Attachment

Engineering Calculation
CE-1386 - Stability of SWR Slope Under Increase Phreatic Surface

North Anna Power Station
Units 1 and 2
Virginia Electric and Power Company

VIRGINIA POWER — CALCULATION COVER SHEET

Type	Sub	Station	Unit	Status	System Code(s)
[CALC]	[CIV]	[59]	[00]	[ ]	[ ]

Calc. Number	Rev.	QA Cat.
[CE-1386]	[0]	[SR]

Calc Title (Subject): STABILITY OF SWR SLOPE UNDER INCREASED PHREATIC SURFACE

Key Words: SLOPE STABILITY, PHREATIC SURFACE, STABILITY ANALYSIS

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Originator: [X] Virginia Power Discipline: ____

[ ] Other Firm Name: ____ Vendor Code: ____

EDS Mark Number References:

Station	Unit	System	Prefix	Sequence	Comp. Code	Suffix
[59]	[00]	[SW]	[PIEZO]	[P-23]	[ ]	[ ]
[59]	[00]	[SW]	[PIEZO]	[P-24]	[ ]	[ ]
[59]	[00]	[SW]	[PIEZO]	[P-10]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

[ ] Additional Mark Numbers? (Check if "yes"). See ____.

Objective: TO CALCULATE THE FACTOR OF SAFETY (F.S.) AGAINST FAILURE OF THE DOWNSTREAM SLOPE OF THE SWR, SE SECTION WITH AN INCREASED PHREATIC SURFACE. THE CALCULATION WAS PERFORMED TO JUSTIFY RAISING THE ALLOWABLE TECH. SPEC. LIMIT FOR THE WATER LEVELS AND DEMONSTRATE THE DOWNSTREAM SLOPE REMAINS STABLE UNDER THE INCREASED WATER LEVELS.

Conclusions: THE DOWNSTREAM SLOPE REMAINS STABLE UNDER AN INCREASE IN THE ALLOWABLE WATER LEVEL (P-10 TO EL 280 FT; P-21 & P-22 TO EL 295 FT.) THE ORIGINAL DESIGN BASIS CALC (ODBC) F.S. WAS 1.5. THIS CALC. F.S. = 1.56 STANDARD > 1.5 (STEADY STATE) SEISMIC (ODBC) 1.2 THIS CALC 1.27 INDUSTRY STANDARD > 1.0

Superseded Calcs: THIS CALC. DOES NOT SUPERSEDE THE ORIGINAL DESIGN BASIS CALC, 11715-141, BUT ENHANCES AND UPDATES THE CALC.

	Signature	Date
Prepared By (Print Name): JOHN S. THORNTON Jr	[signature]	3-26-98
Reviewed By (Print Name): M.L. Blough	[signature]	4-9-98
Other (If Applicable Print Name)		

(May 95)

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	System SERVICE WATER (SW	Checked By [signature]		Date 4-9-98

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	System: SERVICE WATER	Checked By: [signature]		Date: 4-9-98

OBJECTIVE

The objective of this calculation is to determine the factor of safety (F.S.) against a slope stability failure of the downstream slope of the Southeast section of the Service Water Reservoir (SWR) under an increased phreatic surface from the current limits identified in Technical Specification 3/4.7.13 (Ref 1). The water level as measured in piezometer P-22 which is located at the west end of the SE section of the SWR (see Figure 1), exceeded the Tech. Spec. allowable limit of el. 280 ft. and the water level as measured in P-10, located at the toe of slope midway through the SE section is approaching the Tech. Spec. limit of el 277 ft. This calculation is performed to justify raising the allowable Tech. Spec. limits for the water levels along the SE section and demonstrate that the downstream slope remains stable under the increased water levels.

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FIGURE 1
ABJ 4-3-98
MHB 4-9-98

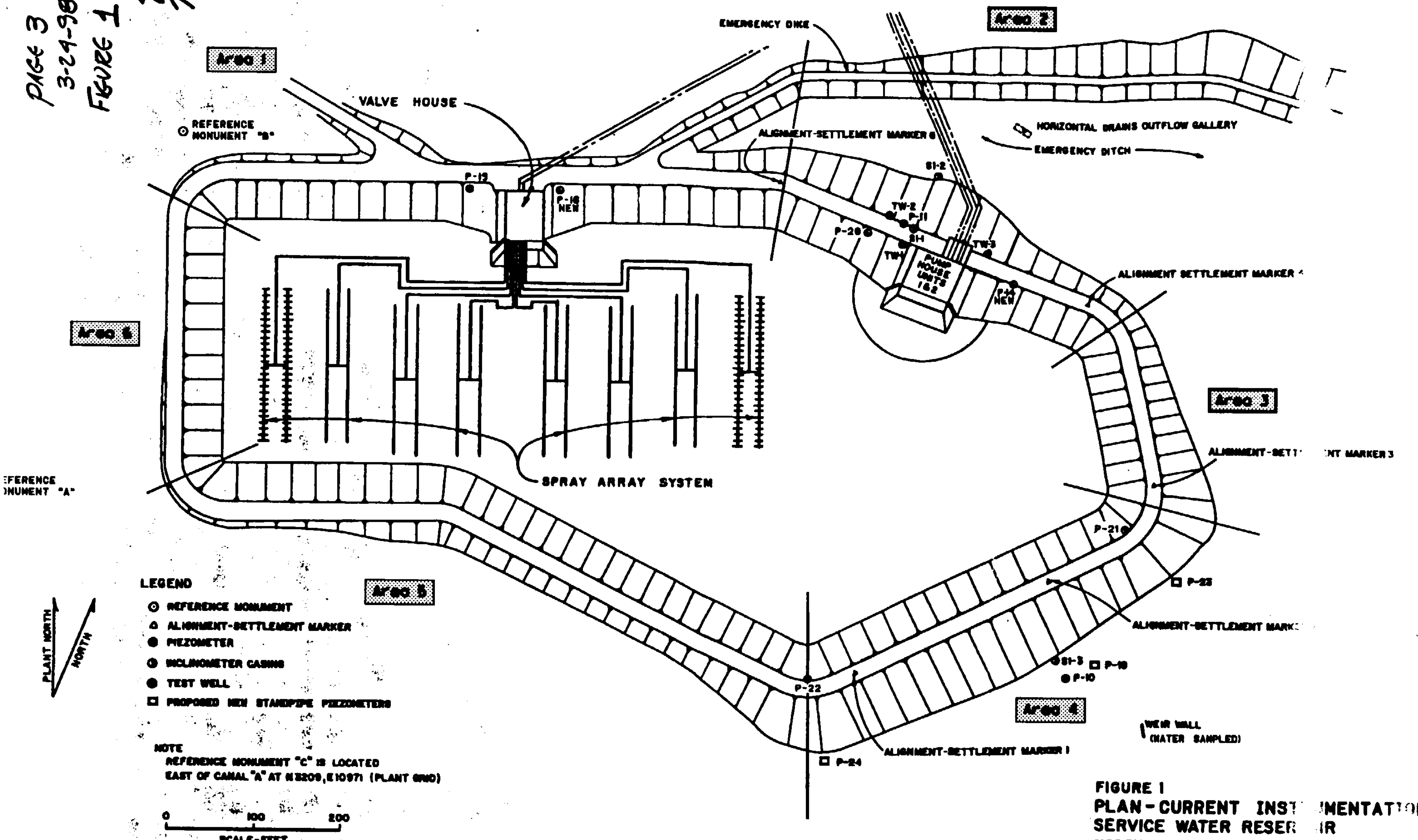

FIGURE 1
PLAN - CURRENT INSTRUMENTATION
SERVICE WATER RESERVOIR
NORTH ANNA POWER STATION

DISCUSSION + BACKGROUND INFORMATION

The original design basis calculation performed in 1974 (Ref. 2) identified the critical section for the downstream steady state seepage case as the section of maximum height located along the SE portion of the SWR. The critical section identified in the calculation was assumed to be 44 ft high (crest el 320 ft, toe el around el 276 ft). The phreatic surface assumed in the calculation extended from the reservoir level (el 315 ft), downstream through the random fill material into the drainage filter exiting the slope two feet below the grade at toe of slope. The critical section from the design basis calculation with the phreatic surface is presented in Figure 2. The calculated F.S. for the critical section and assumed phreatic surface was 1.49 (via computer).

The design basis critical section does not reflect the existing as built dike condition as verified by optical survey performed in June, 1997 (Ref 3). The actual maximum slope height is 37 ft., seven feet lower than the critical section assumed in the design basis calculation.

The location of P-22 is superimposed on the critical dike section depicted in Figure 2. The phreatic surface used in the design

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FIGURE 2

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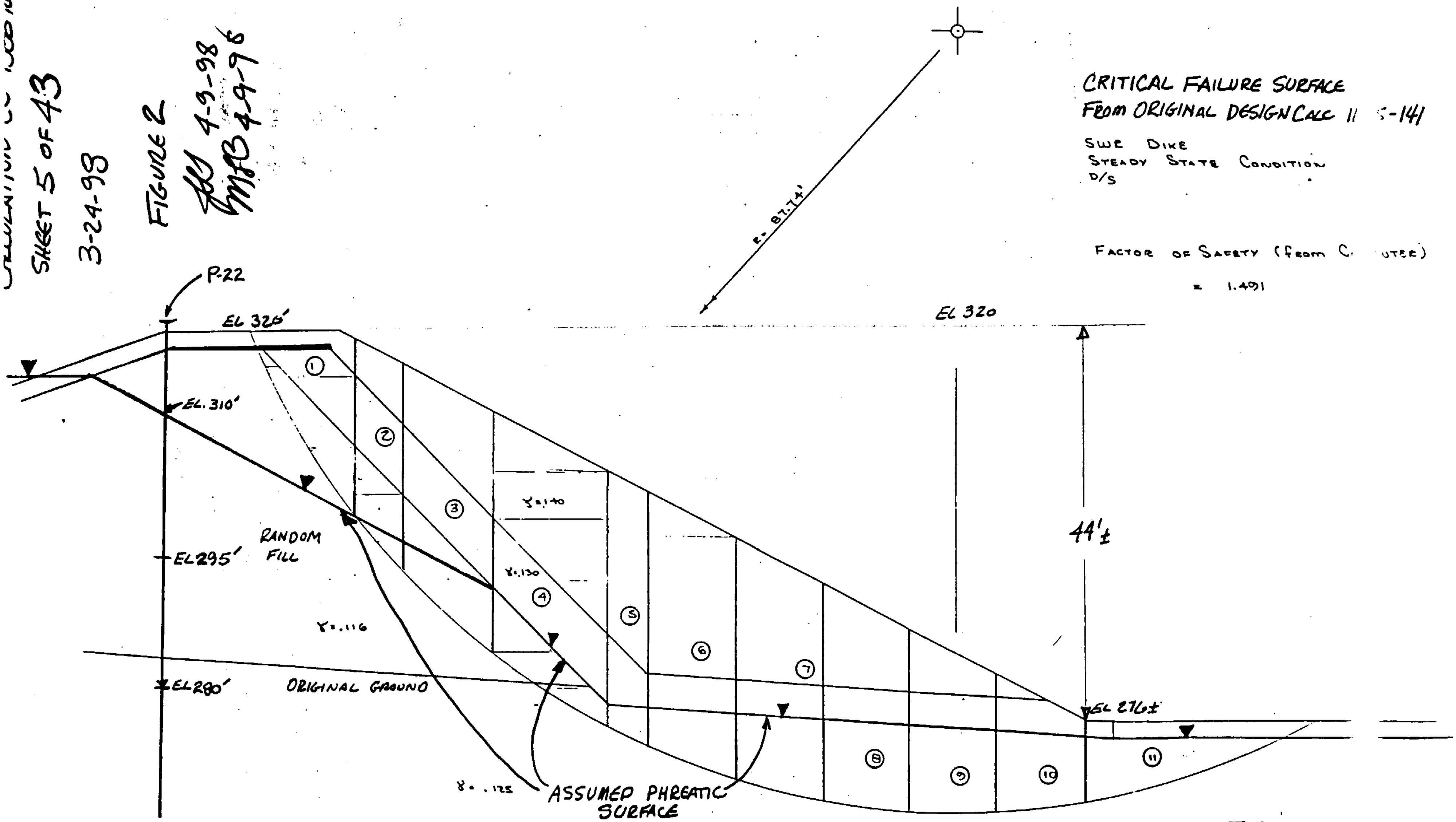

FIGURE 2

FAILURE SURFAC ORIGINAL

DESIGN CALC ATION

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basis calculation corresponding to the location of P-22 is el. 310 ft, 30 ft higher than the maximum level permitted by the Technical Specification (el 280 ft.) and 29± feet higher than the maximum level ever recorded - el 280.9 ft).

