

# Watershed Analysis<sup>1</sup>

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## Abstract

Watershed analyses and assessments for the Kings River Sustainable Forest Ecosystems Project were done on about 33,000 acres of the 45,500-acre Big Creek watershed and 32,000 acres of the 85,100-acre Dinkey Creek watershed. Following procedures developed for analysis of cumulative watershed effects (CWE) in the Pacific Northwest Region of the USDA Forest Service, the present project is comparing the Equivalent Roaded Area (ERA) method used widely in the Pacific Southwest Region of the Forest Service, a method that has several inherent weaknesses. Selected stream reaches have been described in terms of Rosgen channel types, Phankuch stream stability, and V-star ratings. Preliminary results from the ERA method indicate that 4 of 15 subwatersheds in the Big Creek watershed and 7 of 33 subwatersheds in the Dinkey Creek watershed are at or above the threshold of concern. Results from the ERA method indicate that several subwatersheds, but no stream reaches, are of concern. By contrast, results from more specific stream surveys, an inventory of fish habitat conditions, and data on sediment delivery attributable to roads indicate concern for several stream reaches as well.

The Kings River Sustainable Forest Ecosystems Project area is located in Fresno County, approximately 32 air miles northeast of Clovis, California (*fig. 1*). About 33,000 acres of the 45,500-acre Big Creek watershed and 32,000 acres of the 85,100-acre Dinkey Creek watershed are included within the Project's boundaries. Both watersheds drain into the Kings River above Pine Flat Reservoir. Most of the two watersheds are within the Sierra National Forest, although 6,896 acres are on private land.

The Big Creek watershed ranges in elevation from about 1,000 to 6,400 ft, and the Dinkey Creek watershed ranges from about 1,250 to 10,000 ft. Each watershed is subdivided into several subwatersheds—15 for Big Creek and 33 for Dinkey Creek—within the Project's boundaries. These subwatersheds range in size from about 190 to 2,760 acres and average about 1,500 acres. Precipitation, mostly during fall, winter, and spring, ranges from 20 to 80 inches, occurring primarily as snow above 6,000 ft. Rain on snow is common. Summers are dry with low humidity. Air temperature averages from 42 to 60°F. Vegetation types are mixed chaparral, ponderosa pine (*Pinus ponderosa*) forest, mixed-conifer forest, and red fir (*Abies magnifica*) forest.

Cumulative watershed effects (CWEs) are impacts to the environment resulting from the incremental accumulation of impacts of actions, past, present, and in the foreseeable future, regardless of what agency (Federal or nonfederal) or person undertakes these actions. CWEs can result from individually minor but collectively significant actions occurring over a period of time.

The current model used to analyze CWEs—the Equivalent Roaded Area (ERA) method (McGurk and Fong 1995, USDA 1988)—has several inherent

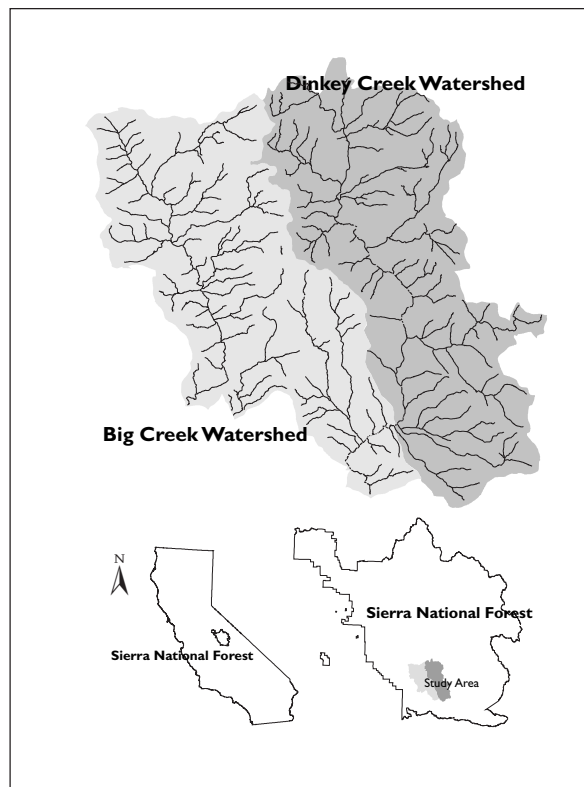
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**Figure 1**—The Kings River administrative study area in the Sierra National Forest in central California includes the 64,000-acre Big Creek and Dinkey Creek watersheds (indicated by shading).



weaknesses, including equal coefficients for disturbances regardless of their distance from stream channels, a lack of sensitivity to sediment yields, and the scale at which the model applies. Current USDA Forest Service direction for ecosystem management requires the development of better methods and models for assessing cumulative watershed effects.

