TENSION PILES

TENSION PILE

The U-Frame foundation does not experience a net tension. The tension piles are included to achieve the required factors of safety against flotation. The anchors are adequate to provide a pinned support for the chamber base when analyzed as fixed at the walls with the uplift acting on the 110 chamber span. The tension pile locations are shown on Plate B-24A, the connection details are shown on Plate B-24B.

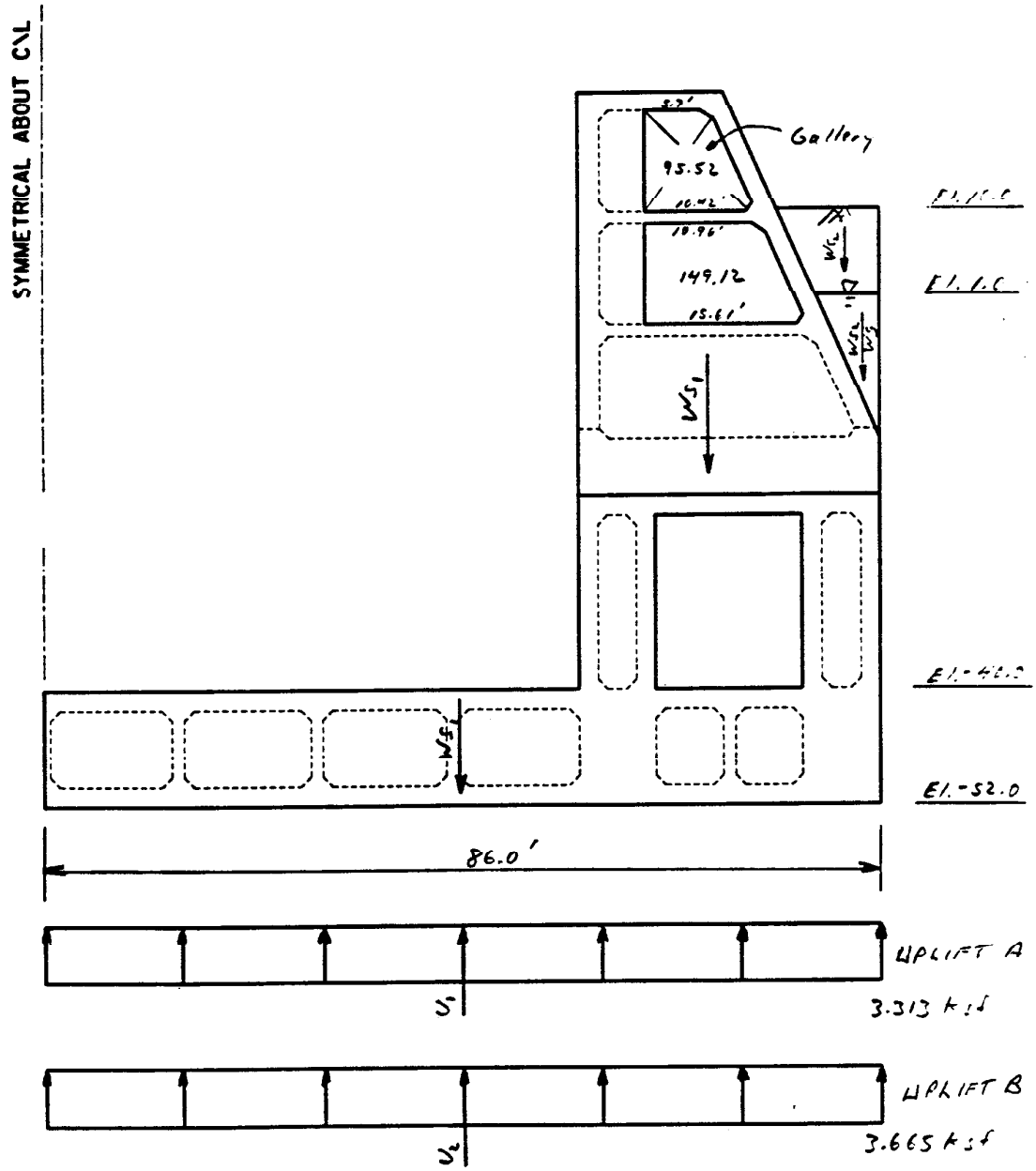
Except for the maintenance dewatering, the factor of safety against flotation for all other load cases equals or exceeds the minimum specified.

