STORMWATER PROGRAM

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Development of the Highway Erosion Assessment Tool (HEAT) for Evaluation of Roadside Slopes

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DEVELOPMENT OF THE HIGHWAY EROSION ASSESSMENT TOOL (HEAT) FOR EVALUATION OF ROADSIDE SLOPES

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BIOGRAPHICAL SKETCHES

Andrew J. Sloan, Ph.D., APSSc is a soil scientist with CH2M HILL in Redding, CA. He has participated in developing and implementing procedures for statewide erosion control evaluations in California for Caltrans, which included development of HEAT. His education is in biology and soil science, while his consulting experience includes work in land treatment of wastewater, vadose zone hydraulic modeling, wetlands, soil characterizations, and statistical analysis.

Ms. Misty Scharff, APSSc has been involved with California State University, Sacramento performing research on erosion and sediment control for Caltrans since 2000. Misty was educated in soil science from California Polytechnic State University, San Luis Obispo, were she assisted in numerous erosion control research studies. Misty has been a member of IECA since 1996.

Ms. Mica Hart, APSS is a consulting soil scientist with CH2M HILL in Redding, CA. She was a component of a Caltrans Statewide Erosion Control Review project team and has experience in consulting, research, and soil classification and interpretation. Her academic background and professional experience are in soil science, irrigation management and viticulture.

Laurel Karren, M.S. is an environmental scientist with CH2M HILL in Sacramento, CA. She worked to develop and implement the Caltrans Statewide Erosion Control Review, including field methodologies and data analysis. She has academic and research experience in vegetative erosion control and watershed management, as well as professional experience with erosion control, water resources and forestry permitting, and environmental assessment and planning. Prior to working at CH2M HILL, Ms. Karren worked as an overseas consultant developing training programs in the agricultural and environment sector in arid and semi -arid regions of West Africa.

Joel Kimmelshue, Ph.D., CPSSc is a Project Soil Scientist and Project Manager with CH2M HILL in Redding, California. He has been consulting with vegetated erosion and sediment control systems for nearly 5 years. Prior to coming to CH2M HILL, Dr. Kimmelshue received his B.S. degree from California Polytechnic State University, in San Luis Obispo and his M.S. and Ph.D. from North Carolina State University, Raleigh. His coursework and research dealt with the dynamics of soil/plant systems.

Brent G. Hallock, Ph.D., CPSS, and CPESC, is a professor at California Polytechnic State University, San Luis Obispo, since 1979. He teaches an undergraduate course in Soil and Water Conservation, an upper division course in Rangeland Resources, and a graduate course in Soil Erosion and Sediment Control. Brent earned Cal Poly's highest award of Distinguished Teacher in 2000. He has taught over 30 seminars and short courses in site analysis, erosion control, and selection of management measures. Dr. Hallock's research grants with Caltrans, RWQCB, and EPA on the use of vegetation in erosion control and water quality total over two million dollars in the past six years.

ABSTRACT

This paper describes the development and implementation a procedure used to evaluate the success of vegetated erosion control throughout the state of California. However, evaluating of the success of vegetated roadside erosion control is a difficult task due to the variability among sites, as well as the multitude of factors that may collectively affect soil and vegetative system stability. To aid in this task, a tool called the Highway Erosion Assessment Tool (HEAT) was developed. HEAT is an end-user software program used for recording, calculating, and summarizing data collected by personnel evaluating the success of vegetated erosion control. Data were collected on-site that related to slope, vegetated coverage, soils, parent material, aspect, and other factors and entered into the program. Climate data were collected before site evaluations, while predictive models, such as Morgan, Morgan, and Finney, and the Revised Universal Soil Loss Equation (RUSLE) were used by the program after site visits to help estimate expected soil loss at each site. The program allowed large amounts of both qualitative and quantitative information to be assembled over the short duration (3 months) of the statewide erosion control evaluation, much of which was then analyzed using statistics or other quantitative methods.

Key Words: Erosion, evaluation, soil, vegetative cover, California

INTRODUCTION

Evaluation of the success of vegetated roadside erosion control is a difficult task due to the variability among sites, as well as the multitude of factors that may collectively affect soil and vegetative system stability. Any effort at understanding the factors influencing erosion control success, particularly those aimed at producing conclusions based on statistical analysis of quantitative data collected in the field requires organized and intense data collection before and during field visits.

This paper describes the development and implementation of a field evaluation procedure used to evaluate the success of vegetated erosion control throughout the state of California. Part of this description includes reference to a tool called the Highway Erosion Assessment Tool (HEAT), a computer program (program) integral to data collection and analysis during evaluation procedures. The program is end-user software used for recording, calculating, and summarizing data collected by personnel evaluating the success of vegetated erosion control.

The development and implemenentation of the program was part of a larger effort to understand the factors affecting the success of vegetated erosion control on California roadways (California Department of Transportation, 2001). This work included a number of qualitative and quantitive approaches to measure erosion losses or potential erodibility, and assess the success of existing erosion control practices.

