FINAL REPORT
CTSW-RT-01-067

Caltrans Statewide

EROSION CONTROL REVIEW

February 20, 2002

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Executive Summary

To improve upon and understand the dynamics of current practices, the California Department of Transportation (Caltrans) developed a Statewide Erosion Control Review. The main goal of this work was to provide a comprehensive, data-rich, and timely review of common Caltrans erosion control problem sites throughout the state. The initial work involved significant efforts to develop a detailed, user-friendly, Excel-based site evaluation program designated as the Highway Erosion Assessment Tool (HEAT). Development of the HEAT program resulted in multiple review iterations by project team members. Concurrent with this effort, contacts with individual district personnel were made for identification of sites meeting the site selection criteria. Field evaluations began in December 2000 and were completed at the end of March 2001. Results summarization and interpretation continued through June 2001.

The objectives of the Statewide Erosion Control Review project include the following:

- To account for extreme variability (e.g., climatic conditions, soils, plant growth, and elevation) across California and develop statewide trends for causes of soil loss from sites assisted by vegetative cover.
- To identify trends of unsuccessful erosion control practices across the entire state and/or within district, climatic, or geographic boundaries.
- To identify, evaluate, quantify (when possible), and summarize the results of the statewide review to assist Caltrans in the continued improvement of statewide erosion control standards. This was to be performed through the development of a comprehensive set of site selection and evaluation criteria, which would establish recommendations for remedying current erosion control problems and suggest changes to future approaches.
- To utilize the extensive collection of historical information and studies about erosion control practices on specific construction efforts and general practices currently used by Caltrans. This information will be incorporated into the study as applicable to build on existing research efforts.

The first task required for this statewide erosion evaluation was the development of an overall project work plan. The work plan identified four tasks that encompassed all work efforts. The tasks involved in this Statewide Erosion Control Review effort included:

- Pre-fieldwork efforts
- Statewide site evaluations
- Results summarization
- Final report preparation

Highway Erosion Assessment Tool Field Evaluation Program

The field methodology included a number of qualitative and quantitive approaches to both measure erosion losses or potential erodibility and assess the success of existing erosion control practices. The study was conducted during an exceptionally wet winter, and germination rates may not have been representative of an average year. HEAT was developed to record, calculate, and summarize these measurements. HEAT is a macro-driven spreadsheet that was designed to aid the research team in data collection and calculations.

The principal challenge in erosion assessment is to determine the nature and magnitude of erosion with regard to the erosion prevention practice employed at the site. However, the abbreviated duration of the project only allowed one visit for each of the 57 sites, rather than continuous monitoring to determine changes to the site 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 HEAT program was designed and utilized to efficiently summarize this information.

Site Selection Criteria

The following list of site selection criteria was developed by the research team. The selection criteria are somewhat general to avoid exclusion of potential candidate sites because of a regionally or geographically non-applicable criterion. The criteria for site selection included:

- Sites of 1 to 10 years in age since last significant construction activities
- Sites where some type of construction specifications, as-builts, and design drawings were potentially available
- Sites that had been experiencing some erosion control challenges
- Sites that had apparent erosion control measures currently being implemented or had been implemented as a part of construction
- Sites designated as a concern by district or headquarter Caltrans staff
- Sites with some successful erosion control, or sites with successful and unsuccessful erosion control practices to offer pair-wise comparisons
- Sites representing significant geographic, climatic, or soil characteristics within a district; sites located in unique "pocket" areas within a district were mostly avoided
- Sites with diverse geographic, climatic, and/or soil characteristics to avoid repetitious evaluations

Criteria were developed as general guidance for site evaluations. These site evaluation criteria were intended to be comprehensive and were used as the basis for HEAT. The specific criteria were classified into the following overall categories:

- General erosion control criteria
- Vegetative criteria

- Soil and topographic criteria
- Climatic criteria

Both quantitative and qualitative methods were used to evaluate the criteria listed above. Whenever possible, quantitative evaluations were conducted rather than qualitative assessments.

Quantification of Erosion Characteristics

The research team evaluated methods of quantifying in-field observations of erosion characteristics. Through accurate quantification of erosion characteristics, it would be possible to objectively and statistically evaluate the data and develop trends or significant relationships between problem erosion sites and the potential causes. This resulted in a quantitative comparison of sites statewide. The research team utilized the following quantitative methods when evaluating a site for erosion severity:

- Water Erosion Prediction Project (WEPP)
- Revised Universal Soil Loss Equation (RUSLE) predictive model
- Morgan, Morgan, and Finney predictive model
- Channel volume calculations
- Slope inclination, aspect, and length
- Climatic measurements
- Vegetative and debris cover percentages
- Rooting depth
- Soil texture and depth to restrictive horizons
- Laboratory-measured soil chemical and physical analyses

A detailed statistical and trend evaluation was conducted on all quantitative data. In some cases, these data yielded non-significant statistical results ($\alpha = 0.15$ level of significance). This was likely the case for expected statistically significant results because of the extreme variability in climatic regimes, soil conditions, elevation, and aspect encountered across the state. Some statistically significant results were determined, and a number of trends were discovered through data evaluation. These trends indicated that slope, site soil conditions, and some climatic factors were the most influential contributors to soil loss on the site evaluated.

