# 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 G** | **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 G.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)* | 884.06 | | | | | |
| *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)* | **9.83** | **9.83** | **11.4** | **19.44** | **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)* | **13.83** | **13.83** | **15.4** | **23.44** | **NA** | **NA** |
| *Uplift @ TW (ft)* | **12.51** | **12.51** | **13.6** | **23.44** | **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 | | | |

| 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<br>2/11/11 | | MBI | SUBJECT | Maple Aquaduct Structure - Retaining Walls<br>Panel G | | |

**Monolith Structure**

| ITEM | | UNIT | QUANITY | UNIT COST | TOTAL Cost |
|---|---|---|---|---|---|
| FURNISH HP14x73 WALL PILING | | LF | 1,381 | 0 | $0 |
| INSTALL HP14x73 WALL PILING | | LF | 1,381 | 0 | $0 |
| PILE TEST, 48.4 ft | Long | EA | 4 | 0 | $0 |
| FOOTING CONCRETE | | CY | 212 | 0 | $0 |
| | Forming | SF | 842 | | |
| STEM CONCRETE | | CY | 239 | 0 | $0 |
| | Forming | SF | 3,426 | | |
| STEEL REINFORCEMENT | | LB | 64,403 | 0 | $0 |
| WALL RAILING | | LF | 83 | 0 | $0 |
| SHEET PILE CUT-OFF WALL | | SF | 830 | 0 | $0 |
| | | | | | $0 |

Structure Length = 83 ft

No. piles = 36 Each

Length = 38.38 ft

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

LENGTH

(FRONT FACE) 10 FT

Native Soil has low permeability assume cut-off minimal to prevent scour

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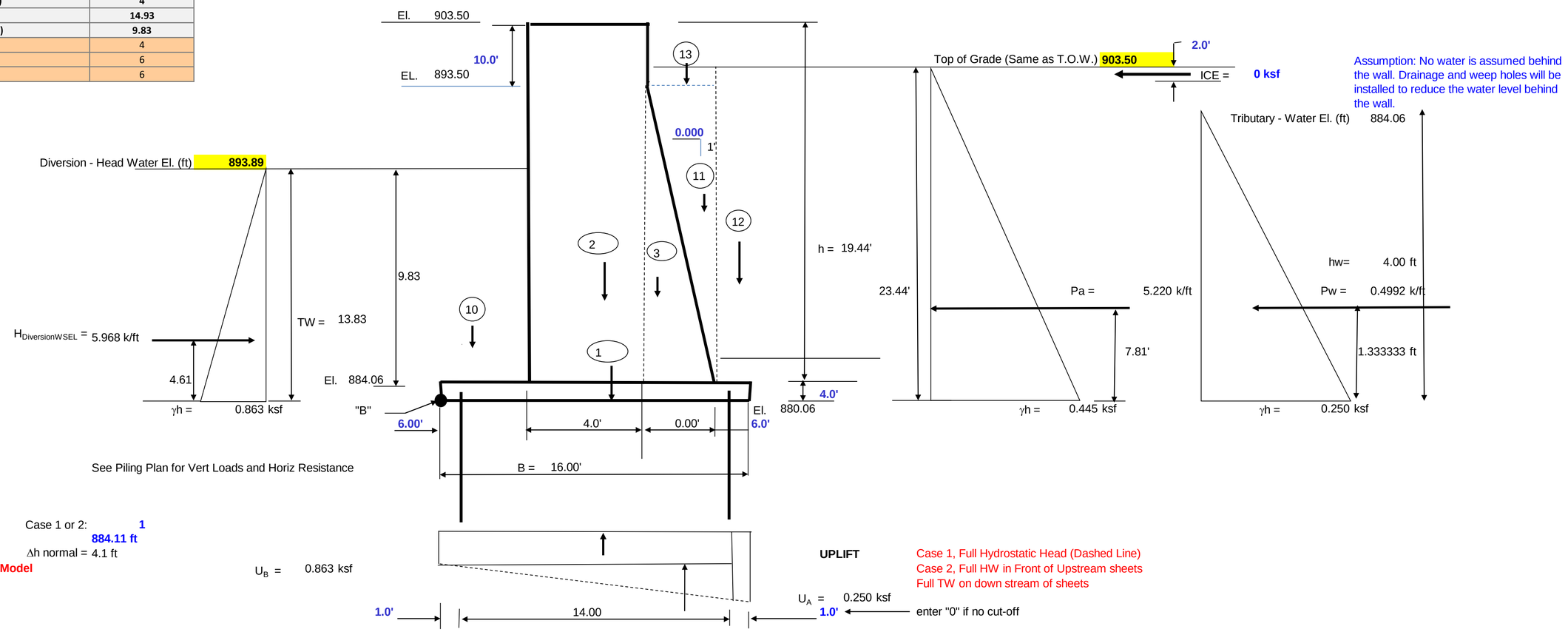
| MBI<br>2/11/11 | | MBI | SUBJECT | Maple Aquaduct Structure - Retaining Walls<br>Load Cases: Case 1 100 yr. flood Panel G | |

| 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) | 884.06 |
| 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) | 9.83 |
| Wall Thickness (ft) | 4 |
| Toe (Ft) | 6 |
| Heel (ft) | 6 |

File:

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

**Non-Overflow Section** **Length = 83.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg




See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.1 ft
**See Geotechnical seepage Model**

$U_B$ = 0.863 ksf

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

$U_A$ = 0.250 ksf
**1.0'** ← 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 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |
| T.W on ftg Stem | 10 | 83 | 6.00 | 9.83 | 0.0624 | rec | 305.5 | 3.00 | 916.4 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **911.5** | $\Sigma M_V$ = | **8,794.9** |

← CONSTANT FOR ALL LOAD CASES

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 0.863 | rec | -1146.1 | 8.00 | -9,168 |
| | $U_A$ | 83 | 16.00 | -0.613 | tri | 407.3 | 10.67 | 4,344 |
| | | | | | ΣU = | **-738.8** | $\Sigma M_U$ = | **-4,824** |

| 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 1 100 yr. flood Panel G | |

**Horizontal Loads**

| | L | H | Pressure | | ICE | arm | Mu |
|---|---|---|---|---|---|---|---|
| | ft | ft | ksf | | K | ft | ft-k |
| **ICE** | 83 | 2.00 | 0.00 | rec | 0.0 | 22.44 | 0.0 |

| | L | Force | | H | arm | Mw |
|---|---|---|---|---|---|---|
| | ft | k/ft | | K | ft | ft-k |
| **SOIL** | 83 | -5.220 | | -433.23 | 7.81 | -3384.96 |
| **Water Loads** | | | | | | |
| $H_{TW}$ | 83 | 5.968 | tri | 495.31 | 4.61 | 2283.38 |
| $H_{HW}$ | 83 | -0.499 | tri | -41.43 | 1.33 | -55.24 |
| | | | ΣWater = | **453.88** | $\Sigma M_W$ = | **-1156.8** |

| | | | |
|---|---|---|---|
| Overturning Moments | $\Sigma M_{OT} = M_U + M_W + M_{ICE}$ = | -5981 | kip-ft |
| Resisting Moments | $\Sigma M_R = M_V$ = | 22914 | kip-ft |
| Sum of Moments | $\Sigma Mnet = M_R + M_{OT}$ = | **16,933** | kip-ft |
| Sum of Vertical Forces | P = Conc + Water + Uplift = | **1,938** | kips |
| Sum of Horizontal Forces | H = Σhorizontal | **21** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 8.74 | ft from Toe |
| | e = B/2 - Xr = | (0.74) | ft |
| | B/6 = | 2.667 | ft |

**CONCRETE QUANTITIES**

| | | | forming | |
|---|---|---|---|---|
| Ftg conc: | 201 | cy (includes stepped) | 842 | sf |
| Stem Conc: | 239 | cy | 3426 | sf |
| Total = | 441 | | | |

