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CLEAR CREEK MANAGEMENT AREA
GEOGRAPHIC INFORMATION SYSTEM (GIS)
PROJECT PROPOSAL

Background

The Clear Creek Management Area is located in southeastern San Benito and west-central Fresno counties, California. It consists of 50,501 acres of public land administered by the Bureau of Land Management (BLM). Primary users of the area consists of mineral exploration and production, livestock grazing, and recreational pursuits such as: hunting, off-road vehicle (ORV) use, and rock and gem collecting.

Major issues identified through the BLM planning system in the management area include: cultural resources; wildlife habitat; recreation; asbestos hazard; watershed concerns; rare, threatened and endangered (RTE) plant habitat; hobby gem and minerals; and unique soils. Land use planning was completed in 1984 in the Hollister Resource Management Plan/Environmental Impact Statement (RMP/EIS). The Clear Creek ORV Designation and Environmental Assessment (EA) was completed in 1981 and the Clear Creek Management Plan and EA in 1986.

Since 1858, the New Idria Mining District, which includes most of the Clear Creek Management Area, has been known for its mineral production. Commercial quantities of mercury, chromite, asbestos, magnesite, benitonite, jadeite, and gem stones have been produced from this locality. The mercury deposits occur principally in the fractured zones on the borders of the serpentine ore body;

chromite, jadeite, asbestos, magnesite, and gem stones such as benitonite and nepunite occur within the serpentine mass; and benitonite occurs in the steeply dipping Tertiary sediments to the north of the intrusive serpentine mass.

Mineral exploration and extraction has been a major surface disturbing activity within the area. There are more than 1,000 mining claims located within the area (February 1983). Chrysotile asbestos is the primary mineral resource currently being mined. Mining and mineral exploration continues to be a major concern. Most of the road and trail construction in the area has been initiated as a result of mineral exploration. The only large scale active mining operation is the King City Asbestos Company (KCAC) (Cal-Idria/Union Carbide) Joe Mine. This open pit asbestos mine is located between Santa Rita Peak and Condon Peak within Section 25, Township 18 South, Range 12 East, Mount Diablo Base Meridian. Mine spoils containing asbestos have been suspected of being transported by seasonal runoff into the San Benito River and downstream toward Hernandez Reservoir. A number of older abandoned mines and exploration sites are located throughout the management area.

The watershed of the management area includes four perennial streams: Clear Creek and the San Benito River, which flow northwest into the Hernandez Reservoir on the western side; San Carlos Creek which supplies water to the historic mining community of Idria on the north; and White Creek which is in Fresno County on the southern side of the management area and joins with Los Gatos Creek before entering the San Joaquin Valley near the community of Coalinga.

In 1970, the area increased in popularity for motorcycle ORV use, partly due to the closure by the BLM of the Panoche Hills/Mercey Hot Springs area located about 20 air miles to the north. Most ORV use is concentrated in or near Clear Creek Canyon. In 1982, off-road recreation vehicle designations were completed for this area with a "limited" designation in Clear Creek Canyon, riparian areas, and grazing areas (16,000 acres); "open" designation for 25,000 acres (mostly barren areas and brushfields), and 2,000 acres "closed" (San Benito Mountain Natural Area and extension and the open pit mine areas)[1/].

Recreation facilities include pit toilets and garbage dumpsters in the Clear Creek Canyon and interpretive signs in the San Benito Mountain Natural Area. Public access is available along the Clear Creek county road which runs through the area from Idria to the Coalinga Road near Hernandez Reservoir. Foot access is also available at the Fresno-San Benito county line on the Coalinga road. Two previous access routes have been closed to public use by

1/ Limited - vehicle use restricted to designated roads, trails, and areas. In addition to vehicle restrictions, vehicle encroachment into brush fields would be prohibited.

Closed - area designated closed to all vehicle use except on county roads and designated routes.

Open - area opened to off-road vehicle activity.

private landowners (near Picacho Store through the Salinas Ramblers' Motorcycle Club property, and the Atlas Mine road up White Creek). Other potential access routes include the Union Carbide road and the Duckworth Canyon road.

