ASSESSMENT OF HILLSLOPE DESIGNS USING RUSLE AT THE COEUR ROCHESTER MINE, LOVELOCK, NV.[1,2]

by

T.J. Toy, S. D. Hasenjager, and S. McLeod[3]

Abstract. The Coeur Rochester Mine is a mountain-top, open-pit, heap-leach operation engaged in the production of silver and gold. The Revised Universal Soil Loss Equation (RUSLE) was used to assess the erosion potential of various reclamation-hillslope designs at this mine. Soil-loss estimates were computed for reclaimed rock-disposal and leach-pad sites as well as natural, undisturbed, sites. Factor inputs reflected the expected post-reclamation hillslope characteristics. The estimated average annual soil loss from the natural hillslopes ranged from 0.16-1.77 T/ha (0.07-0.79 t/ac). The estimated soil loss from the various designs for hillslopes developed on rock-disposal sites ranged from 0.22-3.41 T/ha/yr (0.10-1.52 t/ac/yr). The estimated soil loss from the various designs for hillslopes developed on leach-pad sites ranged from 0.04-0.22 T/ha/yr (0.02-0.10 t/ac/yr). The low soil-loss rates are the result of low R- and C-factor values coupled with a low to moderate K-factor values. These estimates were carefully considered in the selection of appropriate hillslope designs. RUSLE is a powerful tool for assessing the erosion potential of various hillslope designs during the reclamation-planning process.

Additional Key Words: Erosion control, Soil-loss estimation.

[1]Paper presented at the 1997 National Meeting of the American Society for Surface Mining and Reclamation, Austin, Texas, May 10-16, 1997.

[2]Publication in this Proceedings does not prevent authors from publishing their manuscripts, whole or in part, in other publication outlets.

[3]T.J.Toy is Professor of Geography and Geology, University of Denver, Denver, CO, 80208; S.D. Hasenjager is owner of Ecologic, Inc., 4909 Stockdale Hwy, Suite 178, Bakersfield, CA, 93309; S. McLeod is Senior Environmental Co-ordinator, Coeur Rochester, Inc. P.O. Box 1057, Lovelock, NV., 89419

Introduction

Successful reclamation of surface-mined lands requires the control of erosion processes on hillslope surfaces. Accelerated erosion dissects the surface and alters its hydrologic properties, while removing topsoil, fertilizers, other amendments, and seed. Without vegetation cover, high rates of erosion will persist for many years. Discussion of erosion processes is available in Toy and Hadley (1987). It was the purpose of this study to assess the erosion potential of various hillslope designs that could be used in reclamation at the Coeur Rochester Mine, Lovelock, Nevada.

The Study Area

The Rochester Mine is a mountain-top, open-pit, heap-leach operation, located within the Humboldt Range of the Basin and Range Physiographic Province, approximately 41.8 km (26 mi.) northeast of Lovelock, NV. Bedrock geology consists of Triassic extrusive and related rocks overlain by Quaternary alluvium and colluvium. The climate is arid with a mean January temperature of about -1°C. (30°F.) and a mean July temperature of about 24°C. (75°F.) Annual precipitation averages about 250 mm (10 in.). Steep slopes characterize the topography surrounding the mine with gradients of undisturbed ground often exceeding 50% (2:1). The soils in and around the mine include the Cortez very-fine sandy loam, the Roca-Reluctan association, and the Slaven-Iver-Cleavage association. Soil properties vary with parent material and topographic position. Average total plant cover ranges from 21-26%, varying by community. The four plant communities identified in the permit area are: (1) the moist-slope type composed of *Artemesia tridentata* (var. *Wyomingensis*), *Festuca Idahoensis*, and *Poa Sandbergii*, (2) dry-slope type, composed of *Poa Sandbergii* and *Artemesia arbuscula*, (3) the valley-bottom type, largely consisting of *Artemesia Tridentata* (var. *tridentata*), and (4) the wetland type.

Proceedings America Society of Mining and Reclamation, 1997 pp 698-704
DOI: 10.21000/JASMR97010698
https://doi.org/10.21000/JASMR98010698

Assessing Erosion Potential

There are three common methods of erosion assessment: (1) erosion monitoring, (2) rainfall simulation, and (3) erosion-prediction technology.

