APPENDIX F

SETTLEMENT AND STABILITY CALCULATIONS

APPENDIX F

SETTLEMENT AND STABILITY CALCULATIONS

SUBJECT Proposed Modifications
Fortsmouth Reclaim Ash Site

BY FKN DATE 3-23-90 PROJ. NO. 83-302-50
CHKD. BY CFS DATE 3-26-90 SHEET NO. 1 OF 4

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

Problem:

See attached plan. It is currently proposed to raise the top of pile to elevation 89 from elev 51. Six H to one V (6H:1V) side slopes are proposed. How does this change affect settlement and stability?

Settlement:

Vertical stress due to wt of embankment is ~ 89 - 20 = 69' of fly ash @ 100 pcf = 6900 psf.
= 3.5 TSF

Original calcs in GAI Feasibility Report, 83-302, Jan 1984, in App C. See pp 14 of 17 by OLB for initial settlement calc. Est settlement = 0.6 ft for 25 feet of fly ash.

See Dwg 83-305-A15 in that report for consolidation test of ponded fly ash below the liner. (Copy attached).
The average slope of the recompression curve to ~ 3.5 TSF is 0.13. e_o = 1.61
From pp 14 of 17, compressible fly ash below liner ~ 17' thick, P_o = 0.19 TSF

$$S = \frac{C_{cr}}{1+e_o} H \log \frac{P_o + \Delta P}{P_o}$$

$$S = \frac{0.13}{1+1.6} (17') \log \frac{0.19 + 3.5}{0.19} = 1.1 \text{ feet}$$

The liner below the center of the proposed embankment at elevation 89 will settle about 1 to 1½ feet. Differential settlements will be gradual and thus, the liner should not be overstressed due to settlement.

SUBJECT Proposed Modifications
Portsmouth Reclaim Ash Site

BY FRN DATE 3-23-90 PROJ. NO. 83-302-50

CHKD. BY CFS DATE 3-26-90 SHEET NO. 2 OF 4

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

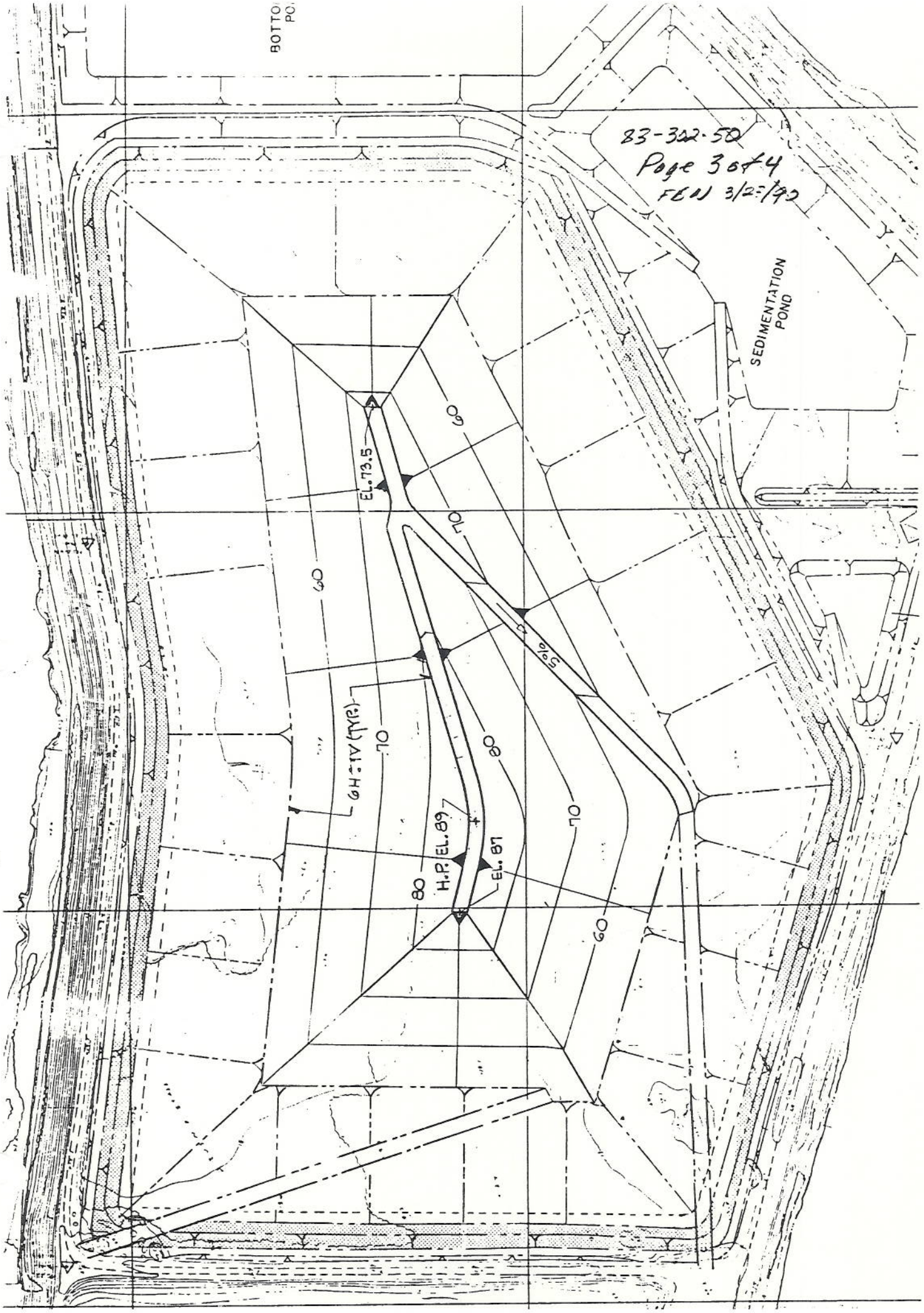
Stability:

See pp 20 of 17, DLB, 1984 rpt, Appn C.