The principal challenge in erosion assessment is determining the nature and magnitude of erosion with regard to the erosion prevention practice or practices employed at the site. The overall statewide erosion control project, including the development of the program, was of limited duration, and only one visit for each of 57 sites was allowed, rather than continuous monitoring to determine changes to sites over time. Given these limitations, site evaluations had to be deductive, whereby the evaluator constructed a reasonable concept of site design, reasons for failure or success, and adherence to specified design. The principle task of the program was to provide an interface for efficient summarization of as much data as possible in a short period of time. The following sections describe the various user interface modules of the program, as well as the procedures employed in collecting data for entry.

METHODOLOGY

The following sections describe the field and data collection methodology used in the statewide vegetated erosion control evaluation program. Descriptions of site selection, field evaluation procedures, and the program user interface are provided.

SITE SELECTION CRITERIA

The following list of site selection criteria was developed by the field evaluators and Caltrans district staff. The selection criteria are somewhat general to avoid exclusion of potential candidate sites because of a regionally or geographically non-applicable criterion. Flexibility in site selection was important to allow for selection of sites with varied characteristics, but still encompassed those that represented the soils and climatic zones within an individual district. The criteria for site selection included:

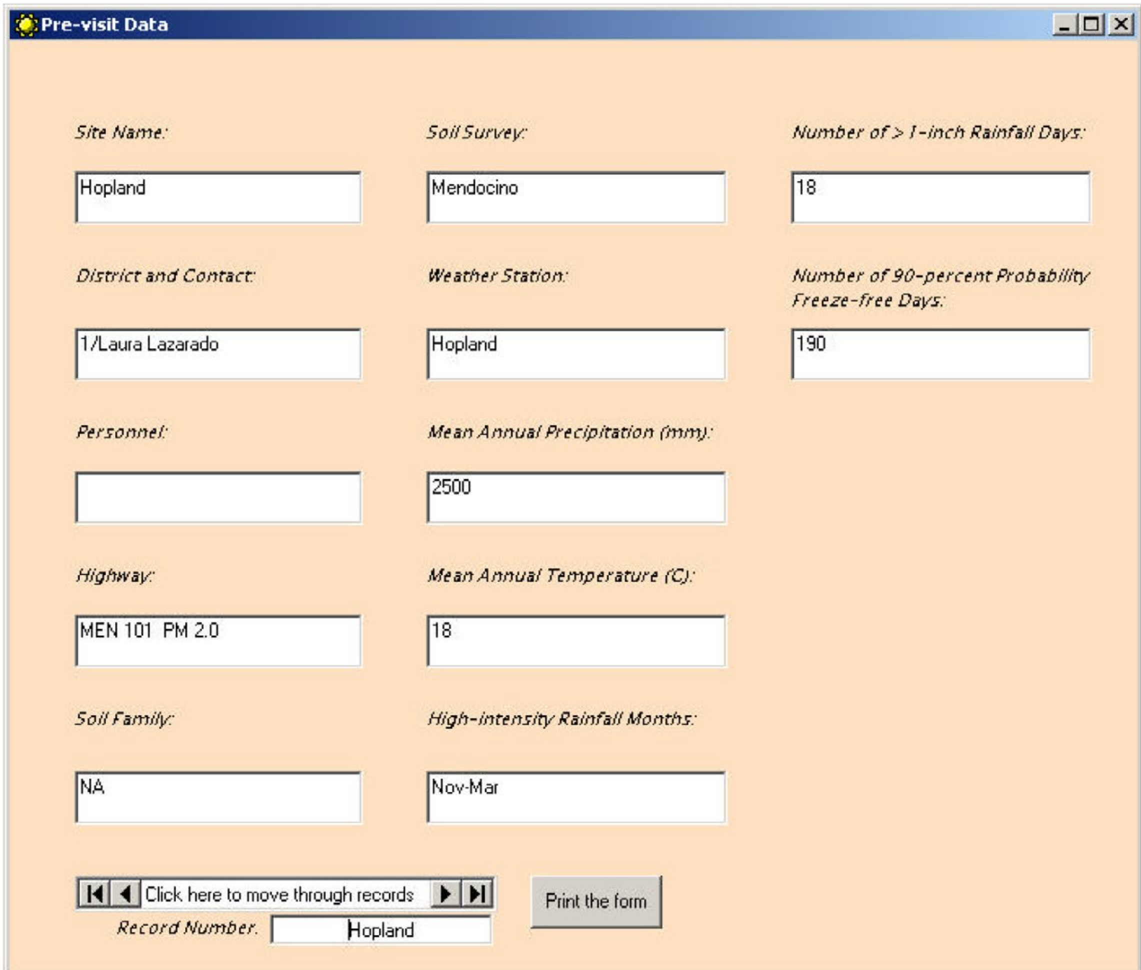
- Sites where the last significant construction activities took place from one to ten years ago
- Sites where some type of construction specifications and design drawings were potentially available
- Sites with a history of erosion control challenges
- Sites that had apparent erosion control measures currently being implemented or implemented as a part of construction
- Sites designated as a concern by district or headquarter highway staff
- Sites with some successful erosion control or sites with successful and unsuccessful erosion control practices to offer paired comparisons
- Sites representing significant geographic, climatic, or soil conditions within a district; sites located in unique “pocket” areas within a district were mostly avoided
- Sites with diverse geographic, climatic, or soil characteristics to avoid repetitious evaluations

