FINAL REPORT

TECHNICAL REVIEW AND EVALUATION OF THE USACERL DEVELOPED EROSION CONTROL MANAGEMENT PLAN (ECMP) AND DOCUMENTS

to

US Army Construction Engineering Research Laboratory
Champaign, Illinois

Contract No. DACA88-90-D-0029, RFP DACA88-91-Q-0446

July 1992

Prepared by
Chris J. Johannsen
Andrew R. Gillespie
D. Fabián Lozano-García
L. Darrell Norton
Phillip E. Pope

Laboratory for Applications
of Remote Sensing

Purdue University

Final Report
Contract No. DACA88-90-D-0029 RFP DACA88-91-Q-0446
to
US Army Construction Engineering Research Laboratory
Champaign, Illinois

by
Chris J. Johannsen, Andrew Gillespie, D. Fabán Lozano-García
L. Darrell Norton, Phillip Pope

Faculty associated with
Natural Resources Research Institute
Purdue University

INTRODUCTION

We received CERL Erosion Control Documents from USACERL pertaining to Task 1 and LRAM documents for Task 2 during the time that the Contracts were being negotiated. Arrangements were made for Purdue University staff to visit FORSCOM, ATRADOC and AMC installations to evaluate the use of these documents. Dr. Muhammed Sharif was the contact at CERL for this work. Reports on each visit and other communications were submitted to him by electronic mail.

TASK 1. REVIEW BACKGROUND INFORMATION ON THE EROSION CONTROL MANAGEMENT PLAN (ECMP).

Visits Conducted

Visits to Army installations for Task 1 were conducted on:

February 12-13, 1992 Red River Army Depot, Texarkana, Arkansas
March 17, 1992, Ft Riley, Kansas
March 23-24, 1992, Ft Benning, Columbus, Georgia

Dr Chris J. Johannsen, Director, Natural Resources Research Institute, Dr. Darrell Norton, Research Soil Scientist with the USDA National Soil Erosion Laboratory and Dr. Muhammed Sharif, CERL participated in all visits. Dr. Andrew Gillespie, Department of Forestry and Natural Resources at Purdue assisted with the Ft. Benning visit since Task 2 had been terminated before all aspects could be completed. Copies of the trip reports are found in Appendix I. Dr. Gillespie and Dr. Phil Pope, Professor of Forestry visited CERL and Ft. Knox personnel at Champaign, IL in October, 1991. A site visit to Ft. Knox was accomplished in November, 1991.

Critique of Technical Content.
The Erosion Control Management Plan (ECMP) along with USACERL Technical Reports N-90/11 (July 1990), N-91/04 (December 1990) and N-90/08 (July 1990) were reviewed by Purdue researchers knowledgeable about soil erosion processes, practices and control.

The ECMP is based on technical data and information pertaining to soil erosion and is close to accomplishing the objective of providing a comprehensive approach in both maintenance and repair (M&R) "of existing erosion control structures/systems and cost-effective selection of new technologies based on conditions unique to the installation's eroded sites". The plan calls for Annual Work Plans so that a calendar can be established for implementing erosion control. The basic principles are shown in diagram form with emphasis on 1) problem identification, 2) needs assessment and 3) costs. The following steps are emphasized:

Step 1: Conduct Preliminary Site Assessment
Step 2: Identify Erosion Related Natural Conditions
Step 3: Examine Erosion Conditions and Contribution Factors
Step 4: Assess Needs
Step 5: Estimate Costs for Erosion Control

The Technical Reports provide more details on "use of current methods, materials and structures used in the application of engineering technology for erosion control". The phases of soil erosion as pertaining to water erosion are accurately stated and illustrated. One major emphasis is on the "materials of soil stabilization" which include a variety of mulches, geosynthetic materials, soil binders and a large number of structures and systems for stabilizing the soil. Another major emphasis is on runoff management and sediment control where excellent illustrations are provided of various practices.

With the ECMP in place, why were find erosion problems and conditions found on the Army installations visited? Why was there no ECMP provided for each installation? There appear to be various reasons and they become more complex as one looks at the Mission of each installation. First, personnel at the installations that have responsibilities for erosion control do not appear to have the needed support from the command. Erosion control has a low priority when the mission of the installation is to prepare equipment and personnel for battle. Erosion is something that happens when it rains and can be overcome with a bulldozer. That may be an overstatement but engineers look at only the mechanical phase of the problem.