The phreatic surface at the toe of slope assumed in the design basis calculation was two feet below the top of ground (el 274 ft) as depicted in Figure 2. The current measured water level in P-10, located 25 ft from toe of the actual slope is around el 276.5 ft, which is 8.5 ft below actual top of ground at the toe of slope. Maximum water level permitted in the Tech. Spec. for P-10 is el 277 ft, 8 feet below existing grade.

Therefore the assumptions used in the design basis calculations are very conservative as compared to the actual conditions stated above.

The design basis calculation assumes 1) a higher than actual section 2) much higher than current allowable or actual phreatic surface at the inboard crest (location of P-22), 3) much higher relative phreatic surface at the toe of slope.

Therefore the design basis calculation is conservative as compared to the actual condition.

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DISCUSSION & BACKGROUND INFORMATION cont'd

Groundwater Levels - The water levels as defined by monitoring of piezometers at the SWR has risen slightly over the last 5 years. This is especially evident along the SE section of the SWR dike. The water level as measured in P-22 exceeded the Technical Specification limit of el 280 ft. on 9/13/96 (see DRN-96-1835, Ref 4) resulting in an engineering evaluation and report dated December 1996 (Ref 5). The report concluded that a gradual increase in water levels had occurred and was caused by a combination of factors one of which was precipitation, but that the stability of the slope remained adequate and a significant increase in seepage from the SWR had not occurred. Plots of the raise in water levels as monitored in piezometers P-22 and P-10 are contained in Ref 5. The water level in P-22 has risen in the eight years since it was installed from a low of el 278 ft to slightly less than el 281 ft. For P-10 the rise over the past 12 years has been from el 274 ft to just under el 277 ft.

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ASSUMPTIONS

The critical section and the assumed phreatic surface used in the original design basis calculation (Ref 2) has been presented in Figure 2

The critical section analyzed in this calculation consists of an as built section through piezometer P-10, approximately midway along the SE section of the dike. The section through P-10 is only two feet lower than the maximum section as defined by the as built survey (Ref. 3). Results of the as built survey of the existing dike along the southeast section is provided in Appendix A. The drawing provides spot elevations at the crest and toe of slope and 50 ft south of the toe of slope. The section through P-10 was selected because it represented the approximate section of maximum height and definitive water elevations at the toe could be obtained through monitoring of piezometer P-10. The phreatic surface assumed for this section is shown on Figure 3. The phreatic surface extends from the reservoir down to the base of the sand filter to P-10. P-22 is superimposed on the figure at its' relative position on the section. The phreatic surface crosses the location of P-22 at el 310 ft and intersects P-10 at el 280 ft. These assumed water levels are conservatively high as the highest water level in P-22 was

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FIGURE 3
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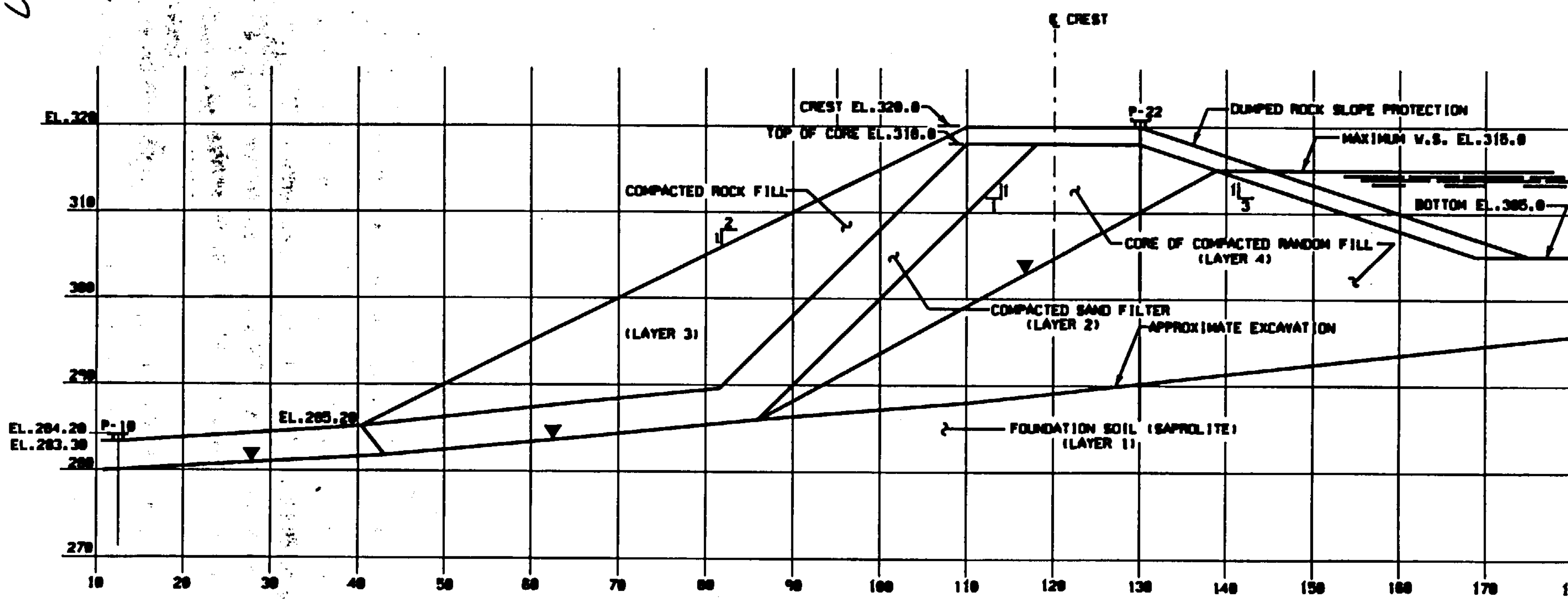


FIGURE 3

SECTION THROUGH P-
SERVICE WATER RESERVOIR
NORTH ANNA POWER STAT

WATER LEVEL @ P10-280, INTERIOR T P-10-310 slightly below el 281. In addition conductivity tests conducted on a water sample taken from P-22 indicate that the water in P-22 is groundwater, not seepage from the SWR. Results of these tests are contained in a letter to the NRC dated January 28, 1998, Serial No. 97-682 (Ref 6). These tests clearly indicate the water monitored in P-22, and P-10 is groundwater (with a maximum el. of approximately 280) not a phreatic surface through the dike.

As in the original design basis calculation (Ref 2), rock was assumed to be present at el 240 ft or below. The failure circles were therefore held above el 240 due to the presence of the rock layer which possesses a much higher shear strength than the foundation soils. The presence of rock in the dike section is also discussed in the UFSAR, Appendix 3E, attachment 5.6 (Ref 7). The same criteria was applied to this calculation i.e. rock is present at el 240 ft. therefore the failure circle is held above el 240 ft since the failure will occur in the weaker (soil) not rock.

The assumption was also made, for the purpose of utilizing a computer assisted search for the critical failure surface, that the failure surface would not be shallower than 10 ft. This restriction does not allow the use of an unrealistically shallow failure surface which may be selected by the computer.

METHOD OF ANALYSIS

The original design basis calculation (Ref 2) used the "Simplified Bishop Method" to obtain the critical circular failure surface, and "Morgenstern Price Method" for the wedge failure method (UFSAR, Section 3.8, Ref 8). The circular failure mode was the most critical. The Simplified Bishop Method uses a conventional two dimensional stability where Factor of Safety against failure (F.S.) = $\frac{\text{Strength to resist driving moment}}{\text{driving moment}}$ or limited equilibrium method.

OR

$$F.S. = \frac{\sum (W-U)\tan\phi \dfrac{\sec\alpha}{1+\dfrac{\tan\phi\tan\alpha}{F.S.\,(\text{assumed})}}}{\sum W\sin\alpha}$$

For effective stress, steady state seepage condition ($\phi > 0$, $C^* = 0$)

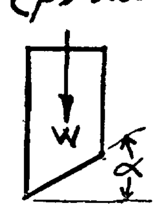
Where

W - Weight of slice

U - uplift on base of slice due to pore pressure (phreatic surface)

ϕ = soil friction angle for base of slice

α = angle of inclination at base of slice →



* C = cohesion

METHOD OF ANALYSIS (cont'd)

The critical failure circle (failure surface with the least F.S) was obtained via computer using SB-SLOPE, from GEOSYSTEMS (Ref 9). This program utilizes the Simplified Bishops method of analysis.

For the downstream face steady state seepage case, a verification run was made with SB SLOPE on the critical section obtained by the original design basis calculation. The same slope geometry, section, height, soil parameters and phreatic surface was used. The results were remarkably similar - SB SLOPE program obtained a F.S. of 1.50 vs 1.49 with the original design basis calculation computer run. Results of the SB SLOPE verification are contained in Appendix B.

Two cases were run for the as built condition with the phreatic surface as discussed and shown in Figure 3. Both focused on the downstream face of the critical section selected along the SE section of the dike.

METHOD OF ANALYSIS cont'd'

CASE 1 - Steady state seepage condition - This case utilizes the soil parameters in the effective stress parameters (ϕ', c'). It was conservatively assumed that no cohesion ($c=0$) was present even in the compacted core, random fill or foundation soils (saprolite).

CASE 2 - Seismic case - Total stress conditions a, consolidation stress parameters were use for soil strength ($\phi + c$ conditions) Some cohesion was present in the compacted random fill and foundation soils (saprolite) and is used in the calculation for this case.

The computer program SB SLOPE was used to determine the minimum F.S. for each case. The results of the computer search for the critical circle - i.e. the coordinates of the failure circle and radius were then used in a hand calculation to verify the results of the computer run.

