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Cumulative Watershed Effects: Applicability of Available Methodologies to the Sierra Nevada

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Abstract: This project has two primary objectives: (1) to review and evaluate existing CWE analysis methodologies for their applicability to foothill and forested areas of the Sierra Nevada and (2) to identify and recommend one or several promising methodologies for further development or site-specific modification for use in the Sierra Nevada. A four-step approach was taken to address the objectives: (1) review and evaluate the literature on existing CWE methodologies, (2) obtain, review, and compare recent case studies of CWE analyses used (a) on national forests in the Sierra Nevada, and (b) by state and local officials for instream flow requirements and effects of multiple water diversions, (3) identify unique or critical biogeoclimatic and socio-economic elements of the Sierra Nevada pertinent to the applicability and use of specific CWE methods, and (4) interview experts in the development and application of CWE assessment procedures. Watershed Analysis methodology is recommended as being most suitable for adaptation and use in the Sierra Nevada.

The Sierra Nevada Ecosystem Project (SNEP) is an assessment of the economic, social, and ecological conditions of the Sierra Nevada ecoregion. Humans have been modifying the landscape in this region for over 150 years, and disturbances such as logging, fire, mining, water development, residential and road construction, and grazing have all occurred in various patterns and intensities across the region. In order to meet the SNEP mandate in terms of land disturbance, an assessment methodology had to be identified. Since the National Environmental Policy Act (NEPA) of 1969, cumulative effects analysis has been required, and state and federal agencies have developed a wide array of guidelines by which human disturbances in a landscape can be evaluated.

This project was designed to inventory and evaluate commonly used cumulative watershed effects (CWE) analysis methods so that SNEP staff would be aware of their strengths and weaknesses. Methods range in spatial scale from site-specific techniques for 100 mi^2 basins, such as Washington State Watershed Analysis approach (Washington Forest Practices Board 1993), to large-scale methods amenable to entire mountain ranges (Menning et al. 1996). This project focused on smaller-scale techniques because considerably more effort has been devoted to their development. This report was prepared early in the SNEP process, however, so the exact scale at which the CWE analysis was to be performed had not yet been established.

OBJECTIVES AND APPROACH

This project has two primary objectives: (1) to review and evaluate existing CWE analysis methodologies for their applicability to foothill and forested areas of the Sierra Nevada and (2) to identify and recommend one or several promising methodologies for further development or site-specific modification for use in the Sierra Nevada. The intent was not to develop a methodology, but rather to assess the currently available procedures for their applicability to the Sierra Nevada.

A four-step approach was taken to address the objectives. (1) Review and evaluate the literature on existing CWE methodologies. (2) Obtain, review, and compare recent case studies of CWE analyses used (a) on national forests in the Sierra Nevada, and (b) by state and local officials for in-stream flow requirements and effects of multiple water diversions. (3) Identify unique or critical biogeoclimatic and socio-economic elements of the Sierra Nevada pertinent to the applicability and use of specific CWE methods. (4) Interview experts in the development and application of CWE assessment procedures (appendixes 1 and 2). (Results from the interviews are integrated with information from the literature review and case studies as inputs to the final recommendations.)

This paper is the product of the above approach. In it we give a brief history and description of cumulative wateshed effects, describe the distinguishing characteristics of the Sierra Nevada, review current CWE methodologies, compare recent case studies, discuss water rights and adjudication as elements of CWE decisions, and assess the applicability of CWE methodologies to the Sierra Nevada and make recommendations to SNEP.

HISTORY OF CUMULATIVE WATERSHED EFFECTS ANALYSIS

Cumulative watershed effects are not a new phenomena. A classic example in California resulted from hydraulic mining in the foothills of the Sierra Nevada during the 1860s. Effects from this activity are still present more than 100 years after the banning of hydraulic mining. Massive amounts of coarse sediment were mobilized and moved downstream, and as a result, channels were filled in and this contributed to the flooding of lowland communities. In what may be the first comprehensive evaluation of CWE in California, Gilbert (1917, cited in Reid 1993) identified several combined effects leading to increased flooding of Central Valley towns and sand and silt bar development in San Francisco Bay. Flooding was caused by the combined effects of stream channel aggradation and the construction of levees to protect agricultural operations. "If these changes had been independent of those wrought by mining debris they would have resulted in the automatic deepening and widening of the channels" (Gilbert 1917, cited in Reid 1993). However, the combined effect caused channel flow capacities to decrease and downstream flooding to ensue.

Sand and silt bar development in San Francisco Bay, although related to incoming mining debris from the Sierra, was more substantially affected by tidal marsh reclamation. "... [E]very acre of reclaimed tide marsh implies a fractional reduction of the tidal current in the Golden Gate. For any individual acre the fraction is minute, but the acres of tide marsh are many, and if all shall be reclaimed, the effect at the Golden Gate will not be minute" (Gilbert 1917, cited in Reid 1993). Mining debris persists and continues to influence hydro-dynamics of the San Francisco Bay and its delta today.

This example illustrates many of the elements and complexities intrinsic to cumulative effects analysis:

- Spatial scales are larger than traditional project-level considerations; hydraulic mining affected approximately one-half of the foothill region on the western slope of the Sierra Nevada.
- Effects are felt off the site of the land-disturbing manipulation or activity; in this case hundreds of kilometers downstream from the hydraulic mining.
- Specific "beneficial uses" that are adversely affected are identifiable (e.g., a safe [non-flooding] and reliable water supply).
- Time scales can be great. Effects of mining persist today; the Sacramento River channel continues to be shallower than before the mining.
- The *combination* of mining effects and the construction of levees produced an effect that would not have resulted necessarily from each action singly.
- Incrementally small effects (e.g., of marsh reclamation) combine over time and space to produce significant repercussions.

Only recently has formalization of concerns gone beyond the effects of site-specific, single-impact land management. Gooselink and Lee (1989), however, point out that the roots of the issue can be viewed as a communal response to accumulating individual acts of environmental degradation, none particularly large or damaging, but when taken together sum to significant and potentially dramatic impacts. Hardin (1968) described this principle elegantly as the tragedy of the commons: the unrestricted use of a common resource by individuals to maximize individual profits, leads to a loss of the resource for both individuals and the public.

The first known published explicit definition of "cumulative effects" in a land management context stems from the National Environmental Policy Act of 1969. Associated with this Act, the federal Council on Environmental Quality (CEQ) defined cumulative impact as:

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (Council on Environmental Quality 1971).

Additional published characterizations of cumulative effects include:

- "... environmental change resulting from the accumulation and interaction of the effects of one action with the effects of one or more other actions occurring on a common resource" (Stull et al. 1987).
- "The impacts of these multiple land uses on biota, soils, atmosphere, and aquatic systems, added together over a drainage basin and time... " (Sidle and Hornbeck 1991).
- "...two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts" (State of California 1984).
- "The changes to the environment caused by the interaction of natural ecosystem processes with the effects of two or more forest practices" (Washington Forest Practices Board 1993).

Other regulatory actions add dimensions to the cumulative effects issue (Cobourn 1989a). Amendments in 1977 to the federal Clean Water Act "stipulated that water quality standards are determined by the highest 'beneficial uses' of the water in question [and] the Act specifically required 'a process to (i) identify, if appropriate, agriculturally and silviculturally related nonpoint sources of pollution including return flows from irrigated agriculture, *and their cumulative effects* [authors' italics], and (ii) set forth procedures and methods [including land use requirements] to control to the extent feasible such sources'" (U. S. Congress 1977). Beneficial uses of water (e.g., fish habitat, domestic water supply) are routinely specified as the focal point of CWE procedures and many of the procedures, provide a measure of the sensitivity of beneficial uses to management (NCASI 1992).

Although less comprehensive than the CEQ definition, the other definitions and regulatory statements share with the CEQ statement a focus on the combined results of multiple individual effects. Other, less obvious implications of the differences between traditional approaches to project-level impact assessment and cumulative effects assessments include:

- *Ecological complexity* — Because traditional approaches quickly lead to unmanageable complexities when extended to a cumulative effects framework, a challenge is to identify relevant ecosystem components as focal points for the cumulative analysis (e.g., identify the key links between physical and biological processes and potential management actions).
- *Incremental environmental change* — At the large temporal and spatial scales used in some cumulative impact analyses, project-scale activities may not be measurable. Changes at the project scale are real, but they may be undetectable with the analytical techniques needed for cumulative scale analyses. In a statistical sense, project-scale change is within the error term of the estimate. This factor further hampers the use of traditional project-level assessment techniques and procedures.
- *Patterns on the landscape* — Pattern is at least as relevant as total area of impact. 50,000 ha of forest in a single block, for instance, will support different wildlife dynamics than fifty separate 1,000 ha tracts. Relevant aspects of pattern from the cumulative effects perspective are patch size, continuity, and contiguity.
- *Boundaries* — Spatial scales of interest vary with the "beneficial uses." A watershed may be the best scale for hydrological problems like water quality and flood potential, but "wolf-sheds" or "bear-sheds" that cross watersheds may be more relevant for cumulative wildlife considerations. These boundary considerations imply that a variable geographical scale is probably desirable, but regulatory constraints may dictate the use of political boundaries or watersheds.

- *Time scales* — In many cases the time frame of induced impacts (e.g., timber harvest and stand regeneration) approximates one human generation. However, ecosystems processes are typically an order of magnitude longer (figure 1). Major hydrologic modifications by humans are essentially irreversible in human time scales. Cumulative impact regulation and analysis should consider these differences between human and ecosystem time frames, particularly in light of the effective irreversibility of some human impacts.
- *Fragmented jurisdiction* — In moving to larger spatial scales, the chance of multiple agency oversight increases. Project-scale impact assessment is typically within the jurisdiction of a single agency. Coherent regulatory approaches are more difficult to develop in a multi-institutional setting than within single-institution frameworks because of conflicting interests, regulatory criteria, and planning horizons, and because landowners may consider it not in their economic self-interest to divulge their future plans (Gooselink and Lee 1989).

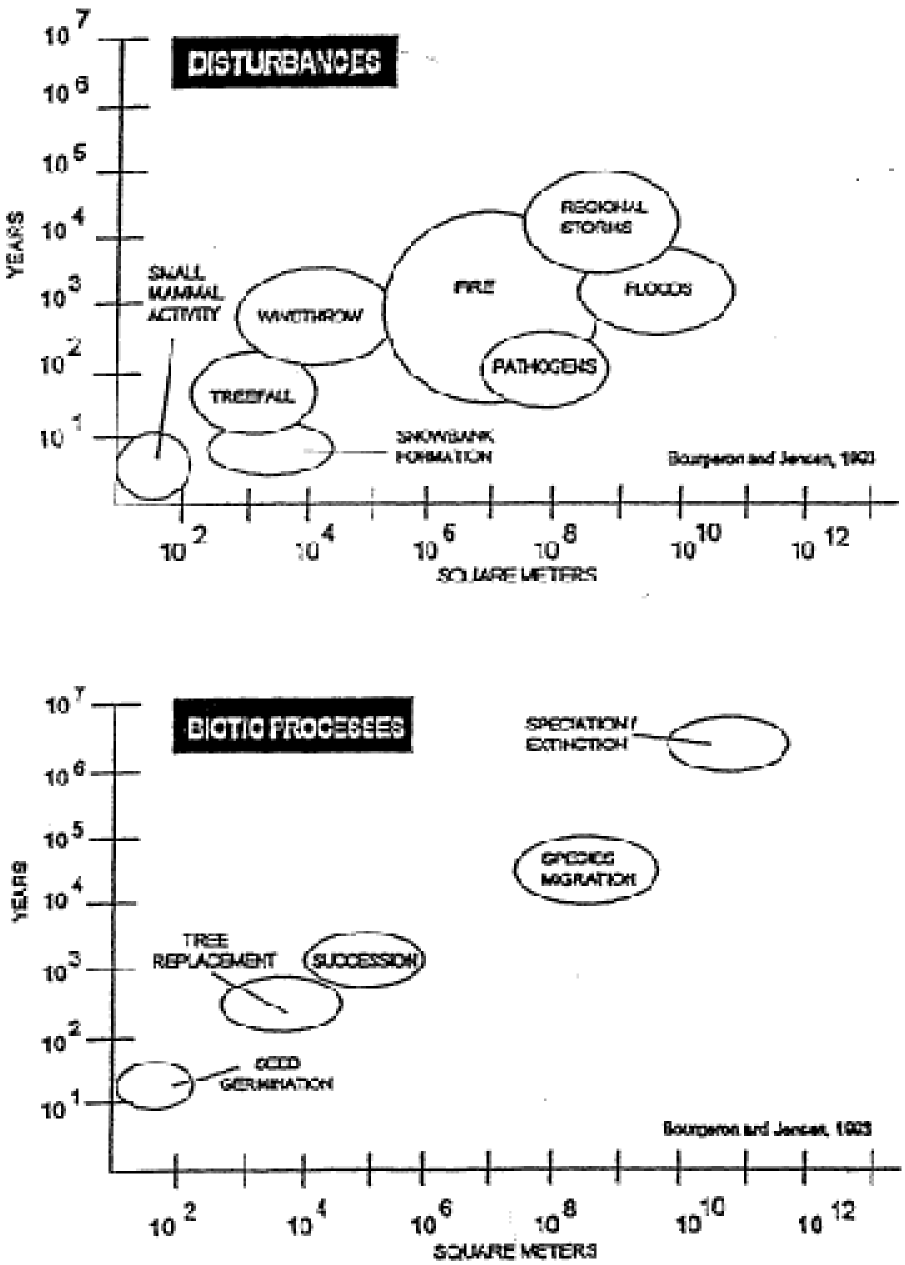

Figure 1. Disturbances and biotic responses occur in many forms and at various spatial and temporal scales (adapted from Bourgeron and Jensen 1993).