The Management Area has particular value for communication site purposes, and at present five sites have been authorized at San Benito Mountain, Santa Rita Peak, and Spanish Lake, with an additional authorization of nine secondary users. Most of the Management Area is under the New Idria National Cooperative Land and Wildlife Management Area withdrawal (segregating the lands from entry under the agricultural land laws).

Soils in the area are unique and of great scientific and educational value. There are two kinds of soils within the Clear Creek area: those developed from materials derived from ultramafic rock (serpentine) and those developed from materials derived from sedimentary rock. Atravesada, Henneke and Hentine soils, found within the serpentine mass, are developed from materials derived from ultramafic rock that is high in asbestos fibers. Gaviota soils, found on sedimentary rock sources, do not contain asbestos. All of these soils are prone to severe erosion, primarily due to steep slope gradients. Atravesada, Henneke, and Hentine soils are low in fertility due to a nutrient imbalance. Barren areas, devoid of vegetation, comprise about eight percent of the area. Gaviota soils are somewhat more productive and lack these barren areas typical of the ultramafic derived soil.

The presence of airborne asbestos dust presents a serious air quality problem in the Clear Creek Management Area. Two studies by Poperdorf and Wenk, University of California, Berkeley in 1979 and 1980 have found that the vast majority of airborne asbestos in the area is generated by human activities, primarily vehicle use. Natural wind conditions are believed to have a negligible effect on dust production. The studies showed that: (1) the air quality hazard is greatest when soil moisture is below 3 percent, roughly from May 15 to October 15; (2) riding behavior can significantly affect exposure levels; (3) dust clouds produced by vehicles dissipate rapidly, the background level of exposure to asbestos dust in the area averaged to be about one-tenth the average exposure of riders, however, those levels can be increased 3 to 10 times by nearby vehicle use; (4) exposure levels of riders monitored were occasionally above Occupational Safety and Health Administration (OSHA) occupational restrictions for short-term exposure (10 fibers per cubic centimeter of air), when this measurement is prorated over a 40-hour week, most exposures were below OSHA's average working-lifetime permissible exposure limits (0.5 fibers per cubic centimeters of air per 8-hour day); (5) users continue to be exposed to asbestos fibers which they carry home on their clothes and vehicles; (6) people who have used the area over the past few years probably will not develop an abnormal disease pattern, however, continued exposure could result in detectable effects in some individuals from a number of exposures over a number of years.

In 1980 asbestos was detected in the San Luis Canal (California Aqueduct) south of Huron, California. Government studies have shown that, during flood events, asbestos-laden water and sediments flow into the Arroyo Pasajero and sometimes into the San Luis Canal (the California Aqueduct) near Huron. It has been assumed that mining activities in the area were the primary source of the asbestos. After a survey of the area in September 1983, two abandoned mines were identified the most likely significant sources of the asbestos. The two sites, Atlas Asbestos Mine and Johns-Manville Asbestos Mine, near Coalinga were added to EPA's National Priorities List which identifies the nation's most serious hazardous waste site for cleanup. Since then, more recent studies indicate that erosion from naturally occurring asbestos deposits may also be contributing to the contamination problem. Both mines are located on the Joaquin Ridge, an area containing one of the largest serpentine deposits in North America. The most abundant serpentine mineral on the ridge is chrysotile asbestos. Most of the Atlas site is on public land, managed by the BLM. The Johns-Manville site is owned by Southern Pacific Land Company.

Environmental Protection Agency (EPA) is currently conducting a Superfund Remedial Investigation to more fully understand the extent of the contamination. The results of this study will be used to determine any public health threats and to identify possible solutions. These cleanup options will be detailed in a report known as a Feasibility Study. After public review and comment on the options, the EPA will select the best way to conduct the cleanup and proceed with work to prevent further public exposure to the asbestos coming from the mines. Ongoing studies indicate the possibility that airborne asbestos in Coalinga may exceed the normal background levels than would be expected. Since asbestos is considered a potential human carcinogen, the EPA's studies will focus on how much asbestos is present and determine what risk it may pose. The Feasibility Study which will examine the feasibility of using various options to control and cleanup the asbestos contamination. The types of options which will be considered include:

- <u>Removal</u> - how much, from where and to where, and ways to handle the material;

- <u>Prevention of movement</u> such as on-site sedimentation basins, dust control, diversion ditches, and wind fences; and,

- <u>Containment</u> - such as capping, pavement, or other types of control of the tailings, piles, streambed sediment, and detention basin sediments.