**STEEL REINFORCEMENT: (assumed)**

| | | Bar # | Spacing | | Length | # of bars | Total wt | | |
|---|---|---|---|---|---|---|---|---|---|
| **a) Footing** | | | in | LB /ft | ft | ea | lb | | |
| Top mat | Transverse: | 9 | 6 | 3.40 | 15.5 | 170 | 8,959 | | |
| | Longitudinal: | 9 | 6 | 3.40 | 84.5 | 32 | 9,194 | | |
| Bot mat | Transverse: | 9 | 6 | 3.40 | 15.5 | 170 | 8,959 | | |
| | Longitudinal: | 9 | 6 | 3.40 | 84.5 | 32 | 9,194 | | |
| | | | | | | | | **cy** | **LB/cy** |
| | | | | | | | **36,305** | 201 | 180.19125 |
| **b) Skin Reinf. On Monolith** | | | | | | | | | |
| Vert Face | Vertical | 9 | 12 | 3.40 | 18.94 | 83 | 5,345 | 10,689.74 | |
| | Longitudinal: | 9 | 12 | 3.40 | 82.5 | 19 | 5,330 | 10,659.00 | |
| Top Face | Transverse: | 9 | 12 | 3.40 | 3.5 | 83 | 988 | | |
| | Longitudinal: | 9 | 12 | 3.40 | 82.5 | 4 | 1,122 | | |
| Dowels | Vertical I.F. | 9 | 12 | 3.40 | 18.9 | 83 | 5,345 | | |
| | Vertical O.F. | 9 | 12 | 3.40 | 18.9 | 83 | 5,345 | | |
| | | | | | | | | **cy** | **LB/cy** |
| | | | | | | | **23,474** | 239 | 98.20031794 |
| | | | | | | Σ = | **59,779** | | |
| | Lap Splices (long. Bars) | 9 | | 3.40 | 8 | 170 | 4,624 | | |
| | | | | | | Σ Bar Wt= | 64,403 | lb | |

**FORCES AT THE BOTTOM OF THE STEM**

| Diversion Face | H | γ | Pbase | V | arm | Mv |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion WSEL | 9.83 | 0.0624 | 0.613392 | 3.015 | 3.277 | 9.878566 |
| Tributary SEL = | 19.44 | 0.019 | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | 0.0624 | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | 0.575 | | 13.3858 |

| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
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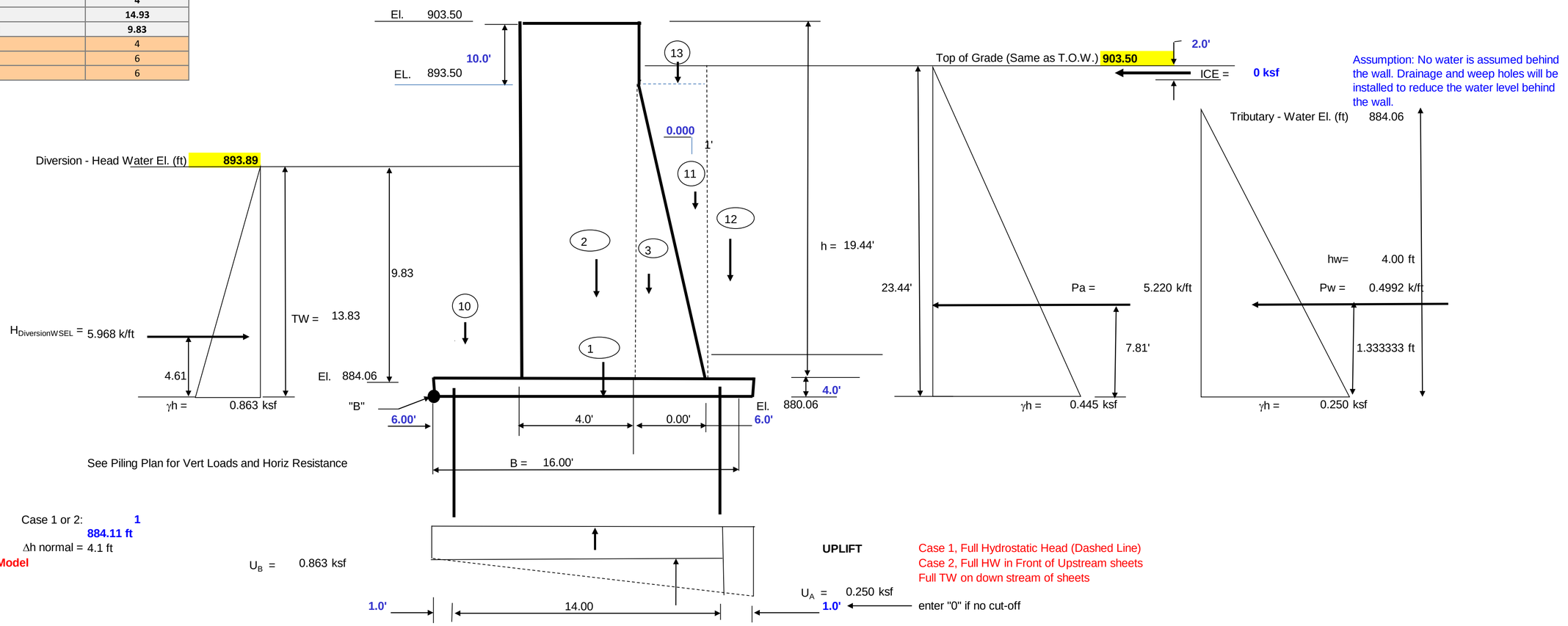
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI<br>2/11/11 | | MBI | SUBJECT | Maple Aquaduct Structure - Retaining Walls<br>Load Cases: Case 2 100 yr. flood + ice Panel G | |

| 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) | 884.06 |
| 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) | 9.83 |
| Wall Thickness (ft) | 4 |
| Toe (Ft) | 6 |
| Heel (ft) | 6 |

File:

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

**Non-Overflow Section** **Length = 83.0 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg




See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = 4.1 ft
See Geotechnical seepage Model

$U_B$ = 0.863 ksf

$U_A$ = 0.250 ksf

**UPLIFT**
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
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 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |
| T.W on ftg Stem | 10 | 83 | 6.00 | 9.83 | 0.0624 | rec | 305.5 | 3.00 | 916.4 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **911.5** | $\Sigma M_V$ = | **8,794.9** |

← CONSTANT FOR ALL LOAD CASES

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 0.863 | rec | -1146.1 | 8.00 | -9,168 |
| | $U_A$ | 83 | 16.00 | -0.613 | tri | 407.3 | 10.67 | 4,344 |
| | | | | | ΣU = | **-738.8** | $\Sigma M_U$ = | **-4,824** |

| 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 G |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ICE** | 83 | 2.00 | 0.00 | rec | 0.0 | 22.44 | 0.0 | |
| | L | | Force | | **H** | arm | **Mw** | |
| | ft | | k/ft | | K | ft | ft-k | |
| **SOIL** | 83 | | -5.220 | | -433.23 | 7.81 | -3384.96 | |
| **Water Loads** | | | | | | | | |
| $H_{TW}$ | 83 | | 5.968 | tri | 495.31 | 4.61 | 2283.38 | |
| $H_{HW}$ | 83 | | -0.499 | tri | -41.43 | 1.33 | -55.24 | |
| | | | | ΣWater = | **453.88** | $\Sigma M_W$ = | **-1156.8** | |

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| Sum of Horizontal Forces | H = Σhorizontal | **21** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 8.74 | ft from Toe |
| | e = B/2 - Xr = | (0.74) | ft |
| | B/6 = | 2.667 | ft |

**FORCES AT THE BOTTOM OF THE STEM**

| Diversion Face | H | γ | Pbase | **V** | arm | **Mv** |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion WSEL | 9.83 | **0.0624** | 0.613392 | 3.015 | 3.277 | 9.878566 |
| Tributary SEL = | 19.44 | **0.019** | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | 0.575 | | 13.3858 |