The context of cumulative effects issues is typically environmental damage or degradation. Positive cumulative impacts can, however, occur. Specific beneficial use characterizations are often the key to identifying positive impacts. Under arid conditions, increased stream flow— potentially resulting from the combined effects of timber harvest (which reduces evapotranspiration) and weather modification (to increase precipitation)—is a positive cumulative effect.

The potential for positive and negative cumulative effects, the relative difficulty in assessing cumulative effects, and in some situations the lack of agency initiative in analyzing potential cumulative effects has led to litigious determination of some cumulative effects issues. Relevant cases in California include:

1. A 1985 decision (*Environmental Protection Information Center v. Johnson* [1985 S. Ct. Sonoma County, CA 216 502]) requiring CWE to be considered in the approval of any timber harvest plan on state or private forests, and

2. A 1987 decision (*Environmental Protection Information Center v. Maxxam* [1987 S. Ct. Humboldt County, CA 79879) in which "the court agreed with EPIC that the Department of Forestry [California] failed to consider adequately the cumulative effects of stepped-up harvest operations by the Pacific Lumber Company after it was purchased by Maxxam Corporation" (Cobourn 1989a).

3. A 1993 decision (*East Bay Municipal Utility District v. California Department of Forestry and Fire Protection*) declared that the Department of Forestry's cumulative effects guidelines were adequately addressing cumulative effects associated with Timber Harvest Plans. The court did, however, direct the Department to stop using their cumulative effects evaluation guidelines as *de facto* forest practice rules unless they were approved as rules by the California Board of Forestry (Pete Cafferata, California Department of Forestry and Fire Protection, personal communication, January, 1996).

Taken to a logical conclusion, quantification of potential cumulative effects is a daunting exercise for numerous reasons. The spatial scale of cumulative effects is large relative to most individual site assessments, and partially because of this, ecological complexity is dramatically increased (Gooselink and Lee 1989). Also, watershed ecosystems involve a complex dynamic between many linked physical and biological processes operating at and across many spatial scales (figure 2). Scientific understanding of these processes is limited. The physical and biological elements of a watershed and its subareas reflect local geology, climate, vegetation, and other factors. Consequently, every watershed is unique, with its own distribution of these factors as well as effects due to the history of past natural or induced perturbations (Washington Forest Practices Board 1993).

> It is clear that an exhaustive cumulative impact analysis following current regulatory procedures would be extremely complex and would cover incremental impacts to a host of environmental processes and organisms resulting from each human activity. In addition, the analysis would have to consider interactions among the activities and indirect impacts caused by them. Since the interactions increase as the square of the number of independent effects, the analysis would soon become entirely unmanageable. Thus, established procedures of environmental assessment may easily become data-limited or too cumbersome to be useful, if they are applied to cumulative assessment of the effects on the regional environment or over an extended period (Gooselink and Lee 1989:118).

Because of these complexities, Gooselink and Lee (1989:118) further argue that "[c]umulative impact assessment breaks new scientific, technical and regulatory ground...The required shift in focus is from species-oriented, linear, causal analysis based primarily on structural features of individual sites, to an ecosystem orientation where functional attributes of large-scale processes are emphasized." This is echoed by Horak et al. (1983) who state, "[t]he demand for cumulative impact assessment requires a complete restructuring of the problem itself; an articulation of the assumptions driving the assessment; new techniques and tools for aggregating diverse impacts; and a search for standards or criteria of significance in order to judge overall, long-range impacts."

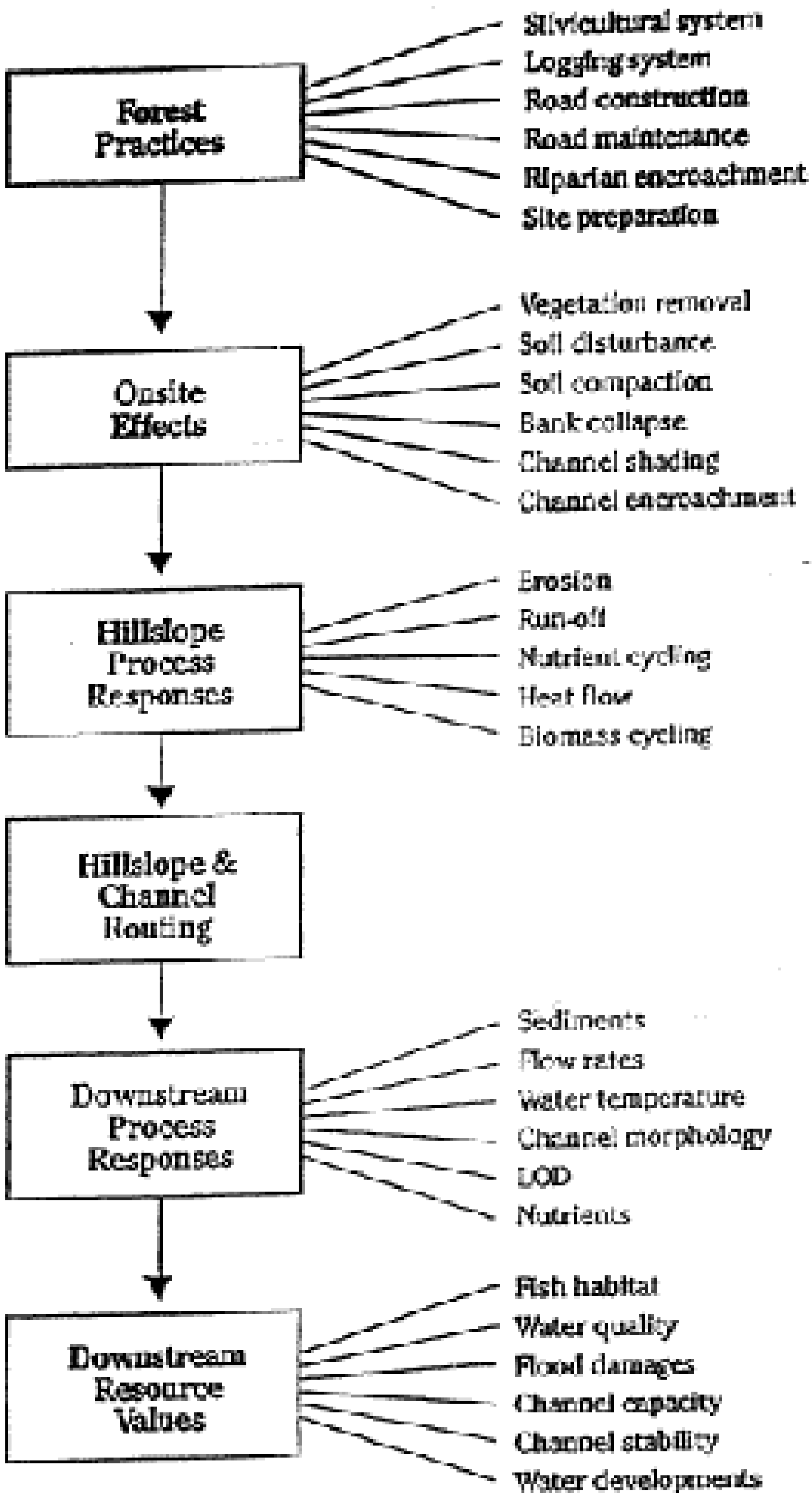

Figure 2. Links between forest management and water resources values. These links are for one type of management activity only, timber harvest. Similar sets of links could be diagrammed for grazing, mining, recreation, etc. (from NCASI 1992).

Because of these challenges, comprehensive methods for assessing cumulative effects have been slow to develop. Although many methods follow the letter of the law, they are not based on the physical and biological processes that actually link management activities to cumulative effects. Emerging, "science-based" approaches, although more effectively addressing the actual cause and effect relationships driving cumulative effects, can be costly and time-consuming. Within this context, the need for an assessment of options for CWE evaluation was identified as an objective for SNEP.

This report focuses on cumulative *watershed* effects; not cumulative effects on other resources. The basic intent of NEPA and other legislation is, however, directed at all cumulative effects. And watershed effects are clearly related to and interwoven with other resource issues. Ultimately, cumulative effects analysis will encompass all of the major resource considerations.

DISTINGUISHING CHARACTERISTICS OF THE SIERRA NEVADA

None of the following characteristics is unique to the Sierra Nevada. However, taken together as a suite of attributes, they characterize the Sierra Nevada as a complex landscape in terms of physical and biological processes and socio-economic issues relevant to estimating and predicting CWE. In terms of CWE, these attributes are best considered in the context of their relevance to hydrological processes; no effort is made here to describe all of the ramifications of each attribute to issues related to land management in the Sierra Nevada.

On the scale of the mountain range as a whole, or at least its western slope, four primary influences overlay and interact with other factors: (1) Many areas are still recovering from hydraulic mining that took place in the 1800s. This continuing recovery is superimposed on (2) recovery from fires in some areas or (3) vegetation buildup in other areas resulting from fire suppression during the last sixty-eighty years, and (4) recovery from timber harvests of varying intensity and spatial scale. In the broad geographical sense, much of the mid-elevation zone of the west slope is a mosaic of conditions driven largely by these four influences. Five major factors characterize the Sierra Nevada:

Climate

The climate on the west slope is conditioned by maritime, temperate influences; on the eastside the continental-dominated climate results in greater extremes in precipitation and temperature. Rainfall onto the snowpack occurs over a wide elevational band, and the extent of the rain-on-snow zone changes appreciably from the northern to the southern part of the Sierra Nevada. Rain-on-snow can accelerate peak flows and increase erosion and sedimentation. Precipitation, air temperature, and other basic climatic attributes also vary widely from north to south and with elevation. Among the many implications of these gradients are the responses by biota that may be at the margin of their geographic range.

Geology/geomorphology

The preponderance of granitic parent material in the southern and eastern Sierra has implications for elevated levels of soil erosivity and sediment production. Sensitive inner gorge lands occur in middle- to lower-elevations on the west slope where the majority of precipitation falls as rain, and where streams are larger and stream power is highest. The inner gorges are found mainly in areas with granitic and metasedimentary rock, and are rare in areas with volcanic rock. Most of the mainstems of the river systems on the west slope were sized by major flood events and are in bedrock. This implies that channels will not change readily. In the upper-elevations, many channel segments are dominated by steep gradients, and consequently are energy-rich and supply-limited. Many of the lower gradient river sections in the foothills are dammed. The low-gradient, alluvial reaches, with their buildup of herbaceous vegetation, become the most sensitive areas of management concern.

Biology

Over a hundred years of resource extraction and grazing have greatly changed many biological systems such that "natural" conditions often are not known. Dams, diversions, and fish stocking have severely affected natural aquatic populations. Although dams have largely eliminated anadromous fish above the foothills on the west slope of the range, anadromous fish issues must be considered in the lower ends of stream systems. Because the water quantity and quality of anadromous fisheries is driven largely by upstream processes, management activities at higher elevation are implicated in downstream anadromous and resident fish issues.

Hydrology

Surface-water flow regulation occurs at a wide range of scales. Impoundments range from major dams to small ponds, and flows are diverted for projects as small as irrigation of personal gardens or as large as domestic water supplies for millions. Hydroelectric power is produced on a range from massive turbines to run-of-the-river, small hydropower installations. Most of the mainstems of the major rivers are heavily regulated. At this broad river basin scale (e.g., the Stanislaus or the Tuolumne Rivers) development implications include:

1. Little free-flowing water. Because water flows into massive reservoirs, activities that could otherwise affect flow magnitude and sediment transport are masked to the extent that suspected cumulative effects cannot be identified.
2. A constancy of surface flows over what may have occurred naturally (e.g., downstream floods and dry periods are rare).
3. Impediments to up- and down-stream fish movement are common.

In many situations these implications combine to implicate the hydropower project itself as *the issue* (e.g., as a potential cause of degraded anadromous fish habitat). These implications also have resulted in a focus of effort on the smaller tributary basins because identification of CWE is easier without the overriding effects of large-scale reservoirs.

Compared to many areas in the Pacific Northwest, the percentage of intermittent streams is high in the Sierra Nevada, and headwater streams (third order and smaller) are more common.

Socio-economic influences

There is a relatively high human population density in the urban-wildlife interface. This results in accelerated "people-related" influences on CWE (e.g., probably more fires, changes in hydrology due to [sub]urban development) and a high (and increasing) demand for high quality water).

The high level of mixed-ownership land, especially in the central Sierra Nevada, implies (1) the need to include numerous parties (both public and private) to effectively solve problems, (2) the high potential for gaps in information available for CWE analysis (e.g., some owners may be unwilling to supply data), (3) "inequities" can arise when management decisions by one owner (typically a public agency) must be constrained because of the potential heavy impact by other owners in a watershed, (4) difficulties in coordinating restoration efforts in problem watersheds, and (5) the potential lack of an impetus for some owners to mitigate for past actions.