Erosion Monitoring.

This method requires measurement of runoff and sediment from hillslope surfaces or measurement of changes in surface elevation (Toy, 1989). A few years of measurements are necessary to characterize erosion rates due to variable climatic conditions. Monitoring was not feasible for this assessment because the reclaimed hillslopes had not yet been constructed.

Rainfall simulation.

This method involves the application of water to hillslope plots and measurements of the runoff and sediment produced by the simulated precipitation event (Lusby and Toy, 1976). Considerable time and expense generally is associated with plot selection and demarcation, assembly of equipment, conduct of the experiments, disassembly of the equipment, and data reduction. Consequently, there are practical limitations on the number and variety of sites that can be examined. Further, this approach has not been extensively tested on steep hillslopes. Rainfall simulation was not feasible for this assessment because: (1) the reclaimed hillslopes had not yet been constructed, (2) there was a need to evaluate several surface types, (3) the usual methods of water application may not be workable, and (4) the experiments must be conducted in wind-free weather conditions.

Erosion-prediction technology.

This method employs erosion-prediction technologies used for planning erosion control on agricultural or other disturbed lands. While there are several methods available for erosion-control planning, historically and worldwide, the Universal Soil Loss Equation (USLE) has been the most common choice. Although originally intended for use on agricultural lands, the USLE was adapted for use on mined lands (Soil Conservation Service, 1977). Shown et al. (1981) state that the USLE appears to be the best available method for evaluating soil loss from hillslopes in mined and reclaimed areas.

The RUSLE Technology.

By 1987 new knowledge concerning erosion processes and erosion-control practices warranted a thorough overhaul of USLE. The improvements of significance for mined-land applications include: (1) enhanced accuracy of the isoerodent (R-factor) map for the western United States, based upon data from more than 1,000 locations, (2) the ability to include the hydrologic and erosional effects of rock fragments on and in the soil, (3) extension of the hillslope gradients through which the equations are valid, and (4) ability to include the tendency of a hillslope surface to develop rills. Renard et al. (1991, 1994) further discuss the development of RUSLE.

The Revised Universal Soil Loss Equation (RUSLE) emerged as the best choice for assessing the erosion potential of various hillslope designs that could be used in reclamation at the Rochester Mine. The Soil and Water Conservation Society (1993) commented that RUSLE can be used with full confidence that the equation meets high scientific standards. RUSLE retains the the factor-based structure of the USLE as shown in equation 1:

$$A = R\ K\ L\ S\ C\ P \qquad (1)$$

Where:

- A = Average annual soil loss (tons ac^{-1} yr^{-1})
- R = Rainfall-runoff erosivity (hundreds of foot • tonf • inch • ac^{-1} yr^{-1})
- K = Soil erodibility (ton • ac • h • $[\text{hundreds of acre-ft} \cdot \text{tonf} \cdot \text{in}]^{-1}$)
- L = Hillslope length (dimensionless)
- S = Hillslope gradient (dimensionless)
- C = Surface cover (dimensionless)
- P = Support practices (dimensionless)

Soil loss and factor values are generally expressed in English units.

The Research Design

The research design consisted of selecting: (1) representative natural, undisturbed, hillslopes, (2) selecting typical reclamation-hillslope designs to be constructed on rock disposal and leach-pad sites, and (3) assembly of necessary input data for the R-,K-,L-, S-,C-,P- factors identified above. The natural hillslopes included east-, north-, and south-facing aspects. These offer one basis of comparison for reclaimed hillslopes. The rock disposal and leach-pad designs provided various conbinations of possible post-reclamation characteristics. It should be noted that the angle-of-repose (AOR) option was included for comparison purposes only and will not be implemented.

RUSLE Inputs.

The rainfall-runoff erosivity (R) for the area was selected through an examination of the isoerodent map and consultations with Natural Resources Conservation Service personnel. It was decided that the most appropriate value for the area of the mine is R = 9. This value was used for all sites.

The erodibility (K) of several possible surface materials was determined using the nomograph method contained within the RUSLE program. The data required for these computations were obtained through field sampling and laboratory analysis, following procedures developed by the Agricultural Research Service (ARS), Tucson, AZ.