LOAD CASE 3 (MAINTENANCE DEWATERING)

RS = 10.0 , LS = 1.0

FLOTATION (UNGROUTED) *

* Grout pad assumed not bonded to precast unit.



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Total Dead Load of Chamber Module per 14' Section (DL_{CM})
(Taken fom pile design input)

$DL_{CM} = DL_{GRAV} + DL_{GALV} + DL_{SOIL}$
= 5821 kips + 3302 kips + 420 kips
= 9543 kips

CHAMBER UPLIFT LOADS

Uplift per 14' Section (UL_{GB})

Load Case

1. Riverside El. 10.0
   Lakeside El. 1.0 Uplift B

2. Riverside El. 10.0
   Lakeside El. 3.0 Uplift B (Extreme Condition)

The tension anchors are designed to provide a minimum Factor of Safety equal to 1.3 for the Maintenance Dewatering Case. The anchors and pile capacity shall also be adequate to provide a pinned support for the base chamber section at the module riverside end. Also, the Factor of Safety for the extreme load case is determined.

Load Case 1 Uplift

H_{avg} = El. 10 - [((El. 10 - El. 1)/1760') X (434'+(446'/2))]
= El. 6.64
Height = (El. 6.64 - El. -52)
= 58.64'
Uplift Pressure = 58.64' X 0.0625 kcf
= 3.66 ksf
Uplift Force = 3.66 ksf X 14' X 172'
= 8825 kips
Factored Uplift = 1.3 X 8825 kips
= 11,472 kips
Required Tension Force
= 11,472k - 9543k = 1930 kips/row

IHNC Lock Replacement

Designed by: P.J.S.
Checked by: MCR

Pile Determination - Maintenance Dewatering, Load Case 3
Chamber: No Water
Tailwater: EL. 1.00

Concrete Weight:

Float-in segment:	1386.00 sf (CADD)	x	14.00 ' strip	x	0.15	=	2910.60	x 2 (other half)	=	5821	kips
Grout:	4.00 ft	x	14.00 ' strip	x	172.00 ft	x	0.1500	=	=	1445	kips
Walls:	786.12 sf (CADD)	x	14.00 ' strip	x	0.15	=	1650.85	x 2 (other half)	=	3302	kips
Water:											
	0.00 ft	x	14.00 ' strip	x	110.00 ft	x	0.0625	=	=	0	kips
	0.00 sf	x	14.00 ' strip	x	0.0625	=	0.00	x 2 (other half)	=	0	kips
Soil:											
Soil with water:	124.83 sf (CADD)	x	14.00 ' strip	x	0.12	=	209.71	x 2 (other half)	=	419	kips
Uplift:											
Tailwater @ El. 1.0: Headwater @ EL. 10.0	3.92 ks (.5(3.84+3.99))	x	14.00 ' strip	x	172.00 ft			=	=	-9427	kips
								Total weight:		1560	kips

Distribute 1560 kips over 172.0 ft: 1560 / 172 = 9.07 kips/ft for a 14' strip

Distribute 125% of load at both ends of monolith and rest of load in middle:

