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Standard Guide for Selection of Methods for Estimating Soil Loss by Erosion[1]

This standard is issued under the fixed designation D6629; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε^1 NOTE—6.1.1 was editorially revised in May 2012.

1. Scope

1.1 This guide describes methods used for estimating soil losses due to rill and interrill erosion. All known methods for water erosion with a sediment yield component are listed. This guide provides complete reference citations for the various methods currently used to estimate soil loss by rill and interrill erosion. The referenced methods contain the rationale and detailed procedures for determining rill and interrill soil loss. For each method listed, specific applicability, limitations, and level of complexity are briefly outlined in terms of the relative spatial scale, land use, hydrology, erosion, time scale, input requirements, and output.

1.2 The referenced methods were developed for specific uses and may not be applicable in all cases. For example, some of the values derived by these methods estimate the amount of soil movement on a field without re-deposition while others account for re-deposition and estimate off-field sediment yield. Most of these methods are not intended to predict sediment yield.

1.3 *Metric (SI) Units.* Some of the methods in this guide are written in the preferred English units. A discussion of the conversion of the final answer to metric units is included in paragraph 6.2.

1.4 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with professional judgement. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this guide has been approved through the ASTM consensus process.*

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

3. Terminology

3.1 While most of the terms used in this guide conform to Terminology D653, some are unique to this guide. These terms relate to soil erosion and are used frequently in the methods outlined in this guide.

NOTE 1—The Natural Resources Conservation Service was formerly the Soil Conservation Service.

3.2 *Definitions:*

3.2.1 *agronomy*—the science of field crop production and soil management.

3.2.2 *denudation*—the sum of the processes that result in the wearing away or the progressive lowering of the earth's surface by weathering, mass wasting, or transportation; also the combined destructive effects of such processes.

3.2.3 *erodibility*—the degree to which a soil is susceptible to erode. Some soils erode more readily than others due to the soil properties.

3.2.4 *erosion*—the wearing away of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, wind, and underground water.

3.2.5 *fallow*—allowing cropland to lie idle, either tilled or untilled, during the whole or greater portion of the growing season.

3.2.6 *fertility (soil)*—the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil are favorable.

3.2.7 *mulch*—a natural or artificial layer of suitable materials that aid in soil stabilization and soil moisture conservation, thus providing micro-climatic conditions suitable for germination and growth.

3.2.8 *pasture*—an area devoted to the production of forage, introduced or native, and harvested by grazing.

3.2.9 *rill*—a small, intermittent water course with steep sides, usually only a few inches deep and, therefore, no obstacle to tillage operations.

3.2.10 *seedbed*—the soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

3.2.11 *soil loss*—for the purpose of this guide, soil loss refers to the movement of soil particles from their pre-erosion location.

3.2.12 *tillage*—the operation of implements through the soil to prepare seedbeds and rootbeds, control weeds and brush, aerate the soil, and enhance breakdown of organic matter and minerals to release plant foods.

4. Summary of Guide

4.1 This guide provides guidance in selecting methods for estimating soil loss by rill and interrill erosion and in predicting the effects of various soil management practices on soil loss.

5. Significance and Use

5.1 A variety of methods exist for this measurement. Each method has its specific applicability, limitations, and levels of complexity. The users of this guide should use the descriptions of the various methods to choose the procedure, which most closely meets their needs. Most of these methods are not intended to predict sediment yield (**6**).

5.2 These methods are used to estimate the soil loss (in mass of soil/unit area/unit time) from rainfall and snow melt for site-specific factors due to rill and interrill erosion. These methods can not be used to estimate soil loss from ephemeral gully or channel erosion.

5.3 The estimates resulting from the methods in this guide do not constitute a design for control of erosion. However, the outputs of these methods may be important input into such a design.

6. Procedure

6.1 The following references provide detailed information and procedures as follows:

6.1.1 *Agricultural Non-Points Source (AGNPS)*

Reference:

• Young, R.A., C.V. Alonso, and R.M. Summer, Modeling linked watershed and lake processes for water quality management decisions, Journal of Environmental Quality, July/September 1990, Volume 19 (3), p. 421-427.

• Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson, AGNPS: a nonpoint source pollution model for evaluating agricultural watersheds, Journal of Soil and Water Conservation, May/April 1989, Volume 44(2), p. 168-173.

Spatial Scale: Up to Medium Watersheds

Land Use: Rural

Hydrology: SCS Curve Number

Erosion: Modified USLE

Time Scale: Single-event

Input Requirements: Land Use, Soils, Topography, USLE parameters by grid cell, Storm rainfall intensity and duration

Output: Storm runoff volume and peak flow, Sediment, Nutrient and COD concentration

Applicability: May be used to evaluate sediment delivery ratios from cells.

