Client:	*GE/UNC*	**Sheet:**	*1* **of** *10*
Project:	*St. Anthony Mine Closeout Plan*	**Date:**	*July 18, 2020*
Description:	*Cover Erosional Stability*	**Job No:**	*233001076*

APPENDIX G.2: COVER EROSIONAL STABILITY AND SOIL LOSS ANALYSES

Revisioning

Rev.	Date	Description	By	Checked	Date
0	*08/18/20*	*Draft for Internal Review*	*M. Kapp / C. Fritz*	*J. Cumbers*	*08/20/2020*

Location and Format

Electronic copies of these calculations are located on the Stantec internal project teamsite.

The following calculations were generated using the following software: MS Excel

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Objective

This calculation sheet describes the erosional stability and soil loss analyses associated with cover designs for Piles 1 through 4 and Pits 1 and 2 at the St. Anthony Mine.

Background

Stantec conducted erosional stability analyses as part of proposed cover design evaluations for Piles 1 through 4 and Pits 1 and 2. Waste material in Piles 1 through 4 are to be directly covered with 2 feet of soil cover. Pit 1 is to be covered with 24 inches of soil cover, which overlays five feet of additional cover material from the Pit 1 highwall excavation. Pit 2 is to be covered with 24 inches of soil cover over eight feet of additional cover material from the South Topsoil pile adjacent to the pit. Each cover surface will be revegetated to enhance erosional stability. The uppermost 24 inches of the covers (which includes the full cover depth in the case of Piles 1 through 4) will consist of material to promote vegetation establishment. For the purposes of these analyses, the cover soil for the proposed design will be obtained from on-site borrow sources and is assumed to have similar material properties as the site borrow materials.

Critical slopes were selected for erosional stability evaluation based on proposed design length and slope grade. The slope selected for combined Piles 1 & 2 is a 3H:1V slope, approximately 375 feet in length. The slope selected for Pile 3 is also a 3H:1V slope, approximately 375 feet in length. A slope of 4.2H:1V with a length of approximately 400 feet was selected for Pile 4. For Pits 1 and 2, Stantec selected the entire length of the proposed cover design slope for evaluation. The proposed cover design for Pit 1 includes a 100H:1.5V slope that is approximately 1,025 feet in length. Pit 2 proposed cover design includes a slope approximately 1,440 feet long at a 100H:1.5V slope. Figure 1 shows the proposed cover design geometries and slopes.

Stantec evaluated the potential for cover soil loss due to surficial erosion using the Revised Universal Soil Loss Equation (RUSLE) as presented in the United States Department of Agriculture (USDA) Handbook 703 (Renard et al., 1997). Calculations were performed for the same covered areas included in the erosional stability analyses and using the same slope properties previously described in this section.

Applicable Codes and Standards

NUREG 1623, Sections 2.2, 3.2, and Appendix A (Johnson, 2002).

Methods

Temple Method

Temple et al. (1987) outlines procedures for grass-lined channel design. These procedures are recommended in Johnson (2002) for areas of vegetated cover and include methods for estimating stresses on channel vegetation as well as the channel surface soils. The evaluation for the vegetated top cover slope used the peak discharge values from the 100-year design storm event (summarized in Attachment A) to represent the effective stresses from runoff on the cover surface. Calculations include the cases for poor and good vegetation establishment and include soil properties based on the laboratory data for the onsite borrow soils.

Stantec evaluated the erosional stability of the cover surface by calculating a factor of safety against erosion due to the peak runoff from the 100-year design storm event. Factor of safety values were calculated as the ratio of the allowable stresses (the resisting strength of the cover vegetation and soils) to the effective stresses (the stresses imparted by the runoff flowing over the cover). The surfaces were evaluated for two conditions: (1) resistance of poor vegetation, and (2) resistance of fair vegetation. The peak unit discharge flow for the top slope (from Table 1) was conservatively multiplied by a flow concentration factor of three (as outlined in Johnson, 2002).

Design Criteria

The critical (lowest) calculated factor of safety for both fair and poorly vegetated ground conditions for Piles 1 through 4 and Pits 1 and 2 were evaluated. NRC design guidance includes a minimum acceptable factor of safety for allowable stress to effective stress on the soil of one or greater (FS >= 1) for any vegetation condition, using the probable maximum precipitation (PMP) (Johnson, 2002). For the purposes of this design, because a 100-year design storm is being applied, Stantec assumed a minimum required FS >= 1.5 for soil erosional stability is applicable for the design.

Time of Concentration

Stantec determined slope ratios (horizontal:vertical) of Pit 1, Pit 2, and Pile 4 from design drawings for the backfilled pits and regraded piles and used design drawings to determine maximum slope lengths for the backfilled pits and regraded piles as inputs. Stantec then calculated time of concentration for Piles 1 through 4 and Pits 1 and 2 using the Kirpich equation as presented in NUREG/CR-4620 (Nelson et al., 1986). As recommended in NUREG/CR-4620 (Nelson et al., 1986), Stantec used a minimum time of concentration of 2.5 minutes.

Design Storm Event

Stantec designed stormwater controls based on a design flood event for the storm with a 1 percent annual occurrence probability (1 in 100-year storm). The study also evaluated the 2-year, 5-year and 10-year storm events under the existing site conditions. Stantec estimated peak discharge values associated with the design flood events at each point of interest on the Site by simulating runoff hydrographs using a center peaking rainfall distribution that included the peak rainfall intensity for every 5-minute interval up to 24 hours.

Peak Unit Discharge

1. Stantec determined maximum slope lengths for the side slopes and the top surface from the revised drawing of the disposal cell (Figure 1 attached).

2. Stantec calculated the time of concentration for the cover slopes by the Kirpich equation as presented in NUREG/CR-4620 (Nelson et al., 1986). As recommended in NUREG/CR-4620 (Nelson et al., 1986), Stantec used a minimum time of concentration of 2.5 minutes.

3. Stantec calculated the rainfall intensity based on time of concentration of a 100-year design storm event.

4. Peak unit discharge calculations used the Rational Method for each slope using a unit width analysis. The procedure used is as described in Johnson (2002) and Nelson et al. (1986).

5. Stantec selected the runoff coefficient of 0.6 based on surface type and vegetation and referenced values in NRC (1990).

6. The cover on the side slopes was represented with slopes of 1 percent (100:1) for Pit 1, 1.5 percent (100:1.5) for Pit 2, and 20 percent (5:1) for Pile 4.

Erosional Stability

Allowable stresses. Stantec calculated allowable stresses for the cover soil using the equations in Temple et al. (1987). Material planned for the cover soil consists of on-site borrow material, therefore Stantec used properties of the sample materials in the analyses. For cohesive soils, erosional resistance is based on the plasticity index (PI) and void ratio of the material.

The equation for allowable shear strength for cohesive soils is:

$$\tau_a = \tau_{ab} C_e^2$$

where τ_a = allowable shear strength (in psf)
τ_{ab} = base allowable shear strength = 1.07*PI2+14.3*PI+47.7)*0.0001 for 10<PI<20
C_e = void ratio correction factor = 1.48 - 0.57e, where e is the void ratio

For a vegetated surface primarily of mixed grasses, the allowable vegetation shear strength is:

$$\tau_{va} = 0.75 C_I$$

Where τ_{va} = allowable vegetation shear strength (in psf)
C_I =cover index = 2.5 [h(M)1/2]1/3
h = stem length (in ft), 0.5 assumed for poor establishment 1.0 for good (average) establishment
M = stem density factor, 67 assumed for poor coverage, 200 for good (average) coverage

The vegetated shear strength was calculated for poor and fair vegetation conditions.