44.00 ft on each end, load is: 9.07 kips/ft x 1.25 = 11.34 kips/ft

so, for 88' of monolith, load is: 88.00 ft x 11.34 = 997.55 kips

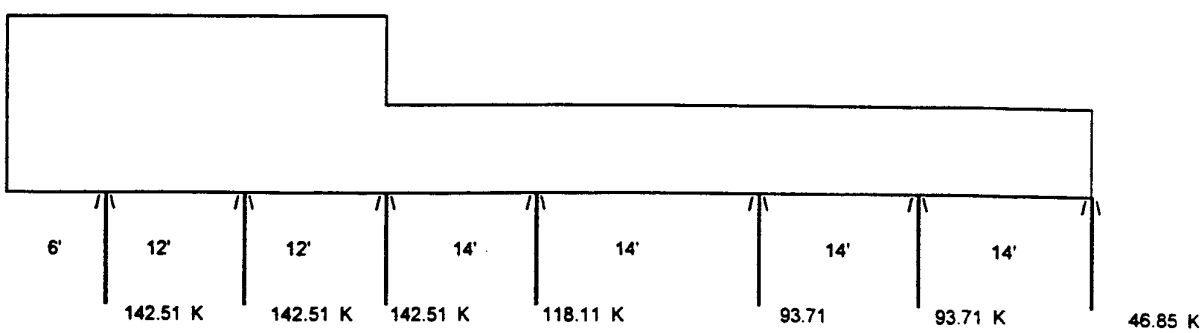
therefore, remaining 84' of monolith will have load of:[(9.07 x 172.00) 997.55] / 84 = 6.69 kips/ft

For 44.00 ft on each end: 88.00 ft x 11.34 / 7.0 piles = 142.51 kips/pile

Using a factor of safety = 2.0, this equates to **142.51 tons/pile**

For 84.00 ft in the middle: 84.00 ft x 6.69 / 6.0 piles = 93.71 kips/pile

Using a factor of safety = 2.0, this equates to **93.71 tons/pile**



TENSION PILE DESIGN

- 3 tension piles per pile row
- 4 tension anchor bars per pile
- Anchor bars ASTM A 687 (fpu = 150 ksi, fy = 105 ksi)
- Allowable Tension Pile Capacity w/ F.S. = 1.5 = 940 kips per pile (See Pile Curve)
- Anchor Permissible Overstress = 1.33

Pile Tension Capacity = 1930 kips/row
= 1930/3 piles per row
= 645 kips/pile < 940 kips available pile capacity

Design connection to resist maximum uplift at the riverside end of the module. This assures that the connection is adequate to act as a pinned support for the base analysis. The Upstream tension connections have a load of 27.11 ksf X 28' = 760 kips.

760 kips/pile < 940 kips available pile capacity

Tension Anchor Design Load = 760 kips / 4 anchors
= 190.00 kips per

<u>Allowable Tension of Anchor Bar (F_t)</u>

F_t = 0.33 F_u (1.33) (per A.I.S.C. Table 1-A)
F_u = 150 ksi
F_t = 0.33 X 150 ksi X 1.33
= 65.84 ksi

Anchor Load = 190.00 kips

Required Area = 190.00 kips / 65.84 ksi
= 2.89 in^2

Anchor Diameter (D)

Area = Π $(D/2)^2$

2.89 in^2 = Π $(D/2)^2$

D = 1.92 in. Use 2 in. Bars

DEVELOPMENT LENGTH (l_d)

Assumptions

1. Coarse threads of threaded anchor rod approximate the grip of a deformed bar (to be test verified)

2. The 2 inch diameter bar ≈ #16 bar, therefore the development length of the #14 bar and #18 bar specified in ACI 318, para 12.2.2 will be averaged.

Development Length

$l_d = (0.085 + 0.125)/2\ f_y\ /\ \sqrt{f'_c}$

f_y = 105,000 psi

f'_c = 4000 psi

$l_d = 0.105(105{,}000\ psi)\ /\ \sqrt{4000}$

= 14.53'

= 14'-6" - **GOVERNS**

$l_{dmin} = 0.03\ d_b\ f_y\ /\ \sqrt{f'_c}$ per ACI 318, 12.2.3.6

d_b = 2 in.

l_{dmin} = 0.03 (2 in.) (105,000 psi) / $\sqrt{4000}$

= 8'-4"

Check Extreme Loading - Load Case 2

H_{avg} = El. 10 - [((El. 10 - El. 3)/1760') X (434'+(446'/2))]

= El. 7.40

Height = (El. 7.4 - El. -52)

= 59.4'

Uplift Pressure = 59.4' X 0.0625 kcf

= 3.71 ksf

Uplift Force = 3.71 ksf X 14' X 172'