EPA is also required to consider the effects of no further control actions. This option would be selected only if taking no further action will adequately protect human health and the environment. Each of the control options will be evaluated to determine how well it satisfies the objective of a safe, reliable, and cost-effective permanent remedy.

The vegetation in the Clear Creek Management Area is extremely unique and of scientific and aesthetic value. There are two distinct divisions of the flora: (1) vegetation on soils derived from serpentine rock sources; and (2) vegetation on soils derived from sedimentary rock sources. The serpentine endemic vegetation is a complex of plant communities dependent upon the soil mineralogy, soil temperature and precipitation. Dominate tree species include Coulter pine (<u>Pinus coultri</u>), Jeffery pine (<u>P. jefferyi</u>), incense cedar (<u>Calocedrus decurrens</u>), and Coulter-Jeffery pine hybrids. As the soil temperature increases and the precipitation decreases, the incense cedar is largely replaced with digger pine (P. sabiniana) and oak species (Quercus sp.). This is the only place known where these three pines (jeffery, coulter, and digger) are found together). In 1971, the San Benito Mountain Natural Area was established to protect a portion of the unique botanical community found in the area.

Several sensitive serpentine endemic plant species are found in the Management Area. Most notable are the San Benito evening primrose (Camissonia benitensis), a federally listed threatened plant and the rayless layia (Layia discoidea). Both plants are annuals and are found only in years of favorable precipitation. The evening primrose has been found in only a few locations - one in the San Benito Mountain Natural Area and at several points within Clear Creek Canyon. The rayless layia has a somewhat more widespread distribution. Another sensitive plant, talus fritillaria (Fritillaria falcata), occurs in one location on San Benito Mountain - its habitat is extremely limited and subject to disturbance from ORV use. Actions have been taken to protect these plants by fencing known habitat areas as part of the ORV implementation plan. An exceedingly rare plant, Pentachaeta exilis aeolica, may occur on public lands in the area. This plant, however, is reported mainly from grasslands off the serpentine area. There are several unique serpentine "vernal pools" or sag ponds found in the area. Three of these pools that support a distinctive riparian vegetation community are found on the north side of Clear Creek Canyon.

The Hernandez Reservoir was constructed as a water conservation project to percolate water back into underground water basins in the southern Santa Clara Valley (Pajaro River Hydrologic Area). It was completed in July 1962 and originally had a capacity of more than 18,500 acre-feet of water. The San Benito County Water Conservation and Flood Control District manages the reservoir. It has been estimated by the San Benito County Water Conservation and Flood Control District that sediment from the upper San Benito River drainage has been filling the reservoir at double the anticipated rate since it was first constructed. The Clear Creek Management Area is one part of the Hernandez Reservoir watershed.

Wildfire occurrence in the area has been historically low with most fires being contained to less than 200 acres in the last 30 years. In 1955, the Burkett Fire burned the lower half of Clear Creek Canyon and most of the Laguna Mountain area on about 9,500 acres (about 3,500 acres was public land). The Los Gatos series fires (#2 & #4) in 1985, consumed more than 26,805 acres (14,850 acres public); and New Idria fire in 1987, burned more than 150 acres of public land. Extensive wildfires can be the cause of increased erosion in the years immediately following the fire until a vegetative cover can be re-established.

Natural erosion has resulted in high sediment loads in various drainages within the area. The region contains outcrops of extremely weathered, fragmented, and decomposed serpentine rock containing chrysotile asbestos minerals. These bare outcrops lack soil or vegetative cover and are often on steep and very steep slope gradients of 30-50 percent or more. Sheet and rill erosion occur during rainfall and runoff events whereby sediment (including asbestos fibers) enters the drainages. The extent of the problem is directly proportional to the storm's magnitude. The degree of that proportionality is unknown.