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| | | | | Load Cases: Case 3 500 yr. flood Panel G | |

| ID# | Case 3 |
|---|---|
| Name | 500 yr. flood |
| Load Category | Unusual |
| Tributary - Water El. (ft) | 896.38 |
| Diversion - Head Water El. (ft) | 895.46 |
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| Wall Thickness (ft) | 4 |
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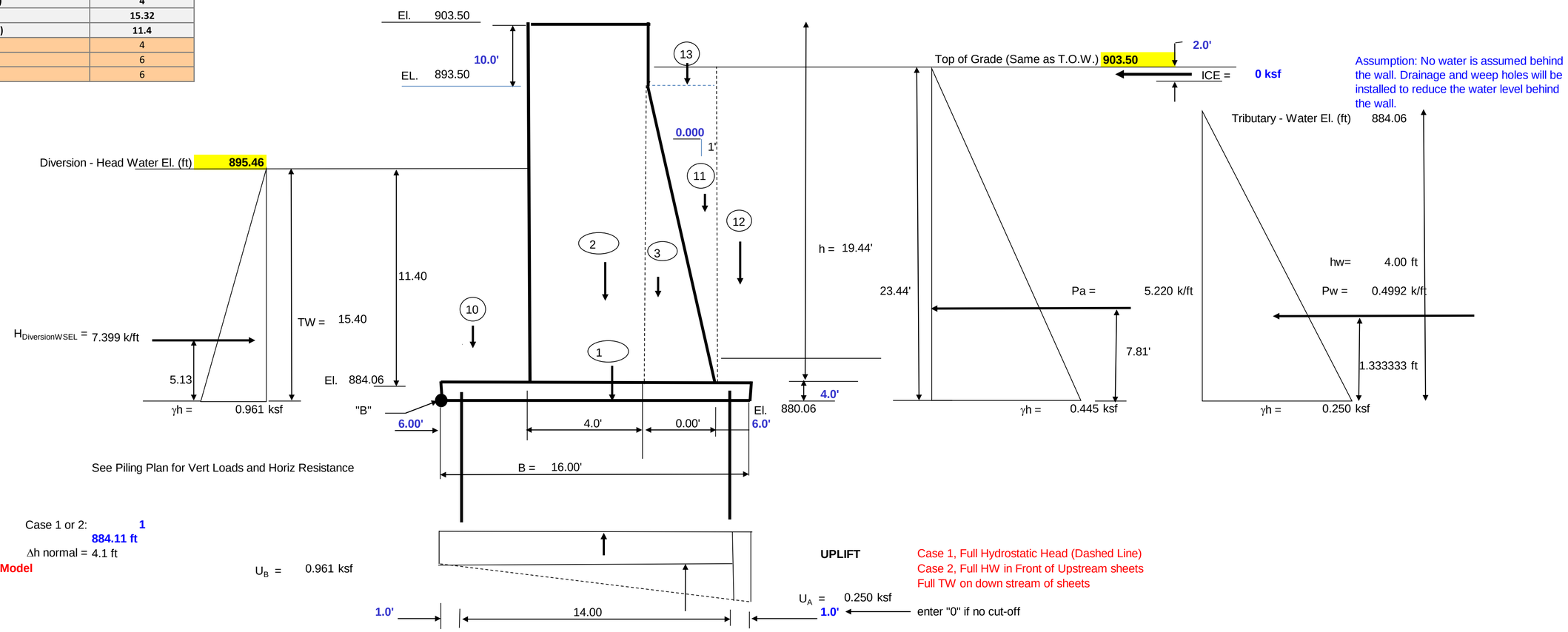


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Δh normal = 4.1 ft
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**UPLIFT**
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enter "0" if no cut-off

| Vertical Loads | Section | L ft | W ft | H ft | γ kcf | shape | V K | arm ft | Mv ft-k |
|---|---|---|---|---|---|---|---|---|---|
| Ftg concrete | 1 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |

← CONSTANT FOR ALL LOAD CASES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T.W on ftg Stem | 10 | 83 | 6.00 | 11.40 | 0.0624 | rec | 354.3 | 3.00 | 1,062.8 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **960.3** | $\Sigma M_V$ = | **8,941.3** |

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 0.961 | rec | -1276.2 | 8.00 | -10,209 |
| | $U_A$ | 83 | 16.00 | -0.711 | tri | 472.3 | 10.67 | 5,038 |
| | | | | | ΣU = | **-803.8** | $\Sigma M_U$ = | **-5,171** |

| 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 3 500 yr. flood — Panel G | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ICE** | 83 | 2.00 | 0.00 | rec | 0.0 | 22.44 | 0.0 | |
| | L | | Force | | **H** | arm | **Mw** | |
| | ft | | k/ft | | K | ft | ft-k | |
| **SOIL** | 83 | | -5.220 | | -433.23 | 7.81' | -3384.96 | |
| **Water Loads** | | | | | | | | |
| $H_{TW}$ | 83 | | 7.399 | tri | 614.15 | 5.13 | 3152.63 | |
| $H_{HW}$ | 83 | | -0.499 | tri | -41.43 | 1.33 | -55.24 | |
| | | | | ΣWater = | **572.72** | $\Sigma M_W$ = | **-287.6** | |

| | | | |
|---|---|---|---|
| Overturning Moments | $\Sigma M_{OT} = M_U + M_W + M_{ICE}$ = | -5458 | kip-ft |
| Resisting Moments | $\Sigma M_R = M_V$ = | 23061 | kip-ft |
| Sum of Moments | $\Sigma Mnet = M_R + M_{OT}$ = | **17,602** | kip-ft |
| Sum of Vertical Forces | P = Conc + Water + Uplift = | **1,921** | kips |
| Sum of Horizontal Forces | H = Σhorizontal | **139** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 9.16 | ft from Toe |
| | e = B/2 - Xr = | (1.16) | ft |
| | B/6 = | 2.667 | ft |

**FORCES AT THE BOTTOM OF THE STEM**

| Diversion Face | H | γ | Pbase | **V** | arm | **Mv** |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion WSEL | 11.40 | **0.0624** | 0.71136 | 4.055 | 3.800 | 15.40806 |
| Tributary SEL = | 19.44 | **0.019** | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | -0.465 | | 7.856304 |

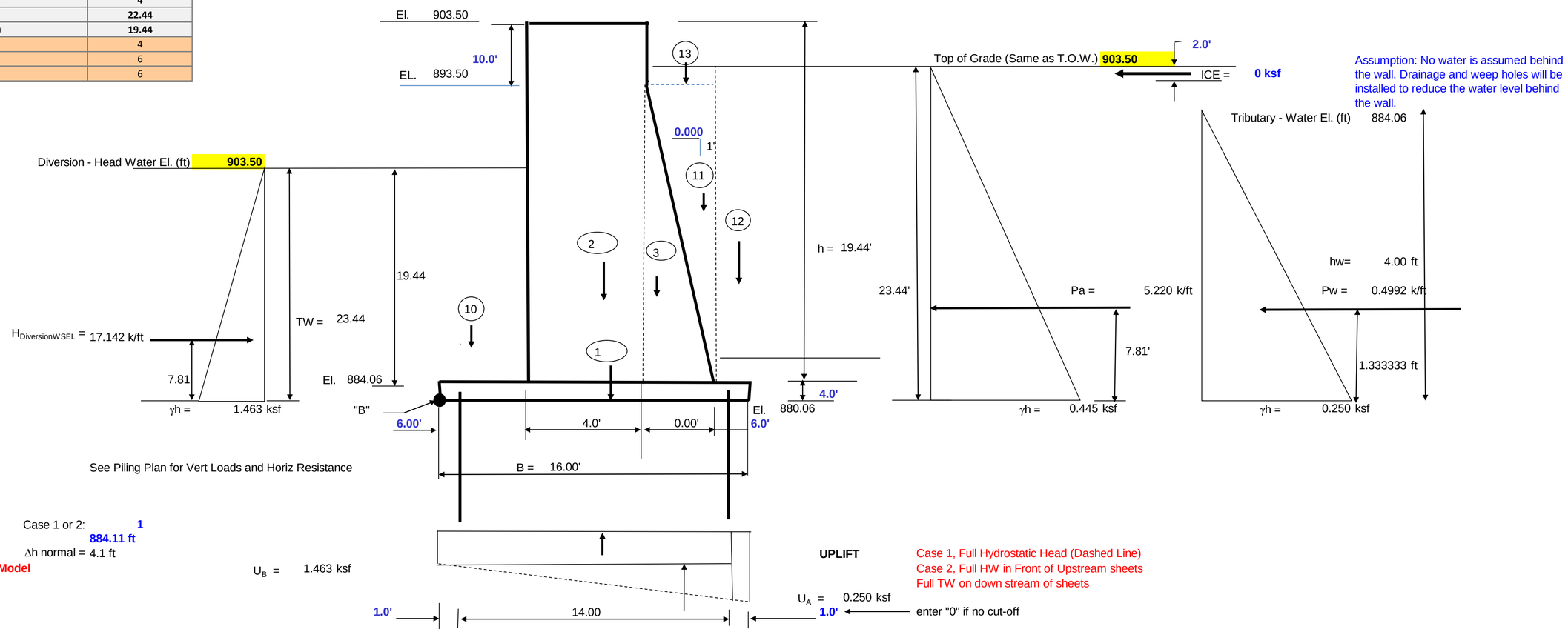
| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
|---|---|---|---|---|---|
| | | | PROJECT NAME | FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4 | |
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI 2/11/11 | | MBI | SUBJECT | Maple Aquaduct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