DATA COLLECTION

The field methodology included a number of qualitative and quantitative approaches to measure erosion losses or potential erodibility and assess the success of existing erosion control practices. This discussion outlines the systematic procedure followed by field personnel utilizing the program before, during, and after a site evaluation. Also discussed briefly is the method by which the program allowed storage and access of data.

Pre-visit Site Data

Pre-visit site data included climate information (e.g., high-intensity rainfall events, temperature, annual rainfall, freeze-free days, etc.) and site evaluation identifiers (e.g., field personnel, district staff, soil type) (Figure 1). Pre-visit site data provided the research team a context in which to evaluate conditions during the visit. This context included the potential for highly erosive conditions (e.g., high rainfall area or poorly developed soil) and the expected success of the erosion control practices. Pre-visit site data also provided a background condition against which existing conditions were compared.



Pre-visit Data

Site Name: Hopland

District and Contact: 1/Laura Lazarado

Personnel:

Highway: MEN 101 PM 2.0

Soil Family: NA

Soil Survey: Mendocino

Weather Station: Hopland

Mean Annual Precipitation (mm): 2500

Mean Annual Temperature (C): 18

High-intensity Rainfall Months: Nov-Mar

Number of > 1-inch Rainfall Days: 18

Number of 90-percent Probability Freeze-free Days: 190

Click here to move through records

Record Number: Hopland

Print the form

Figure 1. Pre-visit site information data sheet, including data from construction specifications, gathered as background before field investigation.

Visit-day Site Data

Visit-day site data were qualitative and quantitative data collected during the actual site visit day. These included observations of the condition of the site (e.g., the type of erosion observed, erosion point sources, etc.), site design (e.g., the presence of slope benches, slope angle, irrigation in use, etc.), and the size of the area. Global Positioning System (GPS) locations were taken at corners of sites to calculate site areas and obtain coordinates for identification on district maps. Visit-day data provided valuable information regarding actual site design, particularly for comparisons to specifications.

Existing Practices

For existing practices evaluations, evaluators reviewed a list of 38 erosion control technologies and determined whether they had been successfully or unsuccessfully implemented or not observed (Figure 2). This evaluation was somewhat subjective regarding the determination of relative success or lack of success. Categorization in the "Implemented with Success" column required that the erosion control practice was successful on the majority of the site. In other words, an erosion control practice that appeared to be fulfilling its role over most locations where it was implemented (a given practice may not be used on the entire site) was considered successful.

