November 21, 2011

Comments Via Email: ForestPlan_Comments@waterboards.ca.gov

Gaylon Lee
Division of Water Quality
State Water Resources Control Board
1001 I Street, 15th Floor
Sacramento, California 95814

Re: Comments on Revised Waiver and Monitoring Section

Dear Mr. Lee:

Thank you for the opportunity to comment on the revised draft Waiver of Waste Discharge Requirements for Nonpoint Source Discharges Related to Certain Activities on National Forest System Lands in California (revised Waiver). These comments are submitted on behalf of the Central Sierra Environmental Research Resource Center, Environmental Protection Information Center, Center for Sierra Nevada Conservation, High Sierra Hikers Association, Sierra Forest Legacy, the Western Watersheds Project, Forest Issues Group, Public Employees for Environmental Responsibility, Wildlands CPR, The Wilderness Society, Los Padres Forest Watch, Defenders of Wildlife and California Watershed Network.

I. INTRODUCTION

On behalf of the organizations collaborating in the submission of these comments, we provide this input in response to the revised Waiver and Attachments relating to monitoring. Based on our review, it does not appear that the substantive changes made to the revised Waiver and attachments avoid the potential that the Waiver activities will have significant impacts to water quality on National Forest system lands. In addition, the changes to the Waiver monitoring fail to raise the minimal level of monitoring or to provide assurance that waiver-approved actions will be adequate to protect water quality. In sum, the revisions continue to fail to address key problems that we identified in previous comments. The waiver as revised and the unchanged BMPs that form the basis for the U.S. Forest Service Water Quality Management Handbook (WQMH) collectively remain inadequate. As now presented, they cannot provide the public with any assurance that water quality violations will be detected or that remedial action will be mandated for water quality degradation on National Forest lands.

Our coalition of environmental groups submitted detailed comments previously with specific reasons why the State Water Board should strengthen and revise the waiver and the USFS WQMH. Despite those detailed comments, the latest revised version of the waiver significantly fails to meet legal obligations. With the revised waiver, the State Water Board continues to rely on unfounded assurances from the U.S. Forest Service that water quality is being adequately protected on National Forest system lands and that new and improved BMPs will sufficiently prevent water quality impacts caused by approved activities during the new waiver period.

In reality, as shown by the evidence submitted with these and our prior comments, demonstrate that past and current Forest Service management based upon BMPs has failed to protect water quality. Future Forest Service activities authorized by the revised Waiver will increase the already significant impacts to water quality, affecting water resources across millions of acres of National Forest lands,. The revised waiver fails to provide a clear and effective program of monitoring that will identify where Forest Service approved activities will result in measurable degradation of water quality. Most important of all, the revised waiver continues to fail to provide any consequences or mandates for rectifying management or altering project activities that degrade water quality once monitoring shows evidence of violations.

II. SPECIFIC COMMENTS RELATED TO WAIVER REVISIONS

A. Continued Failure of Revised Waiver to Establish Actual Performance Standards to Protect Water Quality.

The revised Waiver states that it relies on Forest Service BMPs as "performance standards," as follows:

> The USFS BMPs are <u>programmatic performance standards</u>, not detailed prescriptions nor solutions to specific nonpoint pollution sources. Rather, they are <u>action-initiating mechanisms, processes, and practices</u> that call for the development of site-specific detailed prescriptions designed at the project scale during planning. Development of prescriptions is aided by results from ongoing monitoring, and may also follow direction developed at the National Forests.

This characterization of the revised Waiver and BMPs is demonstrably false. As discussed in our prior comments, the BMPs are not performance standards, but instead simply vague goals that do not initiate or trigger any action on the part of the Forest Service. The changes in the revised Wavier text continue to fail to connect the reality that the BMPs are nebulous, non-measurable, and/or not connected to water quality so that whether or not BMPs are implemented in most cases will not result in any clear protection for water quality on National Forest lands.

Examples of nebulous BMPS are numerous. For example:

> "[R]educe the impacts of erosion and subsequent sedimentation associated with log landings by use of mitigating measures." BMP 1.16 (Log Landing Erosion Control)

> "[P]rotect water quality by minimizing erosion and sedimentation derived from skid trails." (BMP 1.17 (Erosion Control on Skid Trails)

> "[C]ontrol sediment and other pollutants entering streamcourses." BMP 1.19 (Streamcourse and Aquatic Protection)
>
> "Manage livestock to prevent further degradation of riparian areas and wetlands that are not meeting or moving towards desired condition objectives."
>
> "Exclude livestock if monitoring information shows continued livestock grazing would prevent attainment of those objectives."

These and other BMPs do not establish any specific objectives, measurable standards, or triggers that would require the Forest Service to take any action whatsoever. *See* Declaration of Laurel Collins dated November 21, 2011 (Second Collins Decl.); Declaration of Michael Hogan ("Hogan Decl.") *See also* Declaration of Laurel Collins dated August 23, 2011 ("Collins Decl."); Declaration of James R. Furnish ("Furnish Decl.") The BMPs and revised Waiver establish no clarity as to what judgment or who's judgment triggers the need to alter livestock management or at what point "further degradation of riparian and wetlands" is judged to not be "moving towards desired conditions objectives." Vague feel-good language in the BMPs provide no measurable threshold or trigger that will clearly protect water quality. Directives such as excluding livestock if grazing would prevent attainment of the desired condition, or protecting water quality by "controlling" erosion provide no way to measure compliance or a lack of compliance. The State Water Board cannot rely upon positive intentions in the revised waiver text without providing additional specificity, thresholds, and consequences for violations.

In sum, general direction that on-the-ground prescriptions must implement the identified BMPs does not in any way assure that the BMPs will result in protection for water quality. As our coalition of organizations shared in previous comments, the vast majority of BMPs for range management, OHV use, and most other activities on National Forest lands are directives that are nebulous, not easily measured, not clearly connected to water quality protection, or so judgmental that two neutral parties could easily come to opposite conclusions as to whether or not a BMP was implemented.

The decision by the Board not to adopt actual performance standards with measurable triggers for required agency action has the potential for significant impacts to water quality and stream and other wetland resources in California. *See* Collins Decl.; Second Collins Decl.; Hogan Decl.; Furnish Decl. *See also* our prior comments and exhibits. Further, the Board's failure to provide the public with a reasonable alternative to the vague Waiver and BMP language – an alternative that would establish actual performance standards with triggers for required action – violates CEQA's requirements and illustrates again the need for an Environmental Impact Report (EIR) to be prepared for the Waiver project.

B. Continued Failure to Establish an Effective Adaptive Management Scheme.

Adaptive management is likely the most critical component of effectively regulating non-point source pollution on National Forests due to the proven ineffectiveness of existing

BMPs and Forest Service efforts to control non-point source pollution. As discussed above, tor an adaptive management program to be successful in curbing excessive pollution and damage to streams and wetlands, there must be clear standards – measurable in the field through monitoring – that trigger agency action. *See* Collins Decl.; Second Collins Decl.; Hogan Decl. ; Furnish Decl. *See also* Declaration of Eric Holtz ("Holtz Decl.").

The revised Waiver and monitoring attachment, and the Forest Service implementing BMPs, still lacks an effective adaptive management program that will ensure that significant impacts from activities such as logging, OHV road and trail use, and grazing will be avoided in the future. Instead, the revised Waiver, monitoring and BMPs lack clear project objectives (as discussed above), substituting measurable standards of performance with vague policy goals such as protecting water quality or avoiding degradation due to grazing. Collins Decl.; Second Collins Decl.; Hogan Decl.; Furnish Decl. The revised Waiver, monitoring plan (revised Attachment C) and BMPs also do not establish measurable standards that would trigger the need for agency action, nor any timetable that would lead to effective changes to ensure that water quality is protected. The revised Waiver documents also do not require any specific agency response to an ongoing source of pollutant discharge or wetland degradation.

The revised Waiver's failure to adopt an effective adaptive management program means that it will be unsuccessful in avoiding significant water quality impacts in the future, particularly given the Forest Service's lack of adequate budget and resources to monitor and correct water quality problems on the Forests. Collins Decl.; Second Collins Decl.; Hogan Decl.; Furnish Decl.

C. The Revised Waiver Does not Avoid the Potential for Significant Impacts from Grazing

The revised Waiver states that grazing activity or other projects that have potential to have a significant impact on the environment must be treated as a Category B activity. Then in item 50 and subsequent items, the revised waiver discusses sets out a process for the USFS to apply for waiver coverage for ongoing grazing activity. The revised Waiver requires that grazing must be conducted with on-the-ground prescriptions designed to implement the BMPs identified so as to avoid any adverse impacts to water quality.

Despite these additions, the Waiver revisions fail to provide clear language specifying measurable prescriptions or actions to protect water quality and avoid adverse impacts. Instead, the revised text continues to describe administrative intentions that are not directly connected to protecting water quality degradation. In particular, the lack of strong, consistent, and effective water quality monitoring leaves the waiver without the feedback loop to know if general intentions and nebulous BMPs do or don't effectively protect water quality. *See* Declarations of John Rhodes dated November 21, 2011 and August 2011 (Rhodes' Declarations"); Declaration of Robert Derlet dated November 17, 2011 (Derlet Decl.")

The most substantial revision of language in the waiver is found on page 32, where items 12, 13, and 15 have been changed. The revised text now states that a grazing allotment may qualify for enrollment under the waiver if a NEPA analysis and decision are completed during the life of the waiver. This is a classic example of irrational logic. The waiver may be approved for 5 years or it may be rolled over for another 5 years. If after 4 years a grazing allotment is still scheduled for NEPA analysis and an expected decision prior to the conclusion of the fifth year, it would apparently qualify for enrollment. Yet no NEPA would even be completed for the majority of years of waiver enrollment.

The second path to waiver enrollment for a grazing allotment is when no NEPA analysis and decision will likely be completed during the life of the waiver. In this case, the Forest Service can simply collaborate with Regional Water Board staff to still allow the allotment to be enrolled. The only caveat is that the permittee must agree to some nebulous lease terms modified to satisfy water quality requirements. Since the U.S. Forest Service at the Regional level currently insists that current livestock management meets water quality standards throughout the Region, it is clear that major changes will clearly not be required of permittees to "satisfy water quality requirements." Similar to the completely nebulous unspecified and non-measurable content of most BMPs, the new revised waiver text that allows enrollment of allotments without NEPA decisions is simply nonsensical rhetoric. For example, for allotments without NEPA or a decision during the life of the waiver, the revised waiver text calls for the Forest Service to submit the following to the affected Regional Water Board: "the pertinent available NEPA documents… record of decision, and allotment management plan." The category just described these allotments as those without NEPA completed and without an approved decision. Then it suggests that the Forest Service should share NEPA and the record of decision with the Regional Board.

In reality, hundreds of allotments throughout the Region have no NEPA documentation and analysis, nor do they have any record of decision. Yet the revised text in item 12 and item 13 on page 35 makes it clear that it is the intent of the State Water Board that unless there is proven evidence of water quality violations, the Water Board intends to allow the hundreds of non-NEPA allotments to continue enrollment in the waiver until NEPA eventually gets done or the waiver eventually expires. Thus all that rhetoric boils down to the fact that without proof of water quality violations in an allotment, all allotments will be allowed to enroll in the waiver despite no analysis of their impacts and despite no requirements in the allotment management plan that water quality be protected through specific actions.

Finally, one item of text revision deals with benefits justifying some level of impact to water quality. As stated in the third paragraph on page 20, any limited degradation of water quality that may occur is to be consistent with maximum benefit to the people of the state. When it comes to grazing the waiver describes range management as beneficial for the public because it provides natural fodder for livestock, supposedly helping to hold down food costs. We do not believe that this approach is consistent with the Water Code or the Clean Water Act. Further, the suggestion here that further degradation of already significantly degraded wetland areas will be permitted under a theory of multiple use would still require a full CEQA analysis as part of an EIR. Given the existing impacts that have occurred due to essentially unregulated grazing, the Water Board may not take an action that authorizes grazing activities causing future water quality degradation pursuant to a negative declaration under CEQA.[1] *See also* Ex. 7 attached.

1. Changes Made to Grazing Monitoring

On pages 8 and 9 of revised Attachment C, the revised USFS Waiver spells out the Range Allotment Monitoring that is intended to be the primary systematic means for early detection of water-quality problems created by livestock on national forest lands in California.

First and foremost, the USFS is directed by the Monitoring and Reporting Program language to conduct in-stream monitoring for fecal indicator bacteria (FIB) in selected representative high-use recreation sites. The USFS and each affected Regional Board are supposed to collaborate to identify and prioritize designated high-use water-contact recreation sites that are within or immediately downstream of active grazing allotments with recently developed BMPs. While these steps are positive, only a minimum of one such site will be monitored annually in the North Coast, Central Valley, and Lahontan Regions for a total of three such sites. The USFS will collect samples for FIB analyses during the grazing season at intervals that will supposedly be sufficient to determine compliance with basin plan objectives. Standard sampling methods and commercial labs will be used.

With 463 livestock grazing allotments on USFS lands within California and more than 400 allotments being currently grazed, the USFS waiver would only require protocol-consistent FIB monitoring at a single site in three allotments. Just in those three allotments there will be many thousands of acres of actively grazing lands, yet only a single site in each allotment would actually be required to have water quality monitoring. Thus out of tens of thousands of miles of USFS stream corridors and lakeside acres in California that are directly affected by livestock defecation and deposition of fecal indicator bacteria, only three targeted sites would receive any required FIB monitoring consistent with State water quality sampling protocols.

To put this into context, the 2000 Sierra Nevada Forest Plan Amendment EIS showed that 6,459,803 acres of national forest lands in the Sierra Nevada region were actively grazed by cattle, while another 705,282 acres were actively grazed by sheep.

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[1] We note that the revised Waiver's justification on this issue is itself specious and completely unsubstantiated. Only a tiny, minute fraction of livestock animals in California ever grazes on public forest land. Furthermore, the price of beef or lamb is not affected in the slightest by the miniscule percentage of livestock grazing on National Forest system land because world beef prices are now based on availability and demand far beyond the boundaries of the United States. Thus, the supposed public benefit of lower food costs for accepting livestock grazing on National Forest land cannot be justified.

Taken in total, the combined acreage of national forest lands grazed by livestock totaled 7,165,085 acres just within national forest acreage in the Sierra Nevada region.

The magnitude of the livestock grazing impact is at a scale that literally defies clear visualization by the State Water Board. Based on the general figures in the USFS planning documents, over 11,000 square miles of mountainous lands are grazed each year by livestock. Yet across 11,000 square miles of actively grazed land, the FIB monitoring must only be one at three individual sites.

That miniscule amount of protocol-consistent FIB sampling cannot possibly assure that there is effective protection of public health along streams flowing within millions of acres of national forest lands in the State. *See* Rhodes' Decls.; Derlet Decl.

Equally problematic is that even if sampling of that tiny, tiny unrepresentative fraction of allotments reveals that basin plan objectives are actually being violated, no resulting action is triggered nor does the Waiver mandate any consequence (such as removing livestock or reducing subsequent cattle numbers or season of use). All that is required is that the USFS report the FIB monitoring results at least annually to the State and Regional Boards. *See* Rhodes' Decls.; Derlet Decl.

Attachment C of the USFS Waiver also lists additional range monitoring that is to be done within all covered grazing allotments. That additional monitoring, however, either fails to have any direct connection to water quality or the nexus is not measurable.

In Attachment C, each National Forest is directed to do rangeland condition every five years on selected allotments in key areas to track the ecological trend of upland and meadow vegetation. This kind of selective trend monitoring for rangeland condition has been occurring for the past decade on allotments throughout the Region, yet there is no evidence that the trend monitoring has produced any substantial benefits for riparian areas or stream conditions. Instead, the rangeland condition reporting has consistently shown that a large percentage of meadow areas continue to be in fair or poor condition. There is nothing in the Monitoring and Reporting Program requirements that will trigger any significant action for water quality based upon very general rangeland condition trend monitoring. *See* Rhodes' Decls.; Derlet Decl.; Furnish Decl.

Also in Attachment C, each National Forest is directed to inspect allotments to ensure compliance with stocking rates, season of use, allotment boundaries, and other terms and conditions of grazing permits. Such a directive again results in no measurable benefit for water quality.

Within the Stanislaus National Forest, as an example, cows are frequently found by staff of the Central Sierra Environmental Resource Center (CSERC) to be trespassing outside of permitted allotment boundaries. Scattered cows are persistently photographed still grazing on National Forest lands each fall after the off-date for individual allotments has passed. Those violations are always shared promptly with the U.S. Forest Service. Most times no action is ever taken, as can be seen from staff's observation that the trespassing cows are still there days later. Accordingly, in response to Attachment C requirements, whether or not the USFS inspects allotments, violations still occur, and no consequence is mandated for violations of the terms and conditions of grazing permits.

Further, as identified previously inspecting allotments for allotment boundaries and range improvement or other conditions of grazing permits has no direct correlation with protection of water quality. Thus for the purpose of the Waiver, inspection of allotments for terms and conditions does not provide any assurance that water quality will be protected. *See* Rhodes' Decls.; Derlet Decl.

A third monitoring requirement for each National Forest is identified on page 9 of Attachment C. That requirement is that there shall be range utilization monitoring at a minimum at the end of the grazing season to ensure compliance with forage utilization limits. Yet similar to previously cited examples described above, this "monitoring requirement" is an empty directive without any tie to water quality. *See* Rhodes' Decls.; Derlet Decl.

First it is noteworthy that the U.S. Forest Service at public meetings has openly conveyed that it does not have the staff or the resources to actually do range utilization monitoring for each grazing allotment with each national forest. In reality, due to budget limitations, Regional range staff has estimated that 30 to 40% of allotments in the Region actually get monitored by USFS personnel. The remaining 60-70% of allotments either are not monitored or the USFS relies upon the highly dubious reports coming from grazing permittees. Grazing permittees are not only highly biased in that they will not likely report themselves for allowing excessive utilization by their herds, they also are neither highly trained in monitoring or given any consequences for false reporting. Thus the directive for the Forest Service to do range utilization monitoring at a minimum at the end of the grazing season to ensure compliance with forage utilization limits is meaningless. More than half of grazing allotments will never be monitored by USFS personnel in any given season. And even where such monitoring is actually done by USFS staff, there is no direct nexus to water quality impacts.

If cows overgraze a meadow transect area down to the nubs of the grasses to a point below the targeted utilization level, there may be a general relationship that the riparian areas along nearby streams may also be overgrazed. But such a relationship is totally guesswork and does not measure water quality in any fashion. There is no evidence that water quality will be protected from cattle waste by having a key meadow transect with grazing that results in "lower than threshold" utilization targets. Even if the cows don't overgraze that specific meadow strip of meadow, the cows still may stand next to or right in the stream and defecate.

Forage utilization standards do not measure anything directly correlated with water quality. The fact that the Forest Service does not have the staff or resources to even comply with this indirect monitoring requirement further underscores the ineffectiveness of the Monitoring and Reporting program.

The final directive on page 9 of Attachment C of the Monitoring and Reporting program directs the Forest Service to perform BMPEP monitoring annually for randomly selected allotments to assess implementation and effectiveness of the WQMH BMPs. Such a directive seems positive until it becomes clear that this could again be less than one allotment per each national forest. There is no actual water quality monitoring tied to the so-called BMPEP monitoring for effectiveness. Instead, as with other BMPEP monitoring, the monitoring won't measure any real effectiveness of the management practice, but instead will measure whether the management practice was done. If the BMP was done and it didn't protect water quality, it will still be shown as effectively implemented, which does nothing for water quality. Furthermore, the directive says that the BMPEP monitoring will assess vegetation and riparian condition. Yet there is no clarity as to what will be assessed, who will do the assessment, when a violation will be triggered, or what consequence will then take place due to a violation.

All of these criticisms are pivotal to the question of whether or not the Forest Service can be relied upon to fairly and neutrally monitor water quality for impacts from range management activities. In reality, the agency cannot possibly monitor the impacts of grazing to water quality in a fashion that reflects true impacts across 7,000,000 acres of national forest lands just in the Sierra Nevada region alone.

In sum, the monitoring and reporting program:

1) fails to provide an consistent and replicable water monitoring on individual national forests in a manner that would representatively reveal Basin Plan violations in the 411 actively grazed allotments. Instead a minimum of three spots will be so monitored per protocols.

2) fails to acknowledge that even for non-water quality measurements (such as forage utilization) that are directed to be done in each allotment, that the agency does not have the personnel and resources to do those measurements in each allotment.

3) fails to provide any triggers for consequences. If each of the three protocol-consistent sampling sites show violations and if 15% of all allotments show some areas of overgrazing of forage compared to standards, no consequence is mandated.

4) fails to acknowledge that the highly touted BMPEP program does not monitor water quality at all, but instead primarily measures whether checklists of mitigations were implemented.

See Rhodes' Decls.; Derlet Decl.

D. Revised Waiver/ Monitoring Does not Avoid Significant Impacts from OHVs.

The Revised Waiver and monitoring requirements for will not avoid significant sediment discharge from OHV activity. The new waiver changes rely on the Forest

Service's G-Y-R Trail Condition Monitoring program. Under this monitoring approach, however, the Forest Service does not interpret a red condition to require closure. The Waiver conditions also do not require closure of a red area, even though this is G-Y-R policy. Where the Forest Service then lacks the funding to implement restoration, continued OHV use will continue to have significant effects to water quality and aquatic/wetland habitats. *See* Collins Decl; 2nd Collins Decl.

The Waiver conditions also state monitoring will occur annually for high risk areas, and that all OHV trails will be monitored at least every three years. This is inadequate because in any winter season a trail could fail, in which case there would be two entire seasons of significant sediment discharge and damage without any detection or remediation by the Forest Service. In reality, the amount of trails actually monitored on an annual basis will depend on funding, which has been inadequate in the past and will be foreseeably inadequate in the future. *See* Collins Decl; 2nd Collins Decl.

The Waiver conditions also state there will be periodic inspections of OHV routes on a three to five year time frame to identify new unauthorized routes and schedule restoration treatments for routes causing water quality impacts. This time frame is inadequate, as new unauthorized routes could lead to several years or more of OHV impacts on water quality and wetlands before they were even detected. *See* Collins Decl; 2nd Collins Decl. The Forest Service already is aware of numerous unauthorized routes that continue to be utilized by OHVs, without enforcement or restoration. If the Forest Service were to identify sources of sediment pollution coming from unauthorized routes, a lack of staffing and funding in the future would prevent timely if any restoration. *Id.*

In fact, the rate of sediment supply and resulting damage is often considerable within the first hours or days of the initiation of a problem. *See* Collins Decl; 2nd Collins Decl. Lack of adequate inspection following intense storms will provide a persistent conduit for fine sediment delivery, thus contributing to cumulative impacts that will remain undetected by the Forest Service and the Water Board.

The Waiver conditions do not add any standards for when OHV routes must be closed, or even whether an OHV route is causing excessive impacts to water quality. The Waiver states that "monitoring time frames and definitions of triggering events shall be defined in monitoring protocols." The Waiver conditions also provide for a "road patrol" that will "detect and correct" damage on roads and OHV routes in a "timely manner." This section does not provide any information to me about how this will occur. The Waiver states that the protocols for detection and repair procedures will be determined in the future by the Forest Service."

As discussed above, the lack of any discussion in the Waiver documents regarding the actual protocols and standards for determining when a "triggering event" will occur must be discussed as part of an evaluation of whether a regulatory scheme will be able to avoid significant water quality impacts in the future. To defer these determinations to later is unlawful under CEQA and fails to provide the public an adequate opportunity to comment on the effectiveness of the Wavier conditions. As discussed, the Waiver's general lack of quantitative or qualitative definitions or standards associated with what constitutes a "significant" discharge of sediment, or whether closure is required, makes it impossible to understand or assess whether significant water quality impacts will be avoided. The Waiver conditions are not based on any standards but instead are entirely subjective. *See* Collins Decl; 2nd Collins Decl.

As stated by Collins, "How the Forest Service will determine whether a "triggering event" has occurred is a significant issue that should have been presented and discussed according to actual scientifically measurable standards that would trigger remedial action, including closure. In many cases, closure itself can have restorative effects as natural re-vegetation returns to the site. However, where continued OHV use occurs, these sites will continue to be degraded by continued delivery of sediment. In other words, future OHV activity has the potential to cause existing legacy sources of OHV pollution that would otherwise repair themselves over time to instead continue to be significant sources of water quality pollution in the future." 2nd Collins Decl.

In sum, despite Changes to the draft Waiver, MOU and Monitoring and Reporting Program, the proposed Waiver is still likely to have significant environmental effects and therefore requires an EIR. For example, the Rubicon OHV Trail, on the Eldorado National Forest, is under a Cleanup and Abatement Order issued by the Central Valley Regional Water Quality Control Board for pollution resulting from sedimentation, petroleum products and human waste associated with use of the trail. Numerous other roads on the Eldorado suffer similar significant impacts (See Exhibits 1-5 & 7 attached) and if this Waiver is adopted, the impacts will be allowed to continue.[2] This waiver gives the Forest Service a pass on its responsibilities under the Clean Water Act, presumably because it would require too great an effort and too much expense to clean up all the legacy impacts on Forest Service roads and trails.

With regard to funding, we further note that page 5, paragraph 9 of the Waiver has been changed from "….the USFS *does* not have sufficient funding to provide the necessary

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[2] Our prior comments provided numerous exhibits documenting the environmental damage occurring now from USFS roads and trails. Further documentation includes a study (Exhibit 1) showing sedimentation and damage to waterways and riparian areas from roads are supported by a 2006 study based on motorized impacts to resources in the ENF, "Sediment Production and Delivery from Forest Roads in the Sierra Nevada, California," Coe, Drew. Sediment Production and Delivery from Forest Roads in the Sierra Nevada, California. 2006. (Exhibit 1). This Study quantified sediment delivery from ENF forest roads. According to this study, "sediment is being delivered to the streams from 25% of the road network." The same study determined sediment production rates from native surface roads were 12-25 times greater than from rocked roads. That study also explained road sediment delivery can be minimized primarily by reducing the number of stream crossings, rocking the approaches to stream crossings, reducing the length of roads draining to stream crossings, and minimizing gully formation below drainage outlets. Exhibits 2-3 are additional photos documenting ongoing OHV damage on the El Dorado. *See also* Exhibits 4-5 (El Dorado Forest Service road and trail inventory reports.)

road maintenance" to "….the USFS *may* not have sufficient funding to provide the necessary road maintenance…" However, documents submitted by the public during the first comment period, provide solid evidence that the Forest Service does not have anywhere close to the funding needed to maintain its road and trail system. (See Exhibits 100-108 to our prior comments; Declaration of Karen Schambach, Exhibit 25) *See also* Holtz Decl., Furnish Decl. In the face of that funding deficiency, the types of environmental degradation that is evident on California's National Forests will continue and likely worsen.

Our observations are also supported by the ENF Travel Management EIS which cited results of a survey of aquatic features from 2004 to 2007 that shows that 60% of the surveyed stream reaches were receiving excessive amounts of sediment and 90% of the meadows were functioning-at-risk or non-functional. (ENF Travel Management FEIS, p. 3-34).

The Proposed Statewide Waiver regulates NPS activities by conditioning the Waiver on implementation of the new USFS WQMH and other USFS guidelines and policies. One of the cited USFS guidelines is the Travel Management Rule (TMR), which is cited in the Waiver and the IS/MND. There are a number of problems for relying on the TMR as mitigation.

1. Subpart A, which would determine the minimum road system on each National Forest, has not been initiated on most Forests and the Forest Service has no time frame for accomplishing it, nor has it appropriated funding for Subpart A. The IS/MND cannot rely for mitigation on a process that could take years to complete, if ever.

2. Subpart B, which designated which routes would be open to vehicle use on forests, resulted in the designation of some routes that are significant sources of sedimentation. (Exhibits 2 and

3) The Waiver provides a post hoc justification of these designations by another change from the Draft waiver: "Any limited degradation that may occur is consistent with maximum benefit to the people of the state." (Waiver, p. 20) Since many dirt roads on National Forests are so degraded only very high clearance, specialty vehicles are able to navigate them without severe damage, it cannot be reasonably argued that the degradation is consistent with maximum benefit. Indeed, most people of the state would derive much more benefit from having their waterways protected.

In sum, it will take a significant commitment and equally significant funding to minimize road sediment delivery, such as reducing the number of stream crossings, rocking approaches to stream crossings, reducing the length of roads draining to stream crossings and minimizing gully formation below drainage outlets.

E. Additional Monitoring Requirements are Inadequate.

The revised Waiver adds additional monitoring methods to avoid significant impacts to water quality. However, as discussed in the Second Collins Declaration, the Hogan Declaration and the Holtz Declaration, these additional measures will not be adequate to avoid significant impacts due to 1) the limitations of check the box implementation monitoring in providing useful information for review; 2) the failure of the

Forest Service's BMPEP random monitoring program to evaluate site specific adverse effects of high risk Forest Service activities such as logging in stream zones or on steep erodible slopes; 3) the inadequacy of baseline-in channel monitoring to identify ongoing impacts occurring from projects; 4) the lack of timely and action-triggering monitoring for high risk projects; 5) the lack of qualified personnel to conduct the monitoring; and 6) the overall lack of funding.

1. Waiver Will Have Adverse Effects on Water Quality Regulation in Lake Tahoe

The Lahontan Regional Board's regulation of Forest Service logging in the Lake Tahoe Basin. requires the Forest Service to conduct comprehensive effectiveness and forensic monitoring on all high-risk projects in stream zones and on steep slopes in all watersheds that drain to Lake Tahoe. This level of monitoring is essential to avoid additional water quality impacts to Lake Tahoe and its tributary streams. *See* Collins Decl., 2nd Collins Decl.

The revised Waiver reduces this level of monitoring by replacing project specific effectiveness and forensic monitoring with the Forest Service's random BMPEP approach and an ineffective in-stream monitoring program. This has the potential for significant impacts to water quality in the Tahoe Basin and to Lake Tahoe because high risk project BMPs that fail over the winter and spring storm season – not an uncommon occurrence – will not be detected in a timely manner. This is particularly true given the Forest Service's plans for substantial logging in the Tahoe Basin over the next 10 years. This lack of adequate effectiveness and forensic monitoring for high risk Forest Service projects has the potential for significant water quality impacts to waters in Tahoe Basin that are not avoided by the revised Waiver and monitoring. *See* Collins Decl., 2nd Collins Decl.

F. Amended Project Required Recirculation of Negative Declaration

The revised Waiver and monitoring add provisions that were intended to make up for the lack of adequate monitoring in the original Waiver, as documented by the previously circulated negative declaration. Under CEQA, these changes at the least should have been examined in a recirculated negative declaration, which did not occur in this case.

III. Conclusion

For all of the above reasons, the revised Waiver and the Monitoring and Reporting program in Attachment C fails to provide any assurance that water quality objectives will be protected from the widely occurring water quality impacts that are documented by the comments and exhibits submitted.

Our coalition of conservation organizations urges the State Water Board to reject the current weak version of the U.S. Forest Service WQMH and to withhold any waiver until a strong, feasible, and effective water quality monitoring program is designed and is combined with clear and meaningful consequences for violations identified by the monitoring.

Thank you for your time and consideration.
Sincerely,
/s/ John Buckley
John Buckley On behalf of Commenters

Exhibits

1. Coe Study
2. Photos of EDNF road and trail damage
3. Photos of EDNF road and trail damage
4. EDNF 2008 Road Sediment Inventory Study
5. EDNF 2008 Road Sediment Inventory Study
6. Forest Service Strategy for Lake Tahoe
7. Declaration of John Buckley with Photos

THESIS

SEDIMENT PRODUCTION AND DELIVERY FROM FOREST ROADS IN THE SIERRA NEVADA, CALIFORNIA

Submitted by

Drew Bayley Rogers Coe

Department of Forest, Rangeland, and Watershed Stewardship

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY DREW BAYLEY ROGERS COE ENTITLED "SEDIMENT PRODUCTION AND DELIVERY FROM FOREST ROADS IN THE SIERRA NEVADA, CALIFORNIA" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

Adviser

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ABSTRACT OF THESIS

SEDIMENT PRODUCTION AND DELIVERY FROM FOREST ROADS IN THE SIERRA NEVADA, CALIFORNIA

Sediment production and sediment delivery from unpaved forest roads was assessed in the Sierra Nevada of California from 1999 to 2002. Sediment production was measured on 27-65 road segments over 3 years in a mixed rain-snow regime. Sediment delivery was evaluated by conducting a detailed survey of 20 km of unpaved roads with 285 distinct road segments.

Sediment production rates varied greatly between years and between road segments. Sediment production rates from native surface roads were 12-25 times greater than from rocked roads. On average, recently-graded roads produced twice as much sediment per unit of storm erosivity as roads that had not been recently-graded. Unit area erosion rates were 3-4 times higher in the first wet season than in either of the following two wet seasons, as the first wet season had near normal precipitation and a higher proportion of rainfall. An empirical model using the product of road segment area and slope (A*S), annual erosivity, and the product of road segment area and a binary variable for grading (A*G) explained 56% of the variability in sediment production. Road sediment production is best mitigated by rocking native surface roads, decreasing sediment transport capacity by improving and maintaining drainage, and avoiding sites where unusual soil characteristics increase road surface or ditch runoff.

Twenty-five percent of the surveyed road length was connected to the channel network. Stream crossings accounted for 59% of the connected road segments, and gullying accounted for another 35% of the connected road segments. The travel distance of sediment below road drainage outlets was controlled by the presence or absence of gullies, soil erodibility, traffic level, and road segment length. The amount of sediment delivered from episodic gully erosion below road segments (0.6 Mg km^{-1} yr^{-1}) is comparable to the amount of sediment being delivered from the road surface (1.4 Mg km^{-1} yr^{-1}).

An analysis of the data from this and other studies shows that road-stream connectivity is strongly controlled by mean annual precipitation and the presence or absence of engineered drainage structures (R^2=0.92; p<0.0001). Road sediment delivery can be minimized primarily by reducing the number of stream crossings, rocking the approaches to stream crossings, reducing the length of roads draining to stream crossings, and minimizing gully formation below drainage outlets.

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1.0. INTRODUCTION

Sediment is one of the most common causes of water quality impairment for streams and rivers in the U.S. (http://oaspub.epa.gov/waters/national_rept.control#TOP_IMP). Unpaved roads are the dominant source of surface erosion in many forested landscapes (Megahan and Kidd, 1972; Reid and Dunne, 1984; Bilby et al. 1989; Luce and Black, 1999). Road-derived sediment has been shown to increase turbidity and suspended sediment concentrations, alter channel substrate and morphology, and adversely affect water quality (Cederholm and Reid, 1981; Bilby et al., 1989; Waters, 1995). Data on road erosion and sediment delivery rates are critical for assessing road impacts on aquatic resources, and a sound understanding of road erosion processes is needed to minimize road sediment production and delivery.

Since 1999 researchers from Colorado State University have attempted to quantify hillslope erosion rates in the Sierra Nevada of California. Sediment fences (Robichaud and Brown, 2002) were used to measure sediment production rates from roads, timber harvest, wildfires, prescribed fires, and recreational off-highway vehicle use. The initial data showed median sediment production rates from roads were nearly an order of magnitude higher than any other source except a recent high-severity wildfire (MacDonald et al., 2004) (Figure 1.1). Given that unpaved forest roads are a ubiquitous feature in the Sierra Nevada landscape, the goal of this study was to quantify sediment production and sediment delivery from unpaved forest roads.

There is a paucity of data on road sediment production and delivery in the Sierra Nevada of California. Regional knowledge on the magnitude and controls of these processes is important for site-scale mitigation of road erosion and sediment delivery. Data on road erosion rates and sediment delivery are vital for assessing and predicting cumulative watershed effects.

In this thesis Chapter 2 examines sediment production from unpaved forest roads, and Chapter 3 examines the delivery of sediment from unpaved forest roads to the channel network. The overall objectives were to: (1) measure sediment production rates from unpaved roads over three wet seasons; (2) identify the dominant controls on road sediment production and develop predictive models; (3) document and quantify the hydrologic and sediment pathways that control the delivery of sediment from unpaved roads to the channel network; and (4) compare connectivity results from the Sierra Nevada with data from other studies.

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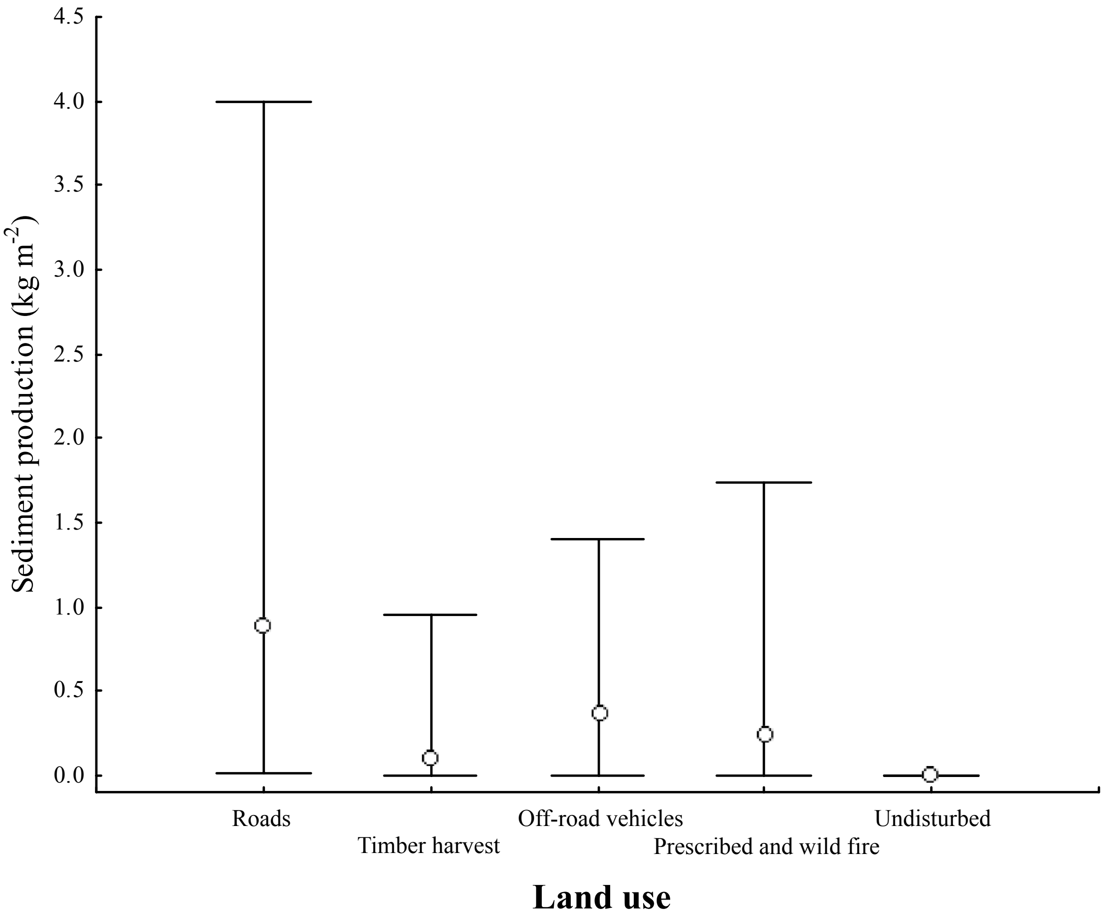

Figure 1.1. Mean and range of sediment production rates by type of land use. Circles represent the mean and bars indicate the range of measured values (from MacDonald et al., 2004).

2.0. SEDIMENT PRODUCTION FROM FOREST ROADS IN THE SIERRA NEVADA

ABSTRACT:

This study used sediment fences to measure sediment production from 27-65 road segments over three wet seasons in the Sierra Nevada of California. The first wet season had near-normal precipitation and annual storm erosivity (EI_A). The second and third wet seasons had below normal precipitation, and EI_A was less than 50% of the long-term mean as most of the precipitation fell as snow rather than rain. The mean sediment production rate from native surface roads was 0.81 kg m^{-2} in the first wet season versus 0.22 and 0.23 kg m^{-2} in the second and third wet seasons, respectively. The median sediment production rate from ungraded native surface roads was 15 times greater than rocked roads. Comparisons among segments showed that recently-graded native surface roads produced twice as much sediment per unit storm energy as ungraded native surface roads. Sediment production on native surface roads was best predicted by the product of road area times road slope (A*S), annual erosivity, and the product of road area and a binary variable for grading (A*G) (R^2=0.56). Normalized sediment production rates on mid-slope roads increased with decreasing soil depth. This increase is attributed to the greater interception of subsurface stormflow and resulting increase in road surface runoff. Road sediment production can be reduced by rocking native surface roads, increasing the frequency of road drainage structures, avoiding locations that generate more road surface and ditch runoff, and minimizing grading and traffic. The study illustrates the difficulties of predicting road erosion rates, particularly in a mixed rain-snow climate.

2.1. INTRODUCTION

Unpaved roads are the dominant source of surface erosion in many forested landscapes (Megahan and Kidd, 1972; Reid and Dunne, 1984; Bilby et al. 1989; Luce and Black, 1999). Road-derived sediment has been shown to increase turbidity and suspended sediment concentrations, alter channel substrate and morphology, and adversely affect water quality (Cederholm and Reid, 1981; Bilby et al., 1989; Waters, 1995). Data on road erosion and sediment delivery rates are critical for assessing road impacts on aquatic resources, and a sound understanding of road erosion processes is needed to minimize road sediment production.

Several studies have identified unpaved roads as a major sediment source in the Sierra Nevada of California, but none of these studies directly measured road erosion rates. Forest roads were estimated to contribute 74% of the sediment produced from a 194 km^2 catchment in central Sierra (Euphrat, 1992), and 19% of the sediment yield for a 6.8 km^2 catchment in the southern Sierra (Reid and Dunne, 1996). Both of these studies used the Universal Soil Loss Equation (USLE) to estimate sediment production rates. Unpaved roads have the highest disturbance coefficient in the methodology used to assess cumulative watershed effects on national forest lands in California (Cobourn, 1989), but there are no data on either the relative or the absolute contribution of unpaved roads to landscape-scale sediment production rates in the Sierra Nevada.

The extrapolation of road erosion rates to the Sierra Nevada from either the Pacific Northwest (Reid and Dunne, 1984; Bilby et al., 1989; Luce and Black, 1999; Luce and Black, 2001a) or the Idaho batholith (Megahan and Kidd, 1972; Megahan, 1974; Burroughs and King, 1989) is uncertain given the mixed rain-and-snow regime and the relative lack of winter traffic. The freezing level of winter storms usually fluctuates between 1000 m and 2500 m (Kattelmann, 1996), and this causes a corresponding fluctuation in the depth and extent of snow cover. As a result, the erosive energy available for sediment detachment and sediment transport changes according to whether the precipitation falls as rain or snow (Cooley et al., 1988).

Given the lack of data on road erosion rates in the Sierra Nevada and the concern over anthropogenic sediment inputs (Millar, 1996), there is an urgent need to quantify road sediment production rates and road erosion processes. A better knowledge of the magnitude and controls of road erosion processes is important for site-scale mitigation of road erosion. Furthermore, data on road erosion is vital for assessing and predicting cumulative watershed effects. With these considerations in mind, the objectives of this study were to: (1) measure sediment production from ungraded native surface roads, recently-graded roads, and rocked roads in mid-elevation areas in the central Sierra Nevada; (2) determine the temporal variability in road sediment production rates within and between winter wet seasons; (3) identify the dominant controls on road sediment production; and (4) develop empirical models for predicting road sediment production.

2.2. BACKGROUND

Sediment production from unpaved roads is a function of the erosive energy applied to the road surface and the erodibility of the road surface (Luce and Black, 1999; Ziegler et al., 2000a; Luce and Black, 2001a). Erosion from road surfaces can be partitioned into rainsplash and hydraulic components (Ziegler et al., 2000a):

$$e = e_s + e_h \qquad (2.1)$$

where e is the net erosion rate from the road surface, e_s is rainsplash erosion, and e_h is the hydraulic erosion from overland flow. Rainsplash erosion results from the force of falling raindrops and is a function of storm intensity, raindrop size, storm depth, and soil erodibility (Wischmeier and Smith, 1978; Brown and Foster, 1987; Renard et al., 1997).

Hydraulic erosion is a function of the sediment transport capacity of overland flow and can be expressed by:

$$e_h = k\,(\tau - \tau_c)^{n} \qquad (2.2)$$

where k is an index of the erodibility of the soil, τ is the shear stress applied by overland flow, τ_c is the soil's critical hydraulic shear strength, and n is an exponent between 1 and 2 (Kirkby, 1980; Nearing et al., 1994). Shear stress is defined as:

$$\tau = \rho_w\, g\, d\, s \qquad (2.3)$$

where ρ_w is the density of water, g is the acceleration due to gravity, d is the depth of overland flow, and s is the water surface slope (Wohl, 2000). Since the mean flow depth (d) is a function of discharge (Knighton, 1998), hydraulic erosion is proportional to the amount of road surface runoff.

Road surface runoff is typically generated by Horton overland flow (HOF) plus the interception of subsurface flow (ISSF) by road cutslopes (Megahan, 1972; Luce and

Cundy, 1994; Ziegler and Giambelluca, 1997; Ziegler, 2001c; Wemple and Jones, 2003). Hence, total road surface runoff (Q_t) can be described as:

$$Q_t = Q_{HOF} + Q_{ISSF} \tag{2.4}$$

where Q_{HOF} is the runoff due to HOF generation and Q_{ISSF} is the runoff due to ISSF. HOF from a road surface is calculated by:

$$Q_{HOF} = (P - I)\ A \tag{2.5}$$

where P is precipitation intensity, I is the infiltration rate of the road surface, and A is the road surface area.

The volume of Q_{ISSF} is related to upslope soil properties, including the saturated hydraulic conductivity (K_s), depth to bedrock, hillslope gradient, topographic or bedrock contributing area, antecedent moisture conditions, and storm precipitation (Freer et al., 1997; Sidle et al., 1995; Freer et al., 2002; McGlynn et al., 2002; Weiler and McDonnell, 2004). ISSF occurs when the depth of the road cut (D_R) exceeds the depth to the water table (D) (Wigmosta and Perkins, 2001; Wemple and Jones, 2003). Assuming that the soil overlies a relatively impermeable layer, D will be smaller for shallow soils than for deeper soils, and roads crossing shallow soils will have a higher likelihood of intercepting subsurface flow. Conversely, the runoff from roads on deeper soils is more likely to be dominated by Q_{HOF} (Ziegler et al., 2001c).

The dependence of road sediment production rates on the erodibility of the road surface has been well documented (Megahan, 1974; Ziegler et al., 2000; Ziegler et al., 2001a,b; Luce and Black, 2001a,b). Traffic and road maintenance each increase the erodibility (K) of unpaved road surfaces by increasing the abundance of easily detachable sediment (Reid and Dunne, 1984; Ziegler et al., 2000; Luce and Black, 2001b; Ziegler et al., 2001a,b; MacDonald et al., 2001; Ramos-Scharron and MacDonald, 2005). As the more erodible surface material is removed, the road surface coarsens and becomes more resistant to rainsplash and the shear force exerted by overland flow (Ziegler et al., 2000; MacDonald et al., 2001).

Since the unpaved roads in the Sierra Nevada vary widely in terms of traffic, grading, and soil depth, comparisons between years and segments can help elucidate the importance of these different factors and provide insights into the underlying processes. This information can be used to help minimize sediment production from existing roads, guide future road designs, and set priorities for road rehabilitation or road obliteration.

2.3. METHODS

2.3.1. Site Description

The study area lies on the west slope of the Sierra Nevada mountain range in California, and is bounded to the north by the Rubicon River drainage and to the south by the South Fork of the Cosumnes River (Figure 2.1). Elevations range from 910 to 2000 m. The primary forest type is mixed conifer, but this turns to red fir with increasing elevation (SAF, 1980). The Mediterranean-type climate means that nearly all of the precipitation falls between 1 October and 1 June (USDA, 1985). Mean annual precipitation at the Pacific House rain gage at 1036 m is 1300 mm, but the standard deviation is 440 mm and the range over a 60-year period is from 450 mm to 2310 mm. The majority of the study area is from 1000 to 1800 m a.s.l., which is within the rain-on-snow climatic zone (Cobourn, 1989). Most of the study sites were on the Eldorado National Forest, although some sites were on interspersed Sierra Pacific Industries (SPI) property.

The dominant lithologies are weathered granitic batholith, granitic glacial deposits, andesitic lahar (Mehrten formation), and metasediments (USDA, 1985). The soils are typically coarse-textured loams, and contain up to 60% gravel by weight (USDA, 1985). Most of the soils are over a meter thick, but the range of soil depths is from 0.3 to 1.7 m. Soil erodibility (K) factors range from 0.013 to 0.042 t ha h ha^{-1} MJ^{-1} mm^{-1} (USDA, 1985).

2.3.2. Study Design

Sediment production was measured from road segments using sediment fences (Robichaud and Brown, 2002) over three wet seasons (1999-2000, 2000-2001, 2001-2002). Each study segment had a discrete drainage point (e.g., waterbar, rolling dip, or a relief culvert) so that all of the sediment produced from that segment could be captured by one or more sediment fences. Twenty-seven segments were monitored during the first wet season, 47 segments in the second wet season, and 65 segments in the third wet season (Table 2.1). The road segments were stratified into ungraded native surface roads, recently-graded native surface roads, and rocked roads. Ungraded native surface roads were defined as segments that had not been graded or used for timber hauling within the previous two years. Rocked roads were surfaced with approximately 10 cm of coarse gravel. One rocked road segment had its ditch graded prior to the first wet season, while the remaining rocked road segments (n=9) had no recent grading activity (Table 2.1).

Most of the study segments were designed to be outsloped, but repeated grading had formed a berm along the downslope edge of these segments. This berm held the surface runoff on the road segment until it reached a functioning waterbar or rolling dip. In areas with shallow soils and rock outcrops, the roads were generally insloped and had an inside ditch that was drained by a relief culvert. Most of the segments added in the second and third field seasons were on ridgetop roads in order to minimize cutslope erosion and the interception of subsurface stormflow. Traffic loads were not measured directly, but the recently-graded roads had more traffic because grading was generally a prerequisite to timber hauling.

2.3.3. Measurement Procedures

The sediment fences were constructed of geotextile fabric staked with reinforcing steel rods (rebar) 1.3 cm in diameter and 1.2-1.5 m long. Fences were constructed with Amoco 2130 fabric that had an opening size of 0.6 mm and a flow rate of 405 L min^{-1} m^{-2} (Robichaud and Brown, 2002). Multiple fences were constructed below selected road segments to increase storage capacity and sediment trapping efficiency. Fabric aprons were laid down in front of the sediment fences to facilitate the identification and removal of the deposited sediment.

The length and total width of the road segment draining to each fence was measured to the nearest decimeter. The measured width included the width of the road surface and ditch but did not include the width of the cutslope or fillslope. Road segment slope were measured with a clinometer and recorded as a decimal. The lithology and soil type was determined from the Eldorado National Forest Soil Survey (USDA, 1985) and field verified. The mean elevation of the study sites was 1424 m in 1999-2000, and as additional sites were added this gradually increased to 1510 m in 2001-2002. The elevation of individual sites ranged from 1015 m to 1829 m.

Sediment production was determined by excavating the sediment trapped by the sediment fences and weighing it to the nearest 0.1 kg. After weighing, the sediment was mixed and two samples were taken to determine soil moisture content (Gardner, 1986). The mean moisture content was used to convert the field-measured wet weights to a dry mass, and annual sediment production rates were calculated by dividing the mass of sediment by the contributing surface area of the road segment. Many sites were not accessible during the winter, so the primary data set consists of annual sediment production rates.

Hydrologic data were obtained at three locations (Figure 2.1). Precipitation was measured at Pacific House (PH) at 1036 m with a tipping bucket rain gage that had a resolution of 1.0 mm (http://cdec.water.ca.gov/cgiprogs/staMeta?station_id=PFH). The Pacific House gage is believed to be representative of the entire study area because wet season precipitation is derived from large frontal storms. Snowpack data were taken from the Robbs Powerhouse SNOTEL site (RP) at 1570 m (http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=RBP) (Figure 2.1). Mean daily discharge data were taken from the Michigan Bar gaging station on the Cosumnes River (MB) (http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=MHB), as this drains the southern half of the study area. Although this station is only at 51 m a.s.l., the Cosumnes is the only undammed river in or near the study area and the discharge data at Michigan Bar closely reflect both the magnitude and type of precipitation in the study area.

For each wet season the maximum storm erosivity and annual erosivity were calculated from the rainfall data at Pacific House. Individual storms were defined as precipitation events separated from each other by at least 6 hours (Mutchler et al., 1994). The erosivity (EI_{30}) for each storm was calculated by multiplying the total storm energy (E) by the maximum 30-minute rainfall intensity (I_{30}), (Renard et al., 1997). The total energy (E) for each storm was calculated by multiplying the rainfall energy (e_r) by total storm depth (P). The rainfall energy (e_r) for each storm was calculated by the equation developed for the western U.S. (Brown and Foster, 1987):

$$e_r = 0.29\ [1\text{-}0.72^{(-0.05i)}] \tag{2.6}$$

where i is average rainfall intensity of the storm in mm h^{-1}. The annual erosivity (EI_A) was calculated by summing the EI_{30} values for each wet season.

2.3.4. Statistical Analysis

The primary dependent variable was annual sediment production in kg yr^{-1}. To better assess the effect of the various independent variables, this was normalized by contributing road surface area, road slope, rainfall erosivity, or a combination of these variables (Table 2.2). The significance of each of the independent categorical variables (Table 2.2) was evaluated by post-hoc pairwise comparisons using Tukey's Honestly

Significantly Difference (HSD) (Ott, 1993; STATISTICA, 2003). Sediment production rates were log-transformed for pairwise comparisons when sediment production rates were log-normally distributed. The large sample size for native surface roads (n=109) meant that the sediment production for these segments could be related to each of the continuous independent variables in Table 2 by multiple regression using forward stepwise regression with a selection criteria of α=0.05. The presence or absence of grading was treated as a binary variable. Sources of model errors were explored through residual analyses.

2.4. RESULTS

2.4.1. Road Segment Characteristics

Sediment production was measured from native surface and rocked road segments with a wide range of road surface areas and road gradients. For the native surface road segments, road surface areas ranged from 30 to 2170 m^2 (i.e., 8 to 395 m in length) with a mean of 368 m^2. For rocked road segments the mean road surface area was 29% smaller at 261 m^2, and the range was from 107 to 1022 m^2. The mean road surface area for the recently-graded native surface road segments was 228 m^2 as compared to 561 m^2 for the ungraded native surface road segments. The three segments with the largest road surface area had drainage structures that were no longer functioning and therefore somewhat atypical. The gradients for native surface road segments ranged from 0.02 to 0.21 m m^{-1} with a mean of 0.09 m m^{-1}. Gradients for the rocked road segments were similar (0.05 to 0.20 m m^{-1} with a mean of 0.09 m m^{-1}).

The road segments used to measure road sediment production were typically outsloped and drained by waterbars and rolling dips. Only four of the native surface road segments and one of the rocked road segments (i.e., 15 data points over three wet season) were insloped and drained by inside ditches. Each of these five insloped road segments drained hillslopes with shallow soils less than 0.5 m in depth. The roads were generally under 30-40 years in age, and most had been reconstructed using current best management practices (BMPs) in recent years (D. Arrington, pers. comm., 2000).

2.4.2. Precipitation and Runoff

Annual precipitation in the first wet season was 1290 mm, which is very close to the long-term mean of 1300 mm. In the second and third wet seasons precipitation was only 68% and 82% of the long-term mean, respectively (Figure 2.2). In the first wet season approximately 50% of the annual precipitation fell between 11 January and 14 February, while precipitation in the second and third wet seasons was much more evenly distributed (Figure 2.2).

The total erosivity (EI_A) in the first wet season was 847 MJ mm ha^{-1} hr^{-1}. The EI_A values in the second and third wet seasons were respectively only 441 and 456 MJ mm ha^{-1} hr^{-1}, or less than 60% of the value from the first wet season. In the first wet season the maximum storm erosivity in the first season was 252 MJ mm ha^{-1} hr^{-1} from a 175-mm storm in late January. Since this storm increased the snow water equivalent (SWE) at Robbs Powerhouse by only 4 mm (Figure 2.3), precipitation below this elevation was mostly rain. In the second and third wet seasons the maximum storm erosivity was only 98 and 83 MJ mm ha^{-1} hr^{-1}, respectively.

The SWE data show that the snow cover was thinner and less frequent in the first wet season relative to the second and third wet seasons (Figure 2.3). In 1999-2000 the snowpack at Robbs Powerhouse didn't begin to accumulate until 7 December and meltout occurred by 31 March, resulting in 115 days with snow cover (Table 2.3). SWE was below 70 mm until mid-February, suggesting a lack of snow cover at the lower elevation sites. The peak SWE was 302 mm in the second week of March, which is less than half of the 30-year mean peak SWE of 656 mm.

In the second wet season the first storms were unusually cold and the snowpack began accumulating on 26 October (Figure 2.3). Most of the subsequent precipitation fell as snow, and the SWE steadily increased from mid-December until the peak SWE of 406 mm was reached in early March. Meltout occured on 24 April, indicating 167 days of snow cover (Figure 2.3).

Although some data are missing from the third wet season, by early December there were 150 mm of SWE, indicating that much of the early season precipitation had fallen as snow rather than rain (Table 2.3; Figure 2.3). As in 2000-2001, the snowpack persisted until late April. The greater duration of snow cover in the second and third wet seasons is confirmed by our field observations, as the road segments above 1400 m were generally accessible until mid-February in the first wet season, and largely inaccessible from early January to until late March in both the second and third wet seasons.

The daily discharge data confirm the preponderance of rain and much greater erosivities in the first wet season, as four storms each generated mean daily flows in the Cosumnes River of more than 150 $m^3 s^{-1}$ (Figure 2.4). The largest mean daily flow during the study period was 289 $m^3 s^{-1}$ on 14 February 2000, and this has an estimated recurrence interval of 2.4 years. This peak flow was due to 114 mm of precipitation in 48 hours as measured at the PH rain gage. Since this storm increased the SWE at RP by only 66 mm, almost half of the precipitation below 1570 m fell as rain. Many of the field sites that had been snow covered became accessible during and after this storm, indicating that the high flows were due to a combination of rain and snowmelt.

In the second wet season there were no obvious rain-on-snow events in the annual hydrograph, and the largest daily flow was just 28 $m^3 s^{-1}$ in late March (Figure 2.4). In the third wet season there were four small rain-on-snow events, but the largest daily flow was only 70 $m^3 s^{-1}$, or 24% of the maximum daily flow recorded during the first wet season (Figure 2.4).

2.4.3. Sediment Production Rates by Road Surface Type and Wet Season

The distribution of sediment production rates was highly skewed by a few segments with exceptionally high values (Figure 2.5). For native surface roads the mean annual sediment production rate was 0.32 kg $m^{-2} yr^{-1}$ (Table 2.4), while the median value was only 0.14 kg $m^{-2} yr^{-1}$. Rates were highly variable as the range for native surface road segments was from 0.0002 kg $m^{-2} yr^{-1}$ to 4.0 kg $m^{-2} yr^{-1}$ (Figure 2.5).

The distribution of sediment production rates for rocked roads was even more skewed, as the overall mean of 0.12 kg $m^{-2} yr^{-1}$ was 13 times the median value of 0.009 kg $m^{-2} yr^{-1}$ (Table 2.4). The larger skew was due primarily to one segment that yielded 3.3 kg $m^{-2} yr^{-1}$ in the first wet season. This is nearly 170 times the mean value of 0.02 kg $m^{-2} yr^{-1}$ for the other 29 segment-years of data. The high sediment production rate from this segment was attributed to the fact that the inboard ditch had been graded during the previous summer, and the upslope area had very thin soils and scattered rock outcrops, resulting in visibly high rates of Q_{ISSF}.

The 2.5-fold difference in the overall mean sediment production rates between the native surface and the rocked roads was significant at $p<0.0001$. Given the large amount of skew in the data, the 15-fold difference in median sediment production rates is a more accurate indication of the effect of rocking on road sediment production.

Sediment production rates varied greatly between wet seasons (Figure 2.5). In the first wet season the mean sediment production rate from native surface roads was 0.81 kg m^{-2}, and this was approximately four times the mean values in the second and third wet seasons. The mean sediment production rate for rocked roads in the first wet season was 0.36 kg m^{-2} (Table 2.4). If the one segment with a recently-graded inside ditch is excluded, the mean sediment production rate for the rocked roads was only 0.03 kg m^{-2} in the first wet season. In the second and third wet seasons the mean sediment production rates for rocked roads was only 0.01 and 0.02 kg m^{-2}, respectively.

2.4.4. Other Controls on Road Sediment Production

For native surface roads the annual rainfall erosivity (EI_A) explained 15% of the variability in sediment production rates between years ($p<0.0001$). Maximum storm erosivity (EI_M) and total precipitation explained 14% and 10% of the variability, respectively. EI_A was not significantly related to sediment production rates for the entire data set of rocked roads, but if the extreme outlier in Figure 2.5 is excluded, EI_A explains 20% of the variability in sediment production rates between years ($p=0.02$). Similarly, total precipitation and EI_M each explained about 20% of the variability for rocked roads once the extreme data point in Figure 2.5 was excluded from the data set.

Several segment-scale variables were important controls on sediment production rates for both native surface and rocked roads. For native surface roads, road surface area explained 33% of the variability in sediment production per unit erosivity ($p<0.0001$) (Figure 2.6a). When treated as a continuous variable, road slope was significantly but weakly related to the normalized sediment production rate (kg m^{-2} EI_A^{-1}) for native surface roads ($R^2=0.04$; $p=0.04$). However, the mean sediment production rate for native surface road segments with slopes ≥7% was approximately 75% higher than segments with slopes less than 7% ($p=0.005$; Figure 2.7).

For the native surface road segments, the product of road surface area and road slope (A*S) explained 44% of the variability in sediment production per unit erosivity. Road surface area times slope (A*S) was more strongly correlated with normalized sediment production rates (kg yr^{-1} EI_A^{-1}) for the steeper roads segments ($R^2=0.56$; $p<0.0001$). Sediment production rates were not significantly related to A*S for the native surface road segments with slopes <7% ($p=0.60$).

For the rocked road segments, road surface area explained 32% of the variability in sediment production rates per unit erosivity. Removing the outlier in Figure 2.5 increased the R^2 for this relationship to 0.87 (Figure 2.6b). Road slope was not significantly related to normalized sediment production (kg m^{-2} EI_A^{-1}) ($p=0.73$). In contrast to the native surface roads, road surface area was more strongly related to the normalized sediment production rates than A*S ($R^2=0.48$; $p=0.01$).

The native surface road segments that had been recently graded produced about twice as much sediment per unit erosivity as the ungraded segments (p=0.02) (Figure 2.8). A pairwise comparison indicated that there was no evidence of a decline in sediment production rates between the first and second years after grading (p=0.86). Hence the term recently-graded refers to any segment that had been graded within the past two wet seasons.

A more detailed analysis shows that grading has a strong effect on sediment production rates at lower elevations, but not at higher elevations (Figure 2.9). For the native surface roads below 1400 m, the recently-graded segments produced approximately eight times more sediment than the ungraded segments when sediment production rates were normalized by A*S and EI_A (p=0.0008). In contrast, grading had no apparent effect on normalized sediment production rates for the native surface roads above 1400 m (p=0.92) (Figure 2.9). The recently-graded native surface roads below 1400 m also produced nearly 5 times more sediment than the recently-graded native surface roads above 1400 m, and this difference was highly significant (p=0.0005) (Figure 2.9). For the ungraded roads, there was no significant difference in normalized sediment production rates with elevation class (p=0.14).

Stepwise multiple regression shows that sediment production from native surface road segments is controlled by the product of road surface area and slope (A*S), annual storm erosivity (EI_A), and the product of road surface area and a binary variable for grading (A*G) that has a value of 1 if the segment has been recently graded and 0 if the segment has not been graded. The resultant model is:

$$SP_{ns} = -329 + 3.56\,(A*S) + 0.542\,EI_A + 0.389\,(A*G) \tag{2.7}$$

where SP_{ns} is sediment production for native surface roads in kilograms per year (Table 2.5). The overall model R^2 is 0.56, the adjusted R^2 is 0.54, and the standard error is 142 kg.

2.5. DISCUSSION

2.5.1. Comparisons to Previous Studies

The mean annual sediment production rate for the native surface road segments ranged from 0.23 to 0.81 kg m^{-2} yr^{-1}, with a 3-year average of 0.32 kg m^{-2} yr^{-1} (Table 2.4). Assuming an average road width of 5.0 m, this converts to 1.6 Mg km^{-1} yr^{-1}. Road erosion rates for unpaved roads with moderate traffic in the Olympic Peninsula in the state of Washington were 41 Mg km^{-1} yr^{-1} (Reid and Dunne, 1984), or approximately 26 times higher than the 3-year mean reported here. The overall mean from the present study is 67% of the reported mean erosion rate of 0.48 kg m^{-2} for unpaved roads in the Idaho batholith (Megahan, 1974). The similarity in road erosion rates for the Sierra Nevada and the Idaho batholith might be attributed to the similarities in lithology and climate.

The mean sediment production rate from rocked roads ranged from 0.01 to 0.36 kg m^{-2} yr^{-1}, but the upper end of this range was due to one road segment that had a recently-graded ditch and exceptionally high runoff rates. If this segment is excluded, the mean sediment production rate from rocked roads was 0.02 kg m^{-2} yr^{-1}, and the maximum value for a single segment was 0.09 kg m^{-2} yr^{-1}. These values fall within the range of

0.01-0.21 kg m^{-2} yr^{-1} for rocked roads in the Idaho batholith (Burroughs and King, 1989), but the mean is much lower than the rate reported from the Olympic Peninsula (Reid and Dunne, 1984). Since there was no wet season traffic and five of the rocked road segments were behind locked gates, the lower sediment production rates for rocked roads in the Sierra may be attributed to the lack of wet season traffic and lower precipitation relative to the Olympic Peninsula. This rationale is consistent with data from the Oregon Coast Range, where rocked roads with no traffic and no recent grading produced less than 0.02 kg m^{-2} yr^{-1} (Luce and Black, 2001b).

2.5.2. Climatic Controls on Rainsplash and Hydraulic Erosion

The lower sediment production rates from the native surface roads in the second and third wet seasons is due to the difference in precipitation as well as the difference in the type of precipitation. The first wet season had larger and more intense rain events as well as more precipitation, and the annual rainfall erosivity in the first wet season was nearly double the value in the second and third wet seasons. Perhaps more importantly, the second and third wet seasons were colder so more of the precipitation fell as snow and there was constant snow cover on most of the sites. Snowfall has minimal erosive energy when it hits the soil surface (Cooley et al., 1988), and snow cover protects the road surface from rainsplash erosion during rain-on-snow events.