| 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) | 884.06 |
| 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) | 19.44 |
| Wall Thickness (ft) | 4 |
| Toe (Ft) | 6 |
| Heel (ft) | 6 |

File:

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

**Non-Overflow Section** **Length = 83.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg




See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.1 ft
**See Geotechnical seepage Model**

$U_B$ = 1.463 ksf

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

$U_A$ = 0.250 ksf
**1.0'** ← 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 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |

← CONSTANT FOR ALL LOAD CASES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T.W on ftg Stem | 10 | 83 | 6.00 | 19.44 | 0.0624 | rec | 604.1 | 3.00 | 1,812.3 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **1210.1** | $\Sigma M_V$ = | **9,690.8** |

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 1.463 | rec | -1942.4 | 8.00 | -15,539 |
| | $U_A$ | 83 | 16.00 | -1.213 | tri | 805.5 | 10.67 | 8,592 |
| | | | | | ΣU = | **-1136.9** | $\Sigma M_U$ = | **-6,948** |

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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ICE** | 83 | 2.00 | 0.00 | rec | 0.0 | 22.44 | 0.0 |
| | L | | Force | | **H** | arm | **Mw** |
| | ft | | k/ft | | K | ft | ft-k |
| **SOIL** | 83 | | -5.220 | | -433.23 | 7.81' | -3384.96 |
| **Water Loads** | | | | | | | |
| $H_{TW}$ | 83 | | 17.142 | tri | 1422.81 | 7.81 | 11116.91 |
| $H_{HW}$ | 83 | | -0.499 | tri | -41.43 | 1.33 | -55.24 |
| | | | | ΣWater = | **1381.38** | $\Sigma M_W$ = | **7676.7** |

| | | | |
|---|---|---|---|
| Overturning Moments | $\Sigma M_{OT} = M_U + M_W + M_{ICE}$ = | 729 | kip-ft |
| Resisting Moments | $\Sigma M_R = M_V$ = | 23810 | kip-ft |
| Sum of Moments | $\Sigma Mnet = M_R + M_{OT}$ = | **24,539** | kip-ft |
| Sum of Vertical Forces | P = Conc + Water + Uplift = | **1,838** | kips |
| Sum of Horizontal Forces | H = Σhorizontal | **948** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 13.35 | ft from Toe |
| | e = B/2 - Xr = | (5.35) | ft |
| | B/6 = | 2.667 | ft |

**FORCES AT THE BOTTOM OF THE STEM**

| | H | γ | Pbase | **V** | arm | **Mv** |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion Face | | | | | | |
| Diversion WSEL | 19.44 | **0.0624** | 1.213056 | 11.791 | 6.480 | 76.40506 |
| Tributary SEL = | 19.44 | **0.019** | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | -8.201 | | -53.1407 |

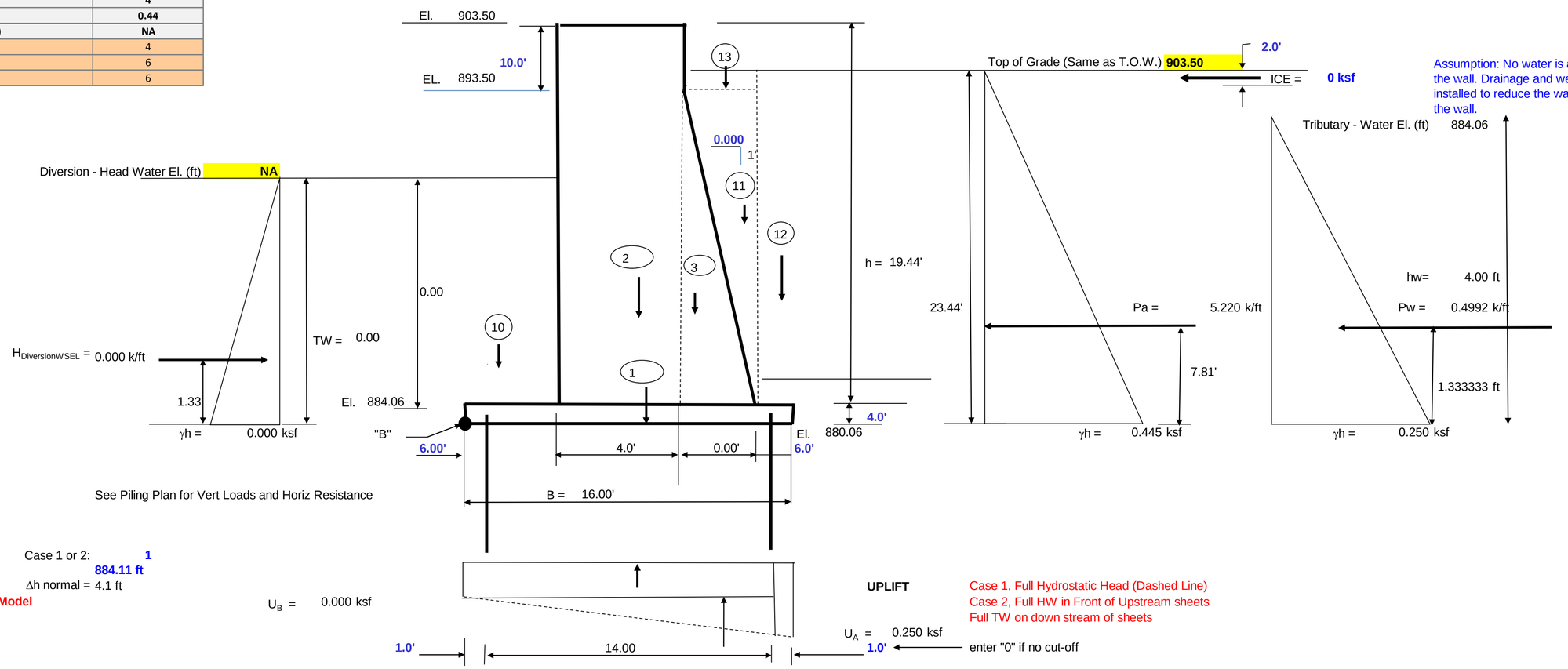
| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
|---|---|---|---|---|---|
| | | | PROJECT NAME | FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4 | |
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI<br>2/11/11 | | MBI | SUBJECT | Maple Aquaduct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

| 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) | 884.06 |
| 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) | 6 |
| Heel (ft) | 6 |

File:

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

**Non-Overflow Section** **Length = 83.0 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 = 4.1 ft
**See Geotechnical seepage Model**

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

| Vertical Loads | Section | L ft | W ft | H ft | γ kcf | shape | V K | arm ft | Mv ft-k |
|---|---|---|---|---|---|---|---|---|---|
| Ftg concrete | 1 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |

← CONSTANT FOR ALL LOAD CASES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T.W on ftg Stem | 10 | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 3.00 | 0.0 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **606.0** | $\Sigma M_V$ = | **7,878.5** |