Second, training in the development of the Erosion Control Management Plan must be done at the very beginning and needs to be reinforced as conditions and personnel change. The natural resources staff appear to have good tenure at a location. The command people are changed frequently. This relates back to the

support that is needed from the top for erosion control. It appeared that little time had been spent on training individuals to develop a successful plan. If the Army wants to see ECMPs for each installation, they will need to develop a training procedure that involves the individuals who will be doing the work as well as those individuals who have the responsibility for the Installation Mission. The ECMP should be done with both parties participating.

The budgets established at the installation appear to be very meager or connected with a project funded for a specific purpose. This may be the result of not having an ECMP in place and therefore not having established a specific budget for the purpose of erosion control. The Natural Resources Staff has many other duties, such as maintenance of the lawns and greenery around the buildings of the base, removal of dead trees, problems associated with the wildlife and many other natural resources concerns.

The equipment available to the Natural Resources Staff is very minimal for erosion control efforts. In fact it appears that much of the work needs to be done on subcontract that may or may not involve the NR Staff. If equipment, such as tractors, discs, seeders and similar equipment needed for establishment of vegetation were made available to the NR Staff then much more preventative maintenance could be performed by them. There would need to be consideration of additional personnel for this purpose which again gets back to the budgets for erosion control.

There appears to be a lack of control or coordination of the use of Army lands which would impact erosion control such as grading roads, maneuvers with heavy equipment, bivouacing in sensitive areas and many other activities. The Natural Resources Staff needs to be appraised of these types of activities so that they can make recommendations relevant to intensity of the activity and also plan for maintenance activities as a result of the activity. The communication with training officers seems to be variable and likely has to start over each time an officer is replaced.

Most of the emphasis for soil erosion control appears to be on mechanical practices versus that of vegetative cover. A close conjunction of these two practices is necessary to provide a good maintenance and continual functioning of the mechanical practices. Mechanical practices should be performed at a time when one can establish a vegetative cover or when mulches and other artificial covers are applied as stated in the ECMP. The appropriate vegetative cover should also be planned in the same way that plans are developed for mechanical practices. The planting of trees without some prevention of rill erosion through vegetative cover provided by grass and legumes would be a case in point.

The prevention of erosion is lacking in the approach of ECMPs. There are a number of activities that can be done such as establishing a good vegetative cover, inner seeding with desirable species, mowing of vegetation to an appropriate height, repairing of rills before they become gullies, diversion of water flow to other areas while erosion control practices are implemented and many other activities. The prevention of erosion should be a high priority. This is something that needs to be instilled in all the Natural Resources Staff at the installations with appropriate funds provided in order that large expenditures are not needed later on.

ECMP Scope Relating to Army Unique Lands and Uses.

Only a small sample of the Army installations was visited but some of the unique Army lands and some of uses which are different from civilian use were observed. The principles of reducing soil loss on normal lands apply to most unique situations as well. Uses which civilians or communities face are also found on Army installations such as operating and maintaining landfills, establishing vegetation on borrow areas and stock piles (these are common occurrences to highway departments and coal mining companies), maintenance of dirt or gravel roads and clearing of timber (common to logging companies). Therefore there are practices which are common to the Army and are dealt with in civilian capacities on a daily basis. The experience gained by cities, counties, state agencies, federal agencies, industries and companies should be consulted.

The Army has some unique land uses such as compaction by tank traffic, concealment of troops and facilities, crossing of streams in open or wooded areas, marching of troops in single file causing stress on vegetation, chemicals used in warfare simulations and many other uses. The ECMP can not be thought of as the final answer but it provides guidelines which give direction toward the solution of problems provided by these uses. Additionally, there are many sources of assistance that could be found by relating the unique Army land use to similar ones in civilian capacities. For example: (1) Compaction of soil by large farm tractors have been studied by many Agricultural Experiment Stations; (2) Golf courses and public parks have been constructed to provide concealment from other activities; (3) National parks have dealt with procedures for allowing motorbikes and overterrain vehicles to cross streams with minimum damage; (4) State parks and riding stables have studied ways of keeping walking and riding trails from being erosion hazards; and (5) Industries have been seeking solutions for chemical spills caused by accidents in transport of their materials.

Assistance of Materials in Development of Effective Erosion Control Plans and Specifications.

