Sediment Discharge and Erosion Assessment Report

San Joaquin County and Delta Water Quality Coalition, Order R5-2014-0029

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Contents

Table of Figures 2
Table of Tables 2
Introduction 3
Background 3
Current Methodology for Determining Erosion Potential 4
Universal Soil Loss Equation 7
Modified Universal Soil Loss Equation 8
Revised Universal Soil Loss Equation 8
Watershed Analysis Risk Management Framework and Similar Models 9
SJCDWQC Methodology 9
Erosion Risk 10
Soils 11
Slope and Slope Length (LS) 11
Soil Erodibility (K) 11
Rainfall Erosivity (R) 12
Results and Discussion 13
Erosion Potential 13
Receiving Water Risk 14
Summary 17
Next Steps 17
References 18

Table of Figures

Figure 1 Map of slope and slope length in the SJCDWQC region 12
Figure 2 K factor in the SJCDWQC region including all four K factor categories 13
Figure 3 Erosion potential in SJCDWQC region. The areas in brown are high risk for erosion and sediment discharge. 14
Figure 4 SJCDWQC member parcels 15
Figure 5 SJCDWQC member parcels on land with the potential to discharge >5 tons/acre/year of sediment 16

Table of Tables

Table 1. Evaluation of empirical and physical models to be used for the SJCDWQC evaluation of risk of sediment erosion. 6
Table 2 Soil characteristics associated with K (soil erodability) values 11

Introduction

As required by R5-2014-0029, the Waste Discharge Requirement General Order (General Order) for Growers in the San Joaquin County and Delta Area, the San Joaquin County and Delta Water Quality Coalition (SJCDWQC), as the third party representing growers within the San Joaquin County and Delta Area, is required to provide an assessment report that identifies the areas susceptible to erosion and the discharge of sediment that could impact receiving waters. This Sediment Discharge and Erosion Assessment Report (SDEAR) uses a simple modeling approach to identify the areas within the SJCDWQC region that have a high risk for erosion and the discharge of sediment. Members with parcels on land with a high risk of erosion and sediment discharge will be required to complete a Sediment and Erosion Control Plan (SECP). A determination of the need to complete a SECP will be based on responses to questions in the Farm Evaluation Plan (FEP) that address the potential for erosion and sediment discharge. The FEP is not required to be submitted by members to the Coalition until June 15, 2015. When the FEP results are known for all members, the Coalition will incorporate the responses into the analysis and provide an updated assessment of the members required to complete the SECP. The updated assessment will be provided on August 1, 2015. The combination of these two tools, the modeling of sediment and erosion risk and the Farm Evaluation Plan self-identification, will allow the SJCDWQC to identify and address erosion potential across the Coalition region.

Background

Agricultural fields may be susceptible to erosion from both irrigation practices and storm water runoff but the potential for erosion and movement of soil to surface waters depends on a series of other factors including:

- Soil erodibility
- Rainfall
- Slope
- Vegetative cover
- Presence/absence of management practices to prevent the generation of sediment, or capture the sediment prior to entering surface waters (e.g. pressurized irrigation, use of PAM, sediment detention basins)

Erosion can result from two processes, soil mobilized by storm water runoff and soil mobilized by irrigation practices. Essentially, any flowing water can mobilize surface soils and, depending on the slope of the ground and the amount of flow, the soil can be transported to surface waters. Flood, sprinkler, and furrow irrigation are irrigation practices that have the highest potential to mobilize sediment whereas pressurized irrigation (drip and microspray) have the lowest potential to mobilize sediment.

Rain runoff can mobilize soil in agricultural fields and result in the discharge of soil to surface waters. The greater the slope and soil erodibility, the more likely a field will have sediment runoff during rain events. Slope and erodibility as well as rainfall intensity must be considered together and a field with

furrow irrigation or with a high slope does not necessarily mean that there is an erosion issue. In addition, there are management practices available to prevent sediment runoff (e.g. vegetative cover at the ends of fields) and/or capture runoff before it enters a downstream waterbody (sediment detention basin).

Given steep slopes and sufficient rainfall, even bedrock will eventually erode resulting in sediment deposition in surface streams. In fact, some erosion is normal and even in relatively pristine watersheds, surface waters normally carry some sediment as they move downstream. If a sediment source is eliminated, the natural energy of the stream will begin to excise the channel as the water removes sediment from the banks. Streams are often subject to anthropogenically generated sediment loads which result in impairment of their designated beneficial uses. Therefore, in order to identify the locations that could be at risk for the discharge of sediment, the SJCDWQC reviewed available methodologies for evaluating the likelihood of erosion from agricultural parcels in either storm or irrigation events and selected a model to calculate the amount of sediment that could be generated from member parcels. At this time, that method is used to identify member parcels at risk for erosion and by August 1, 2015, the SDJCDWQC will submit an addendum with the addition of the FEP responses into the evaluation of erosion risk.

Current Methodology for Determining Erosion Potential

The process for determining erosion potential must involve identifying the factors that control the risk of erosion, use parameters for which data are available for the SJCDWQC region, can be adjusted easily as more/better information becomes available, and is a method that has been vetted in the published literature. A number of models have been developed to predict soil erosion at various scales from individual fields to entire drainage basins. These models can be separated into two groups; empirically based models and physically based models. Both types of models can be useful under the appropriate conditions.