6.1.2 *Army Sedimentation Model (ARMSED)* Reference:

• Riggins, R.E., T.J. Ward, and W Hodge, ARMSED, a runoff and sediment yield model for army training land watershed management, ADP Report N-89/12, 1989, US Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign IL.

• Rice, T.L. and D.B. Simons, Sediment deposition model for reservoirs based on the dominant physical processes, Canadian Water Resource Journal, 1982, Volume 7 (2), p. 45-62.

Spatial Scale: Up to Medium Watersheds

Land Use: Rural

Hydrology: Water Balance, Kinematic Wave Routing

Erosion: Detachment Equations

Time Scale: Single-event

Input Requirements: Land use, Soils, Topography, Detachment coefficients

Output: Storm runoff hydrographs and sediment graphs

Applicability: Limited application, which also requires local calibration.

6.1.3 *Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS)*

Reference:

• Beasley, D.B. and L.F. Huggins, Areal Nonpoint Source Watershed Environment Response Simulation User's Manual, USEPA, Region V, Great Lakes National Program Office, DNAL TD 423.B39, 1981, 54 p.

• Griffin, M.L., D.B. Beasley, J.J. Fletcher, and G.R. Foster, Estimating soil loss on topographically nonuniform field and farm units, Journal of Soil and Water Conservation, July/August 1988, Volume 43 (4), p. 326-331.

Spatial Scale: Up to Medium Watershed

Land Use: Rural

Hydrology: Distributed Storage Model

Erosion: Detachment Equations

Time Scale: Single-event

Input Requirements: Land use, Soils, Rainfall, and Topography

Output: Storm runoff volume and peak flow, and sediment

Applicability: May be used to evaluate sediment delivery ratios from cells.

6.1.4 *Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS)*

Reference:

• Knisel, W.G., G.R. Forster, and R.A. Leonard, Chemicals, Runoff, and Erosion from Agricultural Management Systems: a system for evaluating best management practices, Agricultural management and water quality, Iowa Press, 1983, p. 178-199.

• Knisel, W.G. and G.R. Foster, CREAMS, Chemicals, runoff and erosion from agricultural management systems: a system for evaluating best management practices mathematical models, pollution, Economics, ethics, ecology:roots of productive conservation based on material presented at the 35th annual meeting of the Soil Conservation Society of America, 4-6 August 1980, Dearborn, Michigan, 1981, p. 177-194.

Spatial Scale: Field Scale

Land Use: Rural

Hydrology: Water Balance

Erosion: Detachment Equations

Time Scale: Continuous (daily time stop)

Input Requirements: Land use, Soils, Rainfall, Topography, and Detailed land management practices

Output: Daily runoff, Sediment, Nutrients and Pesticides

Applicability: May be used to determine soil losses from a field site.

6.1.5 *Groundwater Loading Effects of Agricultural Management Systems (GLEAMS)*

Reference:

• Reyes, M.R., R.L. Bengtson, J.L. Fouss, and C.E. Carter, Comparison of erosion predictions with GLEAMS, GLEAMS-WT, and GLEAMS-SWAT models for alluvial soils, Transcript for American Society for Agricultural Engineers, 1958-, May/June 1995, Volume 38 (3), p. 791-796.

• Reyes, M.R., R.L. Bengston, J.L. Fouss, and J.S. Rogers, GLEAMS hydrology submodel modified for shallow water table conditions, Transcript for American Society for Agricultural Engineers, 1958-, November/December 1993, Volume 36 (6), p. 1771-1778

Spatial Scale: Field Scale

Land Use: Rural

Hydrology: Water Balance

Erosion: Detachment Equations

Time Scale: Continuous (daily time stop)

Input Requirements: Land use, Soils, Rainfall, Topography, and Detailed land management practices

Output: Daily runoff, Sediment, Nutrients and Pesticides

Applicability: May be used to determine soil losses from a field site.

6.1.6 *Hydrologic Simulation Program-Fortran (HSPF)*

Reference:

• Donigian, A.S., J.C. Imhoff, and B.R. Bicknell, Predicting water quality resulting from agricultural nonpoint source pollution via simulation-HSPF, Agricultural management and water quality, Iowa Press, 1983, p. 200-249.

• Johanson, R.C., A new mathematical modeling system Hydrologic Simulation Program-Fortran, Transcript of the American Chemical Society Symposium, Washington: 1983 (225), p. 125-147.

Spatial Scale: Large Watershed, River Basins

Land Use: Mixed

Hydrology: SCS Curve Number

Erosion: Detachment Equations

Time Scale: Continuous

Input Requirements: Land use, Topography, Meteorologic and hydrologic data, and Land management practices

Output: Time series of runoff, Sediment, Nutrient, and Pesticides

Applicability: Limited application, which may require local calibration.