Previous research suggests that rainsplash erosion accounts for approximately 50% of the total erosion from unpaved roads (Ulman and Lopes, 1995; Ziegler et al., 2000), and that erosion rates are linearly related to rainfall erosivity (Renard et al., 1997). Since the EI_A in the second and third wet seasons was roughly 50% of the value from the first wet season, if road surface erosion is proportional to rainfall erosivity the sediment production rates in the second and third wet seasons should have been about half of the value from the first wet season. However, the sediment production rates from native surface roads in the second and third wet seasons were roughly one-quarter of the value from the first wet season, or about half of the expected value. This suggests that the more continuous snow cover during the second and third wet seasons may have reduced the amount of rainsplash erosion (e_s) and/or hydraulic erosion (e_h) by an additional 50 percent.

The reduction in e_s due to a shift from rain to snow is self evident, but the effect of this shift on e_h is more complex. Maximum snowmelt rates in the alpine Sierra are on the order of 30 mm d^{-1} (Kattelmann and Elder, 1991), while rainfall inputs can exceed 100 mm d^{-1}. The lower intensity of snowmelt inputs will reduce both the depth and velocity of overland flow and hence e_h. The presence of a snowpack on the road surface should also reduce the velocity of overland flow, but there are no data on this effect. The prediction of road erosion rates is further complicated by the observation that rills up to 10 cm wide can develop under the snowpack.

The amount of runoff on the road surface also will vary with the amount of Q_{ISSF} (Ziegler et al., 2001c; Wemple and Jones, 2003). For the 17 midslope road segments with data from all three seasons, the normalized sediment production rates (kg $A*S^{-1}$ EI_A^{-1}) decreased with increasing upslope soil depth (R^2=0.17; p=0.002). The relationship between upslope soil depth and normalized sediment production was stronger and slightly more non-linear for the rain-dominated first wet season (R^2=0.32) than the snow-dominated second and third wet seasons (R^2=0.15) (Figure 2.10).

The amount of subsurface stormflow (SSF) varies with upslope soil depth and antecedent soil moisture conditions (Sidle et al., 1995; Freer et al., 1997; Freer et al., 2002; Tromp-van Meerveld and McDonnell, 2006b). SSF is threshold driven, in that it requires subsurface saturation along flowpaths before it can occur (Tromp-van Meerveld and McDonnell, 2006a, 2006b). Subsurface saturation occurs first in shallow soils, and shallow soils can generate SSF during small to medium-size storms (Tromp-van Meerveld and McDonnell, 2006b). In the present study, the first wet season had more precipitation, higher rainfall intensities, and generally wetter soil conditions. I hypothesize that: (1) subsurface saturation occurred on hillslopes more often during the first wet season; and (2) the hillslopes with the shallowest soils produced the most SSF. The larger amount of intercepted SSF in the first wet season resulted in more hydraulic erosion and a stronger relationship between upslope soil depth and sediment production (Figure 2.10). The second and third wet seasons were drier and antecedent soil moisture conditions were presumably lower, resulting in less Q_{ISSF} and a weaker relationship between soil depth and normalized sediment production (Figure 2.10b).

2.5.3. Controls on Road Surface Erodibility and Sediment Supply

Rocking the road surface reduced median sediment production rates by at least an order of magnitude, and this can be attributed to the resulting decreases in e_s, e_h, and the supply of erodible sediment. The 5-20 mm gravel protects against e_s (Burroughs and King, 1989) and greatly increase τ_c (Eq. 2.2). Rocking also increases flow roughness, thereby reducing flow velocities and the erosion due to e_h. Rocking may not be effective if the inside ditch is not rocked, as the highest sediment yield for a single road segment

(3.4 Mg) came from a rocked road segment at 1450 m elevation in the first wet season. This 241 m long, midslope segment intercepted SSF from a hillslope with shallow soils on top of relatively impermeable andesitic lahar deposits (USDA, 1985), and it had a recently-graded inside ditch. Large amounts of Q_{ISSF} were observed from the cutslope during moderate and large rainstorms, and field observations indicated that the amount of Q_{ISSF} changed quickly in response to changes in rainfall intensity. The resultant high flows in the ditch were able to transport cobble-sized clasts (>128 mm). Sediment yields from this segment in the second and third wet seasons were only 1-2% of the value from the first wet season, and this indicates that grading generated a large supply of erodible sediment. These results show that rocking can be a very effective means for reducing road erosion, but in some cases road design, maintenance activities, and local site conditions can negate the usual benefits of rocking the road surface.

The lower sediment production rates from ungraded native surface roads relative to recently-graded roads has been attributed to a more limited supply of easily erodible fine sediment (Ziegler et al., 2000; Ramos-Scharron and MacDonald, 2005). The A*G term in the model (Eq. 2.7) indicates that increase in road sediment production due to grading is proportional to the road surface area, and that a recently-graded road segment produces an additional 0.39 kg per square meter of road surface area than an ungraded road segment.

For some of the more easily-accessible segments, sediment production was measured several times within a wet season. The data from four recently-graded road segments show that sediment production rates per unit precipitation were much higher in the early portion of the wet season (Figure 2.11). The high initial sediment pulse can be attributed to the rapid removal of the thick, fine dust layer that had formed on the road surface as a result of grading and timber hauling activities. The subsequent decline in sediment production per unit rainfall suggests that the recently-graded roads rapidly become supply limited as the road surface becomes armored and more resistant to sediment detachment and transport processes. On the other hand, there was no apparent decline in sediment production rates per unit erosivity between the first and second years after grading. The lack of a decline may be due to continuing high traffic loads on many of recently-graded roads, as the combination of grading and harvesting increased the amount of traffic from firewood cutters and recreationists, and the high traffic levels increase the amount of readily-erodible sediment (Ziegler et al., 2001a.). Wheel ruts also began to appear on many of these roads, and the concentrated flow in these ruts also can increase sediment production rates (Foltz and Burroughs, 1990).

Figure 2.9 shows that grading had no effect on sediment production on road segments above 1400 m in elevation. The lack of a grading effect above 1400 m can be attributed to the fact that most of the precipitation falls as snow and there is more continuous snow cover. This shields the erodible dust layer from e_s and e_h, and this apparently minimizes the effects of grading on sediment production.

The effects of lithology and soil erodibility on road sediment production were difficult to discern given the interacting and confounding effects of the other controlling factors. The mean normalized sediment production from road segments on metasediments was four times greater than segments on other lithologies ($p=0.0001$). However, there were only four data points for road segments on metasediments, and each of these road segments had been recently graded. Soil erodibility was positively correlated with normalized sediment production (kg A*S^{-1} EI_A^{-1}) for recently graded native surface roads (R^2=0.19; p=0.0004) (Figure 2.12), but not for ungraded native surface roads or rocked roads. These results suggest that erodibility indices such as lithology and soil erodibility tend to have a secondary influence compared to other variables such as A*S, rainfall erosivity, and grading. Lithology and soil erodibility were only significant when the road surface has been recently disturbed by grading and sediment production rates are relatively high. Lithology and soil erodibility are less likely to be good predictors of sediment production once the road surface is armored.

2.5.4. Model Performance and Implications for Long-term Road Erosion Rates

The empirical model presented in equation 2.7 accounts for 56% of the variability in sediment production rates from native surface roads (Figure 2.13). The model is much better at predicting sediment production rates for road segments with a slope ≥7% (R^2=0.62; p<0.0001) than for segments with slopes <7% (R^2=0.21; p=0.01). The greater predictability for the steeper segments can be partly attributed to the significant relationship between A*S and normalized sediment production (kg EI_A^{-1}) for the steeper segments (R^2=0.56; p<0.0001). In contrast, the normalized sediment production rates for road segments with slopes of less than 7% are not significantly related to A*S (R^2=0.01; p=0.60). The significant relationship for the steeper roads does not appear to be due to the greater spread in A*S data, as some of the flatter road segments also have relatively large A*S values. Other studies have suggested that an increase in road length does not necessarily lead to higher sediment production rates for flatter segments (Luce and Black, 1999; Ramos-Scharron and MacDonald, 2005).

The inclusion of A*S in equation 2.7 indicates that sediment production is a linear function of road surface area and slope. However, the normalized sediment production rates (kg m^{-2} EI_A^{-1}) for ungraded road segments are most strongly related to segment slope raised to the 1.9 power (R^2=0.23; p=0.0007). An exponent of 1.9 is close to the values of 1.5-2.0 reported in other studies (Luce and Black, 1999; Ramos-Scharron and MacDonald, 2005). However, sediment production for the entire dataset is best predicted by a linear function of A*S rather than a non-linear function of A*S.

The empirical model in equation 2.7 doesn't include all of the factors that appear to affect road erosion rates. For example, upslope soil depth was not significant in the overall model, and this may be partly due to the fact that 84% of the data came from ridgetop roads where sediment transport capacity is controlled by Q_{HOF} rather than Q_{ISSF}.

The empirical model also doesn't include a factor for elevation, even though road erosion rates significantly decline with increasing elevation for the recently-graded road segments. This decline is due to the shift from rain to snow and the corresponding increase in the frequency of snow cover. The overall model R^2 increased from 0.41 to 0.54 when EI_A was included, as this accounted for much of the difference in sediment production rates between years. However, EI_A was only measured in one location so it could not account for the spatial variability in rainfall erosivity and snow cover. Since the model doesn't include an elevation term it will tend to underpredict sediment production rates from the road segments at lower elevations. Including site-specific EI_A data could potentially improve the performance of the model.

The empirical model in equation 2.7 provides a useful first estimate of road erosion rates for native surface roads in the northern Sierra, but the measured and predicted road erosion rates are probably low relative to the long-term average. Road erosion studies in other areas have shown that the largest storm events generate most of the erosion (Luce and Black, 2001a; Ramos-Scharron and MacDonald, 2005). In the study area the long-term mean EI_A is between 1020 and 1360 MJ mm ha^{-1} hr^{-1} (Renard et al., 1997), or approximately 20-60% more than the EI_A in the first wet season and 220-310% more than the EI_A in the second and third wet seasons. According to equation 2.7, an ungraded native surface road segment with an average road surface area of 368 m^2 and an average slope of 0.09 m m^{-1} would generate 526 kg of sediment in a year with an EI_A of 1360 MJ mm ha^{-1} hr^{-1}, but only 248 kg in the first wet season when the EI_A was 847 MJ mm ha^{-1} hr^{-1}.

The potential underprediction of road erosion rates may be even greater for the midslope roads, as the record peak flow at Michigan Bar in January 1997 was more than eight times the largest instantaneous peak flow recorded during the study period. The magnitude of SSF can increase by a factor of 75 once hillslope hydrologic connectivity is achieved (Tromp-van Meerveld and McDonnell, 2006b). Given that normalized road erosion showed a non-linear relationship with upslope soil depth in the first wet season, this non-linear relationship is likely to be even more pronounced during wetter years. As a result, one would expect a large increase in erosion due to Q_{ISSF} during wetter years, particularly on the road segments that have a cutbank draining shallow soils.

2.5.5. Implications for Management

This study shows that sediment production rates are at least an order of magnitude lower from rocked roads than native surface roads. Rocking decreases rainsplash erosion

(Eq. 2.1), increases the critical shear stress necessary for erosion (Eq. 2.2), and reduces the supply of easily erodible sediment.

The empirical model (Eq. 2.7) indicates that the product of road surface area and road gradient is an important control on road erosion. However, the model also suggests that sediment production is a linear function of A*S, and that frequent road drainage does not necessarily reduce unit area road erosion. Logic still suggests that sediment production rates can be decreased by reducing road contributing area, as this is consistent with erosion theory and other research (Luce and Black, 1999; Luce and Black, 2001a; Ramos-Scharron and MacDonald, 2005). Frequent road drainage also can reduce the likelihood of sediment delivery to the channel network (Wemple et al., 1996; Croke and Mockler, 2001).

Road surface area can be decreased by increasing the frequency of drainage structures such as waterbars or cross-relief culverts, or by outsloping the road surface. In the study area the periodic grading of outsloped roads often has created berms along the downslope edge of the road segment. By keeping the overland flow on the road surface, these berms effectively increase A*S and hence the sediment production rate. Both road drainage structures and outsloping must be maintained if one wishes to minimize surface runoff and reduce road sediment production.

Rocking and drainage are particularly critical for road segments on hillslopes with shallow soils and rock outcrops, as these site characteristics tend to increase the proportion of rainfall and snowmelt that becomes surface runoff. The resulting increase in runoff will increase erosion from cutslopes, inside ditches if present, and the road surface. Soil depth data are generally available from soil surveys, and these data can help land managers identify the soil types and sites that are most susceptible to Q_{ISSF} and high road surface erosion rates.

The recently-graded roads produced more sediment than ungraded roads. A reduction in the frequency of grading will decrease the supply of easily erodible sediment, and this is particularly important for the lower-elevation roads where the easily erodible surface layer is subjected to more rainfall and higher surface runoff rates. The effects of grading did not appear to diminish over a two year period, but recovery may have been masked by the confounding effect of increased traffic after grading.

2.5.6. Future Research

This study showed that road sediment production rates are a complex response to climate, site, and management factors. A more rigorous and quantitative assessment of these factors will require more controlled, process-based studies. Runoff and erosion rates from the road surface need to be measured on segments with varying upslope soil depths under different antecedent conditions for rain, snowmelt, and rain-on-snow events, respectively. Hillslope piezometers above the road segments would help corroborate the discharge data and determine the relative importance of subsurface stormflow as a function of slope position, upslope drainage area, cutslope height, and soil depth. Storm-by-storm measurements of runoff and sediment production would help indicate the relative importance of Q_{HOF} and Q_{ISSF} on road surface runoff and sediment production rates.

The range and complexity of the interactions between local site conditions (e.g., soil depth, erodibility), road segment properties (e.g., A*S, road maintenance), and climate (e.g., rain vs. snow) have important implications for the use and reliability of spatially-distributed, physically-based models such as WEPP (Water Erosion Prediction Project) (Elliot et al., 1995) and DHSVM (Distributed Hydrologic Soil Vegetation Model) (Bowling and Lettenmaier, 2001; Wigmosta et al., 1994). The accuracy of the model outputs depends upon the representation of the underlying processes. Additional research is needed to help refine the numerical representation of HOF, ISSF, sediment detachment, and sediment transport processes and to help verify these models across a range of climatic and environmental conditions.

2.6. CONCLUSIONS

Sediment production was measured from 139 road segments over 3 years in a mixed rain-snow regime in the Sierra Nevada of California. Sediment production rates varied greatly between years and between road segments. The mean sediment production rate from native surface roads was 0.81 kg m^{-2} in the first wet season as compared to 0.22 and 0.23 kg m^{-2} in the second and third wet seasons, respectively. Sediment production rates from native surface roads were 12-25 times greater than from rocked roads. On average, recently-graded roads produced twice as much sediment per unit of storm erosivity than ungraded native surface roads. An empirical model using the product of road area and road slope, annual erosivity, and the product of road area and a binary variable for grading explained 56% of the variability in sediment production. On midslope roads, normalized sediment production increased with decreasing soil depth.

Most of the interannual variability in sediment production rates can be attributed to differences in the magnitude and type of precipitation, and the resulting effect on rainsplash and hydraulic erosion. The first wet season had near-normal precipitation and much of the precipitation in the lower portions of the study area fell as rain rather than snow. In the second and third wet seasons precipitation was below normal and tended to fall as snow. Unit area erosion rates were 3-4 times higher in the first wet season than the second and third wet seasons due to the higher rainfall erosivity, a less persistent snow cover that helps shield the road surface against rainsplash erosion, and reduced road runoff rates.

Road sediment production is best mitigated by rocking native surface roads, decreasing sediment transport capacity by improving and maintaining drainage, and avoiding sites with soil characteristics that increase road surface and ditch runoff. Grading road surfaces and ditches should be kept to a minimum as this increases sediment production rates. Additional process-based studies are needed to quantify the sources of road and ditch runoff, and to measure the effect of runoff rates on sediment detachment and transport. These data are needed to develop and test spatially-distributed, physically-based road erosion models. Accurate road erosion models are needed to help design effective BMPs and provide guidance for land managers.

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2.7. TABLES AND FIGURES

Wet season	Native surface roads		Rocked roads		
	Ungraded	Recently-graded	Ungraded	Recently-graded	Totals
1999-2000	15	2	9	1	27
2000-2001	15	22	9	1	47
2001-2002	15	40	10	0	65
Totals	45	64	28	2	139

Table 2.1. Number of road segments monitored by wet season and road surface type.

Dependent variables	Independent variables
Sediment production = kg	Road segment slope (S)
Sediment production rate = kg m^{-2}	Road surface area (A)
Normalized sediment production = kg EI_A^{-1}	Road area x slope (A*S)
Normalized sediment production rate = kg m^{-2} EI_A^{-1}	Road area x slope^2 ($A*S^2$)
Normalized sediment production rate = kg $A*S^{-1}$ EI_A^{-1}	Elevation
	Road grading (categorical)
	Road surface type
	Annual precipitation (P)
	Annual storm erosivity (EI_A)
	Maximum storm erosivity (EI_M)
	Soil series
	Lithology
	Soil depth
	Soil erodibility (K factor)
	Soil texture

Table 2.2. List of dependent and independent variables.

Wet season	Start of snowpack	End of snowpack	Number of days with snowpack	Maximum SWE (mm)
1999-2000	7 Dec	31 March	115	302
2000-2001	26 Oct	24 April	167	406
2001-2002	na*	21 April	na	353

* SWE was 150 mm on 6 December 2001.

Table 2.3. Duration of the snowpack and maximum SWE for each of the three wet seasons. na indicates not available.

Wet season	Native surface roads Mean (kg m^{-2})	St. dev. (kg m^{-2})	CV (%)	n	Rocked roads Mean (kg m^{-2})	St. dev. (kg m^{-2})	CV (%)	n
1999-2000	0.81	1.2	148	17	0.36*	1.00	278	10
2000-2001	0.22	0.3	136	37	0.01	0.01	100	10
2001-2002	0.23	0.28	122	55	0.02	0.02	100	10
Mean or total	0.32	0.56	175	109	0.13*	0.6	462	30

* Removing the one segment with the graded inboard ditch reduces the 1999-2000 mean to 0.03 kg m^{-2} and the overall mean to 0.02 kg m^{-2}.

Table 2.4. Mean, standard deviation, and coefficient of variation (CV) of the sediment production rates for each wet season for native surface and rocked road segments.

Variable	Coefficient	Standard error of coefficient estimate	p-value
Intercept	-329	58.1	<0.0001
A*S (m^2)	3.56	0.380	<0.0001
EI_A (MJ mm ha^{-1} hr^{-1})	0.542	0.100	<0.0001
A*G (m^2)	0.389	0.100	0.0018

Table 2.5. Model parameters for predicting annual sediment (kg) from native surface road segments in the study area. The model R^2 is 0.56, the adjusted R^2 is 0.54, and the standard error is 142 kg.

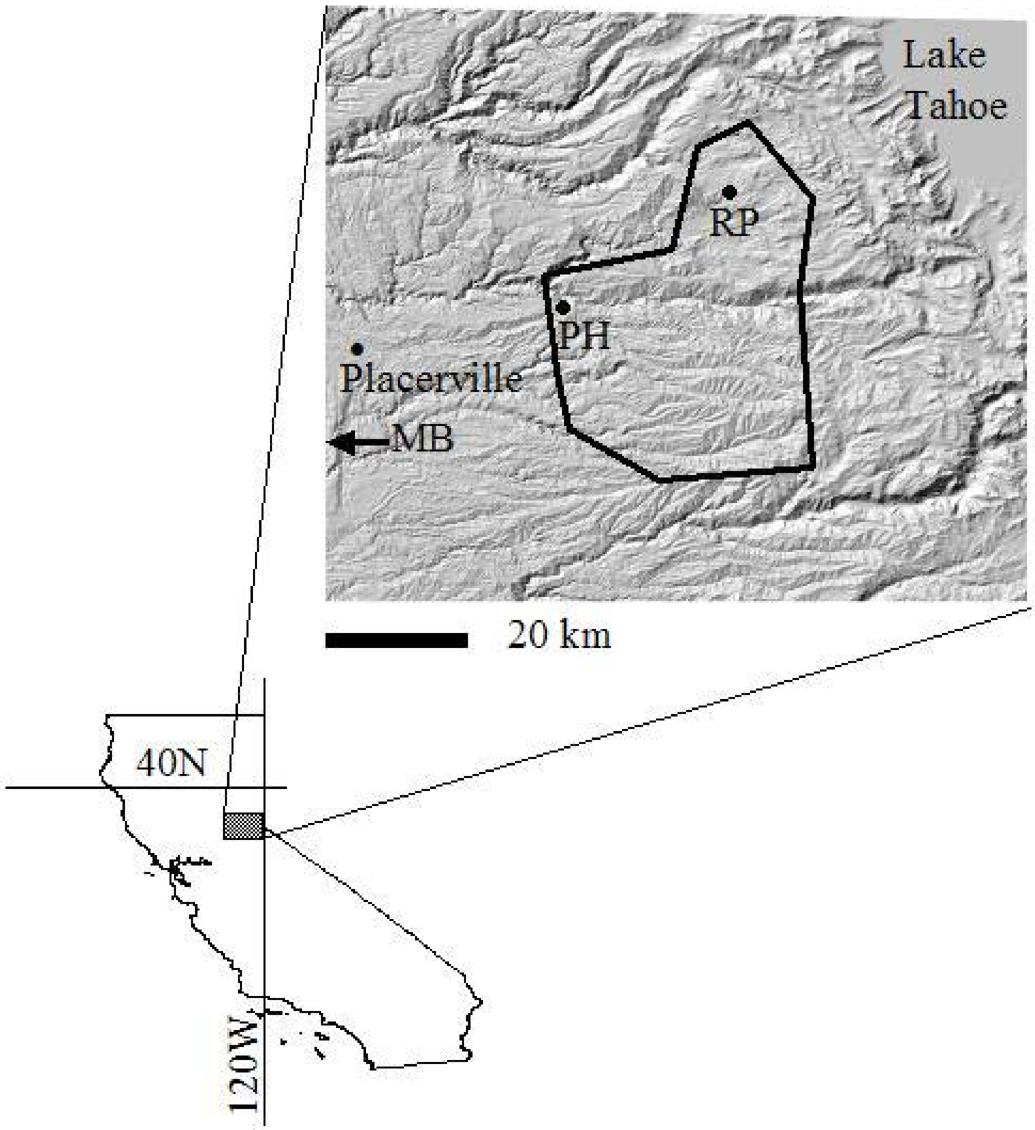

Figure 2.1. Map of the study area. PH is the Pacific House rain gage, RP is the Robbs Powerhouse SNOTEL site, and MB is the Michigan Bar gaging station on the Cosumnes River.

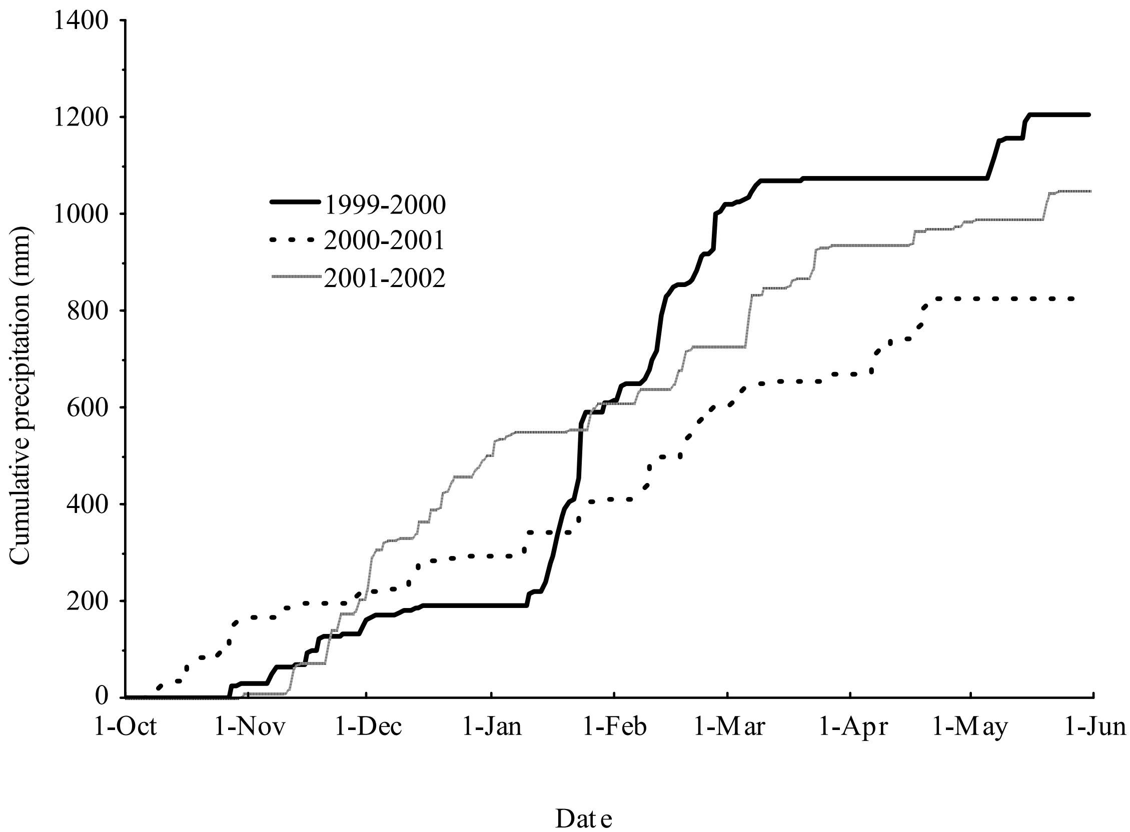

Figure 2.2. Cumulative precipitation at Pacific House from 1 October to 1 June for each of the three wet seasons.

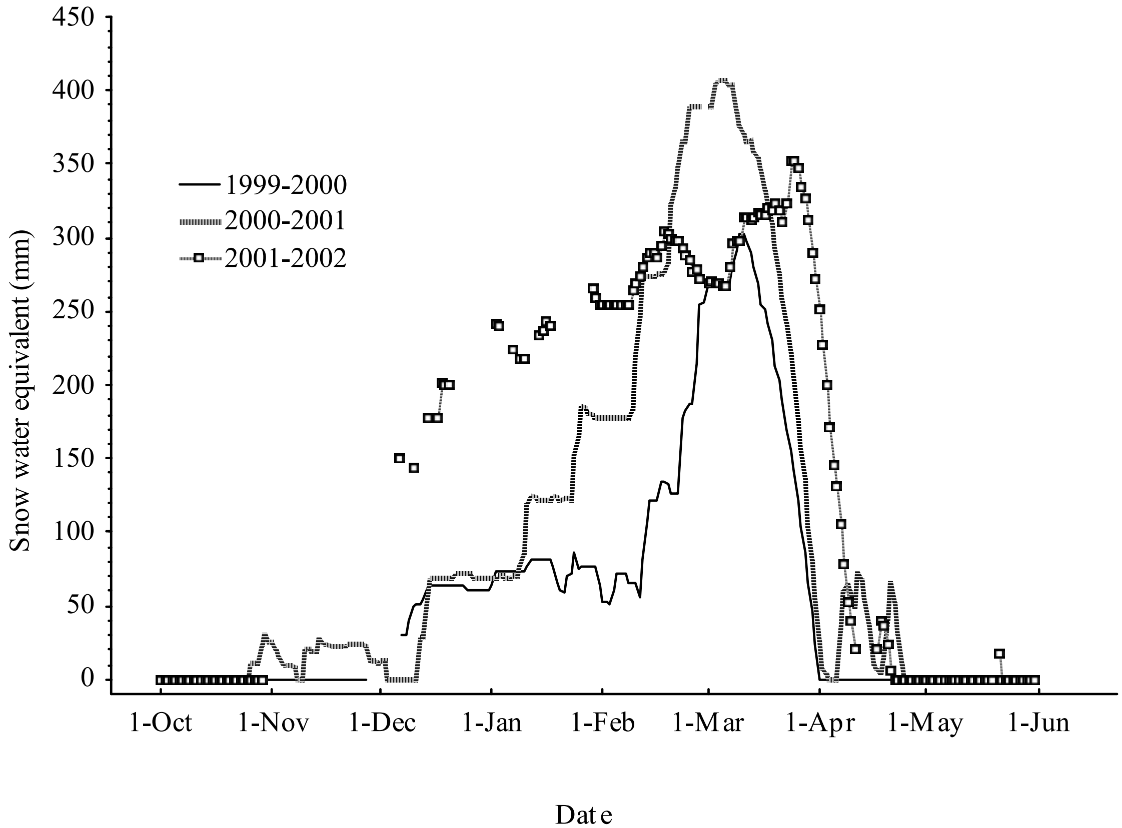

Figure 2.3. Snow water equivalent at Robbs Powerhouse for each of the three wet seasons. Data for 2001-2002 are incomplete.

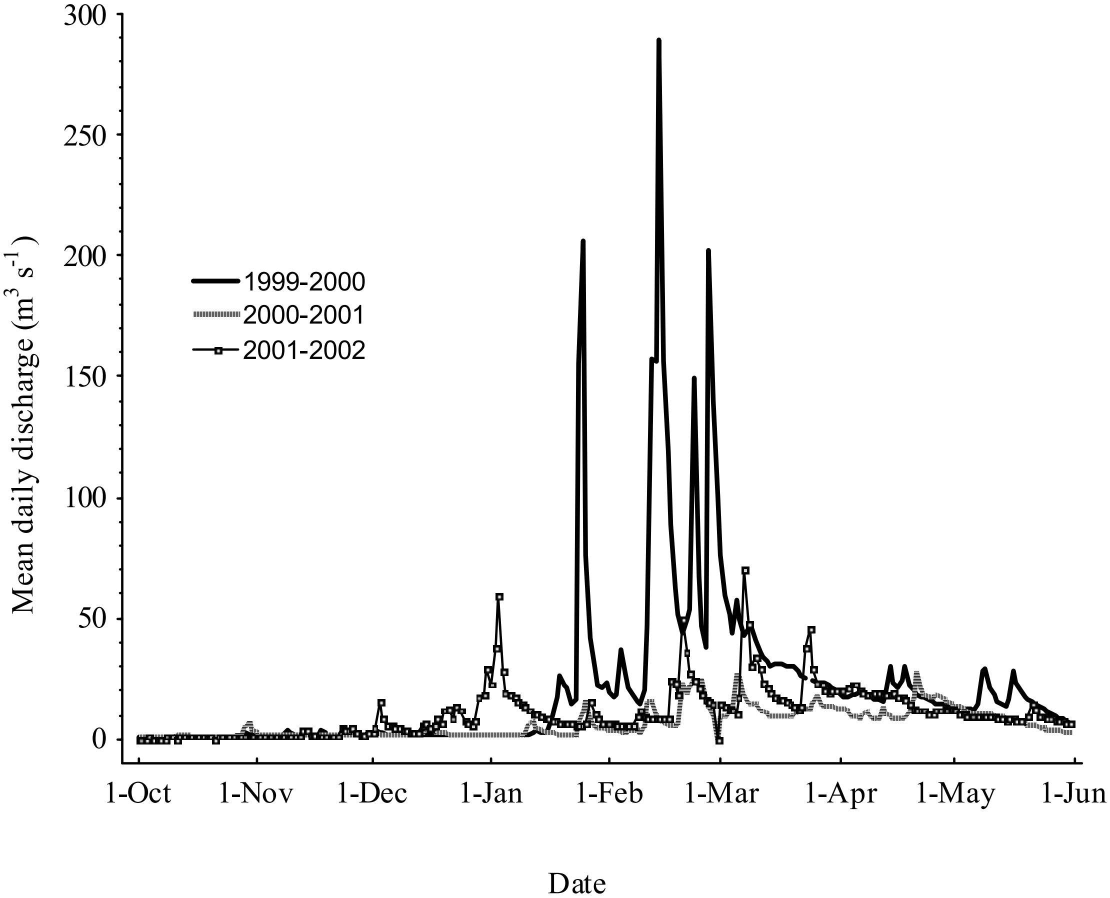

Figure 2.4. Mean daily discharge of the Cosumnes River at Michigan Bar for each of the three wet seasons.

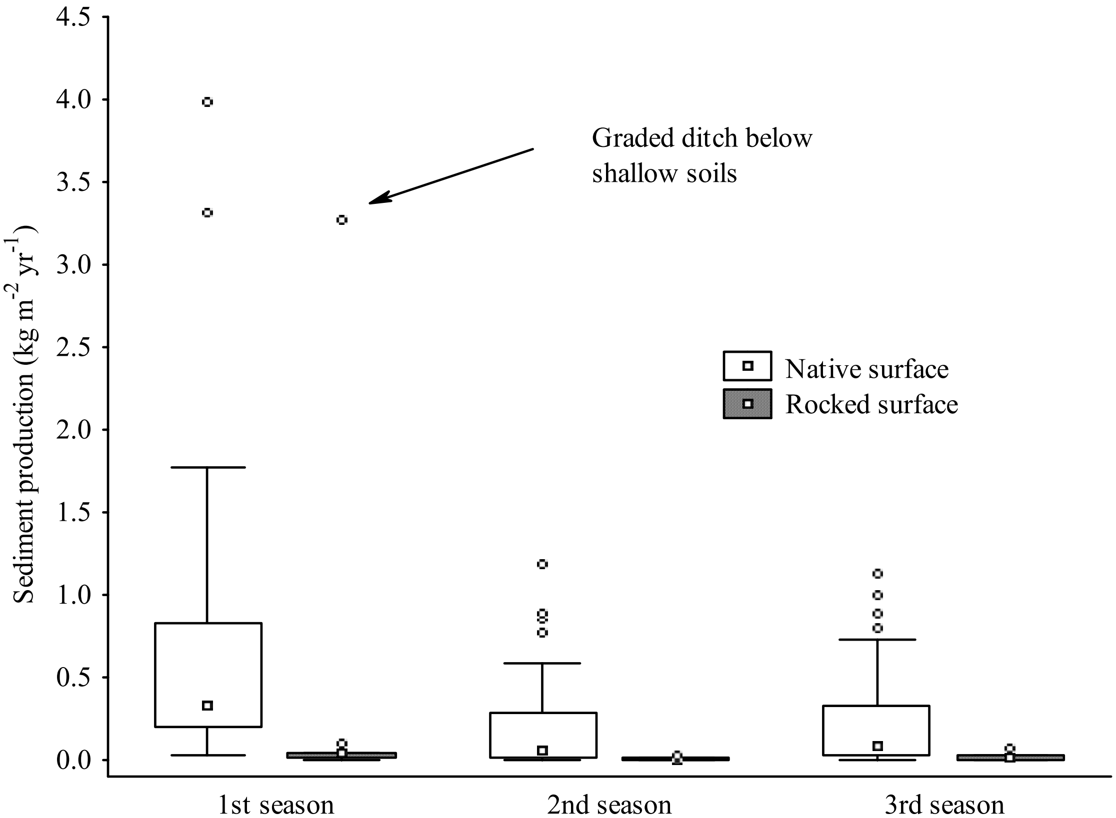

Figure 2.5. Annual sediment production rates for native surface and rocked road segments by wet season. Boxes represent the 25th to 75th quartiles, and the small boxes represent the median value. Circles represent outliers.

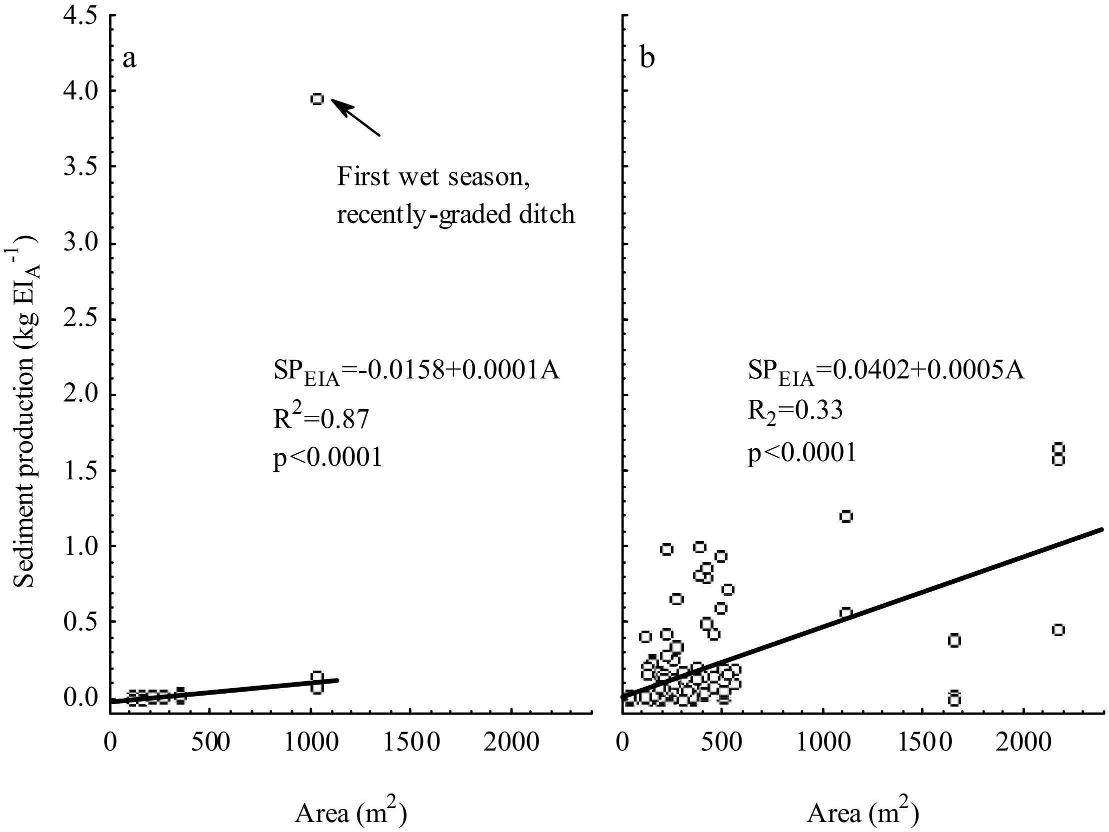

Figure 2.6. Road surface area versus normalized sediment production for: (a) rocked roads, and (b) native surface roads. The data point for the rocked road segment with the graded ditchline is shown, but this point was not included in the regression equation.

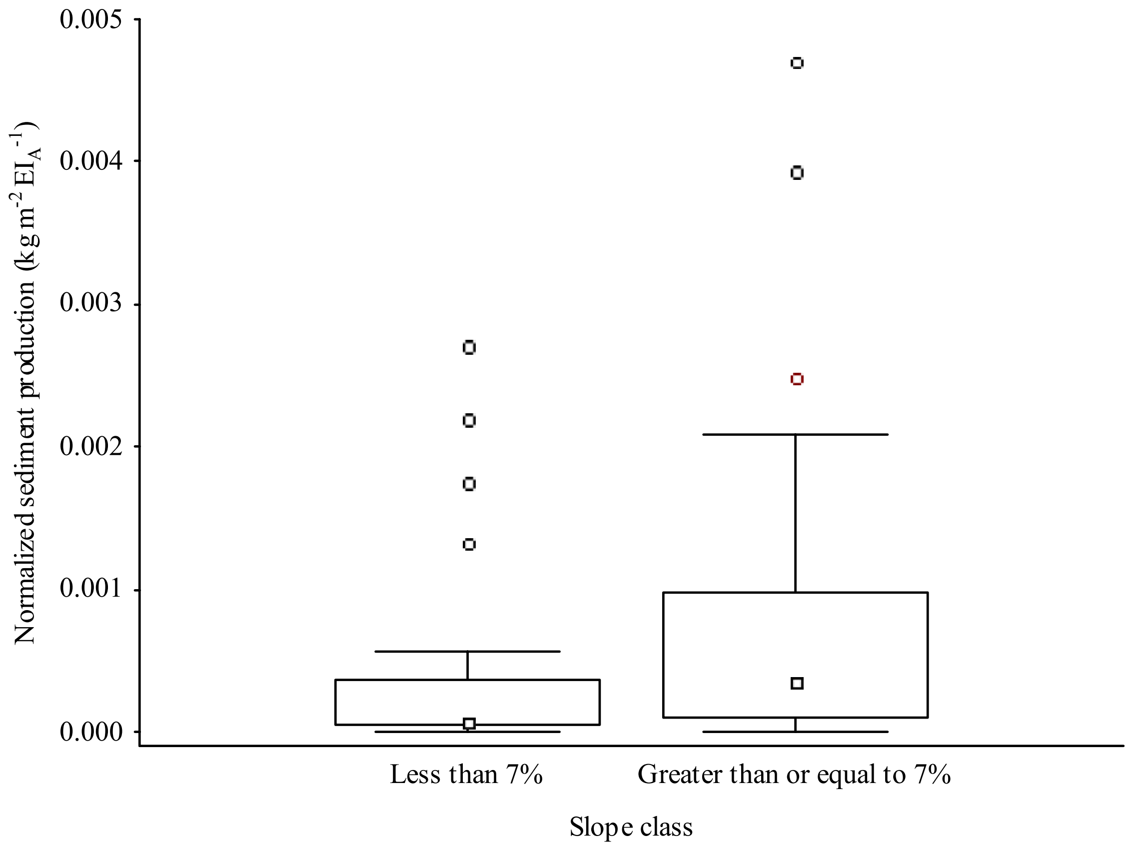

Figure 2.7. Normalized annual sediment production rate for native surface road segments by slope class.

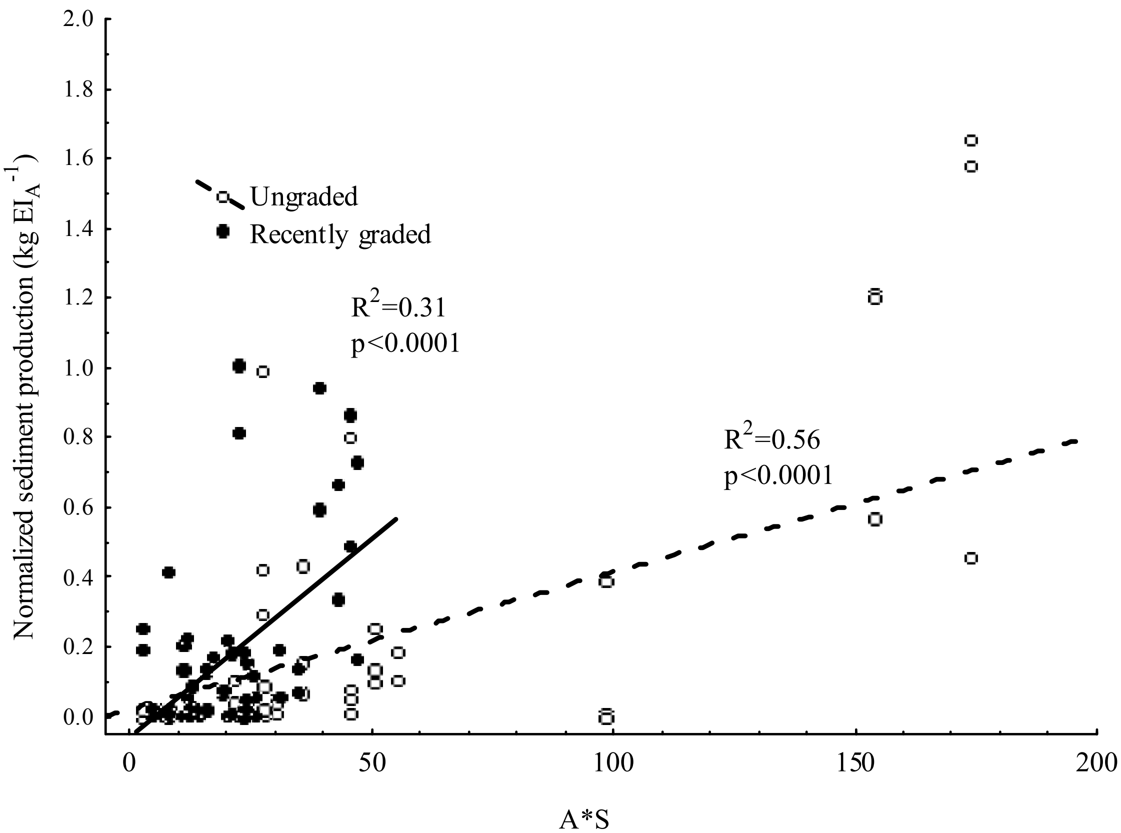

Figure 2.8. Sediment production normalized by EI_A versus road segment area times slope (A*S) for ungraded and recently-graded road segments. Recently-graded roads produce significantly more sediment than ungraded roads when using A*S as a covariate (p=0.02).

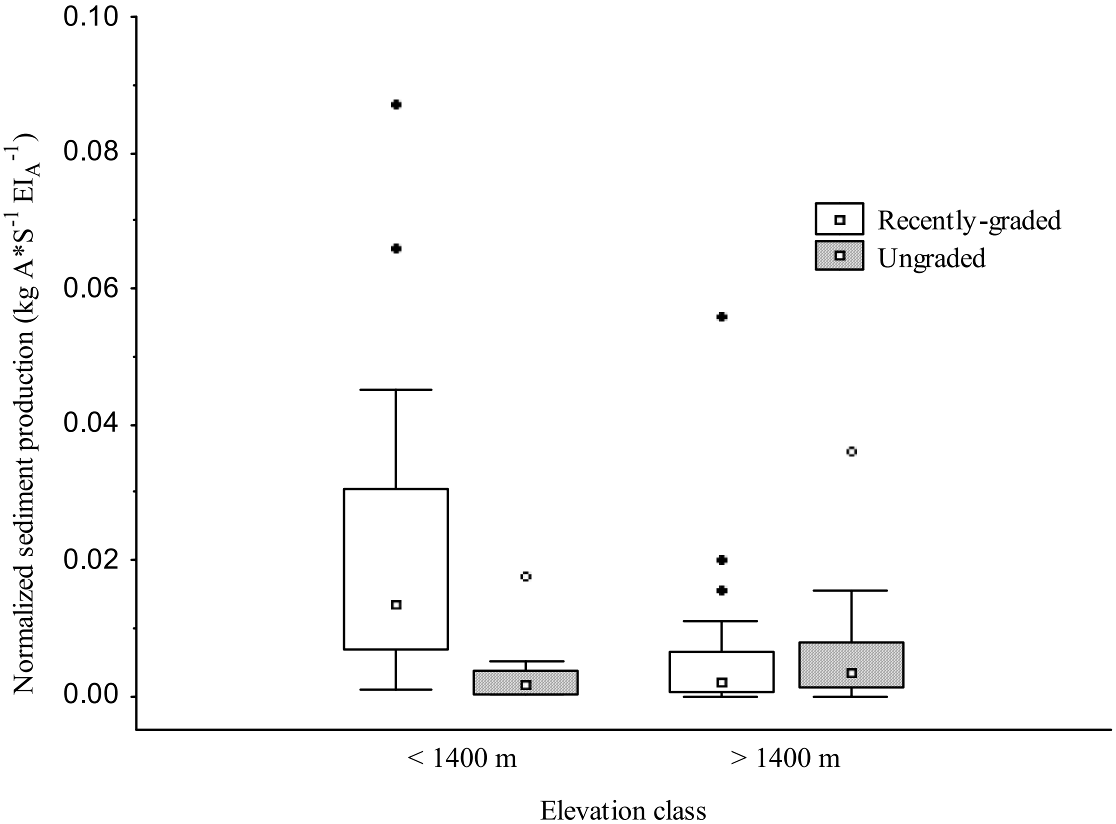

Figure 2.9. Sediment production rates normalized by A*S and EI_A for ungraded and recently-graded road segments by elevation class.

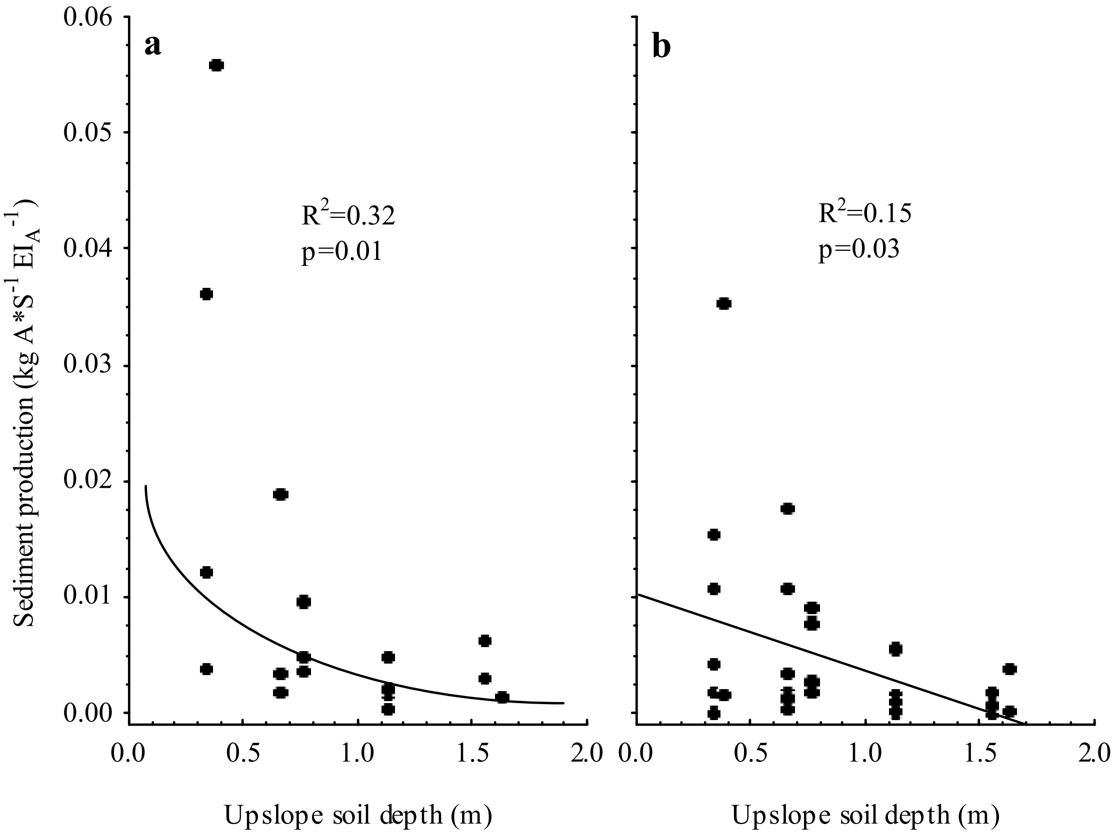

Figure 2.10. Sediment production normalized by A*S and EI_A versus upslope soil depth for midslope road segments in: (a) the first wet season, and (b) the second and third wet seasons.

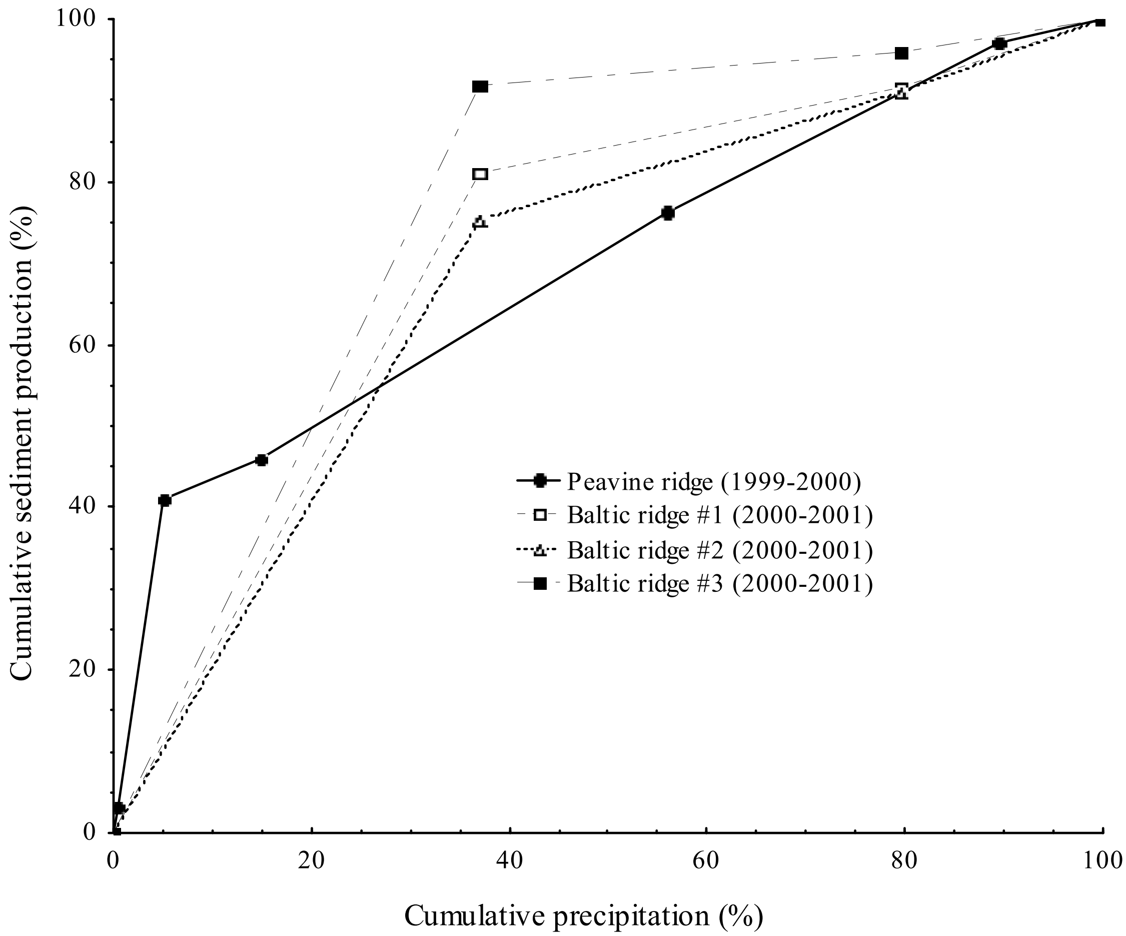

Figure 2.11. Cumulative precipitation versus cumulative sediment production for four recently-graded native surface road segments.

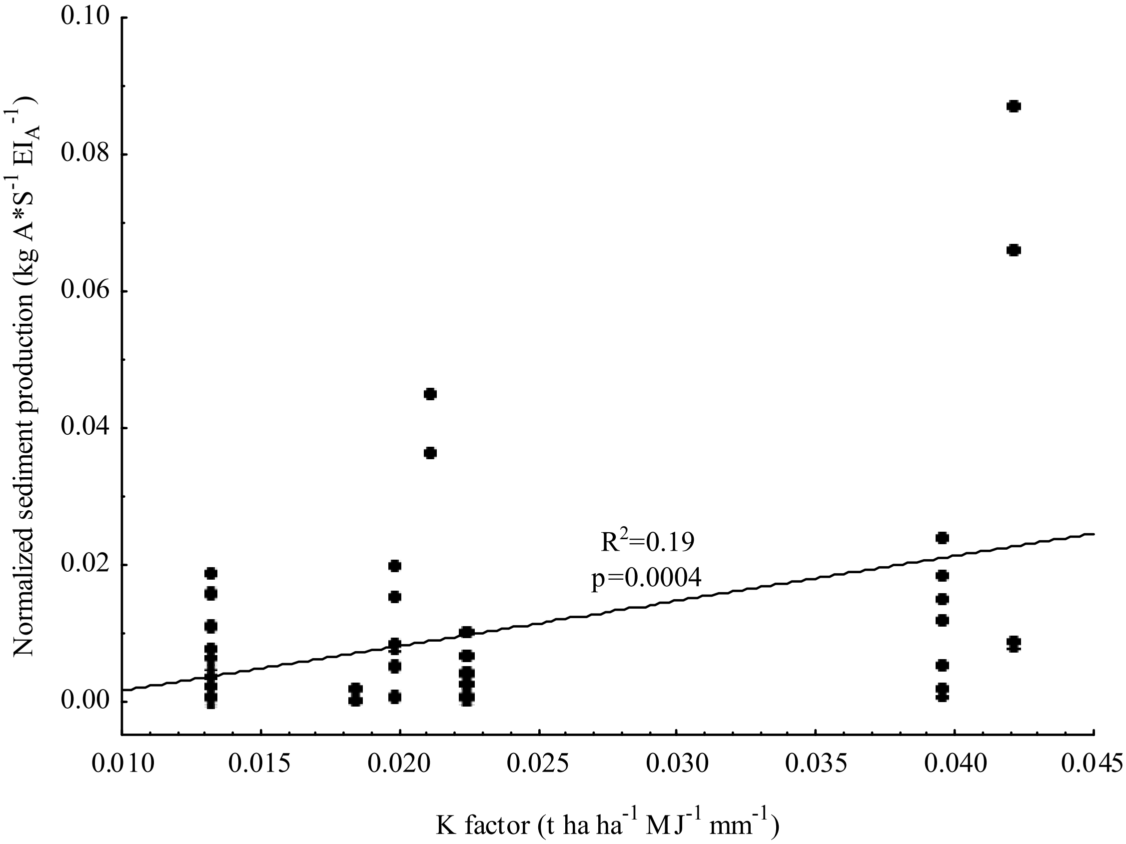

Figure 2.12. Sediment production normalized by A*S and EI_A for recently-graded native surface roads versus the published soil erodibility or K factor.

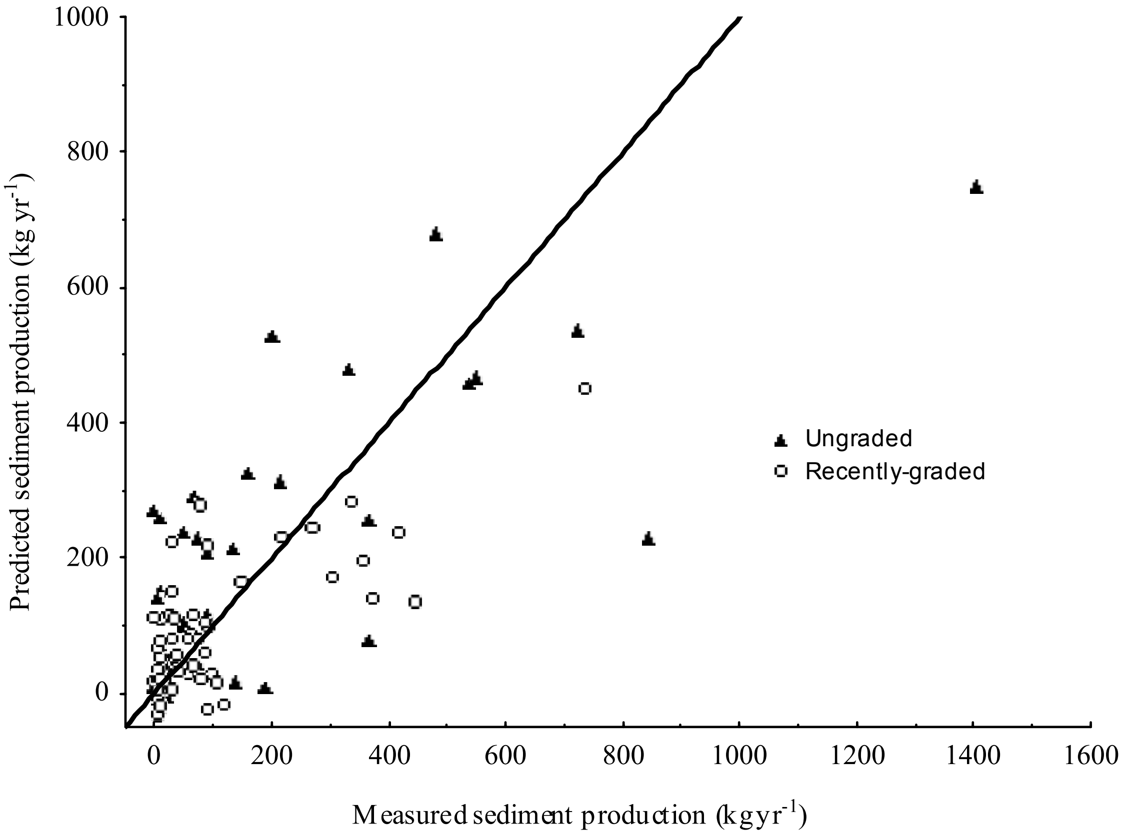

Figure 2.13. Measured versus predicted sediment production for the native surface road segments.

3.0. SEDIMENT DELIVERY FROM FOREST ROADS IN THE SIERRA NEVADA

ABSTRACT:

Sediment delivery was assessed by an intensive survey of 285 road segments along 20 km of roads in the Sierra Nevada Mountains of California. Overall, 16% of the 285 road segments and 25% of the road length were connected to the channel network. Fifty-nine percent of the connected road segments were due to stream crossings, while 35% of the connected segments resulted from road-induced gullies. Six percent of the segments were connected via sediment plumes. Sediment traveled less than 42 m below the drainage outlet for 95% of the road segments. The mean length of road-induced gullies was three times the mean length of road-induced sediment plumes. Thirty-nine percent of the variability in sediment travel distance was explained by the presence or absence of a gully below the drainage outlet, soil erodibility, estimated road traffic class, and road segment length. Gully initiation increased with road segment length, sideslope gradient, road designs that concentrated road runoff, and factors that affected the roughness and infiltration capacity below the drainage outlet. The presence or absence of gullying below a road segment was predicted with 90% accuracy by a logistic regression model. Road-induced gully volume was significantly related to the product of road length and hillslope gradient, soil erodibility, and road drainage type (R^2=0.60). The magnitude of sediment delivery from episodic gully erosion is 0.6 Mg km^{-1} yr^{-1}, compared to 1.4 Mg km^{-1} yr^{-1} of sediment delivered from road surfaces. Road sediment

delivery can be minimized by reducing the number of stream crossings in new road construction, disconnecting road drainage from stream crossings, frequently draining road segments on steep or erodible soils, and outsloping roads. An analysis of data from this and other studies shows that the proportion of road length that is connected to the stream channel network is strongly correlated with mean annual precipitation and the presence or absence of engineered drainage structures (R^2=0.92).

3.1. INTRODUCTION

Unpaved roads are chronic sediment sources in many parts of the western United States (Megahan and Kidd, 1972; Reid and Dunne, 1984; Luce and Black, 1999). Erosion from forest roads can exceed natural erosion rates by one or more orders of magnitude (Megahan and Kidd, 1972; Reid and Dunne, 1984; MacDonald et al., 2001; Ramos-Scharron and MacDonald, 2005). The resulting sediment can adversely impact aquatic resources if it is delivered to the channel network (Cederholm et al., 1981; Waters, 1995; Nelson and Booth, 2002; Suttle et al., 2004). Therefore, it is important to quantify the amount of road sediment that reaches the channel network and understand the causal mechanisms for road sediment delivery.

Several recent studies have assessed road-to-stream connectivity to help predict the hydrologic effects of roads (Wemple et al., 1996; La Marche and Lettenmaier, 2001; Bowling and Lettenmaier, 2001), and the potential for road-related sediment to be delivered to the channel network (Croke and Mockler, 2001). The most obvious road-to-stream connection occurs at stream crossings (Wemple et al., 1996; Croke and Mockler, 2001). Connectivity also occurs when road-generated Horton overland flow (Q_{HOF}) and intercepted subsurface stormflow (Q_{ISSF}) induce gullies that extend to the stream network (Montgomery, 1994; Wemple et al., 1996; Croke and Mockler, 2001; La Marche and Lettenmaier, 2001; Bowling and Lettenmaier, 2001). Road-related sediment also may travel downslope as sediment plumes, and some of this sediment can be delivered to the channel network (Haupt, 1959; Megahan and Ketcheson, 1996; Brake et al., 1997).

Studies in the Pacific Northwest (Montgomery, 1994; Wemple and Jones, 1996; La Marche and Lettenmaier, 2001) and southeastern Australia (Croke and Mockler, 2001) have shown that road sediment delivery is controlled by factors such as road segment length, road drainage type, hillslope gradient, hillslope curvature, and distance to the stream. However, little is known about the controlling factors for road sediment delivery in the mixed rain-snow climate in the California Sierra Nevada. The one study on road-stream connectivity in the Sierra Nevada focused on paved road networks (Montgomery, 1994), and data from different areas are needed to better understand the site-specific controls and variations in road-to-stream connectivity.

Along with high-severity wildfires, unpaved roads in the Sierra Nevada have the highest surface erosion rates in the Sierra Nevada (MacDonald et al., 2004). Data on road-to-stream connectivity are needed to predict and model the delivery of sediment from forest roads, and for assessing cumulative watershed effects. The resulting information can be used by land managers to help disconnect road sediment sources from the channel network and prioritize road maintenance and restoration efforts.

The specific objectives of this study were to: (1) characterize and quantify the pathways that control the delivery of runoff and sediment from unpaved forest roads to the channel network; (2) quantify the effect of the different site-scale factors on road-stream connectivity; (3) develop empirical models to predict road-stream connectivity; and (4) compare connectivity results from the Sierra Nevada with data from other studies.

3.2. BACKGROUND

The connectivity between roads and stream channels depends on a variety of factors. Conceptually, road-stream connectivity should increase with an increase in road and stream density due to the resultant increase in the number of stream crossings (Jones et al., 2000). In the western Cascades of Oregon, road-stream crossings accounted for almost 60% of all connected road segments (Wemple et al., 1996). The magnitude and importance of road connectivity at stream crossings will depend on the road design (e.g., outsloping), the proximity of road drainage structures on either side of the stream crossing, and all of the other factors that affect road runoff and erosion.

For the road segments that do not intersect that channel network, the travel distance of road-derived sediment depends on the amount of road-derived runoff and the factors that control the sediment transport capacity of runoff below the road drainage outlet (Megahan and Ketcheson, 1996). For roads dominated by Horton overland flow (Q_{HOF}), road length and road surface area are surrogates for the amount of runoff from a given road segment (Montgomery, 1994; Luce and Black, 1999; Chapter 2). However, for roads dominated by the interception of subsurface stormflow (Q_{ISSF}), the amount of road runoff will vary with other factors, such as the upslope drainage area and the ratio of cutslope height to soil depth (Montgomery, 1994; Wigmosta and Perkins, 2001; Wemple and Jones, 2003).

The sediment travel distance below the road segment also depends on the hillslope gradient, hillslope roughness, road drainage type, and time since construction (Haupt, 1959; Packer, 1967; Burroughs and King, 1989; Megahan and Ketcheson, 1996; Brake et al., 1997). Research in Idaho has shown that road sediment travel distance is controlled by hillslope gradient, obstructions on the hillslopes below the road drainage outlets, and road drainage type (Burroughs and King, 1989; Megahan and Ketcheson, 1996). In the Oregon Coast Range newly-constructed roads have longer sediment travel distances than older roads (Brake et al., 1997).