Recreational use of forested lands is greater in the Sierra Nevada than in most other regions of the United States. This is compounded by the diversity of recreational uses and the increasing use of wildlands by users with non-traditional values.

The constituency for CWE issues is effectively statewide because of the high degree of water regulation via dams and diversions. Water fin conveyed rom the Sierra to the major metropolitan areas of California and to irrigated agricultural operations statewide. The values of the water users (e.g., urban dwellers and irrigators) may conflict, and the result is a lack of consensus on water policy, as seen today in California. A corollary harks back to the 1800s. Land-use actions in the Sierra Nevada have downstream implications. In the 1800s it was hydraulic mining during the

Gold Rush; today salinization of the San Francisco Bay Delta and mortality of juvenile fish in the Delta are CWE issues driven largely by actions undertaken in the Sierra Nevada and the foothills.

SELECTED METHODS FOR PREDICTING AND ESTIMATING CUMULATIVE WATERSHED EFFECTS

Reid (1993) presents comprehensive documentation of major procedures used in California or the West for CWE prediction through 1991. Much of the following text on the Equivalent Clear-cut Area, Klock Watershed Cumulative Effects Analysis, Equivalent Roaded Area, R-1/R-4 Sediment-Fish Model, California Department of Forestry Questionnaire, Water Resources Evaluation of Non-point Silvicultural Sources, Limiting Factor Analysis, and Rational Approach is taken directly from Reid (1993).

Except for the Synoptic Approach, the methods listed here are directed to forested lands. A variety of approaches has been used. Some methods include development of disturbance indices for comparing sites or management alternatives; others address physical and biological processes. This distinction, between "science-based, cause and effect" approaches, and indexing methods is at the heart of the current debate over the future of CWE assessment procedures.

Equivalent Clear-cut Area (ECA)

One of the earliest CWE analysis procedures was developed by the U. S. Forest Service (USFS) for use in northern Idaho and Montana (U. S. Forest Service 1974; Galbraith 1975). The primary impact of concern was channel disruption, and this was assumed to be caused primarily by increased peak flows from reduced transpiration due to logging. Channel disruption was assumed to be an index of impacts on many beneficial uses, so specific impacts were not considered.

Application of the model first requires calibration for an area. The extent to which each management activity increases water yield is determined as a function of vegetation type, elevation, and age of the activity. Although these relationships could be defined for many land uses, only those related to timber management are usually included. Values for each land-type and land-use category are then compared to values for a clear-cut to calculate the area of clear-cut that would produce the same change, and this is used to calculate the equivalent clear-cut area (ECA) coefficients. The amount of monitoring data required for full calibration of model coefficients is usually prohibitive, so professional judgment is often used to define ECA coefficients.

Once the model is calibrated, application to particular sites requires measurement of the area of each land-use activity in each elevation zone and vegetation type. Areas are multiplied by ECA coefficients and summed to calculate total change in water yield, and altered water yield is assumed to be proportional to altered peak flows. Allowable thresholds for flow modifications are specified by law in northern Idaho, and calculated values are compared to the mandated thresholds. Allowable increases may be modified according to the perceived stability of channels in an area.

The ECA model is not presented as a complete CWE analysis method. Provisions are not made to evaluate the effects of other types of land use; other mechanisms of channel destabilization or peak-flow increase are not analyzed; other types of environmental changes are not considered; and specific impacts are not addressed. In effect, the estimated increase in water yield is used as an index of potential impact rather than as a predictor of impacts.

Because ECAs are calculated for a particular time, they do not account for past impacts that might interact with conditions at the evaluation time. Thus, the persistent effects of old landslides are not accounted for in an ECA analysis. Potential impact is assumed to be proportional to a year's transgression, and the recovery period for the impacted resources is implicitly assumed to be the same as that for water yield on a clear-cut. This means that the model does not apply to morphological changes that are cumulative through time. Figure 3 illustrates this problem. In this case, the driving variable (e.g., increased runoff, sediment input) has a relatively quick recovery period, but the impacted feature (e.g., channel width, volume of stored sediment, smolt mortality) takes considerably longer to recover from the effects of the temporary alteration in the driving variable (isolated activity). Even though the sequence of land-use activities is carried out in such a way that the driving variable has ample time to recover, the disturbance frequency is too high to allow recovery of the impacted feature between disturbances, and the impact accumulates through time (repeated activity). To assess a temporally cumulative impact, recovery periods of both impacts and driving variables would have to be considered.

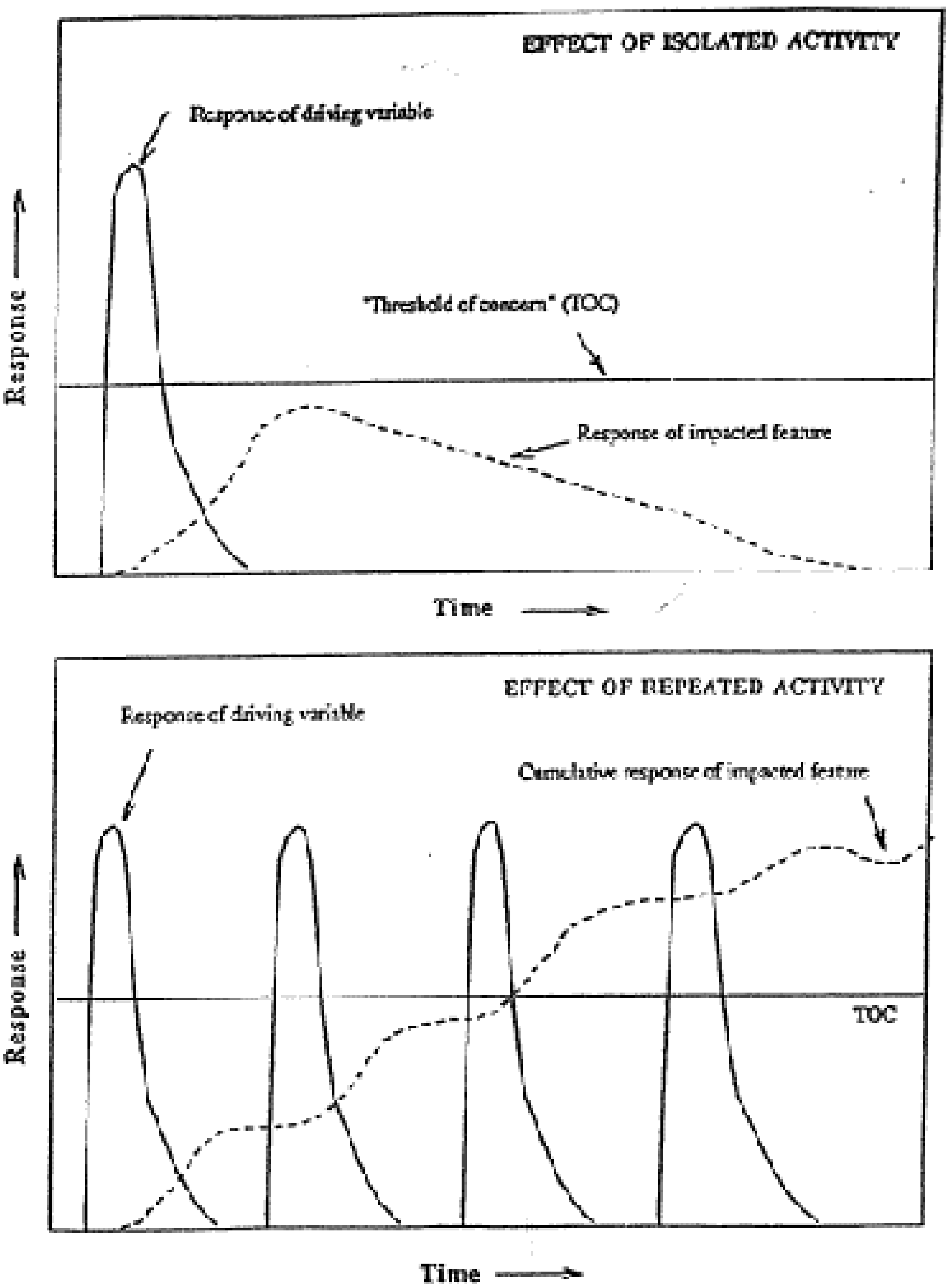

Figure 3. Cumulative effect of differing recovery times for a driving variable and an impact (after Reid 1993).

A model can be applied to a new site only if its assumptions are valid there. The ECA model assumes that (1) channel disruption is caused by increased peak flows, (2) increased peak flows are proportional to increased water yield, and (3) increased water yield is proportional to area logged. If these assumptions are valid for a particular area, then the model may be appropriate, but the assumptions must be tested carefully if the model is to be applied with confidence. Several studies have compared water-yield increases predicted by ECA with measured changes. King (1989) showed a 44% underestimate by ECA in basins smaller than those the model was designed for, and Belt (1980, quoted in King 1989) found a 38% underestimate in appropriately sized basins.

The theoretical foundation for the ECA method is weak. Logging is known to increase water yield by reducing transpiration, but this increase occurs primarily during the drier seasons and rarely affects the highest peak flows. However, peak flows may be significantly increased by logging in areas subject to rain-on-snow events, because more snow accumulates and then melts faster in cleared areas. This is likely to have a more significant effect on channel-modifying peaks than altered transpiration. An index of clear-cut area may fortuitously address both mechanisms of change, but numerical predictions are likely to be unfounded because the underlying processes are different.

Klock Watershed Cumulative Effects Analysis (KWCEA)

Klock (1985) adapted and combined elements from other CWE assessment methods into an equation to analyze CWE potential from timber management in the Washington Cascades. The impact of concern is again channel destabilization, but the driving mechanism is assumed to be increased sediment input. The KWCEA equation combines factors for local climate (the R-factor of the Universal Soil Loss Equation; Wischmeier and Smith 1978), susceptibility to surface erosion (the USLE K-factor adjusted by a disturbance index for logging practice and recovery through time), a landslide occurrence factor (a local landslide frequency adjusted by site recovery factors), a topographic factor that incorporates gradient and distance from a stream, and a hydrologic sensitivity factor that indexes increased evapotranspiration after logging. Model application thus requires information on soil characteristics, topography, landslide frequencies associated with logged sites and roads, land-use history, and areas of land-use types. Index values are calculated for each type of site in a watershed, normalized by watershed area, and summed to provide an index of potential impact. An index greater than 1.0 indicates a greater than 50% chance of "increased impact on the downstream aquatic ecosystem."

Unfortunately, no documentation was provided for the derivation of model components, and procedures for assigning relative weightings were not explained. Disturbance and recovery coefficients presumably reflect measurements from central Washington, so the equation must be recalibrated for regions where runoff and erosion processes interact with channels in different ways. But adjustment of component weights for new areas is an indeterminate problem because component indices do not represent physical quantities: there are too many adjustments to make and too little information to guide the adjustments. Klock (1985) did not indicate how impact probabilities were related to index values, the types of impacts considered, or if and how the model was tested. Other references to its application were not found.

The KWCEA model assumes a relatively narrow view of CWE. Only the effects of timber management and roads are considered, and the model is only relevant to those impacts that might be generated by altered sediment input. Because site-recovery functions are used to calculate each year's index, effects that accumulate through time are not addressed. This oversight is particularly relevant to sediment-related impacts, because introduced sediment may be stored for long periods and cause long-term lag effects.

Equivalent Roaded Area (ERA)

USFS Region 5 staff developed the ERA method to index CWE potential from timber management and roads. (For a more thorough treatment of the ERA method, see Menning et al. 1996 in SNEP Volume II). Although recent Region 5 direction (U. S. Forest Service 1988) for CWE assessment does not mandate the use of the ERA method, examples of the ERA approach are prominent in the directive, and most USFS practitioners in Region 5 use some form of the ERA method. A recent example implementing many aspects of the current direction is the Last Chance-Clarks Creek evaluation on the Plumas National Forest (see the Case Studies section of this report).

The original model assumed that channel destabilization is the impact of greatest concern in California, and that destabilization occurs primarily from increased peak flows due to soil compaction. The model has changed considerably since its initial release. The recent version (U. S. Forest Service 1988; Cobourn 1989b) extends the procedure to identify beneficial uses and to address downstream impacts generated by several mechanisms. Impact potential is indexed by relating the impacts expected from each activity to that expected from roads. The sum of indices for a watershed represents the percentage of basin in road surface that would produce the same effects as the existing or planned distribution of management activities. Indices for different planning options can then be compared to rank their potential for producing impacts.

Application of the method first requires identification of important downstream values and the criteria necessary to protect each. A land-use history is developed for the watershed, sensitive sites are identified, and ERAs are calculated for each activity with respect to the mechanism thought to be of greatest concern. Values are summed for the watershed and normalized by the area to calculate the total ERA percentage, and this is compared to the allowable threshold identified for the area. If the calculated ERA value is higher than the threshold, then the area may be singled out for further evaluation by other means.