The semi-improved and unimproved network of county-maintained roads and mining-exploration roads and trails are subject to very high runoff and erosion. Between 1981 and 1983, streams have claimed roads entirely in some locations, thus contributing large amounts of sediment down stream.

ORV use is another source of sediment production. Soil loss has been noticeable to some degree in vehicle use area. However, the amount of increase compared to natural erosion is unknown.

Wildfire and its related suppression activities are sometimes a significant contributor to accelerated erosion. Wildfire danger is greatest in the non-serpentine areas. With the extensive road and trail networks and the number of users of the Clear Creek Management Area, there is a moderate potential for wildfires during the dry period. The amount of erosion contributed by such fires is dependent upon the size of area burned, the steepness of the slope gradient, the type of soils, and other factors.

Applicability of GIS

With enactment of the Superfund Amendments and Reauthorization Act (SARA) in 1986 and implementation of Executive Order Number 12580 in 1987, BLM is required to proceed with due diligence to address all sites identified on the EPA's National Priorities List. The Atlas Asbestos Mine Remedial Investigation/Feasibility Study (RI/FS) will provide a number of extensive background sampling studies which are designed to provide sufficient data for the development of a set of cleanup strategy alternatives; this data will also be analyzed on effectiveness and cost factors.

The development of a GIS database in conjunction with the RI/FS effort has been identified as a reasonable means to deal with this problem and provide a basis for implementing an "areawide" approach to the asbestos hazard problem in the Clear Creek Management Area. The EPA supports this concept of an "areawide" approach to this problem.

Additional applications would include day-to-day requirements for the management area and documentation of the implementation of the Clear Creek Management Plan.

Geographical Area

The Clear Creek Management Area includes approximately 50,501 acres of public land. The map base for the Management Area is six 7.5 minute (1:24,000) USGS quadrangles. The density of public land on each quadrangle varies. The 7.5 minute quadrangles in the Management Area are:

Santa Rita - 36120C5

San Benito Mountain - 36120C6

Hepsedam Peak - 36120C7

Ciervo Mountain - 36120D5

Idria - 36120D6

Hernandez Reservoir - 36120D7

Data Themes

The following data themes constitute the minimum baseline information required for this GIS project:

1. Public Land Survey
2. Land Status
3. Mines/Disturbed Areas
4. Drainages (Watershed boundaries, stream order, etc.)
5. Topography/Digital Elevation Model (DEM) (Slope, aspect)
6. Geology (Faults, shear zones, fracture orientation, landslides, etc.)
7. Roads/Trails
8. Vegetation
9. Improvements/Facilities
10. Soils
11. Asbestos Hazard/Area of Critical Environmental Concern (ACEC) Boundaries
12. Weather/Climate (localized conditions affecting)

Map theme data will be digitized from 1:24,000 USGS topography quadrangle maps. All data themes will be mapped on base mylar or paper topographic quadrangles by Hollister Resource Area personnel. Digitization of map data will be completed under contract. The Resource Area will designate a GIS Project Coordinator to facilitate quality control of map data and contract products.

<u>GIS Output Products</u>

The Clear Creek Management Area GIS Project is expected to produce the following tabular and graphic output products:

1. Erosion hazard rating model - a comparative rating based upon input data themes and using the linear Revised Universal Soil Loss Equation (RVUSLE) for analysis (components include: soil erodibility, rainfall and runoff, cover and management, and support practice). See attachment 1 - The RVUSLE/GIS project for details.

2. Delineation of asbestos hazard throughout the serpentine ore body - also a determination of relative percent of asbestos content in soils throughout the ore body.