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 0.000 | rec | 0.0 | 8.00 | 0 |
| | $U_A$ | 83 | 16.00 | 0.250 | tri | -165.7 | 10.67 | -1,768 |
| | | | | | ΣU = | **-165.7** | $\Sigma M_U$ = | **-1,768** |

| 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 G | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ICE** | 83 | 2.00 | 0.00 | | rec | 0.0 | 22.44 | 0.0 |
| | L | | Force | | | **H** | arm | **Mw** |
| | ft | | k/ft | | | K | ft | ft-k |
| **SOIL** | 83 | | -5.220 | | | -433.23 | 7.81' | -3384.96 |
| **Water Loads** | | | | | | | | |
| $H_{TW}$ | 83 | | 0.000 | | tri | 0.00 | 1.33 | 0.00 |
| $H_{HW}$ | 83 | | -0.499 | | tri | -41.43 | 0.00 | 0.00 |
| | | | | | ΣWater = | **-41.43** | $\Sigma M_W$ = | **-3385.0** |

| | | | |
|---|---|---|---|
| Overturning Moments | $\Sigma M_{OT} = M_U + M_W + M_{ICE}$ = | -5153 | kip-ft |
| Resisting Moments | $\Sigma M_R = M_V$ = | 21998 | kip-ft |
| Sum of Moments | $\Sigma Mnet = M_R + M_{OT}$ = | **16,845** | kip-ft |
| Sum of Vertical Forces | P = Conc + Water + Uplift = | **2,205** | kips |
| Sum of Horizontal Forces | H = Σhorizontal | **-475** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 7.64 | ft from Toe |
| | e = B/2 - Xr = | 0.36 | ft |
| | B/6 = | 2.667 | ft |

**FORCES AT THE BOTTOM OF THE STEM**

| | H | γ | Pbase | **V** | arm | **Mv** |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion Face | | | | | | |
| Diversion WSEL | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Tributary SEL = | 19.44 | **0.019** | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | 3.590 | | 23.26436 |

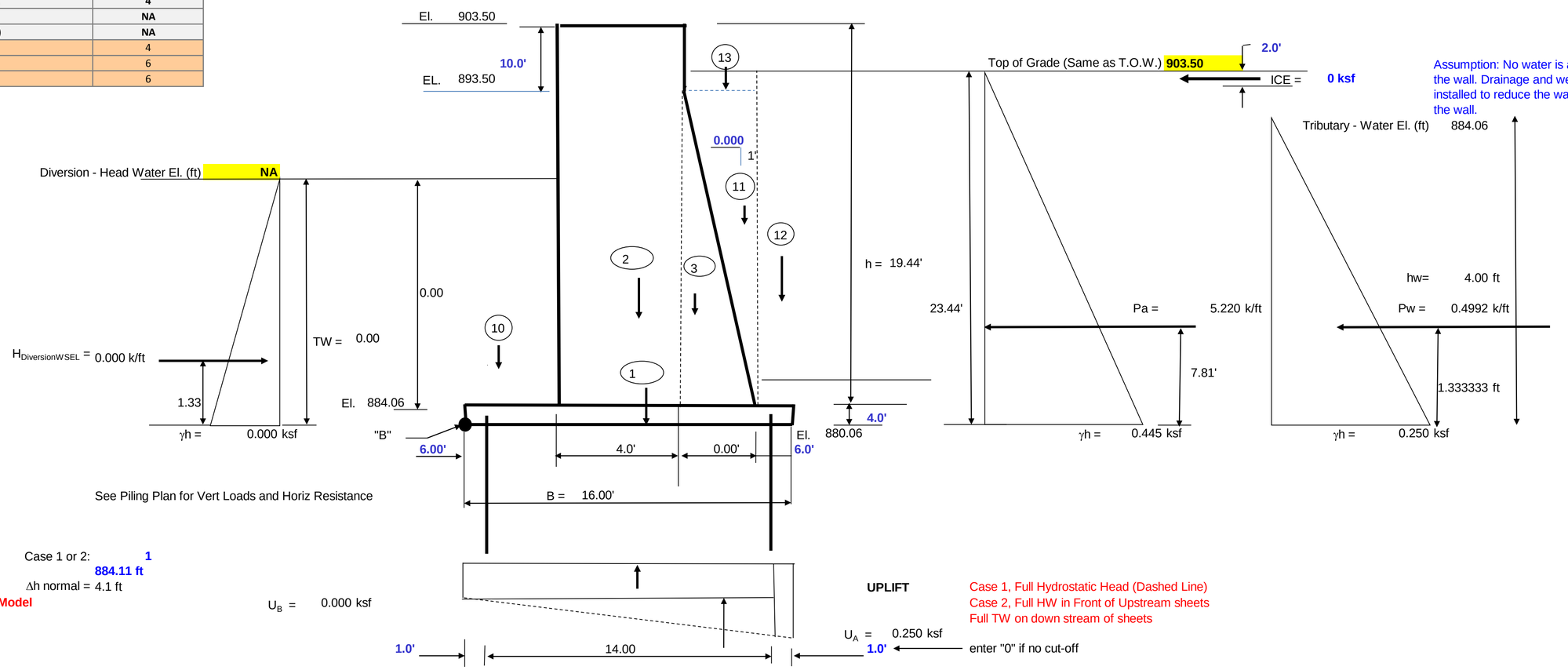
| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
|---|---|---|---|---|---|
| | | | PROJECT NAME | FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4 | |
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI<br>2/11/11 | | MBI | SUBJECT | Maple Aquaduct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

| 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) | 884.06 |
| 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) | 6 |
| Heel (ft) | 6 |

File:

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

**Non-Overflow Section** **Length = 83.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg




See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = 4.1 ft
**See Geotechnical seepage Model**

$U_B$ = 0.000 ksf

$U_A$ = 0.250 ksf

**UPLIFT**
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
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 | 83 | 16.00 | 4.00 | 0.15 | rec | 796.8 | 8.00 | 6,374.4 |
| **Stem** | 2 | 83 | 4.00 | 19.44 | 0.15 | rec | 968.1 | 8.00 | 7,744.9 |
| Batter | 3 | 83 | 0.00 | 9.44 | 0.15 | tri | 0.0 | 10.00 | 0.0 |
| | | | | | **D.L. Concrete** | ΣVc = | **1764.9** | $\Sigma M_V$ = | **14,119.3** |

← CONSTANT FOR ALL LOAD CASES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T.W on ftg Stem | 10 | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 3.00 | 0.0 |
| H.W. on Stem Slope | 11 | 83 | 0.00 | 9.44 | 0.12 | tri | 0.0 | 10.00 | 0.0 |
| H.W. Above Slope | 13 | 83 | 0.00 | 10.00 | 0.12 | rec | 0.0 | 10.00 | 0.0 |
| Soil on Footing | 12s | 83 | 6.00 | 19.44 | 0.0626 | rec | 606.0 | 13.00 | 7,878.5 |
| H.W. on Footing | 12w | 83 | 6.00 | 0.00 | 0.0624 | rec | 0.0 | 13.00 | 0.0 |
| | | | | | **D.L. Water** | ΣVw = | **606.0** | $\Sigma M_V$ = | **7,878.5** |

| Uplift Loads | | L ft | W ft | Pressure ksf | | U K | arm ft | Mu ft-k |
|---|---|---|---|---|---|---|---|---|
| | $U_B$ | 83 | 16.00 | 0.000 | rec | 0.0 | 8.00 | 0 |
| | $U_A$ | 83 | 16.00 | 0.250 | tri | -165.7 | 10.67 | -1,768 |
| | | | | | ΣU = | **-165.7** | $\Sigma M_U$ = | **-1,768** |

| 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 G | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ICE** | 83 | 2.00 | 0.00 | rec | 0.0 | 22.44 | 0.0 | |
| | L | | Force | | **H** | arm | **Mw** | |
| | ft | | k/ft | | K | ft | ft-k | |
| **SOIL** | 83 | | -5.220 | | -433.23 | 7.81' | -3384.96 | |
| **Water Loads** | | | | | | | | |
| $H_{TW}$ | 83 | | 0.000 | tri | 0.00 | 1.33 | 0.00 | |
| $H_{HW}$ | 83 | | -0.499 | tri | -41.43 | 1.33 | -55.24 | |
| | | | | ΣWater = | **-41.43** | $\Sigma M_W$ = | **-3440.2** | |

| | | | |
|---|---|---|---|
| Overturning Moments | $\Sigma M_{OT} = M_U + M_W + M_{ICE}$ = | -5208 | kip-ft |
| Resisting Moments | $\Sigma M_R = M_V$ = | 21998 | kip-ft |
| Sum of Moments | $\Sigma Mnet = M_R + M_{OT}$ = | **16,790** | kip-ft |
| Sum of Vertical Forces | P = Conc + Water + Uplift = | **2,205** | kips |
| Sum of Horizontal Forces | H = Σhorizontal | **-475** | kips |

| | | | |
|---|---|---|---|
| Location of Resultant | Xr = ΣM / P = | 7.61 | ft from Toe |
| | e = B/2 - Xr = | 0.39 | ft |
| | B/6 = | 2.667 | ft |