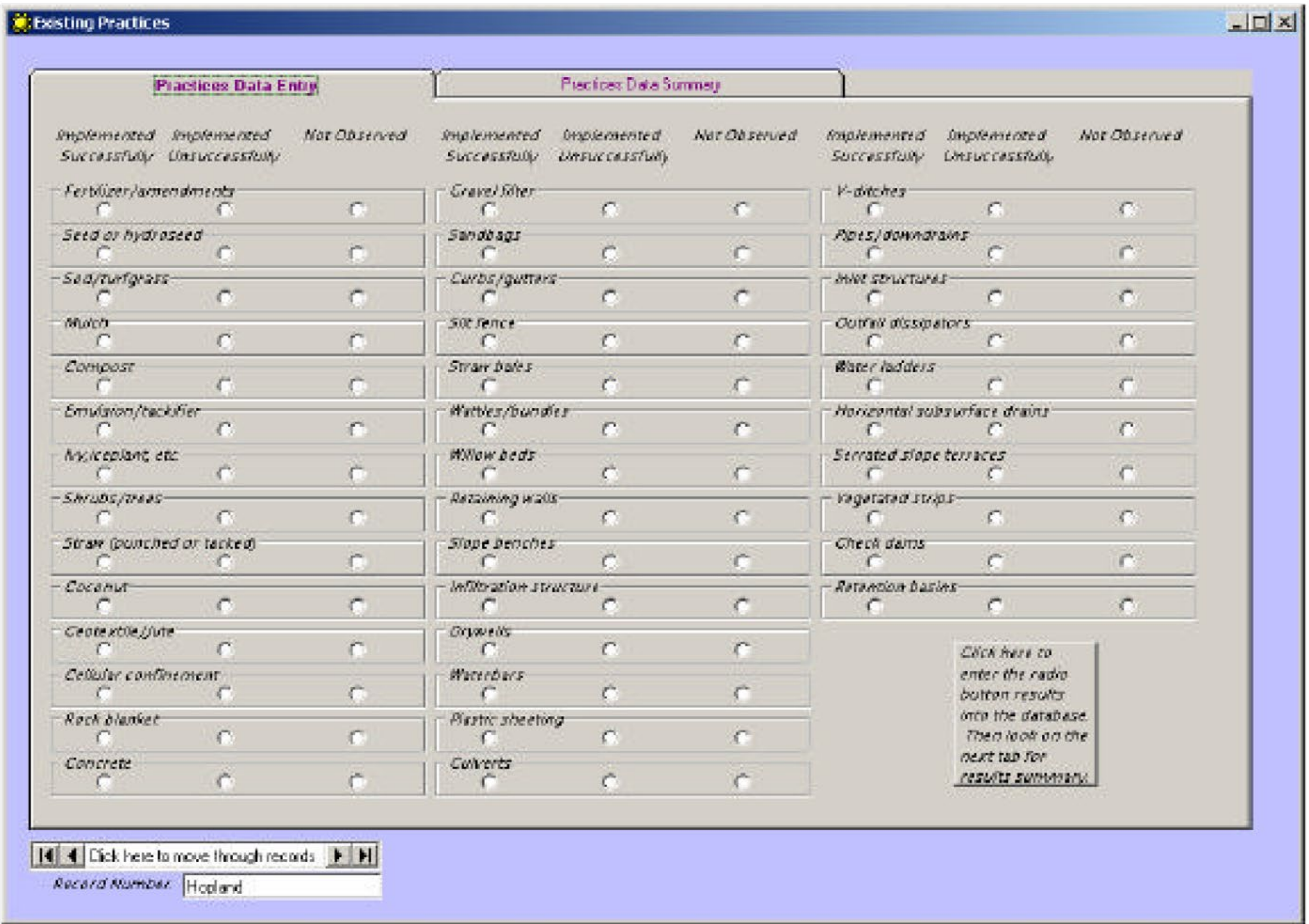
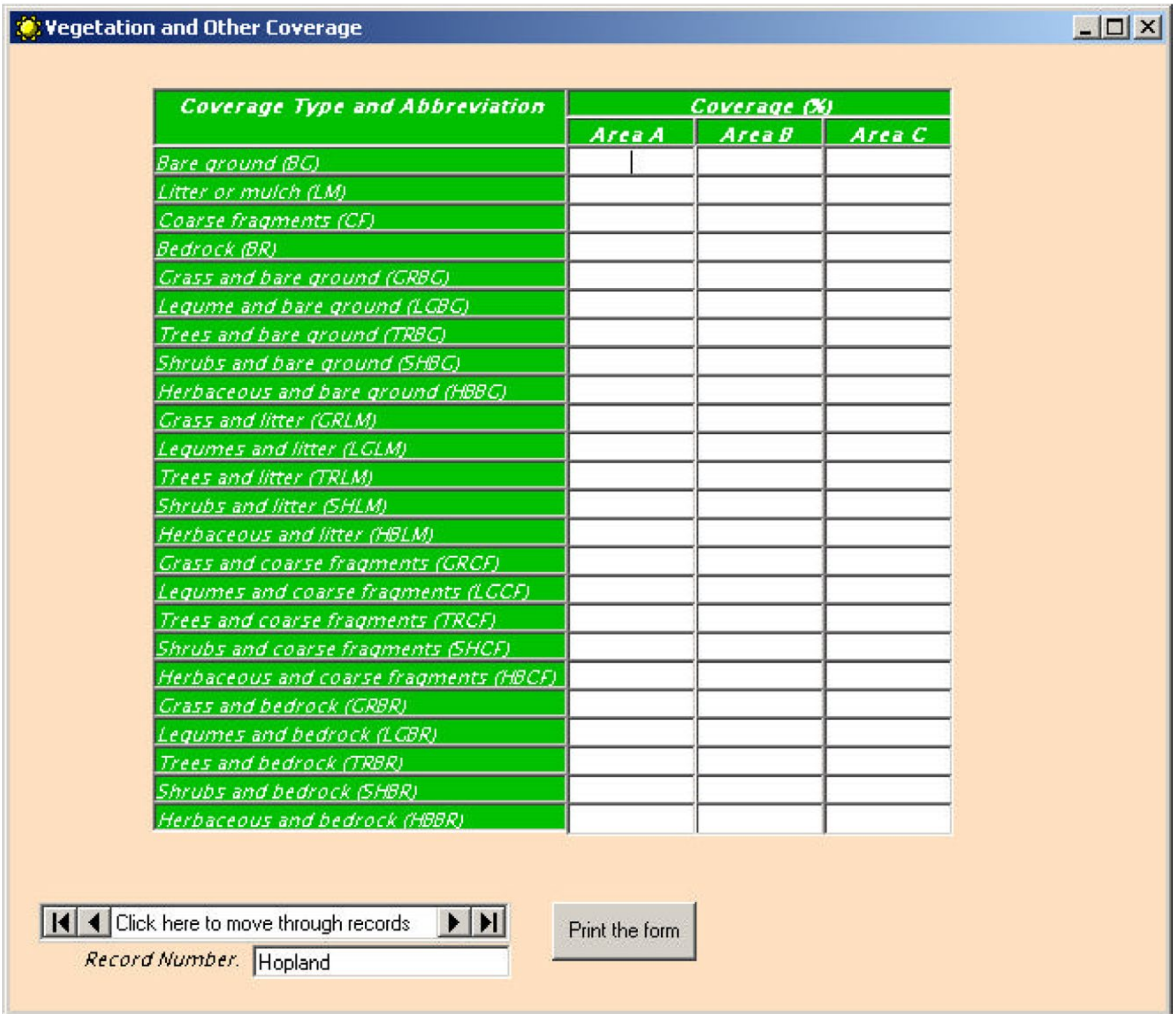