Empirical models tend to require less data and are easier to apply, particularly over large areas. However, empirical models suffer from a lack of specificity and do not incorporate mechanism. Despite this, the results of empirical models can be reasonably accurate and reflect the underlying processes generating the erosion and sediment load without modeling the actual physical processes causing erosion and discharge.

Physically based models attempt to capture the physics of the system and if specified properly, can be used to provide significant insight into the behavior of the system of interest. They can also be more amenable to manipulation for conducting “what if” scenarios to investigate the effects of management practices on the variable of interest, e.g. erosion. However, these models may be so complex that it is difficult to determine how to translate management practices into specific changes in the model parameter values or physical processes (equations) simulated in the model. Generally, the downside of physically based models is that they require that the physics of the system be specified properly and there generally needs to be a large amount data available to both parameterize and validate the model.

The SJCDWQC evaluated representative empirical and physical based models (Table 1) to select an approach to analyzing erosion potential.

Table 1. Evaluation of empirical and physical models to be used for the SJCDWQC evaluation of risk of sediment erosion.

Model Criteria	Universal Soil Loss Equations (USLE, MUSLE & RUSLE2)	Watershed Analysis Risk Management Framework (WARMF)	Watershed Erosion Prediction Project (WEPP)	Soil and Water Assessment Tool (SWAT)
1. Includes factors that control the risk of erosion	✓	✓	✓	✓
Vegetative Cover	✓ (MUSLE)	✓	✓	✓
Slope	✓	✓	✓	✓
Soil Erodability	✓	✓	✓	✓
Management Practices	✓	Yes	✓	✓
2. Uses parameters for which data are available for the SJCDWQC region	Yes	Yes	No	No
3. Model can be adjusted easily as additional information becomes available	Yes	No	No	No
4. Method has been vetted in literature	Widely used	Has been calibrated to portions of the Central Valley	Yes	Yes
Overall Pros and Cons	Requires relatively small amount of data; unable to model multiple scenarios	Requires a large amount of data; more complex than necessary for the current use	Models the processes; requires a large amount of data	Models the processes; requires a large amount of data

Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) is one of the most widely used empirical models for estimating soil loss from agricultural basins. It was developed from field studies in Midwest and was originally parameterized for small watersheds in central Iowa. Since its development, it has been applied in agricultural watersheds throughout the world.

The model is a single equation using six variables to estimate the annual soil loss under specific rainfall conditions:

$$A = R \times K \times L \times S \times C \times P$$

where A = annual soil loss, R = rainfall erosivity (rainfall intensity), K = soil erodability (in mg MJ^{-1} mm^{-1}) when the field is bare, L = slope length, S = field slope, C = crop management factor, and P = conservation practice. The parameter C can be further decomposed into:

$$C = (\sum_1^j (f_j \times c_j))/m$$

Where *j* is the index for crop stage periods, N = the number of crop stages over the analysis period, and m is the number of years in the analysis period. The cover management factor *c* is assumed to be constant across any single crop stage but can vary across crop stages. Also, the equation treats all rainfall as if there is a single rain event. Accounting for storm to storm variation in rainfall is not possible with the USLE.

The equation was developed for application on a relatively small scale, e.g. individual fields or small regions, but with the advent of sophisticated Geographic Information System software, it has been applied across large landscapes. The problem with the application of the USLE across a wide area is the need to properly define and provide numeric values for the C and P terms in the equation. As originally developed, the C and P terms required substantial information about crop management and conservation practices applied to specific fields. As the application of the USLE was scaled up to the landscape scale, information on C and P became more difficult to acquire and aggregate for all fields. Consequently, the values of the C and P variables used in the model became more difficult to determine. To avoid this problem, C and P were categorized and numeric values were developed for standard management and conservation practices which provided some consistency across applications but do not completely solve the problem. Unless information is known about C and P at a fine scale, the problem of properly parameterizing the model at the scale of the landscape remains.

Modified Universal Soil Loss Equation

The Modified Universal Soil Loss Equation (MUSLE) was developed to add additional specificity to the rainfall event driving erosion. MUSLE has been used throughout the world (e.g. Sadeghi and Mizuyama 2010). The equation was increased to seven variables by expanding rainfall erosivity to include terms for both the amount of rain and the peak flow rate which provides an estimate of rainfall intensity. The MUSLE equation is:

$$S = 11.8(Q \times q_p)^{0.56} \times K \times L \times S \times C \times P$$

where S = sediment yield in tons, Q = runoff volume in m^3, q_p is peak flow rate in m^3s^{-1} and K, L, S, C, and P are the same factors as from the USLE. The term involving runoff volume and peak flow rate are parameters used to calculate rainfall erosivity (R in the USLE).

Revised Universal Soil Loss Equation

The Revised Universal Soil Loss Equation (RUSLE) is the most recent advance in the USLE family of equations and has been used extensively (e.g. Evans and Seamon 1997). RUSLE was developed in an attempt to bring greater flexibility to the model by incorporating quantification of both rill and interrill erosion. There are two versions of the model; RUSLE1 and RUSLE2. The equations are the same as for the USLE except estimates are made on a daily basis and summed to estimate annual sediment yield. According to the RUSLE2 manual, the RUSLE2 can be used to estimate soil loss across large areas by selecting sample points over an inventory area and calculating the soil loss for each sample point. The loss at each point is then aggregated to estimate soil loss across the entire area. The user's manual warns that the user should not use spatially averaged values for slope length and steepness, soil characteristics, and cover-management conditions, and then attempt to calculate soil loss using these spatially averaged values. Using spatial averaging introduces inaccuracies due to the nonlinearities in the RUSLE2 equations.