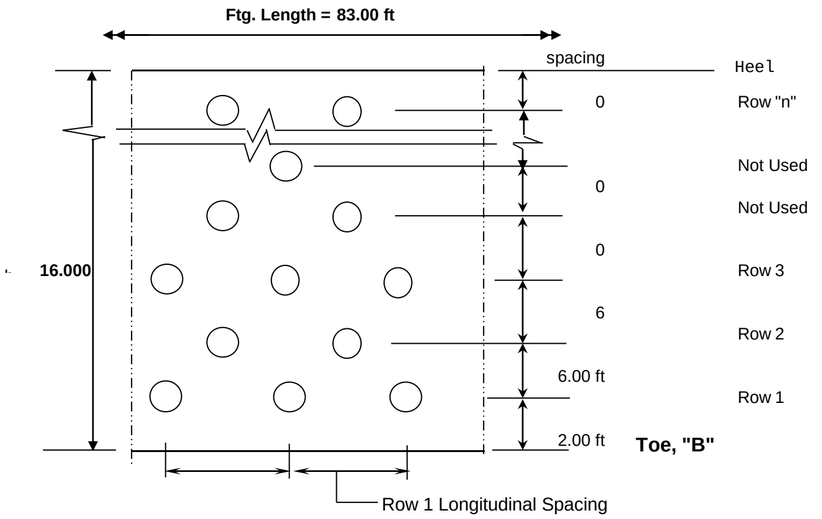
**FORCES AT THE BOTTOM OF THE STEM**

| | H | γ | Pbase | **V** | arm | **Mv** |
|---|---|---|---|---|---|---|
| | ft | kcf | | K | ft | ft-k |
| Diversion Face | | | | | | |
| Diversion WSEL | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Tributary SEL = | 19.44 | **0.019** | 0.36936 | 3.590 | 6.480 | 23.26436 |
| Tributary WSEL = | 0.00 | **0.0624** | 0 | 0.000 | 0.000 | 0 |
| Sum | | | | 3.590 | | 23.26436 |
| **Net Forces** | | | | 3.590 | | 23.26436 |

| 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<br>Panel G | |

**PILE FOUNDATION DESIGN**

**FLOW**




L = 83.00 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" | **13** | 26.50 | 1 | 34 |
| Row 1 to Row 2 | **6.00 ft** | 8.0 ft | **5.00 ft** | **0** | "/12" | **12** | 14.00 | 2 | 17 |
| Row 2 to Row 3 | **6.00 ft** | 14.0 ft | **5.00 ft** | **0** | "/12" | **11** | 16.50 | 3 | 17 |
| Row 3 to Row 4 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 4 to Row 5 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 5 to Row 6 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 6 to Row 7 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 7 to Row 8 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 8 to Row 9 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 9 to Row 10 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 10 to Row 11 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 11 to Row 12 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 12 to Row 13 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 13 to Row 14 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Row 14 to Row 15 | **0.00 ft** | 0.0 ft | **0.00 ft** | **0** | "/12" | **0** | 41.50 | 0 | 0 |
| Last Row to Heel | 2.00 ft | | | | | | | | |
| | 16.00 ft | | | | | **ΣN =** | **36** | | 68 |

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

**Pile Properties:** Pile Type: **HP** (C.I.P or HP) Pile Length = **38.4 ft**

HP Nominal Depth, h = **14.0 in**

Wt. per ft, plf **73**

Ftg EL. 880.06

Pile Tip El. 842.68

Pile Cap Embed = **1.00 ft**

**Total pile Length = 1,382 LF**

**Pile Group Properties**

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **7.67 ft**

| | Dist. From N.A. to Pile Row | d | N | $I = N * d^2$ |
|---|---|---|---|---|
| 1 | Dist. To Row 1 | 5.67 ft | 13 | 417.4 |
| 2 | Dist. To Row 2 | -0.33 ft | 12 | 1.3 |
| 3 | Dist. Row 3 | -6.33 ft | 11 | 441.2 |
| 0 | Row 4 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 5 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 6 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 7 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 8 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 9 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 10 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 11 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 12 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 13 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 14 (not used) | 0.00 ft | 0 | 0.0 |
| 0 | Row 15 (not used) | 0.00 ft | 0 | 0.0 |
| | | | 36 | $\Sigma I =$ **860.0** |

| ALLOWABLE LOADS (from Geotechnical) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Service** | **Allowable Pile Loads** | | | | | | |
| ID# | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | |
| Name | 100 yr. flood | 100 yr. flood + ice | 500 yr. flood | T.O. Levee | Normal flow + ice | Construction | |
| Load Category | Usual | Unusual | Unusual | Extreme | Usual | Unusual | |
| Allwable Lateral Capacity (tons) | 18.0 tons | 21.0 tons | 21.0 tons | 24.0 tons | 11.5 tons | 21.0 tons | |
| Allowable Pile Capacity (tons) - Axial | 57.2 tons | 76.2 tons | 76.2 tons | 99.4 tons | 31.4 tons | 76.2 tons | |
| Safety Factors | 2.00 | 1.50 | 1.50 | 1.15 | 2.00 | 1.50 | **w/o Group effects** |

**Summary Pile Reactions**

| Load Combinations | Allowable Pile Capacity (tons) - Axial | Pile Loads (tons/pile) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Max. Vertical Load (Tons) | Horiz Pile Group Capacity (k) | Check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Case 1 | **57.2 tons** | 20.1 | 27.3 | 34.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.6 | 1,296 | **OK** |
| Case 2 | **76.2 tons** | 20.1 | 27.3 | 34.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.6 | 1,512 | **OK** |
| Case 3 | **76.2 tons** | 17.2 | 27.2 | 37.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 37.3 | 1,512 | **OK** |
| Case 4 | **99.4 tons** | -8.9 | 27.6 | 64.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 64.0 | 1,728 | **OK** |
| Case 5 | **31.4 tons** | 30.8 | 30.6 | 30.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 | 828 | **OK** |
| Case 6 | **76.2 tons** | 31.0 | 30.6 | 30.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 31.0 | 828 | **OK** |

Max Service : P = **64.0**

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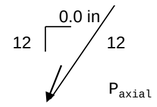
| | | | PROJECT NAME | FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4 | |
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI 2/11/11 | | MBI | SUBJECT | Maple Aquaduct Structure - Retaining Walls<br>Panel G | |

The moment about the neutral axis of the pile group becomes

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

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

Paxial = 1.000 Pvert




**FORCE RESULTANT** (see Stability Analysis)

| CASE | Event | | Vertical Load P (kips) | Horizontal | ΣM toe (kip- | e toe = M toe / P | e NA= X NA - e toe | M NA = P * e NA |
|---|---|---|---|---|---|---|---|---|
| **Case 1** | **100 yr. flood** | **Usual** | 1,938 | -21 | 16,933 | 8.74 | -1.07 | -2078 |
| **Case 2** | **100 yr. flood + ice** | **Unusual** | 1,938 | -21 | 16,933 | 8.74 | -1.07 | -2078 |
| **Case 3** | **500 yr. flood** | **Unusual** | 1,921 | -139 | 17,602 | 9.16 | -1.49 | -2871 |
| **Case 4** | **T.O. Levee** | **Extreme** | 1,838 | -948 | 24,539 | 13.35 | -5.68 | -10447 |
| **Case 5** | **Normal flow + ice** | **Usual** | 2,205 | 475 | 16,845 | 7.64 | 0.03 | 62 |
| **Case 6** | **Construction** | **Unusual** | 2,205 | 475 | 16,790 | 7.61 | 0.05 | 117 |