3. Rehabilitation models for specific sites.

4. Weather/climate data (monitoring network)

5. Cartographic output for analysis, documents, public meetings, and alternative assessments.

Scheduling

FY 88

Action	Date
Area staff to prepare data for digitizing	8/30/88
Digitizing contract preparation	8/1/88
Contract Obligation	8/15/88

FY 89

Action	Date
Prepare output models	by 2nd qtr FY 89
Erosion hazard rating model	
Asbestos hazard delineation	
Rehabilitation model	

Training

FY 88 - Data preparation for digitizing

FY 89 - GIS/Land Information System (LIS)/Map Overlay and Statistical System (MOSS) training for selected resource specialists. Hollister RA Physical Scientist to be project leader.

FY 90 - GIS/LIS/MOSS training for selected resource specialists

Hardware

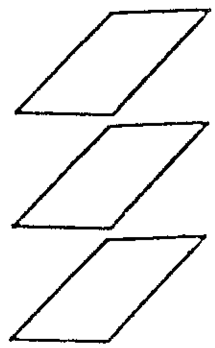
Initially, the Hollister RA will require remote GIS capabilities and access to the PRIME Level A (9955-II) at the California State Office in Sacramento. The project is designed so that the early phases will only require that the resource area has graphic terminals and printer to provide the resource specialists with the ability to access the project data base and apply the analytical capabilities of our GIS software. In FY 88 a monochrome graphic terminal with a laser printer is funded for acquisition. The initial data base development will be accomplished by contract with the data stored on the PRIME Level A in Sacramento. Additional support will be available from the Bakersfield District Office, California State Office, and the Denver Service Center where there is more GIS technical capabilities.

Beginning in FY 89 additional GIS equipment will be needed in the Hollister RA. Again the initial need will focus on providing additional access to the GIS database in the Level A in Sacramento. A color terminal with compatible color ink-jet printer included in the FY 89 ADP and Data Communications Plan. The subsequent need will focus on providing full GIS capabilities at the resource area. In order to accomplish this, a PRIME Level D (2450) CPU will be necessary to support additional GIS peripheral equipment providing a complete GIS work station. The anticipated costs for GIS equipment in FY 89 are approximately $60,000.

Prepared by:	John W. Key, Soil Scientist	JUN 3 1988 Date
Reviewed by:	Steve Addington, Resource Management Specialist	June 7, 1988 Date
Reviewed by:	John H. Skibinski ADM, Lands and Renewable Resources	JUN 3 1988 Date
Reviewed by:	Jon Foster, GIS Coordinator California State Office	14 JUNE '88 Date
Recommended by:	Dave Howell Area Manager, Hollister	6/17/88 Date
Approved by:	Robert D. Rheiner, Jr. District Manager, Bakersfield	6/17/88 Date

THE RVUSLE/GIS
PROJECT

$$A = R * K * L * S * C * P$$



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INTRODUCTION

The purpose of this project is to develop means of interfacing the linear Revised Universal Soil Loss Equation (RVUSLE) with the Geographic Information System (GIS) in the Bureau of Land Management. It requires understanding the operational capabilities of the GIS which includes the Automated Digitizing System (ADS), the Map Overlay and Statistical System (MOSS), the Maps Analysis Package (MAPS) and the PRIMOS operating system, as well as developing a field level familiarity with the RVUSLE. The final product is to be a user friendly software module capable of calculating soil erosion potential using the RVUSLE for up to quadrangle size areas and producing output in form of soil erosion maps which then can be used for further resource analysis and management.

Analysis of watershed soil-loss conditions and erosion susceptibility is necessary to "evaluate current watershed conditions in relation to potential or desired conditions, to assess the susceptibility of watershed conditions to impairment, and to evaluate the feasibility or desirability for altering watershed conditions through management activities"[1] Dennis Phillippi lists several applications of soil erosion information in his USLE for Rangeland[2].
These are:

1. Predicting average annual erosion rates under various land-use and management conditions.
2. Providing landowners with conservation alternatives in reducing sheet and rill erosion rates.
3. Predicting how much soil loss can be reduced by changes in management systems and cultural practices.
4. Providing local erosion rate data for

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[1]Jackson, William L. and Foster, John, Watershed Analysis for Large Planning Areas, BLM Internal Completion Report, October 1986.