Each national forest is expected to identify local concerns and mechanisms and calibrate coefficients for characteristic site types, and Haskins (1987) outlined this procedure for the Shasta-Trinity National Forest. Recent practices often cause less impact than older ones, so changes in land management procedures must be identified and accounted for, and recovery curves for various activities and site types must also be defined. Calibration ideally incorporates monitoring data for the identified impact mechanism from different land-use activities in that area, but the necessary data are rarely available, and calibration usually depends on professional judgment. Disturbances other than timber management and road construction can also be evaluated if their effects are appropriately quantified. Thresholds of concern (TOCs) are to be identified independently for each area and are to take into account inherent differences in sensitivity to impacts. TOCs are usually defined by calculating ERAs for areas showing different levels of impact. Users are expected to exercise judgment in modifying ERA coefficients and TOCs for particular sites.

In essence, the ERA method is an accounting procedure for assessing the instantaneous influence of past, present, and planned activities on the potential for environmental change. The method is designed to provide a screening tool for identifying areas of particularly intense use rather than to predict effects. As an index of use intensity, however, ERAs are likely to be grossly correlated with many types of impacts. The method also provides a framework for organizing local information on land-use impacts and mechanisms of change.

ERAs are not comparable between areas because the method is customized to address issues relevant to each implementation area. ERA coefficients defined for an area where landsliding is the major impact have little relation to those defined where the major concern is increased peak-flows from rain-on-snow events.

Management activities are usually planned to maintain a watershed's ERA below an identified TOC. If the threshold is approached or exceeded, then channel condition may be evaluated by an interdisciplinary team. Proposed activities may be reviewed to determine whether they should be modified or delayed, or whether existing conditions can be improved to lower the ERA values. A basin is assumed to be healthy again as soon as sub-threshold ERA values are reattained, but the recovery times actually required by impacted resources are not considered. The method cannot be used to identify sites where impacts persist from earlier disturbances, thus the method is incapable of addressing temporally accumulating effects: if recovery time for the impacted resource is longer than that for the driving variable, then impacts can continue to accumulate even though the driving variable does not (figure 3). Complementary effects are also excluded, because the method requires identification of a single impact mechanism. Monitoring programs are not yet in place to assess the success of the most recent ERA method in avoiding impacts, and earlier formulations of this method were not independently validated.

The early formulations of the ERA model used the results of a study in southern Oregon that showed peak flow increases in a basin with 12% roaded area (Harr et al. 1975) as the basis for identifying both the driving mechanism for change (increased peak flows) and the TOC (12% compacted area). However, these results are not transferable to California's geology and climate. Ziemer (1981), for example, demonstrated no significant change in peak flows in a California Coast Range watershed with 15% of its surface area compacted. In addition, because channels respond as readily to altered sediment inputs as to altered flows, selection of increased peak flows as the single driving mechanism does not fully address the problem. The most recent implementations of the ERA model avoid these problems by using ERA values primarily as an index of land-use intensity, so the hydrological basis of the original method is no longer important.

To assess the link between ERA and aquatic ecosytem response, McGurk and Fong (1995) compared time series of ERAs and diversity (measures of aquatic community health) for three forested areas with logging and roadbuilding in California. No relationship was found using the standard Region 5 method, but a significant, inverse relationship between ERA and diversity was found when the ERA calculations were limited to a 100-m strip on either side of the channel. Above a 5% no-effect threshold, as ERA increased, aquatic diversity declined. These results shows that an accounting and risk estimation procedure, when constrained, can predict aquatic response and condition.

<u>R-1/R-4 Sediment-Fish Model</u>

USFS researchers of the Intermountain Research Station, resource specialists and managers from USFS Regions 1 and 4, and university researchers worked together to develop a method for predicting fish survival as a function of sediment input in the Idaho Batholith. The procedure has two parts: first, sediment yields are estimated using a method described by Cline et al. (1981), and then the effects of increased yield on fish are calculated using relations presented by Stowell et al. (1983). The R-1/R-4 model addresses settings where deposition of fine sediment is the major impact on fish populations, and where sediment is eroded primarily by surface erosion on logged sites and roads. Components of the method are continually revised to incorporate new research results, and model coefficients are calibrated locally for each application area. Developers of the model stress that it is directly applicable only to the Idaho Batholith, and that results should be taken as broad estimates of trends and relative impacts rather than as precise predictions of change.

Sediment yield is predicted using relations developed from extensive research on erosion process rates as a function of land use in the Idaho Batholith. Average loss rates were calculated for roads, logged areas, and burned sites, and these are applied to the areas of each activity in a watershed to calculate on-site loss rates. A sediment delivery relation from WRENSS (Water Resources Evaluation of Non-point Silvicultural Sources, see later section; U. S. Forest Service 1980) is used to calculate input to streams, and a relation defined by Roehl (1962) allows estimation of delivery to critical stream reaches.

Gravel siltation, summer rearing habitat, and winter carrying capacity were identified as factors limiting salmonid survival. Results of studies in the Idaho Batholith were compiled to provide empirical correlations between substrate embeddedness and sediment yield, between habitat measures and substrate embeddedness, and between fish response and habitat quality. To apply the model, calculations are carried out for critical reaches downstream of a project area. If natural siltation levels are known and conditions prior to the project are measured, then the incremental effect of a planned project can be estimated.

As presented, the model applies only to the Idaho Batholith because its relationships depend strongly on runoff mode, runoff timing, climate, sediment character, erosion process, channel geometry, and species of fish. Use of the model in other areas requires remeasurement of each of the component relations.

This procedure is one of the few that relates land-use activities directly to a resource response, and is unique in its recognition that impact recovery rates cannot be indexed by recovery rates of the driving land use. Once a channel reach is modified, the new condition becomes the baseline for further changes, and effects that accumulate through time can therefore be predicted. The R-1/R-4 model is not a complete model for CWE evaluation because it addresses only one type of CWE from one mechanism, but it is well-founded on research results within the area for which it was developed.

California Department of Forestry Questionnaire

The California Department of Forestry and Fire Protection (CDF) has developed a procedure for use by Registered Professional Foresters to assess CWE potential from timber management (California Department of Forestry and Fire Protection 1994). This procedure differs from all others described in that it relies almost completely on the users' qualitative observations and professional judgment, and it provides only qualitative results. It also addresses a wider variety of uses and impacts than other procedures, and includes many that are not related to water quality, such as recreational, esthetic, biological, and traffic uses and values. It was designed to be used within the time and access constraints of timber harvest plan (THP) development, and a nonquantitative approach was adopted to avoid the complacency that accompanies a numeric, "right" answer.

For biological, recreational, esthetic, and vehicular traffic impact assessment, a four-step process is followed. The user is first asked to construct a resource inventory in the assessment area, and is then asked whether the planned timber operation is likely to produce changes on each of those uses. The third step identifies impacts of past or future projects, and includes projects either under the ownership or control of the timber/timberland owner or not under the control of the owner. Finally, the user is asked whether significant cumulative effects are likely from the proposed operation.

Analysis follows a slightly different procedure for watershed resources assessment. Onsite and downstream beneficial uses are listed. The analysis area for watershed assessments is an "area of manageable size relative to the THP (usually an order 3 or 4 watershed)" (California Department of Forestry and Fire Protection 1994). Existing channel conditions are first inventoried, and adverse impacts from past projects are identified. The user is then asked to rate the magnitude (e.g., "high," "medium," "low") of a variety of potential effects from the proposed project, from expected future projects, and from combined past, present, and future projects. When problems are identified, the assessment should be considered as an indicator of the need for further review by specialists.

The CDF procedure is essentially a checklist to ensure that the important issues have been considered. Although it provides descriptions of possible CWE, it does not specify how the likelihood of their occurrence is to be evaluated, and instead relies on the user's ability to make qualitative predictions based on observations of earlier projects in the area. Validity of the results rests completely on the user's expertise, experience, and professional judgment, so results are not necessarily reproducible. The specified spatial and temporal evaluation scales are based primarily on feasibility of evaluation, rather than on the nature of the potential CWE. This implicitly restricts the types of CWE that can be evaluated, although the procedure permits a larger scope where it is deemed by the user to be necessary.

The procedure's major strengths lie in its flexibility. This is the only CWE evaluation method that requires assessment of more than one type of impact from more than one type of mechanism. It is also one of the few procedures that allows evaluation of temporally accumulating impacts.

Water Resources Evaluation of Non-point Silvicultural Sources (WRENSS)

The most complete process-based approach to evaluating timber-management impacts is the series of procedures referred to as WRENSS (U. S. Forest Service 1980). This collection presents quantitative evaluation procedures for a variety of water-quality impacts, including altered flows, sediment, and temperature. Pollution by nutrients and chemicals is addressed qualitatively, as are changes in dissolved oxygen. Although not specifically intended to address CWE, WRENSS methods are applicable to CWE evaluations.

Application of WRENSS to a CWE analysis would require identification of likely environmental changes generated by a project, likely downstream impacts, and the mechanisms generating them. Appropriate WRENSS procedures would be selected to estimate the magnitude of expected impacts from a planned project, and these values would be added to those calculated for existing projects to estimate the total effect. Because the original focus for WRENSS was water quality, the procedures do not address impacts on other resources, and only the effects of timber management and roads are considered. Evaluation procedures are independent of one another, so modules can be replaced by improved methods as they become available.

The WRENSS procedure for evaluating hydrological change is based on computer simulation modeling of water budgets. The program PROSPER (Goldstein et al. 1974) was used to develop relationships for rain-dominated areas, and WATBAL (Leaf and Brink 1973a, 1973b) for areas with snow. Results are presented as graphs and tables that allow users to estimate changes in evapotranspiration, flow duration, and soil moisture for various logging plans. Stream temperature changes are assessed using the Brown model (Brown 1970).

Sediment modules include methods for estimating surface erosion, ditch erosion, landsliding, earthflow activity, sediment yield, and channel stability. Surface erosion is calculated using a modified Universal Soil Loss Equation (Wischmeier and Smith 1978) and sediment delivery relations, and ditch erosion is assessed by calculating permissible velocity. The landslide module is a step-by-step guide to performing a landslide inventory for an area: the area is subdivided into uniform subareas, hazard indices are calculated for each, and slides are inventoried in representative areas to determine characteristic volumes and delivery ratios as a function of hazard index and land use. Sediment yields are estimated using results of monitoring and process evaluations, and channel stability is indexed by changes in sediment and flow.

WRENSS is neither a CWE model nor an evaluation procedure, but is simply a collection of tools useful for impact evaluation. A CWE analysis using WRENSS would be flexible enough to handle a variety of impact mechanisms, but it would need to use additional methods to assess the effects of other land uses and to evaluate impacts on particular resources. Implementation of most of the procedures requires training in hydrology or geomorphology, and calculations are often complex and time-consuming. WRENSS is the only method described here that is capable of estimating the magnitudes of different types of watershed changes.

Each procedure presented in WRENSS was developed by researchers and resource specialists with relevant expertise, but procedures vary widely in sophistication, approach, and accuracy, and many have been superseded by more effective methods. Some of the methods have been intensively tested, while others have not been validated at all.

Limiting Factor Analysis (LFA)

Reeves et al. (1989) developed the LFA as a procedure for identifying factors that limit coho smolt production in coastal Oregon and Washington, and the procedure can be adapted for use in CWE analysis. Unlike the approaches described above, LFA is designed from the point of view of a particular impacted resource. Any procedure designed to predict CWE, rather than merely to assess their likelihood, must incorporate a component such as this.

The LFA model is in the form of a dichotomous key that leads users through computations to estimate smolt production from data on physical habitat in a watershed. Model application requires detailed surveys of fish populations and areas occupied by various habitat types in a watershed. The procedure is based on extensive fish and habitat surveys that were compiled to disclose patterns of habitat use in the Pacific Northwest. LFA can thus be applied only to sites with population-habitat relationships characteristic of the development area, but the model could be recalibrated for other areas if limiting factors are the same and appropriate relationships can be measured.

Because LFA sums smolt production from different habitat categories, the impacts of changes in habitat distribution can be calculated. Relations between cumulative habitat change and land-use activities would also be required for prediction of CWE, and these are produced in some form by most other models described here. A procedure capable of assessing impacts of timber management on fish would need to couple a trigger-based model such as ECA or ERA with an impact-based model like LFA.

Rational Approach (Grant)

Grant (1987) described a process-based procedure for establishing thresholds of concern for flow-related channel disruption. As was the case with LFA, this method is designed from the point of view of the impact rather than the activity.

Grant reasoned that channels can be disrupted only if their beds and banks are remolded, and this requires mobilization of bed sediment. If increased flows do not affect the frequency of sediment transport, then a river will remain stable. Grant presented equations to calculate flow thresholds for sediment transport as a function of particle size and channel geometry. Projected flow increases can then be compared to threshold discharges to evaluate their potential for altering a channel. The Rational Approach can also provide an index of channel stability.

The Rational Approach illustrates the potential use of process-based information for quantifying the potential effects of changing conditions, but it was not intended to provide a full CWE analysis. Use of the method to evaluate CWE would require its coupling with models that predict flow changes from land use, and with methods to analyze channel destabilization by other mechanisms, such as increased sediment input or riparian disruption.