The various processes and interactions occurring within a watershed are integral to any project that endeavors to apply science-based concepts of ecosystem management at a watershed scale. The watershed analysis briefly described here was undertaken to help understand these processes and interactions in the two watersheds in the Project area. Additional objectives are to characterize current watershed conditions and to develop and test an improved method or model to assess cumulative effects of management activities on watersheds.

## Methods

Selected stream reaches can be described in terms of Rosgen channel types (Rosgen 1994), Phankuch stream stability (Phankuch 1975), and V-star ratings. Together, these data sources can be combined to describe stream channels as aquatic ecological units. The Rosgen stream channel classification divides stream reaches into seven major types that differ in entrenchment, gradient, ratio of width to depth, and sinuosity. Each major stream type is further described by dominant channel material along a continuum from bedrock to silt/clay.

Determination of Phankuch stream stability is a procedure to systematize measurements and describe the resistive capacity of mountain stream channels to the detachment of bed and bank materials and to provide information about the capacity of streams to adjust and recover from potential changes in flow, increases in sediment production, or both.

The V-star rating provides a cross-sectional sample of the depth of fine sediment at the bottom of a stream. It is obtained by pushing a slender, steel bar vertically through the sediment to bedrock or bed load at regular intervals perpendicular to the stream's course and recording the depth of sediment at each point. These data then permit estimation of the fraction of a pool's volume that is filled with fine sediment—an index of sediment supply, water quality, and stream habitat (Lisle and Hilton 1992) (*fig. 2*).

The watershed analysis identified several issues, the most important being CWEs. These can be evaluated in part by determining the sources of high sediment loads in Big Creek and the condition of aquatic habitat in both watersheds. Ecological indicators selected to establish baseline conditions and monitor watershed conditions are ground cover, rates of erosion and sediment delivery, and landslide frequency. ERA is the indicator of CWEs for the ERA method. V-star ratings and the number of benthic macro-invertebrates have been selected as indicators of the quality of fish habitat.

All subwatersheds in both watersheds were mapped and delineated in 1991 to ensure consistent analysis of CWEs. Watershed analyses followed procedures developed for use in the Forest Service's Pacific Northwest Region, as described by Furniss and McCammon (1993):

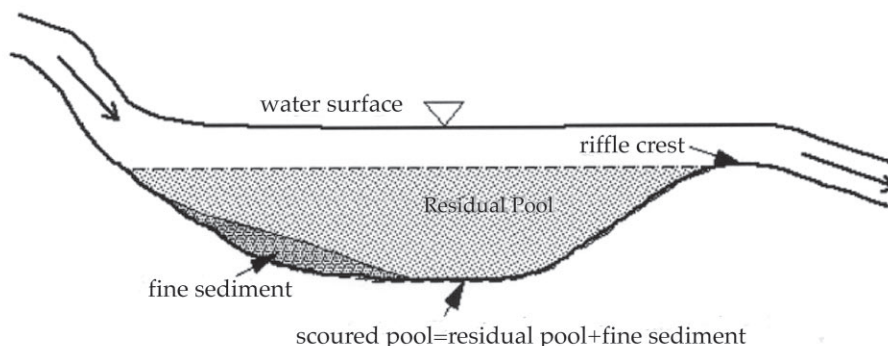
- Identify issues, describe desired conditions, and formulate key questions.
- Identify key process, functions, and conditions
- Stratify the watershed.
- Assemble analytic information needed to address the key questions.
- Describe past and current conditions.
- Describe condition trends and predict effects of future land management.
- Integrate, interpret, and present findings.
- Manage information, monitor, and revise.

CWE analyses were done for Big Creek and Dinkey Creek using the ERA model, a decision-based model that attempts to equate impacts of projects to the impacts of a given acreage of road disturbance. The ERA model has three steps:

1. Determine the threshold of concern (TOC)
2. Determine existing and potential ERAs
3. Determine the potential for CWEs.