6.1.7 *Generalized Watershed Loading Function (GWLF)*

Reference:

• Haith, D.A. and E.M. Laden, Screening of groundwater contaminants by travel time distributions, Journal of Environmental Engineering, June 1989, Volume 115 (3), p.497-512.

• Haith, D.A., Generalized watershed loading functions for stream flow nutrients, water Resource Bulletin, June 1987, Volume 23 (3), p. 471-478.

Spatial Scale: Up to Medium Watershed

Land Use: Mixed

Hydrology: SCS Curve Number

Erosion: Modified USLE

Time Scale: Continuous (daily time stops)

Input Requirements: Daily Meteorologic and hydrologic data, Land use, Soil parameters, and Nutrient loading

Output: Monthly and annual time series of runoff, sediment and nutrients

Applicability: May require some local calibration for more accurate data.

6.1.8 *Modified Universal Soil Loss Equation (MUSLE)*

Reference:

• Edwards, D.R., Analyzing uncertainty in predicted event erosion from small rangeland watersheds, Transcript of the American Society of Agricultural Engineers, July/Aug 1990, Volume 33 (4), p. 1141-1146.

• Johnson, C.W., N.D. Gordon, and C.L. Hanson, Rangeland sediment yields with snowmelt by the MUSLE, Paper - American Society of Agricultural Engineers, 1984, (fiche no. 84-2041).

Spatial Scale: Up to Medium Watershed

Land Use: Rural

Hydrology: Uses estimates of volume runoff and peak flow rate

Erosion: USLE

Time Scale: Continuous

Input Requirements: USLE parameters, Runoff and Peak discharge

Output: Basin sediment yield

Applicability: May be used with a rainfall runoff model to obtain sediment yields.

6.1.9 *Soil Loss (SLOSS)*

Reference:

• Baumhardt, L., A. Trent, and J.C. Hayes, SLOSS, an interactive model for microcomputers, Bulletin of the Mississippi Agricultural Forestry Experiment Station, June 1985, 12 p.

Spatial Scale: Up to Medium Watershed

Land Use: Rural

Hydrology: SCS Curve Number

Erosion: USLE

Time Scale: Annual

Input Requirements: USLE parameters, Channel parameters, GIS data

Output: Mean annual sediment loads

Applicability: Interaction is cumbersome.

6.1.10 *Simulator for Water Resources in Rural Basins (SWRRB)*

Reference:

• Arnold, J.G., Simulation of complex hydrologic basins, Proceedings of the 1989 Summer Computer Simulation Conference, July 24-27 1989, Austin, Texas, p. 682-687.

• Arnold, J.G., P.M. Allen, and G. Bernhardt, Journal of Hydrology, Elsevier Scientific Publishers, February 1993, Volume 142 (1/4), p. 47-69.

Spatial Scale: Medium to Large Watersheds

Land Use: Mixed

Hydrology: SCS Curve Number

Erosion: Modified USLE

Time Scale: Continuous (daily time stop), single-event

Input Requirements: Meteorologic, and hydrologic data, Land use, Soils, and Detailed land management practices.

Output: Daily runoff, Sediment, Nutrients, and Pesticides

Applicability: May be used to evaluate both the sediment and pollutant load from sites and whole watersheds.

6.1.11 *Water Erosion Prediction Project (WEPP)*

Reference:

• Laflen, J.M., W.J. Elliot, J.R. Simanton, C.S. Holzhey, and K.D. Kohl, WEPP: soil erodibility experiments for rangeland and cropland soils, Journal of Soil and Water Conservation, Jan 1991, Volume 46 (1), p. 39-44.

• Elliot, W.J., A.V. Elliot, W. Qiong, and J.M. Laflen, Validation of the WEPP model with rill erosion, Paper from the American Society of Agricultural Engineers, Winter 1991, 11 p.

Spatial Scale: Field Scale

Land Use: Rural

Hydrology: Water Balance, Kinematic Wave Routing

Erosion: Detachment Equations

Time Scale: Continuous or single-event

Input Requirements: Four input files: Climate; slope profile; soil; management

Output: Daily runoff, Sediment, and Nutrient

Applicability: May be used to determine soil losses from a field site.

6.1.12 *Finite Element Storm Hydrograph Model (FESHM)*

Reference:

• Hession, W.C., V.O. Shanholtz, T.A. Dilaha, and S. Mostaghimi, Uncalibrated performance of the finite element storm hydrograph model, Transcript of the American Society of Agricultural Engineers, May/June 1994, Volume 37 (3), p. 777-783.

• Wolfe, M.L., GIS assisted input data set development for the Finite Element Storm Hydrograph Model, Agricultural Applied Engineering, Mar 1992, Volume 8 (2), p. 221-227.