**SERVICE**

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

Vertical Load, P = 1938 kips
Horizontal Load, H = -21 kips
$M_{NA}$ = -2078 kip-ft

36

| **Vertical Pile Loading** | P / N | + | $M_{NA}$* d / Σ I | = Pile Loads | | **Axial Pile Load** |
|---|---|---|---|---|---|---|
| 1 Row 1 | 53.8 | | -13.7 | 40.1 kips/pile | 20.1 tons/pile | 20.1 tons/pile |
| 2 Row 2 | 53.8 | | 0.8 | 54.6 kips/pile | 27.3 tons/pile | 27.3 tons/pile |
| 3 Row 3 | 53.8 | | 15.3 | 69.1 kips/pile | 34.6 tons/pile | 34.6 tons/pile |
| 4 Row 4 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 5 Row 5 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 6 Row 6 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 7 Row 7 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 8 Row 8 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 9 Row 9 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 10 Row 10 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 11 Row 11 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 12 Row 12 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 13 Row 13 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 14 Row 14 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 15 Row 15 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| | | | | **max:** | **34.6 tons/pile** | **max:** **34.6 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 | 13 | 0.0 | 468 | 1.000 | 468 kips |
| 2 Row 2 | 0 | 12 | 0.0 | 432 | 1.000 | 432 kips |
| 3 Row 3 | 0 | 11 | 0.0 | 396 | 1.000 | 396 kips |
| 4 Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 5 Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 6 Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 7 Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 8 Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 9 Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 10 Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 11 Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 12 Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 13 Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 14 Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 15 Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| | | 36 | | 1296 | | **1296 kips** **OK** |

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

Vertical Load, P = 1938 kips
Horizontal Load, H = -21 kips
$M_{NA}$ = -2078 kip-ft

36

| **Vertical Pile Loading** | P / N | + | $M_{NA}$* d / Σ I | = Pile Loads | | **Axial Pile Load** |
|---|---|---|---|---|---|---|
| 1 Row 1 | 53.8 | | -13.7 | 40.1 kips/pile | 20.1 tons/pile | 20.1 tons/pile |
| 2 Row 2 | 53.8 | | 0.8 | 54.6 kips/pile | 27.3 tons/pile | 27.3 tons/pile |
| 3 Row 3 | 53.8 | | 15.3 | 69.1 kips/pile | 34.6 tons/pile | 34.6 tons/pile |
| 4 Row 4 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |

| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
|---|---|---|---|---|---|
| | | | 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<br>Panel G | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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:** | **34.6 tons/pile** | **max:** | **34.6 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 | 13 | 0.0 | 546 | 1.000 | 546 kips | |
| 2 | Row 2 | 0 | 12 | 0.0 | 504 | 1.000 | 504 kips | |
| 3 | Row 3 | 0 | 11 | 0.0 | 462 | 1.000 | 462 kips | |
| 4 | Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 5 | Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 6 | Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 7 | Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 8 | Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 9 | Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 10 | Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 11 | Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 12 | Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 13 | Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 14 | Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 15 | Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| | | | 36 | | 1512 | | **1512 kips** | **OK** |

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

Vertical Load, P = 1921 kips
Horizontal Load, H = -139 kips
$M_{NA}$ = -2871 kip-ft

| | **Vertical Pile Loading** | P / N + | $M_{NA}$* d / Σ I | = Pile Loads | | | **Axial Pile Load** |
|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 53.4 | -18.9 | 34.5 kips/pile | | 17.2 tons/pile | 17.2 tons/pile |
| 2 | Row 2 | 53.4 | 1.1 | 54.5 kips/pile | | 27.2 tons/pile | 27.2 tons/pile |
| 3 | Row 3 | 53.4 | 21.1 | 74.5 kips/pile | | 37.3 tons/pile | 37.3 tons/pile |
| 4 | Row 4 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 5 | Row 5 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 6 | Row 6 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 7 | Row 7 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 8 | Row 8 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 9 | Row 9 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 10 | Row 10 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 11 | Row 11 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 12 | Row 12 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 13 | Row 13 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 14 | Row 14 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| 15 | Row 15 | 0.0 | 0.0 | 0.0 kips/pile | | 0.0 tons/pile | 0.0 tons/pile |
| | | | | | **max:** | **37.3 tons/pile** | **max:** **37.3 tons/pile** |

Assumed lateral Capacity: 42.0 kips/pile

| | **Horizontal Pile Capacity** | **Batter "/ft** | **N** | Resistance due to Batter, kips | Resitance due to Bending, kips | Group Efficiency | Lateral Resitance | |
|---|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 0 | 13 | 0.0 | 546 | 1.000 | 546 kips | |
| 2 | Row 2 | 0 | 12 | 0.0 | 504 | 1.000 | 504 kips | |
| 3 | Row 3 | 0 | 11 | 0.0 | 462 | 1.000 | 462 kips | |
| 4 | Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 5 | Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 6 | Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 7 | Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 8 | Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 9 | Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 10 | Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 11 | Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 12 | Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 13 | Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 14 | Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 15 | Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| | | | 36 | | 1512 | | **1512 kips** | **OK** |

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

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

Vertical Load, P = 1838 kips
Horizontal Load, H = -948 kips
$M_{NA}$ = -10447 kip-ft

| | **Vertical Pile Loading** | P / N | + | $M_{NA}$* d / Σ I | = Pile Loads | | **Axial Pile Load** |
|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 51.1 | | -68.8 | -17.8 kips/pile | -8.9 tons/pile | -8.9 tons/pile |
| 2 | Row 2 | 51.1 | | 4.0 | 55.1 kips/pile | 27.6 tons/pile | 27.6 tons/pile |
| 3 | Row 3 | 51.1 | | 76.9 | 128.0 kips/pile | 64.0 tons/pile | 64.0 tons/pile |
| 4 | Row 4 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 5 | Row 5 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 6 | Row 6 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 7 | Row 7 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 8 | Row 8 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 9 | Row 9 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 10 | Row 10 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 11 | Row 11 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 12 | Row 12 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 13 | Row 13 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 14 | Row 14 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 15 | Row 15 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| | | | | | **max:** | **64.0 tons/pile** | **max: 64.0 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 | 13 | 0.0 | 624 | 1.000 | 624 kips |
| 2 | Row 2 | 0 | 12 | 0.0 | 576 | 1.000 | 576 kips |
| 3 | Row 3 | 0 | 11 | 0.0 | 528 | 1.000 | 528 kips |
| 4 | Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 5 | Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 6 | Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 7 | Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 8 | Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 9 | Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 10 | Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 11 | Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 12 | Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 13 | Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 14 | Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| 15 | Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips |
| | | | 36 | | 1728 | | **1728 kips** **OK** |

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

Vertical Load, P = 2205 kips
Horizontal Load, H = 475 kips
$M_{NA}$ = 62 kip-ft

| | **Vertical Pile Loading** | P / N | + | $M_{NA}$* d / Σ I | = Pile Loads | | **Axial Pile Load** |
|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 61.3 | | 0.4 | 61.7 kips/pile | 30.8 tons/pile | 30.8 tons/pile |
| 2 | Row 2 | 61.3 | | 0.0 | 61.2 kips/pile | 30.6 tons/pile | 30.6 tons/pile |
| 3 | Row 3 | 61.3 | | -0.5 | 60.8 kips/pile | 30.4 tons/pile | 30.4 tons/pile |
| 4 | Row 4 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 5 | Row 5 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 6 | Row 6 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 7 | Row 7 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 8 | Row 8 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 9 | Row 9 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 10 | Row 10 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 11 | Row 11 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 12 | Row 12 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 13 | Row 13 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 14 | Row 14 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 15 | Row 15 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| | | | | | **max:** | **30.8 tons/pile** | **max: 30.8 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 | 13 | 0.0 | 299 | 1.000 | 299 kips |
| 2 | Row 2 | 0 | 12 | 0.0 | 276 | 1.000 | 276 kips |

| 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 G | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | Row 3 | 0 | 11 | 0.0 | 253 | 1.000 | 253 kips | |
| 4 | Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 5 | Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 6 | Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 7 | Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 8 | Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 9 | Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 10 | Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 11 | Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 12 | Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 13 | Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 14 | Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 15 | Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| | | | 36 | | 828 | | **828 kips** | **OK** |