[2]Phillippi, Dennis R., USLE For Rangeland, USDA/SCS Technical Note, May 24, 1978.

discussing erosion control alternatives with ranchers, farmers and industry.

5. Predicting average annual erosion rates from sheet and rill erosion within particular watersheds.

Calculating soil erosion using the USLE can be very work-intensive, requiring gathering of large amounts of field data, or/and painstaking analytic procedures for determination of various factors from maps and remote sensing data. Consequently, it is very desirable to develop an automated procedure which would permit user flexibility in terms of manipulation of data, that would rely on readily available information, and an end result of which was a digital soil erosion map that could be used in various ways for further analysis. In deciding what approach to take in developing this procedure these considerations were taken into account, together with capabilities of BLM's GIS hardware and software and present day developments in the area of watershed analysis from digital data. The RVUSLE/GIS procedure will therefore serve as an extremely useful analytic tool in a variety of resource management decisions.

OUTLINE OF THE MAIN PROCEDURE

At the heart of the RVUSLE/GIS procedure is the overlaying in form of multiplication of maps that hold spatially distributed values for various factors of the Universal Soil Loss Equation. Therefore, it is the multiplication of a K-factor map, which hold K values of each soil unit, by an LS factor map which holds LS values, probably per cell, by a C and P factor map which holds C and P product per land cover-land use unit, and a single R factor value for the entire area. In this way, it will reflect the structure of the USLE:

$$A = R * K * L * S * C * P$$ [3]

where

A is the computed soil loss per unit area,
R is the rainfall and runoff factor
K is the soil erodibility factor
L is the slope length part of the terrain factor
S is the slope gradient part of the terrain factor

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[3] Wischmeier, Walter H. and Smith, Dwight D., Predicting Rainfall Erosion Losses-A Guide to Conservation Planning, USDA Handbook 537, USDA 1978.

C is the cover and management factor
P is the support practice factor

Each of the maps will be assigned appropriate values by the user either through direct input of a value if available, or through calculation by a routine developed to obtain that value. The exception to this is the LS factor map which will be calculated by an algorithm that will not involve user interface, although an alternative could be included where the user will be able to create his own LS factor map bypassing this algorithm. The computer method for obtaining the LS factor map will probably have to be brought into MOSS/MAPS as a separate command.

The multiplication of the maps and the R-value will happen on a cell by cell basis. While this might take more Central Processing Unit (CPU) time than some other methods, it is both necessary and desirable. Each of the maps will have different spatial distribution of values, and the product of the multiplication will be a continuous map of soil erosion potential. Such a map can be, for example, represented in 3-D in MOSS/MAPS. In the three dimensional representation we should be able to clearly see contribution from various factor which can provide useful feedback to the resource analyst. A continuous map can be combined with other maps in a variety of useful ways. I will discuss possible output products in more detail at a later point.

THE INDIVIDUAL FACTORS

1. THE K-FACTOR MAP

The basis for the K-factor map is a digitized soil polygon map which is then rasterized and renumbered with K-values replacing the subject value for each polygon which was automatically assigned during rasterization.

The K-values are entered directly or calculated by a subroutine taken from the RVUSLE which requires user input of % of silt and very fine sand in the soil, % of clay, % of organic matter, soil structure and permeability codes.

The routine for creation of this map would involve reading the subject and value information for a soils map into a table. Then, sequentially, a K value would be assigned for each subject-soil type. As long as there were no more than 64 different types of soils (limitation of the RENUMBER command), which is highly unlikely, the values for each subject would then be renumbered with K-values.

2. THE LS (TERRAIN) FACTOR

The LS factor consists of two components: slope length (L) and slope gradient (S) related together through an empirically derived equation. The slope length and slope gradient can be obtained through geometric analysis of topographic contour maps of the area or through field measurement. Very often slope length data per soil unit is available in soil surveys, although this information can often be incomplete and measure the width of the soil unit rather than actual slope length.[4] Because obtaining L and S information in this fashion is very work-intensive, with the advent digital topographic data in form of Digital Elevation Models (DEM) and Digital Terrain Models (DTM) some work has gone into developing computer algorithms for determining this and other information about watersheds directly from this type of data.