Spatial Scale: Watershed

Land Use: Rural

Hydrology: Water Balance

Erosion: Detachment Equations

Time Scale: Single-event

Input Requirements: Soil survey, Topography, Land use, and Site visit data

Output: Tabular runoff and Sediment yields

Applicability: Limited by application to single events.

6.1.13 *Revised Universal Soil Loss Equation (RUSLE)*

Reference:

• Kautza, T.J., D.L. Schertz, and G.A. Weesies, Lessons learned in RUSLE technology transfer and implementation, Journal of Soil and Water Conservation, September/October 1995, Volume 50 (5), p. 490-493.

• Yoder, D. and J. Lown, The future of RUSLE: Inside the new revised universal soil loss equation, Journal of Soil and Water Conservation, September/ October 1995, Volume 50 (5), p. 484-489.

Spatial Scale: Field Scale

Land Use: Mixed

Hydrology: SCS Curve Number

Erosion: USLE

Time Scale: Continuous or single-event

Input Requirements: USLE parameters

Output: Mean annual runoff and sediment yields

Applicability: General field application.

6.2 Three of these methods are used for field scale estimates and each warrants further discussion.

6.2.1 *Universal Soil Loss Equation/Revised Universal Soil Loss Equation*—This method is used to estimate soil losses due to rill and interrill erosion, on slopes of known length, steepness, vegetation cover, and support practice. The estimated soil loss is predicted using equations, which have been experimentally developed over several decades. These calculations are adaptable to most personal computers (PC) with disk operating systems (DOS); however, the calculations can be accomplished by hand. Information for use in this method is contained in tables available in (**1**) and at the local field offices of the Natural Resources Conservation Service, United States Department of Agriculture. While this method was developed for agriculture, (**2**) describes its uses in estimating erosion from highway construction sites.

6.2.2 *Water Erosion Prediction Project, Hillslope Profile Model (WEPP Version 91.5)*—This method (**3**) is a complex computer model intended to be used as a continuous simulation model, although it can be used on a single storm basis. As a continuous simulation model, it mimics processes important to erosion prediction as a function of time, and as affected by the particular management of the soil, and the climate. Most of the inputs requirements are in understandable terms: planting dates, tillage dates, harvest dates, yields, implement types, etc. More technical information is provided by various sources. For instance, climatic information can be generated by a stochastic weather generator; crop specific information is obtained from the Agricultural Research Service and Natural Resources Conservation Service technical experts; soil information is available from the Natural Resources Conservation Service soil characterization data and soil survey information.

6.2.3 *Chemical Runoff Erosion in Agricultural Management System (CREAMS)*—This method (**4**) is based on a semi-theoretical relationship known as the Foster-Meyer-Onstad (FMO) equation which partitions erosion into two components:

rill erosion and interrill erosion. These relationships are based on detachment as a function of surface shear for rill erosion and rainfall energy for interrill erosion. The equations used in this method are steady state. Single storm estimates can be made using the peak discharge as a flow rate. CREAMS is a model for a field size area and is not intended to estimate sediment yield from a watershed. Computations for this method are too complicated to be made without a computer.

6.3 *Conversion to Metric (SI) Units*— The metrication of this guide involves converting each of the main equation variables to the metric system. The key conversions are:

1 metric ton/hectare = 2.242 tons/acre

1 metric ton-meter/hectare/cm = 0.269 foot-ton/acre/inch

7. Keywords

7.1 agriculture; environment; erosion; sediment yield; soil

REFERENCES

(1) Wischmeier, W. H., and Smith, D.D., "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning," U.S. Department of Agriculture, *Agricultural Handbook* No. 537, 1978, 58 pp. Note: The document is sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Stock No. is 001-000-03903-2.

(2) Fan, J.C., "Measurements of Erosion on Highway Slopes and Use of the Universal Soil Loss Erosion Equation," Ph.D. Thesis, Purdue University, W. Lafayette, IN, December 1987, 364 pp. Note: Dr. Fanning's thesis is available through the University of Michigan's Thesis Reference Microfiche System.

(3) National Soil Erosion Research Laboratory, *NSERL Report No. 6*, WEPP Version No. 6, Water Erosion Prediction Project—Hillslope Profile Model, USDA Agricultural Research Service, West Lafayette, Indiana, September 1991.

(4) United States Department of Agriculture, *SEA Conservation Report No. 26*, CREAMS—A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, Vol. I and II, 1980.

(5) Binger, R.L., Mutchler, C.K., and Murphree, C.E., "Predictive Capabilities of Erosion Models for Different Storm Sizes," Transcript of the American Society of Agricultural Engineers, Vol. 35, No. 2, March/April 1992, pp.505 -513.

(6) Binger, R.L., "Comparison of the Components Used in Several Sediment Yield Models," Transcript of the American Society of Agricultural Engineers, Vol. 33 No. 4, July/August 1990, pp.1229-1238.