Several studies have evaluated the role of gullying on road sediment delivery. In western Oregon, 23% of the road drainage outlets were connected to the channel network via gullying (Wemple et al., 1996). In southeastern Australia 18% of the road sgements were connected to the stream network by gullying (Croke and Mocker, 2001). Road-induced gullies can be both a pathway for delivering road surface runoff and sediment to the channel network (Wemple et al., 1996; Croke and Mockler, 2001; LaMarche and Lettenmaier, 2001), and a source of sediment to the channel network as they develop and enlarge over time.

A gully is more likely to develop below a road drainage outlet as segment length increases (Montgomery, 1994; Wemple et al., 1996; Croke and Mockler, 2001) and hillslope gradient increases (Wemple et al., 1996). Quantitatively, the following relationship has been proposed for gully initiation:

$$L = L_t / \sin \theta \qquad (3.1)$$

where L is the critical contributing length of road necessary to initiate gullying (m), θ is the hillslope angle in degrees, and L_t is an empirical constant that represents the threshold road length (m) (Montgomery, 1994; Croke and Mockler, 2001). Gullies initiate when the product of road length and hillslope gradient exceed the L_t value.

3.3. METHODS

3.3.1. *Site Description*

The study area lies on the west slope of the Sierra Nevada mountain range in California (Figure 3.1). To the north it is bounded by the Rubicon River drainage, and to the south by the South Fork of the Cosumnes River. The primary forest type is mixed conifer, but this turns to red fir with increasing elevation (SAF, 1980). The Mediterranean-type climate means that most of the precipitation falls between November and April (USDA, 1985). Elevations range from 910 to 2000 m, and the mean annual precipitation at 1036 m is 1300 mm. The majority of the study area corresponds with the rain-on-snow climatic zone (Cobourn, 1989). Most of the road surveys were on the Eldorado National Forest, although some sites were on interspersed Sierra Pacific Industries (SPI) property.

The dominant lithologies are weathered granitic batholith, granitic glacial deposits, and volcanic (i.e., Mehrten formation) (USDA, 1985). The soils are typically coarse-textured loams. Most of the soils are over a meter thick, but the range is from 0.3 m to 1.5 m.

3.3.2. *Survey Procedures*

Twenty 1-km road transects were randomly selected and were surveyed in the summer of 2001. Each road transect was identified by randomly selecting one of the 1:24,000 USGS topographic maps in the study area, randomly selecting a section on the selected map, numbering each road in the selected section, and then randomly selecting a road using a random number generator. The roads were broken into subunits at road intersections, and one road intersection was randomly chosen as the starting point for the survey.

Each 1-km road transect was broken into road segments as defined by drainage outlets such as waterbars, rolling dips, or ditch-relief culverts, or a change in drainage direction due to ridges or stream crossings. The length of each segment was measured to the nearest decimeter with a flexible tape. The road gradient was measured at each break in slope with a clinometer, and a distance-weighted mean gradient was calculated for each segment. The width of the road tread was measured at several points and used to determine a mean width. Road segment length times the mean width yielded the road surface area for each segment.

The road segments were classified into three main drainage types: 1) outsloped segments; 2) outsloped and bermed segments; and 3) insloped segments drained by cross-relief culverts. By definition, the outsloped segments had diffuse drainage to the outside edge of the road and onto the hillslope. The outsloped and bermed roads were designed to be outsloped, but the combination of traffic and grading resulted in ruts or a berm along the outside edge that prevented runoff from leaving the road surface; drainage from these segments only occurred at a rolling dip, waterbar, or stream crossing. Segments drained by inside ditches were typically insloped, and were constructed using a cut-and-fill design with periodic relief culverts. If a segment was crowned and had an inside ditch, the road surface was divided into an outsloped and insloped portion and was counted as two road segments. In general, the outsloped roads had been more recently constructed and represented current road construction and maintenance standards, whereas the older roads were more typically insloped.

For each road segment the traffic level was qualitatively assessed as high, medium, or low. High traffic segments had evidence of recent timber hauling and typically had a thick layer of fine sediment on much of the road surface. Moderate traffic segments had evidence of frequent use by recreational traffic but no evidence of recent timber hauling. Low traffic segments had dense brush cover that prevented the use of the road by most vehicles.

Lithology, soil type, and soil depth were determined from soil survey data (USDA, 1985); lithology was field verified. The cutslope height was measured at varying intervals along the road segment length and averaged for each segment. The mean cutslope height to soil depth ratio was calculated for each segment. Hillslope gradients (m m^{-1}) below the drainage outlet and above the cutslope were measured with a clinometer. These values were averaged to obtain a mean hillslope gradient.

Each drainage outlet was assessed for signs of sediment delivery to the channel network using four connectivity classes (CC) (Wemple et al., 1996; Croke and Mockler, 2001) (Table 3.1). Road segments classified as CC1 had no signs of gullying or sediment transport below the drainage outlet, and have a very low potential for sediment delivery. Road segments classified as CC2 had gullies or sediment plumes that extended for no more than 20 m from the drainage outlet, and are considered to have a low to moderate potential for sediment delivery. Road segments identified as CC3 had gullies or sediment plumes that were at least 20 m in length, but ended more than 10 m away from the bankfull width of the nearest stream channel; these were considered to have a moderate to high potential for sediment delivery. Segments classified as CC4 intersected stream channels at stream crossings or had gullies or sediment plumes that extended to within 10 m of the bankfull edge of a stream channel. CC4 segments were classified as connected and have the highest potential for delivering sediment to the channel network (Table 3.1).

If present, the geomorphic feature below each drainage outlet that was used to indicate the sediment transport distance was categorized as either a sediment plume or a gully. Sediment plumes were defined by the presence of diffuse sediment and the absence of an actively incising channel. Gullies were defined by signs of channelized flow and incision. The length of each sediment plume and gully was measured. The top width and maximum depth of each gully was measured at 5-m intervals, and the cross-sectional area was calculated by assuming the gully had a triangular cross-section (i.e., cross-sectional area=1/2 * width * maximum depth). This area was multiplied by the length represented by each cross-section (typically 5 m) to yield a volume, and the sum of these volumes yielded the total volume for each gully.

The condition of the hillslope immediately below the drainage outlet was qualitatively assessed for the factors that may affect gully or sediment plume length. If a road segment discharged onto forest litter, the hillslope condition was categorized as "litter". If a road segment discharged runoff onto dense vegetation (e.g., brush) or large woody debris (LWD), then the hillslope condition was categorized as "energy dissipator". If a road segment discharged runoff onto compacted or disturbed soil, the hillslope condition was categorized as "disturbed".

3.3.3. Statistical Analysis

A variety of statistical methods were used to evaluate the effect of the different categorical and continuous variables on connectivity class, length of sediment plumes and gullies, gully presence or absence, and gully volume (Table 3.2). The mean values of the independent variables were compared across the discrete dependent variables, such as connectivity class or geomorphic feature, using Tukey Honestly Significant Difference (HSD) (Ott, 1993; STATISTICA, 2003). Log-normally distributed data were transformed before the Tukey HSD analysis to meet the assumptions of normality. A value of 0.1 was substituted for zero values for gully volumes, gully lengths, and sediment plume lengths in order to facilitate log transformation. Stepwise multiple regression with a selection criteria of $p<0.05$ was used to develop predictive models for gully and sediment plume lengths. Categorical variables were represented as binary variables in the model selection process. Forward stepwise logistic regression with a selection criteria of $p<0.05$ was used to predict the presence and absence of gullies below the drainage outlet. Additional logistic regression models were explored using Akaike Information Criterion (AIC) best subset model selection process (STATISTICA, 2003). All of the segments at stream crossings were excluded from the datasets used in the multiple and logistic regression analyses since the sediment plume lengths, gully lengths, and gully volumes for these segments were zero. Some gullies and sediment plumes from CC4 road segments were truncated by the stream channel, but they were left in the analysis to increase the sample size.

3.4. Results

3.4.1. Road Connectivity

The road survey covered 20 km of native surface roads and delineated 285 road segments. The mean segment length was 81 m, but lengths were highly variable as the standard deviation was 64 m and the range was from 7 m to 401 m (Table 3.3). The mean road gradient was 6%, and the range was from 0% to 17%. Hillslope gradients averaged 26% and ranged from 0% to 57%. The mean cutslope height for all road segments was 1.9 m, and values ranged up to 8.0 m. Cutslope height was significantly correlated with hillslope gradient (R^2=0.31, p<0.0001).

Seventy-seven percent of the road segments were outsloped but also were drained by waterbars or rolling dips. Fourteen percent were outsloped but had berms that kept the water on the road surface; these also were drained by waterbars or rolling dips. The remaining 9% of the road segments were insloped and drained by relief culverts.

Sixty-four percent of the road segments were on volcanic lithology, and the other 36% were either on weathered granitic (14%) or glacial granitic lithologies (22%). Thirty-one percent of the road segments were classified as having a high level of traffic, 48% had a moderate level of traffic, and 21% were classified as low traffic.

Sixteen percent of the road segments were connected to the stream network (Table 3.4), but these represented 25% of the total road length. Forty-nine percent of the road segments, or 38% of the total length, were categorized as CC1, meaning that there was no indication of gullying or sediment transport below the drainage outlet. Another 28% of the road segments were classified as CC2, indicating that sediment plumes and gullies extended for less than 20 m. Only 7% of the road segments had rills or sediment plumes extending more than 20 m (CC3).

Stream crossings were the dominant causal mechanism for sediment delivery to the channel network, as these accounted for 59% of the connected road segments. Another 35% of the road segments classified as CC4 were connected to the channel network by gullies. Only 6% of the road segments classified as CC4 were connected to the channel network via sediment plumes (Figure 3.2).

Connectivity class tended to increase with longer segment lengths (Figure 3.3). The mean length for the segments classified as CC1 was 63 m versus 109 m for the segments classified as CC4. The road segments classified as CC3 and CC4 were significantly longer than the segments classified as CC1 and CC2 ($p<0.0001$; Figure 3.3).

Connectivity class was strongly related to the type of road design, as approximately 90% of segments that were insloped and drained by relief culverts were classified as CC3 or CC4. In contrast, only 16% of the road segments that were drained by waterbars or rolling dips were classified as CC3 or CC4 (Figure 3.4).

3.4.2. Gully and Sediment Plume Lengths

Sediment travel distances depended on whether the geomorphic feature below the drainage outlet was a sediment plume or a gully (Figure 3.5). If the 25 segments draining directly to a stream crossing are excluded, sediment plumes were present below 29% of the road segments and the mean length was 11.8 m. The longest plume was 183 m, and this was due to road runoff being routed onto and down a skid trail. Gullies were found below just 13% of the road segments, but the mean length was nearly 37 m, or more than three times the mean sediment plume length ($p=0.0001$) (Figure 3.5). Ninety-five percent of the road segments had sediment plumes or gullies that were less than 42 m in length. Sediment plumes accounted for 89% of the geomorphic features present below the CC2 road segments, while gullies accounted for 67% of the geomorphic features below CC3 road segments and 83% of the geomorphic features below CC4 road segments.

The lengths of the sediment plumes increased with traffic class (Figure 3.6). The mean sediment plume length below segments with low levels of traffic was only 3.7 m, or 28% of the mean sediment plume length for roads with high or moderate levels of traffic ($p=0.001$).

Gully length was a power function of the soil K factor ($R^2=0.27$; $p=0.001$), indicating that gully length increased for more erodible soils. Gully length was not significantly correlated with either road segment length ($p=0.07$) or hillslope gradient ($p=0.76$).

Multivariate models could predict only 39% of the variability in gully and sediment plume lengths for the 260 road segments that were not associated with stream crossings. The best model is:

$$\text{Log}_{10}(D) = 0.965 + 1.278(\log_{10} K) + 0.409(\log_{10} L) + 1.431G + 0.420T \quad (3.2)$$

where D is the length (m) of the geomorphic feature, K is soil erodibility (t ha h ha^{-1} MJ^{-1} mm^{-1}) (p=0.004), L is road length (m) (p=0.04), G is a binary variable where 0 represents the absence of a gully and 1 indicates that a gully is present (p<0.0001), and T is a binary variable where 0 represents a low level of traffic and 1 represents a moderate to high level of traffic (p=0.001) (Figure 3.7). The adjusted R^2 for the model is 0.37, and the standard error is only 3.0 m because so many segments have either a very short or no sediment plume or gully.

3.4.3. Controls on Gully Initiation

Gullies were more likely to be present below the longer road segments, segments with relief culverts, and where the ratio of cutslope height to soil depth was greater than 1.0. The mean length of the 36 road segments with gullies was 118 m versus 64 m for the 224 segments without gullies (p<0.0001) (Figure 3.8). Approximately half of the 36 segments with gullies were insloped with relief culverts. The mean ratio of cutslope height to soil depth was 3.1 for segments with gullies; segments without gullies had a significantly lower mean ratio of 2.2 (p=0.001; Figure 3.9). A higher ratio indicates a greater likelihood of intercepting subsurface stormflow and a corresponding increase in surface runoff. Only one of the 36 road segments with a gully below the outlet had a cutslope height that was less than the soil depth.

Gully initiation was not significantly related to hillslope gradient (p=0.14), and there was not a distinct road segment area*slope or length*slope threshold (i.e., L_t) for gully initiation. However, for a given hillslope gradient a gully was more likely to occur below the longer segments (Figure 3.10). No gullies were present for road segments less than 35 m long or hillslope gradients less than 16%.

The presence or absence of gullies below road segments is best predicted by a logistic regression equation:

$$P_G = 1 / 1 + \exp [4.08 - 0.0574(L*S_H) - 3.30C + H_C] \quad (3.3)$$

where P_G is the probability of gullying; $L*S_H$ is the product of road segment length (m) and hillslope gradient (m m^{-1}); C is a binary variable with 0 representing an outsloped or bermed road segment drained by a waterbar or rolling dip and 1 representing an insloped road segment with a relief culvert; and H_C is a variable representing the condition of the hillslope 1 m below the drainage outlet. H_C is equal to zero if the drainage discharges onto forest litter, 7.1 if obstructions are present 1 m below the drainage outlet, and –2.5 if the drainage outlet discharges onto compacted soil (e.g., a skid trail or landing). If the threshold for gullying is $P_G>0.50$, the model has a 49% success rate in predicting the presence of gullies and a 96% success rate in predicting the absence of gullies, resulting in an overall model performance of 90%. If the threshold for gullying is set at $P_G>0.30$, then the model correctly predicts 63% of the gullied segments and 93% of the non-gullied segments for an overall model performance of 89%.

3.4.4. Gully Volumes

Within the study area gullies are important because they are the most common feature connecting roads to streams, and because they also can be an important source of sediment. The mean gully volume for the 36 road segments with gullies was 10.3 m^3, but the distribution was highly skewed as the median gully volume was only 3.9 m^3 and the range was from 0.01 to 153 m^3. The largest gullies are of most interest because these tended to be longer and hence more likely to reach a stream channel. In general, the cross-sectional area of gullies tended to decline as gullies progressed downslope. However, two gullies reached the inner gorge of stream channels and apparently triggered small, shallow landslides. The volume of these two slides (89.2 m^3 and 153 m^3, respectively) accounted for 54% of the total volume of sediment from gullying.

Sixty percent of the variability in gully volumes can be predicted from the following equation:

$$\text{Log10 } V = 1.88(\log10\ K) + 1.32(\log10\ L{*}S_H) + 0.515C + 1.503 \qquad (3.4)$$

where V is gully volume (m^3), K is soil erodibility (t ha h ha^{-1} MJ^{-1} mm^{-1}) ($p=0.04$), L is road length (m), S_H is hillslope gradient (m m^{-1}) ($L{*}S_H$; $p=0.0004$), and C is a binary variable with 0 representing the presence of a waterbar or rolling dip and 1 representing the presence of a relief culvert ($p=0.04$). The adjusted R^2 for the model was 0.57, and the standard error of prediction was 3.8 m^3 (Figure 3.11).

3.5. Discussion

3.5.1. *Gully and Sediment Plume Lengths*

The gully and sediment plume lengths from this study are generally less than or similar to other reported values. For newly constructed roads in the Idaho batholith, the mean length of sediment plumes was 53 m for segments with relief culverts and 12 m for segments with rock drains (Megahan and Ketcheson, 1996). The comparable mean sediment transport lengths for the mixed lithologies in this study were 29 m for segments with relief culverts and 6 m for segments drained by waterbars and rolling dips. However, the mean sediment transport lengths on weathered granitic batholith sites were 37 m for segments with relief culverts and 12 m for segments drained by waterbars and rolling dips. These latter values are very similar to the values from granitic sites in the Idaho Batholith. In central Idaho, the mean gully and sediment plume lengths below relief culverts were 20% shorter on metasedimentary lithologies than volcanic and granitic lithologies (Burroughs and King, 1989). The overall mean sediment travel distance of 8.7 m in this study is very similar to the mean sediment transport distances on sandstone lithology in the Oregon Coast Range of 5.1 m for old roads and 9.3 m for new roads (Brake et al., 1997).

The empirical model developed to predict gully and sediment plume length uses four variables (Eq. 3.2), and each of these variables has a physical basis. Gully or sediment plume length increases with increasing road segment length because the latter is a surrogate for the amount of road surface runoff. An increase in runoff will increase both the amount of eroded sediment and the downslope transport capacity (Luce and Black, 1999). The binary variable for the presence or absence of a gully implicitly recognizes that gullies have more concentrated runoff and a greater travel distance than the more diffuse flow associated with sediment plumes. The greater length with an increase in the K factor reflects the increase in soil erodibility with decreasing particle size and decreasing soil permeability (Lal and Elliot, 1994). Silts and fine sands are more easily detached and transported than larger particles, and a lower permeability will reduce downslope infiltration and thereby increase the travel distance.

Higher traffic levels were associated with an increase in sediment plume length but not an increase in gully length. An increase in traffic on unpaved roads increases the supply of erodible sediment that can be transported below the drainage outlet (Ziegler et al., 2001a; Ziegler et al., 2001b). In this study sediment plume lengths were significantly shorter for roads that were partly overgrown and characterized as having a low level of traffic. The vegetation on these low traffic segments is presumably reducing the amount of both runoff and erosion, and the mean plume length of 3.7 m for the low traffic segments is consistent with this explanation.

3.5.2. Gully Initiation

Gully initiation was more likely with longer road lengths, steeper hillslope gradients, insloped roads, and smoother hillslopes (Eq. 3.3). It has already been shown that longer road segment lengths are a surrogate for increased runoff and flow depths (Luce and Black, 1999). An increase in runoff and hillslope gradient will increase shear stress, and gully initiation is more likely as shear stress increases (Montgomery, 1994). The inclusion of $L*S_H$ in equation 3.3 is consistent with results from the western Cascades in Oregon, where $L*S_H$ was a significant variable in a logistic regression model developed to predict gully initiation below road drainage outlets (Wemple et al., 1996).

The type of road drainage is an important control on gully initiation, as much shorter segment lengths are needed to initiate gullies on insloped roads drained by relief culverts than for outsloped or bermed roads drained by waterbars or rolling dips. Using Equation 3.3 and assuming the mean segment length of 81 m and the mean hillslope gradient of 26%, the probability for gullying increases from 0.05 to 0.61 when a road segment is insloped and drained by a relief culvert as opposed to outsloped and waterbarred. The higher likelihood of gullying can be attributed to the more highly concentrated flow at the outlet of the relief culvert. In southeastern Australia the majority of gullies also were also associated with relief culverts as compared to other types of drainage outlets (Croke and Mockler, 2001). Figures 3.12a and 3.12b show the critical road segment length needed to have a 50% probability of gully initiation for a given hillslope gradient and hillslope condition for two drainage types.

The condition of the hillslope below the drainage outlet is important because this controls other factors, such as surface roughness and infiltration capacity, that directly affect the likelihood of gullying. Gully initiation was least likely when natural energy dissipating obstructions such as brush or LWD were present 1 m below the drainage outlet (Figure 3.12). Gully initiation was most likely when road runoff was discharged onto compacted or disturbed soils, such as skid trails. According to equation 3.3, an outsloped road with a mean length of 81 m and the mean hillslope gradient of 26% has a zero probability of gullying when an energy dissipating obstruction is below the drainage outlet, a 5% probability when the segment discharges onto forest litter, and a 42% probability of gullying if the segment discharges onto compacted soil. The corresponding probabilities for a comparable insloped road are zero, 61%, and 95%, respectively. This indicates that gully initiation below insloped roads with relief culverts is particularly sensitive to the condition of the hillslope below the drainage outlet (Figure 3.12b), and that the placement of energy dissipators below relief culverts are an effective best management practice to prevent gully erosion.

Upslope soil depth was not included in the model to predict gully initiation because it had a p-value of 0.11, but in some situations soil depth can be an important factor in gully initiation. For midslope roads, gullying is more likely when the cutslope height exceeds soil depth, as this will increase the amount of Q_{ISSF} (Wigmosta and Perkins, 2001; Ziegler et al., 2001c; Wemple and Jones, 2003). Soil depth was included when the Akaike Information Criterion (AIC) model selection process was used instead of stepwise regression. If soil depth is added to the predictive model, the success rate of predicting the presence of gullies increased from 48% to 54% when using a P_G of 0.50. Soil depth is much less likely to be important for ridgetop roads or valley bottom roads with small cutslopes, and this is probably why soil depth was not included in the overall model.

3.5.3. Gully Volumes

Gully volumes increased with longer road segment lengths, steeper hillslopes, higher K factors, and the presence of relief culverts (Eq. 3.4). As noted earlier, longer segments increase the amount of road runoff and steeper hillslope gradients increase shear stress and gully erosion (Mongtomery, 1994). Road drainage type determines whether the runoff is partially dispersed or concentrated at the drainage outlet, and the flow velocity. The logistic regression equation used to predict the presence or absence of gullies also explains 29% of the variability in log-transformed gully volumes ($p=0.0007$). This shows that the road segments with the highest probability for gullying also should have the highest gully volumes.

The connectivity data and the predictive equations can be used to calculate the amount of sediment being delivered from road-induced gullying versus the amount of sediment being delivered from road surfaces. The total volume of sediment delivered to the channel network by gully erosion was 355 m^3, or 18 m^3 per km of road. If a bulk density of 1.6 Mg m^3 is assumed, the sediment delivery rate from road-induced gullies is 29 Mg per kilometer of road length. In the western Cascades of Oregon road-induced gullies were associated with flood events with a 30- to 100-year recurrence interval (Wemple et al., 2001). If gullies are assumed to form in response to storms with a recurrence interval of 50 years, the mean annual sediment delivery rate from gullies would be 0.6 Mg km^{-1} yr^{-1}.

This value can be compared to the amount of sediment being produced and delivered from the road surface. The prediction equation for road surface erosion from native surface roads is:

$$SP_{ns} = -329 + 3.56\,(A*S) + 0.542\,EI_A + 0.389\,(A*G) \tag{2.7}$$

where SP_{ns} is sediment production in kilograms per year, A*S is the product of road area and road slope (m^2), EI_A is annual erosivity (MJ mm ha^{-1} hr^{-1}), and A*G is the product of road area and a binary variable (G) with 1 representing a recently-graded road and 0 representing an ungraded road (Chapter 2). This equation was used to predict the amount of sediment being produced from each road segment that was connected by a stream crossing, gully or sediment plume. The calculations assumed a mean annual erosivity of 1360 MJ mm ha^{-1} hr^{-1} (Renard et al., 1997), that none of the roads had been recently graded, and that all of the sediment from a connected road segment was reaching the stream channel. The resulting sediment delivery rate for road surface erosion was 1.4 Mg km^{-1} yr^{-1}, or 2.3 times the estimated gully erosion rate of 0.6 Mg km^{-1} yr^{-1}.

The validity of this comparison depends on the assumptions regarding the storm recurrence interval for gully formation, the mean annual erosivity, the frequency of road maintenance activities, the percent of sediment delivered from the connected segment and the gully, and the accuracy of the sediment prediction model. Road-induced gully erosion may be a larger contributor of sediment to the channel network if gullies form during storms with a shorter recurrence interval. For example, the amount of sediment from gullies would double if gully erosion results from storms with a recurrence interval of 25 years rather than 50 years. The amount of sediment from road surfaces is sensitive to the annual erosivity and the presence or absence of grading. For example, assuming an EI_A of 2000 MJ mm ha^{-1} hr^{-1} would increase sediment delivery from road surfaces from 1.4 to 2.2 Mg km^{-1} yr^{-1}. If all roads are recently-graded, the sediment delivery from road surfaces would increase by 50% to 2.1 Mg km^{-1} yr^{-1}. The key point is that large amounts of sediment can be produced and delivered from road-induced gullies as well as road surface erosion.

3.5.4. *Connectivity*

The road survey showed that 16% percent of the road segments and 25% of the total road length was connected to the channel network. These values are low relative to most other studies. In southeastern Australia, 38% of the road length was connected to the streams in an area with similar Mediterranean climate (Croke and Mockler, 2001). In northwestern California 32% of the road segments were connected to the channel network (Raines, 1991). However, in the drier Front Range of Colorado, 18% of the total road length was connected to the channel network (Libohova, 2003).

An analysis of the data from these and other studies suggests that the percentage of unpaved roads that are connected to the stream network increases with mean annual precipitation and decreases with the presence of engineered road drainage structures such as waterbars, rolling dips, and relief culverts (Reid and Dunne, 1984; Raines, 1991; Wemple et al., 1996; Bowling and Lettenmaier, 2001; Croke and Mockler, 2001; Ziegler et al., 2000; Libohova, 2004; Sidle et al., 2004; A. Ziegler, personal comm., 2003). An empirical prediction equation using these two factors can explain 92% of the variability in road connectivity:

$$C = 12.9 + 0.016\ P + 39.5\ M \tag{3.5}$$

where C is either the percent of road length or percent of road segments that are connected to the channel network, P is the mean annual precipitation (mm), and M is a binary variable with 0 representing roads with engineered drainage structures, and 1 representing roads without engineered drainage structures ($p<0.0001$) (Figure 3.13). Mean annual precipitation explains 41% of the variability in connectivity ($p=0.03$) for the entire dataset, and 84% of the variability in connectivity for roads with engineered drainage structures ($p=0.001$). The standard error of the estimate is 8.2%. To develop this equation it was assumed that the percent of connected segments was equivalent to the percent of the connected road length. Although this assumption is not strictly true because the longer segments are more likely to be connected, it was necessary in order to pool the data collected using each approach.

There are several reasons why mean annual precipitation is the dominant control on road-stream connectivity. Increasing precipitation tends to increase drainage density (Gregory, 1976; Montgomery and Dietrich, 1988), and an increase in drainage density will increase the number of stream crossings. An increase in precipitation also will increase the amount of road runoff, which will increase the number and length of road-induced gullies (Montgomery, 1994; Luce and Black, 1999; Croke and Mockler, 2001).

The binary variable reflects the ability of road drainage structures to disconnect road segments from the channel network. Frequent drainage structures reduce the amount of runoff available for gully initiation and the downslope transport of road-related sediment (Montgomery, 1994; Croke and Mockler, 2001). The careful placement of drainage structures also can help reduce the amount of road drainage that reaches the stream at stream crossings. The coefficient for the dummy variable in Eq. 3.5 indicates that engineered drainage structures will decrease the connectivity by about 40% relative to roads without engineered drainage structures.

3.5.5. Management Implications

The data in Figure 3.13 indicate that road connectivity is lower in the study area than in wetter areas such as the Pacific Northwest, but that sediment is being delivered to the streams from 25% of the road network. A study of 28 pool-riffle reaches in the study area found a positive correlation between estimated road sediment production and residual pool infilling (R^2=0.14; p=0.02) (MacDonald et al., 2003). Relatively small increases in fine sediment can adversely affect fish by decreasing the growth and survival of juvenile fish, and decreasing the availability of invertebrate prey species (Suttle et al., 2004). The response of juvenile fish and invertebrates to fine sediment loading is linear, suggesting that any increase in fine sediment will have a detrimental effect (Suttle et al., 2004).

The results of this study have important management implications for reducing road sediment delivery. First, most roads are connected at stream crossings, so the number of stream crossings should be minimized when designing and constructing unpaved roads. Second, the production and delivery of road sediment to stream crossings can be reduced by rocking the approaches to stream crossings (Chapter 2) and minimizing the length of the road segments that drain directly to the crossing (Eq. 2.7).

Third, the size and length of sediment plumes and gullies can be minimized by reducing road runoff and reducing traffic. This will reduce the amount of sediment that is delivered and the amount of sediment that is generated by gully erosion. The amount of runoff from a road segment can be reduced by shortening the road segment length, outsloping the road surface, and minimizing cutslope heights on shallow soils. Gully initiation below road segments can be minimized by avoiding sensitive sites as identified by hillslope gradient, soil depth, and hillslope condition. Gully initiation also can be minimized by improved road designs in terms of decreasing the spacing of drainage structures, changing road drainage type, and minimizing cutslope height. The road drainage guidelines in Figure 3.12 can be used to minimize the risk of gullying below a road drainage outlet.

Fourth, sediment delivery from gully erosion can be minimized by improved road drainage. Gully volumes and travel distance can be reduced by shortening segment lengths and outsloping the road surface. Managers should avoid insloping road segments on erosive soils and steeper hillslopes. Finally, 95% of road segments transported sediment less than 42 m from the drainage outlet. If roads can be placed or relocated at least 40 m from stream channels, sediment delivery via sediment plumes and gullies should be minimized.

3.6. Conclusions

This study measured the extent to which unpaved forest roads in the Sierra Nevada of California are connected to the stream channel network. A detailed survey along 20 km of unpaved roads identified 285 road segments. Sixteen percent of the 285 road segments and 25% of the road network length were connected to the channel network. Fifty-nine percent of the connected road segments were due to stream crossings, while 35% were connected by road-induced gullies. Only 6% of road segments were connected via sediment plumes.

The mean gully length was 37 m. or roughly 3 times larger than the mean sediment plume length, and the longest gully was 95 m. Multivariate analysis indicated that the length of sediment plumes and gullies below road drainage outlets was controlled by the presence or absence of gullies, soil erodibility, traffic level, and road segment length (R^2=0.39; $p<0.0001$). Road-induced gullies were more frequent on insloped roads drained by relief culverts, longer road segments on steeper slopes, and drainage outlets discharging onto hillslopes with relatively low surface roughness or low infiltration due to compaction. A logistic regression model using these factors had a 90% success rate in distinguishing between gullied and ungullied segments. Gully volume was significantly related to the product of road segment length and hillslope gradient, soil erodibility, and road drainage type (R^2=0.60; $p<0.0001$). Gully volumes were significantly higher below relief culverts than for waterbars or rolling dips. The amount of sediment delivered from road-induced gully erosion was 43% of the amount of sediment delivered from road surfaces. Road sediment delivery can be minimized by reducing the number of stream crossings, outsloping and frequently draining roads on erosive soils and steep hillslopes, and placing new roads further from stream channels.

An analysis of data from 10 studies shows that road-stream connectivity is strongly controlled by mean annual precipitation and the presence or absence of engineered drainage structures (R^2=0.92; $p<0.0001$). The absence of engineered drainage structures will increase connectivity by approximately 40%. The findings of this and other studies indicate that maintaining and improving road drainage is an effective means to reduce road sediment delivery.

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3.7. TABLES AND FIGURES

Connectivity class	Geomorphic criteria	Potential for sediment delivery
1	No signs of gullying or sediment transport below drainage outlet	Low
2	Gullies or sediment plumes <20 m in length	Low/moderate
3	Gullies or sediment plumes >20 m in length, but more than 10 m from stream channel	Moderate/high
4	Gullies or sediment plumes to within 10 m of a stream channel	High

Table 3.1. Road connectivity classes and their estimated potential for sediment delivery.

Dependent variables	Independent variables
Connectivity class (CC)	Road segment gradient (S)
Geomorphic feature (gully or sediment plume)	Road surface area (A)
Sediment travel distance below outlet (m)	Road length (L)
Gully presence or absence	Hillslope gradient (SH)
Gully volume	Cutslope height
	Soil series
	Lithology
	Soil depth
	Soil erodibility (K factor)
	Road drainage type (outsloped, bermed, or insloped with relief culvert)
	Geomorphic feature (gully or sediment plume)
	Hillslope condition

Table 3.2. List of dependent and independent variables used in pairwise comparisons, multiple regression, and logistic regression.

Variable	Mean	Range Minimum	Range Maximum	Std. dev.
Segment length (m)	76	7	401	64
Segment area (m^2)	563	43	5260	587
Segment gradient ($m\ m^{-1}$)	0.06	0	0.17	0.03
Cutslope height (m)	1.9	0.2	8.0	1.1
Hillslope gradient ($m\ m^{-1}$)	0.26	0.01	0.57	0.11
K factor ($t\ ha\ h\ ha^{-1}\ MJ^{-1}\ mm^{-1}$)	0.017	0.013	0.032	0.017
Soil depth (m)	1.0	0.30	1.6	0.40

Table 3.3. Mean, range, and standard deviation of the independent variables used to characterize each segment.

Connectivity class	Number of segments	Percent of total segments	Road length (km)	Percent of total length
1	138	48.4	8.11	37.7
2	81	28.4	5.62	26.1
3	20	7.0	2.25	10.5
4	46	16.2	5.55	25.7
Total:	285	100	21.53	100

Table 3.4. Number of road segments and road length by connectivity class.

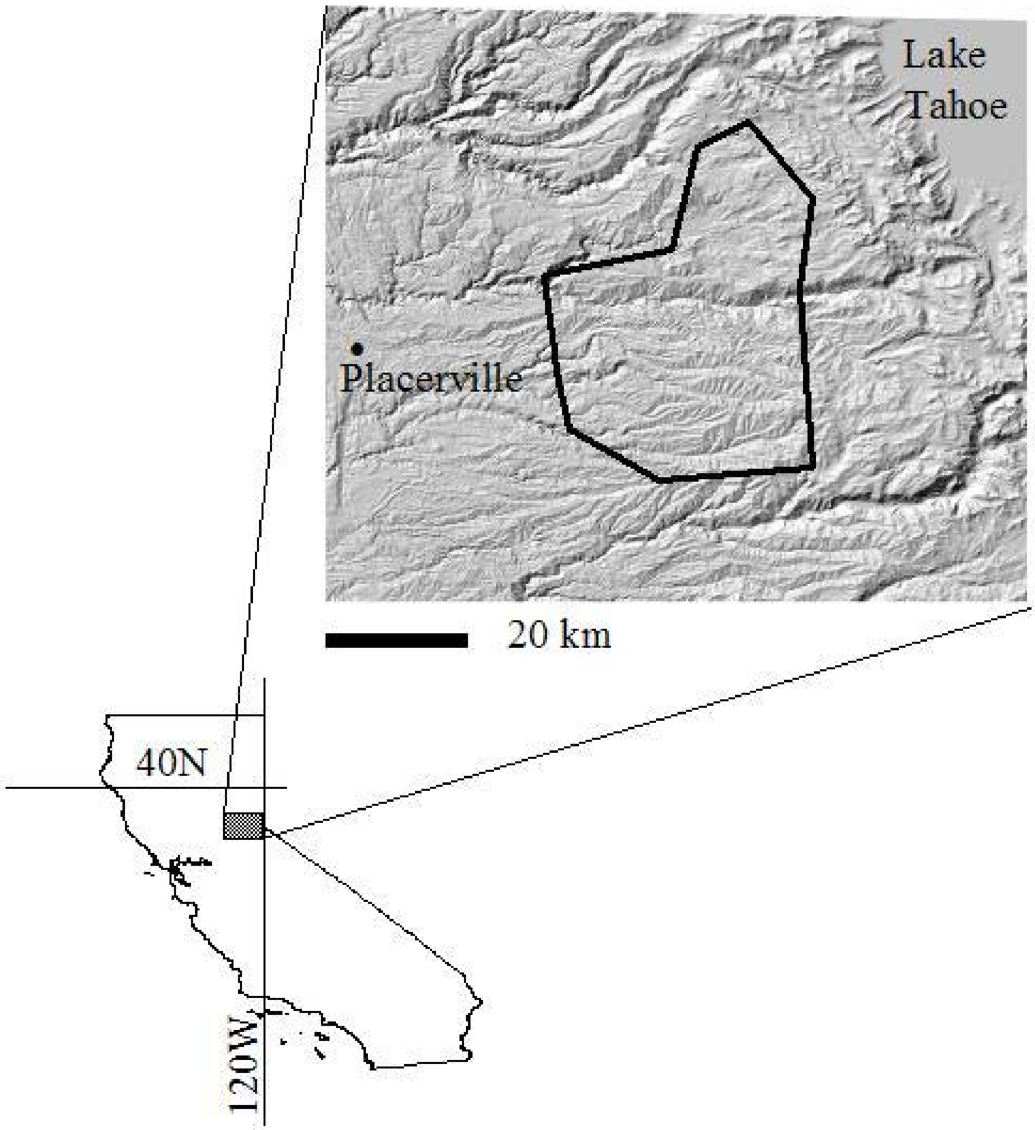

Figure 3.1. Map of the study area.

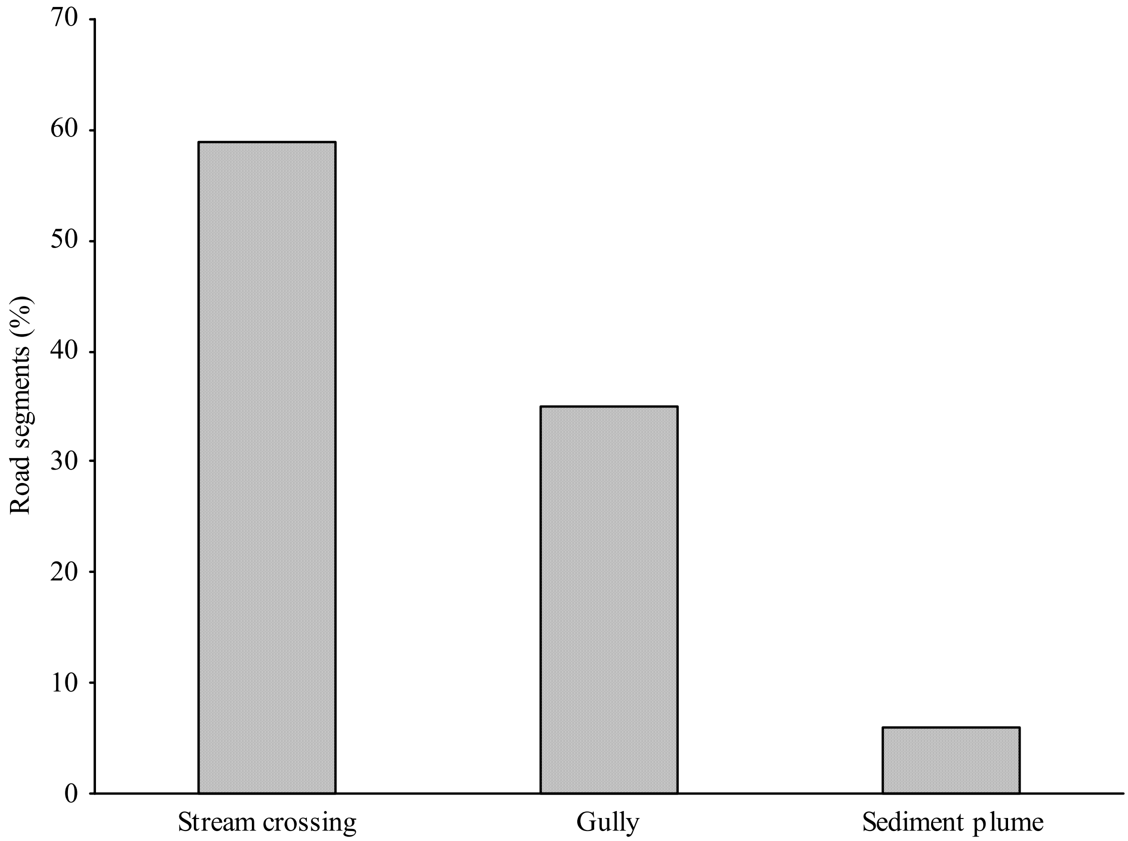

Figure 3.2. Percent of road segments connected to the channel network by causal mechanism (n=46).

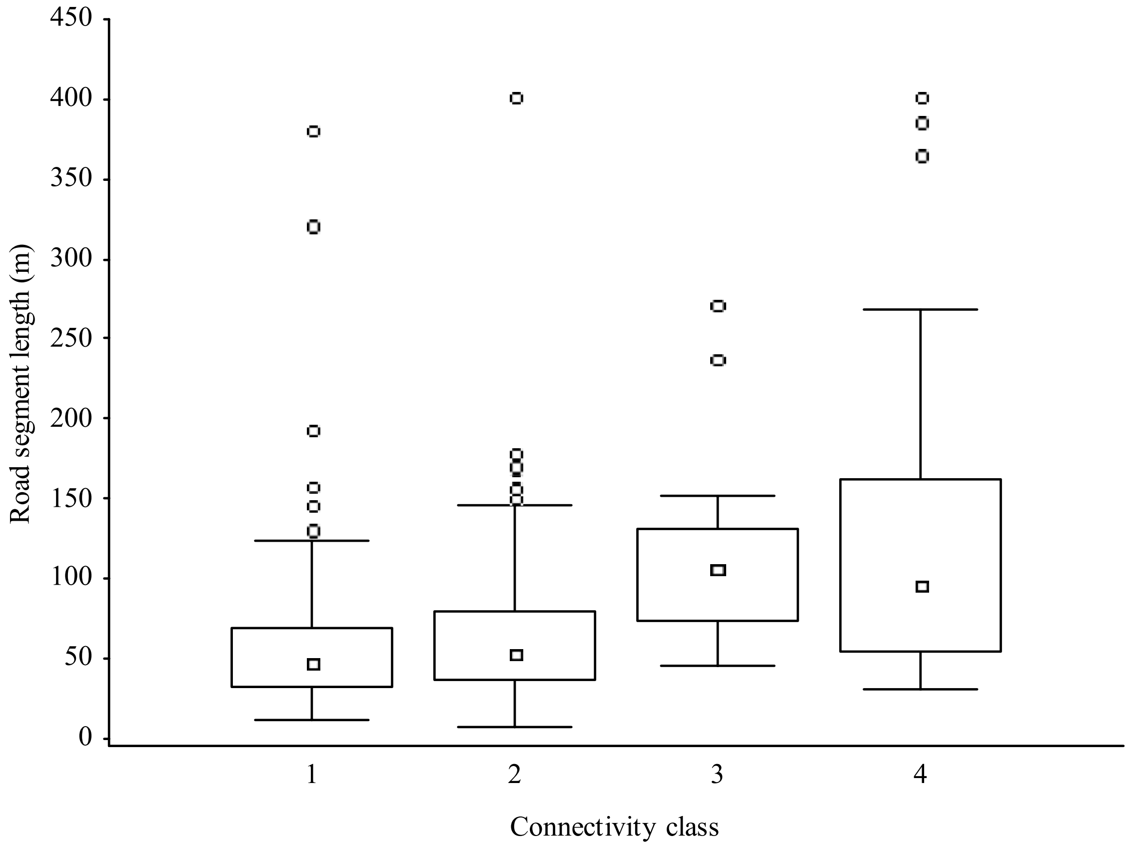

Figure 3.3. Road segment length by connectivity class. The small squares are the median segment length, the boxes indicate the 25th and 75th percentiles, the bars show the 95% confidence interval, and the open circles represent outliers.

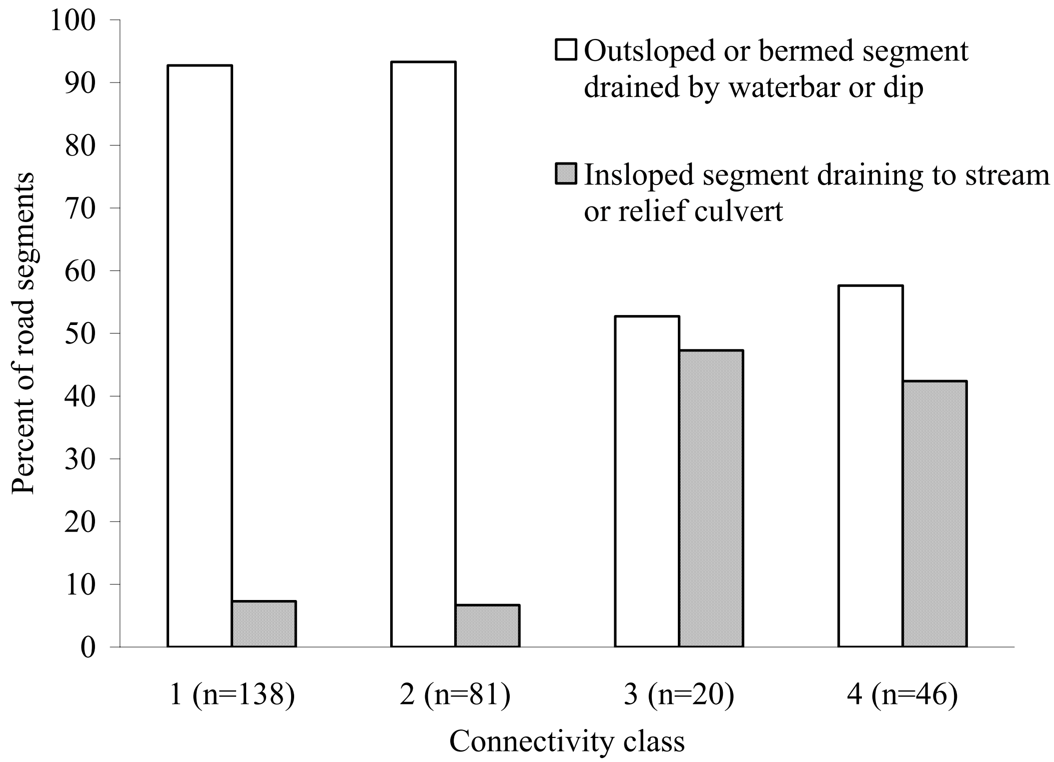

Figure 3.4. Percent of road segments by road drainage type for each connectivity class.

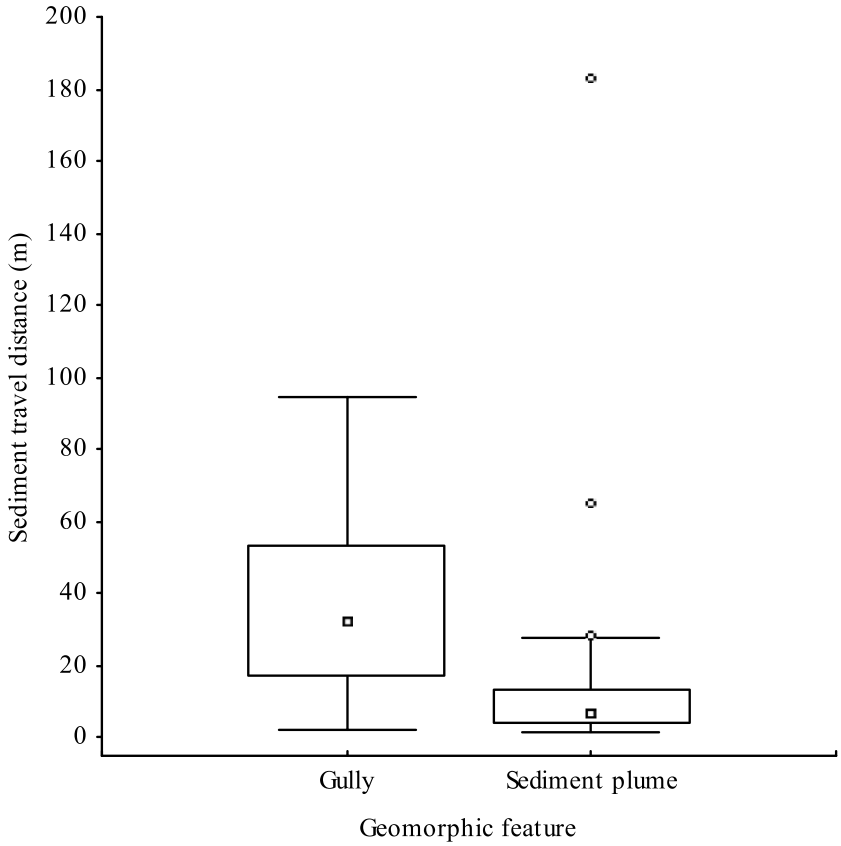

Figure 3.5. Lengths of gullies and sediment plumes for the segments classified as CC2, CC3, and CC4. The small squares are the median length, the boxes indicate the 25th and 75th percentiles, the bars show the 95% confidence interval, and the open circles represent outliers.

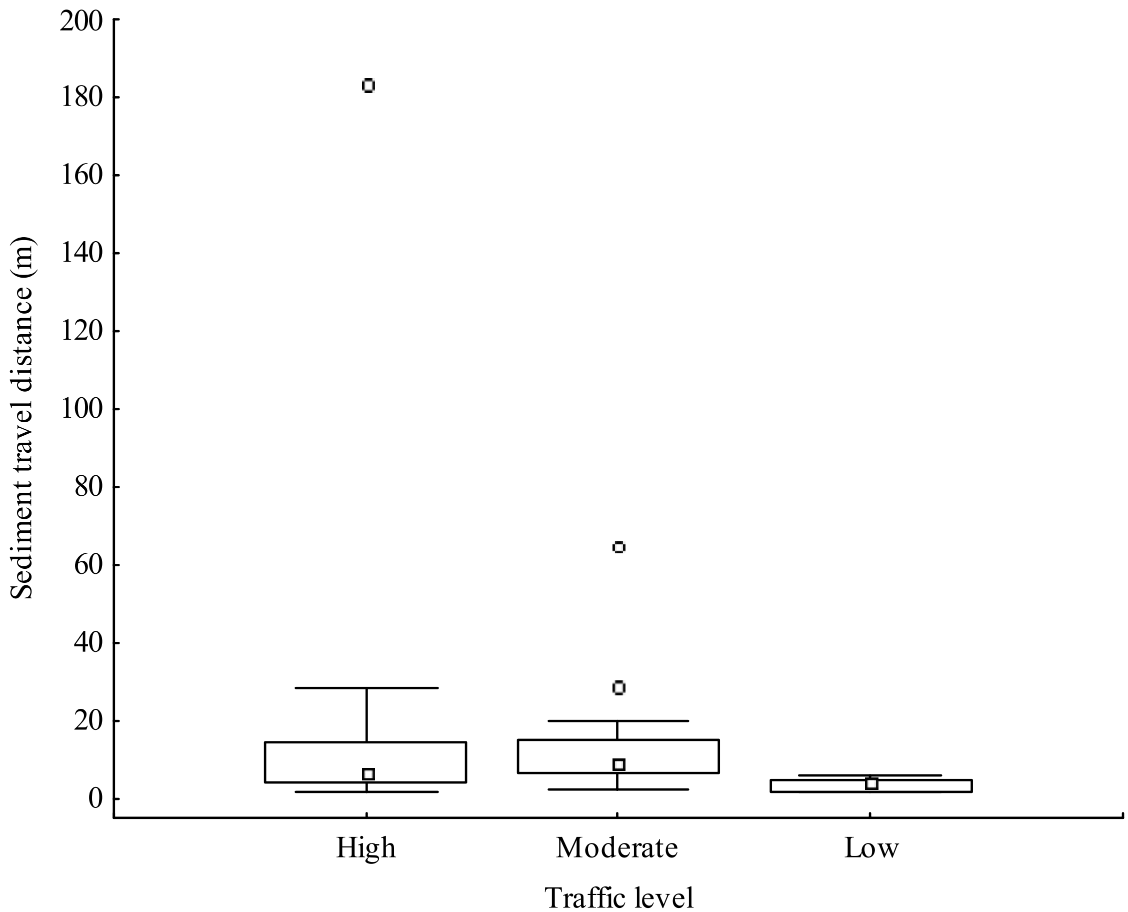

Figure 3.6. Lengths of sediment plumes by traffic level. The small squares are the median segment length, the boxes indicate the 25th and 75th percentiles, the bars show the 95% confidence interval, and the open circles represent outliers.

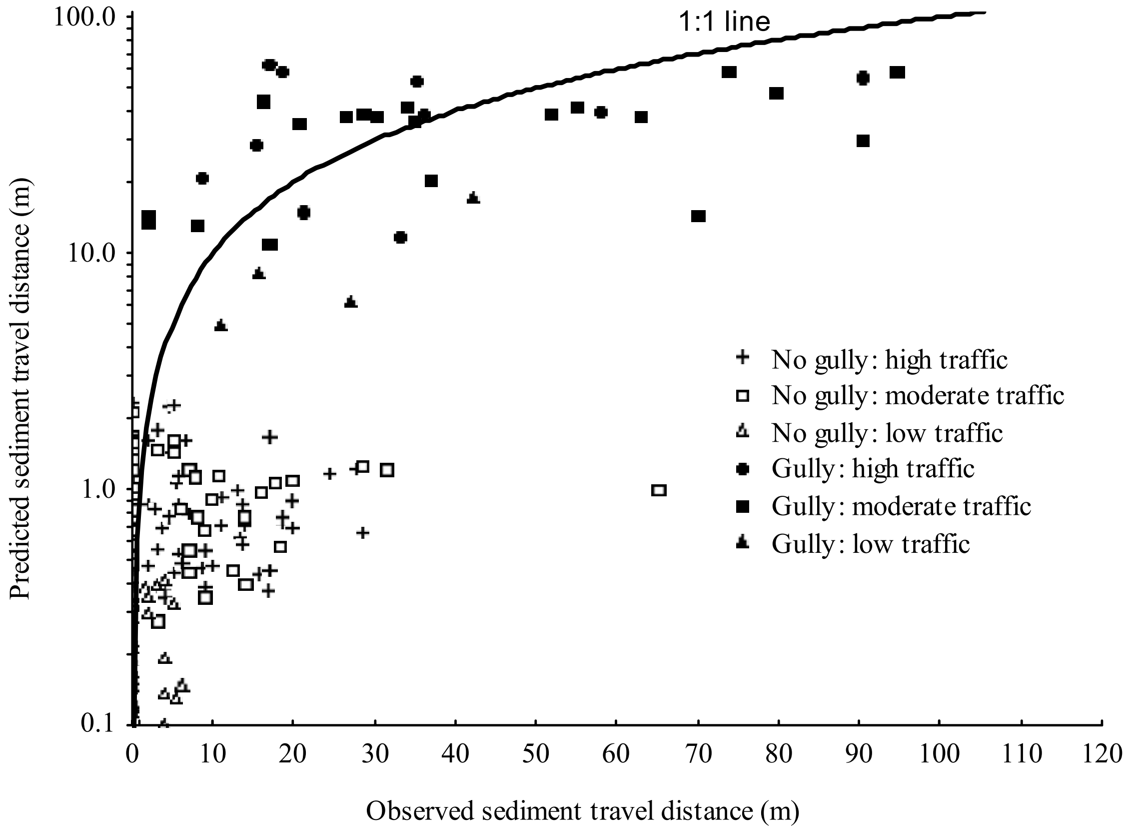

Figure 3.7. Predicted gully and plume lengths versus observed values by geomorphic feature and traffic class.

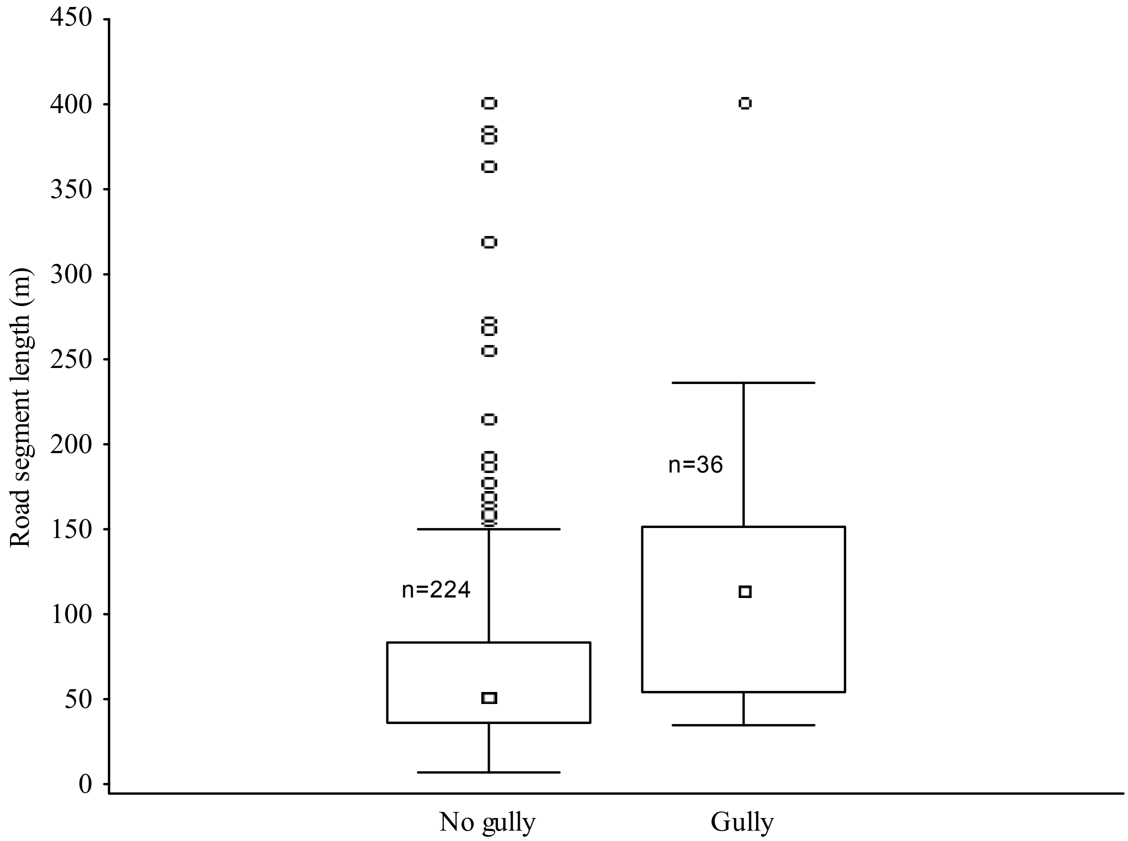

Figure 3.8. Road segment length for outlets with and without gullies. The small squares represent the median road segment length, the boxes indicate the 25th and 75th percentiles, error bars represent the 95% confidence intervals, and the open circles represent outliers.

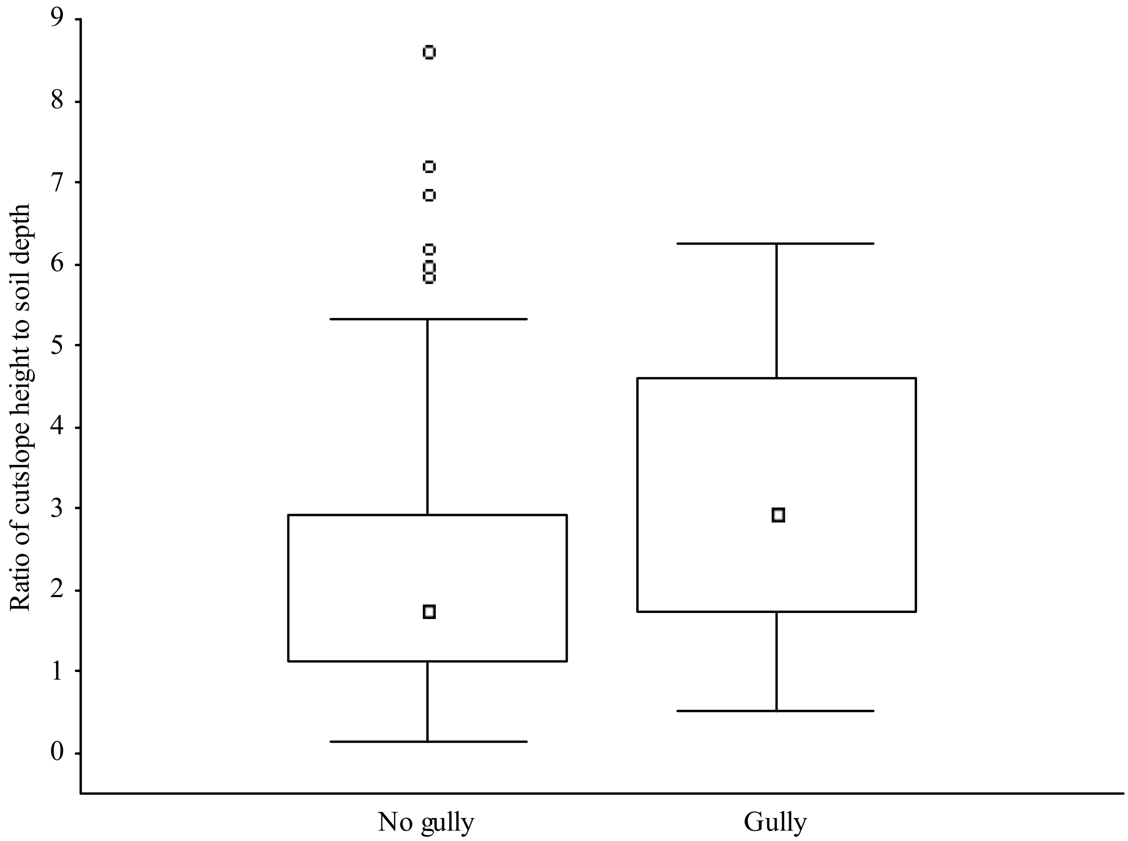

Figure 3.9. Ratio of cutslope height to soil depth for segments with and without gullies below the drainage outlet. The small squares represent the median ratio, the boxes indicate the 25th and 75th percentiles, error bars represent the 95% confidence intervals, and the open circles represent outliers.

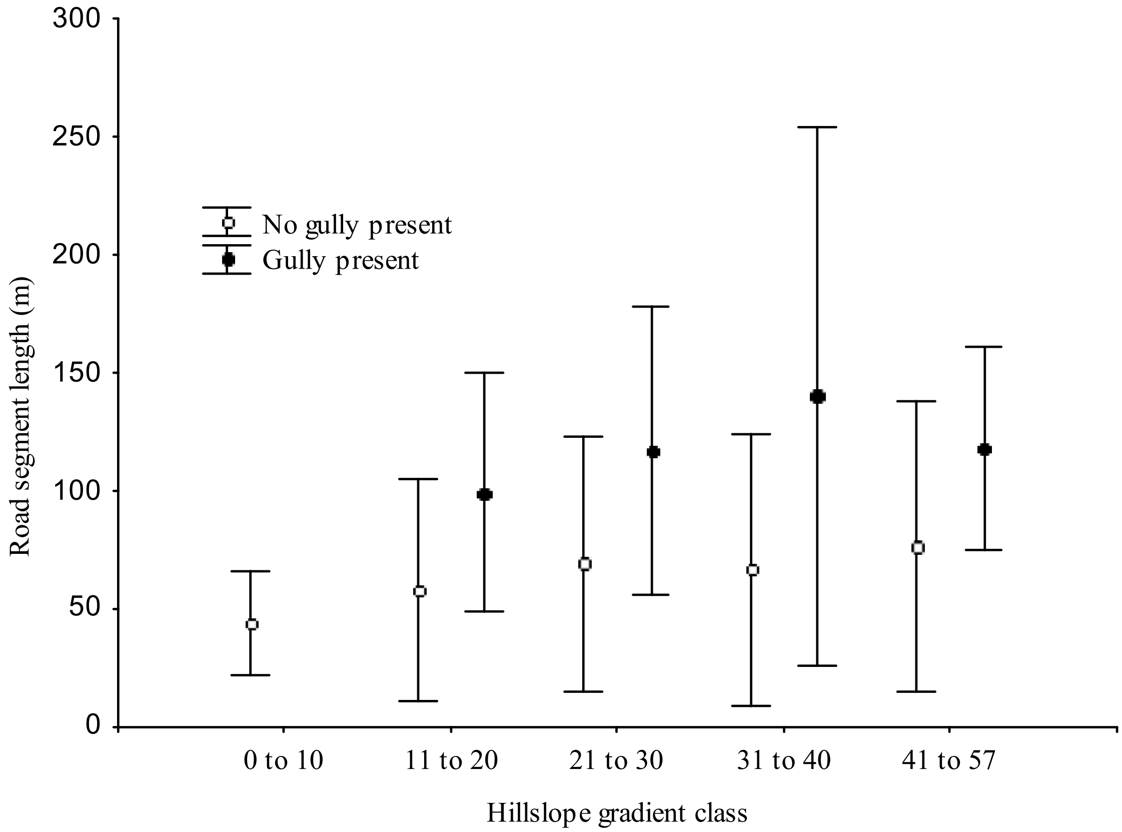

Figure 3.10. Mean road segment length for gullied and ungullied road segments by hillslope gradient class. Bars represent one standard deviation.

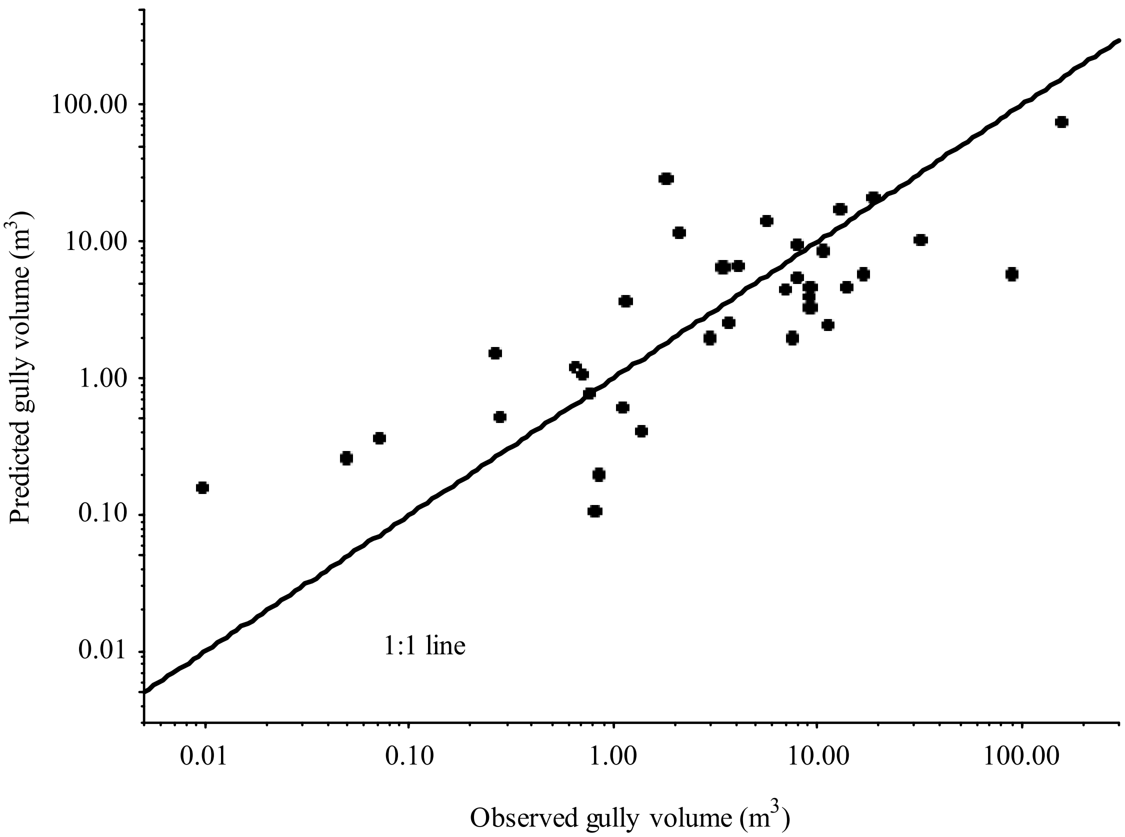

Figure 3.11. Predicted versus observed gully volumes.