There are numerous materials now available from many sources to assist in erosion control. Most of these have been developed through the cooperative efforts between the land grant university and erosion control organizations within a state. While there have been numerous documents developed for agricultural soil erosion, the most appropriate of the available materials pertain to urban soil erosion and to highway construction erosion control. It is noted that the authors of ECMP used many of these types of references in the development of "Erosion Control Management for Army Training Lands".

All Army installations should be encouraged to contact the erosion control organizations such as the Soil and Water Conservation Districts, Soil Conservation Service, Department of Natural Resources, Land Grant Universities and similar organizations within the state or surrounding states at their location. Erosion control practices are tailored to geographic locations because of the difference in soils, vegetation, climate and other factors. The resource materials of the local area would be most helpful to the Natural Resources Staff in developing the ECMPs.

Several materials were located by Purdue researchers and will be discussed in this section. It should be noted that these are only a sampling of the types of materials that are available. The current ECMP Manual relies heavily on materials from the Procedures and Standards for Urban Soil Erosion and Sedimentation Control in Illinois, 1981 edition. This publication was revised extensively in July 1988 and a copy is provided in Appendix II. There are six major principles of erosion and sediment control that are followed through the publication that are worth emphasizing as they are very important to erosion control on Army installations. These are:

- Keep disturbed areas small
- Stabilize disturbed areas
- Keep runoff velocities low
- Protect disturbed areas from storm water runoff
- Retain sediment within the site boundaries
- Implement a thorough maintenance and follow up program

The current revision of the Illinois Manual emphasizes three major areas of soil erosion control which are soil stabilization, runoff control and sediment control. The soil stabilization measures are intended to provide protection of the soil surface from erosive action of falling rain and runoff. The publication provides two main groups of soil stabilization which are vegetative soil stabilization measures and non-vegetative soil stabilization measures. The aspect of the vegetative soil stabilization should be given a higher priority on Army installations as noted earlier. The Illinois publication divides

the state into three zones which are based upon vegetation varieties and adaptations. These type of zones will be found in almost every state and will usually vary from north to south.

The runoff control measures are intended to provide for management of concentrated flow runoff. Most of these are adequately covered in the ECMP.

The sediment control measures are intended to provide for the management of sediment on-site to avoid damage to adjacent properties and/or waterways. Sediment is the result of erosion and needs more emphasis on installation property since one needs to control the sediment before it reaches impoundments meant for drinking water or major stream ways that end up on public or private lands.

Another pertainent publication is the Virginia Erosion and Sediment Control Handbook (Appendix III). Only portions of this handbook are provided as there is some duplication to the Illinois Handbook. The basic principles of design of erosion control were presented as:

1) Plan the development to fix the particular topography, soils, drainage patterns and natural vegetation of the site.
2) Minimize the extent of the area exposed at one time and the duration of exposure.
3) Apply erosion control practices to prevent excessive on-site damage.
4) Apply perimeter control practices to protect the disturbed area from off-site runoff and to prevent sedimentation damage to areas below the development site.
5) Keep runoff velocities low and retain runoff on the site.
6) Stabilize disturbed areas immediately after final grade has been attained.
7) Implement a thorough maintenance and follow up program.

While these principles apply to urban development situations, they would also apply to Army installations. The Handbook lists many different structural and vegetative practices. Details of some of the specific practices such as storm water conveyance channel, outlet protection, riprap, surface roughening, mulching are included as they provide an interesting format and discussion of these practices.

The New York Guidelines for Urban Erosion and Sediment Control (Appendix IV) was designed for land developers and county plan commissions. The format is similar to the Illinois publication which is properly referenced. Section 3 provides specific information on vegetative measures for erosion and sediment control and provides some basic principles for the establishment of vegetation. A portion of this section is included.

Michigan's Department of Natural Resources developed a guidebook for soil erosion and sedimentation control (Appendix V) that

follows similar outlines as shown in previous state publications. A few examples of their vegetative and non-vegetative controls of drainage ways as well as erosion control on borrow and stockpile areas are included. The latter topic would pertain directly to the Red River Army Depot in principle. It is noted that in Michigan the emphasis is placed upon establishing cover immediately on all borrow areas as well as stockpiles. Michigan also included a unified keying system for soil erosion control measures for over 50 different practices. The chart clearly shows where a practice is appropriate to one or more of seven different problem areas.

The National Cooperative Highway Research Program developed a manual of erosion control for use during highway design and construction (Appendix VI). The manual focuses on techniques for predicting the erosion potential of highway construction sites, and for estimating the effectiveness of very controlled practices. Included in this Appendix is a listing of the different erosion control measures, characteristics of the measure and an indication of locations where the measure should be used.