Effective stresses. The effective shear stress on soil due to peak runoff from the 100-year design storm event was calculated as:

$$\tau_e = \gamma d S \left(1 - C_f\right)(n_s/n)^2$$

Where τ_e = effective shear stress (in psf)
γ = unit weight of water = 62.4 pounds per cubic foot (pcf)
d = depth of flow (ft)
S = slope of cover surface (ft/ft), from Table 1
C_f = cover factor (0.375 for poor, 0.750 for good)
n_s = soil grain roughness factor (0.0156 for cohesive soil), and
n = Manning's roughness coefficient for vegetated surface

$$n = e^{C_i\left(0.0133[\ln q]^2 - 0.0954 \ln q + 0.297\right) - 4.16}$$

The effective shear stress on vegetation is calculated as:

$$\tau_v = \gamma d S - \tau_e$$

Where τ_v = effective vegetal stress (in psf)

Factor of Safety

The factor of safety for soil erosion and vegetation stability were calculated as:

$$FS_{soil} = \frac{\tau_a}{\tau_e}$$

$$FS_{veg=} \frac{\tau_{va}}{\tau_v}$$

Where FS = factor of safety against erosion.

Soil Loss (RUSLE)

The RUSLE for calculating soil loss is expressed as:

$$A = R * K * (LS) * C * P$$

where *A* = average annual soil loss by sheet and rill erosion (tons/acre/year)
R = rainfall erosivity factor (dimensionless)
K = soil erodibility factor (dimensionless)
LS = slope length and steepness factor (dimensionless)
C = cover management factor (dimensionless)
P = conservation support practice factor (dimensionless)

The *R*-factor varies greatly by location due to changes in rainfall frequency and intensity. Figure 1 [from USDA-NRCS, NM (1999)] presents isobars for the state of New Mexico which illustrate the variation in *R* across the state. As shown on Figure 2, Stantec located the St. Anthony Mine on the map and selected the *R*-factor corresponding to the nearby isobar.

The *K*-factor represents the susceptibility of the soil particles to detachment by water and is dependent on soil properties such as soil texture, organic matter, structure, and permeability (USDA-NRCS, NM, 1999). Stantec estimated one *K* for Pits 1 and 2 and Piles 1 through 3, and another *K* for Pile 4. As further discussed in the Material Properties section, cover soil properties are the same for the pits and Piles 1 through 3, whereas the Pile 4 cover has slightly different properties. Stantec used the nomograph presented in USDA Handbook 703 to estimate *K* based on the soil properties. Figure 3 and Figure 4 show the nomograph and illustrate the graphical method used to obtain the two *K*-factors based on the properties of the Pits 1 and 2 and Piles 1 through 3 covers, and the Pile 4 cover, respectively.

USDA Handbook 703 presents a table of *LS* values for a range of slope length and steepness combinations. Stantec calculated the *LS*-factor for each covered area based on the corresponding slope lengths and steepness by interpolating between the known values in the USDA table. Figure 5, Figure 6, and Figure 7 show the USDA table with highlighted values corresponding to Pits 1 and 2, Piles 1 through 3, and Pile 4, respectively.

Since cover management practices are expected to be the same for each covered area, a single *C*-factor was calculated for all of the areas. Stantec assumed vegetation would take 10 years to fully establish, thus the *C*-factor was calculated as an average over 10 years to account for changes in the condition of the cover surface over time.

The *C*-factor was calculated as the product of several subfactors, including a cropping system factor, tillage effect factor, expected yield factor, and previous crop factor. Stantec obtained values for these subfactors from a RUSLE spreadsheet analysis created by Kansas State University (Thien, n.d.). Assuming ridge-tilling along the slope contours would be implemented during reclamation, Stantec applied a tillage effect factor of 0.75 to the calculation for each year. Expected vegetation yield was assumed to be average, resulting in a yield factor of 1.0 for each year. Stantec assumed the cover surface would be bare soil for the first year after construction; therefore, a previous crop factor of 1.0 was applied to years 1 and 2. Following year 2, the previous crop was assumed to be grass such that a previous crop factor of 0.52 was applied to years 3 through 10. The cropping system factor is dependent on the current crop (vegetation) system and the percentage of residue cover (Thien, n.d.). The residue cover percentage was increased by 10 percentage points each year, from 0 percent during year 1 to 90 percent during year 10. Table 1 lists cropping system factors presented by Thien (n.d.) for a range of vegetation types and residue cover percentages. For year 1, Stantec used the value for bare crops and 0 percent residue cover. For years 2 through 10, Stantec used values for “other crops” and the residue cover corresponding to the selected year (see bold values in table).

Table 1. Cropping System Factors based on Current Crop and Residue Cover (Thien, n.d.)

Current Crop System	% Residue Cover									
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Corn or sorghum, continuous	0.32	0.28	0.24	0.2	0.16	0.14	0.11	0.08	0.06	0.04
Small grain, continuous	0.25	0.23	0.2	0.17	0.14	0.12	0.08	0.06	0.04	0.03
Small grain after row crop	0.22	0.2	0.18	0.16	0.14	0.12	0.08	0.06	0.04	0.03
Small grain after fallow	0.23	0.21	0.19	0.17	0.14	0.12	0.08	0.06	0.04	0.03
Corn or sorghum after SG	0.3	0.28	0.26	0.2	0.16	0.14	0.11	0.08	0.06	0.04
Soybean continuous	0.43	0.37	0.35	0.3	0.25	0.22	0.2	0.15	0.1	0.08
Soybean or sunflower after SG or RC	0.33	0.29	0.26	0.21	0.17	0.15	0.12	0.08	0.06	0.04
Forage or sorghum drilled after RC or SG	0.3	0.28	0.26	0.2	0.16	0.14	0.11	0.08	0.06	0.04
Other crops after RC or SG	0.33	**0.29**	**0.26**	**0.24**	**0.2**	**0.18**	**0.16**	**0.12**	**0.08**	**0.06**
Special Crops	1.0	0.01	0.02	0.3	1.0	-	-	-	0.01	0.01
Woodland	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bare	**1.0**	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

SG = small grain, RC = row crop

Since the implementation of conservation support practices is not expected at the project site, the *P*-factor was assumed to be 1.0.

Material Properties

Material parameters for the erosional stability analyses were based on proposed borrow source material parameters collected from the 2018 field investigation. Table 2 summarizes the parameters for each material.

Piles 1 through 3 and Pit 2 cover will consist of material excavated from the West Borrow areas. Pit 1 cover will also include material excavated from the North Topsoil pile in addition to material from the West Borrow area. Since these two materials were assumed to originate from the same alluvial deposit in the vicinity of Pit 1 based on visual assessments and lab testing results, data from the two borrow sources were combined into a single dataset to estimate cover properties for Piles 1 through 3 and both pits. This material was assigned a dry unit weight of 117.4 pounds per cubic foot, which was calculated as 90 percent of the maximum dry unit weight obtained from Standard Proctor compaction tests. Specific gravity was assumed to be 2.65. A plasticity index value of 10 percent was selected using Atterberg limit results from both borrow sources. Void ratio was calculated using the assigned dry unit weight, estimated specific gravity, and unit weight of water. Lastly, the D_{75} value was selected to be 0.005 inches based on the average result of mechanical analyses of the North Topsoil and Borrow West soils.