Figure 2. Existing Practices checklist with success-value radio buttons for each of 38 technology categories.

Vegetation

Evaluators used a modified version of the U.S. Bureau of Land Management Rangeland Monitoring Trend Studies Step-Point-Transect Method to record vegetation coverage on the sites (Department of the Interior, 1985). The Step-Point-Transect Method consists of observing points along a 15 m transect at 15 cm intervals. Cover type corresponding to categories including foliar and basal cover was assessed (Figure 3). This method has had wide application and was suited for use with grasses, forbs, shrubs, and trees. On some sites, plant species were collected and sent to California State University, San Luis Obispo for verification of the plant identification.


Vegetation and Other Coverage

Coverage Type and Abbreviation	Coverage (%)		
	Area A	Area B	Area C
Bare ground (BG)			
Litter or mulch (LM)			
Coarse fragments (CF)			
Bedrock (BR)			
Grass and bare ground (GRBG)			
Legume and bare ground (LGBG)			
Trees and bare ground (TRBG)			
Shrubs and bare ground (SHBG)			
Herbaceous and bare ground (HBBG)			
Grass and litter (GRLM)			
Legumes and litter (LGLM)			
Trees and litter (TRLM)			
Shrubs and litter (SHLM)			
Herbaceous and litter (HBLM)			
Grass and coarse fragments (GRCF)			
Legumes and coarse fragments (LGCF)			
Trees and coarse fragments (TRCF)			
Shrubs and coarse fragments (SHCF)			
Herbaceous and coarse fragments (HBCF)			
Grass and bedrock (GRBR)			
Legumes and bedrock (LGBR)			
Trees and bedrock (TRBR)			
Shrubs and bedrock (SHBR)			
Herbaceous and bedrock (HBBR)			

Click here to move through records

Record Number: Hopland

Print the form

Figure 3. Ground cover evaluation with 24 plant, litter, and rock combinations. Evaluations can be performed for up to three areas of the site.

Soils Data

Soils data provide critical information regarding the mechanical stability of the site, fertility, and consequent capacity to provide a substrate for vegetative cover. Soils data collection in the field included descriptions of auger borings or hand-dug pits for up to three locations, corresponding to distinct areas of each site (Figure 4). Data included soil texture, structure, color, and the depth of each horizon. Evaluators also determined the abundance and depth of root penetration, as well as clay, sand, and gravel content.

Overall soil permeability class and parent material were logged to provide information regarding the nature and stability of underlying strata, as well as the infiltration rate. Soil profiles for each study site were described and sampled according to standard protocol (Soil Survey Division Staff, 1993). Soils were sampled from representative areas within the site and were taken at depths corresponding to soil profile descriptions for analysis of selected chemical and physical parameters.