Statewide, 13 factors contributing to soil loss from the sites surveyed were defined. These factors were identified through team consensus after all of the sites had been evaluated and include the following:

- Steep slopes
- Aspect (e.g., north-facing, shaded site)
- Adverse climatic conditions (e.g., intense rainfall, high winds, frost periods, or drought)
- Sparse, absent, or inappropriate vegetation for a particular climate or soil
- Inappropriate or non-functional site design (e.g., toe cutting)

- Poorly designed, maintained, or non-existent site drainage systems (surface and/or subsurface)
- Runon from adjacent watershed areas
- Insufficient irrigation and/or rainfall
- Excessive irrigation or broken systems
- Adverse soil chemical properties (e.g., pH, salts, and nutrient deficiencies/toxicities)
- Adverse soil physical properties (e.g., shallow soils, exposed parent material, high clay or sand contents, poor soil structure, and hard pans)
- Improper site maintenance (e.g., spraying, soil removal, and neglect)
- Improper installation and/or management of non-vegetative erosion control technologies (e.g., blankets, netting, and geogrids)

This list is likely not entirely comprehensive with regard to all causes of erosion and the factors are not presented in order of significance. However, these were the main contributing factors associated with soil loss encountered on sites with vegetative erosion control systems in this study. Of these 13 contributing factors, slope; sparse, absent, or inappropriate vegetation for a particular climate or soil; and adverse soil physical properties were the three most commonly listed factors contributing to soil losses on vegetated erosion control sites. Throughout this report slope is presented as a horizontal to vertical ratio (e.g., 1.7:1 [H:V]).

These quantitative and qualitative results suggest and support the following recommendations:

- Regression analyses were performed on applicable data to determine if a statistical relationship existed between slope and vegetative coverage. The principal objective of this exercise was to identify, if possible, a critical slope where Caltrans' target minimum of 70-percent vegetative cover would be observed. Regressions indicated that while slope significantly affected vegetative coverage ($\alpha = 0.05$), the variability in vegetative coverage was only partly explained by slope (as indicated by a low coefficient of determination) (Mahmood, 2002, pers. comm.). Therefore, a slope corresponding to 70-percent coverage could not be identified. Based on these results, and because this review included only problem sites, it was concluded that a target slope would be best identified with a more focused study that would include a greater number of sites and regionally appropriate values.
- Soil sampling and chemical and physical analysis should be strongly encouraged in all vegetation establishment guidelines for re-vegetation erosion control efforts. A complete agronomic soil analysis performed by many soil and plant testing laboratories should provide the concentrations of all constituents of concern. Understanding site soil chemical and physical parameters through soil testing is a key factor in the successful vegetation of a site. Many times, soil chemical and physical analysis and correct interpretation will yield simple soil amendment or preparation remedies. It is important to

relate the soil sampling results to the seed mix selected. This will ensure that the soil chemical and physical conditions are adequate for the specific species used.

- Seeding operations should be conducted during appropriate timing windows indicated by day length, frost danger, precipitation events, and elevation. Spring and especially early fall are preferred time periods for seeding without irrigation. However, this will vary according to the previously mentioned parameters. Construction delays often dictate timing of seeding. If construction termination occurs outside of the optimum seeding window, temporary non-vegetative erosion control measures should be implemented until seeding can take place. Timing of seeding can generally be based on elevation. Target seeding dates should be October 1 through November 15 for elevations below 2,500 feet, and September 1 through October 15 for elevations above 2,500 feet.

- Site drainage improvements and design should be implemented. Site observations indicated that surface and subsurface drainage design and implementation were many times insufficient to prevent erosion or mass failure or, in some cases, non-existent. Subsurface drainage, including the installation of perforated pipe laterally across hillsides or benches, or downdrains collecting drainage from slope benches, may effectively remove water stored in soil pore spaces. This is particularly critical on sites where soils are unstable and easily erodible. On several sites, cool wet seasons resulted in wet soils and dormant vegetation, where removal by vegetation using subsurface drainage is therefore recommended where appropriate. Although a number of other sites exhibited successful design and maintenance of slope benches and other approaches, other sites exhibited failure to prevent runon, accumulation of water and drainage over slope faces, and slope destabilization from toe cutting.

- If vegetative erosion control is the preferred alternative, species that have aggressive establishment characteristics should be used. It is important to note that it is imperative to avoid propagation of invasive species. As indicated by field observations, many times similar seed mixes were employed on sites with varying characteristics. It is recommended that minimization of sediment loss be tied to a more flexible strategy of selecting species for rapid establishment and not only for ecological integrity or aesthetic appeal. Determination of correct seed mixes/landscape plants should be selected according to areas of the state and site-specific conditions. It was evident that because of the extreme diversity of climatic conditions, soils, and elevation across the state, a generalized, statewide seed mix and application method is not applicable. The desirable colonization of native species on erosion control sites will only occur if the site is stable and supportive of plant growth from the outset.

- A number of sites exhibited mulch layers that were stable and well tacked to the slope, but too thick to allow successful emergence of grasses. Mulch provides beneficial organic matter to the soil, improving moisture retention, soil structure, and in some cases, nutrient holding capacity. However, when heavy applications cover seeds and prevent light penetration or retain excess moisture and cool temperatures, grass will not germinate or emerge. Mulch or straw must therefore be applied in amounts specified by the manufacturer to prevent surficial soil loss and not in amounts that restrict plant growth.

- The nature and soils of sites where freeze-thaw conditions are a concern should be understood. Sites at higher elevations frequently exhibited erosion from freezing and thawing. In this process, water-stored soil pores freeze and expand, thereby expanding the soil and degrading soil aggregates and overall structure. Soil particles suspended on ice crystals or otherwise destabilizing are then easily lost during melting. This phenomenon was observed as it occurred on several sites. If vegetative control is selected in these environments, cover must be established to aid in stabilizing the soil (e.g., through root development) before freezing and thawing conditions begin.
- Site observation on recently constructed sites revealed early stages of erosion, especially gully and slump. Severe advancement of these erosion types may be avoided with basic repair and maintenance. Site inspections and maintenance should be performed frequently during vegetative establishment and less frequently after vegetation is effectively controlling soil erosion.