The RUSLE1 and RUSLE2 equations are similar to those of the USLE with the decomposition of the K term in RUSLE1 becoming:

$$K = \left(\sum_{1}^{k} (f_k \times k_k)\right) / m$$

Where K is erodability, f and m are as above and k is the number of crop stages. RUSLE2 incorporates sediment detachment/deposition dynamics which includes fall velocity of sediment in still water, overland flow rate per unit width of flow, transport capacity and sediment load. RUSLE2 computes the runoff rate using a 10 year storm erosivity term, the NRCS curve number method and a runoff index computed using cover-management variables (USDA-ARS 2003). The improvement of RUSLE2 over

RUSLE1 and the USLE is in the handling of several classes of soil particles and the method used to solve the equations providing a more accurate estimate of soil loss.

Watershed Analysis Risk Management Framework and Similar Models

The Watershed Analysis and Risk Management Framework (WARMF) uses equations originally developed in the ANSWERS model. The model simulates almost every physical process that can affect watersheds including rainfall, snowfall, runoff, nutrient dynamics, dry atmospheric deposition, and many more. The model simulates detachment and transport of clay, silt, and sand separately. Detachment is due to kinetic energy of rainfall and turbulence of overland flow. Rainfall detachment utilizes soil erosivity, rainfall intensity, a rainfall detachment factor, and a cropping factor. Turbulent flow detachment utilizes slope, erosivity, flow per unit area, detachment factor, and cropping factor. Both rainfall detachment and turbulent flow detachment scale to the area of the catchment to estimate total erosion from the watershed on a daily, monthly, or yearly basis. The model also incorporates several equations for deposition of sand that depends on shear stress, shear velocity, Reynolds number, and critical shear stress. Once mobilized, clay and silt are assumed to remain in suspension until they are delivered to a stream. The model takes a significantly large amount of data to calibrate and validate although default values are available for many parameters.

Additional physically based models include the Watershed Erosion Prediction Project model (WEPP, http://www.ars.usda.gov/Research/docs.htm?docid=10621) and the Soil and Water Assessment Tool (SWAT, http://swat.tamu.edu/software/swat-model/). WEPP uses physically based equations to estimate the sediment generation and transport processes (infiltration, surface runoff, plant growth, residue decomposition, hydraulics, tillage, management, and erosion mechanics) at the hill slope and in-stream scales of measurement. SWAT, developed jointly by USDA-ARS and Texas A&M AgriLife Research and Extension, is a river basin or watershed model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. SWAT requires specific information about weather, soils, topography, vegetation, and land management practices occurring in a watershed. SWAT directly models water movement, sediment movement, nutrient cycling, chemical transformation and transport, bacterial transport, and the effect of several land management practices on these processes. Many of the equations used in WARMF are the same equations used in SWAT and many other physically based models as the physical processes describing various processes such as evapotranspiration were developed long ago and are simply inserted into the models. As with WARMF, the data demands of SWAT are considerable and the list of variables used in the model stretches for several pages in the theoretical documentation manual (Neitsch et al. 2009).

SJCDWQC Methodology

The objective of the current assessment is to estimate erosion potential across the SJCDWQC region such that growers with any parcels that could cause discharge to surface waters are identified and the Coalition can work with those growers to guarantee that adequate management practices are in place

to prevent discharge. Estimating erosion potential is a two-step process; 1) assessing erosion and discharge risk across the landscape, and 2) determine if members have the potential to discharge as self-identified in the FEP. Once areas within the Coalition region that have the potential to generate sediment are identified (step 1), FEPs are reviewed to determine which growers have self-identified as having the potential to discharge sediment (step 2). These members will be requested to complete a SECP. The first step is outlined below including the model used to generate potential erosion and the development of the threshold that distinguishes low risk from high risk areas for potential sediment discharge.

Erosion Risk

To estimate erosion potential, it is not necessary to estimate actual soil loss under any particular set of climatic/weather conditions. The critical factors for determining whether or not a there is a risk of erosion and discharge from a parcel is to identify the natural conditions/features that contribute to erosion and the potential for the sediment to move to surface waters. Consequently, the process for determining erosion potential needs to identify the factors that control the risk of erosion, use parameters for which data are available for the SJCDWQC region, can be adjusted easily as more/better information becomes available, and is a method that has been vetted in the published literature. Based on the assessment criteria and overall pros and cons summarized in Table 1, the SJCDWQC utilized equations from the Universal Loss Equation (USLE).

The factors that influence erosion are rainfall amount and intensity measured as rainfall erosivity, soil characteristics such texture, structure, and cohesion, vegetation cover, and slope. As indicated above, vegetation cover can change and while it mitigates erosion potential, an evaluation of erosion potential should not consider vegetation. The vegetation is considered to be a constant across the SJCDWQC region.