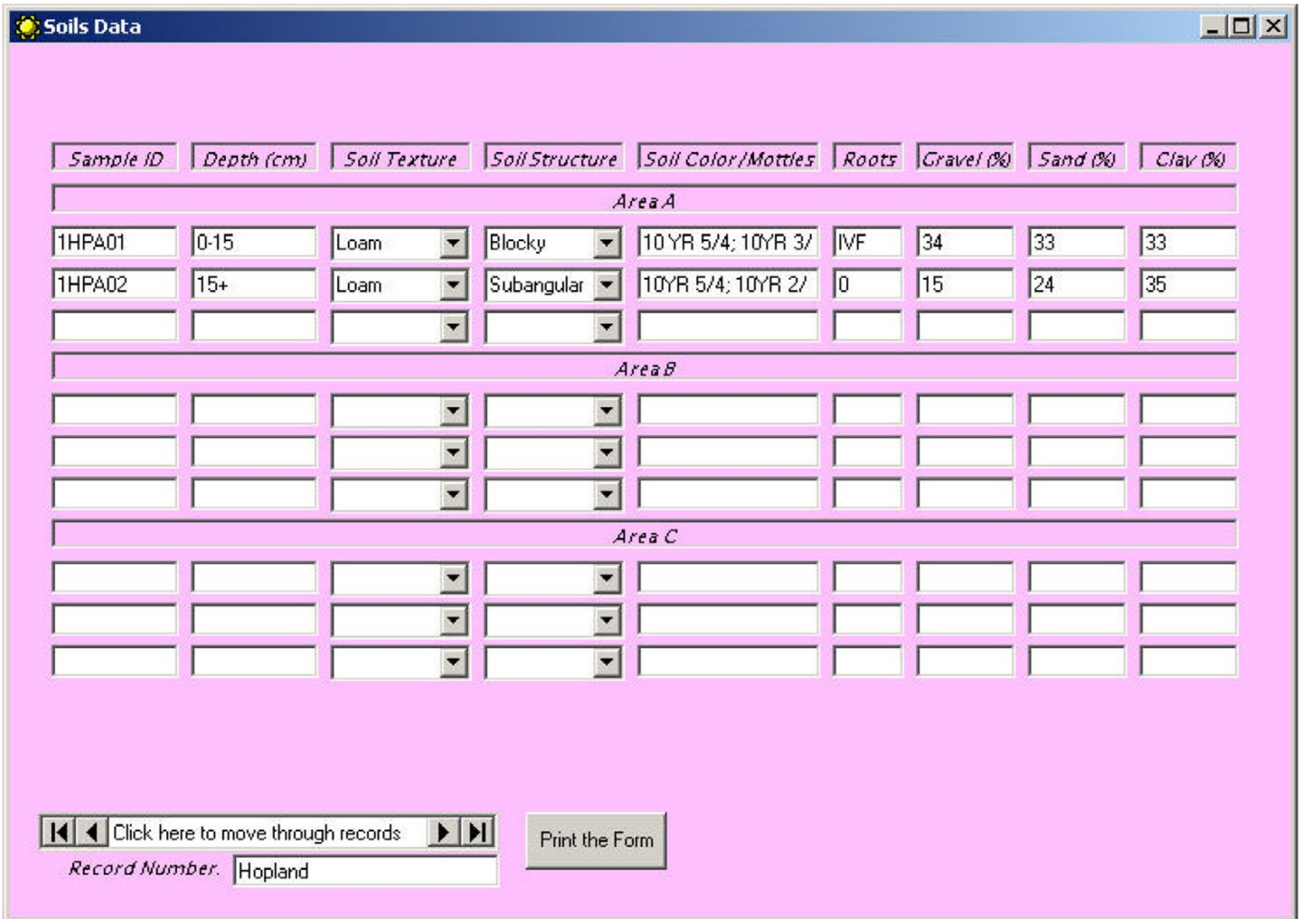


Figure 4. Soils Data entry, with blanks for characteristics such as texture, structure, and color. Soil chemistry data are determined by laboratory analysis.

Channel Calculations

The Channel Erosion Calculator is a volumetric method of estimating soil loss modified from calculating cross sections in a channel (Hudson, 1995). In an area exhibiting channel erosion, a representative channel was chosen. The average depth and width of the channel were measured at four points (Figure 5). The four points were positioned along the channel to correspond to natural changes in channel size or dimension. This representative volume of soil lost per channel was calculated for the total number of channels across the area for an overall estimation of soil loss caused by channel erosion. HEAT had the ability to calculate channel erosion for up to three areas within one site, chosen by field personnel to correspond to varying degrees of channel erosion (size or type of channels). This allowed HEAT to account for sites that are uniformly channeled as well as sites with varying degrees of channeling among different areas.