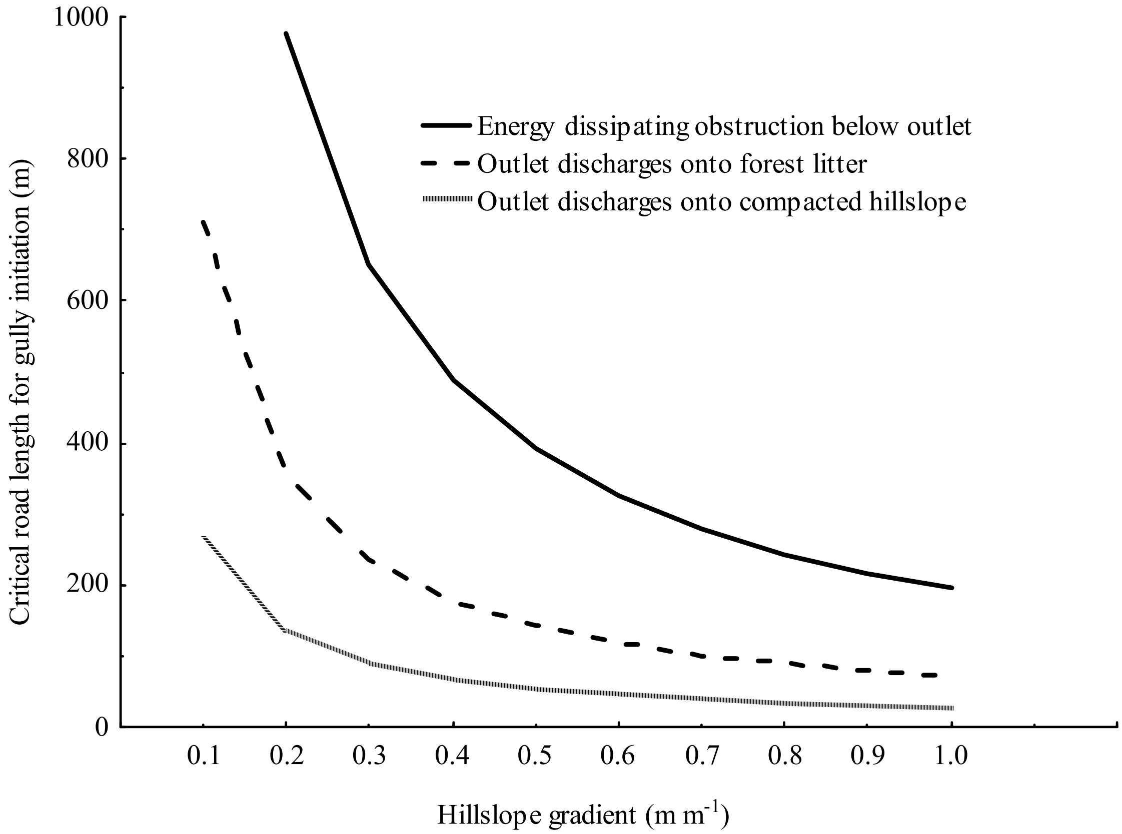

Figure 3.12a. Predicted road segment length thresholds (L_t) for avoiding gully initiation below outsloped roads drained by waterbars and rolling dips. Each curve represents a 50% probability of gullying for a different hillslope condition across a range of hillslope gradients.

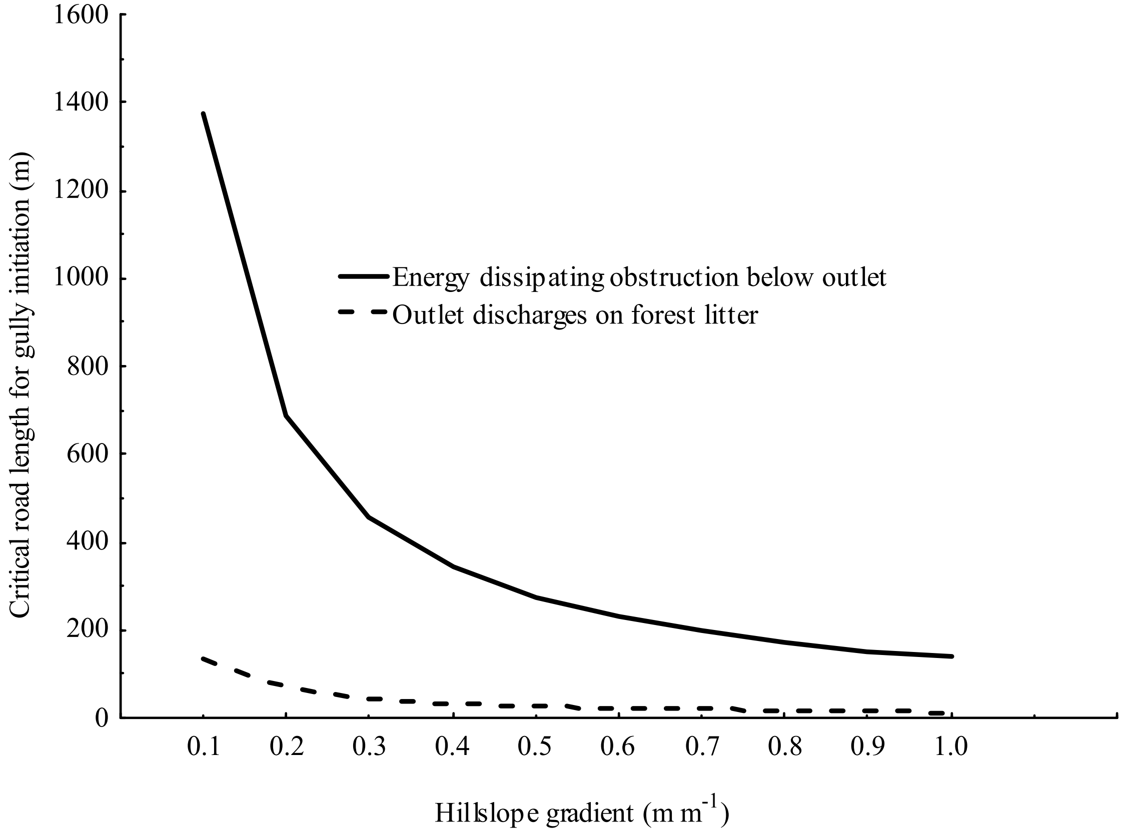

Figure 3.12b. Predicted road segment length thresholds (L_t) for avoiding gully initiation below insloped roads drained by relief culverts. The two curves represent a 50% probability of gullying for two different hillslope conditions across a range of hillslope gradients. No curve is shown for compacted hillslopes as all relief culverts that discharge onto compacted hillslopes are predicted to have gullies.

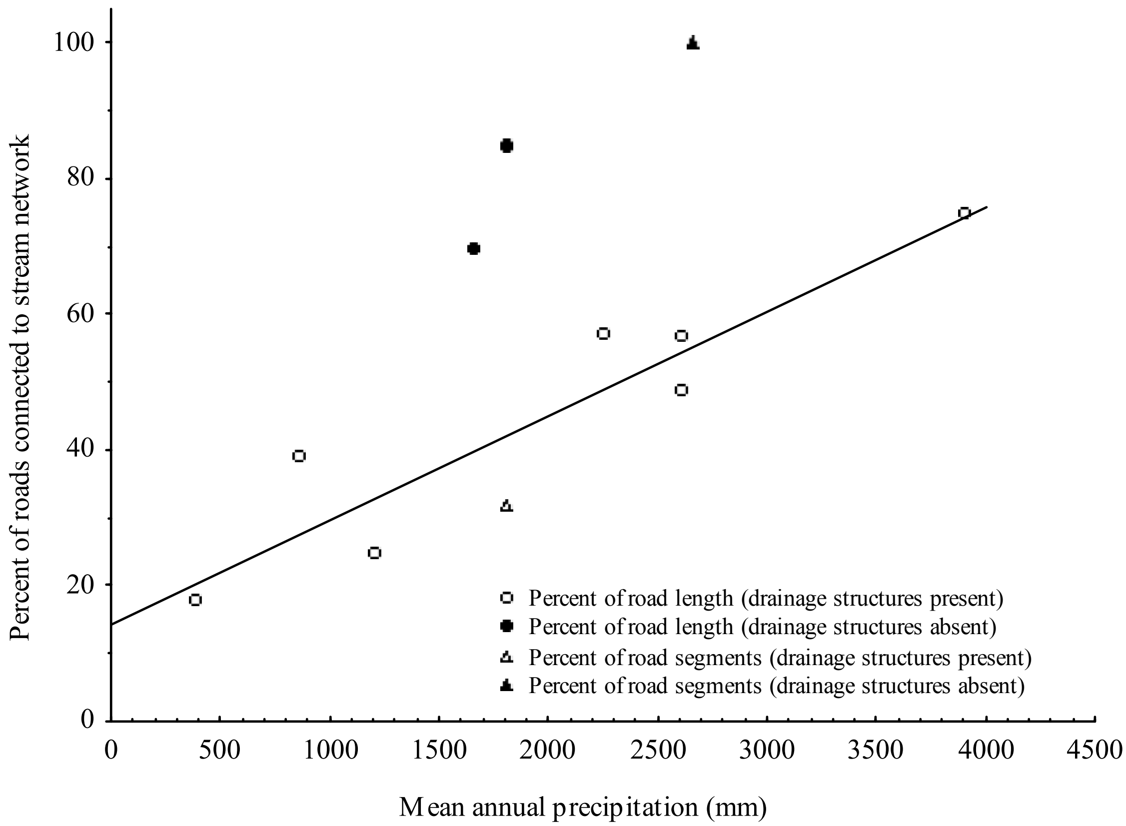

Figure 3.13. Percent of roads connected to the stream network versus mean annual precipitation for roads with and without engineered drainage structures. Regression line is for roads with engineered drainage structures.

4.0. Conclusions

The two studies provide a unique and quantitative understanding of sediment production and sediment delivery from unpaved roads in the Sierra Nevada of California. Sediment production rates varied greatly between years and between road segments. Most of the interannual variability in sediment production rates can be attributed to differences in the magnitude and type of precipitation, and their resulting effect on rainsplash and hydraulic erosion. The first wet season had near-normal precipitation and much of the precipitation in the lower portions of the study area fell as rain rather than snow. In the second and third wet seasons precipitation was below normal and tended to fall as snow. The resultant differences in rainfall erosivity, persistence of snow cover, and road runoff rates meant that unit area erosion rates were 3-4 times higher in the first wet season than in either of the two following wet seasons. On midslope roads with cutslopes, normalized sediment production increased as upslope soil depth decreased, and this is attributed to the increase in intercepted subsurface stormflow (ISSF).

Twenty-five percent of the surveyed road length was connected to the channel network. Stream crossings accounted for 59% of the connected road segments, and road-induced gullying accounted for another 35% of the connected road segments. The travel distance of sediment below road drainage outlets was controlled by soil erodibility, road segment length, traffic level, and the presence or absence of gullies (R^2=0.39). The likelihood of a gully below a road segment increased with longer road segment lengths on steeper slopes, with shallower soils, and road drainage designs that concentrate rather than disperse runoff. A logistic regression model using these factors had a 90% success rate in distinguishing between gullied and ungullied segments. Gully volume was significantly related to the product of road segment length and hillslope gradient, soil erodibility, and road drainage type (R^2=0.60). Gully volumes were significantly higher below relief culverts than below waterbars or rolling dips.

Both studies show that road sediment production and some aspects of sediment delivery are strongly controlled by road area (A) or road length (L), and the interaction of A or L with road gradient (S) or hillslope gradient (S_H). A*S is a surrogate for the sediment transport capacity of runoff on the road surface, and $L*S_H$ is a surrogate for the sediment transport capacity of road runoff below a drainage outlet. Higher $L*S_H$ values increase the likelihood that a gully will form below a drainage outlet and deliver sediment to the channel network. Frequent road drainage serves to reduce both A*S and $L*S_H$. An analysis of existing data on road-to-stream connectivity suggests that the absence of engineered road drainage structures increases road-stream connectivity by 40%.

Both studies indicate that the interception of subsurface stormflow (ISSF) can increase both road sediment production and sediment delivery. Variables such as soil depth and the ratio of cutslope height to soil depth have the potential to explain some of the variability in road sediment production rates and gully initiation. However, the role of ISSF is difficult to include in empirical predictive equations because of the tremendous spatial and temporal variability in the amount and interception of subsurface stormflow.

Overall, these studies show that road sediment production is best mitigated by rocking native surface roads, decreasing sediment transport capacity by improving and maintaining drainage, and avoiding unusual soil features that increase road surface and ditch runoff. Road sediment delivery can be minimized primarily through reducing the number of stream crossings, reducing the length of road segments that drain to stream crossings, rocking the approaches to stream crossings, preventing gully formation below road drainage outlets, and placing new roads further from stream channels. The results of these studies can help managers reduce road sediment production and delivery, and thereby reduce the adverse impacts of unpaved forest roads on aquatic resources.

Exhibit 2

I, Karen Schambach, do hereby declare as follows:

1. I took the following photograph presented as plaintiffs' Exhibit 2-A at Eldorado NF trail 17E12 on October 26, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows the unarmored trail entering a stream crossing (bottom right), where it deposits sediment eroded from the trail.

2. I took the following photograph presented as plaintiffs' Exhibit 2-B at Eldorado NF trail 17E19 on October 26, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows an unarmored trail entering the stream at the bottom of the photo, where it deposit sediment eroded from the trail.

3. I took the following photograph presented as plaintiffs' Exhibit 2-C at Eldorado NF trail 11N23F on October 2, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows the unarmored trail entering the stream at the bottom of the photo, where it deposit sediment eroded from the trail.

1. I took the following photograph presented as plaintiffs' Exhibit 2-D at Eldorado NF trail 11N26F on October 26, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows the trail crossing the stream at the center of the photo, where it deposit sediment eroded from the trail.

1. I took the following photograph presented as plaintiffs' Exhibit 2-E at Eldorado NF Road 9N83 on October 27, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows severe erosion on the road because of the lack of functioning drainage features.

4. I took the following photograph presented as plaintiffs' Exhibit 2-F at Eldorado NF Road 9N83 on October 27, 2011. . The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows erosion on 9N83 due to a lack of functioning drainage structures.

5. I took the following photograph presented as plaintiffs' Exhibit 2-G on Eldorado NF Road 9N01 on October 27, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows erosion on the road due to a lack of functioning drainage structures.

6. I took the following photograph presented as plaintiffs' Exhibit 2-H at Eldorado NF Road 9N83 on October 27, 2011 . The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows the road has intercepted water from a stream due to a lack of functioning drainage structures.

7. I took the following 2 photographs presented as plaintiffs' Exhibit 2-I and 2-J at Eldorado NF trail 17E19 on October 26, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. 2-I shows erosion due to a lack of functioning drainage structures. 2-J shows the stream at the bottom of the trail segment, where the sediment enters the stream.

12-G

12-I

Exhibit 3 – Direct sedimentation to waterways

I, Karen Schambach, do hereby declare as follows:

1. I took the following photograph presented as plaintiffs' Exhibit 3-A on Eldorado NF road 10N26F, on October 25, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows sediment in the stream at the top right of the photo, which has run off the road at the culvert site, because of the lack of drainage features above the stream crossing.

1. I took the following photograph presented as plaintiffs' Exhibit 3-B at Eldorado NF road 9N01 on October 27, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows sediment that has entered a stream at a culvert site, because the stream crossing is the low point in the road segment and there are no functioning drainage features to control the water and sediment on the road above the crossing.

3. I took the following photograph presented as plaintiffs' Exhibit 3-C at Eldorado NF road 14N05 on July 24, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows sediment entering and in the creek at the culvert site (primarily at bottom center of photo) because there are no functioning drainage features to control the water and sediment on the road above the crossing.

4. I took the following photograph presented as plaintiffs' Exhibit 3- D at Eldorado NF road 14N05 on July 24, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows a close-up of sediment in the creek at the culvert site in photo 3-C, above.

5. I took the following 3 photographs presented as plaintiffs' Exhibit 3- E, 3-F and 3-G on Eldorado NF trail 17E24 on September 14, 2011 . The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. 3-E shows clear water above the culvert, 3-F shows sediment entering the stream at the crossing, and 3-G shows the same stream, sediment-laden, below the crossing.

Exhibit 3-E

Exhibit 3-F

Exhibit 3-G

4. I took the following photograph presented as plaintiffs' Exhibit 3- H at Eldorado NF road 9N01 on October 27, 2011. The image has not been altered or enhanced in any way and is an accurate representation of that location on that date. It shows sediment entering a creek at a culvert site because there are no functioning drainage

features on the road above the crossing. Lower end of pipe is at center right, below channel

2008

Road Sediment Source Inventory
and
Risk Assessment

ELDORADO ROAD INVENTORY 2008

****

Alder Creek, Cat Creek, Dogtown Creek, McKinney Creek and Middle Dry Creek Watersheds

****

Project Dates: July 28, 2008 to December 15, 2008

March 27, 2009

Eldorado National Forest
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Table of Contents

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ROAD SEDIMENT SOURCE INVENTORY & RISK ASSESSMENT
Eldorado National Forest – Eldorado 2008 Road Inventory

Abstract

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances, averaging 48 times background from landsliding and 82 times background from surface erosion (USFS, 2004). Consequently, road issues are often at the heart of watershed restoration activities.

On the Eldorado National Forest in 2008, 63.25 miles of Forest roads were field inventoried. These roads lie within five (5) 7th-field drainages – Headwaters Alder Creek, Cat Creek, Dogtown Creek, McKinney Creek and Middle Dry Creek. During this project, 381 sites were inventoried, 49 % of these sites were channel crossings (187); the remainder were hydrologically connected cross drains (194). Stream diversion potential existed at 47% of these sites. Approximately 16.4% of the inventoried road length was hydrologically connected to natural stream courses. Estimated total volume of fill material at channel crossing sites was 76,270 cubic yards, with an average of ~ 410 cubic yards per site. Median fill volume was ~ 132 cubic yards. Additionally, twenty-two (22) active sediment sources (landslides and gullies) between crossings were surveyed.

Because Forest road systems are extensive and road-related restoration is generally expensive, it is valuable to focus potential investments on the sites posing the highest risk/consequences/ impacts. Each site was rated and ranked by considering: [1] <u>risk</u> of failure, [2] <u>consequences</u> of failure (sediment delivered), and [3] <u>impacts</u> of failure (to beneficial uses). For example, a highly ranked site could be one with an undersized pipe, geologic instability upslope, large fill volume with diversion potential, on an anadromous fish stream. Evaluation of all sites concluded that 65% of the total fill volume at channel crossings could be attributed to approximately 10% of the highest ranked sites. In other words, by upgrading channel crossings to reduce the risk/consequences/impacts of failure at only 10% of sites (21 of 187), approximately 65% of total fill volume would be treated !!!

These findings suggest that targeted restoration has the potential to substantially reduce the risks and consequences from road-related sediment delivery. This tool has the demonstrated capability to accelerate watershed recovery in support of the goals of the *Endangered Species Act* and the *Clean Water Act*.

NOTE: The following sections are intentionally brief as the core of this report is contained in tabular and spatial databases. The reader is therefore urged to concentrate on the information presented in the spreadsheet tables [**Appendix A**] and map products [**Appendix C** and **Figures 1**, **3** - following].

Setting

This effort inventoried selected roads within the Headwaters Alder Creek, Cat Creek, Dogtown Creek, McKinney Creek and Middle Dry Creek drainages (watersheds); see Location Map (**Figure 1** below). Work was accomplished through agreements between Resource Management (Fort Jones, California) and ACT2 Forest Service Enterprise Team (Happy Camp, California) and between ACT2 Forest Service Enterprise Team and the Eldorado National Forest.

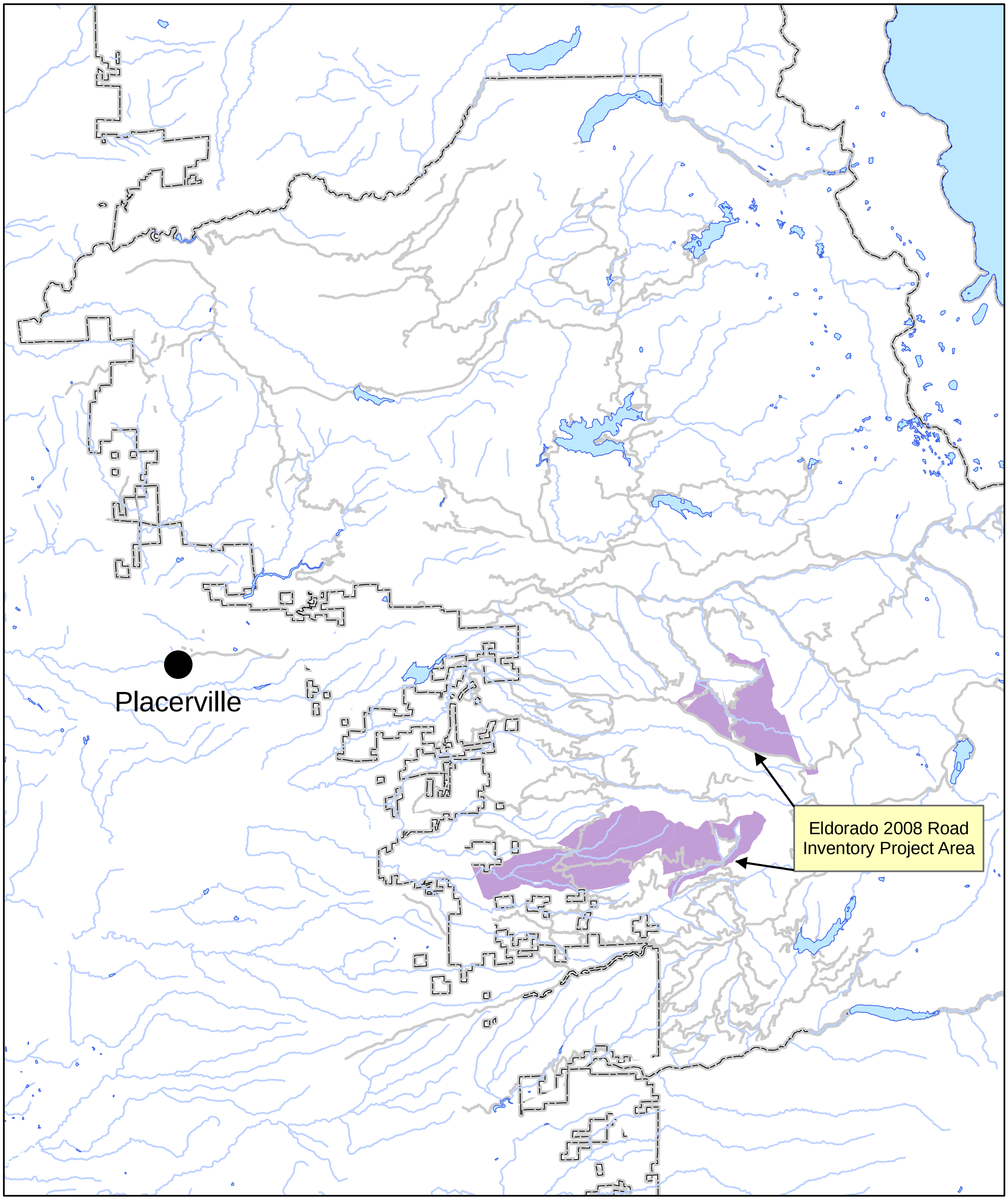
The Eldorado 2008 Road Inventory project area consists of selected roads within five (5) 7^{th}-field drainages [HUC7]. These drainages total 76,270 acres. Headwaters Alder Creek lies within the South Fork American subbasin [HUC4], within the larger Lower Sacramento basin [HUC3]. Cat Creek, Dogtown Creek, McKinney Creek and Middle Dry Creek drainages lie within Upper Cosmnes subbasin [HUC4], within the larger San Joaquin basin [HUC3].

Problem

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances (e.g., Amaranthus, et al. 1985; de la Fuente & Elder 1998; Flanagan, Furniss, et al. 1998a & 1998b; Pacific Watershed Associates 1997; U.S. Environmental Protection Agency 1998), averaging 58 times background from landsliding and 290 times background from surface erosion (de la Fuente & Haessig 1994). Sediment modeling on the Klamath National Forest produced similar numbers – 48 times from landsliding and 82 times from surface erosion (USFS, 2004). In addition, roads can alter hydrology, habitat connectivity, and routing of wood and sediment. These combined effects have the potential to strongly influence downstream aquatic environments critical to anadromous salmonids and other aquatic species. As the availability of road maintenance funds allocated to the Forest Service decreases, down nearly 50% in the past several years, the necessity to evaluate and implement measures which reduce the risk of road related impacts to aquatic systems is greater than ever.

The Klamath National Forest road system sustained over 30 million dollars worth of damage during the "New Year's Day" flood of the winter of 1996-1997 [hereafter referred to as '1997 Flood']. Stream channels, riparian areas, and fish habitat were impacted by excessive scour and deposition during that storm. The impact was severe in some places. Some of these impacts were caused by sediment delivered from roads. *The Flood of 1997: Klamath National Forest Phase I Final Report* (de la Fuente and Elder 1998) estimated that over half of the large road repair sites were at stream crossings. An estimated 22% of these sites resulted in diversion around plugged culverts.

Figure 1 - Location of Inventory Area



Two of the primary types of failures occurring at road-stream crossings include "stream diversion" and "fill failure". A stream diversion occurs when a culvert at a stream crossing fails due to hydraulic exceedance and/or plugging by debris or sediment. If this happens at a stream crossing where the road leaves the crossing at a negative slope (downhill), then the water can flow down the road rather than down its' own natural channel. This often has adverse effects on the watershed, such as saturating road fills which causes failures and the potential to generate debris flows, eroding the road surface, eroding away huge amounts of soil on unstable hillslopes where water does not naturally flow, and causing cascading failures of stream crossings in adjacent drainages into which the stream has been diverted.

Partial or complete failure of crossings fills is the other primary risk posed by stream crossing to downstream aquatic habitat. In addition to the sediment generated by such failures, failures of this type can initiate large debris flows that scour channels, fill pools and strip riparian vegetation from stream banks. Although prediction of crossing failure is difficult, the risk and consequences can be characterized. With this information, risk reduction measures including up-sizing culverts, reduction in fill size, or decommissioning can be targeted toward crossings with high risks, high consequences and impacts before they fail. In addition to evaluating crossings for stream diversion potential, this assessment will assess factors influencing culvert and crossing failure, including consequences at all road-stream crossings.

Purpose

The intent of Forest Service policy and approach to transportation planning is to find a balance between the positive benefits of access and road-associated negative effects on other values and resources, such as clean water, fish, and wildlife; and on maintaining choices for future generations. In Forest Service Chief Dombeck's *Natural Resource Agenda for the 21st Century*, an emphasis was placed on watershed health and restoration, and forest roads. National Forest roads policy has four primary objectives: (1) More carefully consider decisions to build new roads, (2) eliminate old, unneeded roads, (3) upgrade and maintain roads that are important to public access, and (4) develop new and dependable funding for Forest road management.

One Section of the Environmental Protection Agency *Clean Water Action Plan* includes natural resource stewardship on Federal lands. A Key Action in this Section calls for substantially increasing maintenance of forest roads and trails on Federal lands to protect water quality, to improve water quality protection on over 2,000 miles of road per year, and to decommission 5,000 miles of road.

The Road Sediment Source inventories and assessments were conducted to acquire information necessary to prioritize watershed restoration work involving roads so that the most critical, most ecologically-beneficial and cost-effective restoration projects could be more accurately identified and implemented first. The purpose of the Road Sediment Source surveys and analyses was to identify specific locations (Sites) where road drainage structures and fill have the potential to adversely impact watershed processes, then to assess the relative ***environmental risk*** of each identified Site.

Other applications include use: [1] in transportation planning efforts, [2] to define existing and target conditions in other more general planning documents, such as ecosystem analyses, larger subbasin and basin assessments, and TMDL documents (Total Maximum Daily Loads for water bodies listed under Section 303(d) of the *Clean Water Act*), [3] in Forest Service National Roads Policy inventory requirements, and [4] in various management projects, such as timber sales.

The primary objective of the crossing inventory and assessment proposal is to identify high risk/consequences/impact road-stream crossings which pose the greatest threat to aquatic resources, especially sedimentation of anadromous fish habitat. Some or all of the following will characterize high-risk stream crossings:

- large fills at or adjacent to the crossing,
- potential for stream diversion,
- inadequate culvert capacity to pass water, woody debris or sediment,
- unstable geology above site (high debris flow potential) or down slope (high potential for additional erosional effects if crossing fails or diverts stream flow),
- high value beneficial uses that would be adversely impacted if crossing failed.

A secondary objective is to provide education to residents within the area on road crossing risks, mitigation designs, and how these issues affect aquatic habitat. This knowledge can then be applied to strategic transportation planning on <u>private</u> roads. Outreach education would also familiarize area residents with cooperative efforts in watershed restoration and planning.

Methods

This project can be divided into seven general work elements, as shown in Steps 1 through 7 of **Table 1** below.

Field Inventory Methods

Field inventory work was accomplished using procedures detailed in *Field Guide: Explanation & Instructions for Klamath National Forest Road Sediment Source Field Inventory Form - May 14, 1999 [revised May 23, 2000]* (USFS 1999a). <u>See **Appendix B** for complete copy of *Field Guide*</u>. The Forest developed this field guide borrowing and modifying concepts, definitions and procedures from the following sources: [1] Pacific Watersheds Associates procedures for assessing road sediment sources (PWA, 1997), [2] stream crossing environmental risk assessment protocol developed Six Rivers National Forest (Flanagan, et al., 1998a & 1998b), and [3] Forest Service national roads policy as described in *Roads Analysis: Informing Decisions About Managing the National Forest Transportation System* (USFS, 1999b).

In road sediment source field inventories, **all** stream channel-road crossings and **all** hydrologically connected cross drains (ditch relief structures – pipes & dips) were examined and measured (USFS, 1999a). In addition, road-related erosion hazards <u>between</u> channel crossings and hydrologically connected cross drains were surveyed. These sites consisted of landslides (mass wasting) and gullying (surface erosion) features that are currently active or pose future/potential threats of sedimentation. These "between crossing" sites have been nicknamed "tweeners."

Risk Assessment Methods

With limited resources, it becomes necessary and desirable to prioritize sites for treatment. Although treatments may vary from site-specific recommendations to all inclusive road segment proposals, from minor maintenance fixes to major crossing re-design and reconstruction, all sites are subjected to the same initial prioritization scheme. Site information is taken from data collected in the field and drawn from information available from air photos and existing Forest GIS layers. The priority setting of individual sites combines three general elements: (1) site condition – risk & consequences, (2) potential impacts, and (3) opportunity. A high priority site would be high risk, high consequences, with high potential impacts and high opportunity.

Integration of data elements and groups of data elements is shown in **Figure 2** below. Range of values used to assign individual risk/consequence/impact ratings is shown below. These individual rating values for each site are shown in the Tables of **Appendix A.**

Table 1 - Project Outline - General Work Elements

✞ **STEP 1 - Pre-Field Inventory Preparation:** - includes:
- photo identification of "ghost" roads and debris flow scoured channels,
- ID sites with history of problems; based on personal experiences, talks w/ Engineering, etc.,
- training of field crews (office & field),
- assessment of upslope watershed risks from disturbances & unstable geology, and
- preparation of maps & photos for field crew use.

✞ **STEP 2 - Field Crew Inventory of Road Sediment Sources:** - includes:
- identification and characterization of crossing sites [stream channels & 'hydrologically connected' cross drains],
- reconnaissance-level identification of significant features between crossing sites - in preparation for journey-level inventory (Step 3), and
- field identification ("mapping") of "ghost" roads & sediment source inventory of them.

✞ **STEP 3 - Journey-Level Oversight/Inventory:** - includes:
- characterization of significant features between crossing sites (identified in Step 2),
- monitoring of crossing inventory work to ensure Forest-wide consistency (QA/QC), and
- some field verification of photo-interpreted features described above.

✞ **STEP 4 - Data Compilation:** - includes:
- entry of field data into spreadsheets,
- entry of field site locations into GIS, and
- calculation of hydraulic pipe capacity at sites (depending mostly on drainage area).

✞ **STEP 5 - Risk-Consequences-Impacts Assessment (Office):** - includes:
- analysis of data (from Steps 1 - 4 above),
- preliminary site ranking, and
- identification of high risk-consequences-impact sites.

✞ **STEP 6 - Validation of High Risk-Consequences-Impact Sites (ID team- field):** - includes:
- treatment recommendations - fix or not? suggested upgrade or repair?
- estimated cost of treatment - DSR type report (used in ERFO project assessments).
- looking at a watershed scale, did assessment miss significant road-related problems or risks?

✞ **STEP 7 - Final Report:** - includes:
- narrative with summary of findings, prioritization process, upgrade/repair recommenda-tions.
- spreadsheet tables with field data & risk/consequence/impact ratings for all inventoried sites.
- GIS-generated maps showing high priority sites, by type, by specific concern, by overall ranking (prioritization)

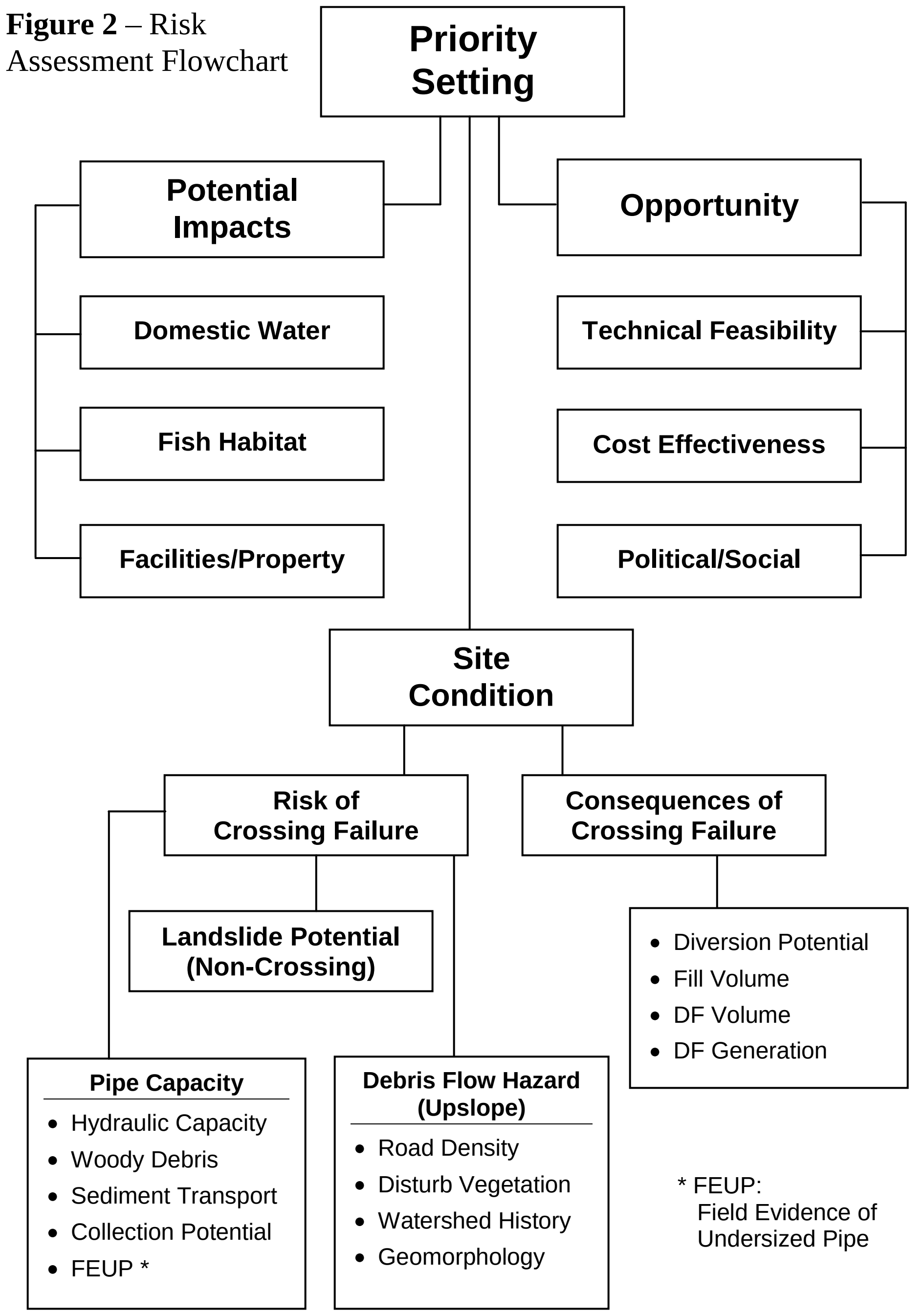
Site Condition:

Site condition is composed of two major elements – risk of failure and consequences of failure. In general, "risk" characterizes upslope and site conditions that measure the probability of failure; "consequences" characterize the downslope results of a failure. Each of these major components is subdivided further. When all elements are combined an overall "site condition" rating is obtained. For example, the highest rated crossing sites would be those with high risk of failure from severely undersized culvert pipe, lengthy contributing ditch, high upslope debris flow risk from past history, large upslope vegetative disturbance and/or unstable geology and high consequences of failure from diversion potential, large fill volume, and high potential for generation of debris flow.

Site risk is the combination of two major elements and a lesser component. The major elements consist of pipe capacity and upslope debris flow hazard. Pipe capacity is a measure of how well individual culverts are designed to handle watershed products, principally, water, woody debris and sediment. Hydraulic capacity of culverts is determined using an empirical culvert-sizing model (developed by US Geological Survey; Waananen and Crippen 1977) that takes into account catchment basin area, differences in elevation between site and ridge top, and local precipitation. Crossing culvert ability to pass woody debris is based on a ratio between culvert diameter and upslope channel width. A culvert's ability transport sediment is based on a ratio between slope of the culvert and upslope channel. Field evidence of undersized pipe and large collection potential of upslope in-board ditch add to the three factors cited above to raise the risk of failure for culvert crossings. Risks associated with upslope debris flow hazards are based on a combination of several elements. Assessment of these risks relies in part on Forest GIS layers. Stability of upslope geomorphology and nature and extent of upslope vegetative disturbances (such as fire and timber harvest) are determined from these GIS layers. Debris flow history at individual sites is obtained from field inventory, historic air photos, and personal accounts. Number and density of upslope roads are considered. Landslide potential at the site is a lesser component that affects a site's overall risk of failure.

Consequences of failure are the second major element that defines site condition. This important element is composed of four unequally weighted factors – fill volume, diversion potential, potential debris flow generation and volume. Of highest importance (weighting) is fill volume. Fill volume is sediment at-risk that is delivered to the stream system if the crossing fails and is therefore very important when considering adverse road-related sediment impacts on aquatic environment. Another major consequence of crossing failures is the diversion of stream from its natural channel and down the road. This diversion can produce gullies and landslide failures. Crossing failures in the steeper headwaters areas of drainages can generate debris flows, many with significant volumes. Potential for generation and subsequent estimation of volume are based on channel and slope steepness, slope position, and stability of geomorphology at the site.

Figure 2 – Risk Assessment Flowchart



Potential Impacts:

This general component characterizes the potential adverse impacts to aquatic habitat should failure occur. "Potential impacts" are the combination of adverse impacts to three beneficial uses – domestic water sources, fish habitat, facilities/property. Impacts must be direct and imply proximity or "closeness."

Domestic potable water sources are rated by number of users – municipal, >5 households, <5 households and none. Sites at perennial streams and within Riparian Reserves are rated by whether or not anadromous or resident fish species are present. Sites are rated by whether or not facilities (buildings, campgrounds, trailheads, etc.) or other roads are directly downstream or down-slope.

Opportunity:

Opportunity rates the "do-ability" of the recommended treatment and is based on three general criteria – technical feasibility, cost effectiveness, and political/social considerations. These elements are based on subjective professional judgment in an interdisciplinary setting. Technical feasibility rates how effective a given treatment will be in reducing risk, consequences, or impacts. Cost effectiveness rates a proposed project on cost necessary to control an estimated volume of sediment at risk and is usually expressed in "$ per cubic yard saved." Political/social considerations include such things as land use, land ownership, access needs, etc.

Risk, consequences, and impacts rating elements (and groups of elements) are scored on the following basis:

Table 2 - Risk - Consequences - Impacts

Unit	Assigned Value 1/	Impact Rating Elements	[data source]
RISK			
Pipe Capacities			
[T]	 3 2 1 0	an expression of hydraulic capacity T = < 10 years T = 10 - 100 years T = > 100 years no pipe or no definable drainage area	[calculated]
[w]	 3 2 1 0	an expression of woody debris capacity - culvert diameter / width of channel w = < .5 w = .5 - 1.0 w = > 1.0 no pipe or no definable channel	[field data]
[s]	 3 2 1 0	an expression of ability of pipe to transport sediment - slope of pipe / slope of channel s = < .3 s = .3 - .6 s = > .6 no pipe or no definable channel	[field data]
[f]	 3 0	field evidence of undersized pipe yes no	[field data]
[cp1]	 3 2 1 0	collection potential - contributing ditch length to first cross drain structure; best-case scenario" - assumes no cross drain plugging > 500 feet 200 - 500 feet < 200 feet no collection potential	[field data]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Impact Rating Elements**	**[data source]**
RISK (Continued)			
Pipe Capacities (Continued)			
[cp2]	 3 2 1 0	collection potential - contributing ditch length to road grade reversal or other feature that breaks collection potential; "worst-case scenario" - assumes plugging of all cross drain pipes > 1,000 feet 250 - 1,000 feet < 250 feet no collection potential	[field data]
[PC]	[PC]	overall pipe capacity risk rating; based on weighted average of previous six data elements, using the following equation: = [3*T + 3*f + 2*w + s + .5*(cp1 + cp2)]	[calculated] **max = 30**
On-Site Slide Potential			
[as]	 3 1 0.5 0	active landslide at site tweener" &/or fresh or horrendous slide at site "older" slide (LMP &/or crew identified) "maybe or suspected" slide - by crew none	[field data]
[SP]	[SP]	temporary category - to be revised when "tweener" data is analyzed =[as]*10	[calculated] **max = 10**
Upslope Debris Flow Potential			
[ur]	 3 2 1 0	upslope road/stream crossings > 3 rd/stream crossings upslope of site (same stream) 2 or 3 crossings upslope (same stream) 1 crossing (same stream) or rd/stream crossings (not same stream) none	[field data]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Impact Rating Elements**	**[data source]**
		RISK (Continued)	
		Upslope Debris Flow Potential (Continued)	
[dv]	 3 2 1 0	percentage of site drainage basin devegetated [fire &/or harvest] = >80 % of drainage area 50 - 79 % 20 - 49 % < 20 %	[GIS]
[rdd]	 3 2 1 0	road density in site drainage basin (miles per square mile - mi/sm) > 3.0 mi/sm 1.0 - 3.0 mi/sm present to < 1.0 mi/sm none; no defined drainage area	[GIS]
[df1]	 3 1 0	debris flow history - from field form clear evidence of recent debris flow at site probable &/or ancient debris flow no evidence observed	[field data]
[df2]	 3 2 1 0	debris flow history - from historic air photos >2 prior failures 2 prior failures 1 prior failure or debris flow none; cross-drains, not rated	[other]
[df3]	 3 2 1 0	site failure history from personal accounts >2 prior failures, or notorious repair or maintenance history 2 prior failures 1 prior failure or debris flow none; cross-drains, not rated	[other]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Impact Rating Elements**	**[data source]**
RISK (Continued)			
Upslope Debris Flow Potential (Continued)			
[gm]	 3 2 1 0	geomorphic character of site drainage basin ("geo10" coding explanation - see below) abundant unstable geomorphic terranes (geo 10 = 1, 2) abundant sensitive terranes (geo10 = 3, 6) steep slopes, gentle granitic, surficial (geo 10 = 4, 5, 7, 8) stable geomorphic terranes (geo 10 = 9, 10)	[GIS]
[UD]	[UD]	overall upslope debris flow potential risk rating; based on weighted average of previous seven data elements, using the following equation: = [3*(df1 + df2) +2*ur + df3 + dv + rdd + gm]*30/36	[calculated] **max = 30**
Total Risk			
[RK]	[RK]	risk; based on the following equation: = [PC +UD]	[calculated] **max = 60**
CONSEQUENCES			
[dp]	 3 0	diversion potential yes no	[field data]
[fv]	 4 3 2 1 0	fill volume at risk > 1,000 cubic yards (cy) 500 - 1,000 cy 100 - 499 cy < 100 cy no fill volume	[field data]
[sp]	 3 2 1	slope position upper third middle lower third	[GIS]

Table 2 - Risk - Consequences - Impacts

Unit	Assigned Value 1/	Impact Rating Elements	[data source]
CONSEQUENCES (Continued)			
[s]	 3 2 1 0	steepness - channel &/or slope at site [from field data] > 35% gradient 15% - 35% gradient 5% - 14% gradient < 5% gradient	[field data]
[ts]	 3 2 1 0	geomorphic terrane stability - at SITE unstable: geo10 = 1, 2 (**"geo 10"** codes *) sensitive: geo 10 = 3, 6 steep/surficial: geo 10 = 4, 5, 7, 8 gentle slope/stable: geo 10 = 9, 10	[GIS]
* explanation of **"geo 10"** coding – Geomorphic Terranes: 1 – Mehrten – lahars, pyroclastic, tuff (steep: > 40% slopes) 2 – granitic (plutonic) rocks (steep: > 40%) 3 – Mva – lahars, flows, volcanoclastic (steep: > 40%) 4 – volcanoclastic – tuff conglomerate, sandstone (steep: > 40%) 5 – Qal - alluvium (steep: > 40%) 6 – Mehrten – lahars, pyroclastic, tuff (gentler: < 40% slopes) 7 – granitic (plutonic) rocks (gentler: < 40%) 8 – Mva – lahars, flows, volcanoclastic (gentler: < 40%) 9 – volcanoclastic – tuff conglomerate, sandstone (gentler: < 40%) 10 – Qal - alluvium (gentler: < 40%)			
[tb]	 3 2 1 0	geomorphic terrane stability – BELOW site easily mobilized: geo 10 = 1, 2 (**"geo 10"** codes *) sensitive: geo 10 = 3, 6 gentle granitic/steep meta: geo 10 = 4, 5, 7, 8 stable/gentle meta: geo10 = 9, 10	[GIS]
[dfg]	[dfg]	potential for debris flow generation from failure at site; based on steepness & geomorphic terrane at site (geo13) = [s + ts] / 2	[calculated]
[dfv]	[dfv]	debris flow volume – based on fill volume, slope position, steepness, terrane below = [fv + sp + s + tb] / 4	[calculated]
Total Consequences			
[CQ]	[CQ]	overall consequences rating; based combination of previous two data elements = [4*fv + dp + dfg + dfv]*60/25	[calculated] **max = 60**

Table 2 – Risk – Consequences – Impacts

Unit	Assigned Value 1/	Impact Rating Elements	[data source]
IMPACTS [to beneficial uses]			
[ws]	 3 2 1 0	water supply sources at risk – potable surface water sources anywhere downstream municipal source > 5 domestic sources or campground any potable source (< 5 domestic) none	[other]
[fb]	 3 2 1 0	site within Riparian Reserve buffer on fish-bearing & perennial streams site within Riparian Reserve buffer on anadromous or TES aquatic species stream site within RR buffer on fish-bearing (i.e., resident only) stream site within RR buffer on non-fish-bearing perennial streams no perennial stream at site and site not within RR buffer	[GIS]
[fa]	 3 2 1 0	downstream facilities at risk non-road facilities at **direct risk*** (e.g., buildings, campgrounds, trailheads) multiple (>1) road/stream crossings downstream single crossing downstream none (or bridge only)	[other]
* **direct risk** means facility is: (1) directly downslope/downstream – a "straight" shot and (2) within same or next higher order stream and (3) less than one mile downstream and (4) located on floodplain (<= 100 year)			
Total Impacts			
[IP]	[IP]	impacts rating; based on combination of previous three data elements = [ws + fb + fa]*30/9	[calculated] **max = 30**
OVERALL RATING			
[OR]	[OR]	overall rating – from integration of all data elements and components above =[2*CQ + RK + SP + IP]*100/220	[calculated] **max = 100**

1/ Assigned Value – highest values are greatest hazard

Results / Discussion

Principal products of the Road Sediment Source Inventory & Risk Assessment include:

(1) an inventory of all channel crossings, hydrologically connected cross drains (ditch relief structures – pipes & dips) and other potential erosion-producing sites between crossings. See **Table 3** for summary information & **Appendix A**, for site-specific details],

(2) an environmental risk/consequences/impacts assessment rating for all sites [see **enclosed CD** – 'rdx_eldorado08.xls'] – risk assessment procedural details, see above,

(3) site summary information – [**Appendix A**],

(4) road list, inventory status and number of inventoried sites by road – FS & private [**Appendix A**], and

(7) spatial displays (GIS maps) of the Road Sediment Source information showing all inventory sites, high risk/consequences/impact sites, and sites with diversion potential [**Figure 3a & 3b** and **Appendix C**].

The following discussion is based on the information shown on **Table 3** below and 'Road Summary Information' [**Appendix A**].

Road miles: Road densities in the Eldorado 2008 drainages (4.78 mi/sq. mi) are considerably higher than the Klamath NF average (1.58). [NOTE: 'Klamath Summary' column in Table 3 represents summary statistics from 13 inventory; 6,823 sites were inventoried in watersheds totally 838,870 acres] Percentage of near-stream road miles (within RCA stream buffers) is 64%, significantly higher than the 27% average for watersheds in USFS Northern Province Forests [northwestern California; USFS, 2000b]. For this study, the high percentage of near-stream roads was part of the project design, which was to select roads for inventory that traveled dominantly through Resource Conservation Area stream buffers. Total length of road within the project area is 216.3 miles, of which, 63.25 miles (29%) were selected for inventory.

Diversion potential & hydrologic connectivity: Approximately 16.4% of inventoried road length routes water directly to stream channels or gullies below the outlets of hydrologically connected cross drains. In other words, for inventoried, the proportion of road length that is hydrologically connected is 16.4%. The majority of this routing of runoff and associated sediment is via road inboard drainage ditches. Diversion potential exists at 56% of all sites and 49% of channel crossing sites.

Debris flows: Nineteen sites (or 5.0% of total) are high risk for upslope debris flows with overall debris flow hazard rating of >= 9.2. This hazard rating combines past debris flow history and disturbance/geologic instability upslope to predict likelihood (probability) of future debris flows.

Overall rating: 'Overall rating' [OR] combines risk, consequence and impact elements to characterize each site, leading to the identification of 'highly rated' or 'high priority' sites (see discussion above; **Figure 2** & **Tables 2 & 3**). Highly rated sites (~top 10%) are those with 'OR' values >= 43.0. For this study, only 3.4% of sites have 'OR' >= 45, compared with ~25% with 'OR' >= 45 for Klamath Summary sites (see **Table 3**). This disparity might be due to the fact that "Impacts" ratings were not done for this assessment.

<u>Fill volumes:</u> Fill volume at all channel crossing sites totals 76,270 cubic yards (CY), averaging 410 CY per site; median is 132 CY. Approximately 65% of this total fill volume can be attributed to just 10% of the highest ranked sites! This implies that sediment at risk at channel crossings could be reduced by 65% if only 10% of sites [21 of 187] were treated.

<u>Patterns:</u> Highly rated sites are distributed throughout the inventory area (**Figure 3a & 3b**). However, high concentrations occur along four (4) roads. Thirteen (13) of the mostly highly rated twenty-one (21) sites (~62%) are found on these four roads:

[1] **10N39** road is a main road that follows (and is adjacent to) Alder Creek in the headwaters area. It has 4 highly rated sites; sites have moderate fill volumes & long in-board ditches. 24 of 30 sites have diversion potential. 105% of the road length is hydrologically connected. Five (of 22) "tweeners" are found on this road.

[2] **11N47** is also a main road in Alder Creek It has 4 highly rated sites. These 4 sites have huge fill volumes, averaging ~8,850 CY. 11 of 13 sites have diversion potential. 59% of the road length is hydrologically connected. Two "tweeners" are found on this road.

[3] **09N17** road is a main road adjacent to Cat Creek and within Dark Canyon (stream proximal). It has 3 highly rated sites, with moderate sized fill volumes. 8 of 9 sites have diversion potential. 94% of the road length is hydrologically connected.

[4] **09N40** is a main road that travels adjacent to Cat Creek. It has 2 highly rated sites, with moderate sized fill volumes. 10 of 14 sites have diversion potential. 48% of the road length is hydrologically connected. One "tweener" is found on this road.

Table 3. Summary Statistics	Klamath Summary 1/	Eldorado 2008
Sites inventoried:		
All:	6823	381
Channel only:	5407	187
[% chan]	79%	49%
Inventoried Road miles (GIS):	2,075.9	63.25
sites/mi:	3.29	6.02
chan. sites/mi:	2.60	2.96
area acres (in 5 7th-field project drainages)	838,870	28,935
rd. mi. / sq. mi. (tot. rd. mi. = 216.3)	1.58	4.78
% inventoried roads near stream 2/	35%	64%
Diversion potential (dp):		
All sites:	3240	215
[% sites w/dp]	47%	56%
chan. sites only:	2400	91
[% sites w/dp]	44%	49%
Hydrologic connectivity:		
rd miles connected to channels:	296.18	10.36
[% of tot. rd. length]	14.3%	16.4%
Overall rating (OR):		
OR > 60	400	1
[% of sites]	5.9%	0.3%
OR = 50 - 60	767	6
[% of sites]	11.2%	1.6%
OR = 45 - 49.9	530	6
[% of sites]	7.8%	1.6%
% sites with OR >= 45	24.9%	3.4%
% sites with OR >= 43		5.5%
FILL VOLUMES [CY]		
All chan. sites [CY]:	3,061,160	76,270
aver. fill / chan crossing:	566	408
median fill/ chan xing		132
Chan. sites w/dp:	1,377,240	50,383
% of vol - all chan sites	45%	66%
total costs to treat: [@ $2,500 / site] 3/	$6,000,000	$227,500
$ / cy sediment saved 4/ :	$4.36	$4.52
Top 10% rated sites:	1,494,644	49,850
	[724 of 6,823]	[21 of 187]
% of vol - all chan sites	49%	65%
total costs to treat top 10%: [@ $30,000 / site] 3/	$30,000,000	$630,000
$ / cy sediment saved:	$20.07	$12.64

1/ = Klamath National Forest summary statistics; 13 inventory areas - 1999, 2000, 2001, 2006

2/ = road miles within 105 meter stream buffer for 5th-field analysis watersheds or ROD stream buffers (Klamath); within RCA (Eldorado)

3/ = KNF Engineering estimated costs - average treatment; $2,500 / site = construct critical dip to fix diversion potential; $30,000 / site = major crossing reconstruction to reduce fill at risk

4/ = PWA assumption ... "at stream crossings with a diversion potential, future gully erosion is difficult to predict. A minimum of the stream crossing [fill] volume was used as predicted value for this table." [Weaver, W.E., and Hagans, D.K., 1999, Storm-proofing forest roads: Pacific Watershed Associates]

Aquatics Model

The purpose of this model is to use site specific information to characterize entire road segments. Model results rate individual roads as to their relative risk, consequences and impacts to aquatic resources. This process and result is termed the 'Aquatics Model' and was developed as part of the Roads Analysis Process [RAP] done on the Salmon River Ranger District (Klamath National Forest) during fall of 2001. Prime objective of the Aquatics Model is to determine which roads pose the greatest threat of increased sedimentation and interruption of the hydrologic regime & riparian reserve integrity.

The Aquatics Model uses twelve (12) rating criteria (see Table 1, Aquatics Model … Process Paper, **Appendix A**). Six of these criteria area are derived from GIS road modeling. The six other are compiled from road inventory information. For this study, only the field inventory information was used. See **Appendix A** for data used, model road segment rating results and analysis process paper.

Table 4 shows the results of the Aquatics Model. Listed are the "top 10" roads, sorted by 'Aquatics Model rating', in descending order. In general, highly rated road segments are characterized by the following: (1) high number of channel crossings over length of the road, (2) high percentage of road length directly connected to stream network, (3) high number of sites with diversion potential, (4) high number of sites with road-related gullies and landslides, (5) high number of 'highly-rated' individual crossing sites, and (6) road contains many crossings, many of which are highly-rated (i.e., weighted sum overall site ratings for a given road segment.

Table 4

Road number	Length	Total sites	Sites/ mile	Channel crossing sites	chan sites / mile	% hydro con- nected	Diversion potential sites	% sites w/ diver potential	Other sediment sources	Highly-rated sites	Overall rating (sum sites)	Aquatics Model rating
10N39	3.462	30	8.7	13	3.8	105%	24	80%	5	4	733.8	33
11N47	2.095	13	6.2	6	2.9	59%	11	85%	2	4	412.5	31
09N17	1.095	9	8.2	4	3.7	94%	8	89%		3	252.7	30
09N40	1.935	14	7.2	6	3.1	48%	10	71%	1	2	379.6	30
09N34C	1.765	13	7.4	7	4.0	0%	7	54%	3	1	291.5	27
09N17D	0.579	6	10.4	4	6.9	0%	3	50%	1	1	164.4	25
09N38	2.142	20	9.3	8	3.7	4%	14	70%			380.0	25
09N91A	0.879	8	9.1	4	4.6	6%	7	88%			208.9	25
09NY08	1.357	12	8.8	6	4.4	4%	6	50%			263.3	25
10N44B	0.538	7	13.0	3	5.6	4%	4	57%			129.9	24
11N46H	0.832	6	7.2	3	3.6	57%	4	67%	4		116.7	24

PRIORITIZED SEDIMENT REDUCTION IMPLEMENTATION PLAN

Project Information:

Summary information is displayed in **Table 3**, where Eldorado 2008 Road Inventory information can be compared with other completed inventory areas within the Klamath National Forest. Clean Water Act's South Fork Trinity River Sediment Total Maximum Daily Loads document sets targets to decrease road-related sediment delivery. Targets of ≤ 1% were set for "crossings with diversion potential" and "stream crossings with significant failure potential … targeting crossings with highest probability of failure and highest consequences." To meet these sediment reduction targets within the project area, diversion potential would need to be corrected at 91 channel crossing sites and 124 hydrologically connected cross drains. At an estimated average cost of $2,500 per site, the total cost would amount to $227,500 to treat channel crossing sites. Cost per yard of sediment saved would be $4.52, using PWA assumptions (see bottom of **Table 3**). To fix the highest risk sites (top ~10% or 49 of 475 sites), at an average cost of $30,000 per site, would total $630,000. This would reduce fill at risk at channel crossings by an impressive 65%. In other words, 65% of all fill volume at all channel crossings is found in the top 10 % of sites (by 'overall rating' described above)!

Field crews collected site information. Risk assessment phase was conducted using this field information and following the outline shown in **Figure 2**. This process rated all inventoried sites on the basis of (1) <u>risk</u> of failure, (2) <u>consequences</u> of failure, and (3) potential <u>impacts</u> from failure. These individual elements were combined to yield an **overall rating**. Overall rating values for each site are displayed in tables of **Appendix A**. Overall rating values identify high risk/consequences/impact sites. Opportunity criteria (see right side of **Figure 2**) must then be applied in order to fully 'prioritize' each site. This last step is beyond the scope of this project and will done in Forest planning processes.

In addition to site-specific information, project data provide road and road segment information for use in transportation planning efforts. Site-specific data can be viewed spatially to characterize individual roads. For example, a high concentration of high risk/consequences/impact sites would highlight this road as a candidate for upgrading or decommissioning, where large crossing fill volumes would be removed during upgrading or decommissioning. Numerous sites with diversion and/or collection potential along a specific road would suggest this road for a project that constructed 'critical dips'.

Transportation Planning:

Road inventory information is critically important in making informed recommendations during transportation planning. Recommendations include identification of roads for one of the following actions: (1) upgrade or 'stormproofing', (2) decommissioning, (3) storage or radical stormproofing, (4) changes in closure status, (5) changes in maintenance level, (6) administrative action (e.g., add to system, special use permit), and (7) status quo (no action). This process is conducted in an interdisciplinary setting, where all resource interests are represented.

These recommendations are based in large part by balancing needs & benefits versus environmental risk & road costs (simplistically, a type of cost/benefit analysis). In general and at extreme ends of the spectrum, if a road is critically essential to Forest land managers or the public and it poses high environmental risks (typically through threat of accelerated sedimentation), then the road is recommended for upgrade. If a road is not critically essential and poses high risks, it would become a candidate for decommissioning. Therefore, upgrading or decommissioning high-risk roads would accomplish sediment reduction. Less costly sediment reduction measures could involve more restrictive closure status or upgrading of maintenance level.

Road Treatments:

While acknowledging that recommendations as to which individual roads will receive which action should be made within the transportation planning process, this project can provide a list of potential sediment reducing road treatments. These treatments are shown in **Table 5** below. As noted at the bottom of **Table 5**, these categories of action are listed in order of increasing costs, construction complexity/difficulty, and project preparation documentation.

Road treatments can be generally divided into those that "winterize" a road and those that "stormproof" a road. Winterizing is a road maintenance activity (see **Table 5**, category [1]). Winterizing a road can reduce chronic and persistent fine-grained sediment generated by surface erosion processes within the road prism during typical winter flow conditions. Road surface grading can reduce the potential for road surface rilling and gullying. Ditch and culvert inlet cleaning can ensure road surface flows remain within designed drainage structures and not on the road itself.

Stormproofing a road can reduce sedimentation from episodic mass wasting and fluvial gullying, triggered by intense precipitation events and resultant high flow regimes. Categories [2] through [7] of **Table 4** are stormproofing measures. Treatments under 'Drainage Problems' address road surface erosion. 'Dips' fix high flows on road surfaces and ditches to (collection potential) and from (diversion potential) channel crossings. 'Major Crossing Re-design' treatments typically reduce fill volumes, allowing the channel crossing to handle debris flows and flood stage hydraulic flows; passage of fish and coarse woody debris is permitted. 'Landslide Remedies' address mass wasting potential from unstable road cuts, fills, or entire road prism. 'Storage' and 'Decommission' treatments storm proof unused roads.

For all types of treatments, "sediment saved" is equal to the total volume of fill at the crossing site. This assumption is advocated by Pacific Watershed Associates (Weaver and Hagans 1999; see bottom of **Table 3** above) and implicitly accepted by California Department of Fish & Game. There is a danger in this assumption. This assumption skews "cost effectiveness" numbers toward construction of critical dips to fix diversion potential and away from major crossing upgrades that reduce substantial fill volumes (e.g, construction of coarse-rock vented ford crossings). This could have the effect of preferentially funding "diversion potential" efforts at the expense of major crossing upgrade projects.

For example, consider a crossing with a 1,000 cubic yard (CY) fill. To construct a critical dip to fix diversion potential may involve removal of 50 CY of material at total cost of $3,000 – yielding cost effectiveness of $3 per CY of sediment saved [$3,000 / 1,000 CY]. After completion of this project, 950 CY of "at-risk" fill volume would still remain. To upgrade the crossing by constructing a coarse-rock vented ford might involve the removal of 900 CY of fill at a total cost of $50,000 - yielding cost effectiveness of $50 per CY of sediment saved [$50,000 / 1,000 CY]. After completion of this project, only100 CY of "at-risk" fill volume would still remain. Based on "cost effectiveness" values [$3 vs. $50], there is a risk that the critical dip project would be funded instead of the major crossing upgrade alterative.

This report does **<u>not</u>** take the position that diversion potential projects should be ignored in favor of major upgrade efforts. <u>Both</u> types of treatments need to be considered. Decisions need to be based on risk/consequences/impacts at individual sites. For example, if a site poses little risk from debris flow or undersized pipe, small to moderate fill volume consequences, and minor impacts, then this site would be low priority for major upgrade, but could be a candidate for a critical dip. However, a site with large fill volume at risk to debris flow or undersized pipe should be considered for a vented ford crossing upgrade or crossing redesign that removes significant fill volume. When considering diversion potential treatments for road segments, do NOT forget critical dips to break collection potential or outsloping of the entire segment.

This approach is consistent with the results of the Klamath National Forest's 1997 Flood Assessment (de la Fuente and Elder 1998). In this study, of inventoried flood damage sites on Forest roads, approximately 400 of 800 sites involved failures at stream crossings. An estimated 22% of the 400 stream crossing sites resulted in diversion around plugged pipes. Often damage was minor. Effects from diverting streams amounted to an estimated 72, 360 CY of failed material or a rate of 9 **CY/mile/decade** (assumes 4,000 miles of Forest road; 1997 Flood, as an event with ~20 year recurrence interval). Road failures at stream crossing where **<u>no</u>** diversion occurred resulted in an estimated 656,360 CY of failed material or a rate of 82 **CY/mile/decade**. Correcting diversion potential will reduce risk, but only a portion of it. Where upslope debris flows caused crossing failures, critical dips would not have been effective. In other words, debris flows did not divert, but punched through crossing fills like a freight train.

Table 5 - Road Treatments - Categories of Actions
[1] <u>Maintenance:</u> ➢ Unplug inlets ➢ Clean ditches ➢ Grade gullies in road surface
[2] <u>Dips:</u> ➢ Critical dips at crossing to fix diversion potential ➢ Dips to break collection potential or hydrologic connectivity ➢ Dips at "eroding pipeless swales"
[3] <u>Drainage Problems:</u> ➢ Road designs that cause gullies ➢ Adding pipes to break hydrologic connectivity ➢ Out sloping road
[4] <u>Major Crossing Re-design:</u> ➢ Upgrade crossing to reduce fill volume ➢ Upgrade crossing to allow passage of debris flows ➢ Other storm proofing measures (e.g., upgrade culvert size, fill slope stabilization) ➢ Upgrade crossing to allow fish passage where restricted
[5] <u>Landslide Remedies:</u> ➢ Buttress unstable cuts ➢ Engineered reinforced fills (e.g., "burrito walls", Hilfiker walls) ➢ Remove failed material
[6] <u>Storage:</u> ➢ Make road geo/hydrologically stable ("hydrologic obliteration"), ➢ But with option of future entry (i.e., not off system) ➢ Take-off not recontoured; pipes removed but some left on site
[7] <u>Decommission:</u> ➢ Make road geo/hydrologically stable ("hydrologic obliteration"), ➢ With NO intention of future entry (i.e., off system) ➢ Take-off recontoured; all pipes removed

Listed in order of **<u>increasing</u>**

- ✓ Costs
- ✓ Construction complexity/difficulty
- ✓ Project preparation documentation (e.g., NEPA, ESA, Engineering design)

This report suggests a broad approach based on looking at fixes for entire roads/road segments or sub-watersheds (drainages). High risk/consequences/impact roads or areas should be considered rather than focusing on high risk/consequences/impact sites in isolation. For example, within an identified high priority 7th-field watershed, high risk/consequences/impact roads should be targeted. Variety and mixes of fixes should be considered – outslope sections of road, major crossing upgrades at certain sites, fix diversion and collection potential in areas, and rock (hard surface with engineered crushed aggregate) sections of road. This mix of road upgrades collectively 'storm-proof' the road – making it better able to withstand the next flood event.