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System: SW	Checked By: MBB		Date 4/9/98

DESIGN INPUTS

The material properties and soil strength parameters used in the original design basis calculation and in this calculation are the same for the respective layers. The properties and parameters are provided in Table 3.8-13 of the UFSAR (Ref 10) which follows. Table 3.8-13 has been modified and marked up to show the layer designation and the selected set of parameters which were used to analyze the steady state and seismic cases.

The slope geometry including, height of slope, position of soil layers and phreatic surface were discussed in previous sections and are shown on Figure 3.

Any other design inputs are referenced in the body of the calculation.

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Table 3.8-13

MATERIAL PROPERTIES AND STRENGTH PARAMETERS, SERVICE WATER RESERVOIR

DESIGNATION OF LAYER USED IN CALC.*	Material	Saturated Density, γs (pcf)	~~Dry Density, γd (pcf)~~	Effective Stress Parameters ϕ' (deg)	Effective Stress Parameters C' (psf)	Consolidation Stress Strength Parameters ϕ_c (deg)	Consolidation Stress Strength Parameters c (psf)
4	Compacted impervious core and select lining	116	~~95~~	32	0	26	0
2	Transition filters	130	~~115~~	38	0	38	0
3	Compacted rock shell	140	~~120~~	43	0	43	0
1	Foundation saprolite	125	~~105~~	30	0	26	0
NOT USED	~~Foundation relic joint~~			~~12~~	~~0~~	~~12~~	

* SEE FIGURE 3

NOT USE IN CALCULATION

STRENGTH PARAMETERS USED FOR CASE 1 (STEADY STATE CONDITION)

STRENGTH PARAMETERS USED FOR CASE 2 (SEISMIC CONDITION)

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REFERENCES

1) Technical Specification 3/4.7.13, Groundwater Level-Service Water Reservoir
2) Calculation 11715-141, SWR Dike Stability Analysis, April 1974, Performed by Stone & Webster Engineering Corporation (the original design basis calculation)
3) North Anna Power Station SWR Slope Survey (Southeast Section) June 1997, performed by Bengtson, DeBell, and Elkin, Ltd.
4) Deviation Report, DRN-96-1835, North Anna Power Station
5) Service Water Reservoir, Groundwater Level Evaluation, NAPS, NP-3141 dated Dec. 1996 and transmitted to the NRC by letter Serial No 96-561 dated Dec. 10, 1996.
6) Response to Dam Safety Audit Related to the Category 1 SWR Dam at North Anna (letter) Serial No. 97-682 dated January 23, 1998.
7) UFSAR, Appendix 3E, Attachment 5, p 6 and Figure 2
8) UFSAR, Section 3.8.4.4, p 3.8-91
9) Geosystem S.B. Slope, Versions 2+3, licensed by Van Gunten Engineering Software (VES, Inc), Fort Collins, Co.
10) UFSAR, Section 3.8, Table 3.8-13, p 3.8-159
11) Engineering & Design Manual, Stability of Earth + Rock-Fill Dams EM 1110-2-1902 Corps of Engineers April 1970
12) Engineering Guidelines for Evaluation of Hydropower Projects, Federal Energy Regulatory Commission (FERC), April 1991

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CALCULATIONS

As stated in previous sections, this calculation was performed to determine the F.S. of the downstream slope of the selected critical section of the SE section of the SWR dike. Two cases and their associated conditions were evaluated.

CASE 1 - Static steady state seepage, effective stress condition. The minimum F.S. for the computer generated critical section was 1.56 with coordinates of the failure circle of X=48, Y=352, and radius R=76.3. Results of the computer generated run are contained in Appendix C

These results were verified by a hand calculation performed on the critical section having the minimum F.S. (presented in Appendix C).

The following sketch (FIGURE 4) presents the critical failure circle as determined by the computer generated solution for the Case 1 (steady state seepage condition) as presented in Appendix C. The slope geometry, and location of the phreatic surface and soil layers are the same as presented in Figure 3.

FROM: FIGURE 4
CASE 1
COMPUTER FILE SWRPION4

METHODOLGY FOR CALCULATING AREAS AND WEIGHTS OF SLICES (ACTUAL SLICE WEIGHT CALC CONTAINED ON PAGES)

SLICES AND GEOMETRY ARE FROM FAILURE SURFACE CROSS SECTION SKETCH FIG 4 PAGE 14

SLICE No — CALCULATION OR METHOD

① All soil is foundation material ($\gamma = 125$ PCF) - calculate triangle

② Trapezoid - area 2 - small triangle (top of figure)
h_i is horizontal dist or really b
$A = 10\left(\frac{6+8.5}{2}\right) - \frac{1}{2}(1)10 = 72.5 - 5 = 67.5$

③ Use $b \cdot h$ (close to parall.)

④ Calculate area of rock shell ($\gamma = 140$) #3 soil Area of triangle - small triangle
#3 soil $A = \frac{1}{2}(5)(2.5) - \frac{1}{2}(5)0.5 = \frac{1}{2}(12.5 - 2.5) = \frac{1}{2}(10) = 5$ ✓
#2 soil A = triangle - small triangle of #1 soil
$A = \frac{1}{2} b(h)\ (4.5) - \frac{1}{2}(2)2.5 = \frac{1}{2}(27.0 - 5) = 11$
#1 soil $b(h) = 5(6) = 30$ + triangle $\frac{1}{2}(3)(4) = 36$

⑤ #3 soil trapezoid - Δ
$\left(\frac{7+6}{2}\right)(10) - \frac{1}{2}(5)10 = 65 - 25 = 40$
#2 soil Parallegram $10(4) = 40$
#3 soil $b \cdot h = (6.5)10 = 65$

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FROM FIGURE 4
CASE 1
COMPUTER FILE SWRPION4

AREA + WEIGHT OF FAILURE SLICES CONT'D

(6) #3 soil (lab) - Trapezoid - triangle

$\left(\frac{11+9.5}{2}\right)10 - \frac{1}{2}(5)(10) = 102.5 - 25 = 77.5$

#2 SOIL $4(10) = 4$

#1 SOIL $7(10) = 70$

(7) SAME METHOD AS 6 trapezoid - small Δ

#3 $\frac{(19.5)+14.5}{2}(10) - \frac{1}{2}(1)(10) = 145 - 25 = 90$

#2 $4(10) = 40$

#1 $5.5(10) = 55$

(8) Trapezoid - Δ (void above) - small Δ #2 soil

#3 $\left(\frac{18.5+18}{2}\right)10 - \frac{1}{2}(5)(10) - \frac{1}{2}2(5) =$

$182.5 - 25 - 5 = 152.5$

#2 parallelogram + small Δ

$4(10) + 5 = 45$

#1 $2.75(10) = 27.5$

(9)

#3 soil $\frac{19.5+9.5}{2}(10) - 25 = 145 - 25 = 120$

#2 parallelogram $\frac{1}{2}(8+8)10 = 80$

#4 large Δ - Δ =

$\frac{1}{2}(9\times9) - \frac{1}{2}(9)(6) = 81 + 54 - 27 = 13.5$

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AREA CALC P3 CONT'D

FROM FIGURE 4
CASE 1
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10 #3 $(10)\left(\frac{14+5}{2}\right) - \frac{1}{2}(5)10 = 95 - 25 = 70$

#2) Same as 9 77

#1 center of slice x w slice

$4 \times 10 = 40$

11 #3 same methodology as 10

$\frac{1}{2}\,7(5) - \frac{1}{2}(2.5)(5) = \frac{1}{2}(5)(7-2.5) = \underline{11.25}$

#2 same method as 10

$7(5.5) = 38.5$

#4 $3(5) = 15$

12 #3 material

assume cap is rectangle - split difference in area on rt. side
b h
$7 \times 2 = 14$

#2 find area of Δ using arc as one side and subtract small Δ of #4 sol.

$\frac{1}{2}(10.5)\,6.5$ — #4 material = 34.13 − 6 (from below) = 28.13

#4 material − Δ below el 315 line − minor Δ

$\frac{1}{2}(7)(4) - \frac{1}{2}(4)(4) = 14 - 8 = \underline{6}$

CALCULATION OF SLICE WEIGHTS

SLICES FROM FIG 4
CASE 1
COMPUTER FILE SWRPIOM

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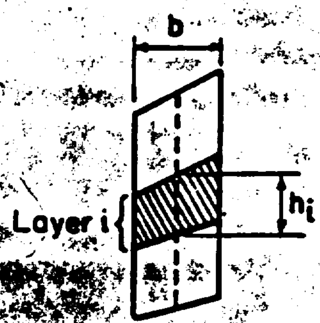

γ_i = unit weight of layer i

h_i = height of layer at center of slice

W_i = partial weight = $b h_i \gamma_i$

ΣW_i = total weight of slice

Slice No.	SOIL No. OR b	h_i	γ_i	W_i	(KIPS) ΣW_i
1	5/2	10.5 = 26.25 · 0.125		: 3.28	3.28
2	10		67.5(.125)	8.44	8.44
3	5	8.5 =		5.31	5.31
4 (#3 soil			5(0.140	0.70	
#2 soil			13.75(0.130	1.43	
#1 soil			36(0.125)	4.50	6.63
5	#3 SOIL		40(0.140	5.60	
	#2 SOIL		40(0.130)	5.20	
			65(0.125)	8.13	18.93
6	#3 soil		72.5(0.14)	10.85	
	#2 SOIL		40(0.13)	5.20	
	#1 SOIL		70(0.125)	8.75	24.8
7	#3 SOIL		115(0.140)	16.10	
	#2		40(0.13)	5.20	
	#1		55(0.125)	6.88	28.18
8	#3	152.5	(0.14)	21.35	
	#2		45(0.13)	5.85	
	#1		27.5(0.125)	3.44	30.64
9	#3	(120)	(0.140)	16.80	
	#2	(80)	(0.13)	10.40	
	#4	(13.5	(0.116)	1.57	28.77

[redacted] TABULAR FORM FOR COMPUTING WEIGHTS OF SLICES.

CALCULATION OF SLICE WEIGHTS CONT'D

SLICES FROM FIG 4
CASE 1
COMPUTER FILE SWRPIONH

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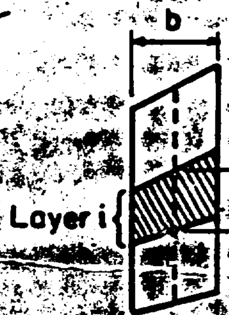


γ_i = unit weight of layer i

h_i = height of layer at center of slice

W_i = partial weight = $b h_i \gamma_i$

ΣW_i = total weight of slice

Slice No.	b	h_i	γ_i	W_i	ΣW_i
10	#3		(70)0.14	9.80	
	#2		(77)0.13	10.01	
	#4		40(0.116)	4.64	24.45
11	#3		11.3(0.14)	1.58	
	#2		38.5(0.13)	5.01	
	#4		15(0.116	1.74	8.33
12	#3		14(0.14)	1.96	
	#2		28.13(0.13)	3.66	
	#4		(6)0.116)	0.70	6.32

[redacted] TABULAR FORM FOR COMPUTING WEIGHTS OF SLICES.