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

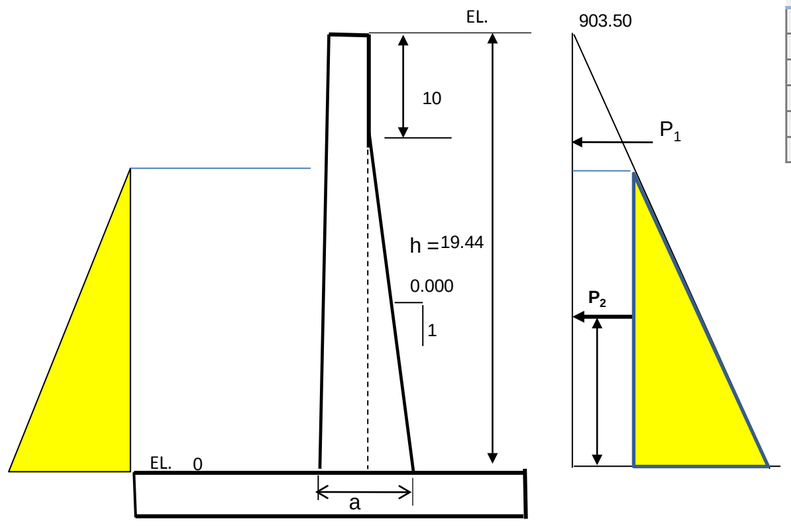
Vertical Load, P = 2205 kips
Horizontal Load, H = 475 kips
$M_{NA}$ = 117 kip-ft

| | **Vertical Pile Loading** | P / N | + | $M_{NA}$* d / Σ I | = Pile Loads | | **Axial Pile Load** |
|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 61.3 | | 0.8 | 62.0 kips/pile | 31.0 tons/pile | 31.0 tons/pile |
| 2 | Row 2 | 61.3 | | 0.0 | 61.2 kips/pile | 30.6 tons/pile | 30.6 tons/pile |
| 3 | Row 3 | 61.3 | | -0.9 | 60.4 kips/pile | 30.2 tons/pile | 30.2 tons/pile |
| 4 | Row 4 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 5 | Row 5 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 6 | Row 6 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 7 | Row 7 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 8 | Row 8 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 9 | Row 9 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 10 | Row 10 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 11 | Row 11 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 12 | Row 12 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 13 | Row 13 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 14 | Row 14 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| 15 | Row 15 | 0.0 | | 0.0 | 0.0 kips/pile | 0.0 tons/pile | 0.0 tons/pile |
| | | | | | **max:** | **31.0 tons/pile** | **max: 31.0 tons/pile** |

Assumed lateral Capacity: 42.0 kips/pile

| | **Horizontal Pile Capacity** | **Batter "/ft** | **N** | Resistance due to Batter, kips | Resitance due to Bending, kips | Group Efficiency | Lateral Resitance | |
|---|---|---|---|---|---|---|---|---|
| 1 | Row 1 | 0 | 13 | 0.0 | 299 | 1.000 | 299 kips | |
| 2 | Row 2 | 0 | 12 | 0.0 | 276 | 1.000 | 276 kips | |
| 3 | Row 3 | 0 | 11 | 0.0 | 253 | 1.000 | 253 kips | |
| 4 | Row 4 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 5 | Row 5 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 6 | Row 6 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 7 | Row 7 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 8 | Row 8 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 9 | Row 9 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 10 | Row 10 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 11 | Row 11 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 12 | Row 12 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 13 | Row 13 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 14 | Row 14 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| 15 | Row 15 | 0 | 0 | 0.0 | 0 | 1.000 | 0 kips | |
| | | | 36 | | 828 | | **828 kips** | **OK** |

| BARR ENGINEERING | | | DATE | 2/11/2011 | SHEET NO. |
|---|---|---|---|---|---|
| | | | PROJECT NAME | FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4 | |
| COMPUTED | CHECKED | SUBMITTED | PROJECT NUMBER | 34091004 | |
| MBI 2/11/11 | | MBI | SUBJECT | Maple Aquaduct Structure - Retaining Walls | |
| | | | | Panel G 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 | 0.58 | 13.386 | 1.27 | 29.58 |
| Case 2 | 100 yr. flood + ice | Unusual | 0.75 | 0.58 | 13.386 | 0.95 | 22.19 |
| Case 3 | 500 yr. flood | Unusual | 0.75 | -0.46 | 7.856 | -0.77 | 13.02 |
| Case 4 | T.O. Levee | Extreme | 0.75 | -8.20 | -53.141 | 13.59 | 88.08 |
| Case 5 | Normal flow + ice | Usual | 1 | 3.59 | 23.264 | 7.93 | 51.41 |
| Case 6 | Construction | Unusual | 0.75 | 3.59 | 23.264 | 5.95 | 38.56 |

**STEM DESIGN VALUES**

| | | |
|---|---|---|
| MU, k-ft/ft | 88.08 | k-ft/ft |
| VU, k/ft | 13.59 | k/ft |

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

**9.3 - Design Strength**

$\phi$ = **0.9** 9.3.2.1 - Tension Controlled sections

**0.75** 9.3.2.3 - Shear and torsion

**FLEXURAL STEEL FOR RECTANGULAR CONCRETE SECTIONS**

| | | |
|---|---|---|
| fy= | 60 | ksi |
| Fc'= | 4 | ksi |
| B1= | 0.85 | |
| Muh = | 88 | k-ft /ft **Includes: hf = 1.3** |
| Vuh= | 13.59 | 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$^2$ = | 51.720 | **ACI 10.5.1** **ACI 10.5.3** |
| REQ'D p= | 0.0009 | **O.K.** p(min)= 3*SQRT(Fc')/fy 200* / fy 4/3*p |
| p= | 0.0012 | 0.00316 0.00333 0.0012 |
| As (REQ'D)= | 0.81 | in$^2$ |

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

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

As = #9 @ 12 = 1.00 in$^2$

**SELECT STEEL**

| | | |
|---|---|---|
| bar #= | 9 | |
| spacing, s= | 12 | in |
| # OF BAR= | 1 | (ENTER 1 IF PER FT, b=12") a |
| As= | 0.999 | in$^2$ |
| d= | 43.4375 | in |
| p = As/bd = | 0.0019 | **O.K. < 0.375pb** **EM 110-2-2104** |
| **p =** | 0.067 | **pb** **MAXIMUM TENSILE REINFORCEMENT** |
| T= As*fy = | 60.0 | k a) For singly reinforced flexural members |
| C= B1*Fc' *b*a = | 299.5 | **a** 1) p = **0.25** pb Recommended limit |
| a= T/C = | 0.200 | in 2) p = **0.375** pb Max. permitted upper limit not requiring special study |
| Mn= T(d - a/2)/12 = | 216.5 | ft-k 3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318 |
| $\phi$ Mn= | 194.9 | ft-k 4) p = >**0.5** pb but ≤ 0.375 pb permitted only if detailed serviceability analysis incl. deflect. Calc. |
| | | b) Use of compression reinf. shall be per ACI 318 |
| | | **> Mu O.K.** |

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

| | | | |
|---|---|---|---|
| Vuh = | 13.6 | k | **NO SHEAR REINF. REQUIRED** |
| Vn = Vuh / $\phi$ = | 18.1 | 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 = | 0.40 | * s |
| but not less than 50bw*s/ fy = | 13.33333333 | * s |
| s max = Av fy / 0.75 sqrt(fc') bw = | 0.00 | in |
| s max = Av fy /50 bw = | 0.00 | in |

**11.5.5.3**

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