Pile 4 cover will consist of material excavated from both the West Borrow and Lobo Tract borrow areas. Based on combined laboratory data from these borrow sources, this material was assigned a dry unit weight of 115.2 pounds per cubic foot, which was calculated as 90 percent of the maximum dry unit weight obtained from Standard Proctor compaction tests. Specific gravity was assumed to be 2.65. A plasticity index value of 10 percent was selected using Atterberg limit results from both borrow sources. Void ratio was calculated using the assigned dry unit weight, estimated specific gravity, and unit weight of water. Lastly, the D_{75} value was selected to be 0.004 inches based on the average result of mechanical analyses of all borrow area soils.

Table 2. Soil Properties

Material	Dry Unit Weight (pcf)	Specific Gravity	Plasticity Index (%)	Calculated Void Ratio	D_{75}[(1)] (in.)
Piles 1 - 3	117.4	2.65	10	0.41	0.005
Pile 4	115.2	2.65	10	0.44	0.004
Pits 1 & 2	117.4	2.65	10	0.41	0.005

(1) Diameter for which 75% of the material is finer

Material properties of the soil covers were used in the soil loss analysis to estimate the soil erodibility factor (*K*). Relevant input parameters for the nomograph shown in Figure 3 and Figure 4 include the percentage of silt and very fine sand (i.e., sand passing the #140 sieve), percent sand (0.10 to 2.0 mm), and percent organic matter. Average silt and sand percentages were obtained from laboratory results for the cover material (see Appendix D of the 2020 Closure/Closeout Plan) and organic matter content was zero. Based on the amount of fines and sand present in the cover materials, Stantec assumed a fine granular soil structure and moderate permeability for each cover. Table 3 summarizes the input properties used to estimate the *K*-factor.

Table 3. Material Properties for RUSLE *K*-factor

Site Facility	Cover Material	% Silt + Fine Sand	% Sand (0.10-2.0 mm)	% Organic Matter	Soil Structure	Permeability
Pits 1 & 2, Piles 1-3	West Borrow / North Topsoil	51	34	0	Fine Granular	Moderate
Pile 4	West Borrow + Lobo Tract	54	28	0	Fine Granular	Moderate

Calculation Inputs

Table 4 presents the time of concentration for Pit 1, Pit 2, and Piles 1 through 4. The time of concentration represents the time it takes for runoff in the upstream extents of the watershed to reach the design point of interest, or basin outlet. Table 5 summarizes the 100-year design storm characteristics.

Table 4. Time of Concentration Summary

Description	Slope (ft/ft)	Slope Length (ft)	Calculated T_c (min)	T_c used to calculate rainfall intensity (min)
Piles 1 & 2 (combined)	0.33	375	1.15	2.50
Pile 3	0.33	375	1.15	2.50
Pile 4	0.24	400	1.36	2.50
Pit 1	0.015	1025	8.18	8.18
Pit 2	0.015	1440	10.62	10.62

Table 5. 100-year Design Storm Summary

	Piles 1 & 2 (combined)	Pile 3	Pile 4	Pit 1	Pit 2
Annual Recurrence :	1/100	1/100	1/100	1/100	1/100
Duration (min) :	2.50	2.50	2.50	8.18	10.62
Intensity (in/hr) :	8.85	8.85	8.85	6.2	5.5

Table 6 presents the peak unit discharge result for Piles 1 through 4 and Pits 1 and 2. The discharge represents downslope flow for a unit-width of the slope. Calculations are attached.

Table 6. Peak Unit Discharge Summary

Description	Slope (ft/ft)	Slope Length (ft)	Calculated Time of Concentration (min)	Peak Unit Discharge (cfs)	Design Discharge (cfs)
Piles 1 & 2 (combined)	0.33	375	2.50	0.046	0.046
Pile 3	0.33	375	2.50	0.046	0.046
Pile 4	0.20	400	2.50	0.049	0.049
Pit 1	0.015	1025	8.18	0.088	0.088
Pit 2	0.015	1440	10.62	0.111	0.111

Table 7 presents the subfactors used to calculate the *C*-factor for the soil loss calculations. Adjusted *C*-factors were calculated for each year of vegetation growth and the resulting average value was used to calculate total soil loss for each covered area.

Table 7. Soil Loss *C*-factor Calculation

Year	Cropping System	Residue Cover %	Tillage Effect	Expected Yield	Previous Crop	Crop/Cover Factor	Tillage Factor	Yield Factor	Previous Crop Factor	Adjusted *C*-factor
1	Bare Soil	0	Ridge-till on contour	Average	Other	1.0	0.75	1.0	1.0	0.75
2	Grass/Legume	10			Other	0.29	0.75	1.0	1.0	0.22
3	Grass/Legume	20			Grass/Legume	0.26	0.75	1.0	0.52	0.10
4	Grass/Legume	30			Grass/Legume	0.24	0.75	1.0	0.52	0.09
5	Grass/Legume	40			Grass/Legume	0.20	0.75	1.0	0.52	0.08
6	Grass/Legume	50			Grass/Legume	0.18	0.75	1.0	0.52	0.07
7	Grass/Legume	60			Grass/Legume	0.16	0.75	1.0	0.52	0.06
8	Grass/Legume	70			Grass/Legume	0.12	0.75	1.0	0.52	0.05
9	Grass/Legume	80			Grass/Legume	0.08	0.75	1.0	0.52	0.03
10	Grass/Legume	90			Grass/Legume	0.06	0.75	1.0	0.52	0.02
									AVERAGE:	**0.15**

Results

Calculation output sheets are included as Attachment A. Table 8 presents a summary of the calculated factors of safety. Table 9 presents a summary of the soil loss calculations for each of the covered site facilities, including each of the factors used in the RUSLE and the resulting average annual soil loss.

Table 8. Summary of Calculated Factors of Safety for Erosional and Vegetation Stability on Vegetated Slopes

Vegetation condition	Soil Erosional Stability					Vegetation Stability				
	Piles 1 & 2 (combined)	Pile 3	Pile 4	Pit 1	Pit 2	Piles 1 & 2 (combined)	Pile 3	Pile 4	Pit 1	Pit 2
Poor	1.5	1.5	1.9	6.0	4.8	1.4	1.4	1.8	10.8	10.9
Fair	5.6	5.6	6.5	19.0	14.5	1.3	1.3	1.5	10.1	10.4

Table 9. Summary of Soil Loss Results

Parameter	Pit 1	Pit 2	Piles 1 & 2 (combined)	Pile 3	Pile 4
Rainfall erosivity factor, *R*	20	20	20	20	20
Soil erodibility factor, *K*	0.39	0.39	0.39	0.39	0.39
Slope length & steepness factor, *LS*	0.26	0.26	10.8	10.8	7.57
Cover management factor, *C*	0.15	0.15	0.15	0.15	0.15
Support practice factor, *P*	1.0	1.0	1.0	1.0	1.0
Average annual soil loss, A (tons/acre/year)	**0.3**	**0.3**	**12.6**	**12.6**	**8.9**

Conclusions

Based on the erosional stability analyses using the methods and material parameters presented above, the representative slope lengths of Pit 1, Pit 2, and Piles 1 through 4 exceed the required minimum factor of safety for soil erosional stability requirements for the 100-year design storm having poor and fair vegetation. Stantec anticipates that the Pile 4 slopes between the downdrains will require active maintenance following large storm events until vegetation is established.