Project and Watershed Monitoring Activity Recommendations

Watershed/road restoration projects resulting from Road Sediment Source surveys and transportation planning would be monitored in the following three ways:

(1) Implementation Monitoring [Were project design standards and specifications achieved?];

(2) Effectiveness Monitoring [Were project objectives met? – Was implemented project effective at meeting these objectives?] and;

(3) Validation Monitoring [Are the assumptions underlying project decisions accurate?].

In addition, all watershed restoration activities involving roads would be subject to random monitoring for compliance with Best Management Practices standards and guidelines.

The ultimate effectiveness and validation monitoring of watersheds where restoration work has been implemented will occur when these treated watersheds are subjected and tested by future high precipitation and runoff events. The test will be to see if future large storms cause less road-related damage because of decommissioning and storm-proofing/upgrading actions that have been implemented.

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EXPLANATION OF FILES ON "CD" [COMPACT DISC]
INCLUDED WITH THIS REPORT

Eldorado National Forest
Eldorado 2008 Road Sediment Source Inventory

DOCUMENTS:

[1] **discussion_eldorado2008.doc**- general narrative report of the project, in MS Word format. Includes introductory material (setting, problem, purpose), methods (field data collection and risk assessment), results, and treatments/recommendations/implementation.

SPREADSHEETS:

[2] **rdx_eldorado08.xls -** multi-tab spreadsheet for road inventory sites in Eldorado 2008 Road Inventory project area, in MS Excel format. Spreadsheet includes specific and detailed information on 381 inventoried channel crossings and hydrologically connected cross-drain sites. Spreadsheet contains raw field data, fill volume calculations, hydrological pipe capacity calculations (based on drainage areas above pipes, etc.), upslope geological ratings, impact ratings, site ratings based on preceding data that includes risk, consequences, and impact rating information and key which explains the rating scheme.

[3] **roads and sites list.xls -** list of roads within the project area, with inventory status and number of inventoried sites per road, in MS Excel format.

[4] **tweeners.xls** – information about other sediment sources between crossings, typically landslides and gullies.

[5] **aquatics model.xls** – Table shows the relative risks associated with the 62 road segments inventoried as part of this project. Ratings are based on the following field inventory data compiled for each road segment: (1) channel crossing count, (2) length of road hydrologically connected, (3) sites with diversion potential, (4) "tweeners" (other sediment sources), and (5) sum of Overall Ratings for individual sites.

GIS GEODATABASE (personal):

[5] **Eldorado2008_RdInv_GDB.mdb** - ArcGIS 9.2 personal geodatabase, contains all spatial data for the project, including:

[1] all_roads = all roads in Eldorado National Forest roads layer (Forest-wide)

[2] contours40 & contours80 = 40' & 80'contours (project area)

[3] ownership = land ownership; Forest Service & not (project area)

[4] plss_sections & plss_townships = public land survey sections & townships (project area)

[5] proj_rds = roads within project area

[6] rdx_eld08 = inventoried sites (project area)

[7] sheds & clipsheds = 5 & 6 - 7th-field drainages composing the project area

[8] streams = streams (project area)

[9] xsheds1 = overlapping drainages upslope of channel crossings with pipes

[6] **Alder_final_34x22_mar09.mxd** and **CatDog_final_44x34_mar09.mxd** – ArcMap project used to create the maps exported to PowerPoint format (see below). ArcMap uses feature classes in **Eldorado2008_RdInv_GDB.mdb** (see above) to create the maps. For each feature class, "Source" path (under Properties → Source → Set Data Source) must be changed to reflect source path location for computer used.

GRAPHICS FILES:

[6] **Alder_34x22_mar09.ppt** and **CatDog_44x34_mar09.ppt** - maps of sites inventoried in Eldorado 2008 Road Inventory project area, in MS PowerPoint format. This file is an electronic version of the 34" x 22" and 44" x 34" folded maps enclosed with this report and must by printed on large format plotter. Maps show all inventoried sites and codes those with diversion potential (green circles) and highly rated sites (orange circles). "Highly rated sites" are those sites with an overall rating of >= 43.0, which represents approximately the top 10% of inventoried channel crossing sites (see **Table 3**). These sites are those with relatively high risks, consequences, and impacts. This cut-off point is arbitrary.

[8] **FIG3_eldorado_17x11_mar09.ppt** - electronic version of same map described above and shown as Figure 2 of this report, as 'slides' in MS PowerPoint format. Size is 17" X 11" landscape.

2009

Road Sediment Source Inventory
and
Risk Assessment

ELDORADO ROAD INVENTORY 2009

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Brush Creek, Lower Slab Creek, Upper Camp Creek, North Fork Cosumnes River- Van Horn Creek, and Upper North Fork Cosumnes River Watersheds

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Project Dates: June 2009 to December 2009
(field data collection)

March 21, 2011

Eldorado National Forest
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Table of Contents

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ROAD SEDIMENT SOURCE INVENTORY & RISK ASSESSMENT
Eldorado National Forest – Eldorado 2009 Road Inventory

Abstract

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances, averaging 48 times background from landsliding and 82 times background from surface erosion (USFS, 2004). Consequently, road issues are often at the heart of watershed restoration activities.

On the Eldorado National Forest in 2009, 316 miles of Forest roads were reported as field inventoried. However, there appear to be a number of roads which should cross stream channels that have no sites recorded (no inventory data). The *known* miles inventoried are far less (183). The values reported include all miles in the project area, unless otherwise specified. Therefore, in some cases true values could actually be much higher when only sites with data are analyzed.

Project roads lie within five (5) 7^{th}-field drainages – Brush Creek, Lower Slab Creek, Upper Camp Creek, North Fork Cosumnes River- Van Horn Creek, and Upper North Fork Cosumnes River Watersheds. During this project, 462 sites were inventoried, 91% of these sites were channel crossings (419); the remainder were hydrologically connected cross drains (43). Stream diversion potential existed at 51% of these sites. Approximately 3% of the inventoried road length was hydrologically connected to natural stream courses. This value is probably much higher, for the reason described above. Estimated total volume of fill material at channel crossing sites was 88, 277 cubic yards, with an average of ~ 191.1 cubic yards per site. Median fill volume was ~ 91.6 cubic yards. Additionally, thirty (30) active sediment sources (landslides and gullies) between crossings were surveyed.

Because Forest road systems are extensive and road-related restoration is generally expensive, it is valuable to focus potential investments on the sites posing the highest risk/consequences/ impacts. Each site was rated and ranked by considering: [1] <u>risk</u> of failure, [2] <u>consequences</u> of failure (sediment delivered), and [3] <u>impacts</u> of failure (to beneficial uses). For example, a highly ranked site could be one with an undersized pipe, geologic instability upslope, large fill volume with diversion potential, on an anadromous fish stream. Evaluation of all sites concluded that 53% of the total fill volume at channel crossings could be attributed to approximately 20% of all inventoried sites. In other words, by upgrading channel crossings to reduce the risk/consequences/impacts of failure at only 20% of sites (92 of 462), approximately 53% of total fill volume would be treated!

These findings suggest that targeted restoration has the potential to substantially reduce the risks and consequences from road-related sediment delivery. This tool has the demonstrated capability to accelerate watershed recovery in support of the goals of the *Endangered Species Act* and the *Clean Water Act*.

NOTE: The following sections are intentionally brief as the core of this report is contained in tabular and spatial databases. The reader is therefore urged to concentrate on the information presented in the spreadsheet tables [**Appendix A**] and map products [**Appendix C** and **Figures 1**, **3** - following].

Setting

This effort inventoried roads within the Brush Creek, Lower Slab Creek, Upper Camp Creek, North Fork Cosumnes River- Van Horn Creek, and Upper North Fork Cosumnes River Watersheds; see Location Map (**Figure 1** below). Crews composed of Eldorado National Forest personnel collected field data. Analysis was accomplished through an agreement between ACT2 Forest Service Enterprise Team and the Eldorado National Forest.

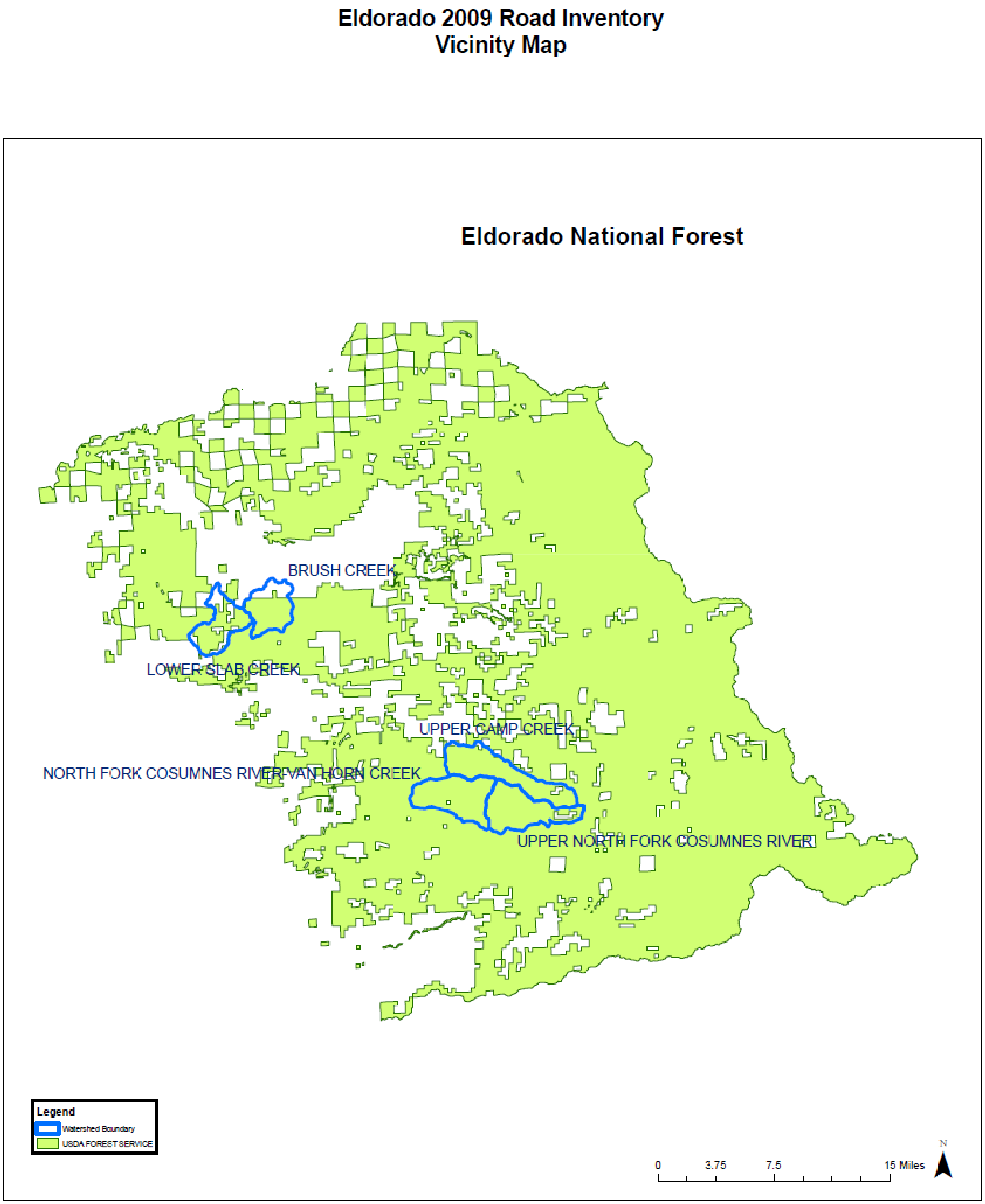
The Eldorado 2009 Road Inventory project area consists of roads within five (5) 7^{th}-field drainages [HUC7]. These drainages total 34,347.6acres. Upper Camp Creek, the North Fork Consumnes River and the Upper North Fork Consumnes River drainages lie within the Upper Consumnes River sub basin [HUC4], within the San Joaquin basin [HUC3]. Brush Creek and Lower Slab Creek drainages lie within the South Fork of the American River sub basin [HUC4], within the larger Lower Sacramento River basin [HUC3].

Problem

Roads are important and costly structures, with pervasive, persistent and potentially cumulative impacts on steep forested land. Roads contribute the highest per acre sedimentation rate of all watershed disturbances (e.g., Amaranthus, et al. 1985; de la Fuente & Elder 1998; Flanagan, Furniss, et al. 1998a & 1998b; Pacific Watershed Associates 1997; U.S. Environmental Protection Agency 1998), averaging 58 times background from landsliding and 290 times background from surface erosion (de la Fuente & Haessig 1994). Sediment modeling on the Klamath National Forest produced similar numbers – 48 times from landsliding and 82 times from surface erosion (USFS, 2004). In addition, roads can alter hydrology, habitat connectivity, and routing of wood and sediment. These combined effects have the potential to strongly influence downstream aquatic environments critical to anadromous salmonids and other aquatic species. As the availability of road maintenance funds allocated to the Forest Service decreases, down nearly 50% in the past several years, the necessity to evaluate and implement measures which reduce the risk of road related impacts to aquatic systems is greater than ever.

The Klamath National Forest road system sustained over 30 million dollars worth of damage during the "New Year's Day" flood of the winter of 1996-1997 [hereafter referred to as '1997 Flood']. Stream channels, riparian areas, and fish habitat were impacted by excessive scour and deposition during that storm. The impact was severe in some places. Some of these impacts were caused by sediment delivered from roads. *The Flood of 1997: Klamath National Forest Phase I Final Report* (de la Fuente and Elder 1998) estimated that over half of the large road repair sites were at stream crossings. An estimated 22% of these sites resulted in diversion around plugged culverts.

Figure 1- Location of Inventoried Watersheds



Two of the primary types of failures occurring at road-stream crossings include "stream diversion" and "fill failure". A stream diversion occurs when a culvert at a stream crossing fails due to hydraulic exceedance and/or plugging by debris or sediment. If this happens at a stream crossing where the road leaves the crossing at a negative slope (downhill), then the water can flow down the road rather than down its' own natural channel. This often has adverse effects on the watershed, such as saturating road fills which causes failures and the potential to generate debris flows, eroding the road surface, eroding away huge amounts of soil on unstable hillslopes where water does not naturally flow, and causing cascading failures of stream crossings in adjacent drainages into which the stream has been diverted.

Partial or complete failure of crossings fills is the other primary risk posed by stream crossing to downstream aquatic habitat. In addition to the sediment generated by such failures, failures of this type can initiate large debris flows that scour channels, fill pools and strip riparian vegetation from stream banks. Although prediction of crossing failure is difficult, the risk and consequences can be characterized. With this information, risk reduction measures including up-sizing culverts, reduction in fill size, or decommissioning can be targeted toward crossings with high risks, high consequences and impacts before they fail. In addition to evaluating crossings for stream diversion potential, this assessment will assess factors influencing culvert and crossing failure, including consequences at all road-stream crossings.

Purpose

The intent of Forest Service policy and approach to transportation planning is to find a balance between the positive benefits of access and road-associated negative effects on other values and resources, such as clean water, fish, and wildlife; and on maintaining choices for future generations. In Forest Service Chief Dombeck's *Natural Resource Agenda for the 21st Century*, an emphasis was placed on watershed health and restoration, and forest roads. National Forest roads policy has four primary objectives: (1) More carefully consider decisions to build new roads, (2) eliminate old, unneeded roads, (3) upgrade and maintain roads that are important to public access, and (4) develop new and dependable funding for Forest road management.

One Section of the Environmental Protection Agency *Clean Water Action Plan* includes natural resource stewardship on Federal lands. A Key Action in this Section calls for substantially increasing maintenance of forest roads and trails on Federal lands to protect water quality, to improve water quality protection on over 2,000 miles of road per year, and to decommission 5,000 miles of road.

The Road Sediment Source inventories and assessments were conducted to acquire information necessary to prioritize watershed restoration work involving roads so that the most critical, most ecologically-beneficial and cost-effective restoration projects could be more accurately identified and implemented first. The purpose of the Road Sediment Source surveys and analyses was to identify specific locations (Sites) where road drainage structures and fill have the potential to adversely impact watershed processes, and then to assess the relative ***environmental risk*** of each identified Site.

Other applications include use: [1] in transportation planning efforts, [2] to define existing and target conditions in other more general planning documents, such as ecosystem analyses, larger subbasin and basin assessments, and TMDL documents (Total Maximum Daily Loads for water bodies listed under Section 303(d) of the *Clean Water Act*), [3] in Forest Service National Roads Policy inventory requirements, and [4] in various management projects, such as timber sales.

The primary objective of the crossing inventory and assessment proposal is to identify high risk/consequences/impact road-stream crossings which pose the greatest threat to aquatic resources, especially sedimentation of anadromous fish habitat. Some or all of the following will characterize high-risk stream crossings:

- large fills at or adjacent to the crossing,
- potential for stream diversion,
- inadequate culvert capacity to pass water, woody debris or sediment,
- unstable geology above site (high debris flow potential) or down slope (high potential for additional erosional effects if crossing fails or diverts stream flow),
- high value beneficial uses that would be adversely impacted if crossing failed.

A secondary objective is to provide education to residents within the area on road crossing risks, mitigation designs, and how these issues affect aquatic habitat. This knowledge can then be applied to strategic transportation planning on <u>private</u> roads. Outreach education would also familiarize area residents with cooperative efforts in watershed restoration and planning.

Methods

This project can be divided into seven general work elements, as shown in Steps 1 through 7 of **Table 1** below.

Field Inventory Methods

Field inventory work was accomplished using procedures detailed in *Field Guide: Explanation & Instructions for Klamath National Forest Road Sediment Source Field Inventory Form - May 14, 1999 [revised May 23, 2000]* (USFS 1999a). <u>See **Appendix B** for complete copy of *Field Guide*</u>. The Forest developed this field guide borrowing and modifying concepts, definitions and procedures from the following sources: [1] Pacific Watersheds Associates procedures for assessing road sediment sources (PWA, 1997), [2] stream crossing environmental risk assessment protocol developed Six Rivers National Forest (Flanagan, et al., 1998a & 1998b), and [3] Forest Service national roads policy as described in *Roads Analysis: Informing Decisions About Managing the National Forest Transportation System* (USFS, 1999b).

In road sediment source field inventories, **all** stream channel-road crossings and **all** hydrologically connected cross drains (ditch relief structures – pipes & dips) were examined and measured (USFS, 1999a). In addition, road-related erosion hazards <u>between</u> channel crossings and hydrologically connected cross drains were surveyed. These sites consisted of landslides (mass wasting) and gullying (surface erosion) features that are currently active or pose future/potential threats of sedimentation. These “between crossing" sites have been nicknamed “tweeners.”

Risk Assessment Methods

With limited resources, it becomes necessary and desirable to prioritize sites for treatment. Although treatments may vary from site-specific recommendations to all inclusive road segment proposals, from minor maintenance fixes to major crossing re-design and reconstruction, all sites are subjected to the same initial prioritization scheme. Site information is taken from data collected in the field and drawn from information available from existing Forest GIS layers. The priority setting of individual sites combines three general elements: (1) site condition – risk & consequences, (2) potential impacts, and (3) opportunity. This assessment serves to identify the first element (risk and consequences), a Forest inter-disciplinary team will need to assess the impacts these sites might have should they fail and the opportunities to fix them. A high priority site would be high risk, high consequences, with high potential impacts and high opportunity.

Integration of data elements and groups of data elements is shown in **Figure 2** below. Range of values used to assign individual risk/consequence ratings is shown below. These individual rating values for each site are shown in the Tables of **Appendix A.**

Table 1 - Project Outline - General Work Elements

x **STEP 1 - <u>Pre-Field Inventory Preparation:</u>** - includes:
- photo identification of "ghost" roads and debris flow scoured channels,
- ID sites with history of problems; based on personal experiences, talks w/ Engineering, etc.,
- training of field crews (office & field),
- assessment of upslope watershed risks from disturbances & unstable geology, and
- preparation of maps & photos for field crew use.

x **STEP 2 - <u>Field Crew Inventory of Road Sediment Sources:</u>** - includes:
- identification and characterization of crossing sites [stream channels & 'hydrologically connected' cross drains],
- reconnaissance-level identification of significant features <u>between</u> crossing sites - in preparation for journey-level inventory (Step 3), and
- field identification ("mapping") of "ghost" roads & sediment source inventory of them.

x **STEP 3 - <u>Journey-Level Oversight/Inventory:</u>** - includes:
- characterization of significant features <u>between</u> crossing sites (identified in Step 2),
- monitoring of crossing inventory work to ensure Forest-wide consistency (QA/QC), and
- some field verification of photo-interpreted features described above.

x **STEP 4 - <u>Data Compilation:</u>** - includes:
- entry of field data into spreadsheets,
- entry of field site locations into GIS, and
- calculation of hydraulic pipe capacity at sites (depending mostly on drainage area).

x **STEP 5 – <u>Risk and Consequences Assessment (Office):</u>** - includes:
- analysis of data (from Steps 1 - 4 above),
- preliminary site ranking, and
- identification of high risk and consequences sites.

x **STEP 6 - <u>Final Report:</u>** - includes:
- narrative with summary of findings, prioritization process, upgrade/repair recommendations.
- spreadsheet tables with field data & risk/consequence ratings for <u>all</u> inventoried sites.
- GIS-generated maps showing high priority sites, by type, by specific concern, by overall ranking (prioritization)

x **STEP 7 - <u>Validation of High Risk-Consequences Sites (ID team- field/office):</u>** - includes:
- Identify potential impacts of high risk/consequences sites.
- treatment recommendations - fix or not? suggested upgrade or repair?
- estimated cost of treatment - DSR type report (used in ERFO project assessments).
- looking at a watershed scale, did assessment miss significant road-related problems or risks?

Site Condition:

Site condition is composed of two major elements – risk of failure and consequences of failure. In general, "risk" characterizes upslope and site conditions that measure the probability of failure; "consequences" characterize the downslope results of a failure. Each of these major components is subdivided further. When all elements are combined an overall "site condition" rating is obtained (called Overall Rating within data tables). For example, the highest rated crossing sites would be those with high risk of failure from severely undersized culvert pipe, lengthy contributing ditch, high upslope debris flow risk from past history, large upslope vegetative disturbance and/or unstable geology and high consequences of failure from diversion potential, large fill volume, and a high potential for generation of a debris flow.

Site risk is the combination of two major elements and a lesser component. The major elements consist of pipe capacity and upslope debris flow hazard. Pipe capacity is a measure of how well individual culverts are designed to handle watershed products, principally, water, woody debris and sediment. Hydraulic capacity of culverts is determined using an empirical culvert-sizing model (developed by US Geological Survey; Waananen and Crippen 1977) that takes into account catchment basin area, differences in elevation between site and ridge top, and local precipitation. Crossing culvert ability to pass woody debris is based on a ratio between culvert diameter and upslope channel width. A culvert's ability to transport sediment is based on a ratio between slope of the culvert and upslope channel. Field evidence of undersized pipe and large collection potential of upslope in-board ditch add to the three factors cited above to raise the risk of failure for culvert crossings. Risks associated with upslope debris flow hazards are based on a combination of several elements. Assessment of these risks relies in part on Forest GIS layers. Stability of upslope geomorphology and nature and extent of upslope vegetative disturbances (such as fire and timber harvest) are determined from these GIS layers. Debris flow history at individual sites is obtained from field inventory, historic air photos, and personal accounts. Number and density of upslope roads are considered. Landslide potential at the site is a lesser component that affects a site's overall risk of failure.

Consequences of failure are the second major element that defines site condition. This important element is composed of four unequally weighted factors – fill volume, diversion potential, potential debris flow generation and volume. Of highest importance (weighting) is fill volume. Fill volume is sediment at-risk that is delivered to the stream system if the crossing fails and is therefore very important when considering adverse road-related sediment impacts on aquatic environment. Another major consequence of crossing failures is the diversion of stream from its natural channel and down the road. This diversion can produce gullies and landslide failures. Crossing failures in the steeper headwaters areas of drainages can generate debris flows, many with significant volumes. Potential for generation and subsequent estimation of volume are based on channel and slope steepness, slope position, and stability of geomorphology at the site.

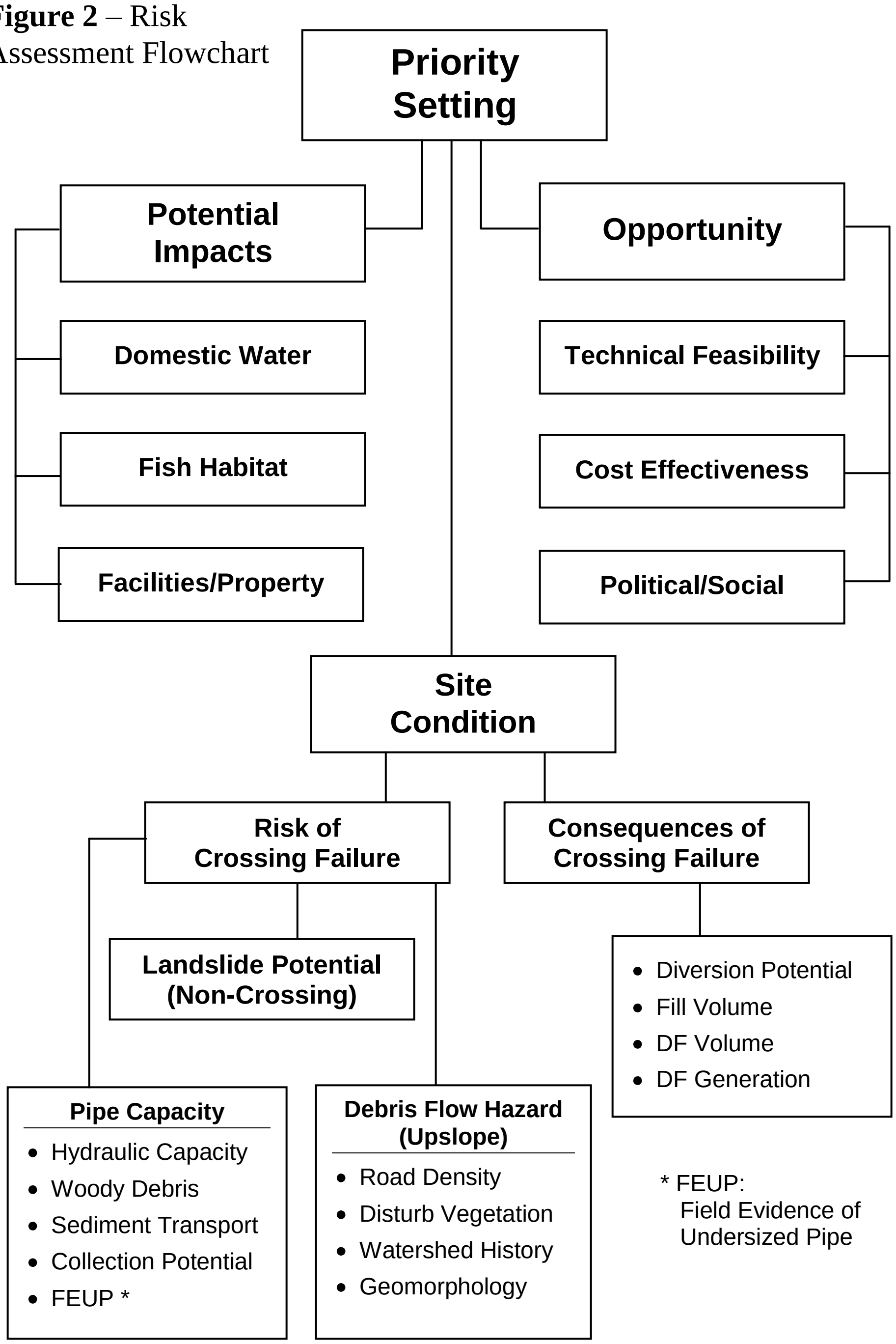


Figure 2 – Risk Assessment Flowchart

Potential Impacts:

This general component characterizes the potential adverse impacts to aquatic habitat should failure occur. "Potential impacts" are the combination of adverse impacts to three beneficial uses – domestic water sources, fish habitat, facilities/property. Impacts must be direct and imply proximity or "closeness."

Domestic potable water sources are rated by number of users – municipal, >5 households, <5 households and none. Sites at perennial streams and within Riparian Reserves are rated by whether or not anadromous or resident fish species are present. Sites are rated by whether or not facilities (buildings, campgrounds, trailheads, etc.) or other roads are directly downstream or down-slope.

Opportunity:

Opportunity rates the "do-ability" of the recommended treatment based on three general criteria – technical feasibility, cost effectiveness, and political/social considerations. These elements are based on subjective professional judgment in an interdisciplinary setting. Technical feasibility rates how effective a given treatment will be in reducing risk, consequences, or impacts. Cost effectiveness rates a proposed project on cost necessary to control an estimated volume of sediment at risk and is usually expressed in "$ per cubic yard saved." Political/social considerations include such things as land use, land ownership, access needs, etc.

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Risk, consequences, and impacts rating elements (and groups of elements) are scored on the following basis:

Risk, consequences, and impacts rating elements (and groups of elements) are scored on the following basis (see Table 2, below):

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Condition Rating Elements**	**[data source]**
		RISK	
		Pipe Capacities	
[T]	 3 2 1 0	an expression of hydraulic capacity T = < 10 years T = 10 - 100 years T = > 100 years no pipe or no definable drainage area	[calculated]
[w]	 3 2 1 0	an expression of woody debris capacity - culvert diameter / width of channel w = < .5 w = .5 - 1.0 w = > 1.0 no pipe or no definable channel	[field data]
[s]	 3 2 1 0	an expression of ability of pipe to transport sediment - slope of pipe / slope of channel s = < .3 s = .3 - .6 s = > .6 no pipe or no definable channel	[field data]
[f]	 3 0	field evidence of undersized pipe yes no	[field data]
[cp1]	 3 2 1 0	collection potential - contributing ditch length to first cross drain structure; best-case scenario" - assumes no cross drain plugging > 500 feet 200 - 500 feet < 200 feet no collection potential	[field data]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Condition Rating Elements**	**[data source]**
		RISK (Continued)	
		Pipe Capacities (Continued)	
[cp2]	 3 2 1 0	collection potential - contributing ditch length to road grade reversal or other feature that breaks collection potential; "worst-case scenario" - assumes plugging of all cross drain pipes > 1,000 feet 250 - 1,000 feet < 250 feet no collection potential	[field data]
[PC]	[PC]	overall pipe capacity risk rating; based on weighted average of previous six data elements, using the following equation: = [3*T + 3*f + 2*w + s + .5*(cp1 + cp2)]	[calculated] **max = 30**
		On-Site Slide Potential	
[as]	 3 1 0.5 0	active landslide at site tweener" &/or fresh or horrendous slide at site "older" slide (LMP &/or crew identified) "maybe or suspected" slide - by crew none	[field data]
[SP]	[SP]	temporary category - to be revised when "tweener" data is analyzed =[as]*10	[calculated] **max = 10**
		Upslope Debris Flow Potential	
[ur]	 3 2 1 0	upslope road/stream crossings > 3 rd/stream crossings upslope of site (same stream) 2 or 3 crossings upslope (same stream) 1 crossing (same stream) or rd/stream crossings (not same stream) none	[field data]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Condition Rating Elements**	**[data source]**
		RISK (Continued)	
		Upslope Debris Flow Potential (Continued)	
[dv]	 3 2 1 0	percentage of site drainage basin devegetated [fire &/or harvest] = >80 % of drainage area 50 - 79 % 20 - 49 % < 20 %	[GIS]
[rdd]	 3 2 1 0	road density in site drainage basin (miles per square mile - mi/sm) > 3.0 mi/sm 1.0 - 3.0 mi/sm present to < 1.0 mi/sm none; no defined drainage area	[GIS]
[df1]	 3 1 0	debris flow history - from field form clear evidence of recent debris flow at site probable &/or ancient debris flow no evidence observed	[field data]
[df2]	 3 2 1 0	debris flow history - from historic air photos >2 prior failures 2 prior failures 1 prior failure or debris flow none; cross-drains, not rated	[other]
[df3]	 3 2 1 0	site failure history from personal accounts >2 prior failures, or notorious repair or maintenance history 2 prior failures 1 prior failure or debris flow none; cross-drains, not rated	[other]

Table 2 - Risk - Consequences - Impacts

Unit	Assigned Value 1/	Site Condition Rating Elements	[data source]
		RISK (Continued)	
		Upslope Debris Flow Potential (Continued)	
[gm]	 3 2 1 0	geomorphic character of site drainage basin ("geo10" coding explanation - see below) abundant unstable geomorphic terranes (geo 10 = 1, 2) abundant sensitive terranes (geo10 = 3, 6) steep slopes, gentle granitic, surficial (geo 10 = 4, 5, 7, 8) stable geomorphic terranes (geo 10 = 9, 10)	[GIS]
[UD]	[UD]	overall upslope debris flow potential risk rating; based on weighted average of previous seven data elements, using the following equation: = [3*(df1 + df2) +2*ur + df3 + dv + rdd + gm]*30/36	[calculated] **max = 30**
		Total Risk	
[RK]	[RK]	risk; based on the following equation: = [PC +UD]	[calculated] **max = 60**
		CONSEQUENCES	
[dp]	 3 0	diversion potential yes no	[field data]
[fv]	 4 3 2 1 0	fill volume at risk > 1,000 cubic yards (cy) 500 - 1,000 cy 100 - 499 cy < 100 cy no fill volume	[field data]
[sp]	 3 2 1	slope position upper third middle lower third	[GIS]

Table 2 - Risk - Consequences - Impacts			
Unit	**Assigned Value 1/**	**Site Condition Rating Elements**	**[data source]**
		CONSEQUENCES (Continued)	
[s]	 3 2 1 0	steepness - channel &/or slope at site [from field data] > 35% gradient 15% - 35% gradient 5% - 14% gradient < 5% gradient	[field data]
[ts]	 3 2 1 0	geomorphic terrane stability - at SITE unstable: geo10 = 10, 9, 8 (**"geo 10"** codes *) very sensitive: geo 10 = 7, 6, 5 slightly sensitive: geo 10 = 3, 4 stable: geo 10 = 2, 1	[GIS]
* explanation of **"geo 10"** coding – Geomorphic Terranes: 10 –Mehrten and lahars(steep: > 40% slopes) 9 – Quaternary alluvium, gravels, and landslide deposits (steep: > 40%) 8 – Plutons and ultramafics (steep: > 40%) 7 – Tertiary volcaniclastic, metasediments, schistose, breccias, and tuff (steep: > 40%) 3 – Tertiary flows, metavolcanics, landslide deposits and sandstone (steep: > 40%) 6 – Mehrten and lahars (gentler: < 40% slopes) 5 – Quaternary alluvium, gravels, and landslide deposits (gentler: < 40%) 4 – Plutons and ultramafics (gentler: < 40%) 2 – Tertiary volcaniclastic, metasediments, schistose, breccias, and tuff (gentler: < 40%) 1 – Tertiary flows, metavolcanics, landslide deposits and sandstone (gentler: < 40%)			
[tb]	 3 2 1 0	geomorphic terrane stability – BELOW site unstable: geo10 = 10, 9, 8 (**"geo 10"** codes *) very sensitive: geo 10 = 7, 6, 5 slightly sensitive: geo 10 = 3, 4 stable: geo 10 = 2, 1	[GIS]
[dfg]	[dfg]	potential for debris flow generation from failure at site; based on steepness & geomorphic terrane at site (geo13) = [s + ts] / 2	[calculated]
[dfv]	[dfv]	debris flow volume – based on fill volume, slope position, steepness, terrane below = [fv + sp + s + tb] / 4	[calculated]

Total Consequences			
[CQ]	[CQ]	overall consequences rating; based combination of previous two data elements = [4*fv + dp + dfg + dfv]*60/25	[calculated] **max = 60**

Table 2 – Risk – Consequences – Impacts

Unit	Assigned Value 1/	Site Condition Rating Elements	[data source]
IMPACTS [to beneficial uses] Not Modeled in this Analysis			
[ws]	 3 2 1 0	water supply sources at risk – potable surface water sources anywhere downstream municipal source > 5 domestic sources or campground any potable source (< 5 domestic) none	[other]
[fb]	 3 2 1 0	site within Riparian Reserve buffer on fish-bearing & perennial streams site within Riparian Reserve buffer on anadromous or TES aquatic species stream site within RR buffer on fish-bearing (i.e., resident only) stream site within RR buffer on non-fish-bearing perennial streams no perennial stream at site and site not within RR buffer	[GIS]
[fa]	 3 2 1 0	downstream facilities at risk non-road facilities at **direct risk*** (e.g., buildings, campgrounds, trailheads) multiple (>1) road/stream crossings downstream single crossing downstream none (or bridge only)	[other]
* **direct risk** means facility is: (1) directly downslope/downstream – a "straight" shot and (2) within same or next higher order stream and (3) less than one mile downstream and (4) located on floodplain (<= 100 year)			
Total Impacts			
[IP]	[IP]	impacts rating; based on combination of previous three data elements = [ws + fb + fa]*30/9	[calculated] **max = 30**
OVERALL RATING			
[OR]	[OR]	overall rating – from integration of all data elements and components above =[2*CQ + RK + SP + IP]*100/220	[calculated] **max = 100**

1/ Assigned Value – highest values are greatest hazard

Results / Discussion

Principal products of the Road Sediment Source Inventory & Risk Assessment include:

(1) an inventory of all channel crossings, hydrologically connected cross drains (ditch relief structures – pipes & dips) and other potential erosion-producing sites between crossings. See **Table 3** for statistical summary information & **Appendix A**, for site-specific details,

(2) an environmental risk and consequences assessment rating for all sites [see **enclosed CD** and spreadsheet 'rdx_eldorado09.xls'] – risk assessment procedural details, see above,

(3) Site Summary information – [**Appendix A**],

(4) Road Summary- roads listed by number with data on the number of inventoried sites by road, aquatics model road rating, and watershed – [**Appendix A**], and

(7) spatial displays (GIS maps) of the Road Sediment Source information showing all inventory sites, high risk/consequences/impact sites, and sites with diversion potential [**Figure 3a & 3b** and **Appendix C**].

The following discussion is based on the information shown on **Table 3** below and 'Road Summary Information' [**Appendix A**].

<u>Road miles:</u> As a comparison, road densities in the Eldorado 2009 drainages (5.87 mi/sq. mi) are considerably higher than the Klamath NF average (1.58). [NOTE: 'Klamath Summary' column in Table 3 represents summary statistics from 13 inventory; 6,823 sites were inventoried in watersheds which total 838,870 acres] Percentage of near-stream road miles (within RCA stream buffers) is 70%, significantly higher than the 27% average for watersheds in USFS Northern Province Forests [northwestern California; USFS, 2000b. Total length of road within the project area is 315 miles, of which all miles were supposedly inventoried, however 132 miles are suspect because no sites were identified, when it appears the road does cross stream channels. This study omitted the roads which lack site data when categorizing the roads into high, moderate and low risks. Therefore the highest risk roads (high aquatics model ratings) are a selection of the worst roads for which we are certain were evaluated. Low risk routes are either truly low risk, or more data needs to be gathered. Suspect routes (may not have been inventoried) are indicated in the **Aquatics Model Table- Appendix A**.

<u>Diversion potential & hydrologic connectivity:</u> Approximately 2% of inventoried road length delivers water and sediment directly to stream channels or gullies below the outlets of hydrologically connected cross drains. In other words, for inventoried roads, the proportion of road length that is hydrologically connected is 2%. The majority of this routing of runoff and associated sediment is via road inboard drainage ditches. Diversion potential exists at 51% of all sites and 48% of channel crossing sites. 81% of highly rated sites have diversion potential.

<u>Debris flows:</u> Twenty-four sites (or 5% of total) are at high risk for upslope debris flows (≥7.5). 7.5 is a benchmark number based on inventory data from the Klamath NF Salmon River Sediment Study. The overall (average) debris flow hazard rating is 3.4. This hazard rating combines past debris flow history and disturbance/geologic instability upslope to predict likelihood (probability) of future debris flows.

<u>Overall rating:</u> 'Overall rating' [OR] rating combines risk and consequence elements to characterize each *site*, leading to the identification of 'highly rated' or 'high priority' sites (see discussion above; **Figure 2** & **Tables 2 & 3**). Highly rated sites (~top 10%) are those with 'OR' values ≥ 42.3. Forty-seven (47) sites have an overall risk (a.k.a Site Condition) value of ≥42.3.

Fill volumes: Fill volume at all channel crossing sites total 88,277 cubic yards (CY), averaging 191 CY per site; median is 91.6 CY. 33,996 cubic yards are associated with highly rated sites. Fills associated with all highly rated sites range from 2,476 cubic yards to 23 cubic yards. 53% of the total fill volume at channel crossings could be attributed to approximately 20% of all inventoried sites. In other words, by upgrading channel crossings to reduce the risk/consequences of failure at only 20% of sites (92 of 462), approximately 53% of total fill volume would be treated. The ten sites with the largest fill volumes are:

Site ID	Type	Overall Rating Interp.	Diversion potential	Vol @ risk	OVERALL RATING
10N50U - 0.50	0	High	1	1215	47.7
12N60B - 0.55	0	High	1	1215	55.3
10N50M - 0.60	0	High	1	1303	50.5
11N80 - 2.80	0	High	0	1577	47.6
10N46.1 - 0.34	0	Moderate	1	1696	41.4
11N80 - 6.13	0	High	1	1709	57.6
09N30A - 1.16	0	High	1	1737	64.8
11N80 - 2.13	0	High	0	2188	49.2
10N50M - 1.80	0	High	0	2392	50.8
10N47B - 0.23	0	High	1	2476	43.9

Patterns: Highly rated sites are distributed throughout the inventory area, (**Figure 3a & 3b**) however higher concentrations of these sites occur along roads 10N46, 09N22, and 11N80. The Upper North Fork Cosumnes River watershed has more highly rated sites (16) than any other watershed within the project area. Site 09N30A 1.16 is the highest rated site (64.8), and of the highest rated sites, has the fourth largest fill (1,737 cubic yards). Road 11N80 (Aquatics Model rated as “high risk”) has 3 highly rated sites with some of the largest (top 10) fill volumes.

Table 3. Summary Statistics	Klamath Summary 1/	Eldorado 2009
Sites inventoried:		
All:	6823	492
Channel only:	5407	419
[% chan]	79%	85%
Inventoried Road miles* (GIS):	2,075.9	183
sites/mi:	3.29	2.7
chan. sites/mi:	2.60	2.3
area acres (in 5 7th-field project drainages)	838,870	34,347.6
rd. mi. / sq. mi. (tot. rd. mi. = 316)	1.58	5.9
Diversion potential (dp):		
All sites:	3240	234
[% sites w/dp]	47%	51%
chan. sites only:	2400	200
[% sites w/dp]	44%	48%
Hydrologic connectivity:		
Total road miles connected to channels:	296.18	8
[% of total road length]	14.3%	2.50%
[% of known inventoried rd. length]		4.30%
[% miles within RCA stream boundary] 2/	27%	70%
Overall rating (OR):		
OR > 60	400	1
[% of sites]	5.9%	0.20%
OR = 50 - 60	767	11
[% of sites]	11.2%	2.30%
OR = 45 - 49.9	530	18
[% of sites]	7.8%	4%
% sites with OR ≥ 45	24.9%	7%
% sites with OR ≥ 43		9%
FILL VOLUMES [CY]		
All chan. sites [CY]:	3,061,160	87362
aver. fill / chan crossing:	566	191
median fill/ chan xing		92
Chan. sites w/dp:	1,377,240	49,962
% of vol - all chan sites	45%	57%
total costs to treat: [@ $2,500 / site] 3/	$6,000,000	$500,000
$/CY sediment saved 4/ :	$4.36	$10.00
Top 10% rated sites:	1,494,644	34535
	[724 of 6,823]	[47 of 462]
% of vol - all chan sites	49%	39%
total costs to treat top 10%: [@ $30,000 / site] 3/	$30,000,000	$1,410,000
$/CY sediment saved:	$20.07	$40.83

1/ = Klamath National Forest summary statistics; 13 inventory areas - 1999, 2000, 2001, 2006

2/ = road miles within 105 meter stream buffer for 5th-field analysis watersheds or ROD stream buffers (Klamath); within RCA (Eldorado)

3/ = KNF Engineering estimated costs - average treatment; $2,500 / site = construct critical dip to fix diversion potential; $30,000 / site = major crossing reconstruction to reduce fill at risk

4/ = PWA assumption ... "at stream crossings with a diversion potential, future gully erosion is difficult to predict. A minimum of the stream crossing [fill] volume was used as predicted value for this table." [Weaver, W.E., and Hagans, D.K., 1999, Storm-proofing forest roads: Pacific Watershed Associates]

*183 miles are known to have been inventoried because site data exists for these miles.

Aquatics Model

The purpose of this model is to use site specific information to characterize entire road segments. Model results rate individual roads as to their relative risk, consequences and impacts to aquatic resources. This process and result is termed the 'Aquatics Model' and was developed as part of the Roads Analysis Process [RAP] done on the Salmon River Ranger District (Klamath National Forest) during fall of 2001. Prime objective of the Aquatics Model is to determine which roads pose the greatest threat of increased sedimentation and interruption of the hydrologic regime & riparian reserve integrity.

The Aquatics Model uses twelve (12) rating criteria (see **Table 1, Aquatics Model Process Paper, Appendix A**). Six of these criteria are derived from GIS road modeling. The six other are compiled from road inventory information. For this study, only the field inventory information was used. See **Appendix A** for data used, model road segment rating results and analysis process paper.

The results of the Aquatics Model show that eighteen (18) of the forty-seven (47) most highly rated sites (38%) are found on the following 10 "worst" roads:

1. **10N46** descends from the ridgeline, crosses Camp Creek, and then climbs to the ridge on the south side of the drainage. The road is 12.0 miles long within the analysis area. It has four (4) highly rated sites with fill volumes of 303, 348, 998, and 208 cubic yards (CY). Twelve (12) of the 26 channel crossing sites have diversion potential. The total fill volume associated with all crossings on this road is 5, 053 CY. 7% of the ditch length is hydrologically connected. There are 4 "tweeners" along the road.

2. **09N19** is adjacent to the Camp Creek channel and crosses the creek in one location. It is 1.6 miles long. The road has three (3) highly rated sites on it with fill volumes of 740, 894, and 778 CY. Two of the six channel crossings have diversion potential. Cumulatively, this road has 2,706 CY of fill material associated with its crossings. 32% of the road length is hydrologically connected. There is one "tweener" on this road.

3. **09N30A** is a spur road which descends from the ridge above the North Fork of the Cosumnes River near its headwaters. The road is 1.5 miles long. It has one highly rated site which has 1737 CY of fill. Three of its five channel crossings have diversion potential. Cumulatively, 2,167 CY of fill are associated with these crossings. 6% of its length is hydrologically connected. There are two "tweeners" on this road.

4. **10N46.1** descends from 10N75 to Camp Creek and then quickly re-joins it. The road is 0.5 miles long. It has 0 highly rated sites, but all three of its channel crossings have diversion potential, as well as one of its cross-drains. Three of the fills associated with channel crossings on this road are fairly small volumes; one site is large with a volume of 1,696 CY. Cumulatively the fill associated with this road is 1, 940 CY.. 35% of its ditch length is hydrologically connected. There are two "tweeners" on this road.

5. **09NY41** follows and then crosses a tributary to the North Fork of the Cosumnes River. It is one mile long within the analysis area. It has two (2) highly rated sites, with fill

volumes of 335 and 104 CY. Four (4) of the 6 stream crossings have diversion potential. Cumulatively, 1, 157 CY of fill are associated with these crossings. 9% of the ditch length is hydrologically connected. There are no “tweeners” found on this road.

6. **10N47A** follows the contour just above Camp Creek. The road is 1.1 miles long. There are no highly rated sites, however three of the six channel crossings have diversion potential. Cumulatively, 1,079 CY of fill are associated with crossings on this road. 5% of the road length is hydrologically connected. There are two “tweener” sites along this road.

7. **10N50M** travels on contour near the north ridge of the Camp Creek drainage, crossing several tributary streams. It is 1.9 miles long within the analysis area. There are three (3) highly rated sites on the road. They have fill volumes of 1,303, 775, and 2,392 CY. Seven (7) of eight (8) channel crossings have diversion potential. Cumulatively, this road has 5,560 CY of fill associated with its channel crossings. 6% of the ditch length is hydrologically connected. There are no “tweeners” on this road.

8. **10N75** travels on contour along Camp Creek (several hundred feet above the stream). It is 4.3 miles long and has three (3) highly rated sites with fill volumes of 308, 747, and 131 CY. Nine (9) of the 12 channel crossings have diversion potential. Cumulatively, 2,288 CY of fill are associated with this road. 9% of the road length is hydrologically connected. There are two (2) “tweeners” on this road.

9. **10N50U** is an upper slope position road which follows along contour in the headwaters of the Middle Fork of Camp Creek. The road is 0.6 miles long. It has one highly rated site with a fill volume of 1,215 CY. Three of its three channel crossings have diversion potential. Cumulatively the road has 1,498 CY of fill associated with its channel crossings. 11% of the road length is hydrologically connected. There is one “tweener” on this road.

10. **12N43** is an upper slope position road located in the headwaters of Slab Creek. The road is 1.1 miles long. There is one highly rated site along the road which has 525 CY of fill. Five of the six channel crossings have diversion potential. Cumulatively, the road has 1,804 CY of fill associated with its channel crossings. 7% of the ditch length is hydrologically connected. There are no “tweeners” along this road.

***Road 11N80** had a risk rating just below the cut-off for the top ten worst roads, however it is rated as “high risk” and has 3 highly rated sites with some of the largest fill volumes!

Table 4 shows the results of the Aquatics Model. Listed are the "top 10" roads, sorted by road number. In general, highly rated road segments are characterized by the following: (1) high number of channel crossings over length of the road, (2) high percentage of road length directly connected to stream network, (3) high number of sites with diversion potential, (4) high number of sites with road-related gullies and landslides, (5) high number of 'highly-rated' individual crossing sites, and (6) road contains many crossings, many of which are highly-rated (i.e., weighted sum overall site ratings for a given road segment.

Table 4 "Top Ten Worst" Roads

Roads	road length	connected (1st x-drain)	Channel Crossing Sites	Crossings per mile	other sites	Types of site	Sites with Diversion potential	"Tweeners"	Highly rated sites	Road Total Rating
	miles	**%**	**Count**	**Count**	**Count**	**Type**	**Count**	**Count**	**Count**	
09N19	1.610	32	6	3.7	0	NA	2	1	3	18
09N30A	1.462	6	5	3.4	0	NA	3	2	1	18
09NY41	1.003	9	6	6.0	0	NA	4	0	2	19
10N46	12.031	7	26	2.2	5	1, 2	12	4	4	19
10N46.1	0.492	35	3	3.0	1	2	4	2	0	18
10N47A	1.098	5	6	5.5	0	NA	3	2	0	19
10N50M	1.927	6	8	4.2	2	1, 2	7	0	3	18
10N50U	0.585	11	3	3.0	0	NA	3	1	1	18
10N75	4.263	9	12	2.8	0	NA	9	2	3	19
12N43	1.084	7	6	5.5	0	NA	5	0	1	18

PRIORITIZED SEDIMENT REDUCTION IMPLEMENTATION PLAN

Project Information:

Summary information is displayed in **Table 3**, where Eldorado 2009 Road Inventory information can be compared with other completed inventory areas within the Klamath National Forest. Clean Water Act's South Fork Trinity River Sediment Total Maximum Daily Loads document sets targets to decrease road-related sediment delivery. Targets of ≤ 1% were set for "crossings with diversion potential" and "stream crossings with significant failure potential … targeting crossings with highest probability of failure and highest consequences." To meet these sediment reduction targets within the project area, diversion potential would need to be corrected at 200 channel crossing sites and 34 hydrologically connected cross drains. At an estimated average cost of $2,500 per site, the total cost would amount to $500,000 to treat the channel crossing sites. Cost per yard of sediment saved would be $10.00, using PWA assumptions (see bottom of **Table 3**). To fix the highest risk sites (top ~10% or 47 of 462 sites), at an average cost of $30,000 per site, would total $1,410,000. This would reduce fill at risk at channel crossings by 39%. In other words, 39% of all fill volume at all channel crossings is found in the top 10% of sites (by 'overall rating' described above).

Field crews collected site information. Risk assessment phase was conducted using this field information and following the outline shown in **Figure 2**. This process rated all inventoried sites on the basis of (1) risk of failure, (2) consequences of failure, and (3) potential impacts from failure. These individual elements were combined to yield an overall rating. Overall rating values for each site are displayed in tables of **Appendix A**. Overall rating values identify high risk/consequences/impact sites. Opportunity criteria (see right side of **Figure 2**) must then be applied in order to fully 'prioritize' each site. This last step is beyond the scope of this project and will done in Forest planning processes.

In addition to site-specific information, project data provide road and road segment information for use in transportation planning efforts. Site-specific data can be viewed spatially to characterize individual roads. For example, a high concentration of high risk/consequences/impact sites would highlight this road as a candidate for upgrading or decommissioning, where large crossing fill volumes would be removed during upgrading or decommissioning. Numerous sites with diversion and/or collection potential along a specific road would suggest this road for a project that constructed 'critical dips'.

Transportation Planning:

Road inventory information is critically important in making informed recommendations during transportation planning. Recommendations include identification of roads for one of the following actions: (1) upgrade or 'stormproofing', (2) decommissioning, (3) storage or radical stormproofing, (4) changes in closure status, (5) changes in maintenance level, (6) administrative action (e.g., add to system, special use permit), and (7) status quo (no action). This process is conducted in an interdisciplinary setting, where all resource interests are represented.

These recommendations are based in large part by balancing needs & benefits versus environmental risk & road costs (simplistically, a type of cost/benefit analysis). In general and at extreme ends of the spectrum, if a road is critically essential to Forest land managers or the public and it poses high environmental risks (typically through threat of accelerated sedimentation), then the road is recommended for upgrade. If a road is not critically essential and poses high risks, it would become a candidate for decommissioning. Therefore, upgrading or decommissioning high-risk roads would accomplish sediment reduction. Less costly sediment reduction measures could involve more restrictive closure status or upgrading of maintenance level.

Road Treatments:

While acknowledging that recommendations as to which individual roads will receive which action should be made within the transportation planning process, this project can provide a list of potential sediment reducing road treatments. These treatments are shown in **Table 5** below. As noted at the bottom of **Table 5**, these categories of action are listed in order of increasing costs, construction complexity/difficulty, and project preparation documentation.

Road treatments can be generally divided into those that "winterize" a road and those that "stormproof" a road. Winterizing is a road maintenance activity (see **Table 5**, category [1]). Winterizing a road can reduce chronic and persistent fine-grained sediment generated by surface erosion processes within the road prism during typical winter flow conditions. Road surface grading can reduce the potential for road surface rilling and gullying. Ditch and culvert inlet cleaning can ensure road surface flows remain within designed drainage structures and not on the road itself.

Stormproofing a road can reduce sedimentation from episodic mass wasting and fluvial gullying, triggered by intense precipitation events and resultant high flow regimes. Categories [2] through [7] of **Table 5** are stormproofing measures. Treatments under 'Drainage Problems' address road surface erosion. 'Dips' fix high flows on road surfaces and ditches to (collection potential) and from (diversion potential) channel crossings. 'Major Crossing Re-design' treatments typically reduce fill volumes, allowing the channel crossing to handle debris flows and flood stage hydraulic flows; passage of fish and coarse woody debris is permitted. 'Landslide Remedies' address mass wasting potential from unstable road cuts, fills, or entire road prism. 'Storage' and 'Decommission' treatments storm proof unused roads.

For all types of treatments, "sediment saved" is equal to the total volume of fill at the crossing site. This assumption is advocated by Pacific Watershed Associates (Weaver and Hagans 1999; see bottom of **Table 3** above) and implicitly accepted by California Department of Fish & Game. There is a danger in this assumption. This assumption skews "cost effectiveness" numbers toward construction of critical dips to fix diversion potential and away from major crossing upgrades that reduce substantial fill volumes (e.g., construction of coarse-rock vented ford crossings). This could have the effect of preferentially funding "diversion potential" efforts at the expense of major crossing upgrade projects.

For example, consider a crossing with a 1,000 cubic yard (CY) fill. To construct a critical dip to fix diversion potential may involve removal of 50 CY of material at total cost of $3,000 –

yielding cost effectiveness of $3 per CY of sediment saved [$3,000 / 1,000 CY]. After completion of this project, 950 CY of "at-risk" fill volume would still remain. To upgrade the crossing by constructing a coarse-rock vented ford might involve the removal of 900 CY of fill at a total cost of $50,000 - yielding cost effectiveness of $50 per CY of sediment saved [$50,000 / 1,000 CY]. After completion of this project, only100 CY of "at-risk" fill volume would still remain. Based on "cost effectiveness" values [$3 vs. $50], there is a risk that the critical dip project would be funded instead of the major crossing upgrade alterative.

This report does **not** take the position that diversion potential projects should be ignored in favor of major upgrade efforts. Both types of treatments need to be considered. Decisions need to be based on risk/consequences/impacts at individual sites. For example, if a site poses little risk from debris flow or undersized pipe, small to moderate fill volume consequences, and minor impacts, then this site would be low priority for major upgrade, but could be a candidate for a critical dip. However, a site with large fill volume at risk to debris flow or undersized pipe should be considered for a vented ford crossing upgrade or crossing redesign that removes significant fill volume. When considering diversion potential treatments for road segments, do NOT forget critical dips to break collection potential or outsloping of the entire segment.

This approach is consistent with the results of the Klamath National Forest's 1997 Flood Assessment (de la Fuente and Elder 1998). In this study, of inventoried flood damage sites on Forest roads, approximately 400 of 800 sites involved failures at stream crossings. An estimated 22% of the 400 stream crossing sites resulted in diversion around plugged pipes. Often damage was minor. Effects from diverting streams amounted to an estimated 72, 360 CY of failed material or a rate of 9 **CY/mile/decade** (assumes 4,000 miles of Forest road; 1997 Flood, as an event with ~20 year recurrence interval). Road failures at stream crossing where **no** diversion occurred resulted in an estimated 656,360 CY of failed material or a rate of 82 **CY/mile/decade**. Correcting diversion potential will reduce risk, but only a portion of it. Where upslope debris flows caused crossing failures, critical dips would not have been effective. In other words, debris flows did not divert, but punched through crossing fills like a freight train.

Table 5 - Road Treatments - Categories of Actions
[1] <u>Maintenance:</u> ➢ Unplug inlets ➢ Clean ditches ➢ Grade gullies in road surface
[2] <u>Dips:</u> ➢ Critical dips at crossing to fix diversion potential ➢ Dips to break collection potential or hydrologic connectivity ➢ Dips at "eroding pipeless swales"
[3] <u>Drainage Problems:</u> ➢ Road designs that cause gullies ➢ Adding pipes to break hydrologic connectivity ➢ Out sloping road
[4] <u>Major Crossing Re-design:</u> ➢ Upgrade crossing to reduce fill volume ➢ Upgrade crossing to allow passage of debris flows ➢ Other storm proofing measures (e.g., upgrade culvert size, fill slope stabilization) ➢ Upgrade crossing to allow fish passage where restricted
[5] <u>Landslide Remedies:</u> ➢ Buttress unstable cuts ➢ Engineered reinforced fills (e.g., "burrito walls", Hilfiker walls) ➢ Remove failed material
[6] <u>Storage:</u> ➢ Make road geo/hydrologically stable ("hydrologic obliteration"), ➢ But with option of future entry (i.e., not off system) ➢ Take-off not recontoured; pipes removed but some left on site
[7] <u>Decommission:</u> ➢ Make road geo/hydrologically stable ("hydrologic obliteration"), ➢ With NO intention of future entry (i.e., off system) ➢ Take-off recontoured; all pipes removed

Listed in order of **<u>increasing</u>**

- ✓ Costs
- ✓ Construction complexity/difficulty
- ✓ Project preparation documentation (e.g., NEPA, ESA, Engineering design)

This report suggests a broad approach based on looking at fixes for entire roads/road segments or sub-watersheds (drainages). High risk/consequences/impact roads or areas should be considered rather than focusing on high risk/consequences/impact sites in isolation. For example, within an identified high priority 7th-field watershed, high risk/consequences/impact roads should be targeted. Variety and mixes of fixes should be considered – outslope sections of road, major crossing upgrades at certain sites, fix diversion and collection potential in areas, and rock (hard surface with engineered crushed aggregate) sections of road. This mix of road upgrades collectively 'storm-proof' the road – making it better able to withstand the next flood event.

Project and Watershed Monitoring Activity Recommendations

Watershed/road restoration projects resulting from Road Sediment Source surveys and transportation planning would be monitored in the following three ways:

(1) Implementation Monitoring [Were project design standards and specifications achieved?];

(2) Effectiveness Monitoring [Were project objectives met? – Was implemented project effective at meeting these objectives?] and;

(3) Validation Monitoring [Are the assumptions underlying project decisions accurate?].

In addition, all watershed restoration activities involving roads would be subject to random monitoring for compliance with Best Management Practices standards and guidelines.

The ultimate effectiveness and validation monitoring of watersheds where restoration work has been implemented will occur when these treated watersheds are subjected and tested by future high precipitation and runoff events. The test will be to see if future large storms cause less road-related damage because of decommissioning and storm-proofing/upgrading actions that have been implemented.

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Weaver, W.E. and D.K. Hagans, 1999, *Storm-Proofing Forest Roads*: Pacific Watershed Associates (PWA), unpublished, 15p.

EXPLANATION OF FILES ON "CD" [COMPACT DISC] INCLUDED WITH THIS REPORT

Eldorado National Forest
Eldorado 2009 Road Sediment Source Inventory

DOCUMENTS:

[1] **discussion_eldorado2009.doc**- general narrative report of the project, in MS Word format. Includes introductory material (setting, problem, purpose), methods (field data collection and risk assessment), results, and treatments/recommendations/implementation.

SPREADSHEETS:

[2] **rdx_eldorado09.xls -** multi-tab spreadsheet for road inventory sites in Eldorado 2009 Road Inventory project area, in MS Excel format. Spreadsheet includes specific and detailed information on 462 inventoried channel crossings and hydrologically connected cross-drain sites. Spreadsheet contains raw field data, fill volume calculations, hydrological pipe capacity calculations (based on drainage areas above pipes, etc.), upslope geological ratings, site ratings based on preceding data that includes risk and consequence rating information and key which explains the rating scheme. Sheets with formulas are separated from sortable sheets (don't sort the red tabs or links will be broken!!!).

[3] **roads_and_sites.xls -** summarized list of roads within the project area, list of "Top 10 Worst Roads", road miles/density per watershed, and Klamath/Eldorado 2009 statistics comparison (Table 3) in MS Excel format.

[4] **tweeners.xls** – information about other sediment sources between crossings, typically landslides and gullies.

[5] **aquatics model.xls** – Table shows the relative risks associated with the 106 inventoried road segments. The 142 questionably inventoried segments are also included. Ratings are based on the following field inventory data compiled for each road segment: (1) channel crossing count, (2) length of road hydrologically connected, (3) sites with diversion potential, (4) "tweeners" (other sediment sources), and (5) sum of Overall Ratings for individual sites. Sheets with formulas are separated from sortable sheets (don't sort the red tabs or links will be broken!!!).

[6] **10_worst_rds_fill_volumes.xls**- Table shows fill volumes of every site, also for each of the "Top 10 Worst Roads".

GIS GEODATABASE (personal):

[7] **Eldorado2009_RdInv_GDB.mdb** - ArcGIS 9.3 personal geodatabase, contains all spatial data for the project, including:

- ProjRds = all roads/routes in Eldorado National Forest project area
- contour_40_ft = 40'(project area)
- ownership = land ownership; Forest Service & non
- plss_sections & plss_townships = public land survey sections & townships
- rdx_eld09 = inventoried sites (project area)
- HUC7 = 7th-field drainages composing the project area
- streams = streams (project area)
- x_sheds = overlapping drainages upslope of channel crossings with pipes
- _site_data=Table data for each inventoried site (from aquatics model xls)
- chan_cross_site_ratings= Table data (simplified) for each channel crossing, includes ratings and diversion potential
- site_data_simple= Table with full inventory field data

[8] **eld_inventory_09_slab_brush_20x30.mxd** and e**ld_inventory_09_camp_cosumnes_25x40.mxd** – ArcMap projects used to create the maps exported to PowerPoint format (see below). ArcMap uses feature classes in **Eldorado2009_RdInv_GDB.mdb** (see above) to create the maps. For each feature class, "Source" path (under Properties → Source → Set Data Source) must be changed to reflect source path location for computer used.

GRAPHICS FILES:

[9] **eld_inventory_09_slab_brush_24x36.pdf** and **eld_inventory_09_camp_cosumnes_34x44.pdf**- maps of sites inventoried in Eldorado 2009 Road Inventory project area, in Adobe Reader (pdf) format. This file is an electronic version of the 24x36'' and 34x44'' folded maps enclosed with this report and must by printed on large format plotter. Maps show all inventoried sites and codes those with diversion potential (pink-dot circles) and highly rated sites (orange-dot circles). "Highly rated sites" are those sites with an overall rating of ≥ 42.3, which represents approximately the top 10% of inventoried channel crossing sites (see **Table 3**). These sites are those with relatively high risks, consequences, and impacts. This cut-off point is arbitrary.

[10] **eld_09_camp_cosumnes_11x17.pdf** and **eld_inventory_09_slab_brush_11x17.pdf**- electronic version of the same maps described above and shown as Figures 3a and 3b within this report. Size is 17" X 11" landscape.