CALCULATION CE-1386 Rev.0
P 24 of 43
[initials] 3-24-98
[initials] 4/9/98

SLICES FROM FIGURE 4
CASE 1
COMPUTER FILE SWE PO 14

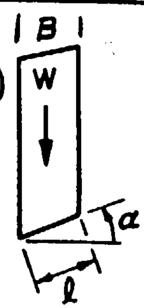
$l = \frac{B}{\cos\alpha}$

									THESE COLUMNS NOT USED FOR SIMPLIFIED BISHOP SOLUTION				
Slice No.	B	SLICE W WEIGHT (KIPS) FROM P 18 + 19	l	$\alpha°$	HEAD ON SLICE h'_w	$\phi°$	PER FT OF l U $U = h'\gamma_w$ $U = 0.0624h'$	ul	$W\cos\alpha$	$W\cos\alpha - ul$	$(W\cos\alpha - ul)\tan\phi$	cl $c=0$	$W\sin\alpha$ (− FOR −∠α) (K)
1	10	3.28	10.7	-20.5	1	30	0.06	0.64					-1.15
2	10	8.44	10.3	-13.5	3	30	0.19	1.96					-1.97
3	5	5.31	5.0	-7.0	5	30	0.31	1.55					-0.65
4	5	6.63	5.0	-4.5	6	30	0.37	1.85					-0.52
5	10	18.93	10.0	1.5	6.5	30	0.41	4.10					0.50
6	10	24.80	10.1	9.0	6.75	30	0.42	4.24					3.88
7	10	28.18	10.5	17.0	5.5	30	0.34	3.57					8.24
8	10	30.64	11.0	25.0	2.5	30	0.16	1.76					12.95
9	10	28.77	11.9	33.0	0	32	0	0					15.67
10	10	24.46	13.7	43.0	0	32	0	0					16.67
11	5	8.33	8.0	51.5	0	32	0	0					6.52
12	6	6.32	12.0	60.0	0	34[1]	0	0					5.47
										Σ		Σ	65.61

(1) ϕ SLICE 12 :

$\phi_{12} = \frac{4'(38°) + 8'(32°)}{12'}$

$= \frac{408}{12} = 34°_{AVE}$



B = WIDTH OF SLICE

c = cohesion intercept
ϕ = friction angle
u = pore pressure
} at base of slice.

h'_w = HEAD OF WATER ABOVE BASE OF SLICE

$$F = \frac{\Sigma (W\cos\alpha - ul)\tan\phi + \Sigma cl}{\Sigma W\sin\alpha}$$

F = ____________ =

← EQ FROM METHOD OF SLICES NOT USED

[redacted] TABULAR FORM FOR CALCULATING FACTOR OF SAFETY BY ORDINARY METHOD OF SLICES.

NOTE: ONLY COLUMNS COMPLETED USED IN BISHOP SIMPLIFIED SOLUTION

CALCULATION | Engineering Work Sheet | POW 14

Project | Rev. No. | Sheet

Subject STABILITY OF SWR DIKE	Prepared By 4SA	Date 3-24-98
System SW	Checked By MJB	Date 4/9/98

NOTE: VALUES TAKEN FROM ... PREVIOUS SPREAD SHEET (P-20)

SIMPLIFIED BISHOP

CASE 1 CONDITION
HAND VERIFICATION
COMPUTER FILE SWRPIONY

$$F = \Sigma\,(W-\overset{U}{u\ell})\tan\phi\left(\frac{\sec\alpha}{1+\frac{\tan\phi\tan\alpha}{F}}\right) \div \Sigma W\sin\alpha$$

F ← ASSUMED F.S.

NO SLICE	W	− $u\ell$	$(W-u\ell)$ (correct)	ϕ	(1) $(W-\overset{U}{u\ell})\tan\phi$	α	(2) $\frac{\sec\alpha}{(1+\frac{\tan\phi\tan\alpha}{F})}$ F: FACTOR OF SAFETY 1.5	1.6	(1)×(2) F: FACTORS OF SAFETY 1.5	1×2 1.6	$\sec\alpha$ or $\frac{1}{\cos\alpha}$
1	3.28	0.64	2.64	30	1.52	-20.5	0.935	0.943	1.422	1.433	1.07
2	8.44	1.96	6.48	30	3.74	-13.5	0.943	0.948	3.526	3.546	1.03
3	5.31	1.55	3.76	30	2.17	-7.0	0.964	0.967	2.092	2.098	1.01
4	6.63	1.85	4.78	30	2.76	-4.5	0.971	0.973	2.680	2.685	1.00
5	18.93	4.10	14.83	30	8.56	1.5	0.990	0.991	8.474	8.483	1.00
6	24.80	4.24	20.56	30	11.87	9.0	0.952	0.956	11.300	11.348	1.01
7	[illegible]	3.57	[illegible]	30	[illegible]	17.0	0.939	0.945	13.342	[illegible]	1.05
8	30.64	1.76	28.88	30	16.67	25.0	0.933	0.942	15.553	15.703	1.10
9	28.77	—	28.77	32	17.98	33.0	0.932	0.949	16.845	17.063	1.19
10	24.45	—	24.45	32	15.28	43.0	0.979	0.992	14.959	15.234	1.36
11	8.33	—	8.33	32	5.21	51.5	1.057	1.080	5.507	5.637	1.61
12	6.32	—	6.32	34	4.26	60.0	1.124	1.156	4.788	4.925	2.00
13						Σ	TOTALS —		100.49	101.57	
14											
15											

FOR F.S (ASSUMED) 1.5 - F.S. = $\frac{100.49}{65.61}$ = 1.53 FOR F.S (ASSUMED) 1.6 F.S. = $\frac{101.57}{65.61}$ = 1.55

$\Sigma W\sin\alpha = 65.61$ (p20)

→ $\boxed{\text{AVE} = 1.54}$ ←

CALCULATIONS cont'd

The hand calculation verifying the computer generated minimum F.S. for the critical circle for the CASE 1 condition was

F.S. = 1.54 Vs. 1.56 (VIA COMPUTER - SEE APPENDIX C.)

THIS IS A VERY CLOSE AGREEMENT (within ≈1%) and verifies the computer generated solution.

CASE 2 - Seismic condition - using total stress soil strength parameters (see p11, DESIGN INPUTS section). The same slope geometry height, phreatic surface and soil layers used in the CASE 1 condition (shown in FIGURE 3) were used in this case.

The soil strength parameters used for the case 2 (TOTAL STRESS) condition are as follows

SOIL 1 - FOUNDATION SOIL (SAPROLITE), C = 720 PSF, $\phi = 26°$

SOIL 2 - TRANSITION (SAND) FILTERS, C = 0, $\phi = 38°$ (same as case 1)

SOIL 3 - COMPACTED ROCK FILL, C = 0, $\phi = 43°$ (same as case 1)

SOIL 4 - COMPACTED RANDOM (CORE) FILL C = 720 PSF, $\phi = 26°$

The SEISMIC coefficients used are consistent with the Design Basis Earthquake DBE as stated in the UFSAR (Ref 8) and the original design basis calculations (Ref 2). The horizontal acceleration $K_h = 0.18g$, and vertical seismic acceleration $K_v = 0.12g$.

Document Type Calc.	Engineering Work Sheet			POW 14
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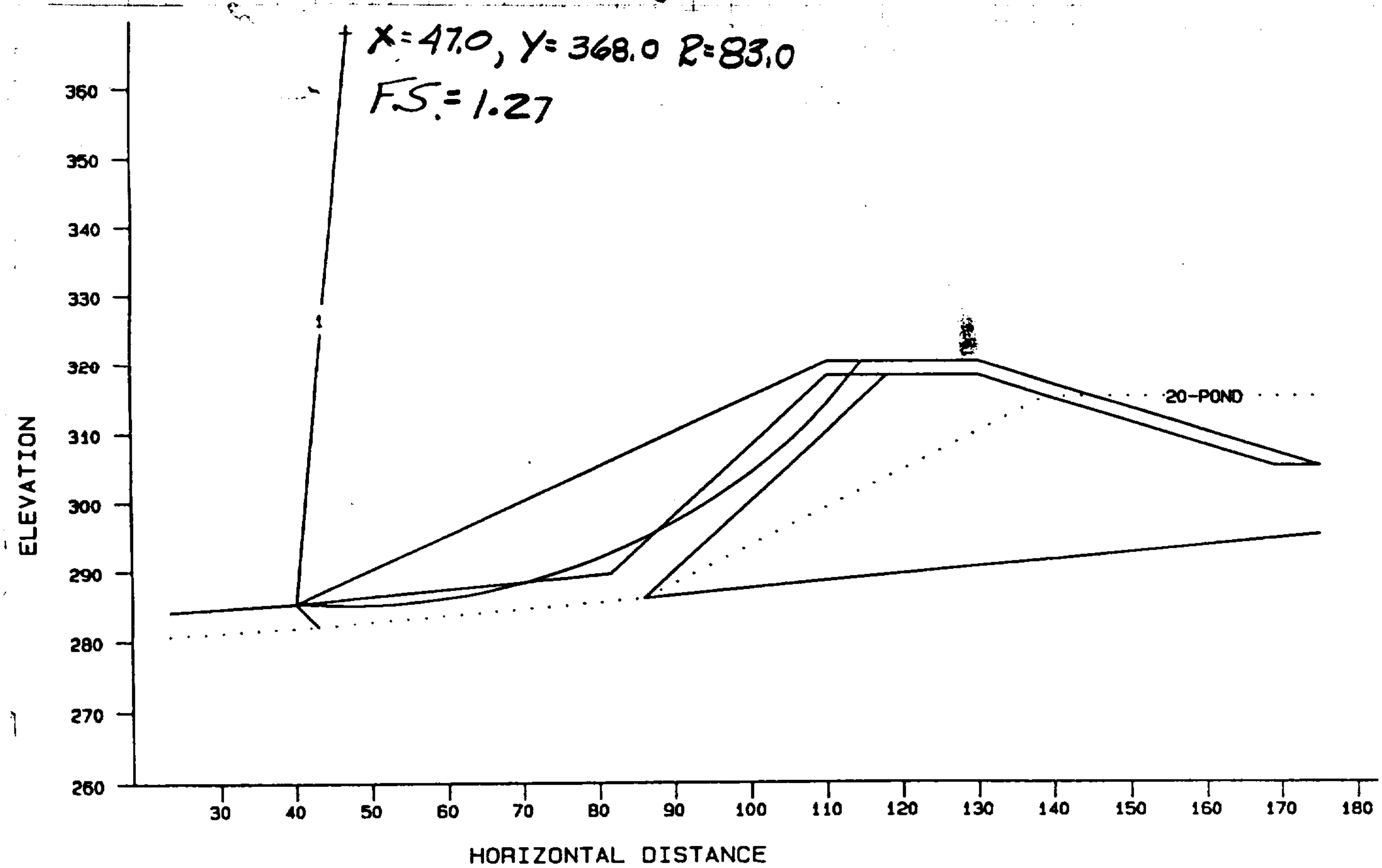
System SW	Checked By MRB		Date 4/9/98	

VIRGINIA POWER

CALCULATIONS CASE 2 cont'd

The computer generated critical failure circle indicated a F.S. of 1.27 with the failure surface located entirely in the granular fill (sand filters and compacted rock fill). This is due to the total stress condition of the soil which mobilizes the cohesion through the soil layers - forcing the failure circle into the granular soils due to the strength of the "cohesive" soils. The "CASE 2" computer solution is presented in Appendix D. A print of the critical failure circle, coordinates of the center of the failure, the section is presented below.