Another type of education material is that of videos. An excellent video titled "Keeping Soil on Construction Sites: Best Management Practices" was developed by the Ohio federation of Soil and Water Districts in cooperation with the Ohio Department of Natural Resources and the Ohio Home Builders Association. A copy of the training course manual used in conjunction with the video is found in Appendix VII.

There are many other reports and publications that are specific to locations or specific problems. Examples of these are shown in Appendix VIII.

In summary, there are many materials that are already available in specific locations of Army installations. The USDA Soil Conservation Service has handbooks and guidelines that are developed for technical assistance in a specific location. Their assistance is also available in developing a soil erosion plan and for technical layout of mechanical practices.

Other Sources of Information

All Army installations should be encouraged to contact the local Soil and Water Conservation District to (1) sign up as a cooperator, (2) make contact with the Soil Conservation Service personnel, and (3) develop a soil erosion plan in conjunction with the District. The Natural Resources/Land Management staff of the installation can use the ECMP in conjunction with the District and develop a joint plan.

Contact should be made with the County Extension Agent(s) in the area for assistance in vegetation establishment and maintenance.

The Extension Service has immediate access to the research from the Land Grant Colleges and Agricultural Experiment Stations. This information would be useful for solving many erosion problems and would assist in preventative measures of soil loss.

Contact should also be made with other colleges and universities in the local area for their expertise since many will have biology and geography departments that can assist with vegetation and GIS. Most will have many resources pertaining to the local area that will result in cooperative projects and cost savings to the installations.

Computing Soil Loss Using RUSLE

The Revised Universal Soil Loss Equation or RUSLE was recently discussed in an article published in the Journal of Soil and Water Conservation, January-February, 1991. A copy of the article is found in Appendix IX. In discussions with the authors, it was found that the computer program and software documentation discussed under "Delivery of documentation", (page 33 of the article) will not be available for at least another 6 months.

Additionally SCS personnel are writing a technical manual and layman's manual for using RUSLE. While CERL personnel requested us to include a layperson's version of RUSLE, we were advised by SCS not to attempt one since it would duplicate their efforts. They indicated that they have had two staff members working on this task for over one year.

Computing Discharge from a Watershed Area

As an addition to this report, a request was made to provide a lay persons description for computing the water flow or discharge from a watershed area. Several detailed descriptions were reviewed for computing discharge developed by state agencies and determined that it would be best to include a good example and comment on how Army installations could use them. The New York Guidelines (Appendix IV) was selected as having the most current and appropriate procedures.

The different methods of computing runoff are:

1) The rational method which establishes an empirical formula, $Q = CiA$, for computing peak rates or runoff. It is useful for estimating runoff on relatively small areas that have had disturbances such as tank traffic, bivouac areas, parking lots and many buildings. The rational equation should be limited to drainage areas of less than 20 acres. The difficulty of using the rational method is that it gives only peak discharge and provides no information on the time distribution of storm runoff.

The Rational Formula is Q = CiA in which:

Q = Peak Rate of runoff in cubic feet per second.
C = Runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff.
i = Average intensity of rainfall in inches per hour for the time of concentration (T_C) for a selected frequency of occurrence or return period.
T_C = Time of concentration, the estimated time required for runoff to flow from the most remote part of the area under consideration to the point under consideration. It consists of the total time for overland sheet flow, open channel flow and pipe flow.
A = Area drained in acres.

The Rational Method is an empirical formula and its accuracy is highly dependent upon the judgement and experience of the user. It is recommended that it only be used when a small watershed or subwatershed has a very high concentration of activity.

2) Computer program for project formulation - hydrology (SCS-TR-20). This software program was developed by SCS Engineering staff to determine runoff volumes and unit hydrographies to estimate peak rates of discharge. The information needed for using the method are a 24-hour rainfall amount, a given rainfall distribution, runoff curve numbers, time of concentration, travel time, and the drainage area. This method works well when there is a complex drainage area that has a series of structures or a number of tributaries with different land uses. It is recommended the procedure not be used for drainage areas more than 20 square miles. Army installations could use a digitizing tablet to define the watershed area or subareas so that accurate drainage areas can be measured. Note that method number four is an improvement over this method.