United States
Department of
Agriculture
Forest Service

Tahoe Regional
Planning Agency

Nevada Tahoe
Resource Team

Nevada Division of
Forestry

Nevada Division of
State Lands

Nevada Fire Safe
Councils

California
Department of
Forestry and Fire
Protection

California Tahoe
Conservancy

California State
Parks

North Tahoe
Fire Protection
District

North Lake Tahoe
Fire Protection
District

Tahoe Douglas Fire
Protection District

Lake Valley Fire
Protection District

Meeks Bay Fire
Protection District

South Lake Tahoe
Fire Department

Fallen Leaf Fire
Department

Lake Tahoe Basin

Multi urisdictional Fuel Reduction and Wildfire Prevention Strategy

For More Information Contact

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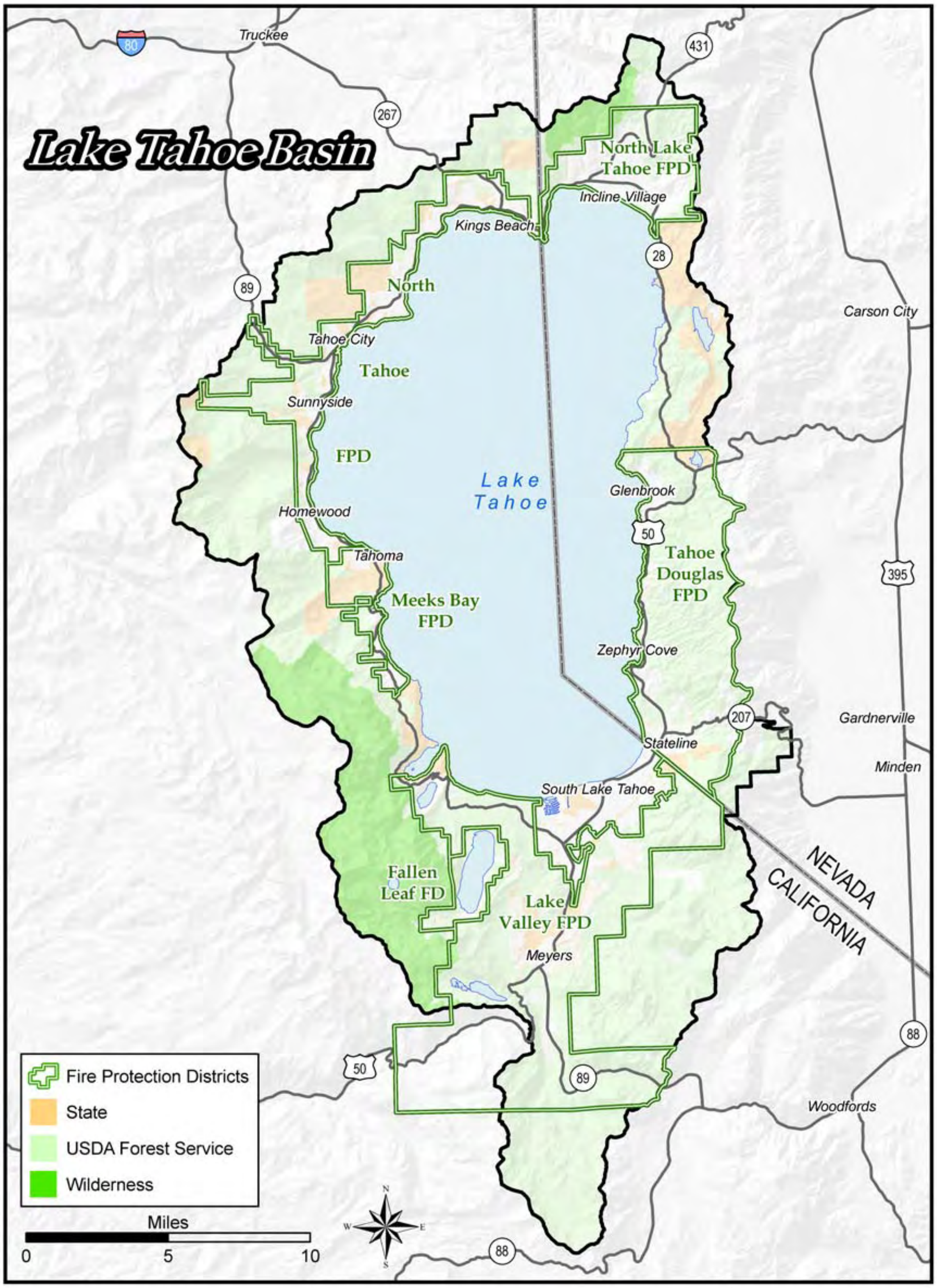
Figure 1. Lake Tahoe Basin Comprehensive Fuels Plan planning area



E ecutive Summary

This Multi-Jurisdictional Fuels Plan for the Lake Tahoe Basin (Basin) facilitates the strategic decisions that must be made by land management, fire, and regulatory agencies to reduce the probability of a catastrophic fire in the Basin. It was developed to comply with the White Pine County Conservation, Recreation, and Development Act of 2006 (Public Law 109-432 [H.R.6111]). It comprehensively combines all existing plans that have been developed within the Basin, and provides a framework for participating agencies to identify priority areas and a strategy to work collaboratively on accomplishing those priorities. In addition, it builds upon fuel reduction projects that have already occurred on more than 13,000 acres and the efforts of community-based fire departments and fire safe chapters that are actively treating fuels around residences.

The plan incorporates approximately 208,800 acres, including portions of Placer, El Dorado, and Alpine Counties in northeastern California; and portions of Carson City, Washoe, and Douglas Counties in western Nevada. It includes nearly 42,000 homes or buildings in the communities of Incline Village, Crystal Bay, Sand Harbor, Glenbrook, Kingsbury, South Lake Tahoe, Homewood, Tahoe Pines, Sunnyside, Tahoe City, Dollar Point, Carnelian Bay, Tahoe Vista, Meeks Bay, Rubicon, Tahoma, and Kings Beach.

Studies in the Basin indicate that current wildland fuels conditions could support high-intensity wildfires that are difficult to suppress. Most communities in the Basin, as part of the National Fire Plan, were designated in the *Federal Register* (2001) as high risk for damage from wildfire. In addition, values uniquely associated with the Basin are also at risk. These include its entire commercial and public infrastructure, the clarity and beauty of Lake Tahoe and its scenic landscapes, its tourism-based economy, and the ecological values of its surrounding forests. Based on this, and because of the recent Angora Fire there, it is commonly acknowledged that the attributes that make the Basin a special place are at an unacceptably high risk of loss from wildfires and that something urgently needs to be done to reduce that risk.

The plan recognizes that wildfire protection in the Basin requires three components:

1. Buildings and homes in the Basin should be built of fire-resistant materials and have effective defensible space[1];
2. Accumulations of hazardous vegetative fuels must be reduced in the areas directly adjacent to communities (Community Defensible Space); and
3. Accumulations of vegetative hazardous fuels surrounding the Community Defensible Space should be reduced in the general forest.

[1] Structures in the Basin should be built using flame and ember resistant materials, and have effective defensible space. In California, all structures built after January 1, 2008 shall be required to be constructed to the Wildland Urban Interface (WUI) Building Standards. In California, all parcels having a structure and which are located on State Responsibility Area (non-federal lands and non-city lands; however, the City of South Lake Tahoe adopted PRC 4291 August 2007) are required to comply each year with Public Resource Code 4291 and California Code of Regulations §1299 for defensible space. The defensible space requirement does not apply to parcels not having structures.

To accomplish these needs, the plan proposes a continued public involvement strategy to work with homeowners on making their residences fire safe. In addition, the plan proposes 49,000 acres of first-entry vegetative fuel treatments and 19,000 acres of maintenance treatments across multiple jurisdictions to create Community Defensible Space and reduce fuels in the general forest. The treatments are designed to reduce potential fire behavior and facilitate conditions that will ensure safe and effective fire suppression. They are prioritized to protect communities and people in areas that are most at risk. Final implementation of the plan will ultimately result in greater protection of the unique values at risk in the Basin including its people, infrastructure, and natural resources.

Implementing all of the proposed projects and maintenance treatments will increase annual accomplishments by 280 percent in the Basin. Implementation of this plan is predicted to cost from $206,000,000 to $244,000,000 over 10 years with annual predicted expenditures of $18,500,000 to $25,500.000. These activities will increase the availability of biomass, wood-based products, and jobs associated with vegetation removal. To ensure its success, cooperating agencies will focus on several key factors. These include addressing current staffing levels and the availability of qualified mechanical operators, collaborating with regulatory agencies, and identifying pathways to implement projects with multiple ownerships. While each responsible agency may have its own prescriptions, guidelines, philosophies, and principles, all agree to the overall priorities and strategic guidelines of this plan. It is recognized that unforeseen events, such as wildfires, may affect the priority, scheduling, size, timing, or implementation of any given proposed treatment; consequently, the plan will be reviewed annually to meet changing conditions within the Basin. The federal, state and local land managers, Lake Tahoe Fire Agencies and Nevada Fire Safe Council will meet annually to review the results of the prior year fuels reduction efforts and identify fuels reduction projects and priorities, within the scope of this Strategy, for each upcoming year. Future projects identified by this group will meet the intent of this Strategy and meet the intent of all the underlying implementation plans including the Community Wildfire Protection Plans for the Lake Tahoe Basin. Projects will be prioritized for funding submission consistent with this Strategy and current direction and intent. Where projects cross jurisdictional boundaries, the group will collaborate on implementing the project with the goal of reducing environmental compliance, permitting and contracting costs.

Section 1 Introduction

Purpose of this Plan

Since 2000, various planning efforts have been completed to study wildland fire risk in the Lake Tahoe Basin. These plans include those prepared by the USDA Forest Service, Lake Tahoe Basin Management Unit (LTBMU), Tahoe Regional Planning Agency (TRPA), California Department of Forestry and Fire Protection (CAL FIRE), Nevada Division of Forestry (NDF), California Tahoe Conservancy (CTC), California State Parks, local Fire Protection Districts including three approved Community Wildfire Protection Plans, and recommendations for the City of South Lake Tahoe. This comprehensive fuels reduction and wildfire prevention plan is a unified, multi-jurisdictional strategic synopsis of these planning efforts. The proposed projects in this plan provide a 10-year strategy to reduce the risk of uncharacteristic wildfire in the Lake Tahoe Basin. The plan's purpose is to propose projects to create community defensible space, to comprehensively display all proposed fuel reduction treatments, and to facilitate communication and cooperation among those responsible for plan implementation. If implemented, this plan will provide greater protection to the people, infrastructure, and resources of the Lake Tahoe Basin.

This plan was developed to comply with the White Pine County Conservation, Recreation, and Development Act of 2006 (Public Law 109-432 [H.R.6111]), which amended the Southern Nevada Public Land Management Act of 1998 (Public Law 105-263) to include the following language:

> *"development and implementation of comprehensive, cost-effective, multi-jurisdictional hazardous fuels reduction and wildfire prevention plans (including sustainable biomass and biofuels energy development and production activities) for the Lake Tahoe Basin (to be developed in conjunction with the Tahoe Regional Planning Agency), the Carson Range in Douglas and Washoe Counties and Carson City in the State, and the Spring Mountains in the State, that are*--
>
> *(I) subject to approval by the Secretary; and*
>
> *(II) not more than 10 years in duration"*

The *comprehensive* plan is supported by 17 partners that each with a role in wildland fuels or fire management in the Lake Tahoe Basin (see "Agencies Involved"). The proposed strategic treatments are *multi-jurisdictional*, occurring on federal, state, county, and private lands (Figure 1 shows plan area). The strategic treatments are *cost effective* because they are economical, based on the tangible benefits produced for the money spent (see "Proposed Project Costs"). "Cost effective" is defined here as targeted, priority-based fuel reduction treatments conducted at a reasonable cost that produce meaningful protection of life, property, and the environment within the operating guidelines defined by this plan. Finally, the plan details potential utilization strategies of vegetation removal products, including *biomass*, which could occur when the plan is implemented (see section "Utilization Potential").

Agencies Involved or Consulted

This plan was developed by the following cooperators:

- California Tahoe Conservancy
- California Department of Forestry and Fire Protection
- California State Parks
- Fallen Leaf Fire Department
- Lake Valley Fire Protection District
- Meeks Bay Fire Protection District
- Nevada Division of Forestry
- Nevada Division of State Lands
- Nevada Division of State Parks
- Nevada Fire Safe Council
- Nevada Tahoe Resource Team
- North Tahoe Fire Protection District
- North Lake Tahoe Fire Protection District
- USDA Forest Service, Lake Tahoe Basin Management Unit
- South Lake Tahoe Fire Department
- Tahoe-Douglas Fire Protection District
- Tahoe Regional Planning Agency

Collaborative Process

The USDA Forest Service Lake Tahoe Basin Management Unit (LTBMU) assumed the lead role in coordinating the development of this plan. LTBMU recruited a cadre of representatives (Planning Cadre) from fire districts and land management and regulatory agencies (see Planning Cadre Members section) to function as a plan work group. The group met at the LTBMU office on February 9, March 9, April 12, and May 7, 2007. Subsequent review and coordination of the plan occurred after those meetings. Participants reviewed and discussed the White Pine legislation, and agreed on a plan outline that would best address the requirements of the bill. Work group representatives served as points of contact for their respective groups or agencies, and provided information used in the development of this plan. Two public informational meetings were held to present the draft recommendations of this plan. The first meeting occurred on August 1 in Kings Beach and the second occurred on August 2 in South Lake Tahoe. These meetings were attended by the Planning Cadre members.

Roles and Responsibilities

The roles and responsibilities of individuals and agencies involved with wildland fire management and prevention planning in the Basin are summarized in Table 1. All individual landowners and most agencies have land management responsibilities. This includes identifying concerns on parcels under their ownership or administration, and recommending and implementing actions that remedy those concerns.

Table 1. Summary of roles and responsibilities of agencies and individuals to implement the strategy

Agency	Land Manage ment	Regulatory	Lead Agency for Environmental Compliance	Funding	Programmatic Oversight
Individual Landowners	X			X	
Tahoe Regional Planning Agency		X	X	X	X
Tahoe Chapter Nevada Fire Safe Council				X	X
USDA Forest Service Lake Tahoe Basin Management Unit	X	X	X	X	X
Fire Protection Districts	X		X		X
California Tahoe Conservancy	X		X	X	
California Department of Forestry and Fire Protection	X	X	X	X	
California State Parks	X		X	X	
Lahontan Regional Water Quality Control Board		X	X	X	
Nevada Division of Forestry	X	X		X	
Nevada Division of State Parks	X			X	
Nevada Division of Environmental Protection		X			
Nevada Division of State Lands	X			X	X

Section 2 Wildland Fuel Reduction Projects

All current planning efforts were reviewed and the proposed wildland fuel reduction treatments were synthesized into this comprehensive plan. In addition, participating agencies reviewed past planning efforts and revised or provided additional treatments. In places, separate planning efforts have called for treatments in the same location. In this scenario, the treatments are designated by the lead implementation agency. In addition, treatments were prioritized into an implementation schedule. Since this plan is strategic, a majority of projects will require site-specific design and planning, which may result in final projects that vary in size, location, and scheduling as compared to this plan. Coordination between agencies as to the implementation and prioritization of projects in the Community Wildfire Protections Plans, to which this plan is tiered, is critical to the overall success of this comprehensive plan.

This plan combines projects from the following sources:

1. *Fuel Reduction and Forest Restoration Plan for the Lake Tahoe Basin Wildland Urban Interface – Tahoe Regional Planning Agency* (TRPA Plan) (Holl 2007) which included:
    a. *North Lake Tahoe Community Wildfire Protection Plan – Nevada Community Wildfire Risk/Hazard Assessment Project* (Resource Concepts, Inc. 2004)
    b. *Tahoe-Douglas Community Wildfire Protection Plan – Nevada Community Wildfire Risk/Hazard Assessment Project* (Resource Concepts, Inc. 2004)
    c. *Community Wildfire Protection Plan for the California Portion of the Lake Tahoe Basin* (C.G. Celio & Sons et al. 2004)
    d. Recommended treatments for the City of South Lake Tahoe based on *Improving Fire Hazard Assessment in South Lake Tahoe, California* (deJong 2003) and *Fire Planning Process for the Urban – Wildland Interface in the City of South Lake Tahoe* (Citygate Associates 2004).
2. *USDA Forest Service Stewardship Fireshed Assessment* (SFA) – 2007
3. *CALFIRE Annual Plans for Amador-El-Dorado Unit and the Nevada-Yuba-Placer Unit*
4. California State Parks
5. California Tahoe Conservancy
6. Nevada Tahoe Resource Team representing Nevada Division of State Lands, Nevada Division of Forestry, and Nevada State Parks

Current Accomplishments

Elected officials and agencies have recognized the need to reduce hazardous fuels and restore forest health in the Lake Tahoe Basin, and several key steps have been taken to address that need. In response to the challenges of elected officials, three Community Wildfire Protection Plans (two in Nevada and one in California) were prepared and approved by local and state agencies (Resource Concepts, Inc. 2004a, 2004b; C.G. Celio & Sons et al. 2004). TRPA consolidated those plans and identified regulatory, operational, and administrative constraints to implement those plans (Holl 2007). The LTBMU completed its Stewardship Fireshed Assessment identifying hazardous fuel treatments throughout the Basin. The City of South Lake has commissioned studies that recommend a series of treatments in and around the city.

All of the land management and most of the local fire agencies have been actively treating hazardous fuels near communities. Prior to 2000, many of the projects did not remove sufficient vegetation to mimic earlier levels of disturbance or achieve the desired condition. However, since 2000, most of the projects have placed forests on a trajectory toward the desired condition. Over 14,000 acres of treatments have been completed in the Lake Tahoe Basin since 2000 (Table 2), with an average annual accomplishment of 1,856 acres in 2005–2006. While acre summaries describe part of the accomplishments in the Basin, it should be noted that many of the urban lots in the Basin are quite small and the number of lots treated Basin-wide is much higher.

The Tahoe Regional Office of the Nevada Fire Safe Council has formed 21 local fire safe chapters in the Basin. These local chapters are community-based organizations where local residents actively engage in obtaining political and financial support to create defensible space and implement projects around their communities.

Table 2. Acres of fuel reduction projects completed by Lake Tahoe Basin agencies since 2000

ear	USDA Forest Service LTBMU	North Lake Tahoe FPD	California Tahoe Conservancy	California State Parks	Nevada State Parks	Nevada State Lands	Total
2000	677	151	120	36	50	26	1,060
2001	691	215	105	56	55	24	1,146
2002	1,260	240	148	80	100	23	1,851
2003	1,254	145	100	53	270	32	1,854
2004	1,918	178	105	91	253	12	2,557
2005	1,913	377	130	96	101	17	2,634
2006	2,160		180		829	20	3,189
Total	9,873	1,306	888	412	1658	154	14,291

* North Lake Tahoe FPD includes projects on federal lands, which were also reported by the LTBMU; therefore, the North Lake Tahoe FPD accomplishments were reduced by 42%, the amount of federal land in the fire district.

Source: TRPA Fuel Reduction Plan prepared by Steve Holl Consulting (2007), Nevada Division of State Lands, LTBMU.

Proposed Projects

Projects were proposed through a variety of plans. For this plan, projects are delineated by lead implementation jurisdiction. For example, projects proposed by Community Wildfire Protection Plans on LTBMU-administered lands are shown as LTBMU projects. In all, over 6,000 fuel reduction units are proposed (see "Lake Tahoe Basin Fuel Reduction and Wildfire Prevention

Strategy Supplement: Proposed Treatment Units"). The treatment units range from 0.1-acre urban lots to 500-acre general forest treatments. They include:

- 1,700 acres of California State Parks
- 3,952 acres of California Tahoe Conservancy lands
- 902 acres of Nevada Division of Forestry-administered or Nevada State Parks lands
- 214 acres of Nevada Division of Lands parcels
- 56,000 acres of USDA Forest Service LTBMU-administered lands, and
- 3,300 acres of treatments on private lands or under local government jurisdictions.

Combined, these represent approximately 68,000 acres of fuel reduction treatments (49,000 acres of first entry and 19,000 acres of maintenance treatments) or approximately 25 percent of the area considered in this plan (Figure 2). More importantly, these proposed treatments occur on a majority of lands in the Community Defensible Space (WUI) and those areas having high to extreme fire behavior. Many of the proposed treatments have not been field verified; therefore, over the lifetime of the plan, the actual acreages may change.

Given the number of units and the wide range in proposed treatment sizes, maps contained in this report summarize potential treatments (Figures 3, 4, 5, and 6). Specific treatment units are listed in the supplement to this plan: "Lake Tahoe Basin Fuel Reduction and Wildfire Prevention Strategy Supplement: Proposed Treatment Units." Although most treatments are scheduled by a specific year (see "Proposed Project Schedule"), for these maps, projects are displayed in 5-year intervals.

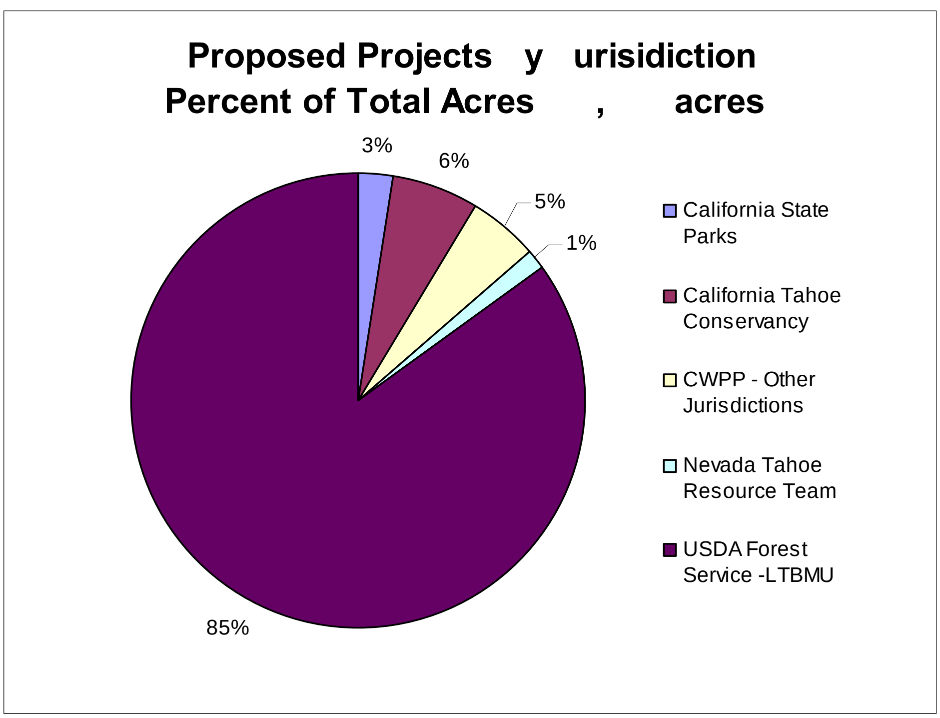


Figure 2. Percent of proposed projects lead by each jurisdiction

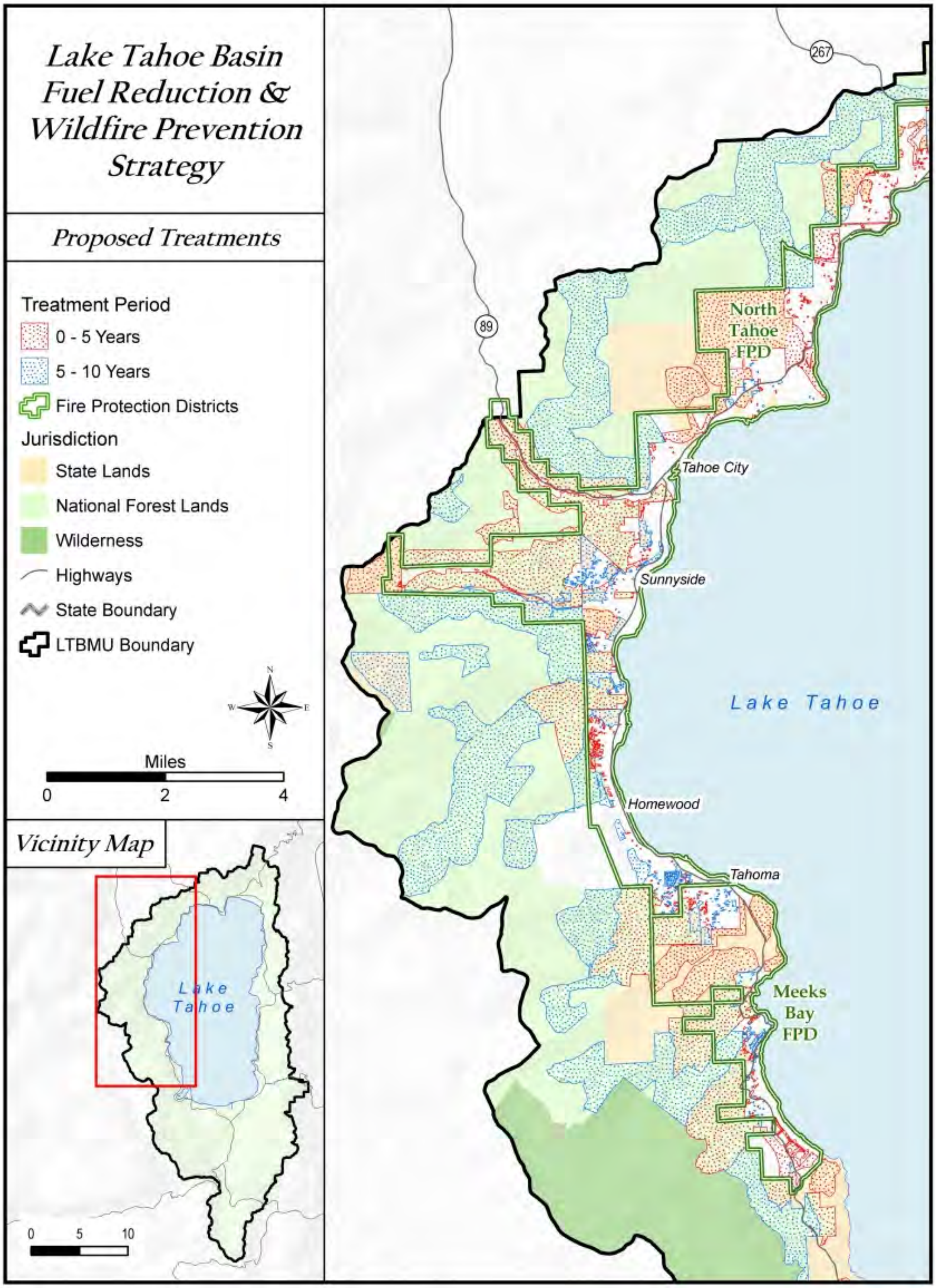


Figure 3. Treatment Map 1

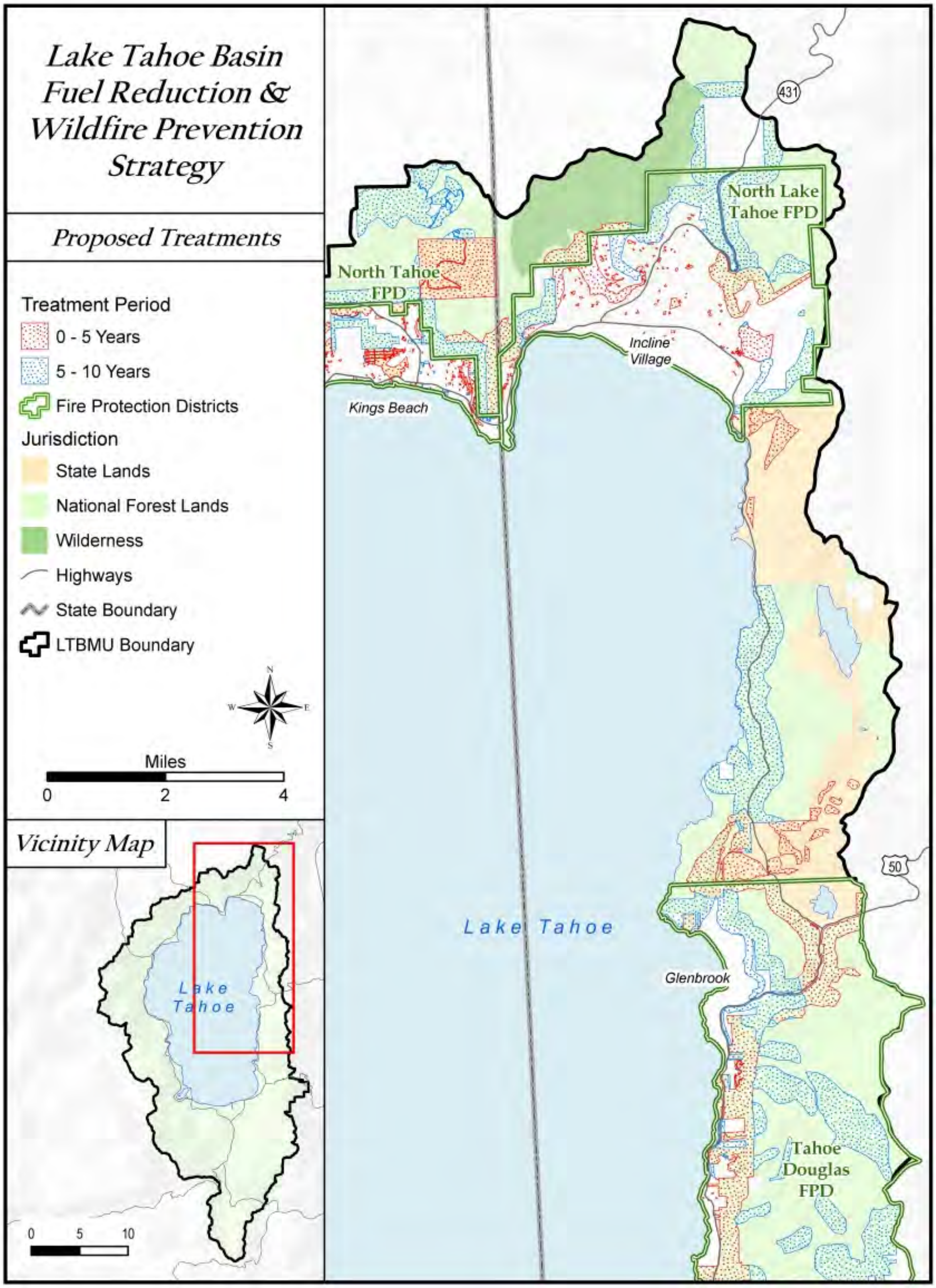


Figure 4. Treatment Map 2

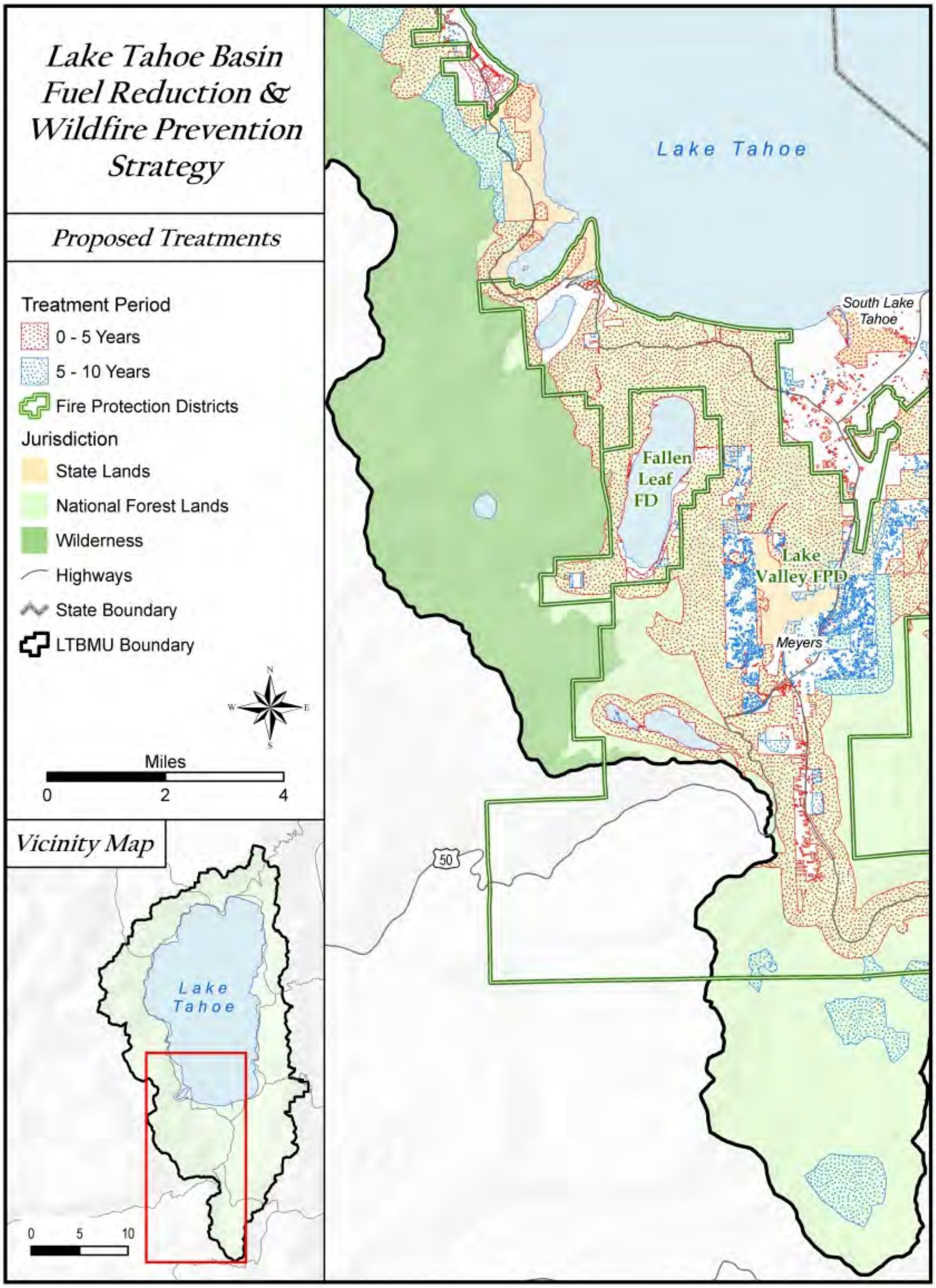


Figure 5. Treatment Map 3

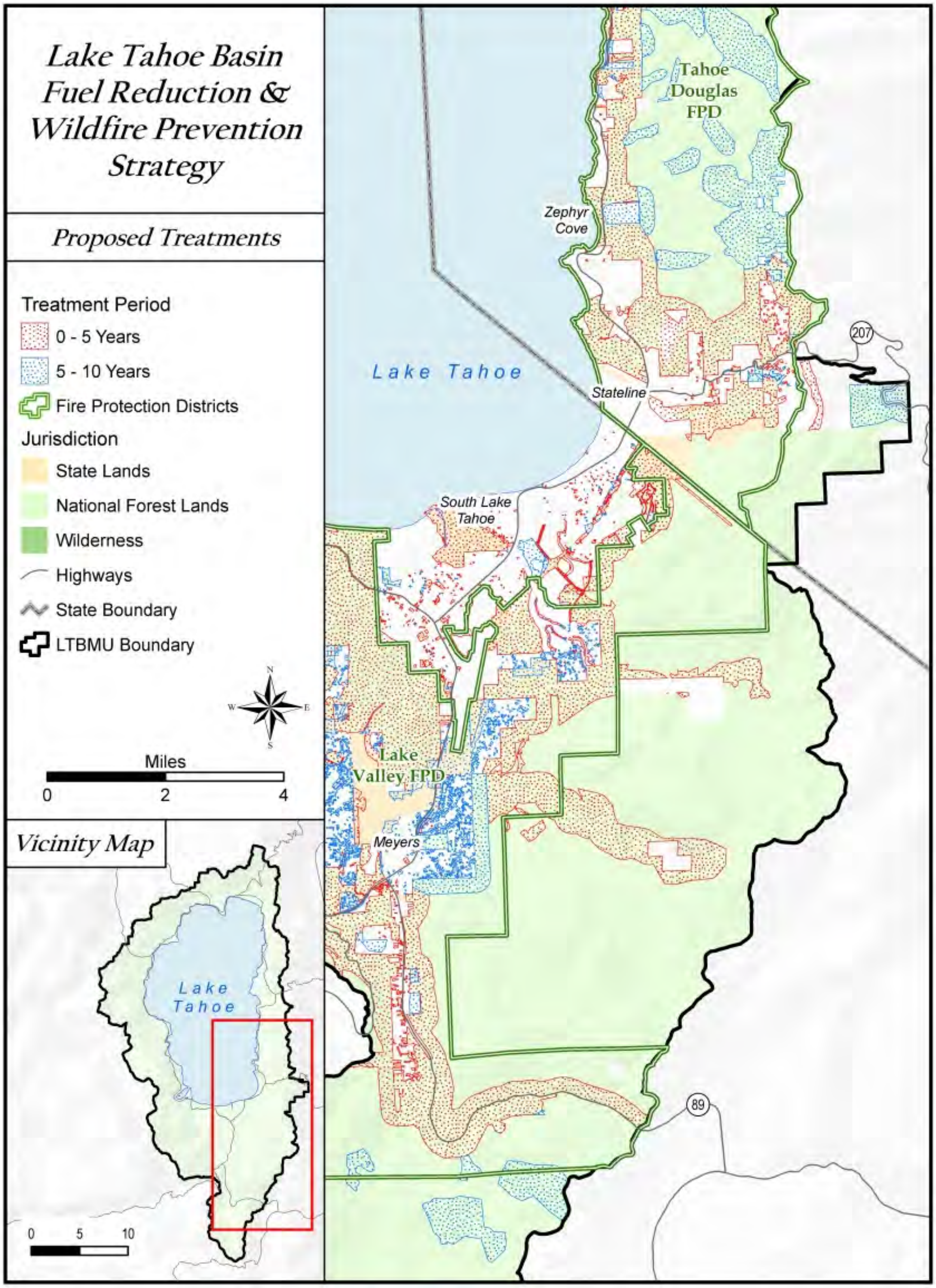


Figure 6. Treatment Map 4

Prescriptions and Treatment Methodologies

In all proposed projects, vegetation structure and composition will be modified with the objective to reduce fire behavior (see "Desired Future Conditions" section). Site-specific *prescriptions* will be developed for each project that explicitly define what vegetation will be removed in the project. To achieve these prescriptions, each project will define a cost effective *treatment* that should be used for that project. General prescriptions and treatment methodologies are described in the subsequent sections.

Prescriptions

Prescriptions vary with location and objective, and in most cases, will require a combination of treatments. Generally, prescriptions will be developed to reduce surface and ladder fuels, thus altering predicted fire behavior by reducing predicted flame lengths to 4 feet or less (under high fire risk conditions), and to reduce tree densities to reduce the potential for a crown fire, reduce competition for resources, and restore forest health.

Treatment areas in the Basin fall into two basic categories: WUI (see Figure 7) and the general forest, the latter being beyond the communities. In general terms, treatment prescriptions within the WUI establish community defense space and focus on the protection of life and property. Prescriptions for the general forest are designed to reduce current wildfire behavior, improve forest health, and achieve other resource management objectives identified during project planning.

Community Defensible Space - Wildland Urban Interface

WUI definitions, terminology, and prescriptions differ among the plans in which this comprehensive plan tiers. However, although each takes a slightly different approach, they all are defining needs of the community defensible space. The TRPA plan, and associated CWPPs, defined WUI as areas generally within ¼ mile of urban centers. The LTBMU extended this WUI definition to be consistent with its Agency management plan. The most inclusive boundary among the plans was used for this comprehensive plan.

Community Wildfire Protection Plan WUI Prescriptions

The three approved Community Wildfire Protection Plans (Resource Concepts, Inc. 2004a, 2004b; C.G. Celio & Sons et al. 2004) identified 110 projects in and around communities. General prescriptions for each project were identified describing vegetation that should be removed to achieve the desired conditions. Recognizing that each agency will develop its own prescription, guidelines for development of prescriptions were identified in the TRPA Plan (Holl 2007) for the covered CWPPs and suggested treatments around South Lake Tahoe. These guidelines focused on vegetation and fuel management in the urban core and defense zone.

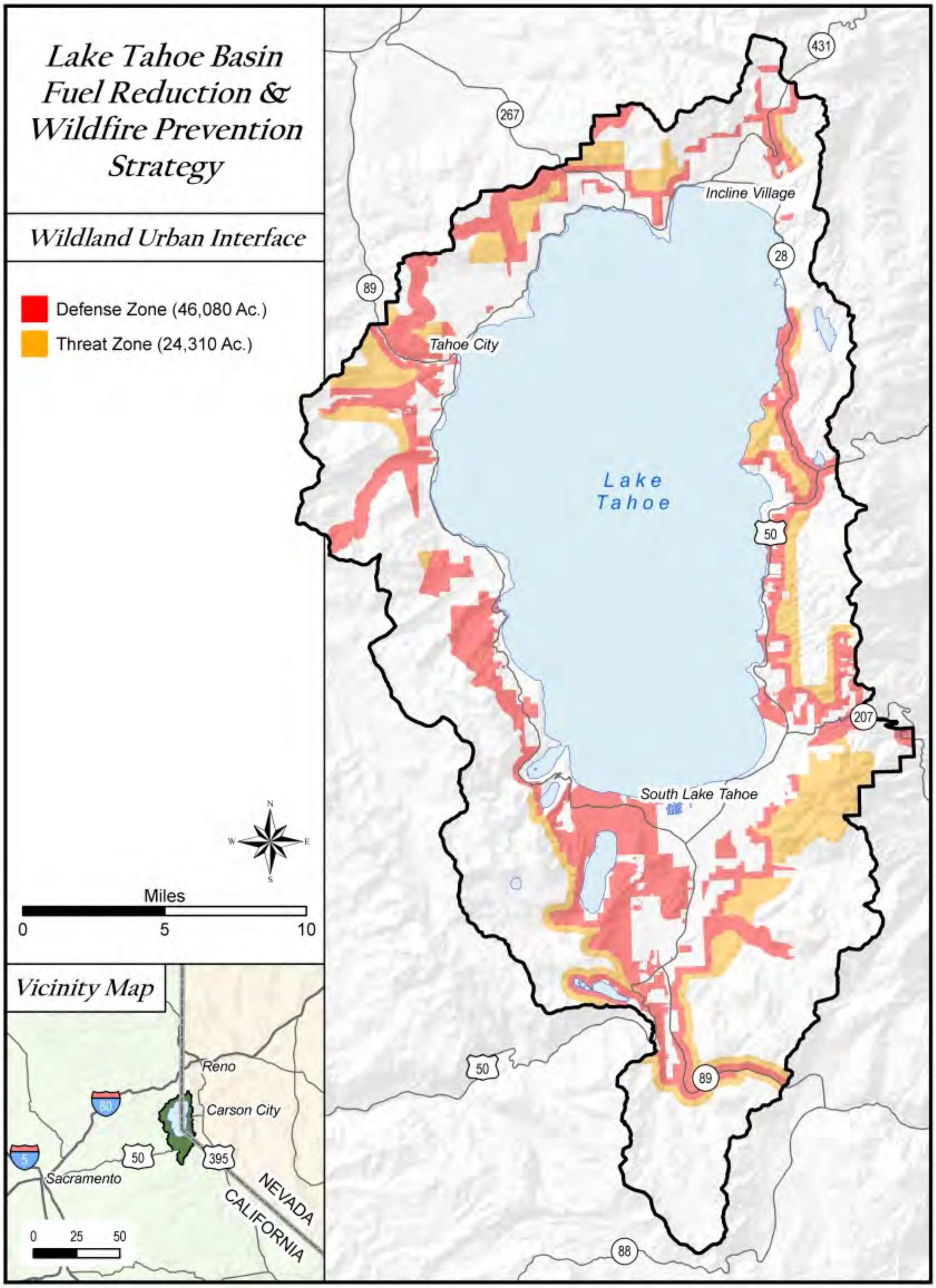


Figure 7. Wildland-urban interface (WUI) areas in Lake Tahoe Basin

Urban Core

All projects on private developed lots and small individual undeveloped lots will be consistent with prescriptions and management practices described in "Living with Fire" (Smith 2004), and in California, the requirements in the California Public Resources Code (section 4291). In California, all parcels having a structure and which are located on State Responsibility Area ("SAR") [non-federal lands and non-city lands] are required to comply each year with Public Resource Code 4291 and California Code of Regulations §1299 for defensible space. The defensible space requirement does not apply to parcels not having structures. The PRC 4291 statute was amended effective January 1, 2006 to increase the defensible space requirement from 0-30 feet to 0-100 feet around structures on SRA lands (California State Board of Forestry and Fire Protection, 2006). Treatments on USDA Forest Service developed and undeveloped lots, as well as other partners owning urban lots, including Nevada Division of State Lands and California Tahoe Conservancy, will be treated in accordance with the following defense zone philosophy.

Defense Zone

Defense zone treatments should be approximately 0.25-mile wide to be as consistent as possible with the historic 5- to 18-year fire return interval. They should reduce the density and basal area of stands (Taylor 2004) by thinning trees from below and retaining tree crown cover of randomly spaced trees. Defense zone treatments should remove sufficient trees or prune residual trees to reduce the risk of a crown fire, reduce surface fuels in conifer stands to achieve surface fire behavior, and reduce the canopy cover and fuel continuity in brush stands to reduce the intensity of fires. In meadows, live and dead and dying lodgepole pines should be removed so that only widely-scattered individual mature lodgepole pines remain.

General Forest Prescriptions

Most of the lands in the general forest are administered by the LTBMU; thus most prescriptions are tiered to the Framework. Prescriptions in areas beyond the WUI maintain the goal of reducing fire behavior to less than 4-foot flame lengths and often balance the needs for other resource goals. In addition, general forest treatments are strategically located to reduce fire potential on a landscape scale. The strategy for implementing treatments relies on an approach where disconnected, but overlapping fuel treatments are effective in changing fire spread and intensity. These disconnected fuel treatments are called *strategically placed large area treatments* (SPLATS). To be effective, the pattern of the SPLATS must interrupt fire spread and the prescriptions must significantly modify fire behavior. The LTBMU Stewardship Fireshed Assessment is a spatially explicit modeling effort that proposed SPLATS in relation to the other previously proposed fuel reduction projects such as those in Community Wildfire Protection Plans. The prescriptions in these SPLATS will be site specific. A visual representation of SPLAT application is presented in Figure 8.

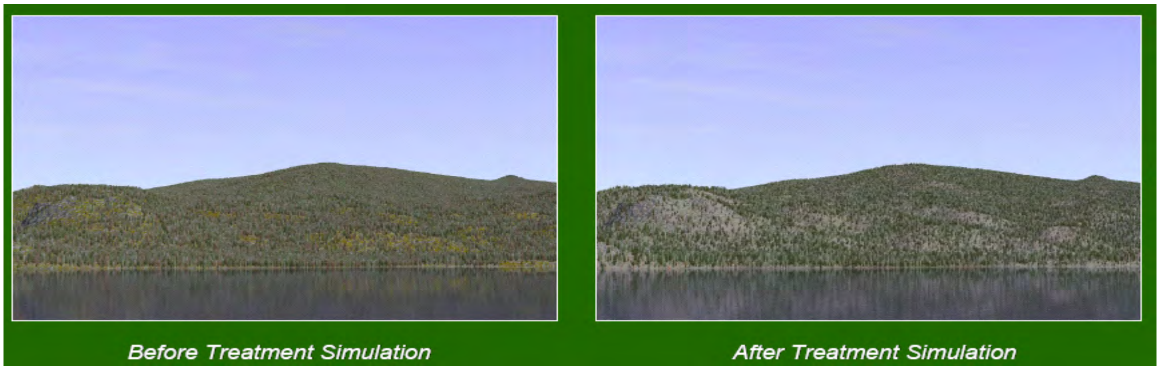


Figure 8. Computer simulation of SPLAT treatments in the Basin

Treatment Methodologies

Treatments are methods used to achieve the prescriptions and desired conditions. Which treatment strategy to use depends upon cost effectiveness, availability of implementation resources, the size and type of vegetation to be removed, and site-specific resource protection needs. The primary treatments used in the Lake Tahoe Basin include (may not apply to every agency):

- thinning (hand and ground based or aerial mechanical)
- pruning
- prescribed burning (pile, broadcast, and understory burning)
- mastication
- chipping

Thinning

Mechanical and hand thinning are used to reduce the number of trees, which affects crown fire potential. Mechanical thinning is generally more cost effective than hand thinning for removal of large trees (trees greater than 16 inches dbh), and allows removal of larger trees to achieve spacing objectives. Ground-based mechanical thinning is generally restricted on slopes more than 30 percent and on sensitive areas, such as stream environment zones. Aerial-based mechanical thinning uses helicopter or cable-based systems to remove trees on slopes greater than 30 percent. Hand thinning is generally limited to the removal of trees less than 16 inches dbh, on steeper slopes, and in sensitive areas.

Pruning

Pruning removes lower branches on trees, increasing the crown-base height (the distance from surface fuels to tree crowns). Pruning is a hand treatment used in conjunction with thinning. Because it is inefficient, its use is generally limited to small areas, such as developed and undeveloped lots where machines may not be able to operate.

Prescribed Burning

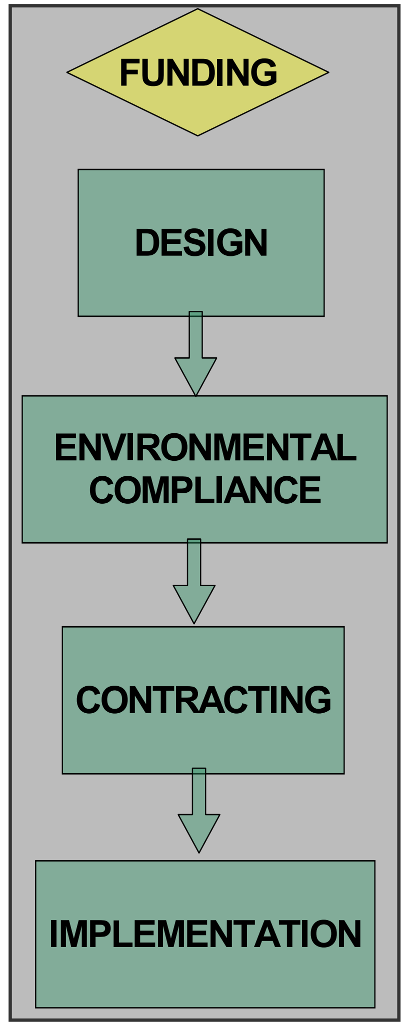
Prescribed burning reduces surface fuels using pile burning, broadcast burning, or understory burning. Pile burning is used on steep slopes where machines are prohibited and adjacent to developed areas. Broadcast burning is used on flatter areas to remove slash created by machine thinning and as a maintenance treatment in areas previously treated. Understory burning is the application of surface fire below an overstory of large trees and is used to restore forest health and to mimic the historic process of low-intensity fire.

Mastication and Chipping

Mastication and chipping are used to reduce ladder and surface fuels. Masticators consist of a head on the end of an articulated arm that moves through the forest on a tracked or rubber-tired machine. Fuels are ground up into irregular-shaped chunks and left on the ground. The irregular-shapes allow air and water to seep between them, hastening decomposition. Chips are created when material is fed into a chipper and either removed from the site as biomass or spread on site. Chipping creates uniform-sized chips that can form an interlocking mat that decomposes very slowly and inhibits regeneration of shrubs and grasses.

Section 3 Proposed Project Schedule

In general, projects were prioritized within the individual plans from which they originated. Those plans gave first priority to establishing community defense zones within the WUI. To combine these prioritizations, an initial schedule of annual treatments was developed using the Scheduler Program available in the "Forest Service Stewardship Fireshed Assessment." The Scheduler Program identifies the sequence of treatments over the entire landscape by maximizing the number of acres treated annually, given an assumed funding level.



Maps of all of the proposed fuel reduction projects were reviewed and individual scheduling units were subjectively identified based on aggregations of proposed treatment units. Scheduling units represent areas of proposed projects and the year when those sets of projects could be treated. Areas of highest risk in the WUI and where treatments were already initiated were designated first. Within all other scheduling units, a set of variables, such as the number of acres in the WUI, treatment costs, treatment acres, and acres of adjacent projects, were assigned a weighted index. These variables were then used by the program to evaluate the most cost effective and efficient distribution of treatments given a set funding level.

Another consideration is the time frame it takes to move an individual project through the process of design, compliance, contracting, and final implementation (see flow chart at right). This process may take several months to several years. The Planning Cadre reviewed the results of the Scheduler Program and made adjustments based upon local knowledge of site-specific projects and to transition more units proposed in the WUI to earlier treatment intervals. The final version of the project schedule, as agreed to in this plan, represents a strategic guide of the general order of project accomplishment. In some cases individual priorities of each participating agency may not be fully represented. Therefore, the schedule of proposed projects in Figure 9 is based on current assumptions. In reality, the schedule would be revised regularly, based on previous accomplishments and anticipated funding levels. Acres of proposed projects by year are displayed in Figures 10 and 11.

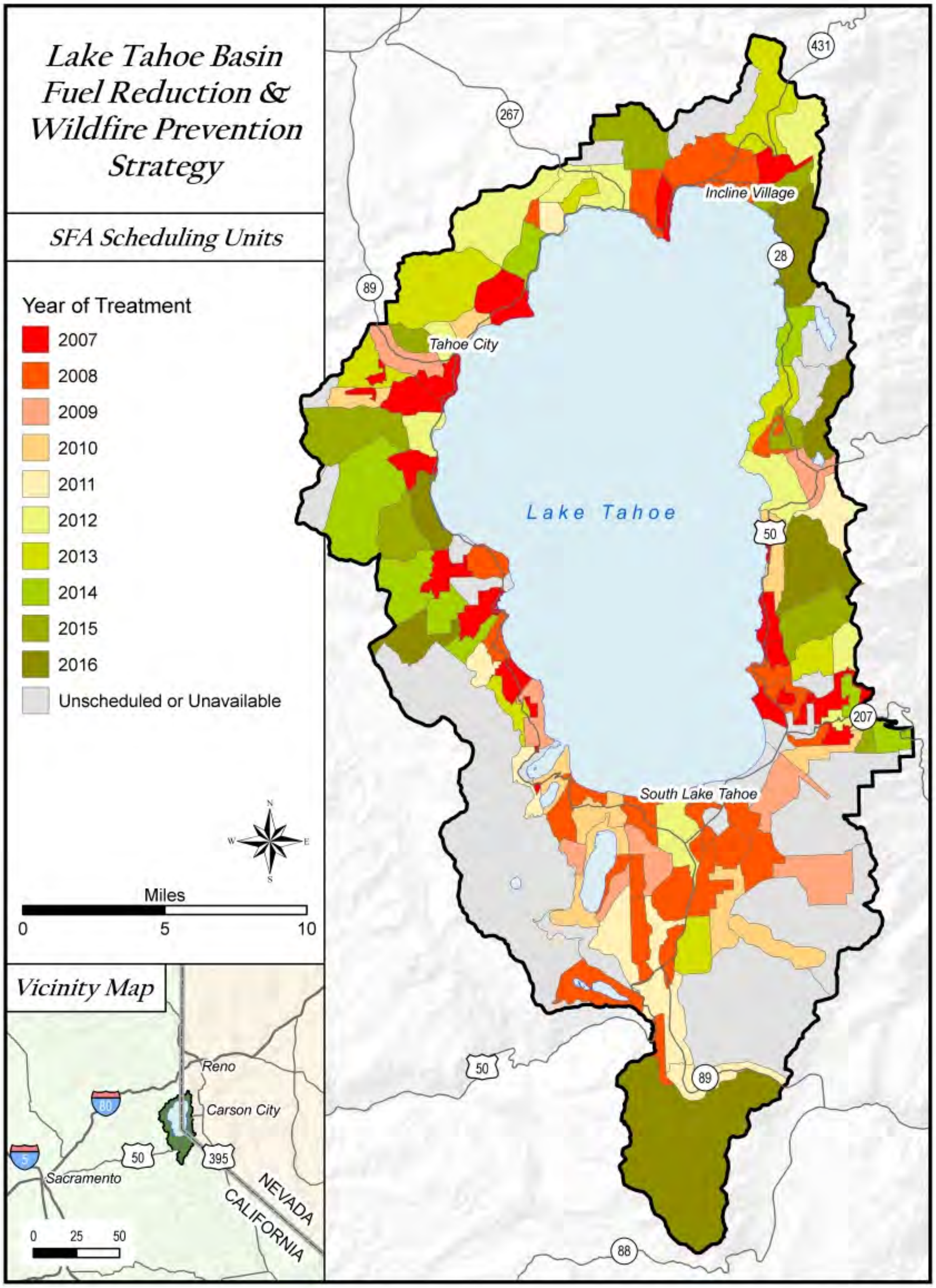


Figure 9. Ten-year proposed project schedule map

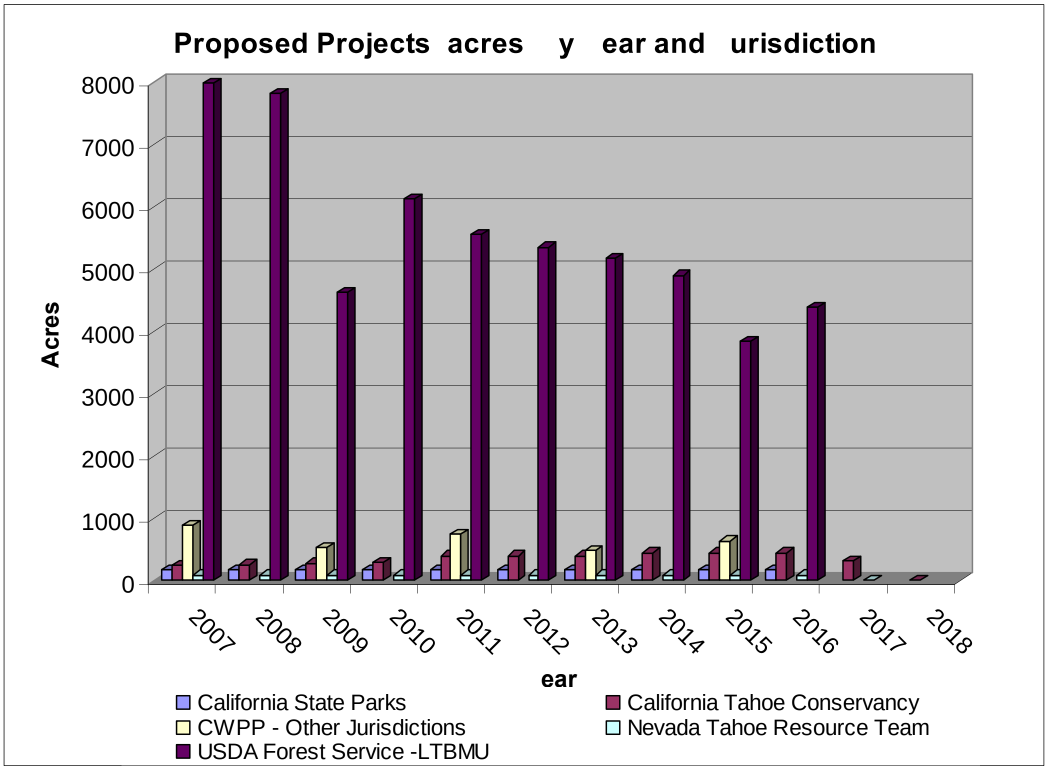


Figure 10. Project acres by year and lead implementation jurisdiction

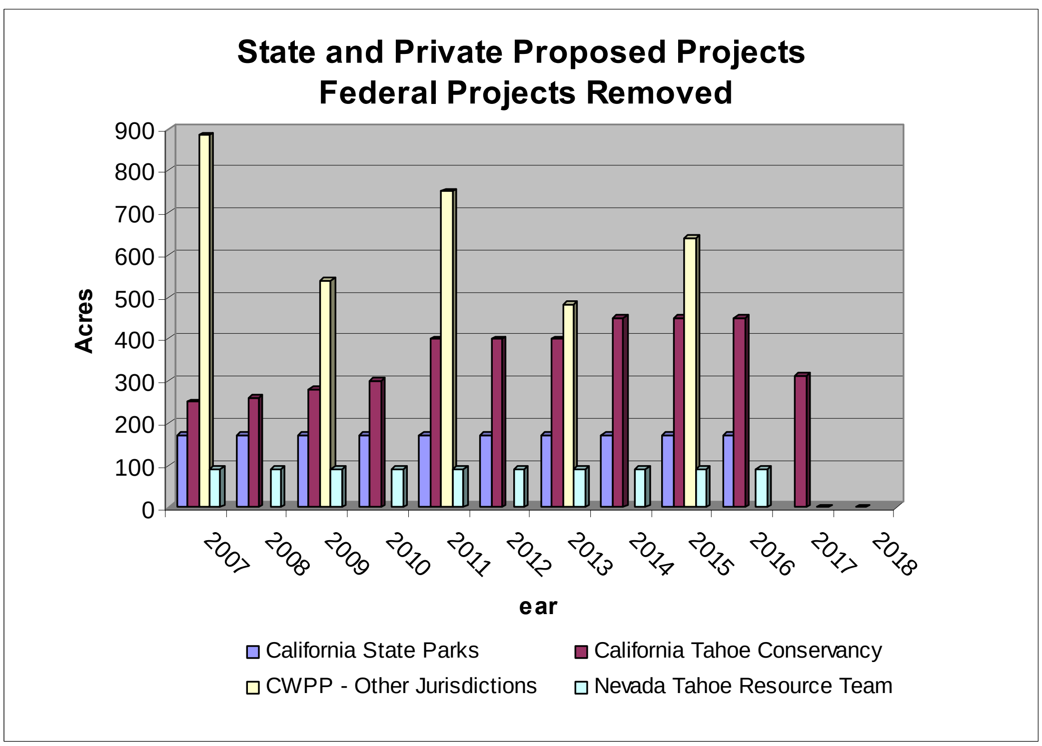


Figure 11. Project acres by year on state and private jurisdictions

Section 4 Proposed Projects Costs

Proposed projects costs reported by different agencies in the Lake Tahoe Basin vary by treatment (Table 3). Accurate comparisons among communities are difficult because of variations in the condition of individual treatment areas and accounting methods, and because the sequence of implementing treatments affects costs. The most detailed projected cost estimates are found in the individual plans from which this comprehensive plan is tiered.

Implementation Costs

In general, implementation costs in the Basin are similar to those reported by Fire Safe Councils or individuals in nearby communities. The exception is mechanical thinning costs, which are generally higher in the Lake Tahoe Basin. This is the result of using a cut-to-length system in the Lake Tahoe Basin that is less cost effective than whole-tree-removal systems, commonly used in other areas. Access required by both systems is similar; however whole tree harvest systems generally require larger landings for processing materials. The key advantage to whole-tree harvest systems is that they do not require a second entry to treat slash and tree tops left by cut-to-length systems as required by most fuel reduction prescriptions. The cut-to-length system has been used almost exclusively in the Basin because it results in less soil disturbance than the whole-tree removal system.

Table 3. Implementation costs in the Lake Tahoe Basin and adjacent communities

	Cost Acre in Different Sierra Nevada Communities					
Treatment	Lake Tahoe Basin	Amador County FSC	Foresthill FSC	El Dorado County FSC	Plumas County FSC	Truckee
Mechanical thinning	$1,000–3,500		$1,250		$600–2,300	$500
Hand thinning	$650–3,500	$1,500–3,000	$1,300*	$1,425	$750–900*	
Chipping	$200–700		$1,100			
Mastication	$700–1,500	$900–1,800			$700–1,300	$700–1,400
Pile burning	$300–700					
Broadcast burning	$400–1500					

* hand thinning and pile burning

Although costs per acre can be lower, hand thinning is not necessarily less expensive than mechanical thinning because it may also require pile burning or chipping to remove all of the harvested material. Additionally, material that is removed is limited to small trees (generally less than 16 inches dbh) and sufficient trees may not be removed to achieve forest health objectives. Mitigation measures associated with environmental compliance, lack of road access, steep topography, operating near residential areas and areas with high recreational use, a limited operating season, and coordination between multiple agencies add significant cost to treatments.

Treatments on urban lots are generally more expensive than those in other areas, where cost estimates have been as high as $10,000 per acre (Resource Concepts, Inc. 2004, page 37).

Planning Costs

Treatment costs in Table 3 represent implementation costs; they do not include costs for project planning (surveys and project design), environmental compliance, final project layout, contracting, or monitoring. Accurate costs for these items are difficult to establish because agencies track these costs differently. Preparation costs of CAL FIRE-required harvesting documents, such as harvesting exemptions and timber harvest plans ("THPs"), for commercial timber operations on non-federal timberland in California vary depending on the project size and complexity. Preparation costs by a registered professional forester, as required by California law for THP documents, typically range from $5,000 to $10,000 per THP. Preparation of exemption documents range from approximately $500 to $5000 per document. Logging costs also vary, depending on project size, complexity, size of material being harvested, harvesting method used, and what the mills are paying per board foot. CAL FIRE does not charge a fee of any type for submittal and review of harvesting documents. Costs are incurred by the registered professional forester and the licensed timber operator for environmental compliance for both project planning and implementation. Landowners must pay a yield tax in most situations.

Cost estimates for planning, environmental compliance, and final layout by the California Tahoe Conservancy on public lots and by California State Parks for approximately 10-acre projects range from $1,500 to $1,800 per acre. The Nevada Tahoe Resource Team estimates that planning costs for their projects range from $700 to $1,500 per acre. Cost estimates for project planning, compliance, and final layout on National Forest System-administered lands in the Basin are approximately 45 percent of their annual appropriation for fuel reduction projects. Using 2006 appropriations and accomplishments (acres treated), these costs were approximately $2,250 per acre. Actual planning costs are substantially less because USDA Forest Service planning areas are much larger than final project areas.

Total Costs of the Proposed Projects

Note that all implementation and planning costs estimates in this plan represent the best-known data at the time of this writing. Market forces and inflation can obviously affect project costs over time. In addition, because all specific prescriptions and treatment methodologies have not been determined for all projects, projected cost estimates must rely on average cost-per-acre ranges. The TRPA plan projected costs for nearly 95 percent of the proposed projects in this plan. That plan estimated average annual expenditures of $21,750,300 over the next 10 years for a total plan cost of $228,613,042 (Figure 12).

Additional proposed treatments and revised planning costs are reflected in this comprehensive plan. For instance, current USDA Forest Service LTBMU projections estimate that proposed projects within their jurisdiction may cost approximately $100,000,000 over the next 10 years or annual expenditure of $10,000,000. Given this wide range of variables and estimates, this comprehensive plan projects that total plan implementation cost will range between $206,000,000 and $244,000,000 over all jurisdictions, with annual expenditures ranging between $18,500,000 and $25,500,000 (based on variation in acres treated by year).

