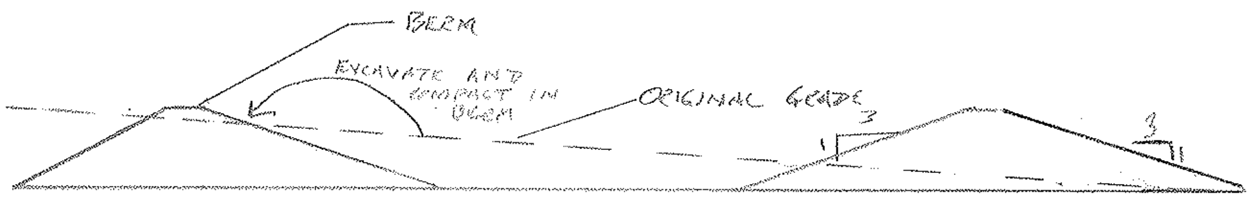
Written by: S. FITZWILLIAM Date: 22 / 06 / 06 (DD MM YY) Reviewed by: [illegible] Date: 23 / 06 / 06 (DD MM YY)

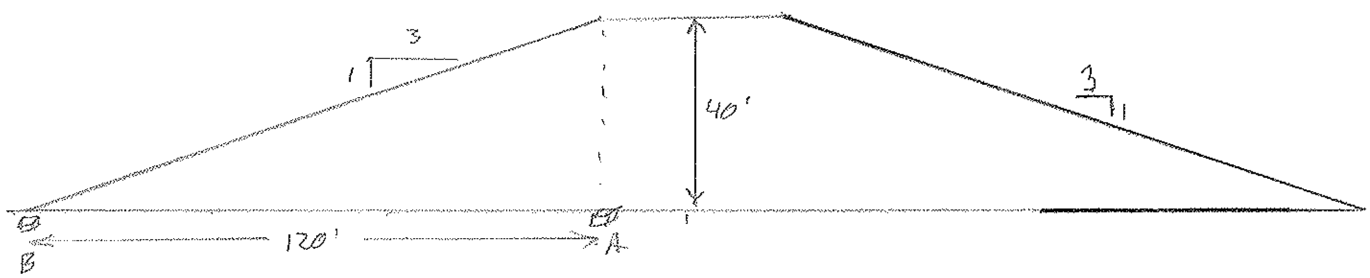
Client: IUC Project: CELL 4A Project/Proposal No.: SC0349 Task No: 01 / 04

SETTLEMENT EVALUATION OF BERMS

SUBJECT: EVALUATE THE DIFFERENTIAL SETTLEMENT UNDER THE LOADING FROM THE BERMS AT THE PERIMETER OF THE CONTAINMENT PONDS, TO ASSESS THE POTENTIAL EFFECT ON THE CLAY LINER



EVALUATE SETTLEMENT UNDER CENTER OF BERM VS. INSIDE OF BERM ON 3:1 SLOPE



FROM BERM COMPACTION TESTS USE $\gamma_{max} = 125\ pcf$ (FILL)

$$P, LOAD = \gamma_{max} H = (125\ pcf)(40\ ft) = 5{,}000\ psf$$

THE FOUNDATION FOR THE BERM CONSIST OF [illegible] SOIL CONSISTING OF SILTY AND CLAYEY COARSE TO FINE SAND

Written by: S. FITZWILLIAM Date: 22/06/06 Reviewed by: GTC Date: 23/06/06

Client: IUC Project: ______ Project/Proposal No.: ______ Task No: ______

EVALUATE THE ELASTIC STRAIN OF THE FOUNDATION DUE TO LOADING UNDER THE BERM

STRESS-STRAIN MODULUS, E_s ⇒ FROM BOWLES, 4th ED. (ATTACHMENT A)

$E_s = 1{,}500$ ksf

USE BOUSSINESQ CASE FOR INFLUENCE UNDER A TRIANGULAR LOAD AS PRESENTED IN DM7.1-171 (ATTACHMENT B)