CALCULATIONS - CASE 2 cont'd

CASE 2 SEISMIC

A hand calculation was performed to verify the computer generated results described on the previous page (p27). The failure surface was superimposed on the geometry of the cross section and the failure surface was broken into 8 slices (the computer generated solution used 80). This enlarged section is provided in Fig. 5 (next page, p 29). The weight of each slice was calculated and the angle α, to the center of each slice from the origin of the failure circle was scaled. The resisting and driving forces were calculated. The slice weights and their seismic components, where applicable, were multiplied by the radius for the critical failure circle to obtain the resisting and driving moments. The slice weight × the seismic (horizontal) component [$K_H(W)$] was multiplied by the respective lever arm (measured from the center of the slice to the center of failure arc). The sum of these moments was added to the driving forces.

The factor of safety for the seismic (CASE 2) condition was calculated as follows:

$$F.S. = \frac{\Sigma \text{RESISTING FORCES}}{\Sigma \text{DRIVING FORCES}} \quad \text{OR} \quad F.S. = \frac{\Sigma M_{RESIST}}{\Sigma M_{DRIVE} + \Sigma K_H W \cdot L_H}$$

CALCULATION OF SLICE WEIGHTS BEGINS ON p 26 AFTER FIG 5

VIRGINIA POWER	Document Type: Calculation	Engineering Work Sheet POW 14		
	Project: TECH SPEC 3/4.7.13 CHANGE REQUEST	Doc. No. CE-1386	Rev. No. 0	Sheet No. 30 of 43
	Subject: STABILITY OF SWR DIKE	Prepared By: [illegible]		Date 3-24-98
	System: SW	Checked By: MJB		Date 4/9/98

VERIFY COMPUTER GENERATED MINIMUM FACTOR OF SAFETY FOR SEISMIC CASE (SLOPE FILE NO. SWRP10SE)

CASE 2
SEISMIC
SLICE WT
CALC

BREAK FAILURE ARC INTO 8 SEGMENTS TO CALCULATE WEIGHT OF EACH SEGMENT AND ∠ FROM PERPENDICULAR. CALCULATE TOTAL AREA BY PLACING HORIZONTAL LINE ACROSS BASE RATHER THAN USING CORD (SLICES 2 THROUGH 7)

CALCULATION ON SEGMENT WEIGHTS

SOIL #2 (FILTER) W = 130 PCF or 0.13 KSF

SOIL #3 (ROCK FILL) W = 140 PCF or 0.14 KSF

SLICE NO

1 Total area triangle = 1/2 BH = 1/2 (9.5)(5) = 23.75

Small area = 1/2 (9.5)(1) = 4.75

Rockfill = (23.75 − 4.75)0.14 = 19(.140) = 2.66 K

Filter = (4.5) 0.13 = 0.59 K

0.59

3.25K

2 Total area = Trapezoid (with base end of failure circle) = B h_{ave} = $\left(\frac{5+8.5}{2}\right)$10 = 6.75(10) = 67.5

Sand filter ≈ (10)1 = 10(0.13) = 1.3 K

Rockfill = (67.5 − 10)0.14 = 57.5(0.14) = 8.05

9.35 K

3 Total Area = Trap. − small Δ = B h_{Ave} − 1/2 B $h_{Δ}$ = 10(11.0) − 1/2(2)10 = 110 − 10 = 100 K

2# soil = lower ($Δ_1$ − $Δ_2$) = [1/2 (2)(10) − 1/2 (1)(10)](.13) = (10 − 5)(.13) = 0.65 K

#3 soil = Total − small trap = 100 − 5 = 95(0.14) = 13.3 K

13.95

CASE 2
SEISMIC
SLICE WT
CALCULATION

SLICE No.

4 Total trapezoid - bottom triangle

$10(14) - \frac{1}{2}(10)\,3.5 = 140 - 17.5 = 122.5$

$W = A\gamma_3 = 122.5(0.14) = \underline{17.15k}$

5 Same methodology

$10(15.5) - \frac{1}{2}(10)(5) = 155 - 25 = 130$

$130(0.14) = \underline{18.2}$ (most all soil is #3 except on small triangle - assume all #3 soil)

6 Same Methodology

$\text{TOTAL } A = 10(15) - \frac{1}{2}(7)(10) = 150 - 35 = 115$

#2 soil = triangle 1 - triangle 2 = $[\frac{1}{2}(11)10 - \frac{1}{2}(7)(10)](0.13) =$

$(55-35)(0.13) = 2.6k$

#3 SOIL total - triangle 1

$A = 150 - \frac{1}{2}(11)(10) = 150 - 55 = 95$

$W = 0.14(95) = 13.3$

TOTAL weight of slice

2.6
13.3
15.9 k

7 Same method

$13(10) - \frac{1}{2}(9.5)10 = 130 - 47.5 = 82.5$

#3 soil = Total (130) - trapezoid bottom including #2 soil)

$A = 130 - \left(\frac{4 + 13.5}{2}\right)(10) = 130 - 87.5 = 42.5$

$W_3 = 42.5(0.14) = 5.95^k$

A of #2 soil = trapezoid - triangle = $87.5 - \frac{1}{2}(9.5)10 = 40$

CASE 2
SEISMIC
SLICE WT
CALCULATION

Slice 7 continued

#2 soil = $W = A\gamma_2 = 40(0.13) = 5.2^k$

TOTAL wt slice 7 =

5.95
5.20
11.15

8 4 $A = \frac{1}{2}(4.5)6 = 13.5$

#2 soil: small $A = \frac{1}{2}(4)3 = 6$ $(6)(0.13) = .78^k$

A of #3 soil: $13.5 - 6 = 7.5$ $7.5(0.14) = 1.05$

1.83^k

VIRGINIA POWER	Document Type Calculation.	Engineering Work Sheet POW 14		
	Project Tech-Spec 3/4.7.13 Change Request	Doc. No. CE-1386	Rev. No. 0	Sheet No. 33 of 43
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SIMPLIFIED BISHOP WORK SHEET

CASE 2 SEISMIC

This case assumes the vertical seismic force is acting up (↑) thereby reducing the weight of the slice. Also, the phreatic surface is located below the critical failure circle such that there is no reduction to slice weight due to uplift of phreatic surface.

Equation for Bishop follows

$K_V = 0.12$

$1 - K_V = 0.88$

$$F.S. = \frac{\Sigma W \tan\phi \left(\frac{\sec\alpha}{1 + \frac{\tan\phi \tan\alpha}{F.S.(assumed)}} \right)}{\Sigma W \sin\alpha}$$

designate this term as ② B

1 SLICE NO	2 UNCORRECTED FOR SEISMIC WEIGHT SLICE	3 1-Kv	4 CORRECTED WEIGHT W_{SES}	5 α DEGREES	6 DRIVING $W_S \sin\alpha$	7 φ	8 ① RESISTING $W_S \tan\phi$	9 ② B 1.3	10 1.4	11 RESISTING ①×② 1.3	12 1.4	13 sec α
1	3.25	0.88	2.86	0.5	0.02	38	2.23	0.995	0.995	2.22	2.22	1.000
2	9.35		8.23	5.5	0.79	38	6.43	0.945	0.958	6.077	6.16	1.01
3	13.95		12.28	12.5	2.66	38	9.59	0.900	.908	8.63	8.71	1.02
4	17.15		15.09	19.75	5.10	43	14.07	0.845	0.855	11.89	12.03	1.06
5	18.2		16.02	27.5	7.39	41.7	14.27	0.831	0.849	11.86	12.12	1.13
6	15.9		13.99	35.25	8.07	38	10.93	0.860	0.882	9.40	9.64	1.23
7	11.15		9.81	44.5	6.88	38	7.66	0.881	0.904	6.74	6.92	1.40
8	1.83	↓	1.61	52.5	1.28	38	1.26	0.912	0.950	1.15	1.20	1.64
				SCALED	32.19					57.96	59.0	

VIRGINIA POWER	Document Type: Calc.	Engineering Work Sheet	POW 14
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System: SW	Checked By: MFB		Date 4/9/98

CASE 2 Seismic

Calculate Seismic Horizontal Forces - Moment due to seismic horizontal component

Assume that the seismic force is also acting up ↑, so slice weight is reduced by 1-Kv. L_H is vertical moment arm SCALED from center of the slice to center of failure circle

SLICE	W	× 1-Kv (1-0.12 OR 0.88)	W_{SEIS}	× K_H =	$W_{SEIS} K_H$	× L_H (ft) =	$M_{H_{SEIS}}$
1	3.25	0.88	2.86	0.18	0.51	81	41.31
2	9.35	↓	8.23	↓	1.48	79	116.92
3	13.95	↓	12.28	↓	2.21	75	165.75
4	17.15	↓	15.09	↓	2.72	71.5	194.48
5	18.20	↓	16.02	↓	2.88	67	192.96
6	15.90	↓	13.99	↓	2.52	61.5	154.98
7	11.51	↓	9.81	↓	1.77	55	97.35
8	1.83	↓	1.61	↓	0.29	49.5	14.36

Σ = 978.1

Subject: STABILITY OF SWR DIKE	Prepared By: [signature]	Date: 4-7-98
System: SW	Checked By: MSB	Date: 4-9-98

CASE 2 SEISMIC

CALCULATE F.S. by dividing resisting force (moment) by driving moment

SUM OF RESISTING FORCES ; ASSUMED F.S. 1.3 from p 33 is 55.78^k

RESISTING MOMENT = RESISTING FORCE (BASE of SLICE) X Radius of failure circle

$\therefore M_{R_{1.3}} = 57.96(83') = 4810.7$ (p33)

Resisting Moment for assumed F.S. 1.4 p 33

$M_{R_{1.4}} = 59.06(83) = 4897.5$

Driving Moment (from p 33)

$M_D = 32.19^k \times 83' = 2671.8^{k'}$

Horizontal driving (seismic) moment from page 34 = $978.1^{k'}$

$$\therefore F.S._{1.3\,assumed} = \frac{4810.7}{2671.8+978.1} = \frac{4810.7}{3649.87} = 1.32$$

$$F.S._{1.4\,assumed} = \frac{4897.5}{3649.87} = 1.34$$

$$\therefore F.S._{,} = \frac{1.32+1.34}{2} = \underline{\underline{1.33}}$$ RESULT OF HAND CALC. CHECK ON COMPUTER GENERATED FAILURE CIRCLE

THE HAND CALCULATION OBTAINED A F.S. of 1.33 VS 1.27 COMPUTER GENERATED ON THE SAME FAILURE CIRCLE. CONSIDERING THAT THE HAND CALC. USED 8 SLICES + THE COMPUTER USED 80 THIS IS CLOSE <5% ∴ VERIFIED BY HAND CALC.