RUSLE calculations indicate that soil loss due to erosion is relatively high for the pile covers (8.9 to 12.6 tons/acre/year) compared to the pit covers (0.3 tons/acre/year) as a result of the steeper and longer slopes of the proposed pile regrade designs. Therefore, temporary erosion control measures and active management of erosion will be required to reduce the soil loss at the piles, until vegetation is established on the covers.

Attachments

Figure 1 – Pit 1, Pit 2, and Piles 1 through 4 Cover Slopes
Attachment H.2.1 – Factor of Safety Calculations

References

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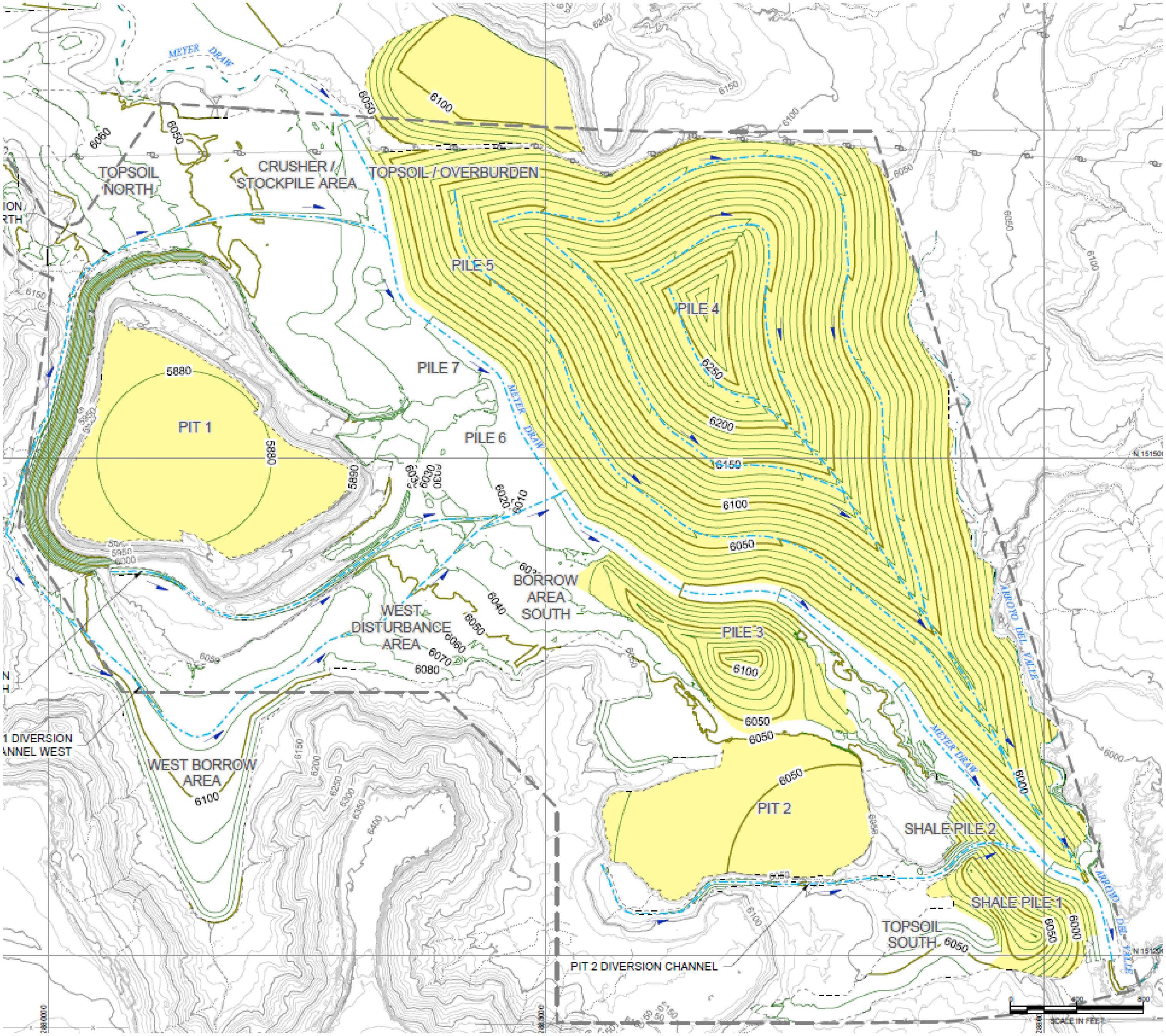