SEE SPREADSHEET #1 ATTACHED

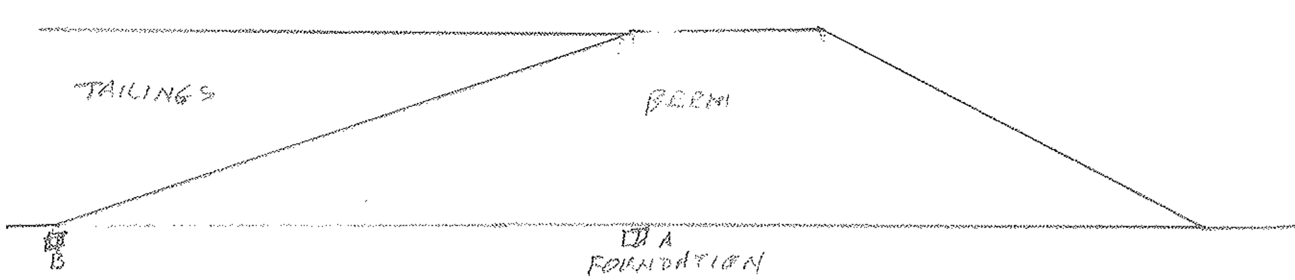
SETTLEMENT UNDER A = 4.4 in
" " B = 2.5 in

$\Delta S = 1.9$ in

LINER IS $\left[(120')^2 + (40')^2\right]^{1/2} = 126.5$ ft LONG

STRAIN IN LINER IS $\frac{1.9}{(126.5)(12 \text{ in/ft})} = 0.13\%$

SUBJECT 2: EVALUATE THE SETTLEMENT UNDER THE BERM UPON FILLING OF THE POND



Settlement due to load under the embankment

B = 120
L = 1000
P = 5000

Under top of berm - Point A

z ft	n = B/z	m = L/z	I	4I	σz = 4I*P ksf	Es ksf	ΔH ft	S in
5	24	200	0.24	0.96	4.8	1500	5	0.192
10	12	100	0.235	0.94	4.7	1500	5	0.188
15	8	66.66667	0.23	0.92	4.6	1500	5	0.184
20	6	50	0.22	0.88	4.4	1500	5	0.176
40	3	25	0.2	0.8	4	1500	20	0.64
60	2	16.66667	0.175	0.7	3.5	1500	20	0.56
80	1.5	12.5	0.158	0.632	3.16	1500	20	0.5056
100	1.2	10	0.14	0.56	2.8	1500	20	0.448
150	0.8	6.666667	0.108	0.432	2.16	1500	50	0.864
200	0.6	5	0.085	0.34	1.7	1500	50	0.68
							Total	4.4376

Under toe of slope - Point B

z ft	n = B/z	m = L/z	I	4I	σz = 4I*P ksf	Es ksf	ΔH ft	S in
5	24	200	0.08	0.32	1.6	1500	5	0.064
10	12	100	0.08	0.32	1.6	1500	5	0.064
15	8	66.66667	0.08	0.32	1.6	1500	5	0.064
20	6	50	0.08	0.32	1.6	1500	5	0.064
40	3	25	0.08	0.32	1.6	1500	20	0.256
60	2	16.66667	0.08	0.32	1.6	1500	20	0.256
80	1.5	12.5	0.08	0.32	1.6	1500	20	0.256
100	1.2	10	0.08	0.32	1.6	1500	20	0.256
150	0.8	6.666667	0.078	0.312	1.56	1500	50	0.624
200	0.6	5	0.07	0.28	1.4	1500	50	0.56
							Total	2.464

SPREADSHEET #1

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Client: IUC Project: CELL 4A Project/Proposal No.: SC0349 Task No: 01/04

UPON FILLING THE POND THE FOUNDATION UNDER B MAY SETTLE DIFFERENTIALLY COMPARED WITH THE THE TOP OF THE BERM AT POINT A.