Subject STABILITY OF SWR DIKE	Prepared By [illegible]	Date 3-24-98
System SW	Checked By MB	Date 4-9-98

CONCLUSIONS

This calculation determines the factor of safety (F.S) of the downstream slope at a section cut through Piezometer P-10 located along the southeast quadrant of the SWR. Two cases were considered - Case 1 - Steady state seepage from maximum storage pool, and Case 2 - Steady state seepage during a seismic (DBE) event. The phreatic surface, slope geometry, and location of the soil layers were the same in both cases. Results of this calculation were compared to the results of the original design basis calculation (Ref 2) and recognized geotechnical and industry standards. The results obtained and comparisons are presented in the following table:

DESIGN LOADING CONDITION	MINIMUM FACTOR OF SAFETY		
	ORIGINAL DESIGN BASIS CALC	THIS CALCULATION	INDUSTRY-REQ'D MINIMUM
CASE 1 - STEADY STATE SEEPAGE	1.49	1.56*	1.5 (1)(2)
CASE 2 - SEISMIC STEADY STATE SEEPAGE	1.19	1.27*	1.0 (1) >1.0 (2)

NOTES: 1) CORP OF ENGINEERS, REF 11   * COMPUTER GENERATED RESULTS

2) FERC, REF 12

CONCLUSIONS cont'd

As evidenced in the proceeding table, the F.S. based on the actual as built dike section, with the water level at P-10 at el. 280 ft. rather than at el 276' (as in the original design basis calculation or Tech Spec. allowable of el 277') is higher than calculated in the original design basis calculation (ODBC). The current condition as reflected in both P-10 and P-22 is more conservative (higher F.S.) than originally assumed. The current and maximum historical water level is much more conservative than that assumed in ODBC. The F.S. obtained in both the ODBC and this calculation are well in excess of those referenced in technical/industry standards. The actual measured water levels along the SE section as obtained by monitoring piezometers P-19, P-21, + P-22 are shown on Figure 6 which follows. The assumed phreatic surface or groundwater level is also shown. Note that this actual surface does NOT extend through the dike as assumed in all previous calculations, but the phreatic surface is located below the base of the dike. The assumed higher than actual phreatic surface used in all calculations is a conservative assumption as the actual surface would yield a higher calculated F.S. This calculation confirms that raising the Tech. Spec. limit on water levels from el 277' to 280' in P-10 and from el 280' to 295' at P21+22 will still provide an adequate F.S.

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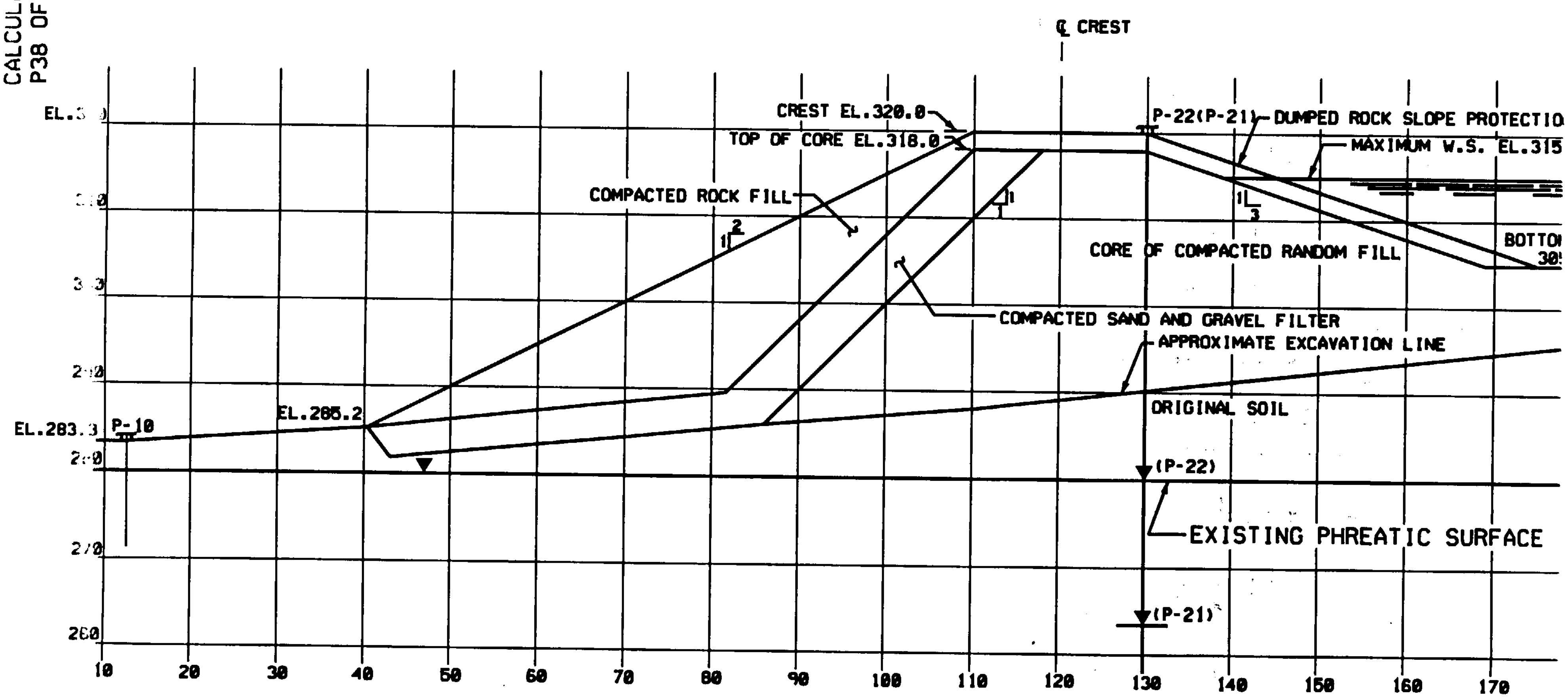


FIGURE 6 - EXISTING PHREATIC SURFA

EXISTING AS-BUILT
SECTION THROUGH P-10
SERVICE WATER RESERVOIR
NORTH ANNA POWER STATION

GROUND WATER LEVEL 280

Document Type CALCULATION	Engineering Work Sheet		POW 14
Project TECH SPEC 3/4.7.13 CHANGE REQUEST	Doc. No. CE-1386	Rev. No. 0	Sheet No. 39 of 43
Subject STABILITY OF SWR DIKE	Prepared By J.S. THORNTON JR		Date 3-24-98
System SW	Checked By MLB		Date 4-9-98

VIRGINIA POWER

APPENDIX A

As Built Spot Elevations along Southeast Section of SWR Dike

OVERSIZE PAGE(S)

****

NOT CONVERTED INTO ELECTRONIC IMAGE FORM.

****

PAPER COPY IS AVAILABLE IN NRC FILE CENTER.

Document Type CALC	Engineering Work Sheet POW 14		
Project TSCR Spec 3/4.7.13 Change Request	Doc. No. CE-1386	Rev. No. 0	Sheet No. 40 of 43
Subject Stability of SWR Dike	Prepared By		Date 3-24-98
System SW	Checked By MLB		Date 4-9-98

VIRGINIA POWER

Appendix B

Comparison of Results of Original Design Basis Stability Calculation with Run Using S.B. Slope Program

SB-SLOPE

Simplified Bishop Slope Stability Analysis

PROJECT: NAPS SWR TS Change 5-28-97

LOCATION: SE Section of dike

FILE: SWRSWC1

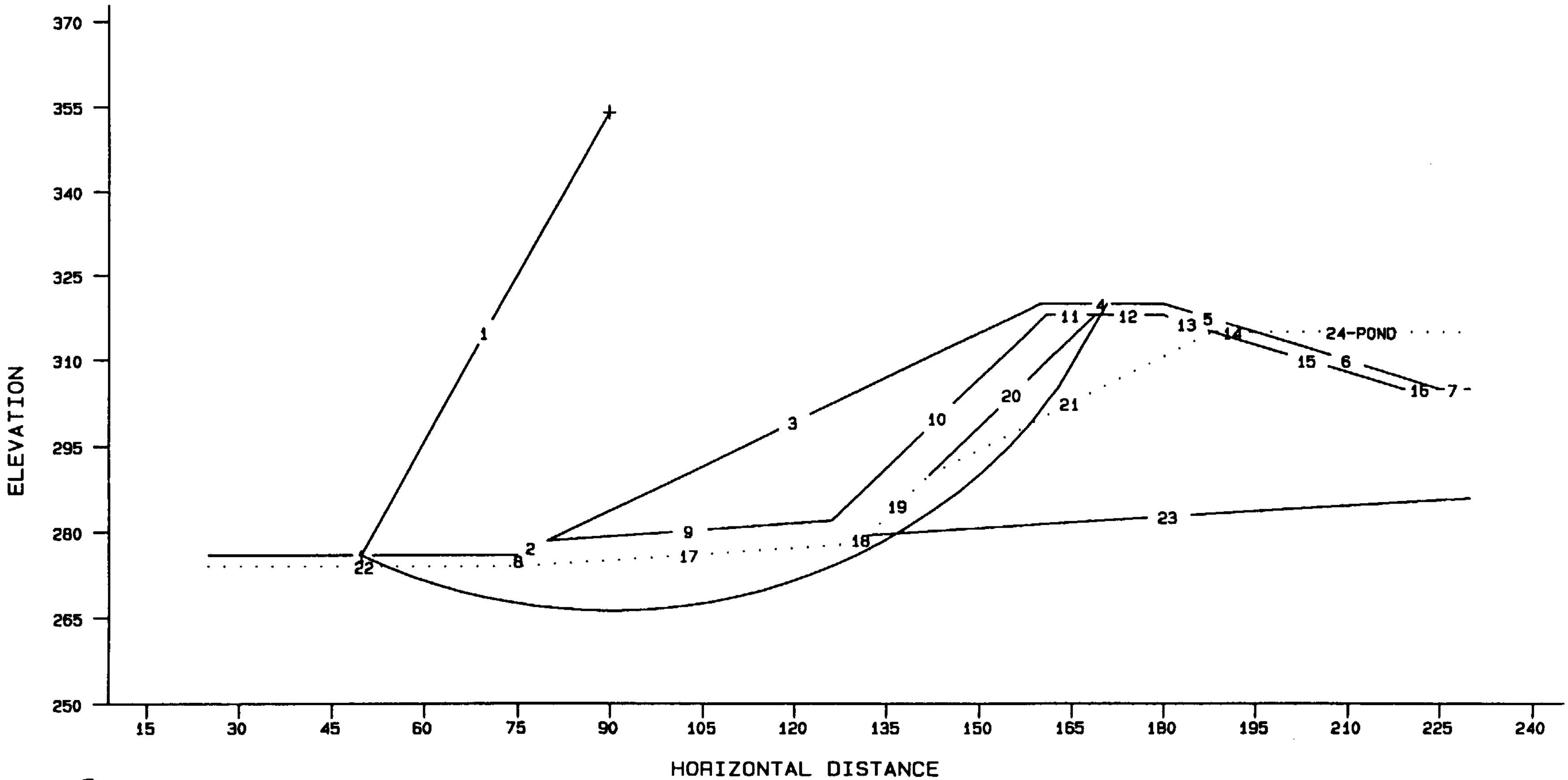
COMPLETE SLOPE CROSS SECTION SHOWN

CIRCLE	X	Y	RADIUS	FS
1	90.0	354.0	87.7	1.50

AGREES WITH SWEC CALC 114 STEADY STATE CONDITION DOWNSTREAM

SEARCH OF 1733 SURFACES GAVE MIN F.S. 1.50 @ X=89.6
Y=358.1
R=93.5

CALC CE 1386 REV0
APPENDIX B
P 1 OF 3, 3-29-98



CALC CC1506 [illegible]
Appendix B
P 2 of 3
3-4-98, [illegible]