Figure 1. Pit 1, Pit 2, and Piles 1 through 4 Cover Slopes

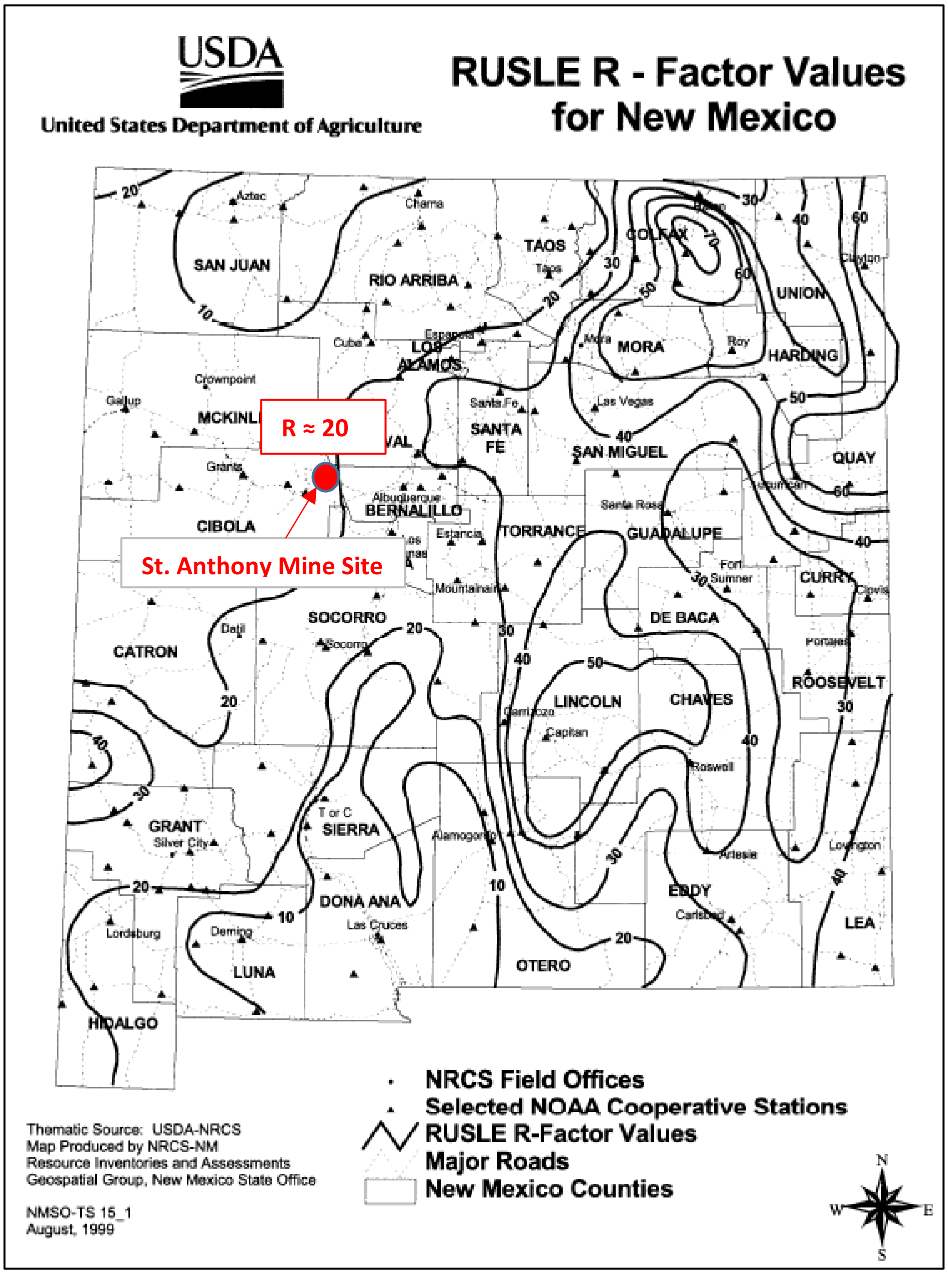


Figure 2. RUSLE *R*-factor Selection

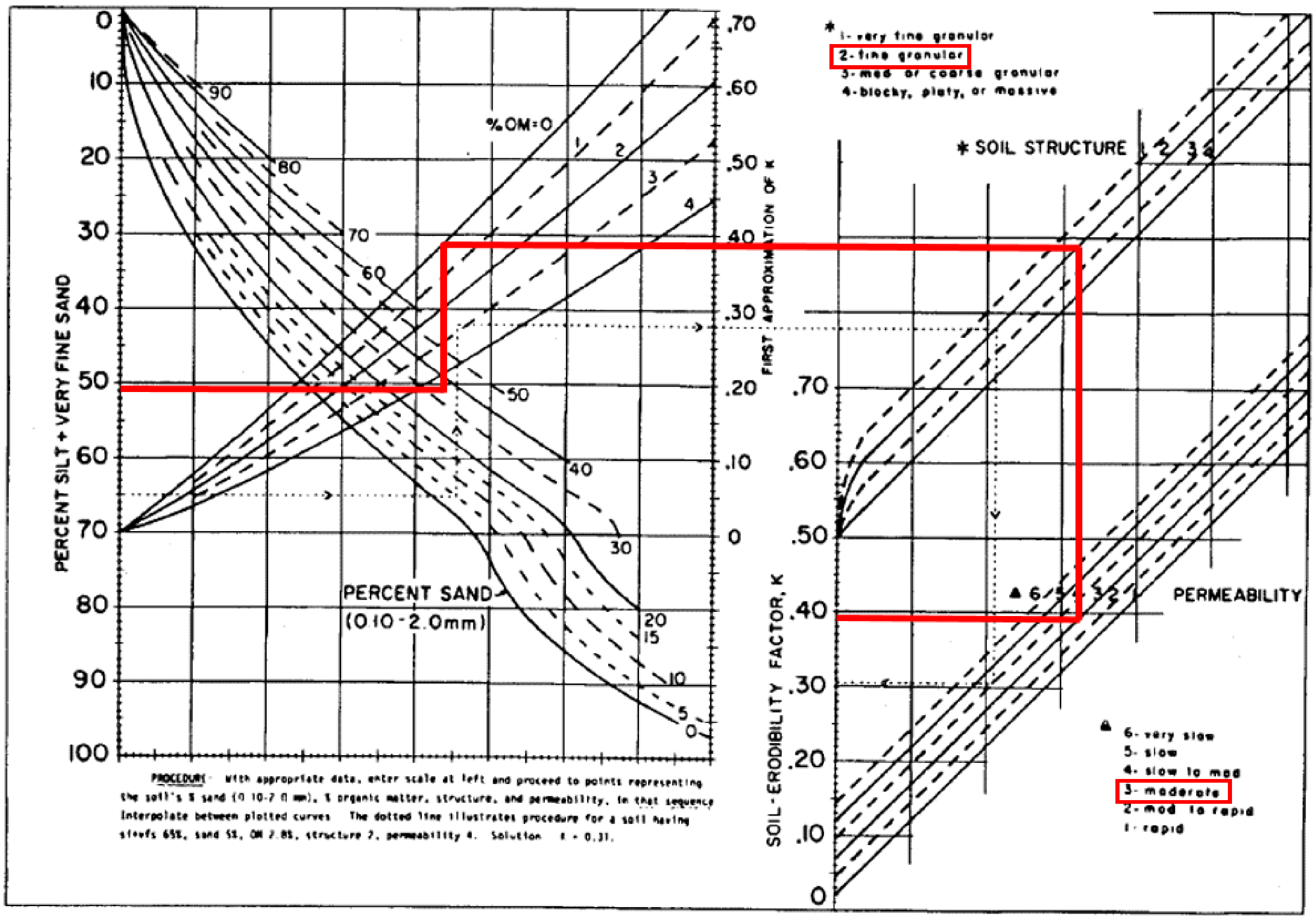


Figure 3. RUSLE *K*-factor – Pits 1 and 2, Piles 1-3

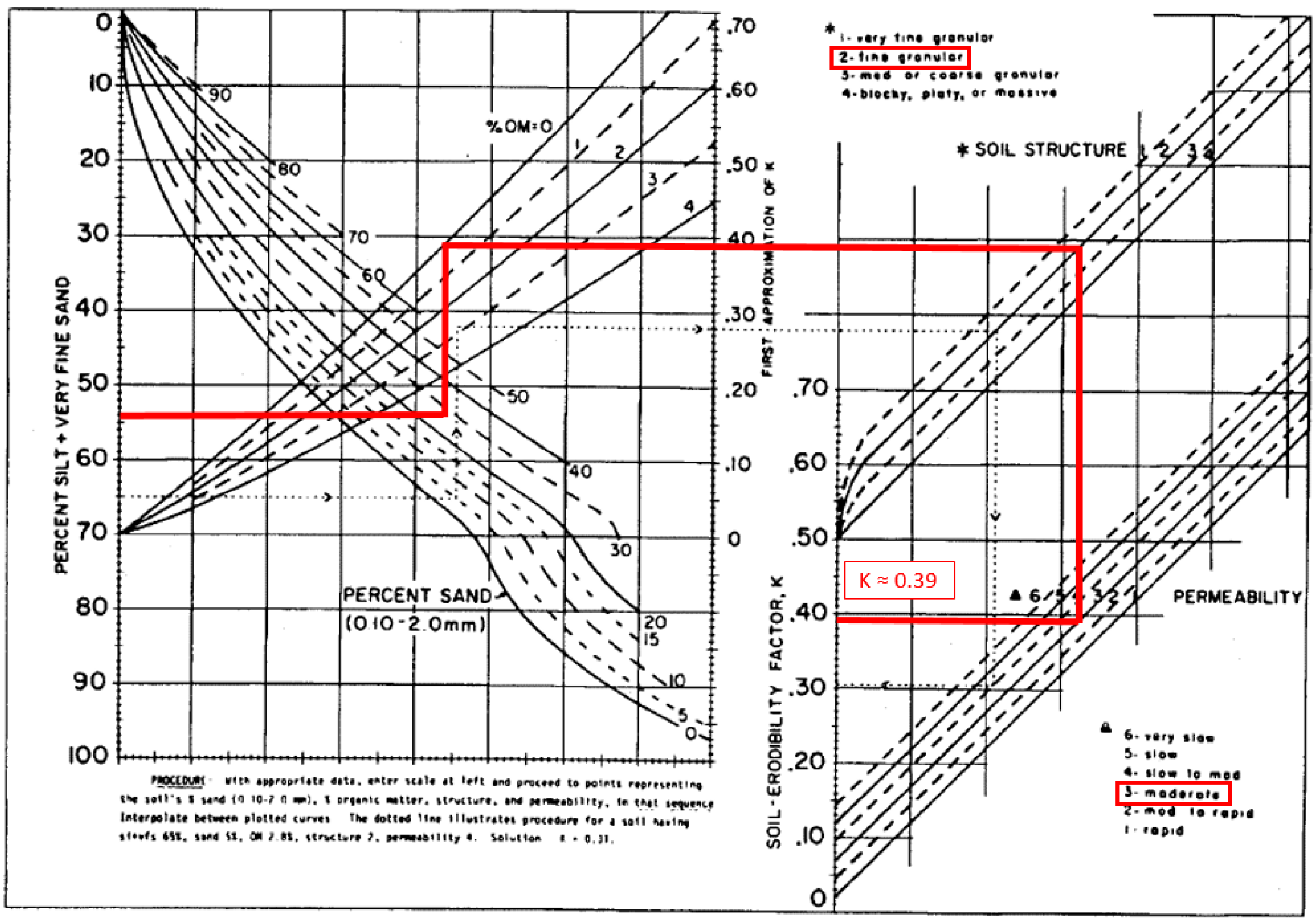


Figure 4. RUSLE *K*-factor – Pile 4

Table 4-1.
Values for topographic factor, LS, for low ratio of rill to interrill erosion.[1]

Pits 1 & 2 Interpolated LS for >1000-ft, 1.5% slope = 0.26

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1] Such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

Figure 5. RUSLE *LS*-factor – Pits 1 and 2

Table 4-1.
Values for topographic factor, LS, for low ratio of rill to interrill erosion.[1]

Piles 1+2 & 3 Interpolated LS for 375-ft, 33% slope = 10.92

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1]Such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

Figure 6. RUSLE *LS*-factor – Piles 1 through 3

Table 4-1.
Values for topographic factor, LS, for low ratio of rill to interrill erosion.[1]

Pile 4 Interpolated LS for 400-ft, 24% slope = 7.57

Slope (%)	Horizontal slope length (ft)																