E_s = 1,000 ksf BERM (ATTACHMENT A)
γ_{max} = 125 pcf

γ_{max} = 125 pcf TAILINGS

E_s = 1,500 ksf FOUNDATION SOIL

LOAD OVER B = (125 pcf)(40 ft) = 5,000 psf

LOAD OVER A = 5,000 psf AT A DISTANCE OF 120 FT

UNIFORM LOADING (AERIAL FILL) UNDER B
ASSUME B = 200 ft FOR INFINITELY
LONG FOOTING, USE DM7.1 - 167 (ATTACHMENT C)

SEE ATTACHED SPREADSHEET # 2

DIFFERENCE IN SETTLEMENT BETWEEN B AND A
IS 8.45 - 6.01 = 2.44 in

STRAIN IN LINER $\frac{2.44}{(124.5)(12)}$ = 0.16 %

Settlement due to load from tailing in pond

B = 200
L = 1000
P = 5000

Under top of berm - Point B

z ft	z/B	I	σz = I*P ksf	Es ksf	ΔH ft	S in
5	0.025	0.99	4.95	1500	5	0.198
10	0.05	0.98	4.9	1500	5	0.196
15	0.075	0.96	4.8	1500	5	0.192
20	0.1	0.92	4.6	1500	5	0.184
40	0.2	0.9	4.5	1500	20	0.72
60	0.3	0.85	4.25	1500	20	0.68
80	0.4	0.8	4	1500	20	0.64
100	0.5	0.75	3.75	1500	20	0.6
150	0.75	0.6	3	1500	50	1.2
200	1	0.52	2.6	1500	50	1.04
300	1.5	0.4	2	1500	100	1.6
400	2	0.3	1.5	1500	100	1.2
					Total	8.45

Under toe of slope - Point A (120/200 = 0.6B from center)

z ft	z/B	I	σz = I*P ksf	Es ksf	ΔH ft	S in
5	0.025	0.9	4.5	1500	5	0.18
10	0.05	0.8	4	1500	5	0.16
15	0.075	0.75	3.75	1500	5	0.15
20	0.1	0.7	3.5	1500	5	0.14
40	0.2	0.6	3	1500	20	0.48
60	0.3	0.5	2.5	1500	20	0.4
80	0.4	0.5	2.5	1500	20	0.4
100	0.5	0.45	2.25	1500	20	0.36
150	0.75	0.4	2	1500	50	0.8
200	1	0.33	1.65	1500	50	0.66
300	1.5	0.29	1.45	1500	100	1.16
400	2	0.28	1.4	1500	100	1.12
					Total	6.01

SPREADSHEET #2

JOSEPH E. BOWLES

FOUNDATION ANALYSIS AND DESIGN

FOURTH EDITION

ATTACHMENT A (1/2)

TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

The *modulus of subgrade reaction* k_s is defined as the ratio of stress to deformation as shown on Fig. 2-37*c*. The units of k_s are the same as unit weight.

The shear modulus G' (and may be subscripted) is defined as the ratio of shear stress to shear strain. It is related to E_s and μ as

$$G'_s = \frac{s}{\epsilon_s} = \frac{E_s}{2(1 + \mu)} \qquad (b)$$

The shearing strain ϵ_s is the change in right angle at any corner of an element as in Fig. 2-37*b* such that

$$\epsilon_s = \text{angle } BCD - \text{angle } B'C'D' \qquad (c)$$

Another concept occasionally used is the volumetric strain, defined as

$$\epsilon_v = \frac{\Delta V}{V} = \epsilon_1 + \epsilon_2 + \epsilon_3 \qquad (d)$$

ATTACHMENT A (2/2)