SINGLE CENTER ANALYSIS
Approximately 40 slices selected
Circle center at X= 90.0, Y= 354.0
[illegible] 1.500 at R= 87.7

GEOSYSTEM SLOPE STABILITY PROGRAM
SB-SLOPE

PROJECT DATA:
Project: NAPS SWR TS Change 5-28-97
Location: SE Section of dike
Filename: SWRSWC1 Description: SWEC Calc 141 H2O@ el310 SE Sec Static effec

ANALYSIS DATA:

Point No.	Coordinates X	Coordinates Y	Line No.	Left Point	Right Point	Soil No.	Phreatic Line
1	25.0	276.0	1	1	2	1	N
2	75.0	276.0	2	2	3	2	N
3	80.0	278.5	3	3	4	3	N
4	160.0	320.0	4	4	5	3	N
5	180.0	320.0	5	5	19	3	N
6	225.0	305.0	6	19	6	3	N
7	230.0	305.0	7	6	7	4	N
8	126.0	282.0	8	2	13	1	N
9	161.0	318.0	9	3	8	2	N
10	180.0	318.0	10	8	9	2	N
[illegible]	219.0	305.0	11	9	17	2	N
[illegible]	[redacted]	[redacted]	12	17	10	4	N
13	76.0	[redacted]	13	10	18	4	N
14	130.0	278.0	14	18	19	3	N
15	132.0	279.5	15	18	11	4	N
16	142.0	290.0	16	11	6	4	N
17	169.0	318.0	17	13	14	4	Y
18	188.0	315.0	18	14	15	4	Y
19	195.0	315.0	19	15	16	4	Y
20	230.0	315.0	20	16	17	4	N
21	230.0	286.0	21	16	18	4	Y
			22	[redacted]	[redacted]	[redacted]	Y
			23	15	21	1	N

Toe water

Soil No.	Density pcf	Cohesion psf	Phi Deg
1	125.0	0	30.0
2	130.0	0	38.0
3	140.0	0	43.0
4	116.0	0	32.0

Both Spencer + Bishop
Auto search (203 failure surfaces)
X=88 Y=356 R=89 F.S.=1.5

Free water surface, left point = 19
right point = 20

Range search; initial parameters:

	min	max	increment
left x	30.0	90.0	5.0
right x	160.0	230.0	5.0

radius increment is 5.0
minimum perpendicular depth is 10.0
limit at elevation 10.0
OVERALL MINIMUM: x = 89.6, y = 358.1, r = 93.5, FS = 1.504

APPENDIX C

RESULTS OF STABILITY ANALYSIS
COMPUTER RUN (S.B. SLOPE) USING
AS BUILT SLOPE GEOMETRY

(CASE 1 CONDITION)

RECORD RUN 11-37 HAND CHECK VERIFICATION PERFORMED ON CIRCLE 1

REVISED GEOMETRY CORRECTING DEFFICIENCIES FOUND BY CHECKER (MLB) – CHIMNEY DRAIN INCREASED to 8' WIDTH, P-10 LOCATED AT AS BUILT LOCATION AND WATER LEVEL ADJUSTED [illegible]

FILE NO SWRP10N4

Appendix C
P 1 of 4

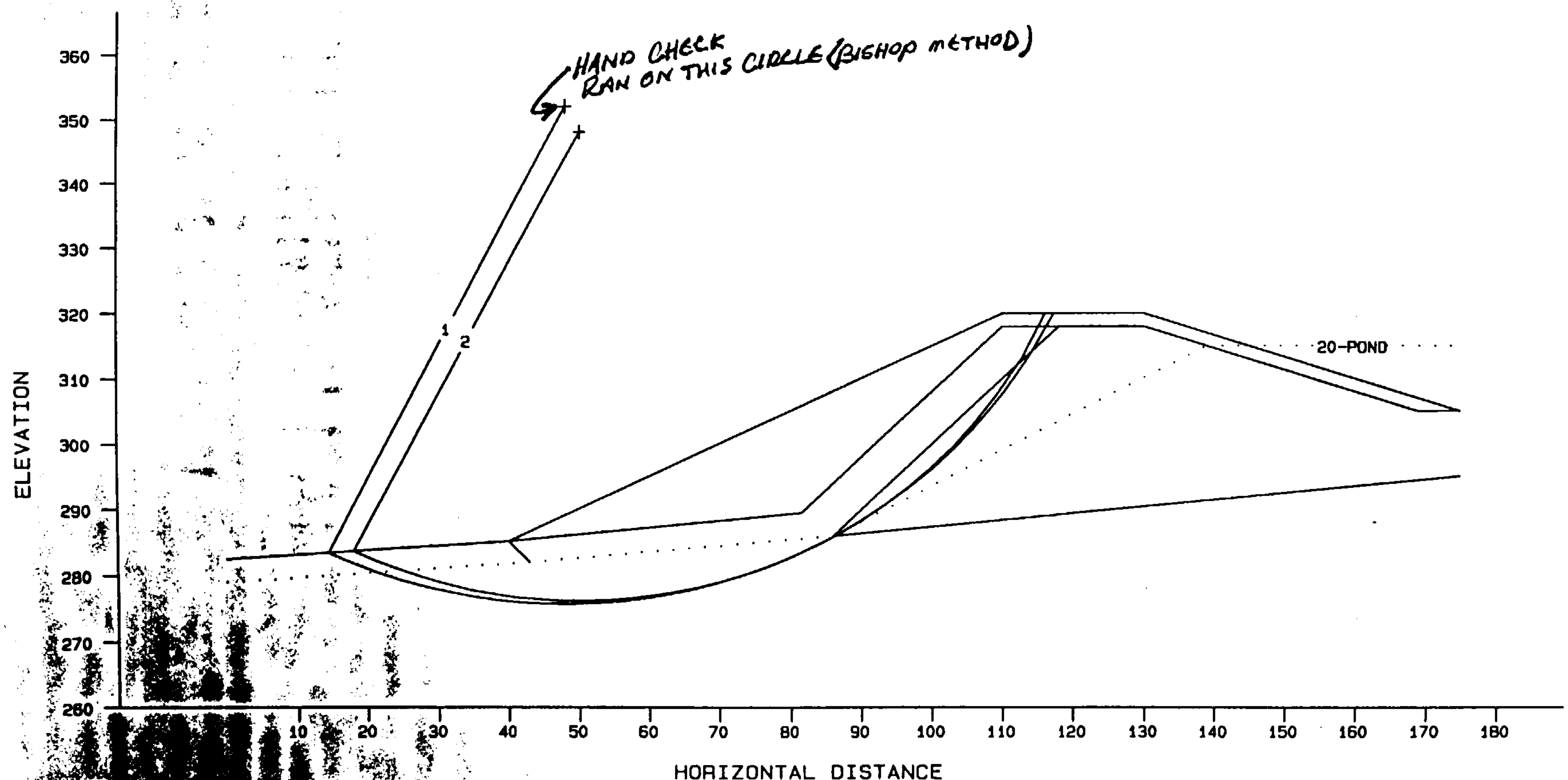
SB-SLOPE

Simplified Bishop Slope Stability Analysis

PROJECT: SWR Tec Spec Change H2O levels in piezometers at SWR
LOCATION: SE section, P-10
FILE: SWRP10N4

COMPLETE SLOPE CROSS SECTION SHOWN

CIRCLE	X	Y	RADIUS	FS
1	48.0	352.0	76.3	1.56 (BISHOP)
2	50.0	348.0	71.8	1.55 (SPENCER)



CC-1534 Rev 0

Appendix C

P2 of 4

File: SWRP10N4 - Sec@P10ToeasbltFIG3E-19 H2O@280/310RecordRev
SINGLE CENTER ANALYSIS
Approximately 80 slices selected
Circle center at X= 48.0, Y= 352.0
[illegible] 1.557 at R= 76.3

GEOSYSTEM SLOPE STABILITY PROGRAM
SB-SLOPE

PROJECT DATA:
Project: SWR Tec Spec Change H2O levels in piezometers at SWR
Location: SE section, P-10
Filename: SWRP10N4 Description: Sec@P10ToeasbltFIG3E-19 H2O@280/310RecordRev

ANALYSIS DATA:

Point No.	Coordinates X	Coordinates Y
1	0.0	282.5
2	40.0	285.2
3	110.0	320.0
4	130.0	320.0
5	145.0	315.0
6	175.0	305.0
7	175.0	315.0
8	81.5	289.5
9	110.0	318.0
10	118.0	318.0
[illegible]	130.0	318.0
[illegible]	139.0	315.0
13	169.0	305.0
14	0.0	279.0
15	43.0	282.0
16	86.0	286.0
17	175.0	295.0

Line No.	Left Point	Right Point	Soil No.	Phreatic Line
1	1	2	1	N
2	2	3	3	N
3	3	4	3	N
4	4	5	3	N
5	5	6	3	N
6	2	8	2	N
7	8	9	2	N
8	9	10	2	N
9	10	11	4	N
10	11	12	4	N
11	12	5	3	Y
12	12	13	4	N
13	13	6	4	N
14	14	15	1	Y
15	15	16	1	Y
16	16	10	4	N
17	16	12	4	Y
18	16	17	1	N
19	2	15	1	N

Soil No.	Density pcf	Cohesion psf	Phi Deg
1	125.0	0	30.0
2	130.0	0	38.0
3	140.0	0	43.0
4	116.0	0	32.0

Free water surface, left point = 5
right point = 7

SWKT1ON4(RECORD RUN AFTER REVIEW

CALC CE-1386 REV 0
APPENDIX C
P 3 OF 4

```
Range search;  initial parameters:
             min      max   increment     (1118 SLICES)
 left x     10.0     60.0      5.0
 right x   100.0    140.0      5.0
 radius increment is   2.0
 minimum perpendicular depth is  10.0
 limit at elevation 240.0
OVERALL MINIMUM: x =  48.1, y = 357.7, r =  81.2, FS = 1.565

Automatic search;  initial parameters:
    initial   increment
 x    48.0       2.0
 y   358.0       2.0
 r               2.0                  (194 TRIALS)
 minimum perpendicular depth is  10.0
 limit at elevation 240.0
OVERALL MINIMUM: x =  48.0, y = 352.0, r =  76.3, FS = 1.557
```

NOW RUN SINGLE CRITICAL CIRCLE USING SPENCER METHOD - RANGE SEARCH

X = 50 Y = 348 R = 71.8 F.S. = 1.55

SPENCER - AUTOSEARCH SAME RESULTS

X = 50 Y = 348 R = 71.8 F.S. 1.55

[illegible] (Reload Run) Spencer Method

CALC. CE-1386 Rev 0
APPENDIX L
P 4 of 4

```
Automatic search;  initial parameters:
    initial   increment
x     48.0        2.0
y    352.0        2.0
r                 2.0
 minimum perpendicular depth is  10.0
 limit at elevation 240.0
OVERALL MINIMUM: x =  50.0, y = 348.0, r =  71.8, FS = 1.554, theta = 18.73
```