	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1]Such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

Figure 7. RUSLE *LS*-factor – Pile 4

ATTACHMENT G.2.1

FACTOR OF SAFETY CALCULATIONS

Client: GE/UNC
Project: St. Anthony Mine
Detail: 30% Design: Pit and Pile Cover Slopes, Erosional Stability
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

Description	Slope (ft/ft)	Slope Length (ft)	Calculated T_c (min)	T_c used to calculate rainfall intensity (min)
Piles 1+2	0.33	375	1.15	2.50
Pile 3	0.33	375	1.15	2.50
Pile 4	0.240	400	1.36	2.50
Pit 1	0.015	1025	8.18	8.18
Pit 2	0.015	1440	10.62	10.62

References

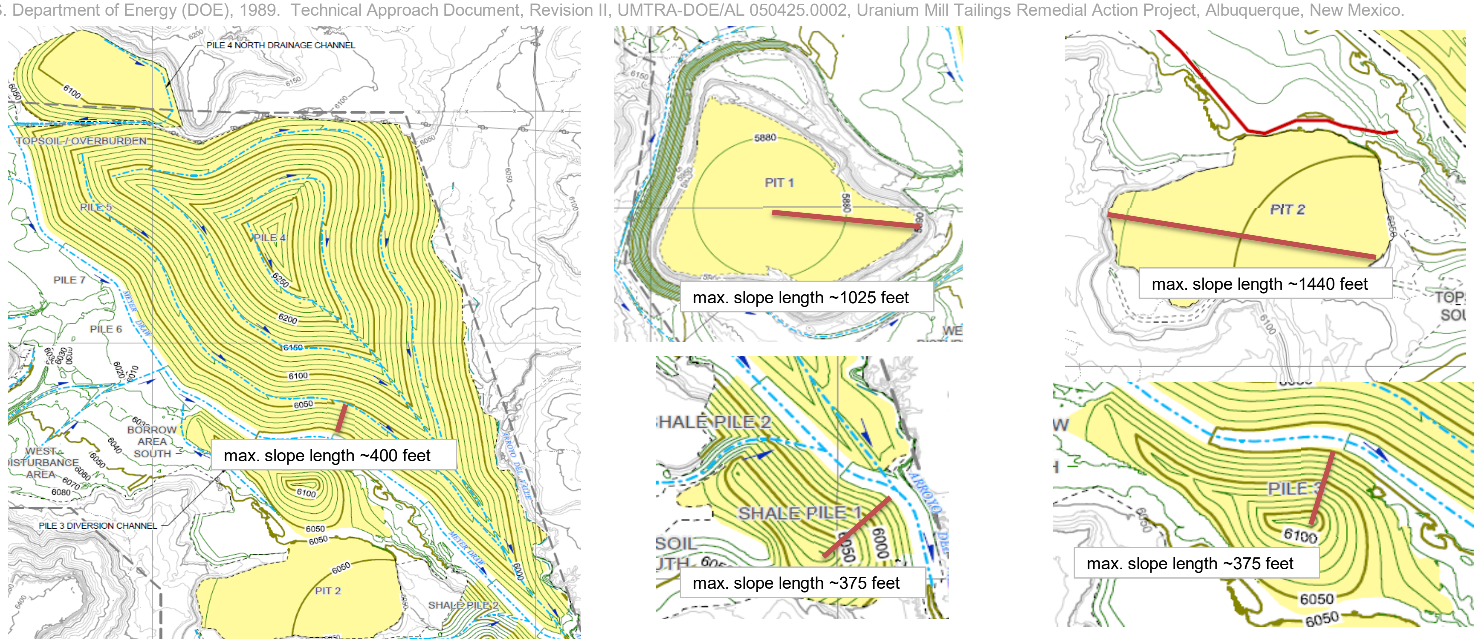
Source: Kirpich (1940) as presented in NUREG CR-4620

Formula: t_c=0.00013*L^0.77/S^0.385 with L in feet, t_c in hours

Minimum T_c = 2.5 minutes based on recommendation on pg. 12 of NUREG CR-4620 (Nelson et al., 1986)

Nelson, J., S. Abt, R. Volpe, D. van Zyl, N. Hinkle, and W. Staub, 1986. "Methodologies for Evaluation of Long-term Stabilization Designs of Uranium Mill Tailings Impoundments." NUREG/CR-4620, U.S. Nuclear Regulatory Commission, June.

U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.