The Synoptic Approach (EPA)

The Synoptic Approach was developed by the U. S. Environmental Protection Agency (EPA) (Leibowitz et al. 1992) for evaluation of cumulative impacts to wetlands for Section 404 (Clean Water Act) permit review. This method is not intended to provide a precise, quantitative assessment of cumulative impacts within an area. Rather, it provides a relative rating of cumulative impacts between areas. The major steps in the Synoptic Approach are:

1. Define goal and criteria (including definition of the objectives and intended use of the assessment, accuracy needs, and assessment constraints).

2. Define synoptic index (including description of the natural setting, definition of the landscape boundary, function and values, identification of significant impacts, and definition of "combination rules").
3. Select landscape indicators (including surveying data and existing methods, assessing data adequacy, description of assumptions, and indicator selection).
4. Conduct of the assessment (including planning for quality assurance and control, map and data analysis, map production, and accuracy assessment).
5. Prepare final report.

The Synoptic Approach provides a framework for making comparisons between landscape subunits through the use of one or more landscape variables, or synoptic indices, for each subunit. Examples of possible subunits are counties, watersheds, and ecoregions. Key elements to the approach are determination of the synoptic indices, landscape indicators, and combination rules by an assessment team.

Four generic, synoptic indices relating to the function, value, functional loss, and replacement potential at the landscape level are defined. They are then replaced by individual indices relevant to the objectives of the analysis. These specific indices serve as the basis for comparing the characteristics of landscape subunits; they also represent the actual functions, values, and impacts of concern to the manager. For example, in an application concerned with nonpoint source nitrogen pollution within an agricultural region, the specific indices for capacity and landscape input might be the maximum denitrification rate and the nitrate loading rate, respectively. A specific synoptic index is typically a mathematical expression that includes several factors. The indices can represent single or combined factors. If a combination of factors is selected, a set of "combination rules" needs to be defined. These rules address issues such as how the factors will be combined (e.g., by addition, multiplication, or some other operation), whether the data will be normalized or whether weightings among factors are equal, and whether the same combination rules apply to all landscape types and across the entire range of conditions within the study area.

Quantifying the indices at the landscape scale would be difficult, if not impossible. Indicators of the actual functions are instead developed as first-order approximations of the particular index. For example, agricultural area could be used as the indicator for nonpoint source nitrate loading. This approximation process carries assumptions that must be described. Use of area as an indicator for landscape function assumes that function or capacity per unit area is similar for all landscape elements (e.g., wetlands) or, if it varies, that landscape units having different unit area response are similarly distributed between landscape subunits.

The Synoptic Approach is not meant to be used to assess the cumulative effects of specific impacts. It is meant to augment the site-specific review process and improve "best professional judgments" and is probably most effectively used at extremely large landscape scales (e.g., states).

Watershed Analysis

In the late 1980s, an interdisciplinary, interagency effort aimed at addressing concerns surrounding management of forested lands was initiated in the state of Washington. A consortium of individuals representing various organizations participates in a Timber/Fish/Wildlife (TFW) Agreement that continues today. TFW cooperators include state agencies (e.g., Washington Departments of Natural Resources, Fisheries, Wildlife, and Ecology), tribes, members of the forest products industry, small private landowners, and environmental groups. One product of the TFW Agreement is a "Watershed Analysis" manual sponsored by the Washington Forest Practices Board and initially published in 1992.

In 1993, President Clinton commissioned an interagency scientific team to develop a set of alternatives for management of forested ecosystems within the range of the northern spotted owl (*Strix occiendtalis caurina*). This effort culminated in the report by the Forest Ecosystem

Management Assessment Team (FEMAT) (1993) entitled *Forest Ecosystem Management: An Ecological, Economic, and Social Assessment*. A major product from FEMAT was the concept of "Watershed Analysis," an ecosystem management approach that shares many elements with the Washington State "Watershed Analysis" procedure. For purposes of clarity in this report, the FEMAT (federal) approach is labeled "FWA" and Washington State approach "WWA."

Both WWA and FWA are evolving, iterative processes that will be improved as experience and knowledge grow. There is formal recognition that both approaches will never be "complete" and that they will be upgraded as new techniques become available. Both approaches are modular so that specific methods can readily be modified or replaced in future editions. Several WWA projects have been completed and pilot FWA projects are underway. Because of the evolving nature of these programs, the following synopses should be viewed as snapshots in time that represent the current state-of-the-art. They should not be considered as descriptions of the ultimate FWA or WWA procedure.

Washington State Watershed Analysis (WWA) The WWA approach is aimed at developing forest plans for individual watersheds based on scientific understanding of significant links between physical and biological processes and management activities (Washington Forest Practices Board 1993). The method defines areas of sensitivity within each watershed and considers resource vulnerabilities based on potential specific impacts to public resources (specifically fish habitat, water quality, or public works) (figure 4). For this purpose, the state of Washington has been divided into approximately 400 watersheds ranging in size from 4,000 to 20,000 ha (10,000 to 50,000 acres). The process is collaborative involving resource scientists and managers representing landowners, agencies, tribes and other interested publics. Resource specialist and management teams conduct the assessment within a two- to five-month time frame. A detailed and specific policy structure encodes the steps, operating rules, key links, and decision requirements for the teams. Products can include area-specific management prescriptions, and monitoring to be implemented by landowners, agencies, tribes, and others to track the effectiveness of the prescriptions and the assessment on which they were based.

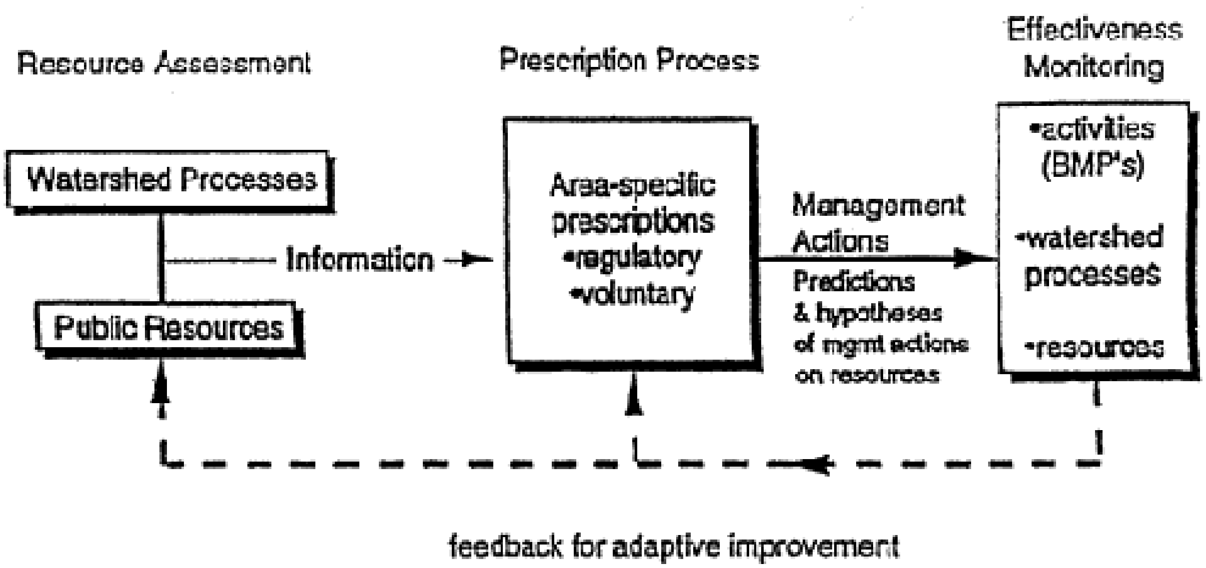

Figure 4. Components of the Washington Forest Practices Board Watershed Analysis methodology (from Washington Forest Practices Board 1993).

The approach incorporates a dual-level hierarchy. Watersheds are first screened by interdisciplinary teams of resource specialists to qualitatively assess their sensitivity to environmental change. If basins are found to be sensitive, they are evaluated by the appropriate experts to define more precisely the potential impacts and management alternatives. Version 2.0 of the Watershed Analysis manual (Washington Forest Practices Board 1993) incorporates resource assessment modules for mass wasting, surface erosion, hydrologic change, riparian function, stream channel assessment, fish habitat, water supply/public works, and routing through the fluvial system. Other modules (e.g., water quality) are planned or under development. Four specific steps are followed:

1. Startup: maps, photos, and data are collected; teams are formed and responsibilities defined.
2. Resource assessment: a trained and certified interdisciplinary team inventories watershed processes and resources following a structured approach to problem definition framed by a series of critical questions. Sensitive areas are located, mapped, and evaluated for potential or existing impacts and risks to public resources.
3. Prescription process: a trained and certified management team develops a tailored set of management prescriptions (potentially including required and voluntary components) that responds to the resource concerns identified by the resource specialists.
4. Wrap-up: the teams complete the report for public review prior to final acceptance of the plan.

Once the plan is accepted, further forestry activities in the watershed must be conducted within the provisions of the prescriptions for each sensitive area, unless an alternative plan is approved, with compliance regulated by the Washington Department of Natural Resources. Elements of WWA that differ from many traditional approaches include the "science-based" focus, a reliance upon diligent revision as monitoring provides feedback on whether resources are improving or degrading, a formalized structure, and a reliance on stakeholders within each watershed to make the process succeed.

A basic premise is that a change in erosion, hydrology, or riparian function resulting from forest practices is significant when it is sufficient to cause an adverse change in a public resource of fish habitat, water quality, or public works. Watershed processes (sources or causes) are linked to public resources by the flow of products including sediment, water, wood, and energy that shape and determine the stream environment. Since each watershed possesses distinct environmental conditions, resource characteristics and sensitivities, WWA is premised on the need to define locally active watershed processes that pose significant risks to public resources (e.g., reductions in large organic debris recruited to channels may result in fewer pools and unstable stream beds).

<u>FEMAT Watershed Analysis (FWA)</u> The intent of FWA is to develop and document a scientifically based understanding of the processes and interactions occurring within a watershed. This understanding focuses on specific issues, values, and uses within a watershed. Protecting beneficial uses is a fundamental aim of FWA. Because of the links between headwater areas, valley floors, and downstream users, FWA should encompass the entire watershed, including all owners. Application of FWA should result in reports describing the distribution pattern, types, and relative importance of resource values, altered environmental conditions, and mechanisms of environmental changes in watersheds (Furniss and McCammon n.d.).

Four analytic scales are included in the FWA approach. They are roughly analogous to geographical scales, and the scales are smaller than "river basins" (large, continuous land areas of hundreds to thousands of square miles) and larger than "sites" (a specific activity area within a watershed). The spatial scope of FWA is normally between 8 and 80 km^2 or 5,180 to 51,800 ha (20 and 200 mi^2 or 12,800 to 128,000 acres). FWA suggests that ecosystem elements at the larger scale (e.g., region and river basin) be considered in order for FWA to be relevant.

FWA, somewhat contrary to WWA, is not a decision process in that it does not produce a formal decision notice or record of decision as required by NEPA. Ideally, FWA derives data and information from the larger-scale analyses and plans and provides information to smaller-scale site analyses, both of which are formal decision points under NEPA (Furniss and McCammon n.d.).

FWA is to be carried out by interdisciplinary/interagency teams of resource specialists who are professionally qualified to assess and interpret the structure, composition and function of the ecosystems within a given watershed. These teams incorporate public involvement to ensure that the full range of values, resource needs, and expectations associated with each analysis watershed are included in the analysis. The degree of public involvement varies based on the type and intensity of the issues involved, the availability of existing data and information, and the history of public participation within or adjacent to the subject watershed (Furniss and McCammon n.d.). Steps followed in FWA are:

- identify issues, describe desired conditions, and formulate key questions
- identify key processes, functions, and conditions
- stratify the watershed
- assemble analytic information needed to address key questions
- describe past and current conditions
- describe condition trends and predict effects of future land management
- integrate, interpret, and present findings, and
- manage information, monitor, and update the process.

Products from FWA should include:

- a description of the watershed including its natural and cultural features
- a description of the beneficial uses and values associated with the watershed, and, when supporting data allow, statements about compliance with water quality standards
- a description of the distribution, type, and relative importance of environmental processes
- a description of the watershed's present condition relative to its associated values and uses
- a map of interim "Riparian Reserves"
- a description of the mechanisms by which environmental changes have occurred and a description of the role of specific land-use activities in generating change
- a description of likely future environmental conditions in the watershed, including a discussion of condition trends and of the potential future effects of past activities, and
- interpretations and management recommendations: watershed processes and ecosystem concerns and interactions to be addressed at a project-planning-scale in different parts of the watershed (Furniss and McCammon n.d.).

FWA and WWA share many of the same objectives, goals, and philosophies. Nevertheless, differences do exist. WWA, for instance: uses scientist *and manager* teams—inclusion of managerial teams could expedite understanding of the results and recommendations and foster "buy-in"; has a strictly codified internal structure that forces decision-making—this could speed up the entire analysis process; is more formally codified in state regulations than FWA—WWA cannot order a land owner not to do something on her/his land, but WWA can direct the way an agreed-upon action is carried out; focuses on anadromous fish; and functions by implementing a set of prescriptive Best Management Practices.