= 8934 kips

Available Capacity

Maximum Tension Pile Capacity

Bolt Capacity = $3.14in^2$ X 65.8 ksi = 206 Kips/Bolt

Pile Capacity = 206 X 4 = 824k > 760 Kips

= Dead Load + Pile Capacity

= 9543 + 3(760) = 11823 Kips

F.S. extreme = 11823/8934

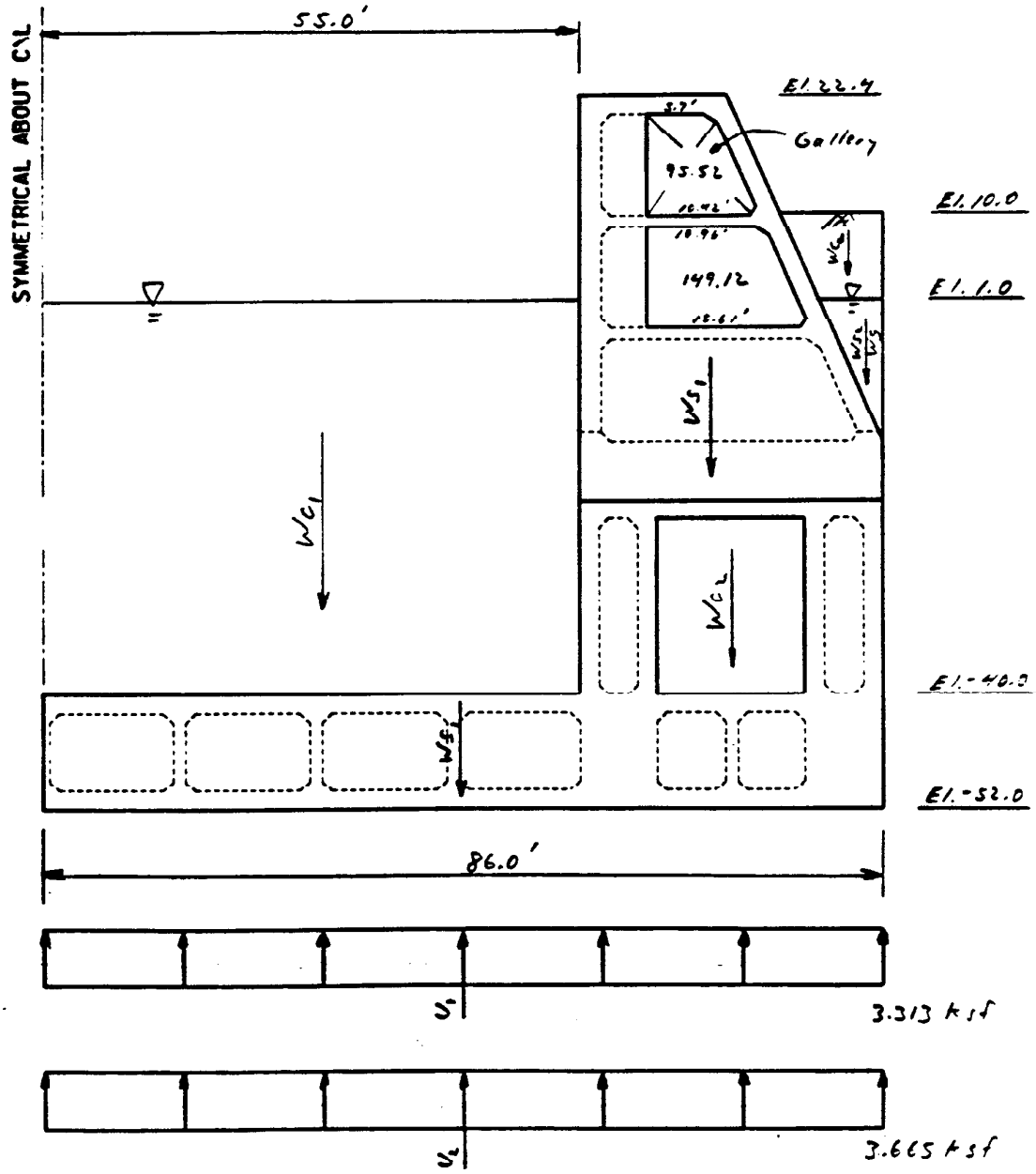
= 1.32

LOAD CASE 1 (NORMAL OPERATION)

RS = 10.0 , LS = 1.0

FLOTATION (UNBONDED)*

* Grout pad assumed not bonded to precast unit.