3) The SCS Curve Number Method. This method is described in the SCS Engineering Field Manual which provides specific procedures for determining the peak discharge rate. This method is primarily applicable for drainage areas from 1,000-2,000 acres. The time of concentration for an area that has not seen a lot of tank traffic or high human activity can be estimated using the formula based on flow length, runoff curve number and average watershed slope as detailed in Chapter 2 of the SCS Engineering Field Manual. Tables, Figures and Exhibits help provide a reliable way for estimating peak discharge and runoff for a range of rainfall amounts, soil types, land use and cover conditions.

4) The SCS-TR-55 Tabular Method. This method provides an approximation of the more detailed SCS-TR-20 method described in number two above. It is especially applicable for measuring the effects of changed land use within any part of the watershed such as an Army maneuver that may have destroyed the vegetation. One should be very familiar with this method as well as that of method number 2 so that one can use the appropriate method for a given situation. The basic data needed to use this tabular method are:

- The drainage area of each subbasin.
- The time of concentration for each subbasin.
- The travel time for each routing of the drainage
- The runoff curve number for each subbasin
- The 24-hour runoff for a selected frequency design storm
- The runoff depth in inches for each subbasin

5) The SCS-TR-55 Graphic Peak Discharge Method. This method will calculate the peak discharge from hydrography analysis and one can use the information gained in Method 2 for this purpose. It is especially useful for calculating the total runoff volume as well as the peak rates or runoff from small watersheds. Like the rational formula in Method 1, the peak discharge method is an empirical model and its accuracy is dependent upon the judgement and experience of the user. The method has been useful for designing erosion and sediment control measures.

Recommendations

1. Provide training course to Natural Resource Staff on developing an Erosion Control Management Plan for their installation.
2. Provide an awareness presentation to Installation Command on developing an Erosion Control Management Plan for their installation.
3. Install GRASS software on computers accessible to Natural Resources Staff of all installations. Assist the installations in providing the proper natural resource layers and databases. Provide training in the use of GRASS for developing and implementing an ECMP.
4. Develop a module for GRASS that will assist in computing water discharge from a watershed area.
5. The ECMP manual emphasizes water erosion with only one page addressing wind erosion. Develop a section for the ECMP that provides a step-by-step procedure for the Natural Resources Staff to plan for controlling wind erosion.
6. Encourage installations to hire retired farmers, who are familiar with the geographic area, as part time employees to assist with preparing seed beds, grass seeding, fertilizing, mowing and other tasks related to vegetation management on eroded or erosion prone areas. The experience of persons who

have spent a good portion of their lives dealing with these tasks would be very valuable to the Army.

7. Develop a layperson's description for calculating water runoff from a drainage area. This was requested by the CERL contact and we determined that it would take considerable time to accomplish a description that it is specific to Army installations. The procedures for calculating discharge are very complicated. The USDA has not developed a simple procedure or description as it requires experienced individuals to make needed judgements.
8. Develop procedures to make Natural Resources Staff and the Command aware of Federal legislation that will have impact on Army activities such as Water Quality Act of 1987, the 1985 Food Security Act and the Endangered Species Act.

TASK 2. REVIEW THE CURRENT USACERL LRAM PROGRAM IN RELATION TO EROSION CONTROL NEEDS AT FORT KNOX.

Immediate Objectives

1. Examine Fort Knox training grounds to assess the potential for using tactical concealment methodology for soil conservation and training mission purposes.
2. Provide study designs of tactical concealment islands and corridors (TCI's and TCC's) that will address potential solutions to both uses.
3. Provide recommendations for study design installation and maintenance.

Project Timeline

During October of 1991, a planning meeting was held at CERL, Champaign IL, to coordinate efforts on the implementation of Task 2 with Fort Knox personnel.

Meeting attendees included:

Dr. William Severinghaus,	CERL
Dr. Robert Riggans,	CERL
Ms. Sara White,	CERL
Mr. Stanley Zellmer,	Argonne National Laboratory
Dr. Michael Barnhardt,	IL State Geological Survey
Dr. Andrew Gillespie,	Purdue University
Dr. Phillip Pope,	Purdue University

During early November, 1991, a site assessment was made of training areas on the Fort Knox installation. Conducting the assessment were White, Zellmer, Barnhardt, Gillespie, and Pope. The need for soil erosion management at Fort Knox is becoming critical as training areas are shrinking due to heavy soil erosion. Two days were spent examining training area vegetation,

soils, geography, physiography, wetlands, and training vehicle activity. Several gully systems were examined for severity, origin, and mitigation methods. Soil samples were taken for fertility and chemical analysis with additional on-site measurements taken of soil physical properties. On-site resources for TCI/TCC construction and protection were identified. These included appropriate tree, shrub, and grass species for stabilizing the soil surface, and bedrock slabs for protecting plantings from training activities. A preliminary delineation was made in the field by the assessment team of the areas to be fortified through gully protection, wetland protection, woodland protection, and soil erosion protection.