Cost Item		Acres	Cost
CWPPs acres y jurisdiction	Federal	6,552	$25,280,736
	California*	2,293	$19,957,600*
	Nevada	75	$289,386
	Local	1,150	$4,437,248
	Private	2,408	$9,291,211
	CWPP Su total	**12,4**	**,2 ,1**
Community Defense Programs			$9,983,000
Program Leadership Staffing			$43,088,587
LTBMU Other Acres		33,260	$96,972,685
Nevada Other Acres		3,100	$9,028,750
Maintenance		18,100	$10,283,842
Reflects revised cost estimate for CTC not in original report		**Total**	**22 , 13, 42**

Figure 12. TRPA Plan projected costs (Holl 2007)

For the reasons described above, treatment costs in the Basin may exceed those in some other areas. However, these costs in the Basin are effective, given the values at risk that are being protected (see section "Values at Risk") and avoidance costs, such as the loss of structures, fire suppression, and post-fire soil, forest and watershed restoration and rehabilitation. For example, the Angora Fire damaged or destroyed more than 240 structures where assessed real estate values averaged $625,000 per acre. Overall Basin residential property values range from $14 to $15 billion in assessed value (see "Values at Risk"). Suppression costs for the 2002 Gondola Fire were $4,500 per acre and those for the recent Angora Fire were $3,800 per acre, which exceed hazardous fuel treatment costs.

Section Utili ation Potential

The primary objectives of the proposed hazardous fuel reduction projects are to reduce the potential of a catastrophic fire, protect valuable assets at risk, and restore forest health. As a result, forest materials that are removed will generally be small trees. Materials that are removed may provide some revenue to reduce the cost of the proposed projects, allowing public funds to be used elsewhere for hazardous fuels reduction. Potential forest products from the proposed projects include biomass, small logs, and large logs.

Biomass

Biomass is used to generate heat, steam, and electricity, and create products such as ethanol, soil amendments, or landscaping material. Developing a biomass facility or utilizing existing facilities in or near the Lake Tahoe Basin would be consistent with recent federal and state policies (Appendix A). However, sustainable production of biomass may be limited because projected biomass outputs from treatments proposed in this plan will decrease significantly in 10 to 15 years.

Holl (2007) determined approximately 4,900 acres would be burned annually if all initial and maintenance treatments were completed as scheduled. Although there are few limitations on burning in the Nevada portion of the Lake Tahoe Basin, the number of allowable burn days in El Dorado and Placer Counties is limited to approximately 55 and 70 days, respectively, between May 1 and November 30 (Placer County Air Pollution Control District 2007)[2]. Assuming the majority of burning occurs during this period, approximately 60 acres per day would have to be burned during spring and fall in California to complete the proposed treatments. Approximately 20 acres would have to burned daily in Nevada, where there are fewer constraints on allowable burn days. Assuming biomass could be removed on all acres proposed for broadcast burning, the number of acres burned could be reduced up to 25 percent (Holl 2007). Additionally, a modern, wood-fired heating system would substantially reduce most emissions compared to traditional burning (Table 4).

Table 4. Emissions from traditional forest burning and a modern wood-fired heating system

Source	Pounds Green Ton Material				
	PM1	NO	SO_2	VOC	CO
Pile burning	19–30	3.5	0.01	8–21	154–312
Broadcast burning	24	4.0	nd	13	224
Efficient wood-fired heating system	1.6	2.13	0.2	0.48	1.3
nd = no data;					

Source: McNeil Technologies (2003)

[2] Average percent of allowable burn days from May 1-November 30, 2004-2006. Placer County allows some burning on marginal burn days, dependent on predictions (A. Hobbs, Placer County Air Pollution Control District). Some pile burning may occur outside of those dates; however, it is minimal compared to the total number of acres burned.

Support for Biomass

Over the past 12 to 18 months, several strategic actions have occurred that collectively provide the impetus necessary to develop and support a biomass program in or near the Lake Tahoe Basin. Key to this success has been commitments for funding and exploration of solutions to resolve regulatory concerns affecting air quality, including:

- The White Pine County Conservation, Recreation and Development Act recently amended (December 2006) the Southern Nevada Public Land Management Act to provide funding for implementation of hazardous fuels treatments, including biomass energy development, in the Lake Tahoe Basin.
- The USDA Forest Service, Lake Tahoe Basin Management Unit provided $355,000 in grants to the South Lake Tahoe High School for replacement of a boiler to heat the school with biomass. Additionally, the LTBMU has awarded a contract to remove excessive fuels as biomass from 105 acres.
- The USDA Forest Service has prepared a Coordinated Resource Offering Protocol study to determine the potential supply of biomass within a 100-mile radius of Grass Valley, California (Mater Engineering 2007).
- In California, the Governor’s 2007 budget included $4.7 million for implementation of hazardous fuels treatments in the Lake Tahoe Basin; including provisions for a $3.5 million grant for development of a biomass facility. An interagency team has been convened to develop a request for proposal for a biomass facility.
- The California Department of Forestry and Fire Protection provided the Sierra Economic and Development District a grant to identify the potential biomass supply in the greater Lake Tahoe area.
- Placer County is providing curbside boxes for residents to deposit biomass removed from their properties and is evaluating construction of a 1-megawatt heat and power facility in the Lake Tahoe Basin.

Availability of Biomass

Machines are required to harvest trees, process them into biomass, and transport the biomass from the project site to a facility. Under current operating conditions, machine access is limited to 0.25 mile from existing roads, making approximately 16,000 acres available for biomass Basin-wide. Every acre available for biomass may reduce the number of acres that could be burned. Therefore, if access can be developed (temporary or permanent), the number of acres available for biomass Basin-wide increases approximately 30 percent to 23,200 acres (Table 5). Temporary access assumes it is only for the project; such access will be removed, and the site rehabilitated once the project is completed.

Table 5. Acres available for biomass removal in the Lake Tahoe Basin*

urisdiction	Availa le ithin 1 4 mile from roads			Availa le ithin 1 2 mile from roads		
	Total acres	Previously Treated	Availa le acres	Total acres	Previously Treated	Availa le acres
Federal	17,124	6,215	10,909	22,792	6,215	16,577
State	4,344	946	3,398	5,679	946	4,733
Local Government	1,682	435	1,247	1,828	435	1,393
Private	618	67	551	578	67	511
Total	23,768	7,663	16,105	30,877	7,663	23,214

* The available acres are the total acres of machine accessible land (< 15% slope on sensitive soils and < 30% slope on other soils) minus private lands in the urban area, wilderness, inventoried roadless areas, research natural areas, and lakes, minus an additional 20% to allow for steam environment zones, brush fields, and operational considerations during final project design. Previously treated acres include treatments completed between 2000 and 2005 (source LTBMU July, 2006).

Biomass availability is also affected by the timeframe identified for completion of the proposed projects. If access is limited to 0.25 mile from a road and all projects are completed within 10 years, approximately 1,600 acres would be treated annually. If temporary access is approved for machines, approximately 2,320 acres would be treated annually over 10 years, or approximately 930 acres annually over a 25-year period.

Additional biomass may be available from private residences in the course of clearing and maintaining defensible space (up to 100 feet clearance) around occupied buildings. Substantial amounts may be available from initial treatments; however, little will be available from subsequent maintenance treatments because little woody material will develop between the frequent treatments.

The amount of biomass available from fuel reduction projects was estimated assuming an average biomass yield of 14.4 green tons (GT) per acre (McNeil Technologies 2003)[3]. Based on the number of acres treated annually, this would provide approximately 23,200 GT annually for 10 years if access were limited to 0.25 mile from a road; or 33,400 GT and 13,400 GT annually, if temporary access was gained, and projects occurred over 10- and 25-year periods (Figure 13).

[3] More recently, Mater Engineering (2007) estimated 11,330 GT of biomass would be available annually from National Forest System lands in the Lake Tahoe Basin. This assumes biomass is obtained from trees less than 7 inches dbh; whereas, the McNeil Technologies (2003) assumed biomass would be obtained from slash from harvested trees less than 12 inches dbh.

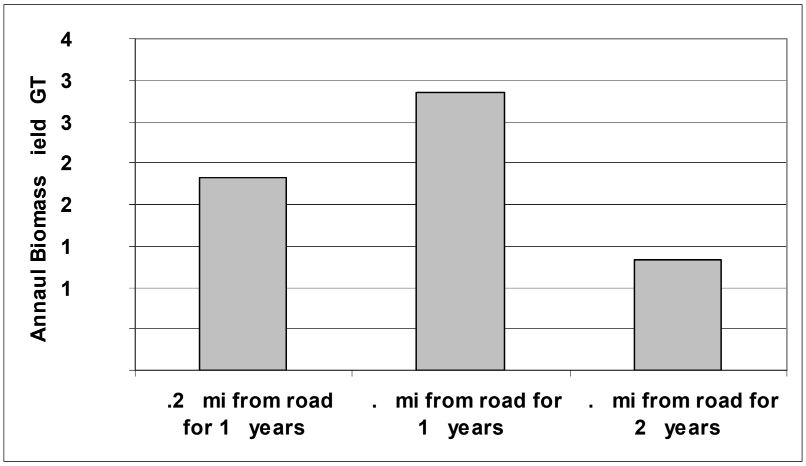


Figure 13. Estimated annual yields of biomass (GT) in the Lake Tahoe Basin with different access capabilities and time periods

Existing Demand for Biomass

Currently, seven agencies, organizations, or companies in or adjacent to the Lake Tahoe Basin are using or are planning to use biomass as product (Table 6). Based on these estimates, they could absorb at least 20,000 GT annually and perhaps more than 35,000 GT annually.

Table 6. Demand for biomass in and near the Lake Tahoe Basin

Facility	Use	Estimated Annual Capacity	Status
Northern Nevada Correctional Center (Carson City, NV)	Electricity–1MW capacity	12,000–24,000 GT[1/]	Operational June, 2007; expansion over the next 3 years is possible
South Lake Tahoe High School	Wood-fired heating boiler	2,200 GT tons[2/]	Planning
Placer County Justice Center	Heat and electricity–1 MW capacity	10,000–16,000 GT[3/]	Planning
Carson City Renewable Energy	Biomass processing yard; Wood chips for correctional center, landscaping, and soil amendment	Large quantities, but not quantified [1/]	Fully operational
Full Circle Compost (Minden, NV)	Landscaping mulches, compost, and soil amendment	3,000–4,000 GT [4/]	Fully operational
Bently Agrow Dynamics (Minden, NV)	Compost and soil amendment for application to company farm	Large quantities, but not quantified [5/]	Fully operational
South Lake Tahoe Refuse	Transfer facility for chips and needles, storage site for South Lake Tahoe High School	Variable[6/]	Operational, proposing to build storage facility

[1] Stan Raddon, Carson City Renewable Energy
[2] McNeil Technologies 2003
[3] Brett Storey, Placer County
[4] Craig Witt, Full Circle Compost
[5] Carlo Luri, Bently Agrow Dynamics
[6] Jeanne Lear, South Lake Tahoe Refuse

Firewood

When possible, agencies may also make available material that could be classified as biomass or small logs (see below) as firewood. For example, Nevada Division of State Lands provides, when possible, the use of firewood to local communities and the citizens of Nevada where treatment is accomplished. This benefits Nevada Division of State Lands by removing the material from the treated parcel and benefits the public by providing a resource at no cost. In addition, Nevada State Parks offers approximately 100 cords of firewood each year at a cost of $45 per cord.

Small Logs

There is a growing interest in the use of small logs for constructing traditional structures (USDA USDA Forest Service 2000b). In the recent Coordinated Resource Offering Protocol study (Mater Engineering 2007), it was estimated the LTBMU would produce 39 million board feet of timber from small logs (defined as trees 7 to 12 inches dbh) during the next 5 years. This represented 5 percent of the volume from the entire study area, defined by a 100-mile radius from Grass Valley, California. This estimate is probably high because most of the material from small logs removed in the Lake Tahoe Basin is projected to be used as biomass.

Small logs have been used to produce pulp, veneer for laminated lumber, oriented-strand board, posts and poles, and sawn lumber. Sawn lumber provides the lower economic return because the juvenile wood that is sawn is subject to extensive warping and cupping. Posts and poles are less susceptible to warping than sawn lumber; however, there is a lack of information on structural use and how to fasten and secure round pieces of wood in traditional structures (USDA Forest Service 2000b).

Large Logs

Fuel reduction treatments in the Lake Tahoe Basin will emphasize removal of small, suppressed, and intermediate trees through prescriptions that thin from below. These prescriptions will include removal of trees greater than 10 inches dbh to be sold as large logs. It is currently estimated that approximately 2,000 acres of mechanical thinning will occur annually in the Lake Tahoe Basin during the next 10 years (Holl 2007). Assuming trees greater than 10 inches dbh yield 4,000 to 8,000 board feet per acre (Young, D., LTBMU; Adams, R., CA Parks), an estimated 8 million board feet of timber will be harvested annually. This is similar to the 7.2 million board feet estimated in the Coordinated Resource Offering Protocol study (Mater Engineering 2007). Although these estimates appear to be large, they represent 5 percent of the volume projected from public lands during the next 5 years in the Coordinated Resource Offering Protocol study area (Mater Engineering 2007).

Section Values at Risk

The Lake Tahoe Basin is a special place. With the spectacular lake as its centerpiece framed by the forested and alpine peaks of the Crystal and Carson Ranges, the area is considered a national treasure. These natural and scenic wonders provide diverse summer and winter recreation experiences that support a strong local economy. The Basin is also home to permanent and seasonal residents whose homes have been assessed at $14 to $15 billion. As a result of the recent Angora Fire, it is commonly acknowledged that the very attributes that make the Basin a special place are at an unacceptably high risk of loss from catastrophic wildfires and declining forest health, and that something urgently needs to be done to reduce the risks and scale of these types of potential losses. In addition to the homes and businesses that operate in the Basin, some of the key values at risk from a catastrophic wildfire are described below.

Communities and Safety

Within the 208,800-acre Lake Tahoe Basin, 70,390 acres (34 percent) are within the WUI. Based on the assessment of values at risk in TRPA's "Fuel Reduction and Forest Restoration Plan for the Lake Tahoe Basin Wildland Urban Interface," the highest ranked communities at risk are Brockway and portions of Kings Beach and Crystal Bay in the north; Heavenly Valley, Meyers, Christmas Valley, and North Upper Truckee in the south; Gold Coast in the west; and Talmont, Tahoe City, Highlands, Dollar Point, and Cedar Flat in the northwest.

Human health is also at risk. Exposure to air pollutants from wildfire smoke is associated with numerous effects on human health, including increased respiratory symptoms or decreased lung function, hospitalization for heart or lung diseases, or premature death. Children and the elderly are more susceptible than adults to air pollutants (SNFPA FEIS 2004, p. 327). In addition, fire fighter safety is at risk as wildfires continue to burn with increased intensity and uncharacteristic fire behavior.

Socioeconomic Considerations

The goals and policies of the Tahoe Regional Plan (TRPA 1986: II-2) states, "The economic health of the Region depends on a viable tourist and recreation-oriented environment…" (USDA Forest Service 2000a [hereafter referred to as Watershed Assessment], p. 633). Although the Basin's population has remained relatively stable over the past decade, growing numbers of residents in the adjoining counties create additional pressures on Tahoe's environment and economy (Watershed Assessment, p. 85). The economy in the Lake Tahoe Basin is based primarily on tourism, recreation, and vacation home ownership. Daily car visitors, skiers, business meetings, seminars, organized summer camp activities, camping, hiking, mountain biking, fishing, and summer water sports bring thousands of tourists from all over the world to the area each year. Like other resort areas, such as Park City, Utah or Sun Valley, Idaho, winter sports are a significant driver of the regional economy. For example, in the North Lake Tahoe Area, winter sports recreation spending contributed nearly $355 million to the local economy (Dean Runyan, 2003). A devastating wildfire could have a direct effect on the tourism industry (ski areas, campgrounds, associated businesses) that would drive repair and rehabilitation costs higher, or possibly lead to closures.

The Lake Tahoe Basin also includes some very high property value homes and businesses where assessed real estate values average $625,000 per acre. The greatest concern with large fires in the Basin is the high property and natural resource values that they threaten (including lake clarity and limited old-growth forests). Even a small wildfire in the Basin is potentially significant because of the juxtaposition of high ignition potential, high density and value of human developments, and high fuel hazard (Watershed Assessment, p. 15). High-intensity wildfires could result in extensive property damage or loss.

Recreation and Scenic Resources

Lake Tahoe is a nationally and internationally renowned icon. The dramatic beauty and ecological uniqueness of the region's landscape defines it more than any fact or figure. Wildfire has the potential to affect large-scale landscape character and scenic integrity. The Land Use Element of the Goals and Policies of the Tahoe Regional Plan's (TRPA 1986: II-2) state,

> *"The primary function of the region shall be as a mountain recreation area with outstanding scenic and natural values . . ."* (Watershed Assessment, pp. 632-633).

Recreation opportunities here are some of the best in the country including California and Nevada State Parks, National Forests, and the activities centered on Lake Tahoe. Recreation and related tourism shapes social, economic, and ecological conditions, and influences policies in the region. Winter sports and water sports related recreation and resorts are a primary attraction for recreationists and drive local tourism and jobs. In North Lake Tahoe, nearly 5,000 jobs are directly related to these activities (Dean Runyan, 2003). In all, the local economy relies on recreation and tourism, which is a more important economic activity than commodity production (Duane 1996; SNFPA FEIS 2004, p. 475).

Water Quality, Watersheds and Riparian Zones

The clarity of Lake Tahoe is world renowned and the loss of that clarity is of concern to many. After steadily declining for 30 years, the lake's clarity hit an all time low in 1997 and has been steadily improving since. High-intensity wildfires could cause large amounts of erosion and sedimentation that would adversely affect water quality (Holl 2007, p. 2-12). Allowing hazardous fuels capable of supporting a crown fire to build up in stream environment zones could have significant effects on water quality in the Lake Tahoe Basin. The loss of vegetation from wildfire would result in erosion and sedimentation, decreasing water quality (Holl 2007, p. 2-11).

Fires can have extraordinary effects on watershed processes and can significantly influence aquatic organisms and the quality of aquatic habitats in many ways (Benda et al. 2003; Rieman et al. 2003; Wondzell and King 2003). Substantial reductions in riparian shading and altered stream flows can increase stream temperatures to extreme levels (Rieman et al. 2003; McMahon and DeCalista 1990). Flooding, surface erosion, and mass wasting (landslides) may increase due to vegetation loss and the creation of hydrophobic (water-repellant) soils. In turn, dramatic increases in sedimentation, debris flows, and wood inputs to streams may occur (SNFPA FEIS 2004, pp. 203-204).

Wildlife Habitat and Forest Vegetation

Wildfire has the potential to damage or destroy suitable habitat for general wildlife, as well as critical threatened, endangered, proposed and other special status species, such as the mountain yellow-legged frog, California spotted owl, northern goshawk, and the osprey.

High-intensity wildfires will directly result in high tree mortality in forest stands, especially within moderate- and high-density forests having increased canopy cover. Tree mortality (representing severity of fire effects on vegetation) likely will be high in most fires, given current surface and ladder fuel conditions (Watershed Assessment, p. 15).

Native flora is also at risk as noxious weeds and invasive species tend to spread rapidly following wildfires. Wildfire areas are especially vulnerable to weed infestation because: (1) equipment used in wildfire suppression and burned area emergency rehabilitation bring weed seeds into an area; and (2) burned areas provide ideal conditions for weed germination. Weed populations can easily gain a foothold before native vegetation has a chance to recover from the fire.

Air Quality

Many factors contribute to Lake Tahoe Basin's air pollution, including pollution from urban areas to the west of Lake Tahoe, dust from roads, automobile emissions, and smoke from wood burning stoves. Wildfires also emit large amounts of particulate matter (PM10 and PM2.5) and carbon monoxide, as well as nitrogen oxides (NOx) and volatile organic compounds (VOCs), which are precursors to ozone. Historically, almost all wildfires have exceeded the national and state standards for particulate matter (SNFP FEIS 2004, p. 348). Other constituents of smoke (gases and chemicals) may also enter the lungs. Some components, such as Benzo-apyrene and aldehydes, can be carcinogenic.

Wildfires result in greater emissions per acre when compared to prescribed burns, commonly exceeding ambient air quality standards. They also often occur under conditions of high temperature and low humidity, when high concentrations of ozone are most likely (SNFP FEIS 2004, p. 326). Although there is currently no quantitative way to fully display the emissions from wildfire as compared to a prescribed burn, the intent of fuels reduction activities is to reduce the size of, and hence the emissions, from wildfire (SNFP FEIS 2004, p. 343).

Section Proposed Project Predicted Outcomes

To determine the efficacy of this plan and its associated proposed projects, it is important to first establish the current wildland fuel conditions, then determine a desired wildland fuel condition for the Basin, and finally determine whether the proposed projects will meet that desired condition.

Current Condition

Background

The number of acres burned by wildfires in the Basin has increased in each decade since 1956 (Figure 14). Although few of those fires have been large, two recent fires—the Gondola and Showers Fires (673 and 294 acres, respectively)—occurred under less-than-extreme fire weather conditions. The 2007 Angora Fire, which burned 3,100 acres and destroyed or damaged more than 340 buildings, was the largest fire ever recorded in the Lake Tahoe Basin and burned at elevated fire weather conditions. Even with highly effective suppression resources, the crown fires and sizes of these fires provide additional evidence that fuel hazards in the Basin have increased substantially and will continue to increase in the years ahead (Holl 2007, p. 1-3).

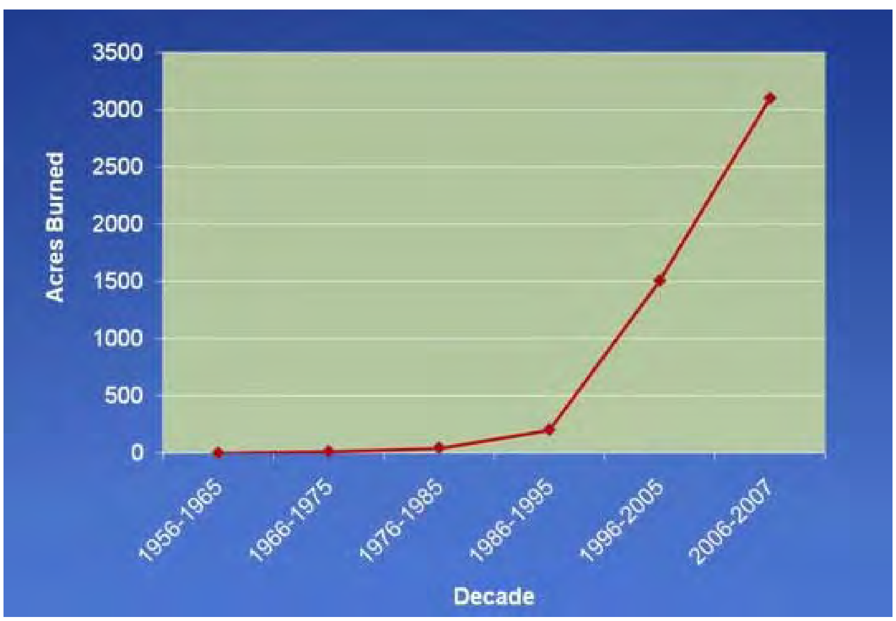


Figure 14. Wildfire acres burned in the Lake Tahoe Basin by decade (Holl 2007)

The long history of fire suppression combined with incidences of drought and insect-induced mortality has resulted in stands with a high concentration of hazardous fuels. This condition has increased the threat of large catastrophic fire and is indicative of a forest where many natural processes have been excluded.

Current Vegetative Conditions and Fire Regimes

Recent estimates indicate that lower elevation forests in the Lake Tahoe Basin have four times the density of trees and higher elevation forests have twice the density of trees when compared to forest conditions prior to 1870 (USDA Forest Service 2000a) (see photo, left). High densities of trees increase competition for nutrients resulting in higher tree mortality rates. Current forest stands exhibit a 70 percent higher disease incidence and 5 percent greater tree mortality than remnant old-growth stands in the Basin (USDA Forest Service 2000a) (see photo below). High rates of tree mortality, particularly white fir (*Abies concolor*), have increased the number of standing dead trees and downed logs. Smaller mid-story trees create fuel ladders that allow fires to readily move into dense crowns. The lack of frequent, low-intensity fires has resulted in accumulations of dead fuels, increased understory shrubs, and dense young trees. As a result, flame lengths and rates of fire spread lead to higher intensity fires (Holl 2007, p. 1-2).

Dense forests in Lake Tahoe

Residential, commercial, and infrastructure construction have also influenced today's vegetation patterns. Not only have large areas of vegetative cover been removed, but the composition of remaining vegetation has been changed through landscaping key to their sustainability.

Historic Fire Regime

Prior to European settlement, fires in the Basin were ignited by lightning or members of the Washoe Tribe, who inhabited the Tahoe Basin during the summer months. The fire return interval varied from 5 to 128 years throughout the entire Basin (Taylor 2004), but fire return intervals were shortest (5 to 18 years) at the lowest elevations around the lake and south to approximately Meyers. Based on historic fire return intervals, it is estimated 2,100 to 8,000 acres burned annually in the Lake Tahoe Basin,

Forest mortality in Lake Tahoe

with approximately 50 percent of that at the lower elevations (USDA Forest Service 2000a). Because frequent fires reduced surface and ladder fuels, fire intensities were low and there was little mortality of mature trees.

As Europeans settled in the Basin, several factors contributed to changes in the fire regime and fuel hazards. The frequent seasonal fires set by the Washoe Tribe were eliminated as the Native Americans left the Basin. Between 1875 and 1895, large-scale clearcutting removed most of the old growth forests in the Basin (Lindstrom et al. 2000). By 1900, the Basin's forests were dominated by seedlings (less than 1 inch diameter dbh), saplings (between 1 and 6 inches dbh), and pole-sized trees (between 6 and 12 inches dbh), with remnant old-growth forests. In conclusion, disturbance by fire was a frequent and normal part of the historic vegetative condition.

Current Fire Regime

Previous management direction that focused on protection of natural resources by suppressing wildfires removed a natural source of vegetation disturbance. Simulated fire behavior in the Basin and observed fire behavior in the Angora, Gondola, Showers, and Pioneer Fires demonstrates current fire behavior is characterized by high-intensity fires. Thus, the fire regime has changed from frequent, low-intensity fires to infrequent, high-intensity fires. High-intensity wildfires will result in high tree mortality in forest stands, could result in extensive property loss, and could cause large amounts of erosion and sedimentation that would adversely affect water quality.

Fire Regime Condition Class

Fire regime condition class is a national landscape classification scheme describing the degree of departure in the current fire regime from the historic fire regime. The classification scheme is based on changes in vegetative characteristics, fuel composition, and fire frequency and intensity and described as low (I), moderate (II), or high (III) departure.

- **Low (I)** condition class is where vegetative characteristics and fire behavior are considered to be within the historic range of variability.
- **Moderate (II)** condition class means vegetative characteristics and fire behavior are moderately altered from historic conditions.
- **High (III)** condition class means vegetative characteristics and fire behavior are highly altered and there is a risk of losing key ecosystem functions.

Fire regime condition classes have been mapped in the Lake Tahoe Basin (Figure 15). Twenty nine percent of the Basin is classified in a Low (I) condition class, 33 percent is classified in a Moderate (II) condition class, and 38 percent is classified in a High (III) condition class. The majority of the WUI in the Lake Tahoe Basin is in condition class III. These are areas where fire behavior has been substantially altered and an intense fire could have significant

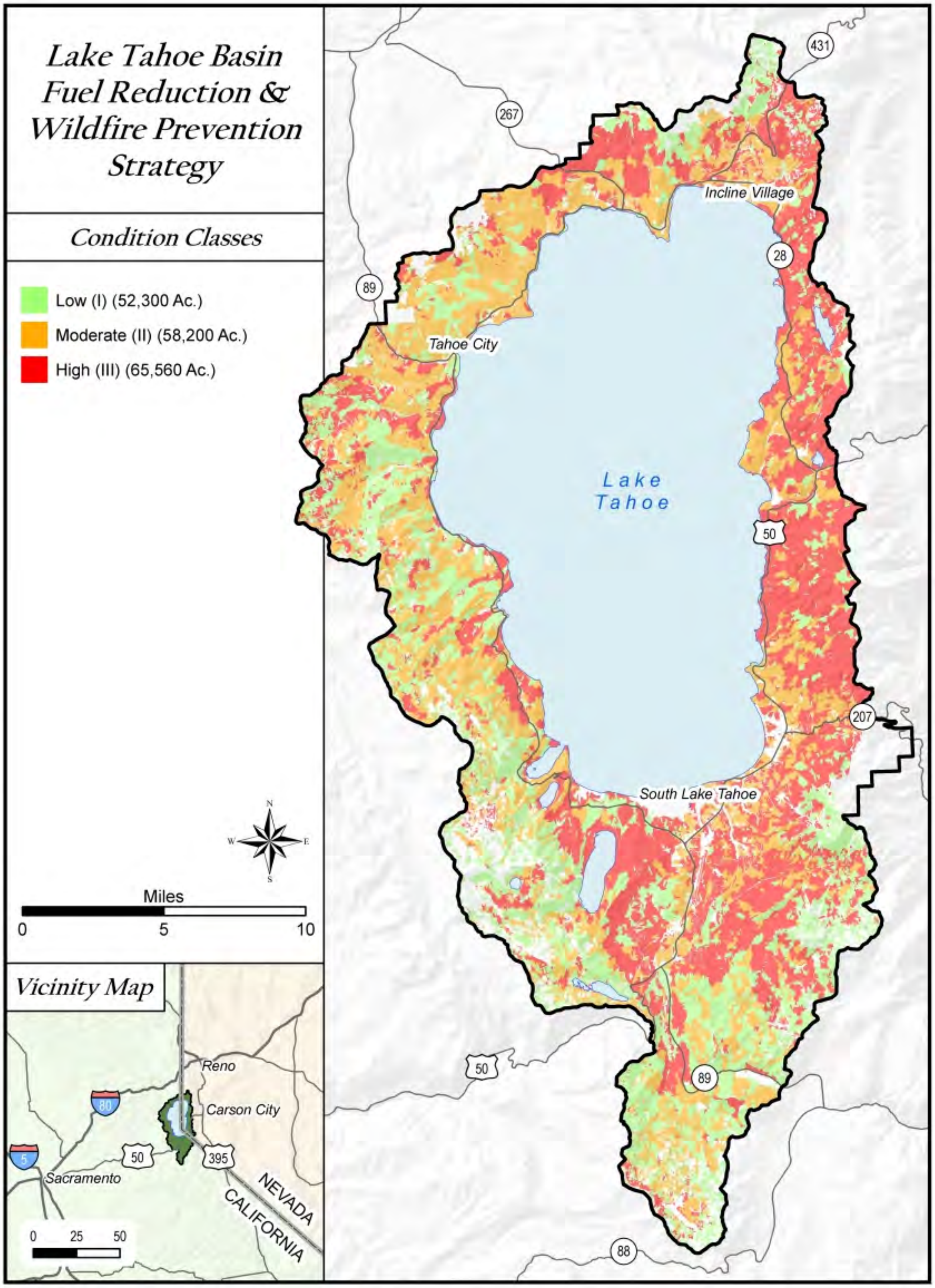


Figure 15. Fire regime condition class map

impacts on the local ecosystem. Areas in condition class II are upper montane forests and alpine areas where historic fire return intervals were much longer than those in the lower montane forest.

Current Wildfire Potential

The Lake Tahoe Basin Watershed Assessment (USDA Forest Service 2000a), SFA, and TRPA Plan quantified and assessed the wildfire threats in the Tahoe Basin. Fuels analyses, ignition history (Figure 16) and fire behavior modeling were used to predict fire susceptibility in the Basin. Wildfire potential based on modeling (FARSITE [Version 4.1.05, 2006], FLAMMAP [Version 3, 2006]), predicted fire behavior characteristics such as flame lengths and fire type. Both models use spatial information on topography and fuels along with weather and wind data. They incorporate existing models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration into a two-dimensional fire growth model. Predicted flame lengths were determined for the Basin using local weather conditions (Figure 17). This analysis found that approximately 42 percent of fuels conditions in the Basin would have flame lengths greater than 4 feet. Predicted fire types under normal weather conditions determined approximately 41 percent of the area would be considered to have low-moderate fire behavior (surface fire). Fire suppression crews can use direct attack strategies on these types of fires. Forty-eight percent is in the high fire behavior class (passive crown fire). Under these conditions, fire crews cannot use direct attack strategies and must rely on mechanized equipment and aerial support to suppress these fires. Approximately 11 percent received an extreme fire behavior rating (active crown fire). Under these conditions, additional resources such as retardant aircraft may be needed to suppress these fires (Figure 18).

In 2004, field surveys were conducted to evaluate fuel hazards, conduct structural assessments in communities, and identify and prioritize fuel reduction projects for Community Wildfire Protection Plans (Resource Concepts, Inc. 2004a, 2000b; C.G. Celio &Sons et al. 2004). When fire behavior was simulated in 60 sample plots in and near communities, 76 percent of the plots would result in a crown fire. These results were similar to fire behavior modeling conducted by the LTBMU (Holl 2007).

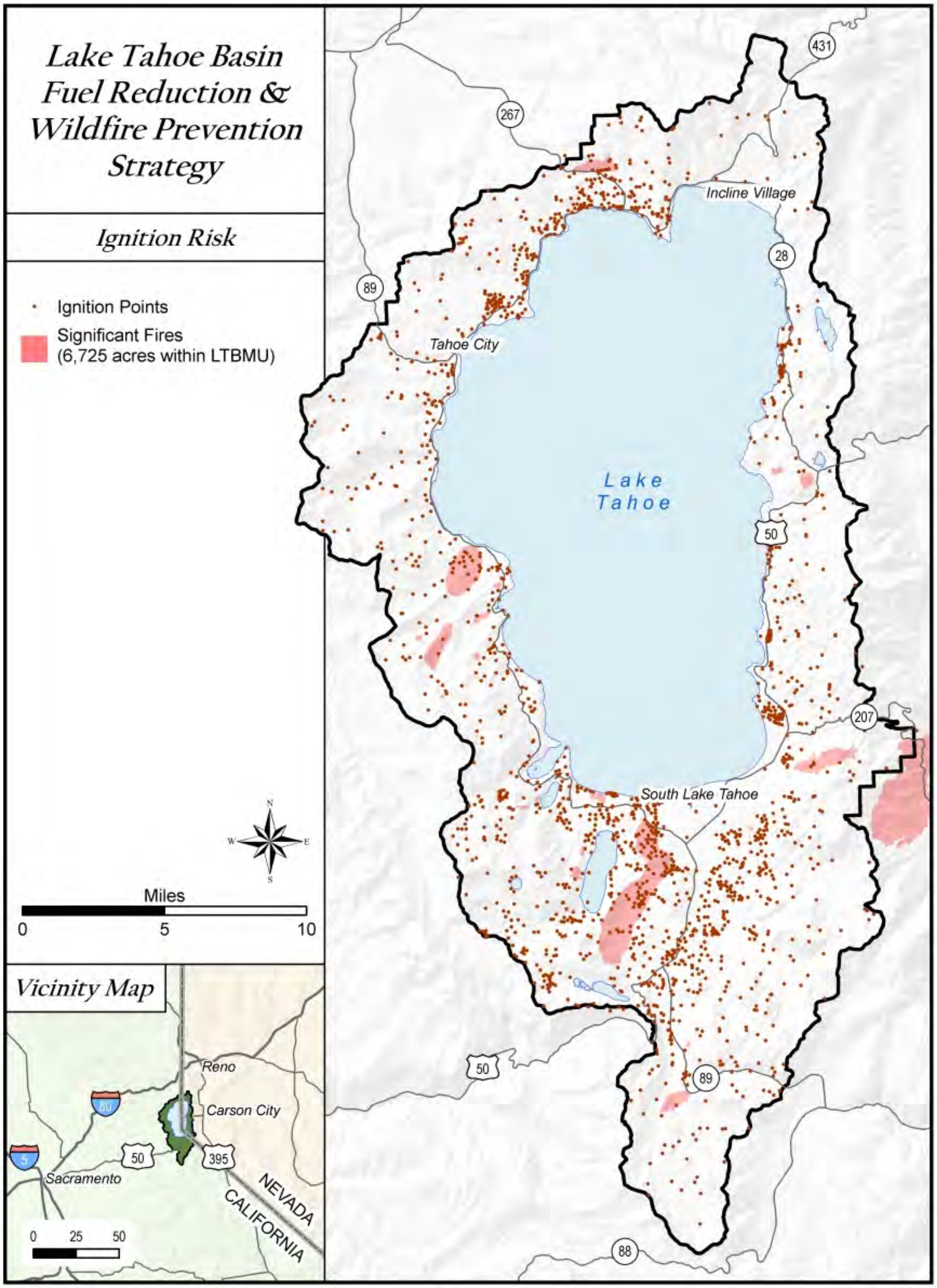


Figure 16. Ignition risk map

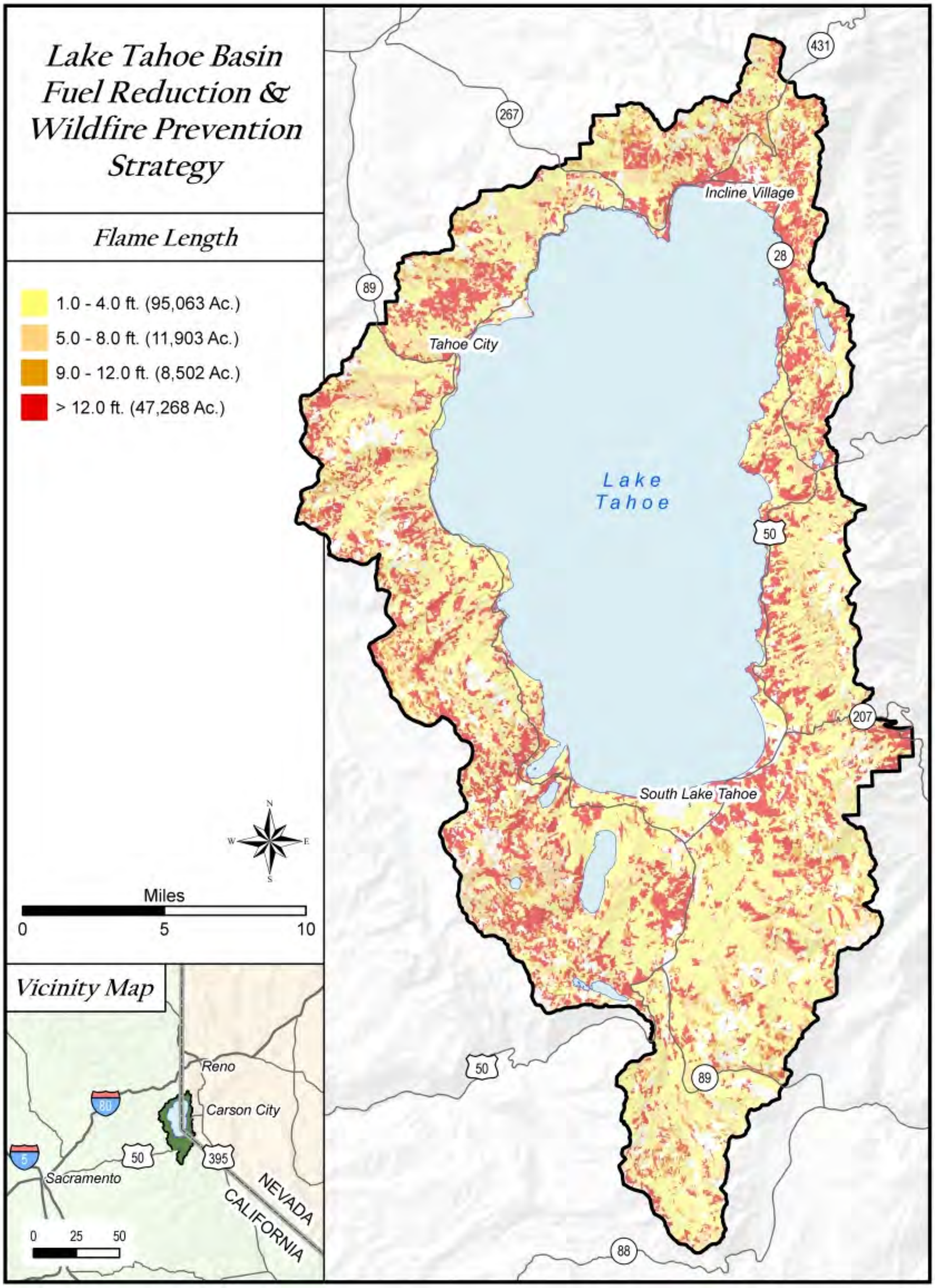


Figure 17. Predicted Fire Behavior: Flame Length

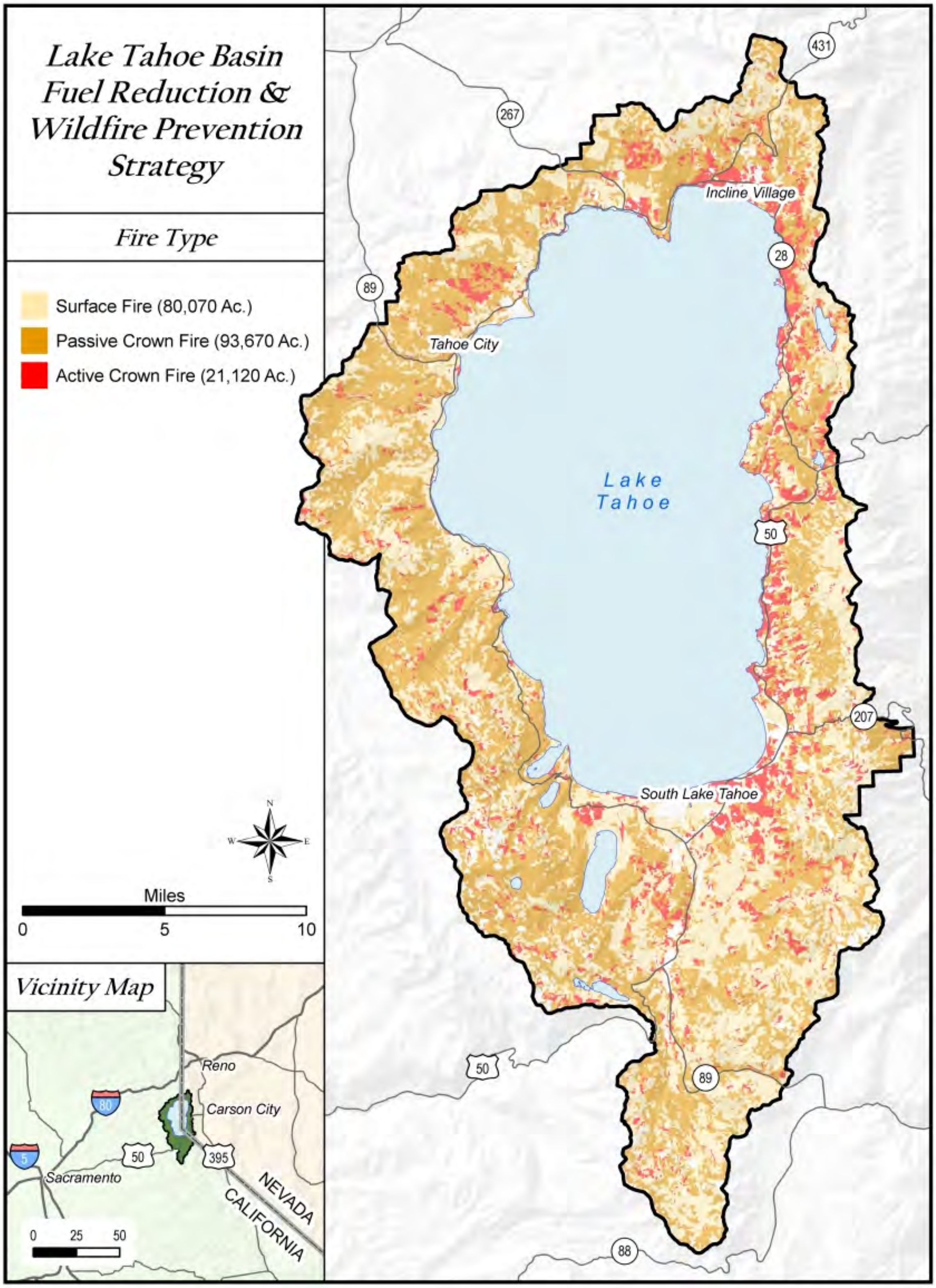


Figure 18. Predicted Fire Behavior: Crown Fire Potential

The majority of homes throughout the Basin lack defensible space (Table 7). The design and type of materials used in the construction of homes and the defensible space around those homes also influence fire behavior. Fire behavior becomes more extreme and uncontrollable in communities or neighborhoods that do not create defensible space, have unenclosed structures such as decks, and are built with flammable materials such as shake roofs. The majority of homes in the Basin have unenclosed structures such as decks, and flammable siding or roofs (Table 7). Estimates provided in Table 7 are from 2004 and considerable work has been accomplished since that time and therefore current estimates of structural hazards may be lower. More detailed evaluations are available in the individual Community Wildfire Protection Plans (Resource Concepts, Inc. 2004a, 2000b; C.G. Celio & Sons et al. 2004).

Table 7. Summary of structural hazards in the Lake Tahoe Basin (2004)

	Average Percentage of Lots or Homes			
Fire District	Without Defensi le Space	With Flamma le Unenclosed Structures	With Flamma le Roof Siding	Structural Rating
North Lake Tahoe FPD[1]	100	84.1	28 / 5.4	
Tahoe-Douglas FPD[2]	40.1	54.7	37.8 / 9.8	
Lake Valley FPD[3]	58.3	66.4		Moderate
South Lake Tahoe FD[4]	53	67	31 / 96	
Fallen Leaf FD[3]	71.3	76.6		Extreme
Meeks Bay FPD[3]	75.2	86.2		High
North Tahoe FPD[3]	87.8	59.4		High

**Note:* different methods were used to report data in the CWPPs.

Source: 1- Resource Concepts, Inc. (2004a); 2- Resource Concepts, Inc. (2004b); 3-C.G. Celio & Sons et al. (2004); 4-de Jong (2003)

Desired Conditions

The desired condition statements are goals that, when implemented, will trend current fire regime condition classes toward their historic norm and reduce fire behavior towards conditions where safe and effective fire suppression can be employed. Generally, this means reducing vegetation in proposed project areas toward historic levels (Low [I] condition class) resulting in fire behavior characteristics associated with surface fires (Table 8).

Table 8. Desired wildland fuel conditions

	Current Trend	Desired Trend
Fire Regime Condition Class	Moderate (II) to High (III)	Moderate (II) to Low (I)
Fire Behavior	Passive to Active Crown Fires with Flame Lengths that exceed 4 feet	Surface Fires with Flame Lengths less than 4 feet

Desired conditions for the planning area are derived from the Sierra Nevada Framework (Framework) (SNFPA SEIS 2004) and the Fuel Reduction and Forest Restoration Plan prepared for TRPA (Holl 2007). Fuel treatments on all federal lands will be consistent with the standards and guidelines identified in the Sierra Nevada Framework (SNFPA SEIS 2004). On all other land ownerships, fuel treatments will be consistent with the regulations, standards, and guidelines of the appropriate regulatory agencies. Desired vegetative conditions are described for the WUI and general forest where management direction and outcomes are clearly different.

Wildland Urban Interface

The WUI consists of three areas: the urban core, where the communities occur; the defense zone, which is the area generally 0.25 mile beyond the urban core; and the threat zone, which is the area up to 1.25 mile beyond the defense zone. The boundary of these areas can be adjusted based on specific site conditions or as determined at the project level (SNFPA SEIS 2004).

Urban Core

The urban core includes developed and undeveloped lots. The desired condition in the urban core is to reduce fire behavior characteristics to a surface fire. In California, defensible space shall be maintained on all non-federal parcels having a structure as required by Public Resource Code 4291. In Nevada, defensible space on developed lots will be established and maintained consistent with “Living with Fire in the Tahoe Basin” (Smith 2004). The desired condition of the undeveloped urban lots managed by the LTBMU and state agencies will be similar to the defense zone, described below.

Defense Zone

The management objective in this zone is to protect communities. In conifer forest types, predicted flame lengths will be less than 4 feet and preferably less than 2 feet, under 90th-percentile weather conditions. Crown base heights (the top portion of trees) will be managed to avoid all crown fires. Crown cover of forest stands will average 40 to 60 percent to allow for adequate spacing between crowns and to reduce surface wind speeds and drying of surface fuels. In shrub types, predicted rates of spread will be reduced 50 percent of pre-treatment simulated estimates. In shrub types with excessive dead material, predicted rates of spread will be reduced by 75 percent of pre-treatment simulated estimates.

Threat Zone

The management objective in this zone is to establish and maintain a pattern of treatments that are effective in modifying fire behavior and trending forests toward Low (I) and Moderate (II) fire regime condition classes. In conifer forest types, predicted flame lengths will generally be less than 4 to 6 feet; however, they may be higher in some locations. Crown base heights will be managed to avoid crown fires. Crown cover will vary and in some areas be less than 40 percent.

Grasses and patches of shrubs will be abundant in conifer stands where flame lengths are currently 6 feet or greater. In shrub types, predicted rates of spread will be reduced to 50 percent of pre-treatment simulated estimates. In shrub types with excessive dead material, rates of spread will be reduced by 90 percent of pre-treatment simulated estimates. Maintenance treatments will keep these areas within the desired conditions.

General Forest

The general forest includes all other lands beyond the WUI and below the alpine zone. The management objective in this zone is to establish a mosaic of treatments that are effective in modifying fire behavior and trending forests toward Low (I) and Moderate (II) fire regime condition classes. No planned treatments will occur in designated wilderness areas or research natural areas. Many planned treatments will be adjacent to existing roads where crews and machines have ready access; therefore, changes in the current forest structure and fuel hazards will be in a mosaic, based primarily on access. Crown cover will vary and in some areas will be less than 40 percent. Grasses and patches of shrubs will be abundant in stands with less than 40 percent canopy cover. In conifer forest types, predicted flame lengths will be less than 4 feet immediately after treatment and crown base heights will be managed initially to avoid the threat of a passive crown fire. In shrub types, predicted rates of spread will be reduced to 50 percent of pre-treatment simulated estimates. In shrub types with excessive dead material, predicted rates of spread will be reduced up to 90 percent of pretreatment simulated estimates. However, flame lengths will gradually increase in treated areas because little or no maintenance will occur in the general forest. Snags and coarse woody debris will continue to accumulate because of the lack of disturbance in most of this zone.

Predicted Outcomes

The existing fuel condition of the Lake Tahoe Basin is in a state of high departure from historical/desired conditions. This condition dramatically increases the potential of a surface fire transitioning into a crown fire. Each of the representative plans, on which this comprehensive plan is built, identify key values that are at risk and the vegetative stands that do not meet the desired conditions that put those values at risk. Proposed projects included in this plan are or will be designed with prescriptions to meet the desired conditions.

General prescriptions are designed to reduce fire behavior to the extent defined in each of the zones defined in this plan. These prescriptions are based upon proven strategies, science, and principles such as those detailed in “Living with Fire” (Smith 2004). The design and priority of the treatments are focused on the WUI and associated egress and transportation routes in the Basin. Approximately 25 percent of the forested acres in the Basin will be treated. Of this approximately 95 percent of the defense zone and 67 percent of the WUI will be treated creating adequate community defensible space (Figure 19).

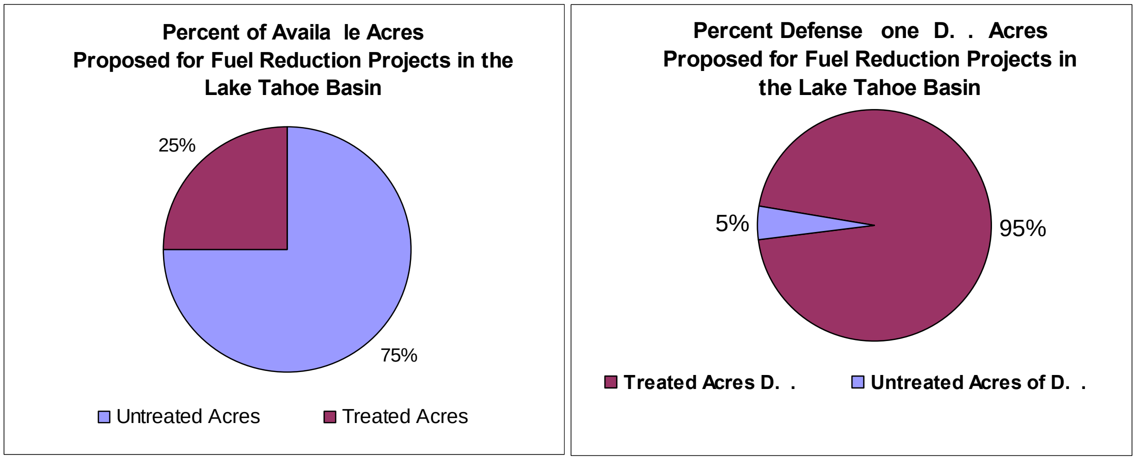


Figure 19. Percent of Basin-wide and defense zone acres proposed for fuel reduction projects

Based on review by wildland fire managers, the projects contained in the plan are expected to move wildland fuel conditions toward their desired fire regime condition class and fire behavior goals. Site-specific modeling of some project areas has confirmed this determination. Fire growth and fire behavior was modeled utilizing FARSITE and FLAMMAP fire simulation programs for multi-jurisdictional projects in the Kingsbury area. Results showed 1) approximately a 42 percent decrease in acres burned, 2) flame lengths were reduced by 27 percent, 3) crown fire potential was reduced by 8 percent, and 4) fireline intensity was reduced by 76 percent (Figure 20). Under this scenario, the outcomes of these combined treatments would meet the desired condition of reducing fire behavior and trending the area towards a lower fire regime condition class.

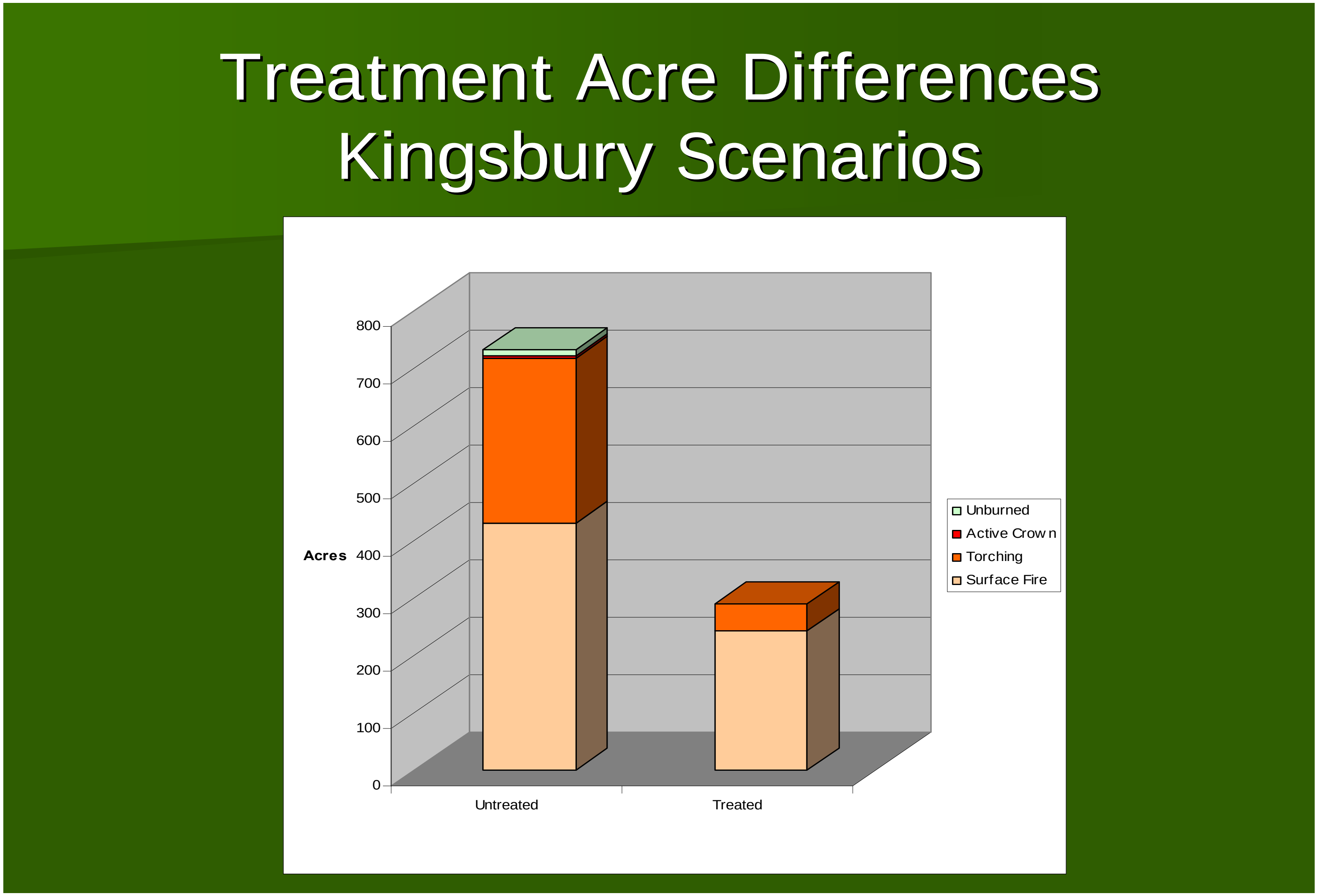


Figure 20. Post treatment outcomes for sample projects in the Kingsbury area

Section Environmental Regulations and Compliance

All individual projects designed to reduce fuel hazards that are proposed by public agencies, funded by public agencies, or that require federal, state, local, or local discretionary approval will be subject to federal, state, or regional environmental regulations. These regulations shape the scope, location, methodologies, timing, and cost of proposed fuel reduction treatments in the Basin.

Environmental regulations (such as the Clean Water Act, Clean Air Act, and Endangered Species Act) are designed to protect or reduce impacts on the environment, and allow the public to participate in agency decision-making processes that may affect the environment (e.g., National Environmental Policy Act and California Environmental Quality Act). Because of the unique values at risk in the Lake Tahoe Basin and complex land ownership, there are numerous regulations governing all activities in the Basin. Unlike other areas in the United States, in addition to federal and state laws, the Bi-state governing TRPA has a comprehensive Code of Ordinances that affects all agencies, organizations, and individuals. The extent of environmental compliance is determined by the land ownership where the project is occurring, the funding agency, the complexity of the project, and the number of regulations that govern a project (Figure 21).

National Policies and Regulations

Several national policies and regulations guide wildland fire management. They include the National Fire Plan, 10-Year Comprehensive Strategy (USDI and USDA 2001); National Fire Plan 10-Year Comprehensive Strategy Implementation Plan (USDI and USDA 2002); Federal Wildland Fire Policy (USDI et al. 1995 [updated 2001]); Healthy Forests Initiative (2002); Healthy Forests Restoration Act (2003); and Protecting People and Natural Resources: A Cohesive Fuels Treatment Strategy (USDI and USDA 2006). This plan is consistent with all of these policies and regulations, which are described below.

The National Fire Plan and 10-Year Comprehensive Strategy

The National Fire Plan was developed by the U.S. Department of the Interior and U.S. Department of Agriculture in 2000 to actively respond to severe wildland fires and their impacts to communities while ensuring sufficient firefighting capacity for the future. It provided direction for the identification of “communities at risk”, which are located in the vicinity of federal lands where wildland fires have the potential to threaten adjacent private lands. Identifying communities at risk has assisted planning for fuel reduction projects on federal lands and increased awareness of wildfire threats in those communities. Communities at risk in the Lake Tahoe Basin are Incline Village, Crystal Bay, Sand Harbor, Glenbrook, Kingsbury, South Lake Tahoe, City of South Lake Tahoe, Homewood, Tahoe Pines, Sunnyside, Tahoe City, Dollar Point, Carnelian Bay, Tahoe Vista, and Kings Beach (*Federal Register*, 66(160): 43384-43435).

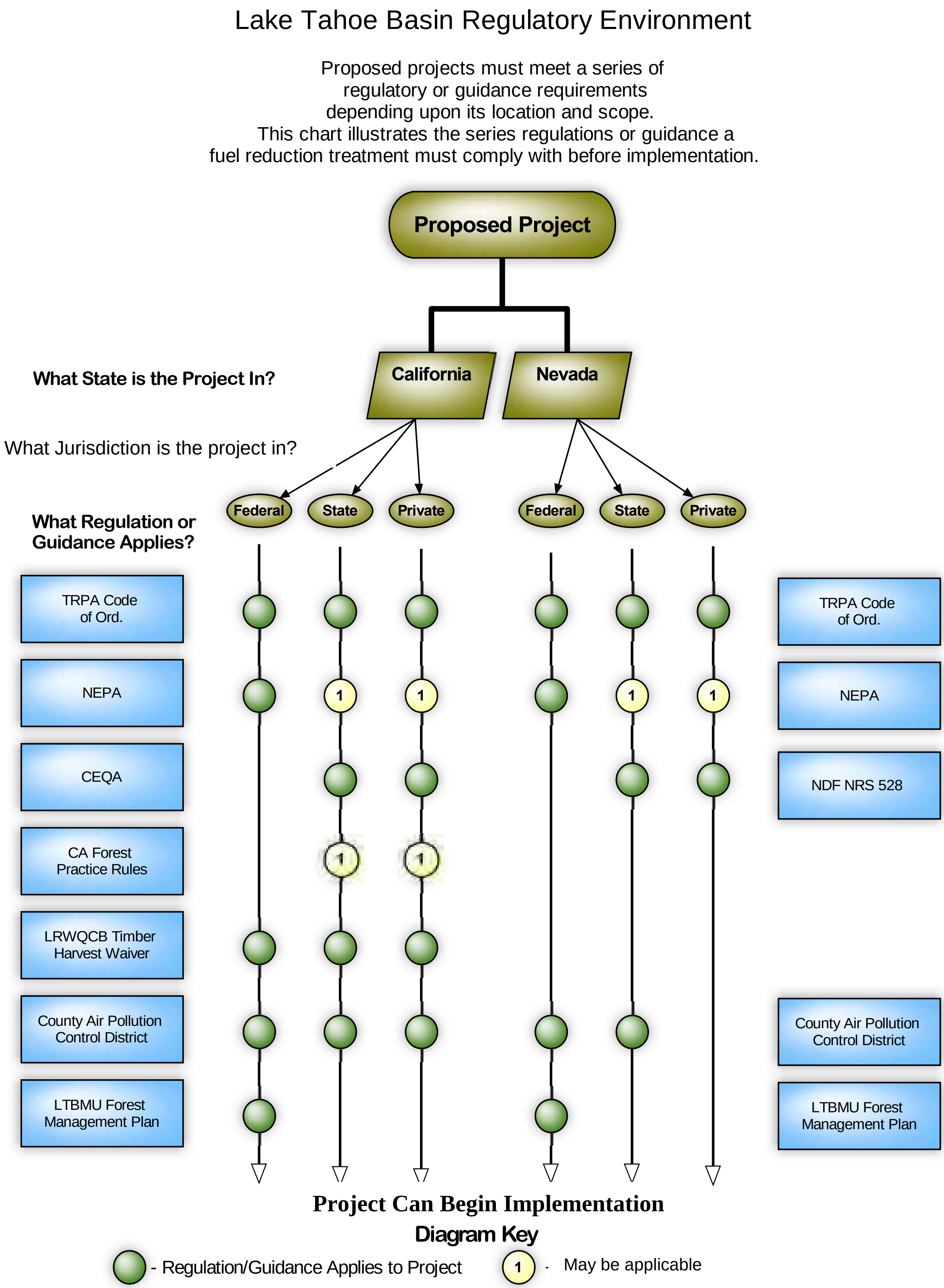


Figure 21. Diagram of the regulatory influences on fire and fuels management in the Lake Tahoe Basin

National Environmental Policy Act

All fuel reduction projects funded by the Federal Government that occur on federal land (such as LTBMU), or require a federal agency to issue a permit, must comply with the National Environmental Policy Act (NEPA). The Act requires agencies to prepare environmental impact statements (EISs), environmental assessments (EAs), or categorical exclusions (CEs) to evaluate potential impacts of proposed projects on the quality of the human environment. These analyses may be used to satisfy other requirements as required by TRPA or the California Environmental Quality Act.

The Healthy Forest Restoration Act (H.R. 1904, December 2003)

The Healthy Forest Restoration Act (HFRA) simplifies the NEPA process by limiting the range of alternatives that are required to be considered in an environmental document that involves fuel reduction or forest health projects designed to protect communities, watersheds, or endangered or threatened species from wildfire. HFRA also changed the USDA Forest Service administrative appeal process for NEPA decisions to a simpler objection process.

HFRA allows communities to designate their WUI; authorizes fuel reduction projects on federal lands in the WUI; requires federal agencies to consider recommendations made by communities at risk that have developed Community Wildfire Protection Plans, and gives funding priority to communities that have adopted Community Wildfire Protection Plans. At the Lake Tahoe Basin HFRA/Wildfire Prevention Summit on March 13, 2004, fire officials from Lake Tahoe accepted the challenge to develop Community Wildfire Protection Plans for its communities. Community Wildfire Protection Plans were prepared for and approved by the state fire and forestry agencies, the fire protection districts and fire departments in the Basin (Resource Concepts, Inc. 2004a, 2004b; C.G. Celio & Sons et al. 2004). EAs and EISs documenting HFRA authorized projects may consider only one action alternative if that alternative meets certain WUI criteria and implements the general actions of an applicable Community Wildfire Protection Plan.

Regional Policies and Regulations

TRPA Regional Plan Thresholds and Carrying Capacities

TRPA's Threshold Carrying Capacities are standards of environmental quality targets to be achieved in the Tahoe Region. The standards identify the level of human impact the Lake Tahoe environment can take before irreparable damage occurs. The thresholds and carrying capacities identify common vegetation, uncommon plant communities, sensitive plants, and late seral-old growth ecosystems.

TRPA Code of Ordinances

TRPA primarily regulates tree removal through Chapter 71 of its Code of Ordinances. Removal of all trees greater than 6 inches in diameter requires a tree permit; however, TRPA has delegated authority to issue tree removal permits to most local fire agencies for defensible space treatments. A tree removal permit must be approved for all projects that require substantial removal of trees, which is defined as removing more than 100 trees greater than 10 inches in diameter in an area greater than 20 acres or on land capabilities 1a, 1b, 1c, 2, or 3 (Bailey 1974), which consist of a wetlands or other sensitive lands.

LTBMU Land Management Plan/Sierra Nevada Framework

All management activities conducted by the LTBMU are governed by the Lake Tahoe Basin Management Unit Land and Resource Management Plan (USDA Forest Service 1988, as amended by the Sierra Nevada Forests Plan Amendment [SNFPA SEIS 2004]). The plan recognized the excessive buildup of fuel hazards in the Sierra Nevada Mountains surrounding the lake and established that the highest priority for fuels treatments would be in the WUI areas.