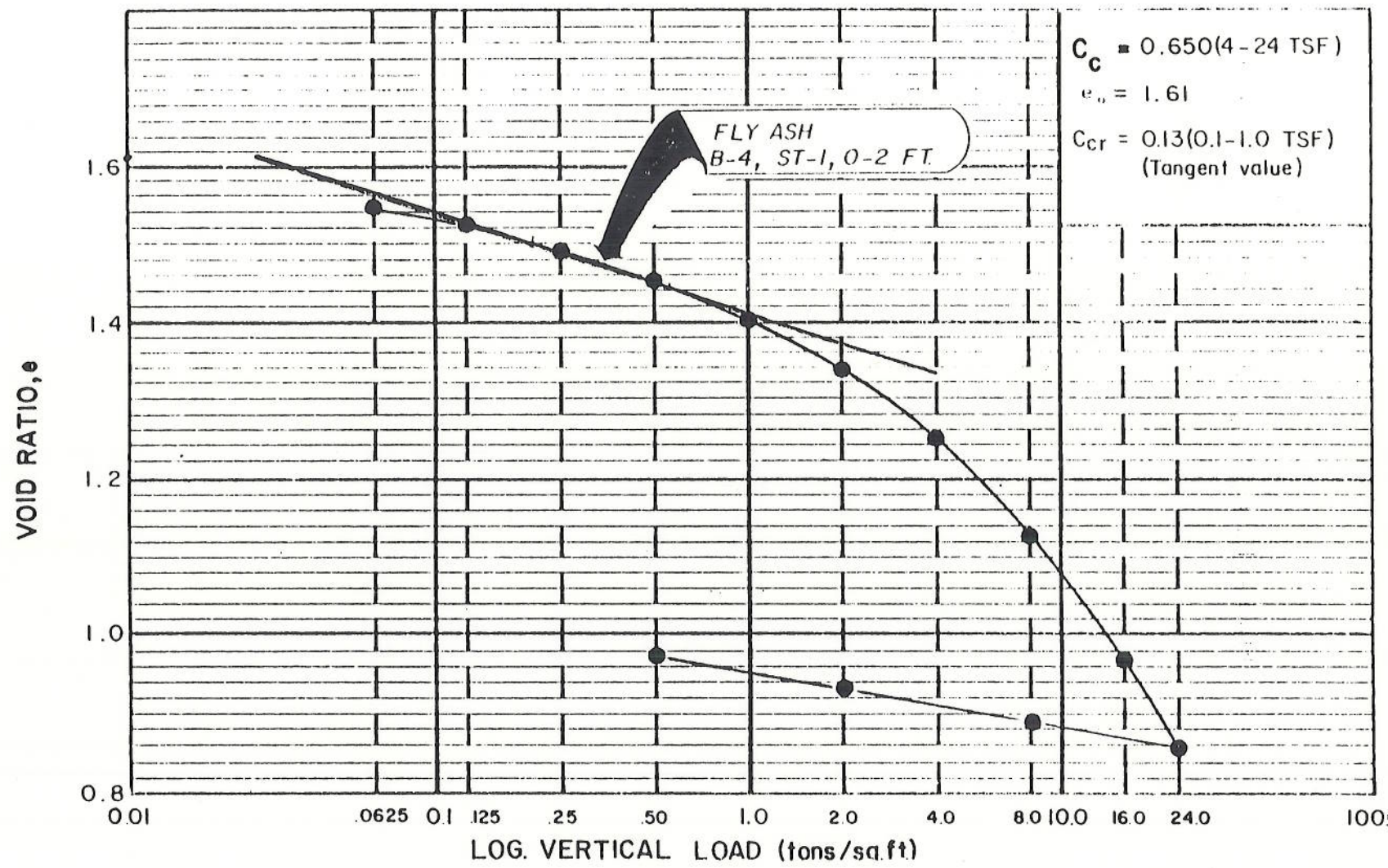
The analysis presented in that calculation remains valid. i.e. a 6H:1V slope with steady state seepage will have a safety factor of ≥ 1.5. The fact that the top of the pile will be more sloped-to-drain at el 89 than the currently planned el 51 top should reduce the steady state seepage conditions within the the ash pile. This may increase stability over the current design. However, there will still be some mounding of water on the liner and lateral seepage toward the toe of the 6H:1V slope. Thus, the previous analysis by DLB still remains applicable.

The addition of the fill above elevation 51 to el 89 is far enough away from the perimeter dikes of the original pond so as not to apply additional surcharge loading to the perimeter dikes. The proposed fill is outside the zone of influence of the perimeter dikes.

It is concluded that the previous analyses remain applicable and that the safety factor against sliding of the proposed addition is ≥ 1.5.


83-322-50
Page 3 of 4
FEN 3/25/92
SEDIMENTATION POND
EL. 73.5
60
70
80
5%
6H:1V (TYP.)
H.P. EL. 89
EL. 87

DWG. NO.



Page 4 of 4
FSW 3/23/93

ONE DIMENSIONAL CONSOLIDATION TEST

CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists
570 Beatty Rd • Pittsburgh,
Monroeville, Pa 15146
412-242 6530

ONE DIMENSIONAL CONSOLIDATION TEST
RECLAMATION OF THE EXISTING ASH POND
PORTSMOUTH POWER STATION

VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA

DWN. ___ CHKD. ___
APPD. ___ DATE ___
SCALE: AS SHOWN
DRAWING NUMBER
83-302-A15
REV

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS.

BY DLB DATE 11/23/83 PROJ. NO. 83-302

CHKD. BY DB DATE 11/29/83 SHEET NO. 1 OF 17

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

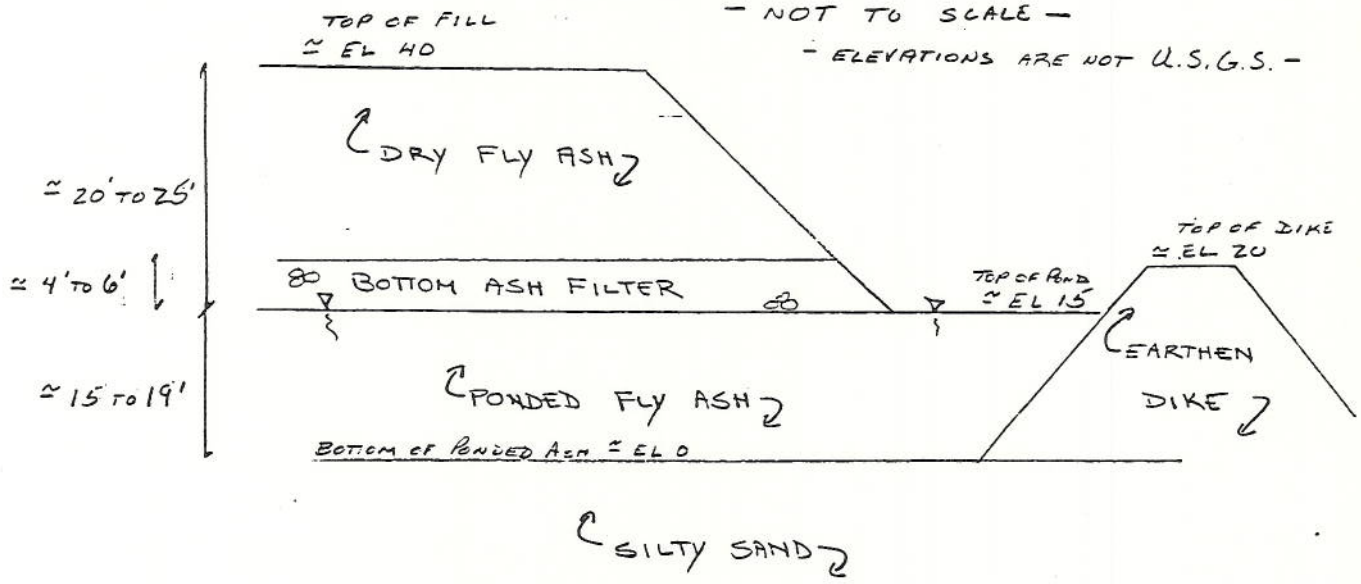
SLOPE STABILITY (FLY ASH EMBANKMENT)

PROBLEM: DETERMINE THE MAXIMUM ANGLE OF SLOPE THAT CAN BE SAFELY MAINTAINED IN A DRY FLY ASH FILL PLACED ATOP PONDED FLY ASH AS SHOWN IN THE FOLLOWING FIG. 1. ASSUMED MINIMUM F.S. = 1.5