On the other hand, FWA: has a wide latitude in prescriptive choices, largely because FWA focuses on federal lands; develops an "objective" (technical) understanding of how systems work in each analysis area—value-based socio-economic-cultural considerations on what is best for an area are not prominent; and encompasses a bigger land base for analysis (4,000-20,000 ha [10,000-50,000 acres] for WWA and 5,180-51,800 ha [12,800-128,000 acres] for FWA) that could potentially lead to different conclusions from a WWA conducted on the same land.

National Council of the Paper Industry for Air and Stream Improvement (NCASI)

The National Council of the Paper Industry for Air and Stream Improvement (NCASI) also advocates a hierarchical approach to CWE evaluation for application on timber-industry lands throughout the five western forested states. An initial screening procedure assesses watershed sensitivity, evaluates existing conditions, documents the existence of important downstream watershed values (beneficial uses), and defines how changes in hydrologic processes caused by forest management activities are linked to downstream watershed values. A second level of analysis is triggered when the initial screen predicts potentially unacceptable cumulative effects that cannot be controlled by management solutions (National Council of the Paper Industry for Air and Stream Improvement 1992).

This approach incorporates specific cause and effect links between hillslope management actions and in-channel fluvial responses. As a conceptual procedure, the method should be designed to meet the following objectives (National Council of the Paper Industry for Air and Stream Improvement 1992):

- Identify the important hydrologic and geomorphic processes of concern.
- Describe the relationships between environmental damage and beneficial uses by evaluating the physical processes linking on-site disturbances to downstream effects.
- Provide a measure of the sensitivity of beneficial uses to management.
- Describe effects of land management relative to background conditions (including natural variability and historic disturbance), and develop methods to assess recovery factors.
- Utilize methods that are understandable, reproducible and practical, and supported by available resource information.
- Provide evaluations of CWE that are based on measured physical or biological effects rather than indirect indicators of change (e.g., percent area cut), thus allowing assessment of accuracy in actively managed watersheds.
- Describe the uncertainty caused by gaps in technical knowledge.

The current focus of the NCASI CWE program is to fill in critical information gaps on the cause-effect links and to work with individual states to better define the process links (Walter Megahan, NCASI, personal communication, July 1994).

Idaho Forest Practices Method

In 1991 ,an inter-institutional task group was charged through an amendment to the Forest Practices Act of the State of Idaho to (1) review and evaluate existing tools for assessing CWE on beneficial uses and water quality, (2) develop processes and procedures for making assessments of CWE in any given watershed, and (3) formulate methods for controlling CWE and protecting water quality and beneficial uses, based on the results of these assessments. The process is designed to be systematic, structured, reproducible, defensible, and adaptive, thereby ensuring its technical and practical integrity. It is designed to give trained evaluators an understanding of: inherent hazards of the landscape within a watershed, and current conditions within a watershed relevant to hydrologic processes and to the disturbance history. A review draft of the proposed method became available for public comment in mid-1994 (Cumulative Effects Task Force n.d.).

The process consists of an assessment of fine sediment in stream bottoms, channel stability, sediment delivery, water temperature/stream shade, nutrients, and hydrology. A fisheries element is not included, and the process is limited to forest practices; effects of grazing, mining, recreation, or other nonforest practice activities are not addressed. The method provides keys to determine whether CWE exist for any of the factors assessed, along with guidance to help landowners design management practices to alleviate adverse conditions and prevent CWE problems from future forest practices.

Outcomes from the method include the following potential courses of action: allow forest practices to proceed using standard Best Management Practices; help resource managers redesign forest practices, and/or correct the identified watershed problems so that practices may proceed; or delay forest practices in those situations where technological solutions to adverse CWE are not available.

CASE STUDIES OF CWE ASSESSMENT PROCEDURES USED BY SELECTED NATIONAL FORESTS IN THE SIERRA NEVADA

A strong case can be made that historic attempts at cumulative effects analysis were, in many ways, the first attempts at practical landscape level analysis, in that generally watersheds larger than project areas were analyzed. Admittedly, nearly all of these analyses were functionally focused. Recent biodiversity and ecosystem health issues (e.g., Pacfish, FEMAT) have affirmed the need for integrated landscape analysis (i.e., integrated between resources, agencies and stakeholders, and geographic scales). In a sense, the objectives of CWE assessment have broadened.

In the past, CWE analyses were conducted to fulfill the NEPA requirement for assessment of cumulative effects. Analysis was project driven, rather than geographically based (e.g., a timber sale rather than a basin plan). Since about 1985, all timber sale project planning included cumulative effects analysis. The existing USFS Region 5 methodology recommends analysis of second or third order basins, and this was almost always the scale used for project assessments.

It is unfair to judge analyses of the past against a set of recently developed objectives, and that is not the intent of this review. The objective of this section is to review cases of CWE analysis for processes and components that will aid managers in addressing questions of ecosystem assessment in the Sierra Nevada. Four cases were selected for review:

1. The Meiss Allotment on the Lake Tahoe Basin Management Unit, as an example of a CWE analysis driven by the grazing issue.
2. The Last Chance-Clarks Creek evaluation on the Plumas National Forest, because a recent USFS Region 5 restoration review identified strengths in this analysis.
3. The Lower North Fork Cosumnes River watershed on the Eldorado National Forest, because the forest recently (June 1993) revised its CWE analysis process.
4. The Peppermint-Holby watersheds on the Sequoia National Forest, because this forest has a well-established CWE assessment procedure.

These cases represent a range of Sierran geography and management activities, but their representation of the quality and type of CWE assessments is not known.

No rating of the case studies was attempted. Instead, they were reviewed with numerous questions in mind. The factors considered are included in appendix 3. Essentially, the review centered on two questions: (1) How well is the situation (including watershed condition and risk of alternatives) explained to the decision maker and public? (2) How well does the analysis consider system function and process?

<u>Case 1: Environmental Assessment of the Meiss Grazing Allotment (Lake Tahoe Basin Management Unit)</u>

<u>Purpose of the Assessment</u> Development of an Allotment Management Plan was the project objective. The analysis centered on stream and fish habitat conditions in the headwaters of the Upper Truckee River and Big Meadow Creek. There are approximately 4,000 ha (10,000 acres) within the analysis area, including 32 km (20 miles) of stream.

<u>Procedure and Findings</u> The assessment procedure consisted of comparing the existing condition against desired conditions set forth as Forest Plan objectives, and assessing the impact of a variety of alternative range management strategies on those conditions. Fisheries habitat was identified as the key resource issue. Also discussed were downstream water quality issues, but the

in-stream fish condition was selected for analysis, as it was thought to be most sensitive to management.

Streams within the planning area were stratified by geomorphic type, and streams types thought to be most sensitive to grazing were selected for further analysis. Indicators of habitat condition for each stream type were used to describe condition. These factors were stream shading, in-stream cover, residual pool volume, and percentage substrate as fines. The indicators were measured for selected stream reaches, and compared to standards for the stream types contained in the Forest Land Management Plan. Professional judgment was used to assess how each project alternative would effect current condition.

The project alternatives were evaluated against downstream water quality objectives (e.g., nutrients, turbidity) set with the aim of protecting Lake Tahoe. In this case, water quality sampling data indicated that Big Meadow Creek met Upper Truckee Basin water quality objectives. An unwritten assumption was that improvement of water quality (specifically temperature and sediment) within the allotment would meet downstream objectives in Big Meadow Creek and Lake Tahoe.

Review/Summary of Meiss Grazing Allotment Case The analysis focused on components of the stream system that were most sensitive to the management activities (streams were stratified). Assessment of condition was based on field measurement of indicators. The comparison of alternatives did not use models; the evaluation criterion was the probability (rated in subjective terms) of each alternative's chance of meeting the stated objectives. There were clearly defined resource objectives or "desired conditions" against which to compare existing conditions.

Case 2: Last Chance-Clarks Creek (Plumas National Forest)

Purpose of the Assessment Evaluate risk of proposed salvage timber harvest on subdrainages within this watershed. Chronic watershed and stream degradation within the watershed was recognized, and a method was needed to assess the relative condition of subwatersheds to both focus future inventories and to assess the risk of salvage logging in the subwatersheds.

Procedure and Findings A two-phase approach was followed, a large-basin analysis coupled with a ecosystem management project. The large-basin analysis followed the steps outlined in the Region 5 Cumulative Effects Handbook (U. S. Forest Service 1988). This included consideration of:

- Beneficial uses of water, with water quality protection criteria including no reduction in channel condition, and no reduction in streamside and riparian vegetation except for incidental situations such as road crossings or as necessary for structural stream restoration.
- Recovery objectives aimed at improving the trend for all channels rated poor, reducing daily maximum summer temperatures to 20˚C (68˚F) in all perennial streams, and increasing the abundance and diversity of riparian vegetation.
- Watershed history, including a description of the levels of both grazing (number of animal unit months) and timber harvest (board feet harvested) from the 1920s on.
- Mechanics for initiating CWE. Accelerated erosion was identified as the primary CWE process. Roads and stream bank erosion were named as primary sediment sources.
- Watershed sensitivity. Alluvial channels and meadows were identified as the most sensitive watershed components in the drainage.

The assessment divided a 40,470 ha (100,000 acre) eastside Sierra watershed into fifteen subwatersheds. Existing information was used to evaluate the condition of each of the smaller drainages using road density, road condition, channel stability, and the ERA procedure as input information. This evaluation was aided by a joint Soil Conservation Service-Forest Service evaluation of watershed, channel, and road conditions conducted in 1989.

Four criteria were used to rate relative levels of disturbance and condition in the watersheds. These were: ERA, miles of stream/mi^2 in fair or poor condition (Pfankuch rating), road density (miles/mi^2), and density of roads with severe erosion problems (miles/mi^2). No attempt was made to weight these criteria. Rather, subwatersheds were ranked for each, and a clear trend was apparent. Three of the watersheds (Clarks, Cottonwood, Granite) rated very high (poorest condition) for all criteria, indicating they had greatest need for additional analysis and treatment. Another four basins were classified in the next condition class.

Recommendations for management included increased use of appropriated funds targeted for restoration (versus KV [Knudsen-Vandenberg] funding, which is generated from timber sale receipts), road improvement planning and funding, accelerated revision of allotment management plans (AMP), linkage of AMP and salvage sale planning in these watersheds, revised approaches to post-wildfire treatments, and increased monitoring of poorly understood system components (e.g., vegetation recovery rates).

The information presented in the Last Chance Assessment served as an impetus for the second phase of the overall evaluation, the Clarks Creek Ecosystem Management Project. A desire to conduct salvage logging within the watershed was the primary project driver, but the larger scale Clarks assessment caused a different approach to be taken.

Site specific analysis of the basin revealed that both stream channels and riparian areas were far below potential condition. Stream bank erosion and sloughing rates were high. Riparian plant community diversity and vigor was low. Grazing and roads were identified as the two primary factors contributing to the poor condition.

As the project was planned, the following objectives were set: (1) increase upper bank and flood plain ground cover to 95% live vegetation, (2) increase tree-shrub layer riparian cover to 35% (low-flow period), (3) reduce ERA value to below 80% of the TOC (see ERA description), and (4) reduce road erosion by 50%.

Planning for timber sales, allotment management, and restoration were conducted concurrently. Management strategies were revised, roads were closed, and stream bank restoration undertaken.

<u>Review/Summary of Last Chance-Clarks Creek Case</u> The discussion of watershed history laid out plausible cause-response scenarios for causes of the current condition, and helped to identify key watershed processes and mechanisms. Existing data from a variety of sources were used effectively. The initial large-scale assessment identified issues and characteristics common to all subbasins, and provided a logical basis for addressing smaller-scale issues. The need for integration of planning across functional boundaries was a predictable outcome of the landscape-scale analysis, this in turn produced a link between management and restoration prescriptions. ERAs were essentially used as a screening tool (along with road density and channel condition) in the large-scale analysis. Though carried through as a condition criteria at the smaller (Clarks Creek) scale, other basin-specific criteria were added (e.g., miles of road and channel and riparian condition indicators).

<u>Case 3: Lower North Fork Cosumnes River (Eldorado National Forest)</u>

<u>Purpose of Assessment</u> Evaluate susceptibility to adverse cumulative off-site watershed effects. The specific case reviewed was the Lower North Fork Cosumnes River CWE analysis.

<u>Procedure and Findings</u> The same steps outlined in the Last Chance-Clarks example were employed in this case. Forest planning watersheds (approximately 1,200-4,047 ha [3,000-10,000

acres]) were the unit of analysis. CWE susceptibility using ERA was based on a comparison of the calculated ERA value and the TOC for that watershed. Risk levels ran from low (<50% of TOC) to very high (>100% of TOC). This comparison served as an initial screening of condition, which was then modified by using watershed and stream condition information, a rating of the quality of information used in the screening (good data means higher confidence), and as needed, additional field survey of watershed and channel condition. Risk levels corresponded to different levels of resource protection during project implementation.

Watershed sensitivity rated very high, primarily due to a large proportion of inner gorge land, and soils with very high erosion hazard. The level of ERA disturbance was calculated at 5.2%, about one-half of the recommended TOC. An overall risk level of moderate was assigned to the watershed due to a lack of fishery habitat condition data, poor condition of the Upper North Fork watershed, and long-term drought conditions which may have delayed triggering of adverse effects.