The definition of the L factor is the length of slope from the origination of overland flow to the area where deposition begins or flow enters a well defined channel (gully). The LS value obtained from a table, graph or calculated from the equation always uses this full slope length. If a situation of extensive changes in gradient along a slope length occurs, the average gradient generally used here is not adequate and a slope can be divided into equal segments (usually not more than three) for which percentage of erosion can be easily calculated. The total LS factor is obtained by using the overall slope length as one of the elements, and the particular gradient as the other, multiplying the result by percentage of erosion expected from a particular segment. It is for the same reason of the necessity of using the entire slope length that the L factor information given per soils unit are not adequate and will tend to underestimate erosion. A soil unit usually covers only part of the slope rather than its entire length.

Considering the definition of the L factor, one of the best possible ways to determine slope length was documented by Dennis Phillippi in his USLE For Rangeland (USDA/SCS Technical Note)[5] in which he describes partitioning of a watershed into mini-basins and determining L from measurements within a mini-basin from top of the divide to the channel. Algorithms for determining mini-

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[4]Morris-Jones, D. R., Application of Remote Sensing and Computer Geographic Information System Technology to Estimating Soil Erosion Potential, PhD Thesis, University of Wisconsin, Madison, Wisconsin, 1985, p.140.

[5]Phillippi, Dennis R., USLE for Rangeland, USDA/SCS Technical Note, May 24, 1978.

basins from a DEM have been developed by Susan Jenson[6] of the USGS and Marj Larson[7] from CERL. At the present time, from conversations with the authors, the algorithms are not yet complete and would be difficult to apply directly to our needs. They should however be considered for future development of the RVUSLE/GIS method, as well as other applications which require partitioning of an area into watersheds and mini-basins.

The best algorithm for determining slope length found to date was developed by Michael Spanner[8] of Government Technicolor Services at NASA/AMES Laboratories. The method begins with the first cell (first row, first column) of a DEM. The program begins searching upwards of the cell, in other words it looks within a 3x3 matrix for a cell with the biggest positive elevation difference from the center cell. Then it calculates the pythagoranean distance between the two cells, and continues its search for the next highest cell within the constraint that it won't look at cells the aspect of which is greater than 45 degrees from the aspect of the previous cell. It continues to calculate the pythagoranean distance as it continues upslope until it reaches a point where there are no cells at higher elevations. At that point the search has reached the top of the ridge. The value of all the distances added is tacked onto the cell it started from. Then the algorithm proceeds to next cell (first row, second column) and repeats the search. In this way steepest pathways to each cell are found, and the length of the path leading to each cell is assigned to that cell. The decreasing distance assigned to each cell along a particular path could be said to reflect decreasing erosion for that segment of the path closer to the source. Michael Spanner claims that his method has high correlation with geometric methods of obtaining slope length from topographic contour maps.

At this time we don't have the complete documentation of this method, however, further information with source code will be arriving soon. After it is ascertained that the algorithm does what it is suppose to do it will be necessary to bring it into the system. At the present time it seems like the best approach, and one of its benefits is that it provides slope

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[6]Jenson, Susan K., Automated Derivation of Hydrologic Basin Characteristics from Digital Elevation Data, Auto-Carto 7 Proceedings, Washington, D. C., March 11-14, 1985, p.301-310.

[7]Larson, Marjorie and White, Dale, WATSHED - A Proposed Method for Automated Extraction of Watershed Geometric and Topologic Information from Digital Elevation Data, unpublished.

[8]Spanner, Michael A., The Use of Digital Elevation Model Topographic Data for Soil Erosion Modeling within a Geographic Information System, Technical Papers of the 49th Annual Meeting of the American Society of Photogrammetry, Washington, D. C., March 13-18 1983, p. 314-323, 1983.

length values per raster.