COMPUTATION SHEET

PROJECT	PAGE 8 OF 15	COMPUTED BY OCB	DATE 6/96
SUBJECT		CHECKED BY	DATE

FLOTATION - CASE 1 (NORMAL OPERATION)

Concrete (WS1)

Lower Precast Vault (Filled)

$A = 1659.75 - 273.75 = 1386.0$ ft.^{2} (CAAA)

$W = 1386.0(14.0)(.15) = 2,910.6^k$

Upper Cast in Place Slab and Walls

$A_v = 1017.45 - 95.52 - 149.12 = 772.81$ ft^2

$W_v = 772.81(14.0)(.15) = 1622.9^k$

$A_o = 149.12$ ft.^{2}

$V_o = 149.12(1.25) = 186.4$ ft.^{3}

$V_L = .5(1.0)(1.0)(2)(6.2 + 10.72 + 11.46 + 16.11) = 44.69$ ft.^{3}

$W_{oc} = (186.4 + 44.69).15 = 34.7^k$

TOTAL CONCRETE (WS1) = 4568.2^k

Backfill (WS2)

Saturated Soil (El. 10.0 to 1.0)

$A = 76.68$ ft.^{2}

$W = 76.68(14.0)(.120) = 128.8^k$

Submerged Soil (El. -13.75 to 1.0)

$A = 48.15$ ft.^{2}

$W = 48.15(14.0)(.0575) = 38.8^k$

TOTAL BACKFILL (WS2) = 167.6^k

COMPUTATION SHEET

PROJECT	PAGE 9 OF 15	COMPUTED BY DCB	DATE 6/96
SUBJECT		CHECKED BY GHY	DATE

Water (Wc)

Operator Controled

$A = 41.0(55.0) + 18.25(15.0) = 2,528.75$ ft.²

$W = 2528.75(14.0)(.0625) = \underline{2,212.7^k}$

Water (Wg)

Gravity Controled

$A = 48.15$ ft.²

$W = 48.15(14.0)(.0625) = \underline{42.1^k}$

Uplift-1 (U_1)

$U_1 = 3.313(86.0)(14.0) = \underline{3988.9^k}$

Uplift-2 (U_2)