The SJCDWQC is using an empirical modeling approach, specifically the USLE family of equations, to evaluate erosion potential. These equations capture the two variables most critical to the analysis; soil erodability and slope. For example, when using the MUSLE:

$$A = 11.8\left(Q \times q_p\right)^{0.56} \times K \times L \times S \times C \times P$$

where A is the annual soil loss, the values of C and P can all be treated as constants and removed from the model. As indicated above, the Q and q_p terms are used to calculate R, rainfall erosivity.

The erosion potential becomes an equation based on R (rainfall erosivity), K (erodability), L (slope length), and S (slope). Data for these parameters are obtainable from GIS coverages available for the SJCDWQC region and are also readily obtainable from soils data available on Google Earth.

Soils

Soils data for the SJCDWQC region are complete for the Coalition region. Slope data were obtained using the representative slope gradient (slope_r, Component table, NRCS Soil Survey data) which reports the difference in elevation between two points and is expressed as a percentage of the distance between those points.

Slope and Slope Length (LS)

The San Francisco Bay Regional Water Quality Control Board recently mapped erosion potential of the state and classified land over 4% slope as being susceptible to erosion. No individual risk was associated with any slope and slope, S, was combined with slope length, L, as a joint factor.

There are two locations within the Coalition region with elevated values of the LS parameter; the high Sierra Nevada Mountains and the Mt. Diablo region on the west side of the Coalition region (Figure 1). The majority of the Coalition agricultural region is located in very low LS values. However, recent development of the Sierra Nevada foothills for commodities like almonds has resulted in some agricultural areas with relatively elevated LS values as a result of development on relatively steep slopes.

The LS factor is the combination of slope and hill slope length and provides the effect of topography on erosion. The analysis used the State Board's data for the combined LS term which are accessible at ftp://swrcb2a.waterboards.ca.gov/pub/swrcb/dwq/cgp/Risk/.

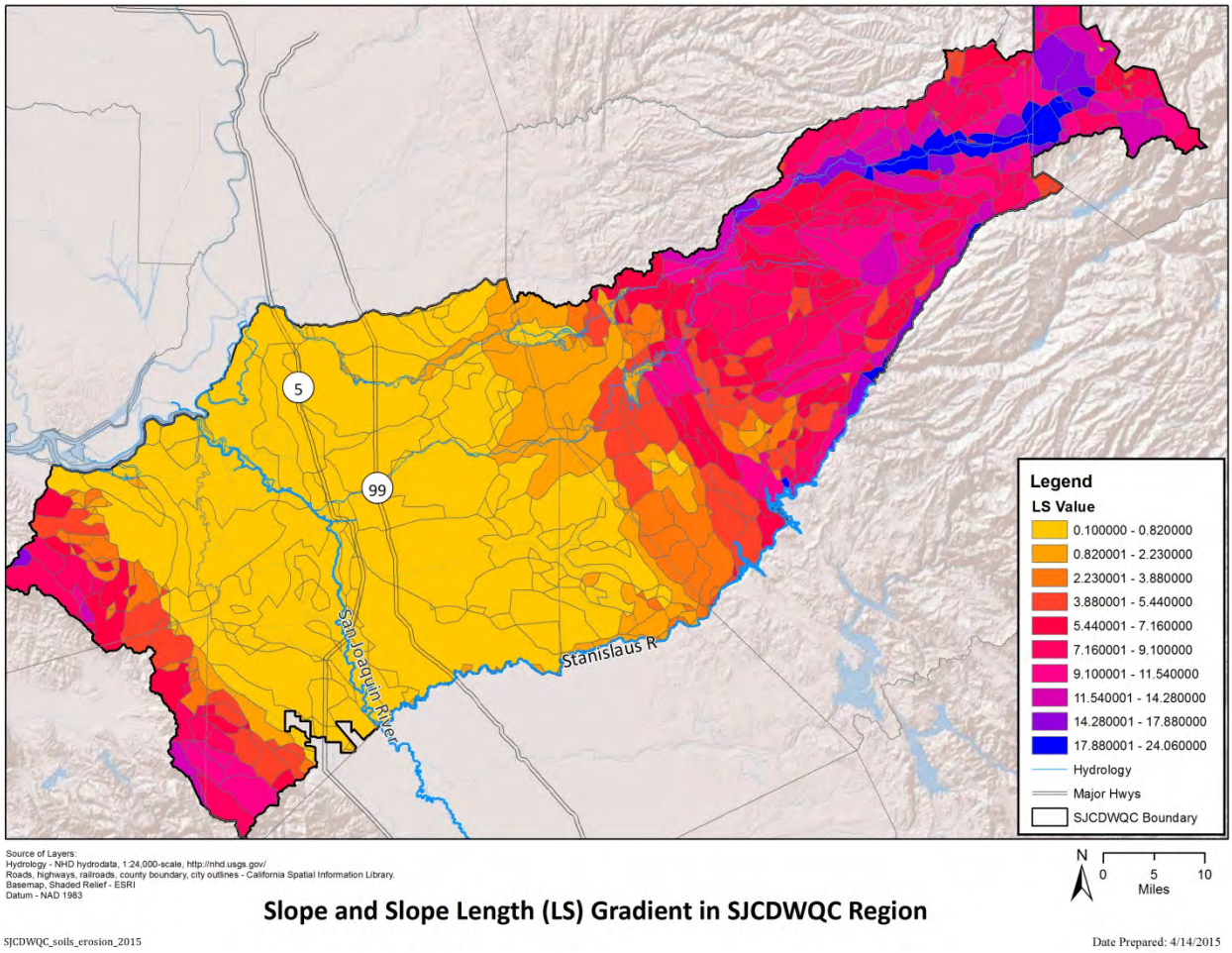
Soil Erodibility (K)