The topographic factor (LS) also was determined using the tables and relations contained within the RUSLE program. Post-reclamation topographic maps and derived hillslope transects provided the necessary input data. In some cases both natural and potential reclamined hillslopes exceeded 305 m (1000 ft) in length. Long hillslopes in this environment are the consequence of low rainfall-runoff erosivity, coarse surface materials, and geologic controls. After consultation with ARS personnel, the lengthy hillslopes were divided into component segments of less than 305 m (1000 ft.) Experimentation with various segment lengths and summation of the resulting soil- loss indicated that hillslope length does not substantially influence soil loss rates in this environment, again due to the low rainfall-runoff erosivity and coarse surface materials. The maximum soil loss for a component segment at a site is included in Table 1 for comparison.

The surface-cover factor (C) for each site was determined using the sub-factor method contained within the RUSLE program. The data inputs for these computations reflect the estimated cover resulting from successful reclamation and includes both vegetation and rock fragments.

The support practice (P) value for each hillslope was selected after consideration of two surface characteristic: (1) the surface of both natural and reclaimed hillslopes will be very rough with a mantle of loose rock fragments, and (2) there is some tendency for surface sealing by the matrix of fine-textured materials between the rock fragments. Accordingly, it was decided that the most apropriate value is P = 0.90 for all hillslopes. In addition, diversions or slope breaks, will be constructed at vertical intervals of 61 m (200 ft) on the hillslopes of the rock disposal sites with gradients of 50% (2:1). The effect of this practice on the hydrology and erosion of these hillslopes is also taken into account in the computation of hillslope length.

The Results

The results of the RUSLE soil-loss calculations are presented in Table 1. The average annual soil losses for the area of the mine are low due to low R-factor values, low C-factor values, and low to moderate K-factor values. The low C-factor values primarily are due to high percentages of rock-fragments covers on both natural and reclaimed hillslopes. The low to moderate K-factor values primarily are due to coarse soil and surface-material textures.

The average annual soil loss for natural hillslopes ranges from 0.16-1.77 T/ha/yr. (0.07-0.79 t/ac/yr.) The range for the reclaimed rock disposal sites is 0.22-3.41 T/ha/yr. (0.10-1.52 t/ac/yr.) while the range for the leach pad sites is 0.04-0.22 T/ha/yr. (0.02-0.10 t/ac/yr.)

The maximum soil loss rate for a component of a natural hillslope is 2.47 T/ha/yr. (1.10 t/ac/yr.) occurring on a part of the south-facing site. The maximum rate for a component of a reclaimed rock disposal site is 3.59 T/ha/yr. (1.60 t/ac/yr.) occurring on the South RDS if constructed at the angle of repose. The maximum rate for a component of a leach pad site is 0.29 T/ha/yr. (0.13 t/ac/yr.) occurring on a Stage IV site with slightly more erodible surface material.

Conclusions

The foregoing estimates of soil loss from reclaimed hillslopes can be interpreted by comparison with: (1) general soil-loss tolerances for agriculture in the area of the mine, (2) soil-loss tolerances for the soils in the vicinity of the mine, or (3) estimated soil loss from natural hillslopes. According to Natural

Table 1: Soil loss estimates for natural and various reclamation-hillslope designs[1,2].