FIGURE 1

- NOT TO SCALE -

- ELEVATIONS ARE NOT U.S.G.S. -



ASSUME STRENGTH PARAMETERS AS FOLLOWS

FOR DRY FLY ASH AND BOTTOM ASH MATERIAL $\phi = 25^{\circ}$ * $C = 0$ PSF (SEE REF 1, PG 2-32

* ASSUME FLY ASH AND BOTTOM ASH ARE HOMOGENEOUS. THIS IS CONSERVATIVE

REF 1 "COAL ASH DISPOSAL MANUAL", 2ND EDITION, EPRI, CS-2049 BY GAI CONSULTANTS, OCTOBER 1981

REF 2 SLOPE STABILITY SHORTCOURSE FOR PENNDER, by P.M. WIMBERLY AND R.A. BRAGG, GAI CONSULTANTS, INC., 1983

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 11/23/83 PROJ. NO. 83-302

CHKD. BY DB DATE 11/29/83 SHEET NO. 2 OF 17

GAI CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

CONSULT THE DESIGN CHARTS BY E. HOEK (SEE REF 2, APP 10)

CHOOSE GROUNDWATER FLOW CONDITION 2 TO SIMULATE SITE CONDITIONS (SEE REF 2, PT 10, PG 233)

FROM CIRCULAR FAILURE CHART NO. 2 (REF 2, APP 10, PG 235)

$$\frac{c}{\gamma H \tan\phi} = 0$$

$$\frac{\tan\phi}{F} = \frac{\tan 25^\circ}{1.5} = 0.311$$

0.311 ROUGHLY CORRESPONDS TO A SLOPE ANGLE $\alpha \cong 9^\circ$

6H:1V IS 9.5°

MAXIMUM MAINTAINABLE SLOPE IS ABOUT 6H:1V

NOW, USE STRENGTH PARAMETERS DETERMINED BY SCHNABEL ENGINEERING ASSOCIATES AND CONTAINED IN A REPORT TO VEPCO DATED 5/30/83

STRATUM DESCRIPTION	PARAMETERS
WITHIN ASH POND - VERY LOOSE, BLACK, FLY ASH FILL (N = 1 TO 3)	$\gamma_{WET} = 99.9$ PCF $w_c = 68.8\%$ $\phi = 30^\circ$ $C = 0$ $\gamma_{DRY} = 58.9$ PCF

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 11/23/83 PROJ. NO. 83-302

CHKD. BY DB DATE 11/29/83 SHEET NO. 3 OF 17

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

AGAIN, FROM HOEK'S CIRCULAR FAILURE CHART NO. 2 (REF 7, APP 10, PG 235)

$$\frac{c}{\gamma H \tan\phi} = 0$$

$$\frac{\tan\phi}{F} = \frac{\tan 30^\circ}{1.5} = 0.385$$

0.385 ROUGHLY CORRESPONDS TO A SLOPE ANGLE $\chi \simeq 11^\circ$

5H : 1V IS 11.3°

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 11/23/83 PROJ. NO. 83-302

CHKD. BY DB DATE 11/29/83 SHEET NO. 4 OF 17

CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

CONSOLIDATION SETTLEMENT

CONSIDER AGAIN FIGURE 1 (SHEET 1)

IT IS NOTED THAT TEST BORING DATA COMPILED BY SCHNABEL AND GAI INDICATE THAT THE DEPTH OF THE PONDED FLY ASH LAYER VARIES FROM 15' TO 19'.

ASSUME THE PONDED FLY ASH TO BE NORMALLY CONSOLIDATED
CONSIDER CONSERVATIVE CASE WHERE LAYER THICKNESS H = 20'

INITIAL EFFECTIVE STRESS AT MID POINT OF LAYER

* $\bar{\sigma}_{v_0} = (100\,pcf)(10\,ft) - (62.5\,pcf)(10\,ft) = 375\,psf$

OR 0.19 TSF

ADDITIONAL STRESS DUE TO LOADING OF A 25FT DRY FLY ASH FILL

* $\Delta\sigma = (100.0\,pcf)(25\,ft) = 2500\,psf$

OR 1.25TSF

REFERRING TO THE PRESSURE VS. STRAIN PLOT ATTACHED (SEE SHEET 5)

STRAIN CORRESPONDING TO 1.25 TSF LOAD = 5.1%
STRAIN CORRESPONDING TO 0.19 TSF LOAD = 1.3%
$\Delta\delta = (5.1 - 1.3)\% = 3.8\%$

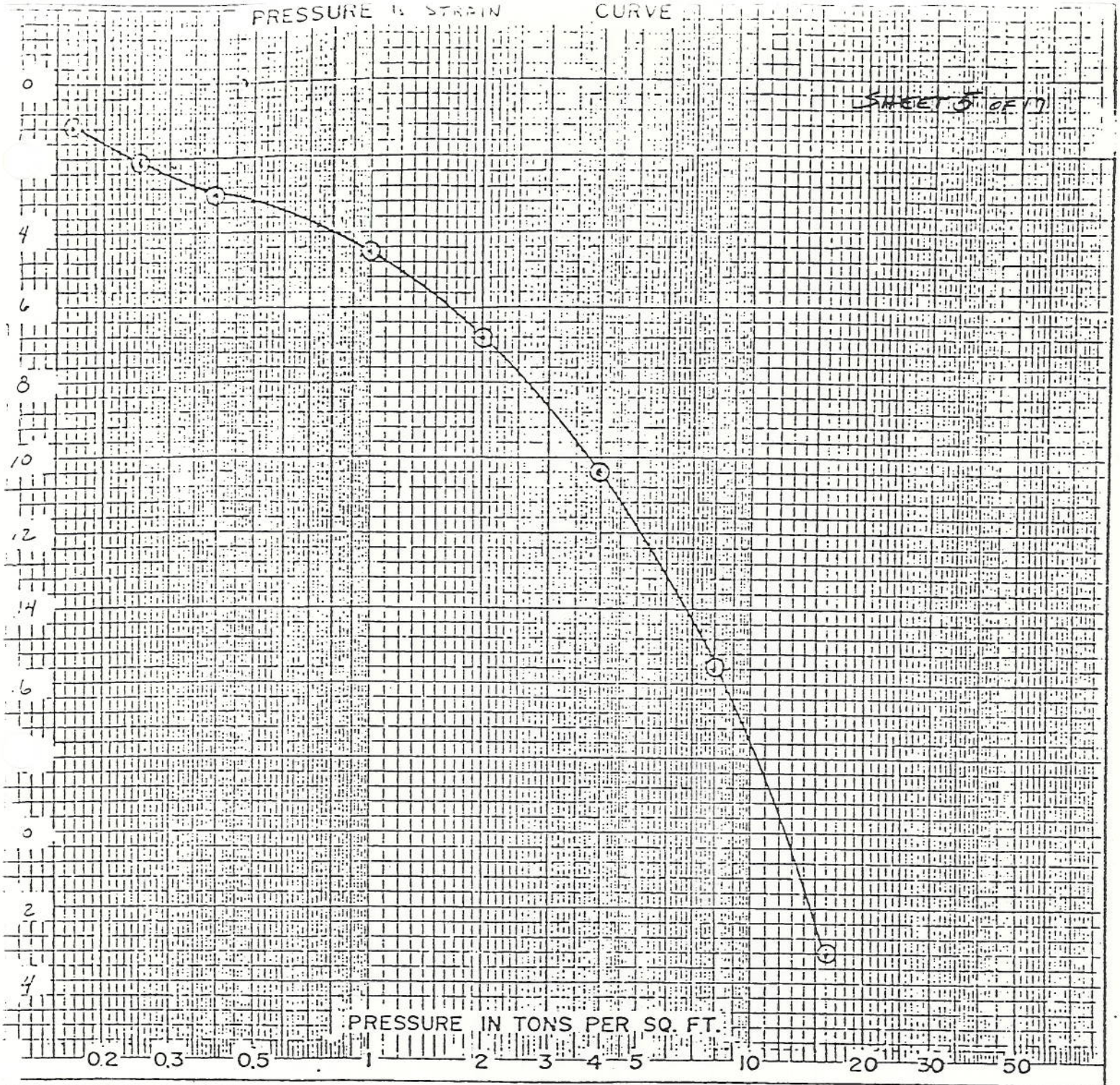
∴ TOTAL CONSOLIDATION OF THE 20FT LAYER OF PONDED FLY ASH SUBJECTED TO A 1.25 TSF LOAD IS AS FOLLOWS:

$(20\,feet)(0.038) = 0.76\,feet$

* SEE SOIL PARAMETERS LISTED EARLIER ON SHEET 2
$\gamma_{MAX} = 100.0\,pcf$ IS ASSUMED FOR DRY FLY ASH FILL

PRESSURE vs STRAIN CURVE

SHEET 5 OF 11



ESCRIPTION OF SPECIMEN:

FLY ASH

ASSIFICATION: STRATUM DESIGNATION: A(3)

IAMETER OF SPECIMEN (in.)	2.50
TIAL THICKNESS OF SPECIMEN (in.)	1.00
ITIAL VOID RATIO, e_o	1.014
BABLE PRECONSOLIDATION STRESS (tsf) P_c	N/A
PROXIMATE OVERBURDEN STRESS (tsf) P_o	0
OMPRESSION RATIO; FROM ½ TO 1 (tsf)	0.0373
MPRESSION INDEX; FROM ½ TO 1 (tsf)	0.0751
ECOMPRESSION RATIO; FROM TO (tsf)	—

SCHNABEL ENGINEERING ASSOCIATES

CONSOLIDATION TEST

BORING NO.: B-6 DEPTH: 2'

PROJECT: ASH POND VEPCO

- PORTSMOUTH, VIRGINIA

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 11/24/83 PROJ. NO. 83-507

CHKD. BY OB DATE 11/29/83 SHEET NO. 6 OF 17

GAI CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

RATE OF CONSOLIDATION

AN ESTIMATE OF THE TOTAL TIME OF CONSOLIDATION WILL BE MADE USING THE FOLLOWING EQUATION

$$t = \frac{H^2}{C_v} = \frac{\gamma_w m_v H^2}{K}$$ (EQ 27.12, LAMBE & WHITMAN, pg 410)

WHERE $\gamma_w = 99.4$ PCF (SEE SHEET 2)

$H = 10$ FT $\Rightarrow$ ONE-HALF THICKNESS OF THE PONDED FLY ASH LAYER. ASSUME DOUBLE DRAINAGE.

$K = 1.0 \times 10^{-5}$ CM/SEC (SEE REF 1, pgs 2-33, 34)

m_v = COEF OF VOL. CHANGE = $\frac{0.435\, C_c}{(1+e_o)\sigma_{va}}$
(SEE LAMBE & WHITMAN, TABLE 12.7, pg 157)

COMPRESSION INDEX $C_c = 0.0722$ (SEE SHEET 8)

$e_o = 1.014$

σ_{va} = AVG OF INITIAL AND FINAL STRESSES
$= (375 + 2500)$ PSF $/ 2 = 1437.5$ PSF
OR 0.719 TSF

$$t = \left(99.4 \tfrac{LB}{FT^3}\right)\left[\frac{(0.435)(0.0722)}{(1+1.014)\left(1437.5 \tfrac{LB}{FT^2}\right)}\right]\frac{(10\,FT)^2\,(2.54\,CM/IN)(12\,IN/FT)}{(1.0\times10^{-5}\,CM/SEC)}$$

$t = 3.3 \times 10^5$ SEC = 91.3 HRS OR 3.8 DAYS

IF SINGLE DRAINAGE WERE TO BE ASSUMED, THEN,

$H = 20$ FT

$\therefore\ t = 1.31 \times 10^6$ SEC = 365.2 HRS OR 15.2 DAYS

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS.

BY DLB DATE 11/28/83 PROJ. NO. 83-302

CHKD. BY DR DATE 11/29/83 SHEET NO. 7 OF 17

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

SUPPLEMENTARY CALCS APPLIED TO SCHNABEL LAB RESULTS

CONSOLIDATION TEST (SEE SCHNABEL REPORT DATED MAY 30, 1980)

SPECIMEN DIMENSIONS

DIAMETER $d = 2.50$ IN

RADIUS $r = 1.25$ IN

INITIAL THICKNESS = 1.0 IN

INITIAL VOLUME $= (1.25\text{ in})^2(1.0\text{ in})(\pi) = 4.909\text{ in}^3$

INITIAL VOID RATIO $e_o = 1.014$

VOLUME OF SPECIMEN $= V_{VOIDS} + V_{SOLIDS} = 4.909\text{ in}^3$

VOID RATIO $e = \frac{V_{VOID}}{V_{SOLIDS}}$

AT e_o $\quad 1.014\,V_S = V_V$

$V_V + V_S = 4.909\text{ in}^3$

$1.014V_S + V_S = 4.909\text{ in}^3$

$V_S = 2.437\text{ in}^3$

$V_V = 2.472\text{ in}^3$

AT 20% STRAIN

SPECIMEN THICKNESS = 0.8 IN

SPECIMEN VOLUME $= (1.25\text{ in})^2(0.8)(\pi) = 3.927\text{ in}^3$

$V_S = 2.437\text{ in}^3$

$V_V = (3.927 - 2.437)\text{ in}^3 = 1.490\text{ in}^3$

$e_{20\%\text{ STRAIN}} = \frac{1.490\text{ in}^3}{2.437\text{ in}^3} = 0.6114$

RELATE % STRAIN TO $\%\,\Delta e$

$\Delta e = e_o - e_{20} = 1.014 - 0.6114 = 0.4026$

$\frac{\Delta e}{e_o}(100) = \frac{0.4026}{1.014} = 39.7\%$

$\therefore$ 20% STRAIN CORRESPONDS TO 39.7% CHANGE IN e

CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

AT 5.1% STRAIN

$$\frac{0.4026}{20} = \frac{\Delta e}{5.1}$$

$$\Delta e = e_0 - e_{5.1} = 0.1027$$

$$e_0 = 1.014$$

$$1.014 - 0.1027 = e_{5.1}$$

$$e_{5.1} = 0.9113$$

AT 1.3% STRAIN

$$\frac{0.4026}{20} = \frac{\Delta e}{1.3}$$

$$\Delta e = e_0 - e_{1.3} = 0.0262$$

$$1.014 - 0.0262 = e_{1.3}$$

$$e_{1.3} = 0.9878$$

THE RECOMPRESSION INDEX C_c FOR THE INTERVAL OF LOADING FROM 0.19 TSF TO 1.25 TSF CAN NOW BE CALCULATED AS FOLLOWS:

$$C_c = \frac{\Delta e}{\Delta \text{Log} P} = \frac{0.9878 - 0.9113}{0.19 - 1.25} = \underline{\underline{0.0722}}$$

SUBJECT VEPCO - PORTSMOUTH POWER STATION
ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 12-9-83 PROJ. NO. 83-302

CHKD. BY DB DATE 1/4/84 SHEET NO. 9 OF 17

JMJ CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

DETERMINE TOTAL VOLUME OF WATER TO BE SQUEEZED FROM THE FLY ASH POND AS A RESULT OF CONSOLIDATION.