Several other considerations exist in using DEM data. Most of the DEMs are Level I which means that they contain raw, unsmoothed data which might contain pits reflective of the digitizing process. Most of the watershed analysis algorithms include smoothing routines which remove the pits before further processing. Another consideration is the presence of microrelief which causes deposition, but which will not show on a DEM. In one study[9], which also used one of Spanner's earlier versions of the slope length algorithm, the number of moves uphill was limited to three upon consultation with an expert on the area of study. Furthermore, presence of channels and roads will probably have to be accounted for. The need for these improvements will partially depend on the accuracy of other data that goes into the RVUSLE.

The S factor can be easily calculated from the already existing slope algorithm in MOSS/MAPS. The LS factor can be than obtained as a value per cell using the appropriate equation. The calculation can be performed using the MATH command or can be put into the Spanner algorithm directly, if that is possible.

3. THE R FACTOR

The R factor will be entered or calculated from latitude and longitude. It will exist only as a single value by which all the cells in each map will be multiplied.

4. THE C AND P FACTORS

The RVUSLE in its present form has a relatively thorough method for calculation of the C factor for rangelands. For areas which are under cultivation a table is used to establish the P factor.

If the C factor is not known the RVUSLE asks for following input: % of canopy cover, average canopy height, surface % of rock, gravel, litter,and vegetation, root mass in the top 4" of soil and roughness values associated with field conditions, and calculates the C value from this input.

The base map for the C and P values will be a digitized land use-land cover map, or a vegetation map. This map will be rasterized and its subjects will be read into a table with their associated values. Repetition of the RVUSLE code concerning C

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[9]Morris-Jones, D.B., Application of Remote Sensing and Computer Geographic Information System Technology to Estimating Soil Erosion Potential, PhD Thesis, University of Wisconsin, Madison, Wisconsin, 1985.

and P values will associate a C*P product with each of the subjects, with the limit of no more than 64 different subjects. Then the map will be renumbered with C*P product replacing the original values.

INPUT CONSIDERATIONS

To summarize, there will be two types of input: user input and digitized data in form of maps which will include a DEM, a Soil Units Map, and a Land Use-Land Cover or Vegetation Map. The user input, with the exception of the LS factor calculations, will control the types of numbers associated with each of the factors. To put it simply, the RVUSLE code controls the values, while the digitized maps control the spatial distribution of these values. The GIS provides the necessary capabilities for the processing of both.

A very important consideration with respect to the digitized maps is that they have the same cell size, the same projection, and the same number of rows and columns. If that is not the case, the GIS will not be able to perform the multiplication. MOSS/MAPS is capable of reprojecting vector maps, and maps can be trimmed to the necessary number of rows and columns. When rasterizing the user can specify desired size of a cell.

The sources of the map data will be the United States Geological Survey and BLM field offices.

POSSIBLE OUTPUT PRODUCTS

As mentioned before, this method will produce a continuous map of soil erosion potential which then can be processed further in a variety of different ways. A continuous map can be SCOREd or TOTALed with a soils map, a vegetation map or map of other relevant units to produce information on soil erosion potential for those units. It can be extracted for levels of potential, it can be contoured and represented in three dimensions. To summarize, a continuous map of soil erosion potential can be used for a variety of analyses possible on the MOSS/MAPS GIS, and can become a useful component of resource analysis and resource management decision. Additionally, by changing the input values of various factors of the RVUSLE, several models of soil erosion can be prepared to approximate the real situation of erosion for the area. This provides immediate feedback with respect to the accuracy of the RVUSLE, as well as furnishing a method whereby a good approximation of the real soil erosion can be easily prepared for a large area.

VALIDATION

While the various components of the program will have to be tested for their accuracy, software errors that could occur, user friendliness,etc. it is not within the scope of this project to test the RVUSLE itself. While this method will provide a relatively fast way of testing the RVUSLE for large areas, as discussed above, it is only interfacing the equation with the Geographic Information Systems and therefore making it a more powerful tool. It is not changing anything within the RVUSLE. In that sense, the author is not responsible for proving that the erosion data thus obtained are accurate, but that this method of interfacing with the GIS does not change the RVUSLE structurally in any way. For example, it will be up to the author to compare the accuracy of the automated means of determining the LS factor with the geometric means from topographic maps.