$U_2 = .5(3.594 + 3.736)(86.0)(14.0) = \underline{4,412.7}$

FACTORS OF SAFETY

CASE 1-1

$$FS = \frac{4568.2 + 167.6 + 2212.7}{3988.9 - 42.1}$$

$FS = \underline{1.76}$

CASE 1-2

$$FS = \frac{4568.2 + 167.6 + 2212.7}{4412.7 - 42.1}$$

$FS = \underline{1.59}$ *

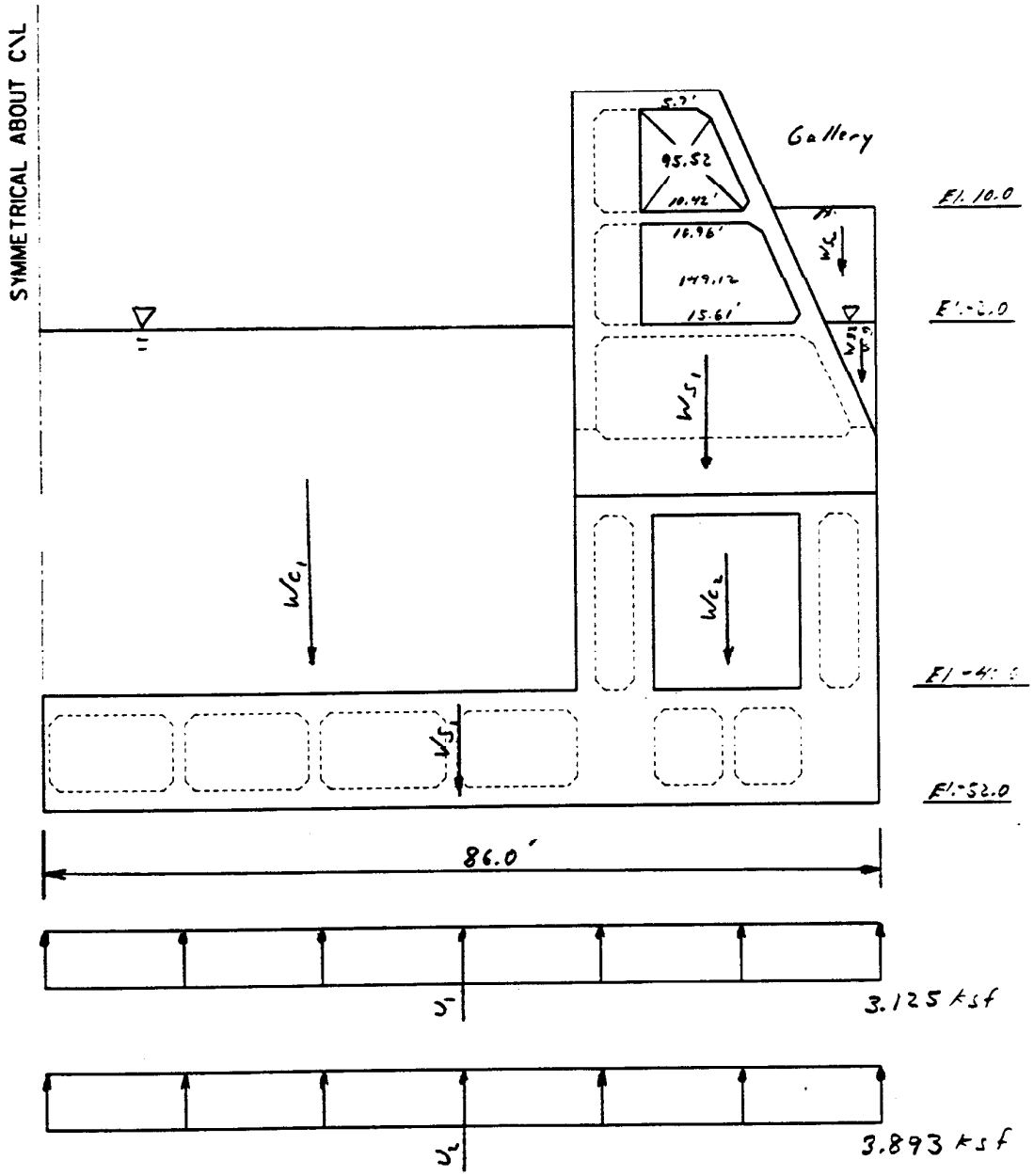
* Torsion piles not required.
$FS > 1.5$

LOAD CASE 2A (MAXIMUM OPERATION)

RS = 17.6, LS = -2.0

FLOTATION (UNBONDED)*

* Grout pad assumed not bonded to precast unit.



COMPUTATION SHEET

PROJECT	PAGE 11 OF 15	COMPUTED BY CCR	DATE
SUBJECT		CHECKED BY	DATE

FLOTATION - CASE 2A (MAXIMUM OPERATION)

Concrete (WS1)

Lower Precast Vault (Filled)

$A = 1659.75 - 273.75 = 1386.0$ ft.^{2} (conc)

$W = 1386.0(14.0)(.15) = \underline{2,910.6^k}$

Upper Cast in Place Slab and Walls

$A_v = 1017.45 - 95.52 - 149.12 = 772.81$ ft^2

$W_v = 772.81(14.0)(.15) = \underline{1622.9^k}$

$A_o = 149.12$ ft.^{2}

$V_o = 149.12(1.25) = 186.4$ ft.^{3}

$V_c = .5(1.0)(1.0)(2)(6.2 + 10.32 + 11.46 + 16.11) = 44.09$

$W_c = (186.4 + 44.69).15 = \underline{34.7^k}$

TOTAL CONCRETE (WS1) = $\underline{\underline{4568.2^k}}$

Backfill (WS2)

Saturated Soil (El. 10.0 to -2.0)

$A = 94.28$ ft.^{2}

$W = 94.28(14.0)(.120) = \underline{158.4^k}$

Submerged Soil (El. -13.75 to -2.0)

$A = 30.55$ ft.^{2}

$W = 30.55(14.0)(.0575) = \underline{24.6^k}$

TOTAL BACKFILL (WS2) = $\underline{\underline{183.0^k}}$

COMPUTATION SHEET

PROJECT	PAGE 12 OF 15	COMPUTED BY ACG	DATE 1/96
SUBJECT		CHECKED BY [illegible]	DATE

Water (W_c)