Site	K	LS	C	P	Max A T/ha/yr. (t/ac/yr.)	Mean A T/ha/yr. (t/ac/yr.)
Natural Sites						
1 East	0.38	33.49	0.005	0.90	1.17 (0.52)	1.17 (0.52)
2 North	0.43	22.22	0.001	0.90	0.16 (0.07)	0.16 (0.07)
3 South	0.46	35.34	0.006	0.90	2.47 (1.10)	1.77 (0.79)
Rock Disposal Sites (RDS)						
4 North (50%)	0.21	29.39	0.002	0.90	0.22 (0.10)	0.22 (0.10)
5 East (AOR)[3]	0.29	56.41	0.006	0.90	1.91 (0.85)	1.91 (0.85)
6 South (50%)	0.27	29.15	0.008	0.90	1.43 (0.64)	1.14 (0.51)
7 South (50%)	0.21	28.22	0.005	0.90	0.67 (0.30)	0.54 (0.24)
8 South (AOR)	0.28	47.87	0.014	0.90	3.59 (1.60)	3.41 (1.52)
9 West (50%)	0.27	25.15	0.004	0.90	0.63 (0.28)	0.49 (0.22)
10 West (50%)	0.21	25.87	0.005	0.90	0.63 (0.28)	0.49 (0.22)
11 West (AOR)	0.27	27.85	0.011	0.90	3.36 (1.50)	1.50 (0.67)
12 In Pit(50%)	0.21	27.19	0.004	0.90	0.47 (0.21)	0.43 (0.19)
13 In Pit(50%)	0.21	27.19	0.004	0.90	0.43 (0.19)	0.40 (0.18)
Leach Pads						
14 I&II (33%)	0.35	9.16	0.002	0.90	0.11 (0.05)	0.11 (0.05)
15 I&II (33%)	0.26	9.16	0.001	0.90	0.04 (0.02)	0.04 (0.02)
16 IV (40%)	0.31	17.08	0.002	0.90	0.29 (0.13)	0.22 (0.10)
17 IV (40%)	0.26	17.08	0.002	0.90	0.18 (0.08)	0.22 (0.10)

[1] Factor products may not equal mean soil loss due to individual factor rounding errors [2] R-factor = 9 in all cases
[3] AOR = Angle of Repose

Resources Conservation Service personnel the general soil-loss tolerance is 11.21 T/ha/yr. (5 t/ac/yr.) Published soil-loss tolerances for soils in the vicinity range from 4.48-11.21 T/ha/yr. (2-5 t/ac/yr.) (Soil Conservation Service, 1994). Estimated soil loss from natural hillslopes are contained in Table 1. None of the soil-loss estimates for the possible hillslope designs exceed the general or soil-specific soil-loss tolerances. Only the soil-loss estimates from the hypothetical angle-of-repose hillslope designs exceed the range of soil-loss estimates for the natural hillslopes.

The following recommendations are offered on the basis of these analyses for this erosional environment. Reconstructed hillslopes should not exceed a gradient of 50% (2:1). A concave or convexo-concave hillslope profile is preferred because this configuration encourages deposition of sediments derived from upslope at the base of the hillslope.

Erosion control is essential to reclamation success. Management of erosion processes begins during reclamation planning. RUSLE is a powerful tool for assessing the erosion potential of various hillslope designs. In the future, such assessments may be strongly recommended in support of the reclamation plans included in mining-permit applications.

Literature Cited

Lusby, G.C. and T.J. Toy, 1976. An evaluation of surface-mined spoil area restoration in Wyoming using rainfall simulation. Earth Surface Processes and Landforms, 1:375-386.
https://doi.org/10.1002/esp.3290010406

Renard, K.G., G.R. Foster, G.A. Weesies, and J.P. Porter, 1991. RUSLE: Revised universal soil loss equation. Journal of Soil and Water Conservation, 46(1): 30-33.

Renard, K.G., G.R. Foster, D.C. Yoder, and D.K. McCool, 1994. RUSLE revisited: Status, questions, answers, and the future. Journal of Soil and Water Conservation, 49(5): 213-220.

Shown, L.M., D.G. Frickel, R.F. Hadley, and R.F. Miller, 1981. Methodology for hydrologic evaluation of a potential surface mine, The Tsosie Swale Basin, San Juan County, New Mexico. U.S. Geological Survey, Water Resources Investigations, Open File Report 81-74, 57p.

Soil and Water Conservation Society, 1993. RUSLE: User's guide. Soil and Water Conservation Society, Ankeny, IA., 165p.

Soil Conservation Service, U.S. Dept. of Agriculture, 1977. Preliminary guidance for estimating erosion on areas disturbed by surface mining activities in the interior Western United States. Interim Final Report, EPA-908/4-77-005, 57p.

Soil Conservation Service, U.S. Dept. of Agriculture, 1994. Soil survey of Pershing County, Nevada, East Part. 742p.

Toy, T.J., 1989. An assessment of surface-mine reclamation based upon sheetwash erosion rates: Earth Surface Mining and Landforms. 14: 289-302.
https://doi.org/10.1002/esp.3290140405

Toy, T.J. and R.F. Hadley, 1987. Geomorphology and reclamation of disturbed lands. Orlando, Florida, Academic Press, 480p.