St. Anthony Design Storms

Intensity (in/hr)	1/2	1/5	10	25	50	1/100	1/200	1/500	1/1000
5	**2.69**	**3.9**	**4.72**	**5.77**	**6.58**	**7.44**	**8.3**	**9.46**	**10.4**
10	**2.05**	**2.96**	**3.59**	**4.39**	**5**	**5.65**	**6.3**	**7.2**	**7.92**
15	**1.69**	**2.45**	**2.96**	**3.63**	**4.12**	**4.68**	**5.24**	**5.96**	**6.52**
30	**1.14**	**1.65**	**2**	**2.44**	**2.78**	**3.14**	**3.52**	**4**	**4.4**
60	**0.71**	**1.02**	**1.24**	**1.51**	**1.72**	**1.95**	**2.17**	**2.48**	**2.72**
120	**0.41**	**0.58**	**0.71**	**0.87**	**0.99**	**1.13**	**1.27**	**1.46**	**1.61**
180	**0.29**	**0.4**	**0.49**	**0.59**	**0.68**	**0.77**	**0.87**	**1**	**1.1**
360	**0.16**	**0.23**	**0.27**	**0.32**	**0.37**	**0.41**	**0.46**	**0.52**	**0.57**
720	**0.09**	**0.12**	**0.15**	**0.18**	**0.2**	**0.22**	**0.24**	**0.27**	**0.3**
1440	**0.05**	**0.07**	**0.08**	**0.09**	**0.11**	**0.12**	**0.13**	**0.15**	**0.16**

	Piles 1+2	Pile 3	Pile 4	Pit 1	Pit 2
Annual Recurrence:	1/100	1/100	1/100	1/100	1/100
Duration (min):	2.50	2.50	2.50	8.18	10.62
C	88.79	88.79	88.79	88.79	88.79
e	0.89	0.89	0.89	0.89	0.89
f	7.77	7.77	7.77	7.77	7.77
Intensity (in/hr) :	8.85	8.85	8.85	6.2	5.5

IDF Fitting	c	e	f
1/2	**32.168**	**0.8903**	**7.8226**
1/5	**46.998**	**0.895**	**7.8636**
10	**57.275**	**0.8961**	**7.9534**
25	**70.558**	**0.8981**	**8.0195**
50	**78.29**	**0.8924**	**7.7297**
1/100	**88.785**	**0.8921**	**7.768**
1/200	**100.21**	**0.8939**	**7.8952**
1/500	**113.35**	**0.8918**	**7.8198**
1/1000	**120.75**	**0.8847**	**7.4822**

References

Calculation information can be found in Appendix E

$$i = \frac{c}{T_d^e + f}$$

Where:

i = The design rainfall intensity (mm/hr)

T_d = The storm duration of the specific return period

c, e, f = Fitting parameters

Client: GE/UNC
Project: St. Anthony Mine
Detail: 30% Design: Pit and Pile Cover Slopes, Erosional Stability
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

UNIT DISCHARGE RUNOFF CALCULATIONS

Description	Slope Length (ft)	T_c used to calculate rainfall intensity (min)	Rainfall Intensity (in/hr)	Peak Unit Discharge (cfs) for a one-foot width	Peak Unit Discharge (cfs) for a one-foot width used for erosion analyses
Piles 1+2	**375**	2.50	8.85	0.046	0.046
Pile 3	**375**	2.50	8.85	0.046	0.046
Pile 4	400	2.50	8.85	0.049	0.049
Pit 1	1025	8.18	6.21	0.088	0.088
Pit 2	1440	10.62	5.55	0.111	0.111

Unit Discharge Notes/References

Incremental rainfall duration percentage of one-hr PMP, NUREG CR-4620 (Table 2.1) and DOE 1989 (Table 4.1)
Calculated. DOE, 1989. Equation (2), page 66.

0.6	Runoff Coefficient, C	NRC, 1990
2.5	Minimum T_c (min)	Recommendation on pg. 12 of NUREG CR-4620 (Nelson et al., 1986)
	Peak Unit Discharge, q=CIAw	C and I defined above, Aw=Unit width or slope length times a 1-foot width

References

Nelson, J., S. Abt, R. Volpe, D. van Zyl, N. Hinkle, and W. Staub, 1986. "Methodologies for Evaluation of Long-term Stabilization Designs of Uranium Mill Tailings Impoundments." NUREG/CR-4620, U.S. Nuclear I
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 1990. Final Staff Technical Position Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites.. August 1990.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Piles 1+2 - Erosional Stability (poor vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

3	Top Slope, (Xhoriz:1vert)	Design geometry
0.330	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
18.3	Slope Angle, θ_0 (deg)	Calculated from design geometry
375	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.5	Representative Stem Length, h_{stem} (ft)	Lower bound stem length for proposed cover vegetation, assumes poor establishment (see existing conditions photo right)
67	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with poor coverage selected to represent established cover vegetation.
0.375	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), poor assumed 50% reduction of grass mixture factors

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

4.00	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.00	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.1289	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.102	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.147	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
1.45	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0192	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
2.08	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
1.5	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.4	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Piles 1+2 - Erosional Stability (fair vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

3	Top Slope, (Xhoriz:1vert)	Design geometry
0.330	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
18.3	Slope Angle, θ_0 (deg)	Calculated from design geometry
375	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.75	Representative Stem Length, h_{stem} (ft)	Stem length for proposed cover vegetation, assumes fair establishment
133	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with fair coverage selected to represent established cover vegetation.
0.6	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), fair assumed 20% reduction of grass cover factor

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

5.13	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.85	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with 10 ≤ PI ≤ 20
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.2351	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.146	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.147	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
1.01	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0053	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
3.01	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
5.6	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.3	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pile 3 - Erosional Stability (poor vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

3	Top Slope, (Xhoriz:1vert)	Design geometry
0.330	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
18.3	Slope Angle, θ_0 (deg)	Calculated from design geometry
375	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.5	Representative Stem Length, h_{stem} (ft)	Lower bound stem length for proposed cover vegetation, assumes poor establishment (see existing conditions photo right)
67	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with poor coverage selected to represent established cover vegetation.
0.375	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), poor assumed 50% reduction of grass mixture factors

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

4.00	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.00	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with 10 $\leq$ PI $\leq$ 20
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.1289	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.102	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.147	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
1.45	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0192	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
2.08	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
1.5	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.4	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pile 3 - Erosional Stability (fair vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

3	Top Slope, (Xhoriz:1vert)	Design geometry
0.330	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
18.3	Slope Angle, θ_0 (deg)	Calculated from design geometry
375	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.75	Representative Stem Length, h_{stem} (ft)	Stem length for proposed cover vegetation, assumes fair establishment
133	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with fair coverage selected to represent established cover vegetation.
0.6	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), fair assumed 20% reduction of grass cover factor

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

5.13	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.85	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.2351	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.146	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.147	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
1.01	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0053	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
3.01	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
5.6	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.3	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pile 4 - Erosional Stability (poor vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

4.2	Top Slope, (Xhoriz:1vert)	Design geometry
0.240	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
13.4	Slope Angle, θ_0 (deg)	Calculated from design geometry
400	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
115.2	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.435	Calculated Void ratio	Calculated
0.004	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.5	Representative Stem Length, h_{stem} (ft)	Lower bound stem length for proposed cover vegetation, assumes poor establishment (see existing conditions photo right)
67	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with poor coverage selected to represent established cover vegetation.
0.375	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), poor assumed 50% reduction of grass mixture factors

Other

62.4	Unit Weight of Water, γ_w (pcf)

CALCULATIONS

4.00	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.00	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.23	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0289	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.1289	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.112	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.147	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
1.31	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0154	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
1.67	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
1.9	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.8	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.