Soil erodibility factor was obtained from GIS coverages of K_w which quantifies the susceptibility of soil particles to detachment and movement by water and is adjusted for the effect of rock fragments. Erodibility ranges from 0.02 to 0.65 (Table 2). All moderate textured loams and high silt content soils were considered to be potentially susceptible to erosion and therefore, any areas with K ≥ 0.20 were considered to be at elevated risk for erosion, however, erosion risk was not evaluated based on K values alone. The GIS coverage of K factor was obtained from the Soil data from NRCS (Gridded Soil Survey data for California, 2013) (Figure 2).

Table 2 Soil characteristics associated with K (soil erodability) values

Fine textured, high clay	low	0.05 – 0.15
Coarse textured, sandy	low	0.05 – 0.20
Medium textured, loams	moderate	0.20 – 0.45
High silt content	high	0.45 – 0.65

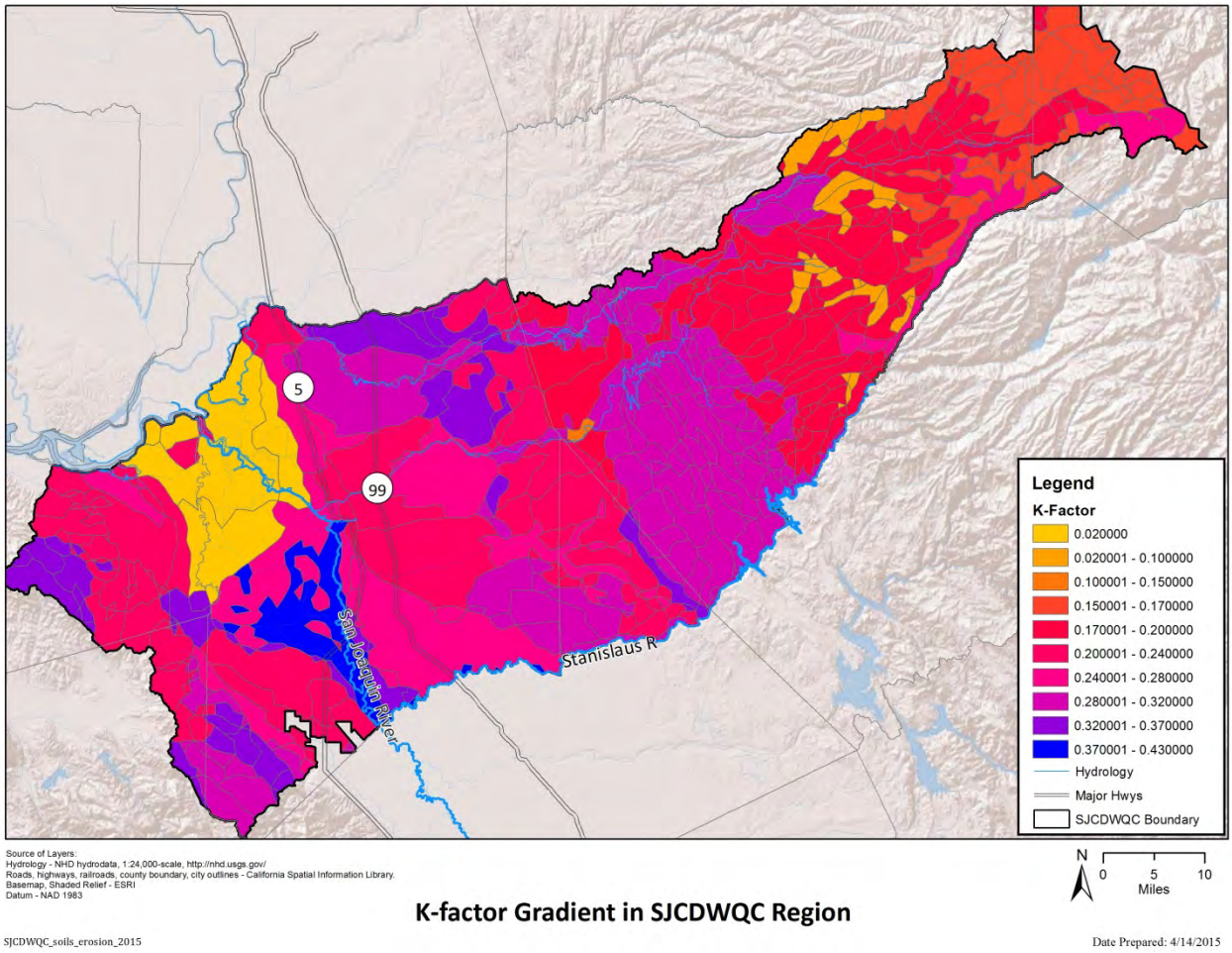
Figure 1 Map of slope and slope length in the SJCDWQC region



Rainfall Erosivity (R)

R is rainfall erosivity which is a measure of rainfall intensity and the potential for a rainstorm to mobilize sediment from the land surface. A GIS map of erosivity in the form of isoerodants (equal erosivity) is one alternative method to estimate rainfall erosivity. The isoerodants are provided by the State Board and can be found at http://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/constpermits/guidance/rusle_r_isoerodent.pdf. Rainfall erosivity values for this project were developed from the isoerodant coverages developed by the State Board. Use of the isoerodant values provides a fine scaled evaluation of erosivity.