### **Step 1—Determine the Threshold of Concern**

The TOC is determined for each subwatershed, based on its natural sensitivity. Subwatersheds have higher TOCs when they have high percentages of sensitive landforms (steep ground, landslide potential), highly erodible soils, and highly



**Figure 2**—Schematic cross section of a pool along its longitudinal profile, showing fine sediment and residual pool.

bifurcated networks of stream channels. The Sierra National Forest uses low, moderate, and high sensitivity levels, ranging from 3.5 to 6.0 ERAs, to reflect TOCs. These values have been corroborated with field data: watersheds with sensitive landforms, highly erodible soils, and a high bifurcation ratio responded to disturbance with compacted soils, high amounts of sediment in stream channels, and less than optimum fish habitat.

### **Step 2—Determine Existing and Potential ERAs**

The management history of affected subwatersheds is determined, and each ground disturbance is rated and assigned an ERA coefficient according to the nature and age of the disturbance. Hydrologic recover is considered when determining the ERA for any given disturbance, assuming that a disturbance could recover to an ERA value of nearly zero if enough time has passed. Values for various existing disturbance areas are then summed to estimate the total existing percent ERA value for the subwatershed. Values for proposed activities are then assigned an ERA coefficient using those established for the Sierra National Forest, and these are summed with the existing ERA values to estimate a total ERA value for the subwatershed if the activities were to occur.

### **Step 3—Determine Potential for CWEs**

If the total ERA for a given subwatershed exceeds the TOC, it is determined to have a higher risk for CWEs. In addition, qualitative field data may be collected to determine whether CWEs are occurring. These field data could include stream condition inventories, soil quality, and condition of fish habitat. In some cases, activities have been postponed to allow natural recover, or watershed restoration has been undertaken to speed recover. In other cases, the proposed activity was implemented after site investigations found healthy soils and streams.

## **A Model for Watershed Condition**

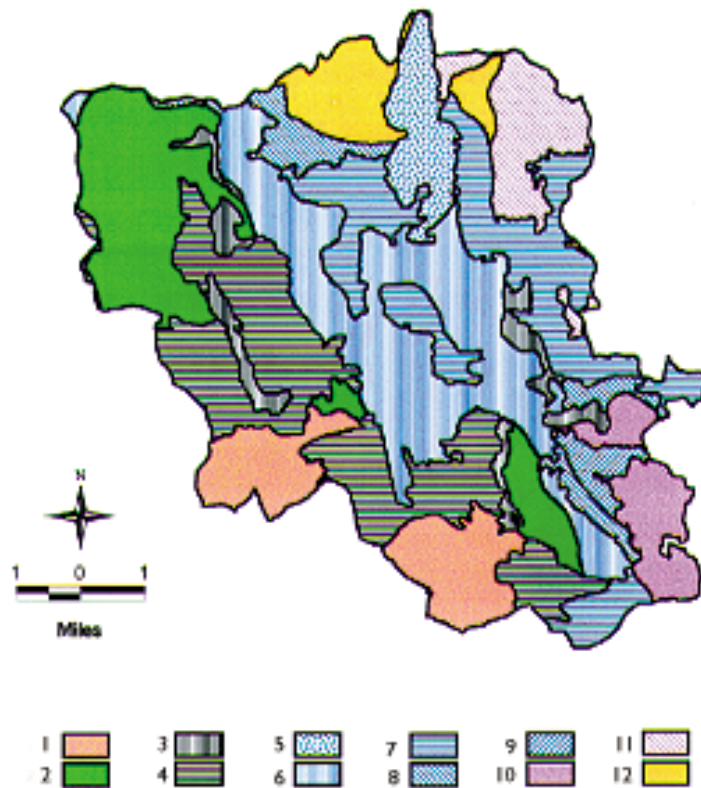
The model for assessing watershed condition is a process-based model that can be applied at several scales and considers natural disturbances to determine whether a watershed is degraded. The model evaluates conditions and interrelations of upland watershed areas and riparian areas. It can be used for any of the aforementioned ecological indicators (for example, ground cover and sediment delivery rates). The model has five steps that can be done concurrently or consecutively. I use rates of erosion and sediment delivery as examples to describe the model.