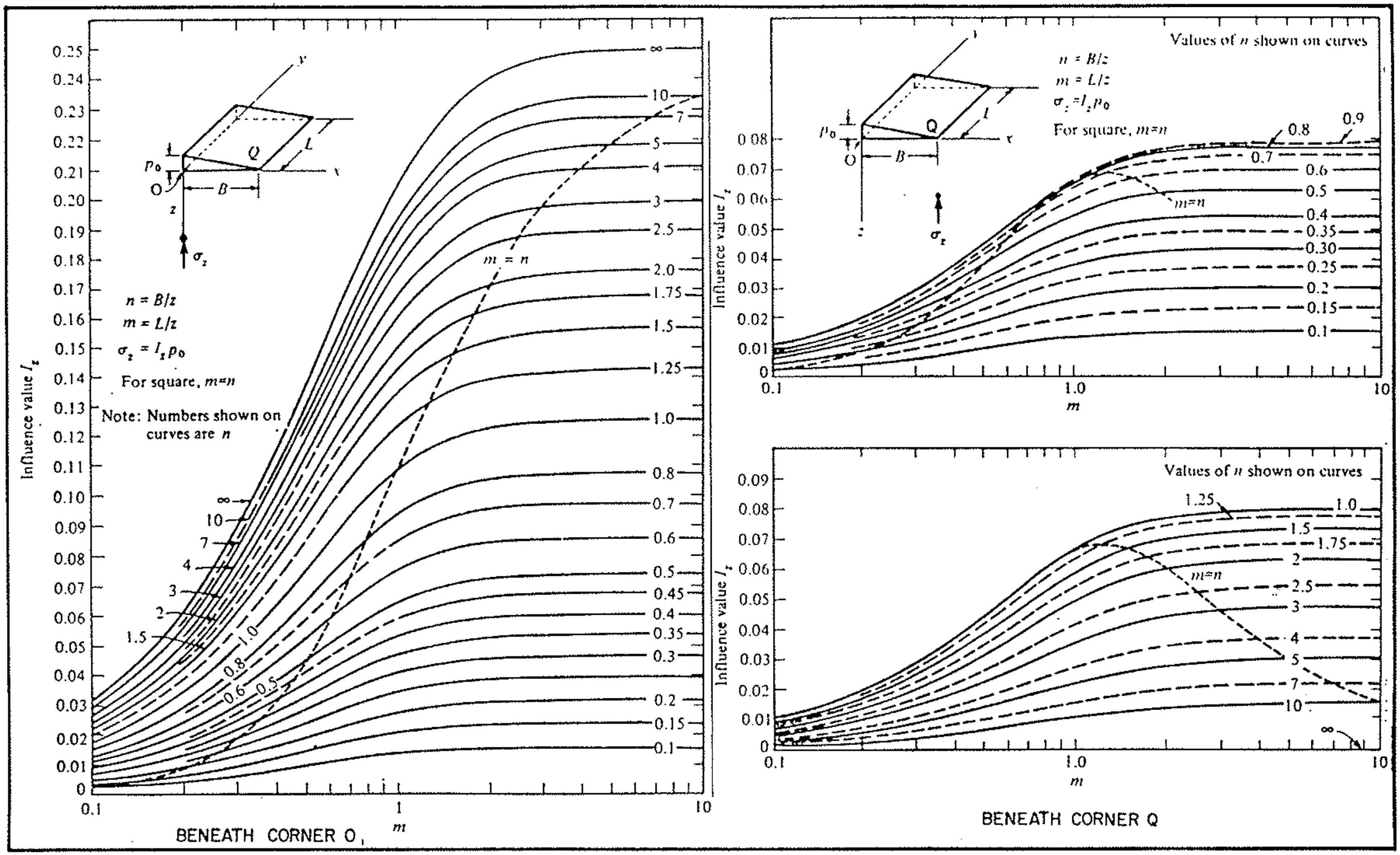
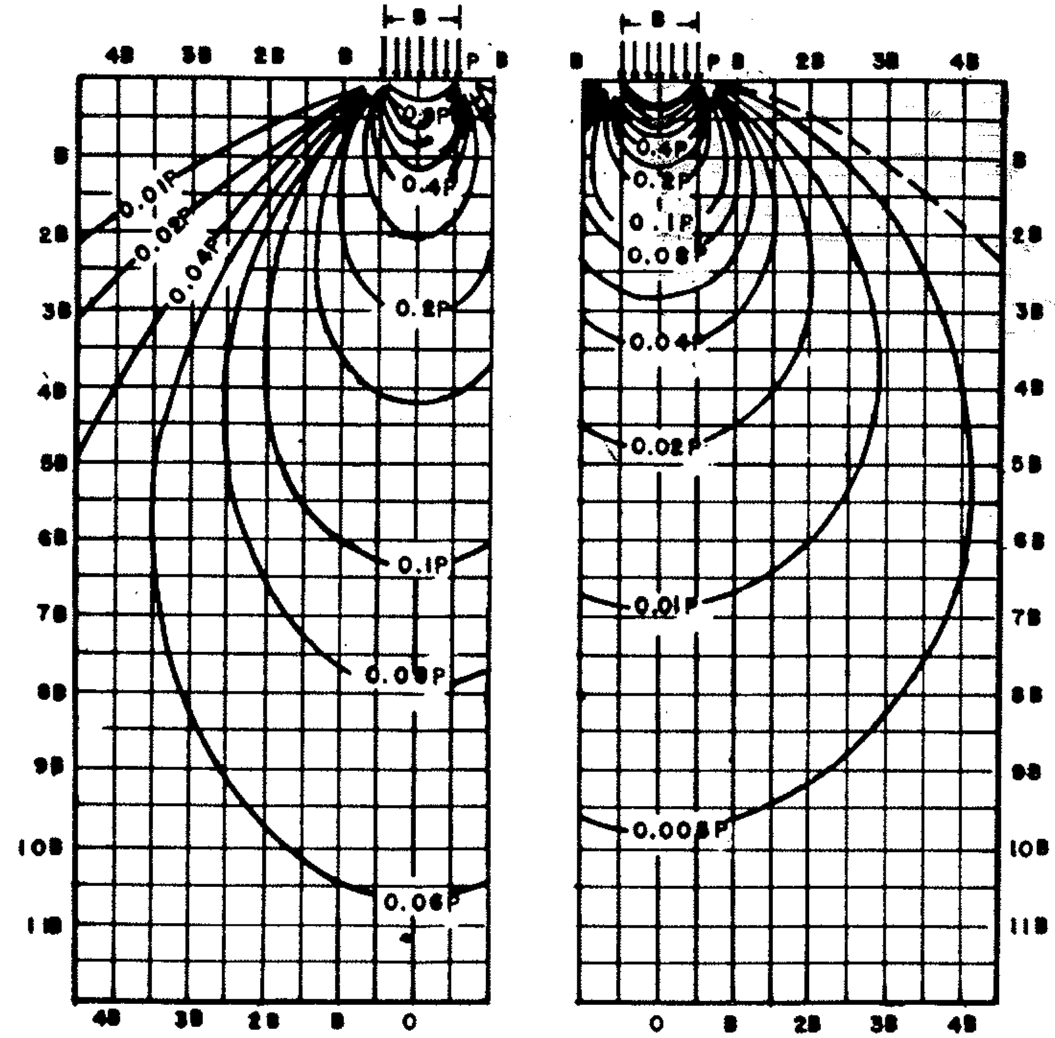


FIGURE 7
Influence Value for Vertical Stress Beneath Triangular Load
(Boussinesq Case)

ATTACHMENT B



a. INFINITELY LONG FOOTING

b. SQUARE FOOTING

SQUARE FOOTING

GIVEN

FOOTING SIZE = 20'X 20'

UNIT PRESSURE P = 2 TSF

FIND

PROFILE OF STRESS INCREASE BENEATH CENTER OF FOOTING DUE TO APPLIED LOAD

B = 20' P = 2 TSF

Z (FT)	Z/B	σ_z TSF
10	0.5	0.70 X 2 = 1.4
20	1	0.38 X 2 = 0.76
30	1.5	0.19 X 2 = 0.38
40	2.0	0.12 X 2 = 0.24
50	2.5	0.07 X 2 = 0.14
60	3.0	0.05 X 2 = 0.10

FIGURE 3
Stress Contours and Their Application

ATTACHMENT C