Figure 2 K factor in the SJCDWQC region including all four K factor categories

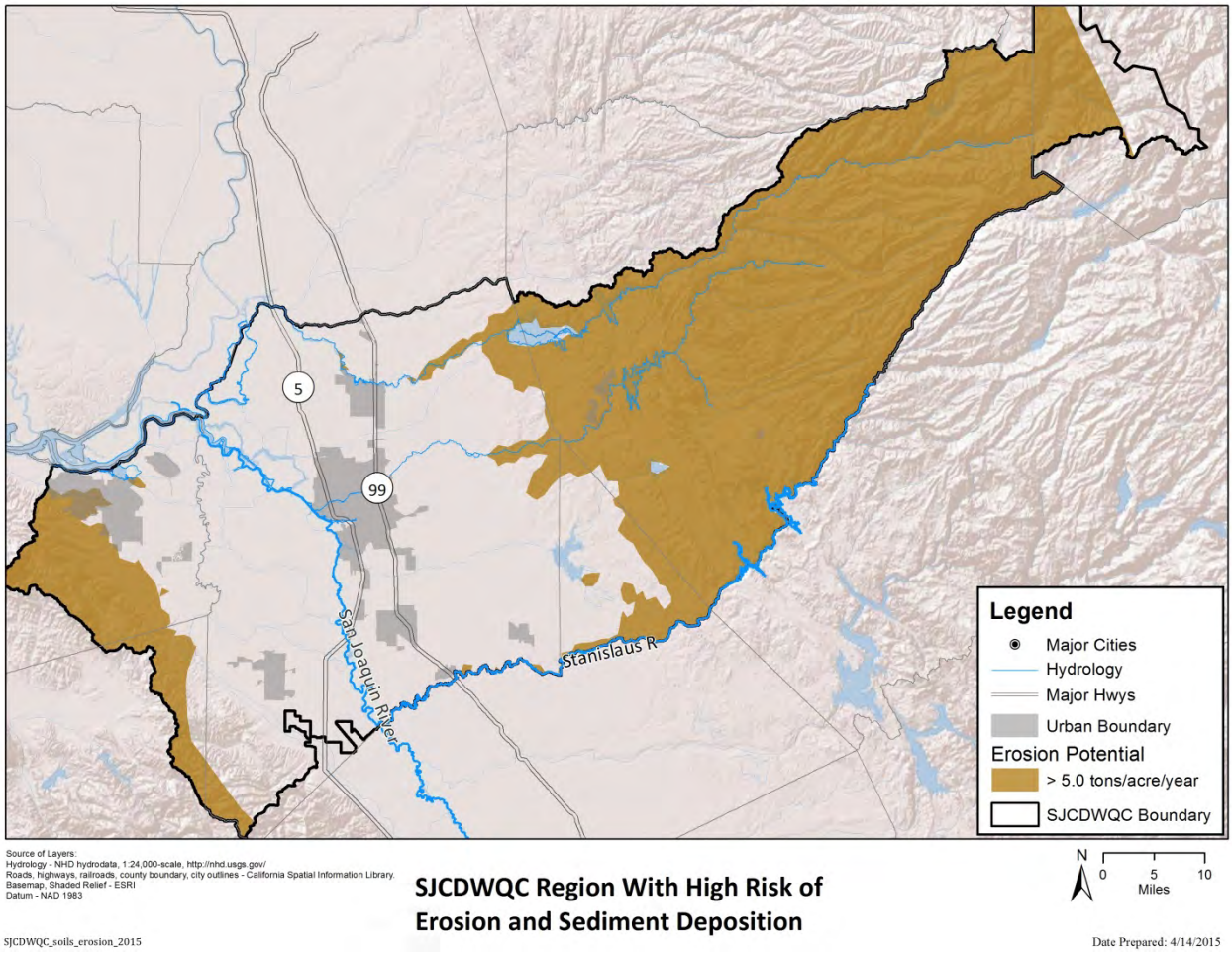


Results and Discussion

Erosion Potential

The four parameters, R, K, L, and S, were multiplied to develop a range of erosion potential values for the entire SJCDWQC region. For the current analysis of erosion risk in the SJCDWQC region, the threshold value must be dichotomous; Low Risk and High Risk. Any area within the SJCDWQC region with an erosion potential of >5 tons/acre/year will be considered high risk (Figure 3). This value was selected because the Natural Resources Conservation Service determined that a soil loss of 5 tons/acre/year is the value above which, farming is not sustainable. In addition, a parcel will be considered high risk if the member self-identifies on their Farm Evaluation Plan as having the potential to discharge sediment to surface waters (see below). The self-identification will be evaluated after the FEPs are returned to the Coalition by June 15, 2015. An addendum to the SDEAR will be provided by August 1, 2015.

Figure 3 Erosion potential in SJCDWQC region. The areas in brown are high risk for erosion and sediment discharge.