### **Step 1—Stratify the Watershed**

Watersheds in the Kings River Project area were stratified using data from the Forest Service's existing Ecological Unit Inventory (EUI), which can be used to classify and delineate areas of similar ecological form and function (*fig. 3*). Components of an ecological unit include bedrock or unconsolidated deposits, geomorphic processes and landform, soil type, and potential natural vegetation.

### **Step 2—Describe the Reference (“Normal”) Variability for Rates of Erosion and Sediment Delivery**

Earlier studies estimated mean rates of sediment delivery at 110 tons/mi<sup>2</sup>/year for the North Fork of the Kings River (Breazeale 1972) and 43 tons/mi<sup>2</sup>/year for small basins in the Teakettle Experimental Watershed (Dunne and Reid 1985). These estimates are mean, long-term rates for watersheds with heterogeneous geology, geomorphology, soils, and vegetation. The studies did not consider natural disturbance regimes or the range of variation among areas as they recovered from disturbances.



**Figure 3**—Ecological landscape units stratifying the Kings River Project area by geology, soils, geomorphology, and potential vegetation: 1 = Granodiorite; deep to moderately deep thermic (Auberry-Ahwahnee, Tollhouse complex); mass wasting, fluvial; chaparral. 2 = Granodiorite; deep mesic (Holland-Shaver complex); fluvial, mass wasting; ponderosa pine. 3 = Granodiorite; shallow, mesic (Chawanakee-Tollhouse complex); mass wasting, fluvial erosion; ponderosa pine. 4 = Granodiorite; deep mesic (Holland family); fluvial erosion, mass wasting; ponderosa pine. 5 = Glacial deposits, Granodiorite; deep, frigid (Sirretta family); mass wasting, fluvial, relic glacial depositional; mixed conifer. 6 = Granodiorite; deep, mesic (Shaver-Holland complex); fluvial, mass wasting; mixed conifer. 7 = Granodiorite; moderately deep to deep, frigid (Ledford-Gerle-Cannel-Cagwin complex); fluvial; mixed conifer. 8 = Granodiorite; moderately deep, frigid (Cagwin family); mass wasting, fluvial; mixed conifer. 9 = Metamorphic; deep, frigid (Ledford-Gerle complex); fluvial; mixed conifer. 10 = Metasedimentary; moderately deep to deep, frigid (Cagwin-Cannel complex); fluvial; red fir. 11 = Mixed lithology; moderately deep to deep, frigid (Cagwin-Sirretta complex); fluvial, relic glacial; red fir. 12 = Granodiorite; moderately deep to shallow, frigid (Cagwin-Rock Outcrop complex); fluvial, mass wasting; Jeffrey pine.

The reference variability for rates of erosion and sediment delivery, in tons/mi<sup>2</sup>/year for each major ecological map unit of the two watersheds, will be determined by modeling fire and high precipitation events as the major disturbances. For example, rates of erosion and sediment delivery are at their highest in the first year after a fire, decreasing over time as vegetation recovers. Eventually these rates would be expected to fluctuate mainly in response to variation in precipitation events, then characterizing the “reference variability.”