California Environmental Quality Act (CEQA)

Fuel reduction projects on private lands and state lands that require approval by a local or state agency must comply with CEQA or a functionally equivalent program (e.g., the California Forest Practice Rules). The documentary requirements for CEQA are very similar to those for NEPA. Most projects in the Basin will require an initial study and negative declaration to comply with CEQA. Projects involving hand thinning only require a categorical exemption. In some cases, if a CAL FIRE-required harvesting document is prepared in lieu of a traditional CEQA document (such as Timber Harvest Plan) when harvested material has a commercial purpose, it must be signed and prepared by a California Registered Professional Forester. Also, timber operations must be conducted by a California Licensed Timber Operator. Some small projects, such as defense zone clearing, are generally exempt from CEQA or a functionally equivalent program. In addition, opportunities exist to complete CEQA and NEPA documents using a joint analysis.

California Timber Harvest Plans

The cutting and removing of trees for a commercial purpose as per Public Resource Code 4527 require the preparation and submittal of a CAL FIRE harvesting document. Most of these documents, such as timber harvest plans, conversion exemptions, fuels reduction exemptions, etc, are required to be prepared and signed by a California Registered Professional Forester as per Public Resource Code 4581.

California PRC 4291

PRC 4291 applies to everyone that owns or maintains a structure on lands covered with flammable vegetation. It requires homeowners to create defensible space around their structures where firefighters can provide protection during a wildfire. However, it should be noted that enforcement of these provisions can only be accomplished to the extent that funding and manpower of responsible agencies allow.

Lahontan Regional Water Quality Control Board Basin Plan

The California Water Quality state board sets statewide policy for the implementation of state and federal laws and regulations. The Lahontan Regional Water Quality Control Board is responsible for protecting water quality and enforcing the California Water Code and the Clean Water Act. It enforces its Water Quality Control Plan that includes implementation plans and policies.

Nevada Division of Forestry NRS 528

NRS 528 regulates forest practices and reforestation on private and state lands in Nevada.

Nevada NRS 472.041

NRS 472.041 is the enforcement of certain provisions of Uniform Fire Code regarding clearance of vegetation around structures. It should be noted that enforcement of these provisions can only be accomplished to the extent that funding and manpower of responsible agencies allow.

Agency Regulatory Responsibility

Several land management and regulatory agencies are responsible for complying with and enforcing regulations in the Lake Tahoe Basin. They include the USDA Forest Service, Tahoe Regional Planning Agency (TRPA), Lahontan Regional Water Quality Control Board, California Department of Forestry and Fire Protection, Nevada Division of Forestry, California Tahoe Conservancy, California State Parks, local Fire Protection Districts, and the Tahoe Regional office of the Nevada Fire Safe Council.

Land Management Agencies

USDA Forest Service Lake Tahoe Basin Management Unit

The USDA Forest Service Lake Tahoe Basin Management Unit (LTBMU) is responsible for managing approximately 80 percent of the land base and its resources in the Lake Tahoe Basin. All management activities conducted by the LTBMU are governed by the Lake Tahoe Basin Management Unit Land and Resource Management Plan (USDA Forest Service 1988, as amended by the Sierra Nevada Forests Plan Amendment [SNFPA SEIS 2004]).

California Department of Forestry and Fire Protection (CAL FIRE)

CAL FIRE is responsible for enforcing the California Forest Practices Act on state and private timberland in California. CAL FIRE is also responsible for providing input or enforcing, depending on local situation, pre-development fire protection stands (PRC 4290), defensible space law (PRC 4291), and the Wildland Urban Interface Building Code.

In addition, CAL FIRE works with other internal programs, such as the California Office of the State Fire Marshal, California State Board of Forestry and Fire Protection, and CAL FIRE's Fire and Resource Assessment Program (FRAP). The California Office of the State Fire Marshal is also part of CAL FIRE. The mission of the State Fire Marshal is to protect life and property through the development and application of fire prevention engineering (such as the Wildland Urban Interface Building Standards), education, and enforcement. The California State Board of Forestry and Fire Protection's ("Board") mission is to provide policy leadership and to generate public interest and support in those matters key to the future of the state's forest and rangelands, including but not limited to PRC 4291, the California Forest Practice Act, and PRC 4290. The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) assesses the amount and extent of California's forests and rangelands, analyzes their conditions and identifies alternative management and policy guidelines..

California State Parks

There are six State Parks within the Basin: Burton Creek State Park, Ward Creek State Park, Sugar Pine State Park, D.L. Bliss State Park, Emerald Bay State Park, and Washoe Meadows State Park. The mission of California State Parks is to provide for the health, inspiration, and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation. Their role is also to manage the natural resources on lands they administer.

California Tahoe Conservancy

The California Tahoe Conservancy (CTC) is an agency within the Resources Agency of the State of California. Its jurisdiction extends only to the California side of the Lake Tahoe Basin. It was established to develop and implement programs through acquisitions and site improvements to improve water quality in Lake Tahoe, preserve the scenic beauty and recreational opportunities of the region, provide public access, preserve wildlife habitat areas, and manage and restore lands to protect the natural environment.

The properties managed by CTC within the Basin consist of about 4,800 parcels; of which the average size is one-third acre or less. Most of these parcels are within the WUI. The CTC is also responsible for planning and implementing projects on their respective lands that restore ecosystem health by reducing fuel hazards. They are responsible for ensuring their plans are consistent with federal, state, and local laws, regulations, and policies.

Nevada Division of Forestry

The Nevada Division of Forestry manages all forestry, nursery, endangered plant species, and watershed resource activities on certain public and private lands within the Basin. The Division also provides fire protection of structural and natural resources through fire suppression and prevention programs and other emergency services. The Nevada Division of Forestry is responsible for enforcing Nevada Revised Statutes (NRS) 528.

The Nevada Tahoe Resource Team, an interagency team within the Department of Conservation and Natural Resources, is responsible for implementing forest health and fuel reduction projects on State of Nevada property in the Lake Tahoe Basin.

Nevada State Parks

The Nevada Division of State Parks administers and manages the Lake Tahoe State Park, which includes beaches, fishing, and camping, and over 13,000 acres of backcountry recreation. The Carson Range State Parks in conjunction with the Nevada Tahoe Resource Team has prepared a plan to reduce fuel hazards and restore forest health in the park.

Nevada Division of State Lands

Nevada Division of State Lands manages 485 urban parcels in the Lake Tahoe Basin from Crystal Bay to Kingsbury, Nevada. These are managed by Nevada Tahoe Resource Team (see above). The urban parcels are managed by the State Lands forester and a seasonal forester; there are 140 urban parcels (106 acres) in Douglas County and 345 urban parcels (108 acres) in Washoe County. These parcels are managed in accordance to a MOU with the TRPA as well as Nevada Laws on Forestry and Fire, Nevada Revised Statues 472, 527 & 528, which pertain to establishing a healthy forest and watershed protection of trees and flora by recognizing implemented forest practices.

Regulatory Agencies

Tahoe Regional Planning Agency

The Tahoe Regional Planning Agency (TRPA) is a bi-state agency created by the states of Nevada and California to lead a cooperative effort to preserve, restore, and enhance the unique natural and human environment of the Lake Tahoe Basin. TRPA enforces the TRPA Regional Plan.

Lahontan Regional Water Quality Control Board

The Lahontan Regional Water Quality Control Board is responsible for water quality and enforcing California State Water Code. It regulates forest management practices and activities on stream environment zones.

California Air Resources Board

The Lake Tahoe Basin is its own air basin, shared by California and Nevada. Air quality in the Tahoe Basin is managed by two state agencies, the California Air Resources Board of the California Environmental Protection Agency and Nevada Bureau of Air Pollution Control; and three county agencies, Placer County Air Pollution Control District (APCD), El Dorado County APCD, and Washoe County District Board of Health. The state agencies determine if burning is allowed on a daily basis. The individual county agencies are responsible for issuing burn permits and enforcing state regulations.

Nevada Department of Environmental Protection

Nevada Department of Environmental Protection plays a role in air and water quality in the Lake Tahoe Basin for the Nevada Division of State Lands and their urban parcels. Nevada Division of State Lands is required to apply for a burn permit when burning in Douglas County of the Lake Tahoe Basin. In addition, the Washoe County District Health Department is involved with the burn permit process in the Washoe County portion of the Lake Tahoe Basin. MOUs with these agencies require Nevada land management agencies to follow their guidelines and regulations in smoke management.

Section Pu lic Education and Wildfire Prevention Plans

Key to the success of the proposed community defense and general forest-based treatments in this plan is continued public outreach to facilitate private landowners in the Basin to develop defensible space around individual homes and buildings. Surveys conducted in 2003 and 2004 determined 70 percent of the residences did not have adequate defensible space to protect them from a wildfire (Resource Concepts, Inc. 2004a, 2004b; C.G. Celio & Sons et al. 2004). While defensible-space clearing around rural residences has been the law for a long time in California, it is only recently being enforced.

Intertwined with these physical facts are social issues. Most of the Basin's residents elected to live in Lake Tahoe to take advantage of the rural setting or the diverse recreation opportunities. Previous experiences undoubtedly forged many of their concepts of what forests provided and how they should be managed. federal and state policies strongly advocated fire suppression. Media attention of extensive clearcut logging on public lands in the 1970s and 1980s initiated a common belief that all logging sacrificed irreplaceable natural resources.

Faced with these challenges, federal, state, and local agencies and organizations have made substantial progress to reduce fuel hazards and educate the public. Currently, all of the federal and state land management agencies and local fire agencies develop and provide information in various formats to educate the public.

Under the Cooperative Fire Agreement between CAL FIRE and the LTBMU, the LTBMU is responsible for wildland fire suppression on all SRA lands in California within the Basin. CAL FIRE does not have fire suppression resources stationed in Lake Tahoe. Nevada Division of Forestry provides fire protection for state lands on the Nevada side of the lake. Seven fire protection districts provide municipal fire protection in Lake Tahoe: South Lake Tahoe FD, Lake Valley FPD (Meyers), Fallen Leaf VFD, Meeks Bay FPD, North Tahoe FPD (Tahoe City), North Lake Tahoe FPD (Incline Village), and Tahoe Douglas FD (south of Incline to Stateline, Nevada). LTBMU works cooperatively with every fire department on mutual aid, public education, and Basin-wide community fire planning, including hazard fuel reduction.

Current Efforts

Fire Prevention Plans: To various extents, each cooperating agency has developed a wildfire prevention plan. For example, the USDA Forest Service has developed a comprehensive prevention plan that focuses on education, detection, engineering, and enforcement. This plan details patrolling, media outreach, public education, and annual public events that the LTBMU actively supports. The plan is implemented by a dedicated prevention staff that includes three fire prevention technicians and a fire prevention officer.

One-on-One Contacts: All of the local fire agencies and the Nevada Fire Safe Council provide staff that meets with individual residents during defensible space inspections and during subsequent clearing operations. While these contacts are time consuming and inefficient, they may be the most effective because they are focused and result in the desired effect. Additionally, these organizations also provide free literature to residents, with the most common being "Living with Fire – A Guide for the Homeowner." This handout was developed by the University of Nevada Cooperative Extension, with over two million copies printed, including a customized version for the Lake Tahoe Region. The Nevada Division of State Lands also distributes a programmatic brochure prior to fuel related projects as part of its community outreach.

Community Events: All of the federal, state, and local agencies participate in demonstrations and community events, including several sponsored by the Nevada Fire Safe Council, which developed and nurtured 21 Fire Safe Chapters in individual communities throughout the Lake Tahoe Basin. These chapters are instrumental in encouraging individuals in those communities to actively participate in defensible space clearing and establishing fuelbreaks adjacent to communities. They are also sponsoring free barbeques in a few communities to encourage residents to participate in and learn how defensible space should be developed. The Nevada Fire Safe Council also developed and mailed over 7,000 flyers announcing three regional demonstrations in 2007. These demonstrations have occurred in a selected neighborhood on the north shore, south shore, and in Incline Village, where hands-on demonstrations of defensible-space clearing have be discussed and performed by staff.

Websites and Public Service Announcements: The majority of the local fire agencies and Nevada Fire Safe Council host websites that offer extensive information on defensible space inspections, defensible space requirements, free chipping services to dispose of hazardous fuels, and links to other sources of information. The most common link is to http://www.livingwithfire.info, a multi-agency sponsored website that provides extensive information on what residents should do before, during, and after a wildland fire. All of the agencies also support and participate in public service announcements that focus on defensible space requirements and public safety.

Future Efforts

The current efforts have resulted in substantially more residents complying with the defensible space requirements. Additional efforts will be required in the future to obtain defensible space compliance from the large number of absentee residents whose periodic visits focus on recreation. Efforts should also be focused on educating residents and regulatory agencies about changing the current forest conditions to restore the health of those forest stands and encouraging residents to develop defensible space around their homes. Therefore, an effective education program will be continued that addresses the following two paradigms:

- It is the responsibility of landowners to create and maintain defensible space around their structures (required in California per PRC 4291); and
- Lake Tahoe's forest ecosystems and watersheds will thrive under a managed disturbance regime.

Section 1 Conclusions

The key values of the Lake Tahoe Basin are at risk to catastrophic wildfire due to dense and overstocked forests. Implementation of this plan will help protect the people, property, and natural values of the Basin by changing fire behavior in prioritized stands in the Basin into a less volatile state. Across many jurisdictions, this plan will treat approximately 68,000 acres over the next 10 to 15 years. These treatments were proposed by the 17 participating agencies and were designed to meet the local and Basin-wide needs of their particular jurisdictions. The treatments range from small urban lots to large strategically placed general forest treatments (discussed previously as SPLATs). Collectively, treatments are predicted to reduce potential fire behavior and trend treated forests towards desired fire regime condition classes. Implementation of this plan is predicted to cost from $206,000,000 to 244,000,000 over 10 years with annual predicted expenditures of $18,500,000 to $25,500.000.

While this plan proposes fuel reduction treatments in and around communities and the general forest throughout the Basin, one key to its success is the simultaneous development of defensible space around private residences, buildings, and the general infrastructure of the area. Participating agencies and organizations will facilitate this through an active education and enforcement campaign.

The partners to this plan and the Planning Cadre recognize that collaboration on several key focus areas should continue to ensure this plan’s success. These focus areas include:

- Identifying pathways for regulatory collaboration in areas such as air quality, stream environment zones, limited operating periods, and watershed protection;
- Strategies to reduce planning and implementation costs associated with access issues and the use of innovative treatment techniques;
- Facilitating partnerships with potential biomass end users;
- Developing and maintaining an adequate staff and contractor resource pool to implement the proposed projects; and
- Identifying efficient mechanisms to implement projects over multiple jurisdictions.

Finally, this plan will only be as successful as the continued commitment that each participating agency has to coordinate, communicate, and collaborate with each other and the people they serve. This continuing commitment will result in responsive and cost-effective wildfire prevention that ultimately will protect the people and values at risk treasured in the Lake Tahoe Basin.

The federal, state and local land managers, Lake Tahoe Fire Agencies and Nevada Fire Safe Council will meet annually to review the results of the prior year fuels reduction efforts and identify fuels reduction projects and priorities, within the scope of this Strategy, for the upcoming year. Future projects identified by this group will meet the intent of this Strategy and meet the intent of all the underlying Implementation Plans including the Community Wildfire Protection Plans for the Lake Tahoe Basin. Projects will be prioritized for funding submission consistent with this Strategy and current direction and intent. Where projects cross jurisdictional boundaries, the group will collaborate on implementing the project with the goal of reducing environmental compliance, permitting and contracting costs.

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California Tahoe Conservancy http://www.tahoecons.ca.gov/

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Appendi A Biomass Federal State Policies

The following federal and state policies and resolutions have been developed to support the development of a biomass facility(s) in or near the Lake Tahoe Basin.

- The Healthy Forest Restoration Act of 2003 (H.R. 1904) encourages the accelerated adoption of technologies that use biomass and the establishment of small-scale business enterprises that make use of biomass (Title 3, Section 202).
- The Federal Energy Act of 2005 (P.L. 109-190) authorized the appropriation of federal subsidies for biomass development for a 10-year period (2006-2016). Specifically, it provides grants not to exceed $20 per green ton (GT) of biomass to current operators of biomass facilities and grants for developing or researching biomass opportunities.
- The Western Governor's Association adopted a resolution, the Clean and Diversified Energy Initiative, to develop 30,000 megawatts (MW) of clean and diverse energy by 2015 and accepted a set of recommendations to implement that recommendation in June 2006.
- California and Nevada passed renewable portfolio standards requiring energy producers and suppliers to include 20 percent and 15 percent, respectively, of renewable energy in the mix of available energy provided in those states.
- The Nevada Legislature's Task Force on Renewable Energy approved a resolution encouraging the beneficial use of biomass, which will be forwarded for adoption during the 2007 legislative session.
- In April 2006, Governor Schwarzenegger signed an Executive order reaffirming the 20 percent target for energy production and directed the Resources Agency and Energy Commission to coordinate efforts among state agencies to promote the use of biomass.
- In February 2007, Governor Gibbons signed an executive order supporting development of renewable energy and focusing on streamlining the permitting process.
- The USDA Forest Service recently drafted a woody biomass utilization strategy that focuses on providing sustainable supplies of materials, empowering entrepreneurial partnerships, using the best science and technology, and effective marketing (USDA Forest Service, January 9, 2007).

Appendi B Cooperating Agency Letters of Support

California Tahoe Conservancy
California State Parks
Nevada Division of Forestry
Nevada Division of State Lands
Nevada Division of State Parks
Nevada Fire Safe Council
USDA Forest Service
Tahoe Regional Planning Agency
Tahoe Basin Fire Chiefs
- Fallen Leaf Fire Department
- Lake Valley Fire Protection District
- Meeks Bay Fire Protection District
- North Lake Tahoe Fire Protection District
- North Tahoe Fire Protection District
- South Lake Tahoe Fire Department
- Tahoe-Douglas Fire Protection District

STATE OF CALIFORNIA — THE RESOURCES AGENCY

ARNOLD SCHWARZENEGGER, *Governor*

CALIFORNIA TAHOE CONSERVANCY
1061 Third Street
SOUTH LAKE TAHOE, CA 96150
(530) 542-5580

September 24, 2007

To Whom It May Concern:

The California Tahoe Conservancy very much appreciates the efforts of the USDA Forest Service, Lake Tahoe Management Unit in leading the effort to develop the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. The plan provides a solid framework for the coordinate effort to address fuels issues in the Tahoe Basin.

The California Tahoe Conservancy has been actively engaged in the development of the plan, which incorporates the Conservancy's Fuels Management efforts into the comprehensive plan.

The Conservancy fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together and coordinate their activities.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Sincerely,

Richard J. Robinson
Natural Resources Program Manager

State of California • The Resources Agency
Arnold Schwarzenegger, *Governor*

DEPARTMENT OF PARKS AND RECREATION
Ruth Coleman, *Director*

Sierra District
PO Box 266
Tahoma, CA 96142

August 15, 2007

To Whom It May Concern:

Over the past six months, the Sierra District of California State Parks has been actively engaged in the preparation, assemblage, and review of the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. Prior to that, we developed plans for our jurisdiction which have now been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Sincerely,
Ron Anderson For Pam Armas

Pam Armas
Sierra District Superintendent
California State Parks

ALLEN BIAGGI, *Director*
Department of Conservation
And Natural Resources

JIM GIBBONS
Governor

PETE ANDERSON
State Forester Firewarden

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
NEVADA DIVISION OF FORESTRY
2478 Fairview Drive
Carson City, Nevada 89701
Phone (775) 684-2500 Fax (775) 684-2570

8/23/2007

To Whom It May Concern:

Over the past six months, the Nevada Division of Forestry has been actively engaged in the preparation, assemblage, and review of the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. Prior to that, we developed a separate plan for our jurisdiction which has now been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Pete Anderson
State Forester Firewarden

ALLEN BIAGGI
Director

Department of Conservation
and Natural Resources

PAMELA B. WILCOX
Administrator

JIM GIBBONS
Governor

State Land Office
State Land Use Planning Agency
Nevada Tahoe Resource Team
Conservation Bond Program -Q1

Address Reply to

Division of State Lands
901 S. Stewart St. Suite 5003
Carson City, Nevada 89701-5246
Phone (775) 684-2720
Fax (775) 684-2721
Web www.lands.nv.gov

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Division of State Lands

8/22/2007

To Whom It May Concern:

Over the past six months, the Nevada Division of State Lands has been actively engaged in the preparation, assemblage, and review of the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. Prior to that, we developed a separate plan for our jurisdiction which has now been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Pamela Wilcox
Nevada Division of State Lands Administrator

ALLEN BIAGGI
Director
Department of Conservation and Natural Resources

DAVID K. MORROW
Administrator

JIM GIBBONS
Governor

STATE OF NEVADA

Address Reply to:
901 S. Stewart Street, Suite 5005
Carson City, Nevada 89701-5248

Phone: (775) 684-2770
Fax: (775) 684-2777
stparks@parks.nv.gov
http://parks.nv.gov

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF STATE PARKS

August 23, 2007

To Whom It May Concern:

Subject: Letter of Support

Over the past six months, the **Nevada Division of State Parks** has been actively engaged in the preparation, assemblage, and review of the 10-Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. Prior to that, we developed a separate plan for our jurisdiction which has been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of the 10-Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Sincerely,

David K. Morrow,
Administrator

The Nevada Fire Safe Council

Andrew List, Executive Director (775) 884-4455 nvfiresafe@charter.net
Terry Sumner, Executive Assistant (775)-884-4455 firesafeoffice@yahoo.com
Pat Murphy, Sierra Front (775) 267-2123 papamurph1110@charter.net
John Pickett, Tahoe Basin, California (775) 220-7675 firesafechapters@yahoo.com
Jason Arnold, Tahoe Basin, Nevada (775) 220-6000 nvfsctahoebasin@yahoo.com
Jessica Mahnken, Tahoe Basin, Lake Valley(775) 577-3739 tahoefiresafe@sbcglobal.net
Mike McCarty, Northeastern Nevada (775) 744-2526 mmnfsc@hotmail.com
Kim Otero, Southern Nevada (702) 496-4114 nvfscsouth@mvdsl.com

Post Office Box 2724 Carson City, Nevada 89702
Phone (775) 884-4455 * fax (775) 884-4457 * www.nvfsc.org

December 3, 2007

Terri Marceron, Forest Supervisor
Lake Tahoe Basin Management Unit
35 College Drive
South Lake Tahoe, CA 96150

The Nevada Fire Safe Council, working with 30+ grass roots communities throughout the Lake Tahoe Basin, supports the *Lake Tahoe Basin Multi-Jurisdictional Fuel Reduction and Wildfire Prevention Strategy*. We believe that the plan and processes set forth in the strategy represent a multi-jurisdictional and unified approach to reducing the risk of catastrophic loss due to wildfires in the Lake Tahoe Basin.

As part of this strategy, the Nevada Fire Safe Council is dedicated to working with private landowners, fire protection districts and fire departments, and governmental entities to reduce fuels that increase the wildfire risk throughout the Basin and also educate the general public about the importance of fire prevention and creating defensible space within and around neighborhoods.

We look forward to the implementation phase of this plan and working with our private and public partners to fire safe the Lake Tahoe Basin.

Sincerely,

Andrew List, Executive Director
The Nevada Fire Safe Council

United States Department of Agriculture | Forest Service | Lake Tahoe Basin Management Unit | 35 College Drive
South Lake Tahoe, CA 96150
(530) 543-2600

File Code: 5150-1
Date: August 14, 2007

,

To Whom It May Concern:

Over the past six months, Lake Tahoe Basin Management Unit of the U.S. Forest Service has been actively engaged in the preparation, assemblage, and review of the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan (Plan). Prior to that, we developed a Stewardship Fireshed Assessment (SFA) that lays out our 10 year strategy and program of treating hazardous fuels and improving forest health on the National Forest. This SFA has now been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin.

Sincerely,

TERRI MARCERON
Forest Supervisor

TAHOE REGIONAL PLANNING AGENCY

128 Market Street
Stateline, Nevada
www.trpa.org

P.O. Box 5310
Stateline, Nevada 89449

(775) 588-4547
Fax (775) 588-4527
Email: trpa@trpa.org

To Whom It May Concern:

Over the past six months, the Tahoe Regional Planning Agency (TRPA) has been actively engaged in the preparation, assemblage, and review of the 10 Year Lake Tahoe Basin Multi-Jurisdictional Comprehensive Fuels Plan. In 2004, the TRPA helped developed Community Wildfire Protection Plans with the Tahoe Basin Fire Protection Districts and in 2007 the TRPA produced the *Fuel Reduction and Forest Restoration Plan for the Lake Tahoe Basin Wildland Urban Interface.* These planning efforts have been incorporated into this Plan.

We fully support and endorse the goals and objectives of this Plan. We believe this will serve as a comprehensive framework from which all agencies involved in hazardous fuels reduction in the Lake Tahoe Basin can work together from and coordinate their activities. This Plan is an excellent example of the collaborative manner in which long range planning and work is proposed and carried out in the Lake Tahoe Basin.

We look forward to participating in the implementation of this Plan and reducing the risk of wildfire in the Lake Tahoe Basin

Sincerely,

John Singlaub
Executive Director

Tahoe Basin Fire Chiefs

September 20, 2007

Ms. Terry Marceron
Forest Supervisor
Lake Tahoe Basin Management Unit
35 College Drive
South Lake Tahoe, Ca 96150

Subject: Letter of Support for the Lake Tahoe Basin Multi- Jurisdictional Fuels Reduction and Wildfire Prevention Strategy.

Dear Supervisor Marceron,

Over the past eight months the Lake Tahoe Basin Fire Chiefs have been involved in the preparation, assemblage, and review process of the 10 Year Lake Tahoe Multi-Jurisdictional Comprehensive Fuels Plan. We support this plan with the following understandings.

The plan recognizes the importance of the Wildland-Urban Interface (WUI) as a priority. The Lake Tahoe Basin Chiefs believe the WUI around the urban areas of at least a quarter mile should be the priority for treatment and funding. These are the areas that would best protect lives, property, and where the highest densities of ignitions occur.

Secondly, the coordination with the CWPP's (Community Wildfire Protection Plan) is critical to the success of the plan for cost effective purposes.

Members:

Michael D. Brown, Fire Chief
North Lake Tahoe Fire PD
866 Oriole Way
Incline Village, NV 89451

Duane Whitelaw, Fire Chief
North Tahoe Fire PD
P.O. Box 5879
Tahoe City, CA 96145

Guy LeFever, Fire Chief
Tahoe Douglas Fire PD
P.O. Box 919
Zepher Cove, NV 89448

Jeff Michael, Fire Chief
Lake Valley Fire PD
2211 Keetak Street
Tahoe Paradise, CA 96155

Lorenzo Gigliotti, Fire Chief
South Lake Tahoe Fire Dept.
2101 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

John Pang, Fire Chief
Meeks Bay Fire PD
P.O. Box 189
Tahoma, CA 96142

Chris Sauer, Fire Chief
Fallen Leaf Fire Department
241 Fallen Leaf Road
South Lake Tahoe, CA 96158

We suggest that all the cooperators sit down annually to discuss and prioritize fuels treatment project proposals to bring forward to the annual SNPLMA funding meetings for their funding application each year. The success of the plan will hinge on this cooperative approach.

Should you have any questions regarding this matter, please feel free to contact anyone of the following:

Chief Michael D. Brown
775-831-0351

Chief Duane Whitelaw
530-583-6913

Chief Jeff Michael
530-577-3737

Chief Lorenzo Gigliotti
530-542-6167

Chief John Pang
530-542-1343

Chief Chris Sauer
530-542-1343

Central Sierra Environmental Resource Center
Box 396 • Twain Harte, CA 95383 • (209) 586-7440 • FAX (209) 586-4986
Visit our website at: www.cserc.org or contact us at: johnb@cserc.org

November 17, 2011

State Water Resources Control Board
1001 I Street, 15th Floor
Sacramento, CA 95814

Dear Members of the Board:

These photos show more clearly than any words that USFS management is not protecting water quality and watershed values despite assurances that BMPs are currently effective. **Because the minimal changes in the revised waiver still rely upon BMPs that fail to provide clear, measurable standards and thresholds, or consequences for water quality violations, the revised waiver and the connected Water Quality Management Handbook will result in the continuation of USFS activities that fail to protect California's water resources and watersheds under U.S. Forest Service management.**

Steep hillsides are often an inviting challenge for off-road vehicle riders. With limited personnel to patrol or to stop such damage, there is only rare USFS intervention or enforcement to prevent such activities. Ruts discharge sediment into downstream waters.

Cattle that graze along streams crumble stream-banks. Grazing also reduces or eliminates the deep-rooted native riparian vegetation of a healthy stream corridor.

A pocked and trampled spring (above) and an overgrazed streamside riparian area (below) -- where algae is choking the water from livestock wastes and nutrients…

This spring and seep at Deer Creek on the MiWok District is consistently degraded by cows.

Countless USFS roads are poorly maintained or not maintained at all due to budget cuts.

Sediment from 100's of miles of dirt roads and off-road vehicle routes washes into streams.

Overgrazed meadows can become compacted and springs are often polluted.

Stream-bank damage year after year adds up to significant water quality impacts, especially when the USFS doesn't even do annual monitoring for stream-bank impacts despite having standards and BMPs that direct there to be such monitoring.

When roads that cross both USFS and private forest land remain open during wet season periods after soils are saturated, major ruts create channels that can discharge sediment downslope into streams.

KEY MESSAGE TIE TO THESE PHOTOS:

The revisions to the waiver and to the waiver attachments do not contain changes that measurably improve the weak and nebulous language that makes the waiver legally deficient. The revised waiver is not adequate to ensure that the damage to watershed resources and the contamination of water that are visually revealed in the above photos will somehow be curtailed or corrected.

During the Stakeholders Committee process, representatives of the State Water Board and the USFS heard many concerns shared by a variety of interests – especially about the weak, inadequate Best Management Practices (BMPs). In particular, the BMPs for OHV use and the BMPs for range management were criticized for being nice sounding statements that in reality often are completely at odds with actual Forest Service management and reality on the ground. OTHER SETS OF PHOTOS WERE SUBMITTED. The photos reveal clearly the water quality and watershed impacts now occurring.

OHV BMPs MISLEAD THE STATE BOARD

The revised waiver does not change BMPs. OHV BMPs on paper provide for closing off-road-vehicle routes whenever soils are saturated and rutting will occur, but on some national forests such as the Stanislaus Forest, the USFS has approved Motorized Vehicle Management Plans that <u>require</u> the national forest <u>to keep open hundreds of miles of roads and routes all year-round</u> – including the fall, winter, and spring stormy seasons. On the Stanislaus Forest, OHV routes have NEVER been closed for even a single day due to wet soil conditions in the areas that are most popular for riding dirt bikes and all-terrain vehicles.

GRAZING BMPs AND REVISED AMP SCHEDULE MISLEAD THE STATE BOARD

Grazing BMP's direct the Forest Service to use Allotment Management Plans to protect water resources from grazing, but 324 grazing allotments on FS lands in California have no Allotment Management Plans, 16 years after Congress directed the agency to complete all AMPs. The Forest Service now sets a schedule pretending that they will complete NEPA analysis for those 324 allotments soon, but local FS staff openly admit that they have no funding nor enough staff to even make a dent in the backlog due to so many allotments that have no AMP plans. Yet the USFS wants the Water Board to believe those 324 plans covering hundreds of thousands of acres will be completed within the Waiver period and that new requirements in those plans will magically stop grazing degradation as shown in the photos in these comments. That claim is not based on reality.

The revised allotment NEPA schedule shows, for example, that the Stanislaus Forest will somehow succeed in completing AMPs for 10 allotments by 2013, when the Forest hasn't completed 10 allotments in 16 years. The Forest Service routinely sets ideal end dates and almost never meets those dates. Most of the 324 allotments without AMPs will still be without approved NEPA plans for the entire five-year waiver period.

The revised waiver also fails to acknowledge economic realities. New range management BMPs call for annual monitoring, but the FS doesn't have the dollars or staff to do monitoring so for a majority of allotments on some forests, they let the cattle permittees monitor themselves. Not surprisingly, permittees rarely find themselves to be violating standards, while neutral monitoring at the same meadows reveals consistent violations. The only annual monitoring that the Forest Service does on most allotments (forage utilization monitoring) has absolutely nothing to do with water quality or streambank protection. It only measures how much grass the cows have eaten.

Most of the grazing BMPs and most other USFS BMPs are not even measurable to determine whether or not the BMP did or did not protect water quality. One BMP requires the FS to "avoid concentrating livestock in riparian areas and wetlands during the hot season." Since no one herds the cows and most allotments have no active riders, there is absolutely no one moving cows away from water or wetlands on the majority of days during the summer. But the BMP attempts to mislead the Water Board into thinking that someone will avoid letting the cows hang out near water on hot days.

NO BMPs EVEN EXIST FOR REQUIRING THE FOREST SERVICE TO MAINTAIN ROADS

With more than 25,000 miles of roads overall on national forest lands just within the Sierra Nevada region, there are literally thousands of miles of existing roads with deep ruts, erosion, and sediment discharges flowing into streams and rivers. No Forest Service testing for water quality impacts from roads is even done during the wet winter season or during snowmelt. On the Stanislaus Forest alone, in Travel Management Plan documents the agency admitted that the Forest is @$100,000,000 short of needed road maintenance dollars. Budgets are being slashed heavily for next year and likely into the future.

But nothing in the revised waiver or the Forest Service's Water Quality Management Handbook requires the Forest Service to close unmaintained roads or to stop off-road-vehicles from riding on unmaintained routes that run across streams. Nothing in the Waiver or the Handbook require the Forest Service to monitor water quality for roads and to take strong action based on monitoring. Instead, the FS Regional team has openly expressed that it is too expensive for the Forest Service to take on extensive water quality sampling as our Center has recommended if a Waiver is to be granted.

THE WATER BOARD SHOULD NOT APPROVE THE REVISED WAIVER BASED ON A NEGATIVE DECLARATION WHEN THERE IS SO MUCH EVIDENCE THAT SIGNIFICANT RESOURCE IMPACTS ARE OCCURRING FROM LOGGING, RECREATION, LIVESTOCK GRAZING, ROADS, OFF-ROAD-VEHICLE USE, AND OTHER AGENCY APPROVED ACTIONS ON NATIONAL FOREST LANDS WITHIN CALIFORNIA.

INSTEAD THE WATER BOARD SHOULD REQUIRE A FULL EIR WITH CONSIDERATION OF A REASONABLE RANGE OF ALTERNATIVES AND REASONABLE MITIGATION MEASURES FOR THE WIDE RANGE OF SIGNIFICANT WATER QUALITY IMPACTS THAT HAVE BEEN AND THAT CONTINUE TO TAKE PLACE ON NATIONAL FOREST LANDS WITHIN THE STATE.

John Buckley, executive director
Central Sierra Environmental Resource Center
Box 396
Twain Harte, CA 95383

Watershed Sciences
1128 Fresno Ave
Berkeley Ca 94707
(510) 514-8204
collins@lmi.net

REVIEW OF REVISED WAIVER AND MONITORING REQUIREMENTS
Laurel Collins, November 20, 2011

I have reviewed the revised draft ñWaiver of Waste Discharge Requirements for Nonpoint Source Discharges Related to Certain Activities on National Forest System Lands in Californiaò (ñWaiverò) and the Attachment ñCò monitoring conditions.

The purpose of this review was to assess whether the revised Waiver and monitoring conditions would be adequate to avoid significant impacts to water quality and beneficial uses in the National Forests in California. For several reasons, I do not believe that the revisions made will avoid these impacts and provide significant protection of beneficial uses.

1. The Revised Waiver Relating to Impacts of OHV and Road Activities on Water Quality.

As discussed in my prior declaration (dated August 23, 2011), numerous studies document how OHV use can have significant impacts to water quality and beneficial uses due to sediment discharge to water bodies caused by increased runoff and concentration of flow particularly from compacted trails that initiates hillside and stream channel erosion. Documents in the record also demonstrate that OHVs have had significant impacts on water quality, as well as aquatic and seasonal wetland habitats on National Forest lands in California.

The revised Waiver adds specific monitoring requirements that appear to be a condensed version of the Forest Serviceõs BMPs, yet none of the BMPs for OHVs have been amended.

The monitoring BMPs proposed for OHVs will not avoid significant sediment discharge from OHV activity. The exhibits I reviewed in the prior declaration demonstrate that the Forest Service has a large number of existing trails that have been scored and rated as causing excessive erosion yet continue to be operated.

The new waiver changes rely on the Forest Serviceõs G-Y-R Trail Condition Monitoring program. As I discussed in my prior declaration the problems with this monitoring approach are that the Forest Service does not interpret a red condition to require closure. The Waiver conditions also do not require closure of a red area, even though this is G-Y-R policy. Instead the Forest Service may assign priority to its restoration. Where the Forest Service then lacks the funding to implement restoration, continued OHV use will continue to have significant effects to water quality and aquatic/wetland habitats.

The Waiver conditions also state monitoring will occur annually for high risk areas, and that all OHV trails will be monitored at least every three years. In my opinion, monitoring a substantial number of OHV trails every three years is inadequate because in any winter season a trail could fail, in which case there would be two entire seasons of significant sediment discharge and damage without any detection or remediation by the Forest Service. I also note that the conditions do not specify any minimum number of trails that would have to be monitored each year. In my experience, the amount of trails actually monitored on an annual basis will depend on funding, which has been sorely inadequate in the past.

The Waiver conditions also state there will be periodic inspections of OHV routes to identify new unauthorized routes and schedule restoration treatments for routes causing water quality impacts. The periodic inspections are to be conducted on a three to five year time frame. This time frame would also appear inadequate, as new unauthorized routes could lead to several years or more of OHV impacts on water quality and wetlands before they were even detected. Further, the Forest Service already is aware of numerous unauthorized routes that continue to be utilized by OHVs, without enforcement or restoration. If the Forest Service were to identify sources of sediment pollution coming from unauthorized routes, a lack of staffing and funding in the future would prevent timely if any restoration. The rate of sediment supply and resulting damage can often be quite high within the first hours or days of the initiation of a problem. For example, sediment production from a landslide on a road fill adjacent to a stream can provide a large and sudden supply of sediment to the stream and then quickly taper off. Rill and gully erosion on a road tread might be episodic but sediment supply would be most punctuated during intense storms where placement and continued maintenance of water bars could have easily prevented the perpetual delivery of sediment to a channel. The lack of inspection following intense storms will provide a persistent conduit for fine sediment delivery, thus contributing to cumulative impacts that will remain undetected by the Forest Service and the Water Board.

The Waiver conditions do not add any standards for when OHV routes must be closed, or even whether an OHV route is causing excessive impacts to water quality. The Waiver states that ñmonitoring time frames and definitions of triggering events shall be defined in monitoring protocols.ò

The Waiver conditions also provide for a ñroad patrolò that will ñdetect and correctò damage on roads and OHV routes in a ñtimely manner.ò This section does not provide any information to me about how this will occur. The Waiver states that the protocols for detection and repair procedures will be determined in the future by the Forest Service.ò

In my opinion, the protocols and standards for determining when a ñtriggering eventò will occur must be discussed as part of an evaluation of whether a regulatory scheme will be able to avoid significant water quality impacts in the future. As I stated in my prior declaration, the Waiverøs general lack of quantitative or qualitative definitions or standards associated with what constitutes a ñsignificantò discharge of sediment, or whether closure is required, makes it impossible to understand or assess whether significant water quality impacts will be avoided. The Waiver conditions are not based on any standards but instead are entirely subjective.

The lack of definable thresholds has the potential for allowing significant water quality impacts to continue. How the Forest Service will determine whether a ñtriggering eventò has occurred is a significant issue that should have been presented and discussed according to actual scientifically measurable standards that would trigger remedial action, including closure. In many cases, closure itself can have restorative effects as natural re-vegetation returns to the site. However, where continued OHV use occurs, these sites will continue to be degraded by continued delivery of sediment. In other words, future OHV activity has the potential to cause existing legacy sources of OHV pollution that would otherwise repair themselves over time to instead continue to be significant sources of water quality pollution in the future.

For all these reasons, it is my opinion that the revised Waiver has the potential for significant impacts to water quality due to OHV activities that will continue in the future.

2. The Waiver's Changes for Monitoring for Projects

The revised Waiver relies on a number of monitoring methods to avoid significant impacts to water quality. In my opinion, none of these methods will ensure that future projects will avoid significant impacts to water quality.

First, the Waiver relies on checklists for implementation of on-the-ground prescriptions to protect water quality. In my opinion, the checklist implementation monitoring will not provide useful information about whether the BMPs were properly installed, they only represent the training and interpretive ability of the individual doing the checklist Even more importantly, checking a box that a BMP was installed provides no information about whether the BMP was effective in avoiding significant water quality impacts following rain events and snow melt. This is because, in my experience, Forest Service mitigation measures put in place after logging projects are completed often fail or are not always effective in avoiding sediment discharge following the winter and spring storm season, particularly in the higher, steep-sided elevations

Without verifiable compliance using such techniques as pre and post project photo monitoring points - as is required by the Lahontan Waiver - it is not possible for a regulatory agency to ensure that adverse impacts to water quality did not occur and are being prevented. Ideally, reproducible quantitative measurements of erosion sites should be made to establish the amount of sediment or excess runoff supplied to a channel (that causes sediment supply from downstream channels adjusting to increased peak flows) and should be accompanied by qualitative information that assigns sediment to different source types that establishes cause and effect. Without this, there cannot be sufficient adaptive management and protection of water quality is inadequate.

Second, the revised Waiver relies on the Forest Serviceõs Best Management Practices Evaluation Program (BMPEP), which is based on *random* monitoring of Forest Service Projects. In my opinion, the BMPEP has the potential for significant impacts because it does not require project specific monitoring for high risk projects, and thus the immediate environmental damage from such projects may be undetected and unremedied.

In my opinion, effectiveness and forensic monitoring is needed to determine the influences of large events such as rain on snow events that have been shown to produce some of the largest negative impacts in the Sierra. In these extreme conditions it will be important to establish if BMPs and other erosion control remedies are able to perform. Under the BMPEPõs random monitoring approach, the majority of high-risk projects will not be monitored for BMP effectiveness following the winter season. In my experience this is the most crucial time for BMP review because it is common for BMPs to fail during these rain on snow events, which can lead substantial sediment production and delivery of sediment to streams because the problems were not identified in a timely manner. During these types of storm events, Sierran streams often attain their highest flood stages. This means that they often have the capacity to transport and potentially disperse large volumes of fine-grained sediment great distances form their original sources of origin, yet degrading water quality in a way that pervasively goes unmeasured and therefore unreported. In my experience working in the Sierra Nevada, for example, I have observed that logging activities on steep slopes and even within stream zones have discharged tons of sediment into adjacent channels.[1]

Third, the Waiver relies on ñRetrospective Hillslope Monitoring of Past Management Activitiesò which is to evaluate the effectiveness of BMPs after they have been in place for 3 to 5 years. This monitoring process appears to only apply to projects that have already undergone random effectiveness monitoring. As discussed, that leaves out the majority of high-risk projects. Further, even for those projects monitored, the timeline for this process is vague, and lacking in any triggering mechanism to remedy ineffective BMPs. Instead, the Waiver states only that ñrecurrence interval estimates will be compared to long-term effectiveness monitoringò in BMPEP reports. Nothing in this section suggests that projects that continue to discharge sediment or other pollutants will be remedied on any set time frame.

Fourth, the Waiver relies on Baseline In-Channel Monitoring as an alternative to project specific monitoring. In my opinion, in-channel monitoring

[1] For example, in areas undergoing fuel reduction activities -- and even on slopes less than 50 percent -- mechanical disturbance of the soil surface can destroy the added soil cohesion that is provided by the fine roots of vegetation (Booker Dietrich and Collins,1993) (see CV for cited references). This added soil cohesion is particularly critical in steep areas that are often found in or near (within 500 feet of) stream environment zones. With even light mechanical disturbance and creation of bare soils, some soils will create a series of rill networks similar to hydrophobic soils, especially during intense rainfall. These rill networks might later be covered by snow or destroyed as vegetation recovers. Without effectiveness and forensic monitoring, these land use-related sediment sources might go undetected yet create significant negative impacts.

will not detect potentially significant impacts from ongoing projects for a number of reasons that include legacy effects, issues of storage upstream or transport beyond the monitoring site, and the lag times that are often associated with a project impact, a storm trigger of certain intensity, and then the unique geomorphic response time of the particular landscape to an impact. For example, when Douglas firs are cut there is a lag time if 5 to 7 years in the decay of the root structure. After this time, the shear strength in the soil is at itøs lowest to resist future landsliding. Then it might take a few seasons until a triggering storm causes a landslide to mobilize. The sediment and woody debris delivered from the slide might cause a debris jam in the channel that then backups more sediment and creates a nick point in the channel. This debris jam rots and then releases tons of sediment that has been stored upstream of the monitoring site years later and goes undetected. In-channel monitoring typically tests the water quality and bank structure at a particular downstream location. But this does not mean that the upstream impacts of a particular project are being detected.

In-stream random effectiveness monitoring is NOT going to be a suitable substitute for post project effectiveness monitoring following the winter season because it will miss many projects, especially high priority projects, where repairs are needed, it will not directly link cause and effect to identify the necessary remediation, maintenance repairs, or failed BMPs.

Further the Waiverøs in-channel monitoring approach will be extremely limited to a few watersheds, and thus will not address numerous watersheds in which currently active projects with the potential for significant water quality impacts.

Finally, in my opinion, it will be highly unlikely that the in-channel monitoring described in the Waiver will ever provide any relevant data regarding the impacts of project activities on water quality. This is because there is no discussion about making sure that the monitoring in-stream sites can be cross-compared to each other or that the paired watersheds can really provide an adequate comparison. In the case of the in-stream monitoring sites it is often very difficult to find reaches that can be suitably compared because a stream monitoring reach might consist of more than one type of stream class condition. The Rosgen Stream Classification system has been used by the US Forest Service in many Sierran streams. If a monitoring site consists of several different stream classes, such as presumed stable B or C type channels at a reference reach and it is cross compared to another site that has unstable G or F classes or even another reach that has all stable B-type reaches, the expected channel sediment transport and localized sediment supply would be very different. This equates to comparing apples and oranges and therefore would not be statistically valid or yield useful information for assessing effectiveness of BMPS. In addition monitoring larger watersheds far downstream from the project effects will only dilute the influence of the project and likely make its impacts undetectable within the resolution of error of the monitoring technique.

In addition to different channel classes not be expected to have similar sediment supply rates or stability conditions, the geomorphic conditions from one site to another might be very different depending on geology, stream gradient, confinement and/or entrenchment within a valley floor, bed load size and supply, bed material conditions, riparian vegetation, aspect, and legacy land use. Paired watersheds that do not have these kinds of confounding factors are nearly impossible to find and attempting to compare watersheds that do not have similarities in all these characteristics, among others, can render useless data and misleading information, as well as a poor use of public funds for data collection that could otherwise be used to protect resources.

There is also the problem associated with lag times as discussed in a previous paragraph, particularly associated with routing of sediment (storage in bars, behind debris jams, and on floodplains, as well as differential transport of different grain sizes from a site)

Fifth the revised Waiver proposes to do some project level monitoring *if* baseline in-channel monitoring is not done. As discussed above, the proposed in-channel monitoring will not ensure that projects discharging significant amounts of pollutants will be detected on a timely basis. For that reason alone, this mitigation measure is inadequate.

Further, even where in-channel monitoring *does not occur*, the project level monitoring is limited to watersheds that are over a threshold of concern (TOC) as measured by the Forest Service Handbook 2509.22. The Waiver does not discuss or explain what constitutes the TOC or how the Forest Service measures TOC for a particular watershed

In my opinion, this limitation also prevents the Waiver from ensuring that significant impacts to water quality are being avoided. For example, the most common method for determining whether a watershed is above the TOC is based on the ñequivalent roaded area,ò(ERA) which measures the relative permeable surface areas within a particular watershed. In my opinion, this type of measurement has little to do with whether particular projects in the watershed are causing significant impacts. In fact, many projects such as logging in stream zones or on steep erodible slopes may not contribute to the ERA for a watershed, but will contribute to significant pollution discharge to streams and wetlands. Cable logging, for example, can often cause water to be concentrated into skid pathways that can then cause rills and gullies to deliver sediment to stream courses. In this case, roads would not be a predictor of sediment supply or negative impacts. Similarly, the logging, which for this technique commonly is applied to steep slopes, could be associated with increased landsliding years after the roots decay and the sediment supply would not be detected within the period of monitoring.

In addition, in my experience, limiting project level effectiveness monitoring to watersheds above the TOC is inadequate to avoid significant water quality impacts. Regardless of whether or not a particular watershed is above a TOC, the site specific impacts to water quality may still be significant. In my experience working in the Sierra Nevada, I have observed that the logging activities on steep slopes and within stream zones have the potential to discharge substantial amounts of sediment. Sediment sources are not dependent upon the creation of impermeable surfaces but may occur from site specific activities such as the collapsing of hills or banks, the turning of machinery, skidding loggings, reducing soil cohesion due to root loss, the extension of channel heads upslope into previously unchannelized swales (zero order basins) due to increased runoff, etc. In many of these instances, the overall ratio of impermeable surface in a watershed will be practically irrelevant since the source of pollution is coming from a specific site of discharge. Just the loss of interception can change the amount of groundwater in the soils, timing at which saturation occurs, and can increase total runoff, thereby inducing downstream channel adjustments, such as bank or bed erosion, to accommodate more flow. Hence, more downstream offsite sediment production can be caused from a site without necessarily having a high impermeability rating. Landslides can also be mobilized in areas that are not necessarily steep or have a high impermeability rating due to changes in evapotranspiration.

Another example are the watershed impacts from mechanical treatments, which do not affect TOC within a watershed. Mechanical disturbance of the soil surface can destroy the added soil cohesion that is provided by the fine roots of vegetation (Booker Dietrich and Collins, 1993) (see CV for cited references). This added soil cohesion is particularly critical in steep areas that are often found in or near (within 500 feet of) stream environment zones. With just light mechanical disturbance and creation of bare soils, intense rainfall in some soils can create a series of rill networks similar to those found in hydrophobic soils following intense fires. These rill networks might later be covered by snow, litter, or destroyed as vegetation recovers. Without effectiveness and forensic monitoring, the land use-related sediment sources might go undetected yet create significant negative impacts. Effectiveness and forensic monitoring is particularly needed to determine the influences of large events such as rain on snow events that have been shown to produce some of the largest flood impacts in the Sierra. In these extreme conditions, it will be important to establish if BMPs and other erosion control remedies are able to perform.

A system should be in place to modify or fix erosion control applications that are not functioning properly or that might be creating larger problems. I have often observed that under moderate rainfall conditions, erosion control applications might only function well for the first few storms of the season, but need maintenance or modification to continue to perform throughout the remainder of the season. Adaptive maintenance is essential to minimize negative impacts and in order to do this, effectiveness monitoring is key. In my opinion, the absence of such monitoring could lead to substantial amounts of sediment discharge in flooding events because the problems would not be identified in a timely manner. After logging, thinning, salvage operations, or other fuel modification activities that cut trees there is a subsequent loss in soil strength to resist surface erosion and landsliding. This is caused by the decay and loss of small and large roots. For example, studies have shown that large roots of conifers, such as Douglas fir, decay in about 5-7 years (Coats and Collins, 1981). This is before roots of germinated seedlings can contribute significant added cohesion. At this point, forest soils dominated by conifers can be at their weakest to resist mass wasting from landslides. These kinds of impacts that provide fine sediment to any portion of the stream network, even along small headwater ephemeral channels, can influence any particular designated ñclassò or size of downstream channel. The source area for many debris slide type landslides is colluvial hollows or zero order basins. These slides can be initiated by increases in soil saturation and decreases in added soil cohesion as influenced by silvicultural practices. Zero order basins are often well above the channel head or areas that would be identified as stream protection zones, yet landslides emanating from these source areas can quickly evolve into debris torrents, bulking up with sediment already within the channel, and travel long distances downstream along a runout pathway until the stream gradient flattens enough to induce deposition. Debris torrents are extremely destructive and channel recovery from negative impacts can take years.

For this reason, in my opinion it is essential that forensic and effectiveness monitoring <u>should not</u> be based upon a TOC calculation but instead on whether the particular proposed activity has the potential for discharge to water bodies in the Basin.

Further, as discussed below, limiting monitoring to watersheds above TOC monitoring does not address watersheds that drain to waters that are water quality impaired. Thus, cumulative pollution impacts that occur in a non-TOC watershed but which drain to a listed water body - such as Lake Tahoe, discussed below - will be significant, but will not be monitored under the Waiver.

In addition, the Waiver requires that effectiveness monitoring at the project level shall be limited to ñin-channel beneficial use monitoringò above and below the downstream end of the project site. As discussed, in-channel monitoring is not adequate to detect the failure of a BMP on a particular project. For example, a project BMP may have failed over the course of the winter storm season, but in the absence of an inspection of the project itself, a randomly timed in channel monitoring exercise is unlikely to detect the substantial pollution discharge that likely occurred at the time and following failure.

Finally, the Waiver states that BMPEP protocols will be used to evaluate all high-risk activities at least once for each activity during the waiver enrollment. This provision is confusing in that it does not explain whether this would apply to all high-risk projects or categories of activities. Even if the provision were to apply to ñprojects,ò the Waiver does not identify what constitutes a ñhigh-riskò project and thus there is no way to determine the scope of this monitoring. Finally, this provision only requires evaluation once during the duration of the waiver, which is five years. This approach would allow for a high-risk project BMP to fail during the winter season, but continue to discharge pollution for up to 4 years until finally detected.

In my opinion, adequate project specific effectiveness and forensic monitoring requires prompt monitoring following winter storm events and after the winter season. Otherwise, project discharges with significant effects on water quality may occur for years without any correction. In my experience, a single failed project may discharge significant amounts of sediment due to BMP failure during and following a single winter season.

3. Effect of Waiver on Water Quality Regulation in Lake Tahoe

I am familiar with the Regional Board’s regulation of Forest Service logging in the Lake Tahoe Basin. Basically the applicable Waiver requires the Forest Service to conduct comprehensive effectiveness and forensic monitoring on all high-risk projects in stream zones and on steep slopes in all watersheds that drain to Lake Tahoe. As stated in my other submitted comments, in my opinion this level of monitoring is essential to avoid additional water quality impacts to Lake Tahoe and its tributary streams.

The revised Waiver reduces this level of monitoring by replacing project specific effectiveness and forensic monitoring with the Forest Service’s random BMPEP approach and an ineffective in-stream monitoring program. In my opinion, this has the potential for significant impacts to water quality in the Tahoe Basin and to Lake Tahoe because high risk project BMPs that fail over the winter and spring storm season – not an uncommon occurrence – will not be detected in a timely manner. This is particularly true given the Forest Service’s plans for substantial logging in the Tahoe Basin over the next 10 years. In my opinion, this lack of adequate effectiveness and forensic monitoring for high risk Forest Service projects has the potential for significant water quality impacts to waters in the Tahoe Basin that are not avoided by the revised Waiver and monitoring attachment.

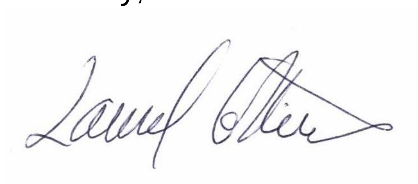
4. Adaptive Management Concerns Have Not Been Addressed.

In my opinion, the revised Waiver and monitoring still lack an effective trigger mechanism through which monitoring results through in-stream monitoring and BMP forensic and effectiveness monitoring can lead to necessary changes on the ground to avoid further impacts to water quality and the stream environment. By adopting quantitative measurements such as those discussed above, triggers could be identified that would result in further investigation or corrective actions. For example, if the measurements showed that the sediment particle size class for all habitats was becoming finer within or immediately downstream of the project site and not upstream, this would trigger an analysis of what is happening at the site to create negative impacts. Changes in stream class to ones that are indicative of instability, or changes in bank height that indicate pervasive incision or aggradation could also be triggers. The existing Lahontan waiver that applies in Lake Tahoe has specific triggers to ensure that when BMPs have not been adequately implemented or are not operating effectively over time, the problems that are identified must be corrected, and that more intensive monitoring shall occur until that has been accomplished. I believe that these are the minimum level of monitoring requirements that would be necessary to meet this objective.

Where only implementation monitoring is required, and not project specific forensic and effectiveness monitoring, this would not ensure that adverse impacts would be avoided because mitigation measures put in place after logging projects are completed, often fail or are not effective in avoiding sediment discharge.

Finally, without verifiable compliance using such techniques as pre- and post-project monitoring points, it is not possible for a regulatory agency to ensure the avoidance of adverse impacts to water quality. Ideally, reproducible quantitative measurements of erosion sites should be made to establish the amount and type of sediment supplied to the stream system and should be accompanied by qualitative information that assigns sediment supply to different source types, and establishes cause and effect. Without this there cannot be sufficient adaptive management.

Sincerely,



Laurel Collins

AREAS OF EXPERTISE

- Fluvial Geomorphology
- Tidal Wetland Geomorphology
- Sediment Budgeting
- Landslide Mapping
- Landscape Aerial Photo Interpretation
- Geomorphic Effects of Wildfire and Land Use Impacts
- Stream Restoration Design

EDUCATION

University of California, Berkeley B.A., Earth Sciences, 1981

PROFESSIONAL HISTORY

Watershed Sciences, Owner/Director 2001-to date

San Francisco Estuary Institute, Environmental Scientist, 1999-2001

Independent Consultant, Environmental Sciences, 1989-2001

University of California, Staff Researcher, 1984-2001

Lawrence Berkeley Laboratory, Senior Research Associate, 1992-1993

East Bay Regional Park

REPRESENTATIVE EXPERIENCE

Ms. Collins has been a geomorphologist since 1981 specializing in fluvial and tidal wetland geomorphology, sediment budgeting, landslide analysis, stream monitoring and mapping, and analysis of geomorphic change from natural and anthropogenic influences, Ms. Collins has conducted sediment budget and source analysis in Sonoma Watershed for the Regional Water Quality Control Board and has served as an Expert Witness for testimony pertaining to Geomorphology.

As Owner/Director of Watershed Sciences consulting firm established 2001, Ms. Collins has been directly involved in the following projects:

- Sediment Source Analysis for development of a TMDL in Sonoma Creek watershed for the Sonoma Ecology Center and the San Francisco Regional Water Quality Control Board.
- Evaluation of impoundments as red-legged from habitat for the Point Reyes National Seashore.
- Development of action plan and methodologies for conducting a sediment budget analysis on Alameda Creek for Alameda County.
- Geomorphic analysis of Crow Creek to assess impacts of land use practices and natural processes for Alameda County.
- Expert Witness for Determination of Natural versus Artificial conditions of the Mitchell Slough of the Bitterroot River, Montana, for Doney, Crowley, Bloomquist, Payne, Uda PC.
- Sediment source evaluation and conceptual plans for reducing sedimentation in Eden Creek for Alameda County.
- A sediment source analysis and sediment budget in Sonoma Watershed for the Regional Water Quality Control Board and subcontractor for the Sonoma Ecology Center.
- Assessment of flooding and geomorphic change in the lower Sonoma Creek Watershed for the Coastal Conservancy and Southern Sonoma Resource Conservation District.
- Geomorphic assessment of long-term processes associated with the maintenance of redï legged frog breeding habitat of Point Reyes National Seashore, U.S.N.P.S.
- Geologic and geomorphic mapping of Strawberry Canyon in Berkeley, California, for the Committee to Minimize Toxic Waste and Urban Creeks Council.
- Development of conceptual plans for restoration and

District, Resource Analyst 1983-1986, Geologist, 1986-1991

Center for Natural Resource Studies, John Muir Institute, Environmental Scientist, 1980-1983

U.S. Geological Survey, Hydrologic Field Assistant, 1980-1982

California Department of Forestry, Field Assistant, 1979-1980

California Academy of Sciences, Paleontology Department Student Assistant, 1978.

AFFILIATIONS

American Geophysical Union, 1986-to date

Geological Society of America, 1983-2001

California Forrest Soils Council, 1980-1991

TEACHING

Watershed Analysis, Sierra Nevada Field Station, San Francisco State, 1998-2003
Hydrology Summer Field Course, Teton Science School, 1991 and 1996

geomorphic analysis of lower Wildcat Creek for City of San Pablo and Urban Creeks Council.

- Preliminary assessment of opportunities and constraints for restoration and fish barrier removal in lower Ignacio Creek (Arroyo San Jose), Marin County for Friends of Ignacio Creek and City of Novato.
- Survey of longitudinal profile of lower Carriger Creek, Sonoma County, for the Southern Sonoma Resource Conservation District.
- Geomorphic analysis of silvicultural impacts on sediment supply of Sulphur Creek, Plumas County, for the U.S.F.S. and Plumas Corporation.
- Geomorphic analysis of lower Carriger Creek for the Klamath River Information System, William Kier Associates.
- Stratigraphic analysis, carbon dating, and history of geomorphic change at Last Chance Creek near Stone Dairy, Plumas County for the Plumas Corporation.

As Geomorphologist for the San Francisco Estuary Institute, Ms. Collins:

- Developed of a ñWatershed Science Approachò for field methodologies to assess and analyze changes in the delivery of water and sediment as affected by Euro-American land use practices in California.
- Conducted a scientific study of physical processes and land use impacts in Wildcat Creek, Contra Costa County, for the San Francisco Estuary Institute. Developed a field-based methodology for quantifying natural versus man-related sediment supplies.
- Applied the Watershed Science Approach to San Antonio Creek, Marin County, for the Southern Sonoma Resource Conservation District.
- Applied the Watershed Science Approach to Carriger Creek, Sonoma County for the Southern Sonoma Resource Conservation District.

As an Independent Consultant, Ms. Collins was served as the following:

- Consulting Geomorphologist for the Napa Resource Conservation District to establish and help educate different stewardship groups and to develop protocols to collect data on stream geometry to monitor channel change.
- Consulting Fluvial Geomorphologist Geomorphology Consultant for AECOS and Institute for Sustainable Development to conduct a watershed analysis for Waimanalo Creek, Waimanalo, and Mokapu Channel, Marine Corps Base, Oahu.

SCIENTIFIC ADVISORY BOARDS

Technical Advisory Committee for Management of Lagunitas Creek, Marin Municipal Water District

South Bay Salt Pond Restoration Project, Sediment Workshop Leader, County of Alameda

Science Review Group for Napa Watershed Project of the San Francisco Estuary Institute

Pescadero Creek Technical Advisory Committee, San Mateo Resource Conservation District

San Pablo/Wildcat Technical Design Advisory Council, City San Pablo

Hill Area Fuel Reduction Committee, University of California at Berkeley

Mayors Task Force of Forestry and Vegetation, City of Oakland

- Fluvial and Tidal Geomorphology Consultant for Marin County Flood Control District to conduct a watershed analysis of Novato Creek, Marin County, with special focus on sedimentation and sediment sources to the Novato Flood Control Project.
- Fluvial Geomorphology Researcher contracting with the Point Reyes National Seashore, to conduct research and monitoring of the second and third year hydrologic and geomorphic effects of the 1995 Vision Fire on Muddy hollow Creek, Marin County.
- Fluvial Geomorphology Researcher for the West Marin Environmental Action Committee to conduct research and monitoring of the first year effects of the 1995 Vision Fire in the Inverness Ridge, Marin County.
- Teacher with Dr. Luna B. Leopold and Dr. Scott McBain for the Teton Science School, Jackson, Wyoming at the Hydrology Workshop on fluvial hydrology, field methods and watershed analysis.
- Fluvial Geomorphology Consultant to U. S. Department of Justice for research on Reserved Water Rights Case on the effects of water diversion on the Fraser River, Lostman Creek, and Indian Creek, Colorado, plus expert testimony.
- Fluvial Geomorphology Consultant to EA Engineering, to perform watershed analyses for a 100-Year Sustained Yield Program for the Noyo River, Mendocino County. Analyses included documentation of channel conditions, determining impacts of logging upon hydrology and fluvial geomorphology of coho salmon habitat, sediment production and landsliding; and advising policy makers on ways to reduce future impacts from timber harvesting.
- Fluvial Geomorphology Consultant to U.S.F.S., to determine the Holocene and recent geomorphic history of the South Fork Kern River in Monache Meadows, Southern Sierra Nevada, Inyo National Forest. Analysis was conducted of flood frequency; channel incision and sediment transport regimes and related to climate change and land use practices for the last 200 years.
- Geomorphology Consultant to law firm of Lossing and Elston, San Francisco, to prepare expert testimony on the effects of fire upon slope stability, landsliding, runoff and erosion.

As a Staff Researcher in the Department of Geology and Geophysics, University of California at Berkeley, Ms. Collins was involved with the following:

- Fluvial geomorphology research for the Pacific Southwest Forest and Range Experiment Station, U.S.F.S. to produce detailed stream maps, longitudinal profiles, and cross sections within and outside of cattle exclosures in the Golden Trout Wilderness, Inyo National Forest, California.

- Tidal marsh geomorphology and hydrology research in the Petaluma Marsh, Sonoma County.
- Fluvial hydrology research on braided channels in regions of Wyoming and Idaho.
-

Senior Research Associate for Lawrence Berkeley National Laboratory to conduct geologic field mapping, analysis and report preparation of site characteristics for the LBNL Hazardous Waste Handling Storage Facility in Strawberry Canyon, Berkeley, California.

Teacher for San Francisco State Sierra Nevada Field Station for undergraduate course in stream restoration, watershed analysis, and stream monitoring techniques.

District Geologist for East Bay Regional Park District, Oakland, Ca. Responsibilities included identification and analysis of geological hazards; direction of geologic and hydrologic research programs; publication of research findings; formulation of District policy pertaining to fuel break management, and resource management relative to hydrologic and geologic issues; preparation of expert testimony; preparation and review of Environmental Impact Reports; assessment and restoration of steelhead habitat in Wildcat Creek, Berkeley Hills.

Geologist/Hydrologist for the Center for Natural Resource Studies, John Muir Institute, Inc., Berkeley, to conduct field study and analysis of flood effects and instream flow requirements of San Lorenzo River, Santa Cruz, California; assessment of geologic hazards and evaluation of fish habitat Grider Creek, Klamath National Forest; assessment of cumulative impacts of silvicultural practices in the Sierra National Forest; assessment of the effects of silvicultural practices on site productivity in California forest lands; and publication of research findings.

Hydrologic Field Assistant, for Water Resources Division, US Geological Survey, Menlo Park, to conduct field study and analysis of 1) earthflows in Redwood National Park, California; 2) river morphology as effected by volcanic activity, Mt. St. Helens, Washington; 3) interactions among hillslope and stream processes in the San Lorenzo River, Santa Cruz, California; and 4) publication of findings.

Student Assistant for the California Department of Forestry, Sacramento, to conduct field study and analysis of the effects of logging activities and the effectiveness of the Forest Practice Regulations on rates of erosion in private forest lands throughout California.

Student Assistant for Geology Department, California Academy of Sciences, San Francisco assisting with the curation of fossil genera of ammonites and echinoids for Dr. Peter Rhoda.

PUBLICATIONS AND REPORTS

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