<u>Review/Summary of Lower Nork Fork Cosumnes River Case</u> The results are tied to management prescriptions. Assessments take into account the availability and quality of data. The analysis addresses a larger scale. As disturbance levels increase (as measured by ERAs), the need for assessment of field conditions increases.

<u>Case 4: Peppermint-Holby Watersheds (Sequoia National Forest)</u>

<u>Purpose of Assessment</u> Objective of this evaluation was to assess the risk of a planned timber sale activity on two watersheds each approximately 1,200 ha (3,000 acres) in area.

<u>Procedure and Findings</u> A modified version of the ERA method was employed. Historic and planned activities were given disturbance values, to which a delivery coefficient was applied. The delivery coefficient was a product of six factors including slope, delivery distance, ground cover, and soil characteristics. Six other factors were used to derive a watershed sensitivity rating. These factors were soil, topography, climate, geology, vegetation, and channel type. A TOC was assigned to each watershed based on its sensitivity rating. Calculated ERA values were then compared to the TOC to evaluate the risk of adverse impacts. A monitoring plan was developed to track the response of in-channel variables to the management activity. Monitoring factors included fish habitat typing, macroinvertebrates, and turbidity.

<u>Review/Summary of Peppermint-Holby Watersheds Case</u> The need for monitoring was recognized and addressed. Watershed sensitivity was recognized and channel condition was used as a sensitivity component.

<u>Lessons Learned from the Case Studies</u>

NEPA promotes actions which will minimize environmental damage, and develop an understanding of the interrelationships of all components of the natural environment and the effects of human activities on the environment. It requires that direct, indirect, and cumulative effects be considered when conducting an environmental analysis.

The four cases reviewed had different objectives, but, as with any CWE analysis, they sought to provide the decision maker and the public with a clear picture of the condition of the resource, relevant issues, and possible consequences of alternative activities. In reviewing the case studies, some basic questions were asked. To what degree did the analysis reach these objectives? How well are the components and interrelationships understood? And, does the analysis help the decision maker take actions that minimize environmental damage?

The answers are somewhat nebulous, as might be expected from cases using different methods to assess different issues at different times and places. Each analysis presented information that could help a decision maker in assessing risk. Some of the analyses are quite clear while others require futher explanation for the decision maker and public to best put the information (and therefore the amount of acknowledged and unknown risk) in perspective. Condition (and analysis) indicators closest to the uses of concern (or the issue of concern) are probably best at clearly describing the condition. In other words, "temperature in degrees" is probably a better indicator than "percent shading," and certainly better than "amount of timber removed."

None of the analyses did an adequate job of describing the interrelationships between system components and processes. They can best be seen as indices rather than assessments of cause-effect relationships.

Integration The case studies showed very little evidence of public or interagency involvement. Such interaction is essential in identifying (or verifying) issues and beneficial uses, and in assembling the most accurate description of historic conditions, events, and patterns. (The one exception is the Sequoia example. The analysis procedures were developed as part of a mediated settlement that included extensive public involvement).

The degree of interdisciplinary assessment varied, but was generally low. The Meiss example centered on fisheries habitat, which was appropriate, but integration with watershed processes was not strong. Integration of resource functions in the other cases was weaker. In almost all cases the uses of concern are biological in nature, and the mechanisms are often physical; there is a need for improved integration between physical and biological specialists.

Watershed History and Disturbance Regimes The Last Chance case provided a good description of watershed and beneficial use history. The Meiss case did this to a lesser extent. Consideration of historic conditions (i.e., management history), with the intent of helping to explain how a particular watershed functions, is an important element that should receive more attention in CWE analysis.

With the exception of the Last Chance case, existing condition was not discussed in the context of historical trends. Discussion of the trends (some indicator of condition) relative to a desired condition or objective, and how alternatives might affect these trends is valuable but was generally lacking. In the simplest terms, discussion of conditions should describe what the conditions are, what they were in the past, and how alternative management activities might affect them in the future. The consideration of past conditions (especially as influenced by historical activities and disturbances) should greatly assist specialists in evaluating the potential impacts of alternatives on existing conditions.

In general, there was little discussion or inclusion of disturbance regimes (natural or induced) in the case studies. Disturbance regimes should be a component of historical reviews and should also be included in discussions of risk. In general, the ERA-based approaches (except for references to the effects of drought) seem to assume a static system in terms of natural influences. The Sequoia approach did include climate as a component of watershed sensitivity, but this approach probably diminishes the considerable influence that climatic variation plays in the response of most watersheds to land disturbance activities.

Spatial Scales Three of the four cases attempted, in various ways, to link the analysis of a relatively small watershed to a larger-scale area (i.e., effects farther downstream). Of the four cases, only the Last Chance analysis started at a larger scale and worked upstream to the smaller basins. Beginning with the larger-scale analysis seemed to produce several positive outcomes:

- The "importance" of the smaller drainage relative to larger scale effects was known.
- The large-scale processes, issues, and conditions were known.

- Broad-scale analysis established a priority for evaluation of the smaller drainages. Based on selected criteria, the highest priority areas are identified for further analysis, management, or other action.

Watershed Processes Important watershed processes were clearly identified only in the Last Chance case. The Eldorado and Sequoia cases considered these processes to some degree in their assessments of watershed sensitivity, but they focussed on structural landform sensitivity rather than on dynamic processes. The Meiss analysis addressed condition, and desired condition. The criteria selected for analysis indicated an understanding of stream and riparian processes, and the effects of the proposed management alternatives on those processes, though they were not specifically described. To some extent, key processes can be inferred from the selection of ERA as the measure of disturbance (e.g., in the Sequoia case, sediment is identified as the process of concern), but an explict discussion of watershed processes is recommended.

Watershed-Aquatic System Condition and Models All but one case used more than one criterion to characterize disturbance or condition. In at least one case, the channel criteria were not quantified. Two of the cases relied heavily on condition indicators (versus models or projections). We believe that, historically, USFS approaches have not stressed condition enough, and that future attempts at CWE assessment should place greater emphasis on condition assessment. Methods of assessing condition may vary, the interpretation of data may be difficult or even contentious, but given the error factor associated with nearly every predictive model, more discussion of existing condition (and implications for future management) is warranted. The ideal cumulative effects analysis would clearly distinguish indicators of disturbance (which carry a risk of affecting condition) and indicators of condition, which include the influence of past disturbance.

The Last Chance case, for example, benefitted by describing effects on beneficial uses (e.g., downstream reservoir sedimentation) to support the finding that the watersheds were in poor condition. This is in contrast to techniques which calculate a disturbance indicator, and use it to infer condition. The assessment of the Meiss Grazing Allotment essentially used no disturbance indicators; rather the analysis was of condition, and again (as with Last Chance) poor condition of channels was taken to mean that problems existed.

The recognition of the importance of sensitive lands affecting processes was generally lacking in all the cases. Perhaps this recognition is documented elsewhere (e.g., forest standards and guidelines) and is therefore implied in all analyses, but the analyses reviewed seemed to assume that impact of disturbance on beneficial uses is equal on all landforms and locations. The Sequoia example did account for sediment delivery by considering a variety of factors, including slope and soil texture and distance to streams, but the difference between response and delivery was not explained.

Assessment of Risk The Eldorado assessment included the preparer's level of confidence in the analysis. Because CWE analysis is essentially a risk assessment, it is important to clearly identify the limitations of the analysis, so this can be weighed against potential impacts. The other cases are mute on the level of confidence, though the Meiss and Last Chance cases infer a level of confidence in the explanation of the analysis procedures.

Monitoring Only the Sequoia example included monitoring aimed at validating assumptions made during the analysis. Both the Last Chance and Meiss cases include monitoring to see if conditions meet objectives. Given the present uncertainty in the veracity of currently-available predictive tools, and the uncertainty of assumptions made in more subjective evaluations, an increased level of monitoring is necessary.

WATER RIGHTS AND ADJUDICATION AS ELEMENTS OF CUMULATIVE WATERSHED EFFECTS DECISIONS

This section is not based upon extensive research on water rights or associated procedures. It is based on discussions with staff employees of the California Department of Fish and Game and the California State Water Resources Control Board (SWRCB).

Long before cumulative effects were recognized in the regulatory arena (e.g., NEPA, CEQ), issues that effectively were "cumulative" in nature were addressed through the water-rights system. This section presents two hypothetical illustrations of how California's water-rights systems relates to cumulative in-stream uses of water.

<u>Example 1</u>

An owner of property located on a watercourse observes in the summer of 1993 that the stream dries up. The owner, and other nearby owners of streamside property, expect inappropriate upstream diversions by a country club and mine as the cause. Analysis of historical flow records by staff of the SWRCB shows that although flows varied fifty-to-seventy years ago, the watercourse was seldom dry, or was dry for very short periods of time. More recently (ten-to-thirty years ago) the channel was often dry, and for long periods of time (sixty-to-ninety consecutive days). During the later period (from 1960-1980) development increased drastically relative to the earlier period. This suggests some sort of cumulative impact causing the reduced flows. This scenario quickly leads to a water-rights assessment. Primary players in this scenario are the SWRCB and the court system.

Although "riparian" and "appropriative" rights are typically the two primary rights in this type of situation, two additional types of rights, "pre-1914" and "Spanish land grant," may be involved. Spanish land grant rights are very old and are essentially untouchable by court action. A downstream holder of a Spanish land grant right can successfully adjudicate an upstream holder who does not have a Spanish land grant right.

Although the Board has full knowledge of pre-1914 rights, the actual authority on pre-1914 rights is not as clear. As an example, a legitimate pre-1914 right could take 100% of the flow on a hypothetical watercourse. However, if a state agency (e.g., Department of Fish and Game) cites a formal regulatory edict (e.g., to retain a healthy fishery) which conflicts with the 100% flow pre-1914 right, the SWRCB may be reluctant to step in; the Board may offer a recommendation, for instance to pass through additional flow to support the fishery, but often will not go beyond the recommendation stage.

Riparian rights allow the holder of property adjacent to a watercourse to use water directly; it cannot be stored for use in another season (e.g., cannot pump in winter for use in summer). Riparian-right holders are subject to SWRCB authority, but the SWRCB does not have jurisdiction over riparian rights and the process is not simple. Resolution of conflicts is typically accomplished through court action. Riparian-right holders are required to register their right with the SWRCB, but the SWRCB does not pursue this requirement aggressively and the extent of registration is not known. This means that the amount of diversion or water use is effectively unknown on non-adjudicated watercourses.

Holders of appropriative rights are subject to SWRCB jurisdiction and regulation. This type of right is for a given amount of water during a given season at a given location.

In disputes exemplified by the drying up of the watercourse, a basic intent of the SWRCB staff is to balance the interests of riparian- and appropriative-rights holders at the lowest possible level of conflict. Although riparian-right holders typically have the most fundamental water right, in this case, evaluation of the hydrologic flow data suggests that current water diversion is not the cause of the cessation of flow; flow was intermittent during the 1960s, and possibly earlier. The cause is unknown but most likely is a combination of diversions, including uncontrolled riparian uses.

Options include the following: (1) develop an informal agreement among the parties, (2) issue a "finding" by the SWRCB (a report giving the staff's opinion on the solution of the dispute), (3) one party requests a hearing before the SWRCB to present evidence to convince the SWRCB of the validity of their claim, and (4) sue the SWRCB. In option (3), the adjudication will allocate all water in the basin, with the court deciding a fair and reasonable partition among all users. This action can result in losses of water to riparian-right holders and it effectively converts riparian rights to appropriative rights. One outcome of the adjudication is the establishment of a Water Master who administers the judgment of the court. Federal Water Masters are currently in place on the Truckee, Walker, and Carson Rivers.

An allied function of the SWRCB is the duty and obligation to review water rights in light of the public's use of water. The recent Mono Lake court decision exemplifies this "public trust" issue. Legitimate rights were held by Los Angeles for water from multiple watercourses influent to Mono Lake (i.e., a cumulative effect). In the Mono Lake ruling, the court broadened the previous scope of the public trust to include fisheries, recreation, and other activities and resources in finding that drying up the inflows to Mono Lake was damaging to the public trust. The watercourse referred to in Example 1 may well have been damaged with respect to the public trust. But the only way to make this determination would be court action bringing in all diverters and riparian users.

<u>Example 2</u>

If the town of Plymouth needs 10 cubic feet per second of water to meet projected growth demands, it will file an application with the SWRCB outlining needed facilities, places and type of water use, and other relevant information. As part of this process, Plymouth will eventually document its perspective on fishery concerns. The California Department of Fish and Game (CDFG) does not usually comment on this type of project until notice is made publicly of the project. SWRCB staff reviews Plymouth's documentation and responds with a list of actions needed to comply with the California Environmental Quality Act (CEQA), or to prepare a NEPA document, if appropriate. All issues relevant to CEQA (e.g., bypass flows, fisheries enhancement, wildlife areas, improvements to distribution facilities) must be addressed or mitigated foAfter receipt of this documentation, the SWRCB decides if a negative declaration is adequate or if a complete environmental impact report (EIR) is required. If Plymouth doesn't have the resources to prepare an EIR, the SWRCB may prepare its own EIR, requesting relevant information from Plymouth. The project is then reviewed by the appropriate state departments, and CDFG eventually recommends action on the project after determining in-stream flow needed, effects on riparian vegetation, and other relevant issues. Disagreement among the parties (i.e., CDFG and Plymouth) can go to a formal hearing with presentation of legal arguments. In this scenario, the SWRCB decides the final course of action.