VIRGINIA POWER	Document Type CALCULATION	Engineering Work Sheet		POW 14
	Project TECH. SPEC. 3/4.7.13 CHANGE REQUEST	Doc. No. CE-1386	Rev. No. 0	Sheet No. 42 of 43
	Subject STABILITY OF SWR DIKE	Prepared By [signature]		Date 3-24-98
	System SW	Checked By MLB		Date 4-9-98

APPENDIX D

RESULTS OF COMPUTER GENERATED STABILITY ANALYSIS (S.B. SLOPE)

(CASE 2 - SEISMIC CONDITION)

Results of Range + Auto Search HAND CHECK PERFORMED ON THIS RUN

APPENDIX D

SB-SLOPE

Simplified Bishop Slope Stability Analysis

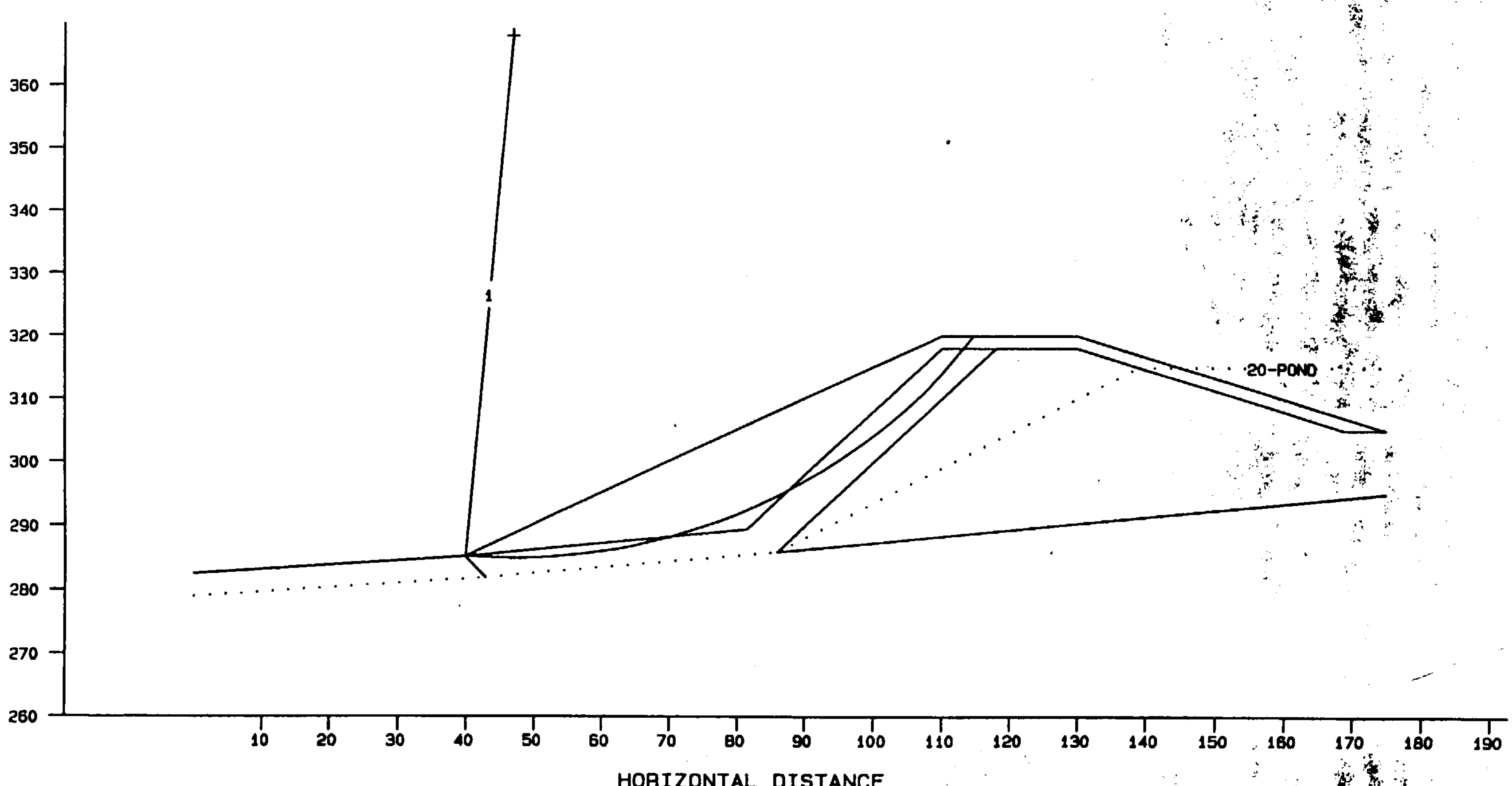
PROJECT: SWR Tec Spec Change H2O levels in piezometers at SWR

LOCATION: SE section, P-10 Seismic Run

FILE: SWRP10SE

COMPLETE SLOPE CROSS SECTION SHOWN

CIRCLE	X	Y	RADIUS	FS
1	47.0	368.0	83.0	1.27 SEISMIC F.S.



File: SWRP10SE - SeisP10ToeasbltFIG3E-19 H2O@280/310RecordRev
SINGLE CENTER ANALYSIS
Approximately 80 slices selected
Circle center at X= 47.0, Y= 368.0
[illegible] 1.272 at R= 83.0

CALCULATION CE-B86 REV 0
APPENDIX D
P 2 OF 4

GEOSYSTEM SLOPE STABILITY PROGRAM
SB-SLOPE

PROJECT DATA:
Project: SWR Tec Spec Change H2O levels in piezometers at SWR
Location: SE section, P-10 Seismic Run
Filename: SWRP10SE Description: SeisP10ToeasbltFIG3E-19 H2O@280/310RecordRev

ANALYSIS DATA:

Point No.	Coordinates X	Y
1	0.0	282.5
2	40.0	285.2
3	110.0	320.0
4	130.0	320.0
5	145.0	315.0
6	175.0	305.0
7	175.0	315.0
8	81.5	289.5
9	110.0	318.0
10	118.0	318.0
[illegible]	130.0	318.0
12	139.0	315.0
13	169.0	305.0
14	0.0	279.0
15	43.0	282.0
16	86.0	286.0
17	175.0	295.0

Line No.	Left Point	Right Point	Soil No.	Phreatic Line
1	1	2	1	N
2	2	3	3	N
3	3	4	3	N
4	4	5	3	N
5	5	6	3	N
6	2	8	2	N
7	8	9	2	N
8	9	10	2	N
9	10	11	4	N
10	11	12	4	N
11	12	5	3	Y
12	12	13	4	N
13	13	6	4	N
14	14	15	1	Y
15	15	16	1	Y
16	16	10	4	N
17	16	12	4	Y
18	16	17	1	N
19	2	15	1	N

Soil No.	Density pcf	Cohesion psf	Phi Deg
1	125.0	720	26.0
2	130.0	0	38.0
3	140.0	0	43.0
4	116.0	720	26.0

Free water surface, left point = 5
right point = 7

Seismic coefficient, horizontal = 0.180
vertical = 0.120

CALC: CE-1386 REV 0
APPENDIX D
P3 OF 4

```
Range search;  initial parameters:
            min      max   increment
 left x      1.0     50.0      5.0
  ght x  110.0    165.0      5.0
 radius increment is   2.0
 minimum perpendicular depth is  10.0
 limit at elevation 240.0
OVERALL MINIMUM: x =   45.1, y = 373.8, r =  88.2, FS = 1.285 - low FS

Automatic search;  initial parameters:
    initial   increment
 x    45.0         2.0
 y   374.0         2.0
 r                 2.0
 minimum perpendicular depth is  10.0
 limit at elevation 240.0
OVERALL MINIMUM: x =   47.0, y = 368.0, r =  83.0, FS = 1.272 - low FS
```

VIRGINIA POWER	Document Type CALCULATION	Engineering Work Sheet		POW 14
	Project TECH SPEC 3/4.7.13 CHANGE REQUEST	Doc. No. CE-1386	Rev. No. 0	Sheet No. 43 of 43
	Subject STABILITY OF SWR DIKE	Prepared By S. Ponton		Date 3-24-98
	System S.W.	Checked By MLB		Date 4-9-98

APPENDIX E

ATTACHMENT 4 - NDCM 3.7

AND

ATTACHMENT 5 - NDCM 3.7

CALCULATION REVIEW CHECKLIST			ATTACHMENT E
Calc No. CE-1386	Rev. 0	Add. —	Page 1 of 2

Questions: A "No" answer to any question requires that an explanation be provided below. NOTE: Reference may be made to explanations contained in the calc or addendum.

Question	YES	NO	N/A
1. Is the Calc No., Revision No. and Addendum No. (if applicable) identified on each page of the Calc and on the first page of each attachment?	[✓]	[ ]	[ ]
2. Does the objective statement identify the reason for performing the calc and give sufficient background information?	[✓]	[ ]	[ ]
3. Have the sources of design inputs been correctly selected and referenced in the calc?	[✓]	[ ]	[ ]
4. Are the sources of design inputs up-to-date and retrievable (and/or a copy attached to the calc)?	[✓]	[ ]	[ ]
5. Where appropriate, have the other disciplines reviewed or provided the design inputs for which they are responsible?	[ ]	[ ]	[✓]
6. Have design inputs been confirmed by analysis, test, measurement, field walkdown, or other pertinent means as appropriate for the configuration analyzed?	[✓]	[ ]	[ ]
7. Are assumptions adequately described and bounded by the Station Design Basis?	[✓]	[ ]	[ ]
8. Have the bases for engineering judgments been adequately and clearly presented?	[✓]	[ ]	[ ]
9. Were appropriate calculation/analytic methods used and are outputs reasonable when compared to inputs?	[✓]	[ ]	[ ]
10. Are computations technically accurate and has the calculation made appropriate allowances for instrument errors and calibration equipment errors? (Reference STD-EEN-0304)	[✓]	[ ]	[ ]
11. Have those computer codes used in the analysis been referenced in the calc?	[✓]	[ ]	[ ]
12. Have all exceptions to station design basis criteria and regulatory requirements been identified and justified in accordance with ANSI N45.2.11-1974?	[ ]	[ ]	[✓]

Comments: (Attach additional pages if needed.)

Prepared By (Print Name)	Signature	Date
J.S. THORNTON O/R	J.S. Thornton	4-9-98
Reviewed By (Print Name)	**Signature**	**Date**
M.L. Blough	M L Blough	4-9-98

CROSS REFERENCE INPUT SHEET **ATTACHMENT**

Calc No. CE-1386					Rev. No. 0	Page 2 of 2
Doc. Rel.	Doc. Type	Number (If applicable)	Rev. No.	Sht. No.	Title	
RF	CALC	11715-140	0	—	SWR DIKE STABILITY ANALYSIS, APRIL 19	

DOC TYPES: See DMIS for others — CALC, CODE, DWG, DCP, DR, EWR, ENGT, JCO, LER, LIST, NRC, PPR, SPEC, STD, TEST, VTM

DOC REL — PA-Potentially Affects, SU-Superseded, RF-References

Note: A DOC REL of PA is to used for all References whi provided design inputs.

(M)