Operator Controled

$A = 38.0\,(55.0) + 18.25\,(15.0) = 2{,}363.75\ ft^2$

$W = 2363.75\,(14.0)(.0625) = \underline{\underline{2{,}068.3^k}}$

Water (W_g)

Gravity Controled

$A = 30.55\ ft.^2$

$W = 30.55\,(14.0)(.0625) = \underline{\underline{26.7^k}}$

Uplift-1 (U_1)

$U_1 = 3.0\,(86.0)(14.0) = \underline{\underline{3{,}762.5^k}}$

Uplift-2 (U_2)

$U_2 = .5\,(4.043 + 3.558)(86.0)(14.0) = \underline{\underline{4{,}687.2^k}}$

FACTORS OF SAFETY

CASE 2A-1

$$FS = \frac{4568.2 + 183.0 + 2068.3}{3762.5 - 26.7}$$

$FS = \underline{\underline{1.83}}$

CASE 2A-2

$$FS = \frac{4568.2 + 183.0 + 2068.3}{4687.2 - 26.7}$$

$FS = \underline{1.76}$ *

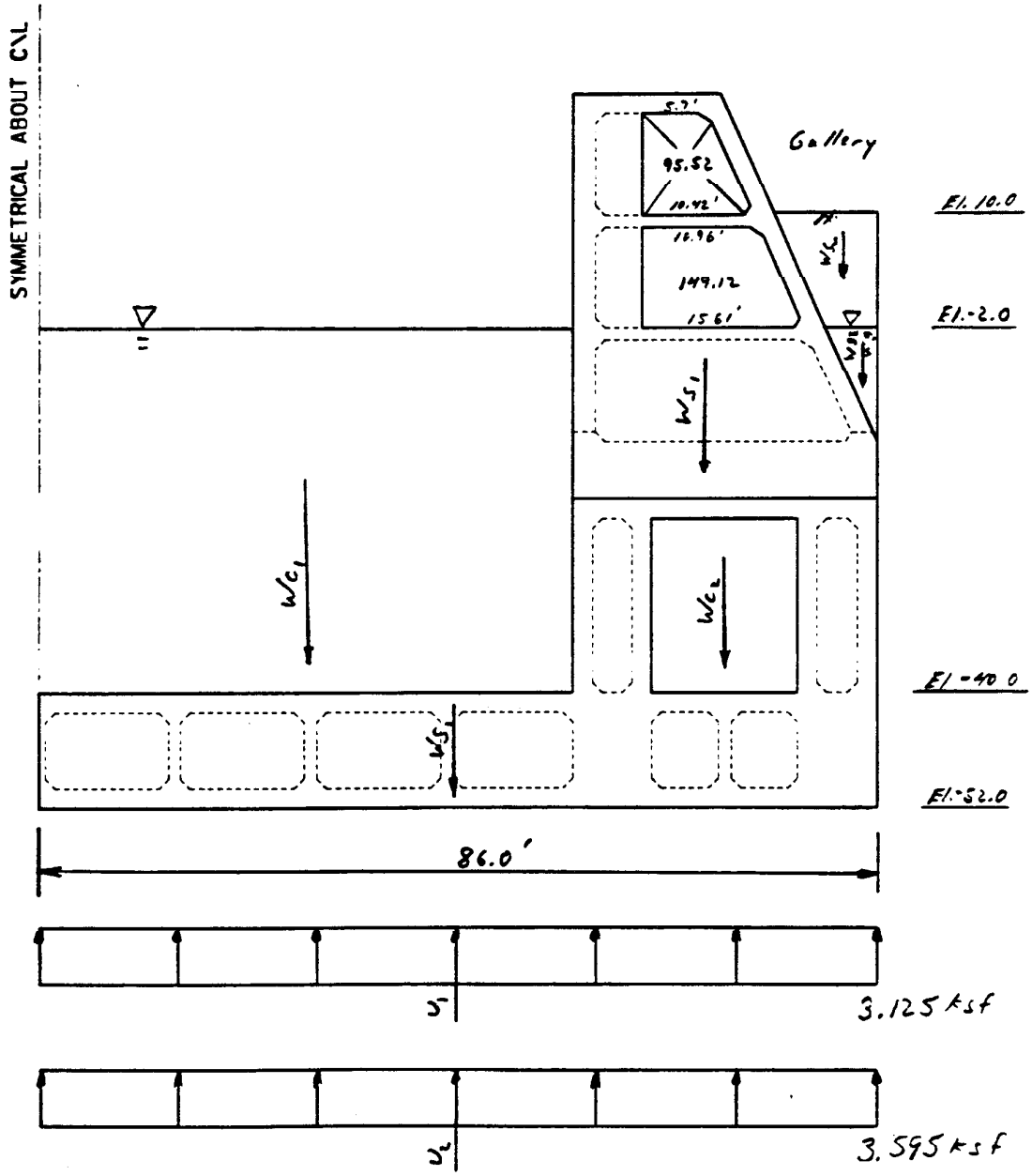
* Tension piles not required.
$FS \approx 1.5$