In late November, Dr. Severinghaus (CERL) and Sara White (CERL) reviewed the discussion ideas formulated during the site assessment visit. A November 27 memo was sent to cooperating scientists requesting specific prescriptions for the Fort Knox test site to be rehabilitated.

Specifically, the following information was requested:

1. Selection of tree and shrub species to be evaluated based on the climatic probability of survival, the potential for the growth form to have tactical concealment value, and an effective growth rate and lifespan.
2. Selection of appropriate planting technology to allow for the highest probability of survival.
3. Selection of gully-head stabilization measures of a variety of types: rip-rap, crushed rock, vegetation, seeding, matting, regrading, and others. The incorporation of these measures into the design and implementation of TCI's/TCC's where possible.
4. Selection of barrier materials and barrier patterns to protect the rehabilitated areas and tactical concealment measures, and to redirect traffic from eroding areas.
5. Development of site-specific specifications.

Aerial photos were provided from which to draw design overlays on the specific test site.

During late November, Drs. Gillespie and Pope drafted a preliminary site plan for CERL. Included were a series of site overlays delineating a base-level of mitigation needed to maintain the training site while providing erosion control and tactical concealment. Additional TCI's/TCC's were included on an additional overlay for greater protection of existing woodlands, islands of trees, or erosion-sensitive areas. Also located were sites for permanent hardened crossings (bridges) for training vehicles to eliminate damage to sensitive areas. Suggestions for different gully control measures were outlined. Drainage control measures were outlined to remove puddling in depressions resulting from the bouncing nature of tank travel. The lack of drainage had caused tanks to navigate around wet areas, expanding the training area into vegetated terrain and destroying trees and

shrubs necessary for the attenuation of gully formation. Recommendations for TCI/TCC design were discussed in relation to meeting tactical concealment needs as well as biological needs of special areas such as wetlands and saturated soils. Attached to the report was a list of potential species to be used at the site. These trees and shrubs were native plants adapted to the lowland and upland conditions found at the test site. The list of trees provided a range of growth rates, tree sizes, growth forms, and propagation sources/techniques. This report was forwarded to CERL where reports from each cooperator were to be combined to present to Fort Knox personnel (Appendix X).

In early Spring, 1992, Dr. Severinghaus and Sara White traveled to Fort Knox to present work-to-date on site design for the training area. From the list of suggested treatments and designs, Fort Knox staff were to select those most pertinent to their training and erosion control needs. At this meeting, Fort Knox staff placed work on Task 2 on hold.

In late Spring, 1992, Sara White informed Dr. Gillespie that work on Task 2 had been terminated.

REFERENCES:

Procedures and Standards for Urban Soil Erosion and Sedimentation Control in Illinois, The Urban Committee of Association of Illinois Soil and Water Conservation Districts, Revised July, 1988.

Virginia Erosion & Sediment Control Handbook, Virginia Soil and Water Conservation Commission, Second Edition, 1980.

New York Guidelines for Urban Erosion and Sediment Control, Empire State Chapter, Soil and Water Conservation Society, October, 1991.

Michigan Soil Erosion & Sedimentation Control Guidebook, Division of Land Resource Programs, Department of Natural Resources, 1990.

Erosion Control During Highway Construction: Manual on Principles and Practices, National Cooperative Highway Research Program Report 221, Transportation Research Board, National Research Council, April, 1980.

Erosion on Wisconsin Roadsides, A Report to Wisconsin Citizens, Cooperative Extension Service, The University of Wisconsin, September, 1969.

Controlling Erosion on Construction Sites, USDA Soil Conservation Service, Agriculture Information Bulletin 347. No date.

Computer Program for Project Formulation-Hydrology, USDA, Soil Conservation Service, SCS Technical Release 20, Washington, D.S. 1983.

Renard,K.G., G.R. Foster, G.A. Weesies and J.P. Porter, RUSLE: Revised Universal Soil Loss Equation, Journal of Soil and Water Conservation, Vol. 46: 30-33, January-February, 1991.