ASSUME PONDED FLY ASH IS 100% SATURATED*.

$S = 1.0 = \frac{V_W}{V_V} \quad \therefore \quad V_V = V_W$ (SEE REF 3, pg 30)

REFERRING BACK TO SHEETS 4 AND 8 FOR THE FOLLOWING:

ANTICIPATED LOAD RANGE = 0.19 TSF TO 1.25 TSF
CORRESPONDING STRAIN RANGE = 1.3% TO 5.1%

$e_{1.3\%\ STRAIN} = 0.9878$ (SEE SHEET 8)

$e = \frac{V_V}{V_S} = 0.9878$ (SEE REF 3, pg 30)

$0.9878\, V_S = V_V$ OR $0.9878\, V_S = V_W$
SINCE $V_W = V_V$ FOR $S = 1.0$

SAMPLE VOLUME @ 1.3% STRAIN = $(1.25\,in)^2(1.0 - 0.013)(\pi) = 4.845\,in^3$
WHERE 1.25 in = RADIUS OF CONSOLIDOMETER RING
1.0 in = THICKNESS OF SAMPLE
1.0 in - 0.013 in = THICKNESS OF SAMPLE AT 1.3% STRAIN

TOTAL VOLUME OF SAMPLE = $V_{SOIL} + V_{VOIDS}$ OR $V_{SOIL} + V_{WATER}$

$V_S + V_W = 4.845\,in^3$

$V_S + 0.9878\, V_S = 4.845\,in^3$

$V_S = 2.437\,in^3$

$V_W = 0.9878\,(2.437\,in^3) = 2.407\,in^3$

* IT IS POSSIBLE FOR THE DEGREE OF SATURATION "S" FOR FLY ASH TO BE GREATER THA 100%, WHICH WOULD RESULT IN A GREATER VOLUME OF FLOW DURING CONSOLIDATION. "S" TO BE DETERMINED IN LAB.

REFERENCES

3. SOIL MECHANICS - LAMBE & WHITMAN

SUBJECT UTILCO – PORTSMOUTH POWER STATION
AS+ DISPOSAL EVALUATION – PRELIMINARY CALCS
BY DLB DATE 12-9-83 PROJ. NO. 83-307
CHKD. BY DB DATE 1/4/84 SHEET NO. 10 OF 17

CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

$e_{5.1\% \text{ STRAIN}} = 0.9113$ (SEE SHEET 8)

$0.9113\, V_S = V_W$

SAMPLE VOLUME @ 5.1% STRAIN $= (1.25\,\text{IN})^2 (1.0 - 0.051)\,\text{IN}\,(\pi) = 4.658\,\text{IN}^3$

TOTAL SAMPLE VOLUME $= V_S + V_W = 4.658\,\text{IN}^3$

$V_S + 0.9113\, V_S = 4.658\,\text{IN}^3$

$V_S = 2.437\,\text{IN}^3$

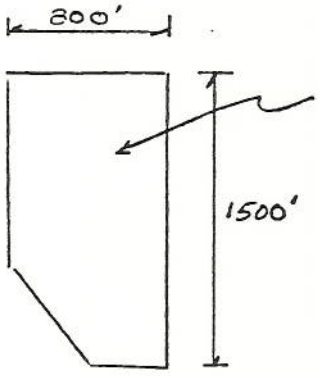
$V_W = 0.9113(2.437\,\text{IN}^3) = 2.221\,\text{IN}^3$

$V_{W\,1.3\% \text{ STRAIN}} - V_{W\,5.1\% \text{ STRAIN}}$ = VOLUME WATER LOST THRU CONSOLIDATION = V_{W_L}

$= (2.407 - 2.221)\,\text{IN}^3 = 0.186\,\text{IN}^3$

V_{WL} / SAMPLE VOLUME $= \dfrac{0.186\,\text{IN}^3 \text{ WATER}}{4.909\,\text{IN}^3 \text{ SOIL}}$

$V_{WL}/\text{CF} = \left(\dfrac{0.186\,\text{IN}^3 \text{ WATER}}{4.909\,\text{IN}^3 \text{ SOIL}}\right)\left(\dfrac{1728\,\text{IN}^3 \text{ SOIL}}{\text{CF SOIL}}\right) = \dfrac{65.47\,\text{IN}^3 \text{ WATER}}{\text{FT}^3 \text{ SOIL}}$ OR $\dfrac{0.038\,\text{FT}^3 \text{ WATER}}{\text{FT}^3 \text{ SOIL}}$



APPROXIMATE DIMENSIONS OF FLY ASH POND

AREA $\simeq (800\,\text{FT})(1500\,\text{FT})(0.8) = 9.6 \times 10^5\,\text{FT}^2$

ASSUME CONSTANT 20 FT DEPTH

VOLUME $\simeq 9.6 \times 10^5\,\text{FT}^2\,(20\,\text{FT}) = 1.92 \times 10^7\,\text{FT}^3$

TOTAL VOLUME OF WATER SQUEEZED OUT BY CONSOLIDATION V_L

$V_L = \dfrac{0.038\,\text{FT}^3 \text{ WATER}}{\text{FT}^3 \text{ SOIL}}\,(1.92 \times 10^7\,\text{FT}^3 \text{ SOIL}) = \underline{\underline{7.3 \times 10^5\,\text{FT}^3}}$

RATE OF FLOW $Q = \dfrac{V_L}{t}$

WHERE $t = 15.2$ DAYS = PERIOD OF CONSOLIDATION

$Q = \dfrac{7.3 \times 10^5\,\text{FT}^3}{1.31 \times 10^6\,\text{SEC}} = \underline{\underline{0.56\,\text{CFS}}}$

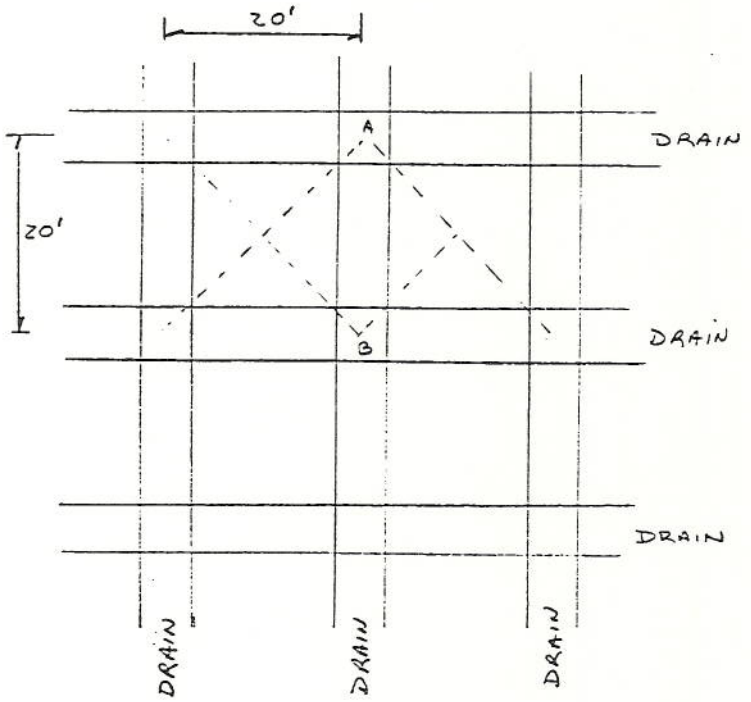
REPRESENTS CONSTANT RATE OF FLOW OVER ENTIRE SITE FOR THE PREDICTED MINIMUM PERIOD OF CONSOLIDATION OF 15.2 DAYS (ASSUMING FREE DRAINAGE)

SUBJECT VEPCO - PORTSMOUTH POWER STATION
ASH DISPOSAL EVALUATION - PRELIMINARY CALCS

BY DLB DATE 12-9-83 PROJ. NO. 83-302

CHKD. BY DB DATE 1/4/84 SHEET NO. 11 OF 17

CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists



DETERMINE WHETHER OR NOT PROPOSED DRAINAGE SCHEME CAN ACCOMMODATE AN AVGERAGE FLOW RATE $Q = 0.56$ CFS

CONSIDER THE ADJACENT PLAN VIEW OF THE PROPOSED DRAINAGE SCHEME.