LOAD CASE 2B (MAXIMUM OPERATION)

RS = 10.0, LS = -2.0

FLOTATION (UNBONDED)*

* Grout pad assumed not bonded to precast unit.



COMPUTATION SHEET

PROJECT	PAGE 14 OF 15	COMPUTED BY OCB	DATE 6/96
SUBJECT		CHECKED BY [illegible]	DATE

FLOTATION - CASE 2B (MAXIMUM OPERATION)

Concrete (WS_1)

Lower Precast Unit (Filled)

$A = 1659.75 - 273.75 = 1386.0\ ft.^2$ (CAAP)

$W = 1386.0(14.0)(.15) = \underline{2,910.6^k}$

Upper Cast in Place Slab and Walls

$A_v = 1017.45 - 95.52 - 149.12 = 772.81\ ft^2$

$W_v = 772.81(14.0)(.15) = \underline{1622.9^k}$

$A_o = 149.12\ ft.^2$

$V_o = 149.12\ (1.25) = 186.4\ ft.^3$

$V_L = .5(1.0)(1.0)(2)(6.2 + 10.92 + 11.46 + 16.11) = 44.69\ ft^3$

$W_{oc} = (186.4 + 44.69).15 = \underline{34.7^k}$

TOTAL CONCRETE (WS_1) = $\underline{\underline{4568.2^k}}$

Backfill (WS_2)

Saturated Soil (El. 10.0 to -2.0)

$A = 94.28\ ft.^2$

$W = 94.28\ (14.0)(.120) = \underline{158.4^k}$

Submerged Soil (El. -13.75 to -2.0)

$A = 30.55\ ft.^2$

$W = 30.55(14.0)(.0575) = \underline{24.6^k}$

TOTAL BACKFILL (WS_2) = $\underline{\underline{183.0^k}}$

COMPUTATION SHEET

PROJECT	PAGE 15 OF 15	COMPUTED BY OCB	DATE 6/96
SUBJECT		CHECKED BY 9/92	DATE

Water (W_c)

Operator Controled

$A = 38.0\,(55.0) + 16.25\,(15.0) = 2{,}363.75\ ft.^2$

$W = 2363.75\,(14.0)(.0625) = \underline{2{,}068.3^k}$

Water (W_g)

Gravity Controled

$A = 30.55\ ft.^2$

$W = 30.55\,(14.0)(.0625) = \underline{26.7^k}$

Uplift-1 (U_1)

$U_1 = 3.125\,(86.0)(14.0) = \underline{3{,}762.5^k}$

Uplift-2 (U_2)

$U_2 = .5(3.690 + 3.500)(86.0)(14.0) = \underline{4{,}328.4^k}$

FACTORS OF SAFETY

CASE 2B-1

$$FS = \frac{4568.2 + 183.0 + 2068.3}{3762.5 - 26.7}$$

$FS = \underline{1.83}$

CASE 2B-2

$$FS = \frac{4568.2 + 183.0 + 2068.3}{4328.4 - 26.7}$$

$FS = \underline{1.59}$ *

* Tension piles not required.
FS > 1.5