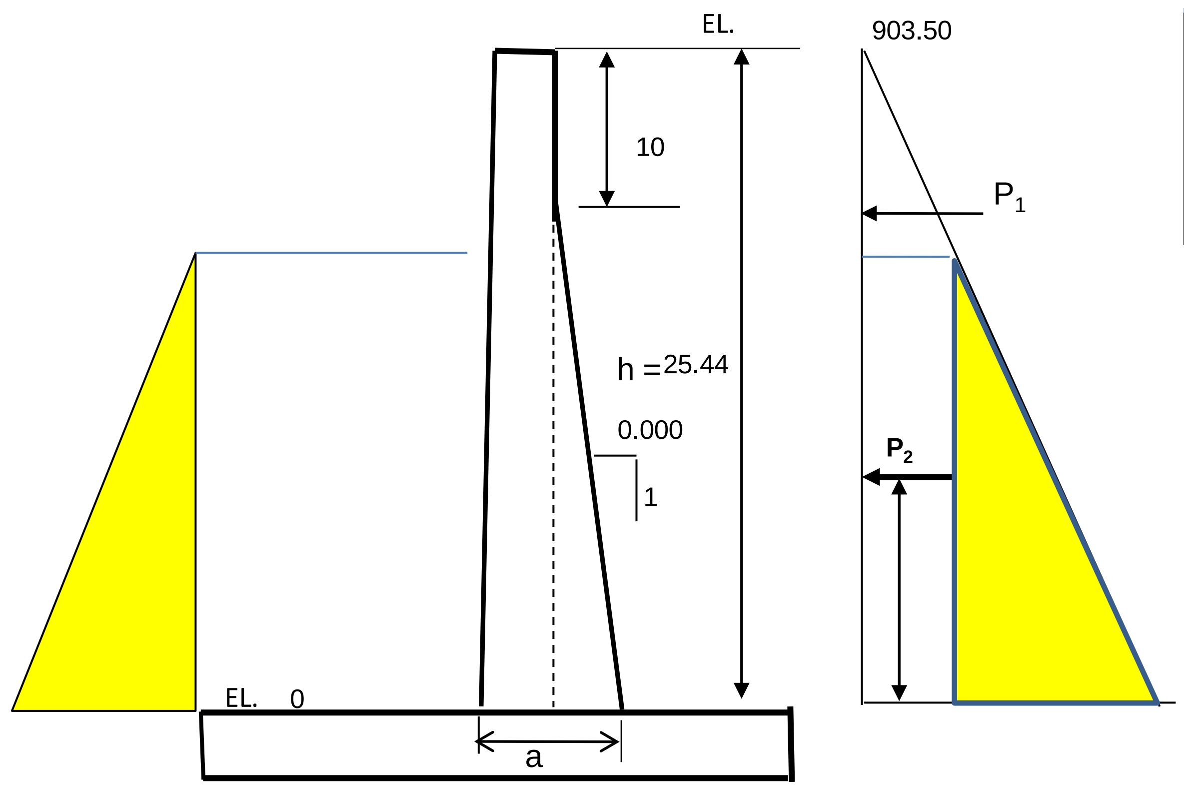
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel F 0	



CASE	Event		HW	TW	Dh	TW -ftg
Case 1	100 yr. flood	Usual	893.89	892.57	1.32	892.57
Case 2	100 yr. flood + ice	Unusual	893.89	892.57	1.32	892.57
Case 3	500 yr. flood	Unusual	896.380	893.66	2.72	893.66
Case 4	T.O. Levee	Extreme	903.500	903.50	0.00	903.50
Case 5	Normal flow + ice	Usual	0.000	0.000	0.00	0.00
Case 6	Construction	Unusual	0.000	0.000	0.00	0.00

LOAD FACTORS

Hf = 1.30 hydraulic Factor
LF = 1.70
Unsual & Extreme = 0.75

TOP THICK = 4.0 ft 48.0 in
Batter at Base = 0.00 ft 0.0 in
a = 4.00 ft 48.0 in

Load Factors - Hydraulic Structures

live load, LL = 1.7
dead load, DL = 1.4
flood level , FL = 1
Fluid, F = 1.7
hydraulic, Hf = 1.3
direct tension hydraulic, Hf = 1.65
ICE = 1.7

WALL DESIGN:

Horizontal Load Components and Moments about Bottom of Stem (Service)

CASE	Event	Condition	Load Factor	H (kips/ft)	Moment (kip-ft/ ft)	Vu (kips/ft)	Mu (kip-ft/ ft)
Case 1	100 yr. flood	Usual	1	-1.67	10.883	-3.69	24.05
Case 2	100 yr. flood + ice	Unusual	0.75	-1.67	10.883	-2.77	18.04
Case 3	500 yr. flood	Unusual	0.75	-3.30	-2.650	-5.47	-4.39
Case 4	T.O. Levee	Extreme	0.75	-14.04	-119.094	23.28	197.40
Case 5	Normal flow + ice	Usual	1	6.15	52.138	13.59	115.22
Case 6	Construction	Unusual	0.75	6.15	52.138	10.19	86.42

STEM DESIGN VALUES

MU, k-ft/ft	197.40	k-ft/ft
VU, k/ft	23.28	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 = 197 k-ft /ft **Includes: hf = 1.3**
Vuh= 23.28 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

$Ru=Mn/bd^2$ = 115.910 **ACI 10.5.1** **ACI 10.5.3**
REQ'D p= 0.0020 **O.K.** p(min)= 3*SQRT(Fc')/fy 200* / fy 4/3*p
p= 0.0026 0.00316 0.00333 0.0026

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

As (REQ'D)= 1.37 in^2 p(min)= 0.0028 /2 → As =0.5*$p_{T\&S}$bh = 0.8064 in^2
As = #9 @ 12 = 1.00 in^2

SELECT STEEL

bar #= 9
spacing, s= 6 in
# OF BAR= 1 (ENTER 1 IF PER FT, b=12") a
As= 1.999 in^2
d= 43.4375 in
p = As/bd = 0.0038 **O.K. < 0.375pb** **EM 110-2-2104**
p = 0.135 pb **MAXIMUM TENSILE REINFORCEMENT**

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

T= As*fy = 119.9 k
C= B1*Fc' *b*a = 671.2 **a**
a= T/C = 0.179 in
Mn= T(d - a/2)/12 = 433.2 ft-k
ϕ Mn= 389.9 ft-k **> Mu O.K.**

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

Vuh = 23.3 k **NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ = 31.0 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= in s = Av * fy * d / (Vu / f - Vc)

11.5.5 - Spacing limits for shear reinforcement

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

USE s= **10.86** in

Vs = (Av * Fy * d) / s = 0.0 k

11.5.6 - MINIMUM SHEAR REINFORCEMENT

A minimum area of shear reinforcement, Av,min shall be provided in all reinforced concrete flexural members where **Vu** exceeds **0.5 f Vc**

NOT REQUIRED IF:
a) SLAB OR FOOTING, vc>vn **O.K.**
b) CONCRETE JOIST ACI 8.11
c) BEAMS W/ h <= 10"
h <= 2.5*Bf
h <= 0.5*tw
d) WALLS (SEE ACI 11.10.1); vc>vn **O.K.**

11.5.6.3

Av,min = 0.75 sqrt(fc') bw*s/fy = 0.55 * s
but not less than 50bw*s/ fy = 18.33333333 * 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