WICK TYPE DRAINS ARE TO BE PLACED AT 20 FT CENTERS AND OVERLAPPED IN PERPENDICULAR ROWS

A TYPICAL 20 FT LENGTH OF DRAIN WILL SERVE TO DRAIN 200 FT^2 OF AREA

RETURNING TO SHEET 9, THE VOLUME OF WATER SQUEEZED PER SQUARE FOOT OF SOIL IS AS FOLLOWS

$$V_{WL}/CF = \frac{0.038\ FT^3\ WATER}{FT^3\ SOIL}$$

$$V_{WL}/SF = \frac{0.038\ FT^3\ WATER}{FT^3\ SOIL}\ (20FT) = \frac{0.76\ FT^3\ WATER}{FT^2\ SOIL}$$

VOLUME OF WATER EXPECTED OVER 200 FT^2 AREA IS:

$$\frac{0.76\ FT^3\ WATER}{FT^2\ SOIL}\ (200\ FT^2\ SOIL) = 152\ FT^3\ WATER$$

∴ THUS, THE MAXIMUM AVERAGE RATE OF FLOW THAT ANY TYPICAL 20 FOOT SECTION OF DRAIN WOULD BE EXPECTED TO ACCOMMODATE IS 152 FT^3 (WATER) DIVIDED BY THE MINIMUM PERIOD OF CONSOLIDATION OF 15.2 DAYS (1.31×10^6 SEC)

$$Q_{200\ FT^2} = \frac{152\ FT^3}{1.31 \times 10^6\ SEC} = \frac{1.16 \times 10^{-4}\ FT^3}{SEC}$$

SUBJECT VEPCO - PORTSMOUTH POWER STATION
ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 12-9-83 PROJ. NO. 83-302

CHKD. BY DB DATE 1/4/84 SHEET NO. 12 OF 17

JAI CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

FROM AVAILABLE LITERATURE PROVIDING ENGINEERING DATA FOR "ALIDRAIN", THE FOLLOWING DATA IS OBTAINED

FREE SURFACE = $180\ mm^2/m$ (SEE REF 4) (DEFINED AS THE FILTER AREA ALLOWING WATER TO ENTER DIRECTLY INTO THE VOIDS, OR CHANNELS, OF THE DRAINS W/OUT BEING OBSTRUCTED BY THE CORE) (SEE REF 5, PG 10)

THE TOTAL FREE SURFACE FOR A 20 FT SECTION OF DRAIN IS AS FOLLOWS (ASSUME BOTH SIDES OF DRAIN TO BE ACTIVE)

$$(20\ ft)\left(\frac{0.3048\ m}{ft}\right)\left(\frac{180\ mm^2}{mm}\right)\left(\frac{1000\ mm}{m}\right)\left(\frac{1\ m^2}{1\times10^6\ mm^2}\right) = 1.097\ m^2$$

COEFFICIENT OF PERMEABILITY (K) OF "ALIDRAIN" = 3.0×10^{-4} cm/s

∴ TOTAL PERMEABILITY OF A 20 FT SECTION OF "ALIDRAIN" IS AS FOLLOWS:

$$(\text{TOTAL FREE SURFACE})(K) = (10.97\ m^2)\left(\frac{3.0\times10^{-4}\ cm}{sec}\right)\left(\frac{1.0\times10^4\ cm^2}{m^2}\right) = \frac{3.29\ cm^3}{sec}$$

COMPARE TOTAL PERMEABILITY OF A 200FT SECTION TO THE MAXIMUM FLOW EXPECTED DURING CONSOLIDATION

$$Q_{200ft^2} = \frac{1.16\times10^{-4}\ ft^3}{sec}$$ (SEE SHEET 11)

REFERENCES

4. "ALIDRAIN", PROMO. LIT. BY VIBROFLOTATION, INC., PGH., PA

5. "VERTICAL DRAINS - THE BACKGROUND AND THEORY OF VERTICAL DRAINS WITH PATICULAR REFERENCE TO ALIDRAIN", NOTE FOR LECTURE IN SKELLEFTEA, B. H. FELLENIUS, AUG. 24, 1977.

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FGH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 12-9-83 PROJ. NO. 83-302

CHKD. BY DB DATE 1/4/84 SHEET NO. 13 OF 17

GAI CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

$$\frac{1.16 \times 10^{-4}\ FT^3}{SEC}\left(\frac{0.0283\ M^3}{FT^3}\right)\left(\frac{1 \times 10^6\ CM^3}{M^3}\right) = \frac{3.28\ CM^3}{SEC}$$

$$Q_{200_{FT^2}} = \frac{3.28\ CM^3}{SEC}$$

∴ MAXIMUM CONSOLIDATION FLOW RATE < TOTAL PERMEABILITY OF DRAIN

$$\frac{3.28\ CM^3}{SEC} < \frac{3.29\ CM^3}{SEC}$$

FINAL NOTE: SINCE THE ACTUAL LOADING RATE IS EXPECTED TO BE MUCH LESS THAN INSTANTANEOUS, THE TOTAL PERIOD OF CONSOLIDATION WOULD BE EXPECTED TO BE CONSIDERABLY LONGER THAN 15.2 DAYS. THUS, THE AVERAGE FLOW RATE DURING CONSOLIDATION WILL BE LESS THAN 3.28 CM^3/SEC.

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS
BY DLB DATE 1/4/83 PROJ. NO. 83-302
CHKD. BY DB DATE 1/4/84 SHEET NO. 14 OF 17

CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

CONSOLIDATION SETTLEMENT

RECALCULATE TOTAL CONSOLIDATION SETTLEMENT USING THE RESULTS OF THE CONSOLIDATION TEST

SETTLEMENT : $S = \frac{C_c H}{1+e_o} \log \frac{P_o + \Delta P}{P_o}$ (SEE REF 6, EQ 2-30)

where C_c = COEFFICIENT OF COMPRESSION IN ANTICIPATED LOAD RANGE
= 0.1132 (SEE DWG 83-302-A15)

H = STRATUM THICKNESS
= 17 FEET

e_o = INITIAL VOID RATIO
= 1.614 (SEE DWG 83-302-A15)

P_o = EXISTING OVERBURDEN PRESSURE
= 0.19 TSF (SHEET 4)

ΔP = CHANGE IN PRESSURE DUE TO LOADING
= 1.25 TSF − 0.19 TSF = 1.06 TSF (SHEET 4)

$$S = \frac{0.1132 (17\ FT)}{1+1.61} \log \frac{0.19 + 1.06}{0.19} = \underline{0.60\ FEET}$$