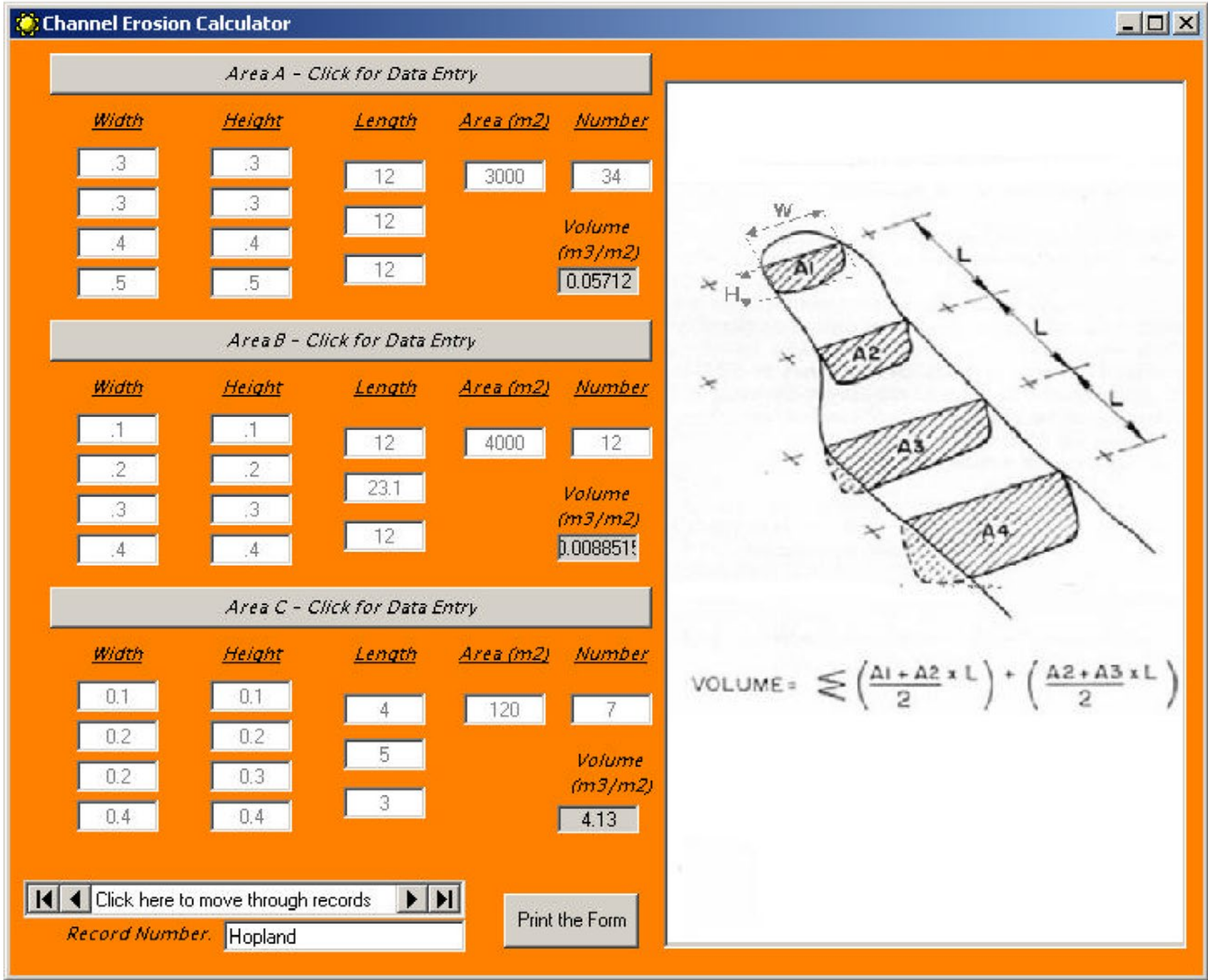


Figure 5. Channel calculations are performed for up to three areas of the site (channel diagram adapted from Hudson, 1995).

Revised Universal Soil Loss Equations (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) is an empirical model based on experimental data that uses a unique set of definitions to estimate average annual soil loss in tons per acre. The RUSLE model calculates average annual soil loss using five factors, including a rainfall erosivity factor, soil erodibility factor, a length-slope factor, a management practice factor (more applicable to agronomic systems), and a crop cover factor. Information about RUSLE, including suggested input parameters, was obtained from Hudson (1995), Agriculture Handbook 03, (1997), and California State University, San Luis Obispo.

Morgan, Morgan, and Finney

The program also included an interface for erosion modeling using the Morgan, Morgan, and Finney model. This approach differs somewhat from RUSLE, in that it allows entry of variable vegetative coverage throughout the year, as well as more soil physical data. As with RUSLE, data input interfaces were supported by help menus that provided typical values for soil physical properties, crop coverage and management, and climate factors.

Field Notes

The Field Notes section of the program consisted of five categories under which field team members recorded their visual observations. Text descriptions included observations of areas surrounding the site (e.g., natural conditions), erosion point sources (e.g., pipes, channels, or road easements), current erosion control effectiveness, wildlife or habitat observations, and a photo record.

Help Menus

In a number of instances, the procedures for field measurements or calculations in the program were not obvious. This was particularly true in execution of the erosion models (e.g., Morgan, Morgan, and Finney and RUSLE) where a variety of decisions regarding input parameters were necessary. To provide assistance on these areas, as well as information regarding erosion control practices in general, the program included a series of help menus.

Help menus included soil and plant parameters for the Morgan, Morgan, and Finney model (Morgan, 1986), as well as rainfall factors and the Wischmeier soil detachability nomograph for RUSLE (Hudson, 1995) (Figure 6). Help menus also included a list of soil erosion control practices and their respective objectives. This list was designed to help in assessing successes or failures of erosion control practices observed during field evaluations.

Data Storage and Retrieval

The storage and retrieval of large quantities of data was accomplished using database access controls linked to Microsoft AccessTM database tables. Many of the objects in the program, such as text boxes for entry of information, were "data-aware," in which data were linked and stored in records in the database program. Each data entry sheet in the program included database control linking that allowed the user to move from one site record to another. Changes to an entry were automatically serialized (saved) to the database.