U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.

U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pile 4 - Erosional Stability (fair vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

4.2	Top Slope, (Xhoriz:1vert)	Design geometry
0.24	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
13.4	Slope Angle, θ_0 (deg)	Calculated from design geometry
400	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.049	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.147	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
115.2	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.435	Calculated Void ratio	Calculated
0.004	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.75	Representative Stem Length, h_{stem} (ft)	Stem length for proposed cover vegetation, assumes fair establishment
133	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with fair coverage selected to represent established cover vegetation.
0.6	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), fair assumed 20% reduction of grass cover factor

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

5.13	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.85	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.23	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0289	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.2351	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.170	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.161	q (cfs/ft), with veg	q calculated
0.013	qcalc - qdesign	Iterate d until q calculated equals q design
0.95	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0044	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
2.52	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
6.5	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
1.5	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pit 1 - Erosional Stability (poor vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

67	Top Slope, (Xhoriz:1vert)	Design geometry
0.015	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
0.9	Slope Angle, θ_0 (deg)	Calculated from design geometry
1025	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.088	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.2654	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.5	Representative Stem Length, h_{stem} (ft)	Lower bound stem length for proposed cover vegetation, assumes poor establishment (see existing conditions photo right)
67	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with poor coverage selected to represent established cover vegetation.
0.375	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), poor assumed 50% reduction of grass mixture factors

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

4.00	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.00	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.0931	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.302	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.265	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
0.88	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0050	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
0.28	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
6.0	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
10.8	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pit 1 - Erosional Stability (fair vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

67	Top Slope, (Xhoriz:1vert)	Design geometry
0.015	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
0.9	Slope Angle, θ_0 (deg)	Calculated from design geometry
1025	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.088	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.2654	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.75	Representative Stem Length, h_{stem} (ft)	Stem length for proposed cover vegetation, assumes fair establishment
133	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with fair coverage selected to represent established cover vegetation.
0.6	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), fair assumed 20% reduction of grass cover factor

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

5.13	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.85	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.1548	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.409	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.265	q (cfs/ft), with veg	q calculated
0.000	qcalc - qdesign	Iterate d until q calculated equals q design
0.65	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0016	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
0.38	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
19.0	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
10.1	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pit 2 - Erosional Stability (poor vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES

Notes:

Slope Geometry

67	Top Slope, (Xhoriz:1vert)	Design geometry
0.015	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
0.9	Slope Angle, θ_0 (deg)	Calculated from design geometry
1440	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.111	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.3329	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.5	Representative Stem Length, h_{stem} (ft)	Lower bound stem length for proposed cover vegetation, assumes poor establishment (see existing conditions photo right)
67	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with poor coverage selected to represent established cover vegetation.
0.375	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), poor assumed 50% reduction of grass mixture factors

Other

62.4	Unit Weight of Water, γ_w (pcf)	

CALCULATIONS

4.00	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.00	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.0829	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.300	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.296	q (cfs/ft), with veg	q calculated
-0.037	qcalc - qdesign	Iterate d until q calculated equals q design
0.98	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0062	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
0.27	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
4.8	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
10.9	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.

Client: GE/UNC
Project: St. Anthony Mine
Detail: Pit 2 - Erosional Stability (fair vegetation)
Job No.: 233001363
Date: 7/1/2020
Calc. By: M. Kapp
Checked By: C. Fritz/J. Cumbers

<u>TEMPLE METHOD FOR EROSION OF VEGETATED SLOPES</u>

Notes:

Slope Geometry

67	Top Slope, (Xhoriz:1vert)	Design geometry
0.015	Cover Surface Grade, S_0 (ft/ft)	Calculated from design geometry
0.9	Slope Angle, θ_0 (deg)	Calculated from design geometry
1440	Original Slope Length, L_0 (ft)	Calculated from design geometry

Flow Characteristics

0.111	Design Flow (cfs/ft)	Calculated. DOE, 1989. Equation (3), page 66.
3	Concentration Factor, F	As recommended in NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 3.
0.3329	Concentrated Design Flow, Q (cfs/ft)	Calculated per NUREG-1623 (NRC, 2002); Appendix A, Page A-7, Step 5.

Cover Soil Properties

10	Plasticity Index, PI	Two Atterberg Limits from Lobo indicate 17 and 22, one other NP, none from WB.
117.4	Dry Density (pcf)	Calculated from Proctor tests on samples from Lobo and West Borrow
2.65	Specific Gravity	Estimate
0.409	Calculated Void ratio	Calculated
0.005	Diameter for which 75% of the Material is Finer, d_{75} (in)	from particle-size for Lobo and Borrow West, median from 15 results

Vegetation

0.75	Representative Stem Length, h_{stem} (ft)	Stem length for proposed cover vegetation, assumes fair establishment
133	Representative Stem Density, M_{stem} (stems/ft^2)	Temple et. al., 1987. page: 44 Table 3.1. Grass mixture with fair coverage selected to represent established cover vegetation.
0.6	Cover Factor, C_f	Estimated after vegetation is established, Temple 1987 (Table 3.1), fair assumed 20% reduction of grass cover factor

Other

62.4	Unit Weight of Water, γ_w (pcf)	

<u>CALCULATIONS</u>

5.13	Retardance Curve Index, C_i	Calculated per Temple et. al., 1987. Equation 1.3
3.85	Allowable Shear Stress on Vegetation, t_{va} (psf)	Calculated per Temple et. al., 1987. Equation 1.17
0.0190	base allowable tractive shear stress (psf) t_{ab} (psf)	Per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML with $10 \leq PI \leq 20$
1.25	void ratio correction factor, C_e	Calculated per Temple et. al., 1987. Table 3.3, Page 47. For cohesive soils, ML
0.0296	Allowable Shear Stress on Soil of Vegetated Slope, t_a (psf)	Calculated per Temple et. al., 1987. Eqn 3.1, Page 43.
0.0156	Manning's coefficient for the soil particles, n_s	Per Temple et. al., 1987. For cohesive soils
0.1335	Manning's Coefficient for Vegetated Conditions, n	Calculated per Temple et. al., 1987. Equation 4.1a
0.398	Assumed Depth of Flow, d (ft)	Iterate d until q calculated equals q design
0.294	q (cfs/ft), with veg	q calculated
-0.039	qcalc - qdesign	Iterate d until q calculated equals q design
0.74	Average Flow Velocity, V (ft/sec)	Calculated as q/d
0.0020	Effective Stress on the Soil, t_e (psf)	Calculated per Temple et. al., 1987. Equation 4.3a
0.37	Effective Stress on the Vegetation, t_{ve} (psf)	Calculated per Temple et. al., 1987. Equation 4.9a
14.5	**Ratio of Allowable Stress to Effective Stress on Soil, FS_{soil}**	Calculated
10.4	**Ratio of Allowable Stress to Effective Stress on Veg., FS_{veg}**	Calculated

References

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis. 1987. *Stability Design of Grass-Lined Open Channels.* U.S. Department of Agriculture, Agriculture Handbook 667.
U.S. Department of Energy (DOE), 1989. Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Albuquerque, New Mexico.
U.S. Nuclear Regulatory Commision (NRC), 2002. Design of Erosion Protection for Long-Term Stabilization; NUREG-1623. September 2002.