REFERENCES

6. BOWLES, J.E. FOUNDATION ANALYSIS AND DESIGN, 2ND EDITION, McGRAW-HILL, 1977

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS

BY DLB DATE 11/23/83 PROJ. NO. 83-302

CHKD. BY DB DATE 1/4/84 SHEET NO. 15 OF 17

CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

RATE OF CONSOLIDATION

REESTIMATE THE TOTAL TIME OF CONSOLIDATION USING A MORE REFINED MODEL AND THE RESULTS OF THE CONSOLIDATION TEST PERFORMED ON THE UNDISTURBED FLY ASH FROM BORING B-4.

$$t = \frac{H^2}{C_v} = \frac{\gamma_w m_v H^2}{K}$$

where $\gamma_{WET} = 86.5$ PCF (SEE TABLE 5)

$H = 17$ FEET MAXIMUM ANTICIPATED THICKNESS OF LAYER, ASSUMES SINGLE DRAINAGE

$K = 7.2 \times 10^{-5}$ CM/S (SEE TABLE 5)

$C_c = 0.1132$ FOR THE RANGE OF LOADING FROM 0.19 TSF TO 1.25 TSF (SEE DRAWING 83-302-A15)

m_v = COEF. OF VOL. CHANGE $= \frac{0.435\, C_c}{(1+e_o)\,\sigma_{vm}}$ (REF 3, pg. 157)

$e_o = 1.614$ (SEE DWG 83-302-A15)

$$t = \left(86.5 \tfrac{LB}{FT^3}\right)\left[\frac{(0.435)(0.1132)}{(1+1.614)(1437.5 \tfrac{LB}{FT^2})}\right]\frac{(17FT)^2(2.54CM/IN)(12IN/FT)}{(7.2\times10^{-5}CM/S)}$$

$t = 1.4 \times 10^5$ SEC $= 38.5$ HRS OR 1.6 DAYS

RECALCULATE USING $C_v = 0.36\ IN^2/MIN$ (AVG VALUE FROM CONSOLIDATION TEST WITHIN LOAD RANGE OF 0.062 TSF TO 1.0 TSF)

$$t = \frac{H^2}{C_v} = \frac{(17FT)^2\,(144 IN^2/FT^2)}{(0.36 IN^2/MIN)} = 1.16 \times 10^5 \text{ MIN OR } 80.3 \text{ DAYS}$$

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS
BY DLB DATE 12/3/83 PROJ. NO. 83-302
CHKD. BY DB DATE 1/4/84 SHEET NO. 16 OF 17

CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

USING RESULTS FROM CONSOLIDATION TEST, DETERMINE TOTAL VOLUME OF WATER TO BE SQUEEZED FROM THE FLY ASH POND AS A RESULT OF CONSOLIDATION (REFER TO SHEET 9)

ASSUME PONDED FLY ASH IS 100% SATURATED ($S=1.0$)*.

$$S = 1.0 = \frac{V_w}{V_v} \quad \therefore \quad V_v = V_w$$

ANTICIPATED LOAD RANGE = 0.19 TSF TO 1.25 TSF

$e_{@\ 0.19\ TSF} \cong 1.5$

$e_{@\ 1.25\ TSF} \cong 1.38$

$$e_{0.19} = \frac{V_v}{V_s} = 1.5$$

$1.5\ V_s = V_v$ OR $1.5\ V_s = V_w$

SINCE $V_w = V_v$ FOR $S = 1.0$

CONSIDER A $1\ FT^2$ SAMPLE AREA THAT IS 17 FEET DEEP

TOTAL VOLUME OF SAMPLE = $17\ FT^3 = V_{SOIL} + V_{WATER}$

$17\ FT^3 = V_s + 1.5\ V_s$

$17\ FT^3 = 2.5\ V_s$

$V_s = 6.8\ FT^3$

$V_w = 1.5(6.8\ FT^3) = 10.2\ FT^3$ @ INITIAL OVERBURDEN

$e_{1.25} = 1.38$

$1.38\ V_s = V_w$

$17\ FT^3 - 0.6\ FT^3 = V_s + 1.38\ V_s$

$16.4\ FT^3 = 2.38\ V_s$

$V_s = 6.89\ FT^3$

$V_w = (6.89\ FT^3)(1.38) = 9.51\ FT^3$ @ TOTAL CONSOLIDATION

VOLUME OF WATER LOST THROUGH CONSOLIDATION FOR SAMPLE $10.2\ FT^3 - 9.51\ FT^3 = 0.69\ FT^3$

SUBJECT VEPCO - PORTSMOUTH POWER STATION
FLY ASH DISPOSAL AREA EVALUATION - PRELIMINARY CALCS
BY DLB DATE 12/3/83 PROJ. NO. 83-302
CHKD. BY DB DATE 1/4/84 SHEET NO. 17 OF 17

CONSULTANTS, INC.
Engineers • Geologists • Planners
Environmental Specialists

FOR ENTIRE POND

APPROXIMATE POND VOLUME = 1.92×10^7 FT^3

$$\frac{0.69 \text{ FT}^3 \text{ WATER}}{17 \text{ FT}^3 \text{ POND}} = \frac{V_L}{1.92 \times 10^7 \text{ FT}^3}$$

V_L = TOTAL VOLUME OF WATER LOST THROUGH CONSOLIDATION OF ENTIRE PONDED AREA

= 7.79×10^5 FT^3 WATER

RATE OF FLOW $Q = \frac{V_L}{t}$

where $t = 80.3$ DAYS = PERIOD OF CONSOLIDATION

$$Q = \frac{7.79 \times 10^5 \text{ FT}^3}{(80.3 \text{ DAYS})(24 \text{ HR/DAY})(3600 \text{ SEC/HR})} = 0.11 \text{ CFS}$$

REFER SHEET 11

DETERMINE MAXIMUM AVG RATE OF FLOW THAT ANY TYPICAL 20 FOOT SECTION OF DRAIN WOULD BE EXPECTED TO ACCOMODATE.

$$\frac{0.69 \text{ FT}^3 \text{ WATER}}{17 \text{ FT}^3 \text{ POND}} = \frac{V_{L200}}{(17 \text{ FT} \times 200 \text{ FT}^2)}$$

V_{L200} = 138 FT^3 WATER = TOTAL VOLUME OF FLOW INTO DRAIN SECTION

$$Q_{\text{DRAIN SECTION}} = \frac{138 \text{ FT}^3}{(80.3)(24)(3600)} = 2.0 \times 10^{-5} \text{ CFS}$$

$$2.0 \times 10^{-5} \frac{\text{FT}^3}{\text{SEC}} \left(\frac{0.0283 \text{ M}^3}{\text{FT}^3}\right)\left(\frac{1 \times 10^6 \text{ CM}^3}{\text{M}^3}\right) = 0.56 \text{ CM}^3/\text{SEC}$$

∴ MAXIMUM CONSOLIDATION RATE < TOTAL PERMEABILITY OF DRAIN

$$\frac{0.56 \text{ CM}^3}{\text{SEC}} < \frac{32.9 \text{ CM}^3}{\text{SEC}}$$

(SEE SHEET 13)

LIQUEFACTION

The potential for liquefaction at the ash structural fill site has been assessed and it is concluded that liquefaction is highly unlikely to occur. Although some site soils and saturated fly ash may be susceptible to liquefaction, an earthquake of sufficient magnitude to cause liquefaction at this site is considered to be improbable.