Receiving Water Risk

The risk to receiving waters from each parcel will be determined by use of the responses provided by individual growers to questions on the SJCDWQC FEP. During the spring of 2015, members are completing their FEP for all of their parcels. Question 3 in Part A – Whole Farm Evaluation, asks "Does your farm have the potential to discharge sediment to off-farm surface waters?" If the response to the question is no, and the parcel is not located in an area already identified as having the potential to discharge 5 tons/acre/year, the parcel will be considered to pose a low risk for discharge of sediment. If the response to that question is yes, the grower will be required to complete a Sediment and Erosion Control Plan. All other land within the Coalition region will be considered low risk for erosion potential.

Member parcels in the SJCDWQC region are provided in Figure 4. The combination of member parcels located on areas with the potential to discharge sediment at >5 tons/acre/year is provided in Figure 5. The combination includes 21,692 member acres that are found on land with a potential to discharge sediment at >5 tons/acre/year.

Figure 4 SJCDWQC member parcels

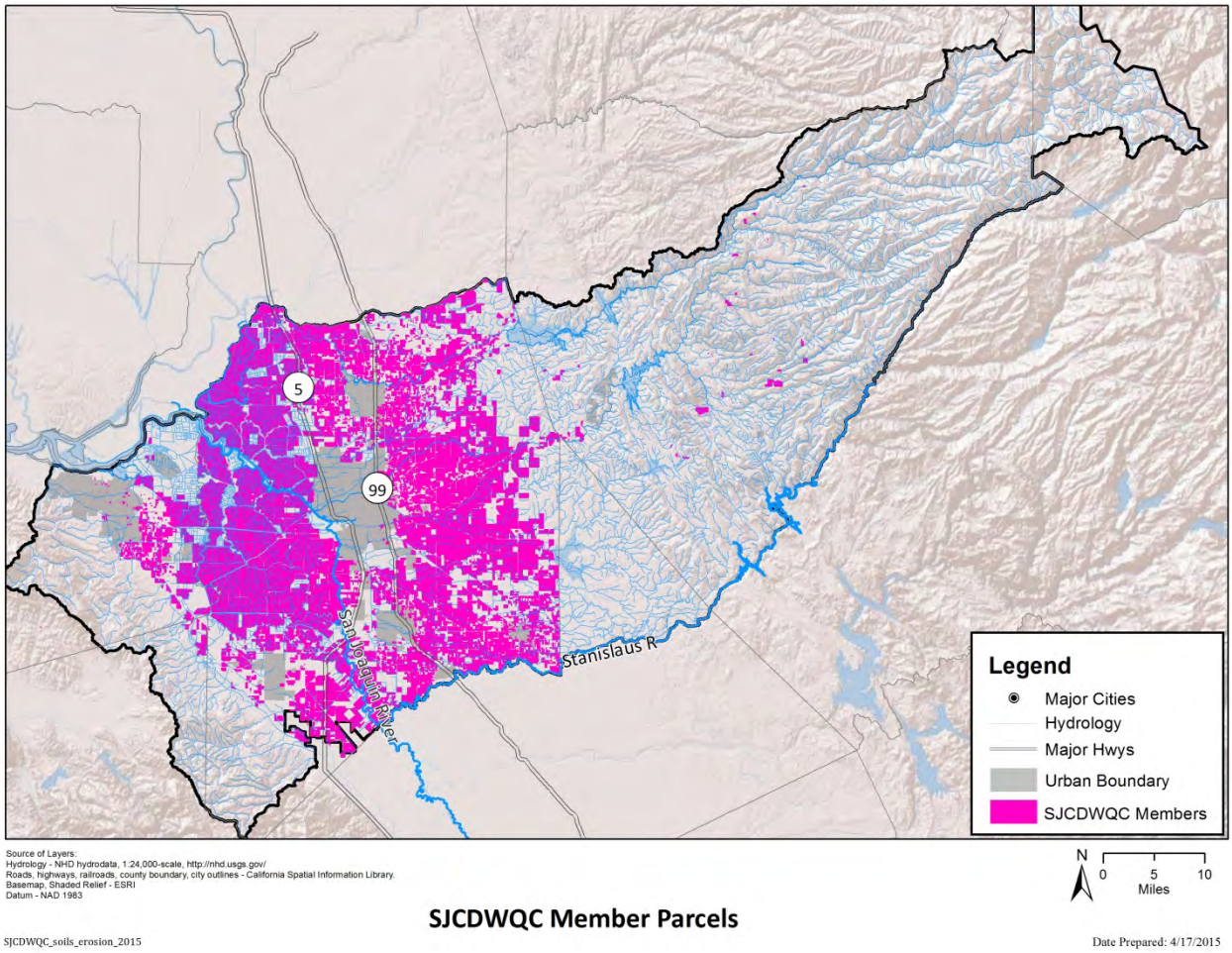
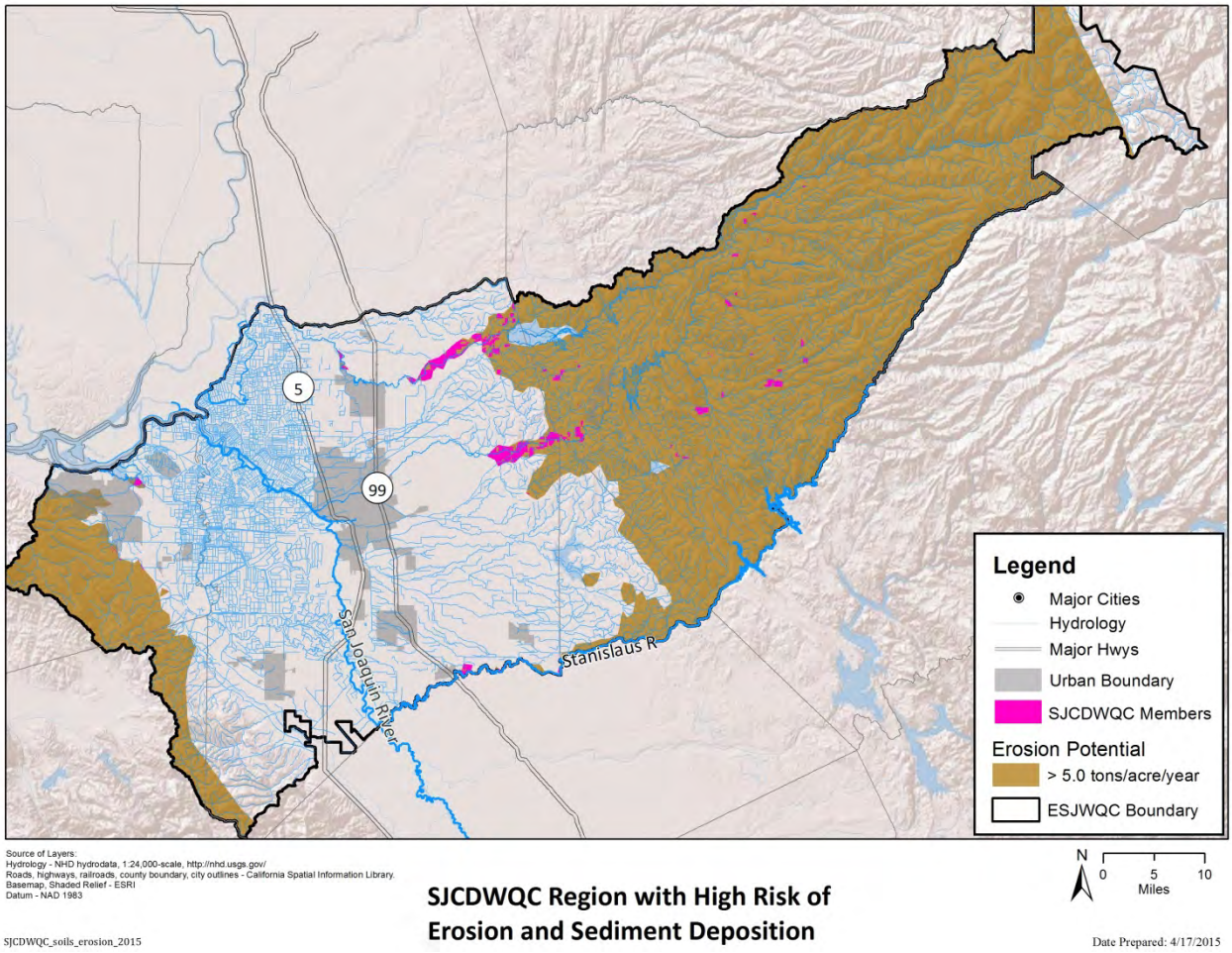