SUMMARY AND RECOMMENDATIONS: COMPARATIVE ASSESSMENT OF CWE METHODOLOGIES

The numerous approaches taken to CWE assessment offer a wide range of options for use in the Sierra Nevada. An area like the Sierra Nevada has a myriad of governmental, quasi-governmental, and private organizations and individuals that either own land or have an acute interest in land management. Agreement on the adaptation of a single (or even a small number of) CWE methodologies may be extremely difficult. Considerations are numerous and include cost of implementing the methodology, skill level and expertise needed, "defendability" of the procedure in a court situation, and availability of input data. Rather than make assumptions about these considerations, we list desirable attributes of a CWE methodology. The procedure(s) should:

- Be scientifically rigorous and specifically link natural or human-induced causes for system changes on the hillslope or in the channel with implications to downstream beneficial uses (e.g., fisheries, domestic water supply).
- Prescribe direct, specific management actions keyed to information collected in the affected basin.
- tie management prescriptions to conditions in the stream, causes for those conditions, and hazards in the watershed,
- include physical and/or biological measures that prompt change in management,
- include all major land uses (e.g., recreation, urbanization, mining, timber harvest, grazing),
- include a monitoring component to determine if prescriptions are implemented as specified,
- assess and track the temporal and spatial distribution of impacts from past actions,
- be structured so that results of the analysis are repeatable and readily verifiable,
- screen levels of disturbance so that the level of the analysis effort matches the severity of disturbances and/or condition of basin,
- incorporate a landscape scale (versus "project" scale), and
- involved all major stakeholders as full partners from the beginning of the process.

An underlying premise is the importance of specifically documenting the logic of all steps undertaken. In this sense, a CWE model or procedure should be seen as a tool, and should not be blindly applied without identification of relevant site-specific issues, processes, values, and concerns.

On a Sierra-wide scale, we believe a method is needed to screen for locations in particular need of a CWE assessment and to generate a priority listing of CWE assessment locations. This screening should include in-channel biological criteria because in-channel attributes often integrate the consequences of hillslope activities. In-channel processes, functions, and attributes also are generally less variable than hillslope attributes, and are consequently better indicators of ecosystem condition. We also see hillslope disturbance as a second important criterion for ranking of sites for CWE analysis.

Once a locality is chosen for CWE assessment, an area-specific screening is needed to identify (a) the socio-economic-cultural issues, values, and concerns which will be distinct to each locality, and (b) the intensity of analysis required. Input to these decisions, and subsequent derivations of watershed history and assessment of current ecosystem processes, require a broad interdisciplinary view of how the specific watershed works, and the involvement of all interested publics. Once the issues, values, and concerns are evaluated and documented, and the intensity of analysis determined, the analysis can move to a more technical phase traditionally conducted as part of many of the currently-available CWE methods.

The method that most closely matches these criteria, and the two-phase approach envisioned above, is Watershed Analysis. This approach, particularly the Washington state version of Watershed Analysis, appears to incorporate the best procedural steps to assure a high likelihood of success. The practitioners of WWA report positive results (e.g., as of August 22, 1994, every WWA had been carried to completion, with participation by all stakeholders [Kate Sullivan, Watershed Analysis Workshop, Portland Oregon, personal communication]). These initial successes imply that the procedure does work. The federal WA may work equally well, or better. Because federal WA projects were not completed at the time of the writing of this report, the veracity of the federal approach is still unknown.

From a procedural perspective, a major selling point of WWA is its codified structure with specific timelines and required results. Another advantage is the inclusion of a formal hand-off process between the scientist and manager. Major pluses of both FWA and WWA are their focus on science-based decisions and the link between causative processes and channel responses. In addition, WWA typically produces specific management prescriptions. The common occurrence of mixed ownerships in the Sierra Nevada is not dealt with well by procedures currently in use in the Sierra. WWA incorporates a codified process that appears to effectively address the mixed ownership dilemma.

WWA could not be transparently applied to the Sierra Nevada. Because the focus of WWA is anadromous fish, the approach would need to be modified for the Sierra. In this sense, FWA is more flexible. Other distinguishing features of the Sierra Nevada would also need to be incorporated into the procedure. Revisions of this type should not be inherently difficult. Both FWA and WWA are flexible procedures meant to be adapted to local conditions.

A comprehensive Watershed Analysis-type approach requires time and money. Agencies that can now produce an ERA analysis in a few weeks involving one or two staff members, may not be willing to accept the expense and time needed for completion of a Watershed Analysis. Watershed Analysis does not assure that all problems will be solved. Scientific unknowns still surround many process links. Understanding of these process links is central to assessing cumulative effects. We argue, however, that while a Watershed Analysis-like process may be relatively costly in dollars and expertise, investment is recouped over the long run, because the results of the process are agreed to by major stakeholders and management can then proceed with little fear of future appeal.

We further realize that regulatory constraints may inhibit Watershed Analysis-type management in the Sierra Nevada. Without FEMAT-based authorities, it is unclear how Watershed Analysis-type approaches could be integrated into the national forest planning process, or if exceptions to that process could be instituted. We believe, however, that a Watershed Analysis-type approach is an important advance worth pursuing.

To the extent that a science-based approach for CWE analysis compliments Ecosystem Management, and to the extent that other states (e.g., Washington) may be considered to be setting a standard by using Watershed Analysis, serious evaluation of Watershed Analysis, or a similar methodology, should be considered for the Sierra Nevada.

As a follow-up recommendation, we suggest that two workshops be convened. The first would involve practitioners and developers of Watershed Analysis-type approaches. It would be aimed at assessing and documenting the realistic opportunities for adapting a Watershed Analysis-type procedure to the Sierra Nevada. Participation by current users of Watershed Analysis, particularly USFS and Washington State department staff and industry representatives, and their counterparts in California, plus developers of Watershed Analysis from the federal and Washington state consortiums, should allow for a comprehensive and open discussion of the pros and cons of Watershed Analysis relative to the Sierra Nevada. Hopefully, in this scenario, potential concerns held by major stakeholders about adoption of a Watershed Analysis-type process would be voiced. This workshop should also address methods for ranking watersheds in the Sierra Nevada for priority CWE analysis. We believe that none of the currently-available methodologies do a good job of screening at this scale.

A second, follow-up workshop should involve managers and decision-makers. This group should have the wherewithal to assess the results of the first (technical) workshop in terms of the political and institutional realities of instituting a Watershed Analysis-type approach to the Sierra Nevada. For instance, are resources actually available to pursue a science-based Watershed Analysis-style approach? Do regulatory restrictions (e.g., requirements of the national forest planning process) limit opportunities for a Watershed Analysis-type approach, and if so, what options are available to deal with the restrictions?

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Appendix 1. CWE Methodology Questionnaire

Name: Date:

Position & affiliation:
Location:

Knowledge of emerging CWE methodologies not yet in print

Knowledge of unique or critical biogeoclimatic or socio-political elements of the Sierra Nevada relevant to CWE assessment

> Any distinctions between subregions within the Sierra (e.g., southern, central, northern, eastern) re: CWE (or perhaps more broadly re management impacts—not necessarily cumulative)

Recommendations on CWE methods (existing or emerging) for use in the Sierra Nevada

Recommendations on necessary qualities of a CWE method appropriate to the Sierra Nevada

Any general considerations about the utility, value, and applicability of specific CWE methodologies

Suggestions on knowledgeable individuals in the field or recently published (or draft) versions of manuscripts on CWE methodologies

Do you know of any court cases involving CWE? If so, any specific information (e.g., issues or names of contestants)?

Do you make CWE determinations?

<u>Practitioners</u>

(i) what procedure do you currently use?

(ii) why do you use it (e.g., mandated by agency? best known method?)?

(iii) what product (specifically) is produced?

(iv) how big are the basins (what geographic scale is addressed)?

(v) what time frame is addressed (do you/how do you incorporate potential future activities, & if so how?)?

(vi) What are the data requirements of the method you use (e.g., topographic quads, photos, land-use history, water quality info)?

(vii) how do you handle mixed ownership situations (how successful [or what types of situations are more likely to yield success] in mixed ownership situation)?

Do they get adequate info in mixed ownership situations?

If so, how?

(viii) what types of management activities do they look at (harvest only? grazing, mining, recreation...?)

If you deal with multiple activities, how do you link them?

(ix) If you had more data, resources, $$, or labor would you have done things differently--a fleshed out product (if so what?)

(x) How would results differ (if had more resources [$$, data, labor])?

(xi) Do you analyze actual watershed (geomorphic) processes? If so, how?

(xii) Do you deal with a range of beneficial uses? If so, what? If not, what is your beneficial use?

(xiii) Do you have any natural resource issues of concern (e.g., site productivity? sediment yields? channel condition? flood flows? fisheries? general water quality? water yield? water temperature? aquatic habitat? onsite vs. downstream? overland flow runoff?)

(xiii) What would you like a CWE methodology for the Sierra Nevada to do differently/better?

(xiv) Any other comments about CWE and CWE methodologies?

Non-Practitioners

How would you describe your function re CWE analysis (researcher? manager? ____?)

What would you like a CWE methodology for the Sierra Nevada to do differently/better?

Any other comments about CWE and CWE methodologies?

Appendix 2. Interviewees

Name	Position/Affiliation/Location
Ann Carlson	Forest Fish Biologist, Tahoe National Forest, Nevada City, CA
John Cobourn	Water Resources Specialist, University of Nevada Cooperative Extension, Incline Village, NV
Larry Costick	Post-graduate researcher, Sierra Nevada Ecosystem Project, University of California, Davis
Sally DeBecker	Technical and Ecological Services, Pacific Gas and Electric Company, San Ramon, CA
Jim Frazier	Forest Hydrologist, Stanislaus National Forest, Sonora, CA
Kass Green	President, Pacific Meridian Resources, Emeryville, CA
George Ice	Research Forest Hydrologist, National Council of the Paper Industry for Air and Stream Improvement, Inc., Corvallis, OR
Matt Kondolf	Associate Professor of Environmental Planning, Department of Landscape Architecture, Univeristy of California, Berkeley, CA
Stafford Lehr	Fish Biologist, California Department of Fish and Game, Pollock Pines, CA
Dale McGreer	President, Western Watershed Consultants, Lewiston, ID
Walter Megahan	Program Manager, National Council of the Paper Industry for Air and Stream Improvement, Inc., Pt. Townsend, WA
Chuck Mitchell	Forest Resource Officer, Eldorado National Forest, Placerville, CA
Louis Moeler	Associate Water Resources Control Engineer, Division of Water Rights, Complaints Unit, California State Water Resources Control Board, Sacramento, CA
John Munn	Project Leader, California Department of Forestry and Fire Protection, Sacramento, CA
Robert Nuzum	Director, Department of Natural Resources, East Bay Municipal Utility District, Oakland, CA
Leslie Reid	Research Geologist, Pacific Southwest Research Station, U. S. Forest Service, Arcata, CA
Winston Wiggins	Assistant Director, Forestry and Fire, Idaho Department of Lands, Boise, ID
Nick Wilcox	Environmental Specialist, California State Water Resources Control Board, Sacramento, CA

Appendix 3. Core Questions for Assessment of Case Studies

Review of the case studies, the steps outlined in the Federal Agency Guide for Pilot Watershed Analysis, and the attributes of a successful CWE methodology described by Reid (1993) contributed to this set of core questions through which the strengths of the case studies were evaluated:

Are the key CWE issues identified?

Are the key system functions and processes which influence those issues identified?

Are the mechanisms which affect function and process identified?

Is there analysis of landform sensitivity (i.e. do some landforms influence or react differently than others)?

Is there recognition of disturbance regimes that drive the processes?

Is there recognition of system component recovery rates (especially that cause and response components may recover at different rates)?

Is the analysis conducted at the appropriate scale, and linked to evaluations of other scales?

Is the procedure flexible enough to account for local conditions, and accept developing technologies?

Does the end product clearly define risk?

Are current conditions described? Are past conditions described? Is a plausible cause-response scenario described which supports the analysis used to predict future impacts?

Are trends defined?

Are analysis procedures technically sound?

Are limitations of the analysis made clear?

Are key questions monitored?

Does the process provide the decision maker with information so that a decision can be made with some degree of confidence?

Does the process tie (logically, clearly) to the issues and beneficial uses?

Are the procedures appropriate for the scale of the analysis? Is there a tie between scales?

Is there any accounting for time scales in assessment of process?

Are the results linked to management prescriptions?

Does the process use all appropriate available information?

What are the key large scale issues and watershed-aquatic processes?

What are the mechanisms important to these processes? Have the mechanisms been active in a time scale relevant to display effects (e.g., fire or 10-year storm)?

What are indicators of this process?

What is the condition as displayed by these indicators?

How will alternatives affect condition?

In particular, what about sensitive lands?

What is the time scale of the response-effect? When might the responses occur? How long will they last? How great is the risk (i.e., are we playing with a firecracker, a grenade, or a bomb?)?

Is the relative accuracy of the assessment made clear?