Subsurface Conditions

No additional subsurface information was obtained for the purposes of this analysis. Subsurface exploration programs previously performed are presented in reports by GAI in 1984 and Schnabel Engineering in 1980. A brief description of the subsurface conditions follows.

Approximately 64 feet of compacted fly ash structural fill is disposed of behind a 5 foot high inner perimeter dikes. Beneath the fly ash and behind the dikes is a 4 foot thick layer of dredged or slurried, saturated fly ash material. The dredged or slurried material is over a synthetic liner. Underlying the synthetic liner is a 20 foot thick layer consisting of previously ponded bottom ash and fly ash. The 20 foot thick layer is not expected to be saturated except under and at the margins of the sedimentation and bottom ash ponds. The elevation of the water table is expected to be near or somewhat above the base of the 20 foot thick layer, which is at the elevation of the adjacent Southern Branch of the Elizabeth River.

The 20 foot thick layer and the ponds are retained by the outer perimeter dikes. Beneath the 20 foot thick layer and the perimeter dikes are deposits of recent alluvium consisting of fine sand, with lenses of silty sand and layers of silty clay.

Based upon grain size and relative density characteristics of the on-site materials, all of the saturated fly ash and recent alluvium are materials that are considered to be potentially susceptible to liquefaction if they happened to be located in areas of significant earthquake activity.

Earthquake Activity. A literature review was performed of historic earthquakes that have been felt in the southeastern United States. Three historic earthquakes were probably felt in southeastern Virginia: the 1811, 1812 New Madrid, Missouri earthquakes; the 1886 Charleston, South Carolina earthquake; and the 1897 Giles County, Virginia earthquake.

New Madrid, Missouri 1811, 1812: A series of three great earthquakes occurred on December 16, 1811; January 23, 1812 and February 7, 1812. The earthquakes were felt for an area of at least 2 million square miles (Coffman and Von Hake, 1973). The three earthquakes had intensity XII near the epicenter.

Regional intensity maps for a New Madrid size earthquake presented in Stander 1982, Street and Nuttli 1990, and MRM Co and Law Engineers, 1980, show that the intensity at the Chesapeake Energy Center ash structural fill site would be about V or VI.

Charleston, South Carolina 1886: On August 31, 1886 a major earthquake of intensity IX-X occurred near Charleston, South Carolina. An isoseismal map from Bollinger, 1977 show that the

intensity at the Chesapeake Energy Center ash structural fill site to be V to VI from the 1886 Charleston, South Carolina earthquake.

Giles County, Virginia 1897: On May 31, 1897 an earthquake with intensity VII was felt over an area of 280,000 square miles. Isoseismal maps prepared by Bollinger, 1981 show the intensity at the Chesapeake Energy Center ash structural fill site from a Giles County earthquake could be as high as VI.

In summary, the largest historical earthquakes to have occurred in the southern and central United States have produced intensities of up to VI on the Modified Mercalli Scale at the Chesapeake Energy Center ash structural fill site. Similar earthquakes, if they were to occur, are expected to produce similar effects on the site. (Note: MMI VI is characterized as an event that is felt by all; with people being frightened and running outdoors, some heavy furniture moving; and a few instances of fallen plaster or damaged chimneys. Damage is slight.)

Seismic risk maps, as presented by the U.S. Army Corps of Engineers, 1983, show that the site is located in seismic zone 1. Seismic zone 1 is an area where minor damage may result from a distant earthquake.

Liquefaction Severity Index

Youd and Perkins, 1987 have developed a technique for estimating the magnitude of lateral spread displacement using a parameter termed Liquefaction Severity Index (LSI). LSI is defined as the maximum lateral spread displacement in inches that is likely to occur on gently sloping deposits that are highly susceptible to liquefaction. Liquefaction is known to have occurred during three

eastern earthquakes: New Madrid 1811, 1812; Charleston 1886; and Sanquenay, Quebec 1988. Using data from these earthquakes, an attenuation curve for LSI was generated (Youd et al., 1989). The Chesapeake Energy Center ash structural fill site for either a Charleston or a New Madrid earthquake, is not included on the chart because the level of shaking is considered too low to cause liquefaction.

Conclusions

A literature search was performed to evaluate the potential for damaging earthquakes at the Chesapeake Energy Center ash structural fill site. The maximum recorded historic earthquake intensity experienced at the site has been a VI. Because of the infrequency of damaging earthquakes in the eastern United States, it is not possible to conclude that earthquake intensities greater than VI will not occur on the site. However, based upon the historical evidence, it is highly improbable that intensities larger than VI will be experienced at the site. This is significant because the threshold for liquefaction of very loose flood plain sands is VII, regardless of earthquake magnitude (Keefer, 1984, Obermeier, 1988). We conclude that the probability of liquefaction damage to the facility is extremely small.

REFERENCES

1. "Feasibility Study, Reclamation of Existing Ash Pond Portsmouth Power Station, Chesapeake, Virginia," prepared for the Virginia Electric and Power Company, Richmond, Virginia, by GAI Consultants, Project No. 83-302, January, 1984.

2. Geotechnical Engineering Study, Ash Pond Dike, VEPCO Power Station, Portsmouth, Virginia, Report Prepared for the Virginia Electric and Power Company, Contract V80072, May, 1990.

3. Coffman, J.L. and C.A. VanHoke, "Earthquake History of the United States," Publication 41-1, 1973.

4. Stauder, W. "Present Day Seismicity and Identification of Active Faults of the New Madrid Seismic Zone," in McKeown, F.A., L.C. Pakiser, eds., Investigations of the New Madrid, MO Earthquake Region: USGS p. 1236-c, P.C. 21-C30, 1982.

5. Street R.L., and O.W. Nuttli, "The Great Central Mississippi Valley Earthquakes of 1811-1812," University of Kentucky Special Publication 14, Series XI, 1990.

6. MRM Company, Engineers and Law Engineering Testing Co., "Regional Seismological Study of Huntingdon District, Corps of Engineers," Unpublished.

7. Bollinger, G.A., "Reinterpretation of the Intensity Data for the 1886 Charleston, South Carolina Earthquake," U.S. Geological Survey pp. 1028-B, 1977.

8. Bollinger, G.A., "The Giles County, Virginia Seismic Zone - Configuration and Hazard Assessment," Proceedings of the Conference on Earthquakes and Earthquake Engineering - The Eastern United States, Knoxville, Tennessee, Vol. 1, September 14-16, pp. 277-308, 1981.

9. Department of the Army, U.S. Army Corps of Engineers, "Engineering and Design Earthquake Design and Analysis for Corps of Engineer Projects," ER 1110-2-1806, 1983.

10. Youd, T.L., and D.M. Perkins, "Mapping of Liquefaction Severity Index," Journal of Geotechnical Engineering, Vol. 113, No. 11, p. 1374-1392.

11. Youd, T.L., D. Perkins, and W.G. Turner, "Liquefaction Severity Index Attenuation for the Eastern United States," Proceedings, 2nd U.S. - Japan Workshop on Liquefaction, Large Ground Deformation and Their Effects on Lifeline, Buffalo, New York. NCEER 89-0032, 1989.

12. Obermeier, S.F. "Liquefaction Potential in the Central Mississippi Valley," USGS Bulletin 1832, 1988.

13. Keefer, D.K., "Landslide Caused by Earthquakes," Geological Society of America Bulletin, V95, pp. 406-421.