### Step 3—Describe Existing Rates of Erosion and Sediment Delivery

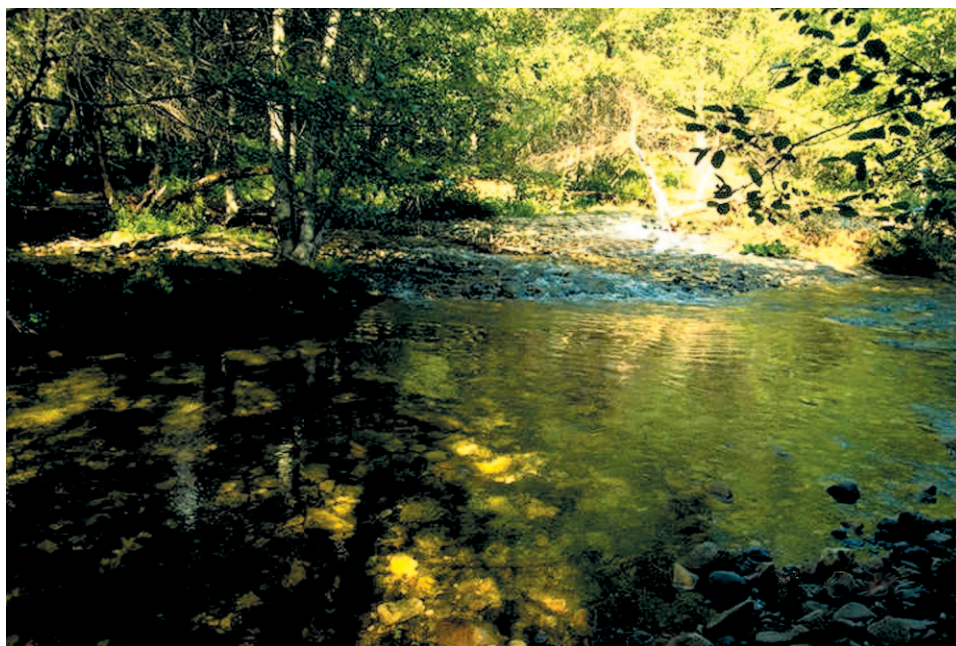
Most erosion and sediment delivery in the Sierra Nevada are assumed to be a result of roads and stream channels. Landslides are not believed to be a major source of sediment. Data have been collected from 50 mi of roads in the Project area to use in the Watershed Erosion Prediction Project (WEPP) model (Elliot and Hall 1997). This is a process-based model with several output options including runoff, soil erosion, and sediment delivery. These data will quantify rates of erosion and sediment delivery for different types of roads (native surface, aggregate surfaced, asphalt surfaced) in different ecological units (major strata).

### Step 4—Describe the Conditions of the Aquatic System

Existing data allow description of selected stream reaches in terms of Rosgen stream channel types, Phankuch stream stability, and V-star ratings. Initial



**Figure 4**—Section of Big Creek showing desired condition of a cobble/gravel-controlled, pool-riffle reach. Notice lack of fine sediment.



analysis of 33 V-star reaches showed that 30 percent had high sediment loads (*fig. 4*). It is not clear, however, whether this has resulted from management disturbances, from natural events, or both. Quantifying sediment sources and estimating rates of sediment transport should help to answer this question.

### ***Step 5—Synthesize Available Data***

Synthesis of available data should establish whether rates of erosion and sediment delivery are within the reference variability. If not, then channel reaches that have high sediment loads and degraded conditions will be assessed to determine which subwatersheds are the sources of sediment. These sources could include native-surfaced roads, other disturbances (for example, gullies) on highly sensitive soils, and extensively in-sloped roads adjacent to channel and road crossings.

### ***Final Step—Identify Opportunities for Watershed Improvement***

Opportunities for watershed improvement could include surfacing native-surfaced roads with gravel or asphalt, redesigning roads from an in-sloped to an out-sloped road prism, obliterating roads in highly sensitive areas, tilling highly compacted soils, and stabilizing gully systems that have developed from past management.

## **Preliminary Results**

A strategy to collect additional data and address the key questions identified in the watershed analysis has been approved and is being implemented. Results of our efforts to develop the conceptual model have resulted in completion of Step 1 and some progress with the remaining steps. A more detailed, landtype-level (1:24,000) EUI has been completed to stratify the watershed by geology, soils, land-forming processes, and potential natural vegetation. Interpretations have been made to describe sensitive landforms, erodible soils, and potential wildlife habitat. This inventory aided in the delineation of boundaries for riparian management zones in the Big Creek watershed, where those

boundaries are set according to guidelines in the Sierra National Forest's Land Management Plan. Some data have been collected and analyzed to determine the reference variability for erosion and sediment delivery rates. These data are being compared with data from other areas in the Sierra Nevada to establish long-term rates for erosion and sediment delivery. Preliminary work has been done to develop a landscape model using these data. Some of this work includes erosion and fire-spread modeling. The next phase is to integrate results from these models.

More than 50 miles of road data have been collected, including road design (width, insloped with ditch or outsloped, slope gradient), surface type, soil type, rill and gully erosion, and percent vegetation on the road cut and fill. These data are being analyzed to determine mean rates of erosion and sediment delivery for road types that occur in unique ecological units.

Stream-condition surveys, including Rosgen Channel typing, have been completed on several of the main tributaries to Dinkey Creek and the main stem of Big Creek. Macroinvertebrate data have been collected from 16 first- and second-order streams in the two watersheds. A final determination about watershed health, however, will not be made until all data are collected and an improved model is developed to analyze watershed condition.

## Acknowledgments

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