Figure 5 SJCDWQC member parcels on land with the potential to discharge >5 tons/acre/year of sediment



Summary

The measure of erosion potential in this report is based on a basin-wide calculation using the USLE family of equations. These equations have been used for decades to estimate annual erosion from irrigated agricultural land. For a majority of published studies, the purpose is to estimate annual erosion for a specific and relatively small location for which it is possible to determine values for all of the parameters in the model. An alternative is to utilize physically based models to estimate erosion potential; however these models require a substantially large amount of data to run.

The SJCDWQC simplified the USLE equations to four terms, rainfall erosivity, soil erodibility, slope length, and slope, to estimate erosion potential across the SJCDWQC region. Erosion potential was quantified as the product of the four terms. The critical value used to determine the areas within the SJCDWQC region that have the potential for erosion and those that do not have a potential for erosion is 5 tons/acre/year. An area with an erosion potential of >5 tons/acre/year is considered to be a high risk area.

Based on this analysis, the majority of the SJCDWQC region has low erosion potential. Areas of high erosion potential exist in the eastern side of the Valley where agriculture extends into the foothills of the Sierra Nevada Mountains. There are some erodible soils that extend west from the foothills along the major rivers but the high erosion potential lands are located to the east of Highway 99. There are also lands with high erosion potential land in the western portion of the SJCDWQC region where the land grades down from the slopes of Mt. Diablo to the east to the Delta.

Next Steps

The Coalition will submit an addendum by August 1, 2015 that incorporates the results of the FEP responses into the analysis, and will also incorporate any additional comments provided by the Regional Board. With the approval of the Sediment and Erosion Assessment Report, the SJCDWQC will contact members located in the areas identified as having a high potential for erosion and request that those members complete the Sediment and Erosion Control Plan (SECP). The SECP will be maintained at the headquarters of the farming operation.

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