CONCLUSIONS

The procedure employed by statewide evaluation of vegetated erosion control sites in California allowed intense data collection over a short period of time. Integral to the collection of quantitative data (e.g., measurements of vegetated coverage, channel erosion volume, etc.) and field observations was the use of a software program for entry and storage of data developed specifically for this project.

Overall, data were collected onsite that related to slope, vegetated coverage, soils, parent material, aspect, and other factors. Climate data were collected before site evaluations, while predictive models, such as Morgan, Morgan, and Finney, and RUSLE were run after site visits to help estimate expected soil loss at each site.

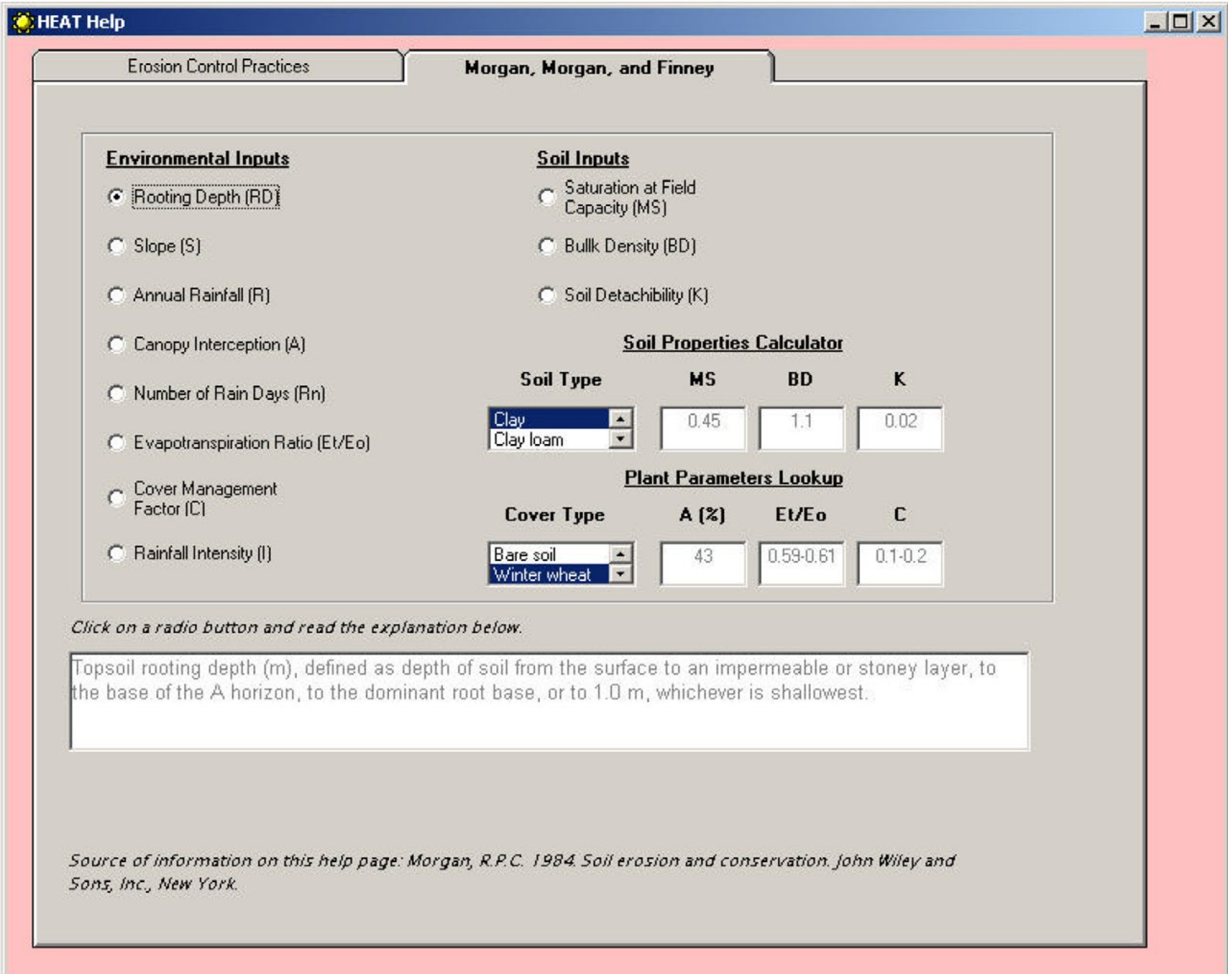


Figure 6. Help menus, such as this set of definitions for the Morgan, Morgan, and Finney model, are included to help users through difficult operations.

Although only the duration of the project only allowed one visit for each site, intense data collection, facilitated by the program, allowed large quantities of information to be assembled in a short period of time. Analysis of results, including quantitative (i.e., statistical) methods was then possible due to the comprehensive nature of data collection.

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