1.1 Soil and Hydrology

1.1.1 Affected Environment

1.1.1.1 Regulatory Framework

Management direction is from the PNF LRMP (USDA 1988) as amended by Herger-Feinstein Quincy Library Group (HFQLG) Final Supplemental Environmental Impact Statement (FSEIS) and Record of Decision (ROD) (USDA 1999a, 1999b, 2003b, 2003c), and the Sierra Nevada Forest Plan Amendment (SNFPA) FSEIS and ROD (USDA 2004a, 2004b). This changes management direction in the PNF LRMP and directs the Forest to adhere to these guidelines in the following resource area:

1.1.1.1.1 Riparian Habitat Conservation Areas (RHCAs)

Apply Scientific Analysis Team (SAT) guidelines. These include the following interim widths for these types of RHCAs: 300 feet (perennial fish bearing streams and lakes; 150 feet (perennial non-fish bearing streams, ponds, wetlands greater than 1 acre, and lakes); 100 feet (intermittent and ephemeral streams, wetlands less than 1 acre, and landslides).

Other features in RHCA determinations include: Top of inner gorge, 100-year floodplain, outer edge of riparian vegetation, or a distance equal to one or two tree heights (depending on stream type).

1.1.1.1.2 Soil Standards

The soil standards and guidelines presented in the PNF LRMP, as amended by the FSEISs and RODs for the Herger-Feinstein Quincy Library Group and the Sierra Nevada Forest Plan Amendment, provide the relevant substantive standards for Forest activities to comply with the National Forest Management Act. The quantitative PNF LRMP standards and guidelines for the maintenance and improvement of soil resources are:

Determine adequate ground cover for disturbed sites outside of streamside management zones during project planning on a case-by-case basis, based on specialist evaluation, using the following table as a guide (a table relating suggested minimum effective ground cover to erosion hazard rating is presented on page 4-44 of the PNF LRMP).

To avoid land base productivity loss due to soil compaction, dedicate no more than 15% of timber stands to landings and permanent skid trails.

Determine retention levels of down woody material on an individual project basis. Suggested retention levels in the SNFPA ROD are 10-15 tons of large down wood per acre for westside vegetation types and 3 large down logs per acre for eastside vegetation types.

The regional soil quality analysis standards presented in FSH 2509.18 of the Forest Service Handbook are not a set of mandatory standards or requirements. Those analysis standards are a set of threshold values that indicate when changes in soil properties and soil conditions would potentially result in significant impairment of the soil productivity potential. They are intended to be used during analysis or evaluation of soil condition. Among the thresholds specific to soil productivity are:

- Use of Erosion Hazard Rating (EHR) to determine necessary soil cover to prevent accelerated erosion.
- Retaining at least 50 percent cover in an activity area of fine organics (less than 3 inches in diameter).
- Retain a minimum amount of large woody debris required to maintain microbial habitat and soil moisture for long term productivity. The amount depends on local ecological type and should be determined by the Forest.
- Retention of at least 90 percent of soil porosity found under natural conditions, determined by sampling of activity areas.
- Determine extent of detrimental soil disturbance that affects soil hydrologic function by using Region 5 Cumulative Watershed Effects Analysis, EHR, or Water Erosion Prediction Project (WEPP).

1.1.1.2 Methods

Proposed ground harvest units were surveyed in November, 2007. Selected units were evaluated using Forest protocol for assessing soil condition and hydrology function. Literature reviews, field notes, Forest monitoring reports, Geographical Information System (GIS) data, and professional judgment were used to support report conclusions. Burn Area Emergency Response (BAER) reports for hydrology and soils were primary sources of information on current conditions. Given that the vast bulk of the project treatment is within the Moonlight Fire perimeter, unless otherwise noted references to BAER reports are to the Moonlight Fire BAER. Soil survey data, survey protocol, and field notes are in the project record. Erosion from ground disturbed by proposed activities was modeled using the Forest Service interface for the Water Erosion Prediction Program (WEPP) and the USFS Region 5 soil erosion model. Relative runoff was evaluated using the R5 Equivalent Roaded Acre (ERA) method.

The WEPP modules, Erosion Risk Management Tool (ERMiT) and Disturbed WEPP provide estimates of soil erosion on basis of an acre of slope using variables for climate, soil texture, slope distance, and groundcover that are average conditions for treated ground. The ERMiT module was used to characterize storm intensity and runoff with erosion. Disturbed WEPP was used to investigate erosion potential according hillslope attributes. Accuracy is highly variable, +/- 50 percent for Disturbed WEPP hillslopes, though improves when averaging erosion across a broad area (Larson and MacDonald 2006; Spigel and Robichaud 2007).

Cumulative impacts are addressed using the ERA methodology outlined in the Forest Service Region 5 Water and Soil Conservation Handbook (1990). The soils analysis uses the timber harvest units as the reference for effects determinations. Long term productivity is assured if at least 85 percent of the timber unit area has soil indicators not in a detrimental condition. Soils cumulative effects are considered using the ERA analysis detailed in the hydrology section. Analysis boundaries are watersheds used for ERA method and are presented in Figure 4. The watersheds delineated for analysis encompass that portion of the Moonlight Fire and Antelope Complex perimeter within which actions are proposed and/or cumulative effects of fire and past harvest with the proposed action are significant. The base GIS layer used to create the project level watersheds was the CalWater 2.2.1 GIS layer from the state of California. The base layer was selected over the PNF corporate layer for two reasons; it is more up to date and it contains the watershed numbering system that the Regional Water Quality boards use (common language).

CalWater 2.2.1 GIS layer was modified to create subdivisions (the project analysis watersheds) based on R5 ERA protocols (watersheds optimally are to be between 2000 and 6000 acres). The analysis area includes complete drainage for all proposed treatment units. Total acreage for the analysis sub watersheds is 87,240.

1.1.1.3 Project Design Features

Design features are used to comply with the PNF LRMP as amended by the Sierra Nevada Framework. A further standard level of protection is provided from use of applicable Best Management Practices. Project design features are:

- Ground-based equipment would be restricted to slopes less than 35 percent except on decomposed granitic soils where equipment would be restricted to slopes less than 25 percent.
- Subsoiling to 18 inches minimum depth of temporary roads and landings within same year as harvest.
- In ground based logging units, trees greater than 24 inches dbh would be topped and limbed with tops and limbs lopped and scattered to a depth of less than 18 inches. In skyline and helicopter units, limbs and tops would be lopped and scattered to a depth of less than 18 inches.
- For alternatives A and C, generally retain an average of 5 to 15 tons of down woody material per acre. Emphasize retention of wood that is in the earliest stages of decay. For alternative D, retain 10 to 20 tons of large down wood per acre over the treatment unit.

The following equipment restriction zones would be established for ground-based logging in RHCAs based on stream type and slope class:

Table 1. RHCA equipment restrictions

Stream Type	Slope Class		
	0–15% (feet)	15%–25% (feet)	Greater Than 25%
Perennial	100	150	No mechanical
Intermittent	50	100	No mechanical

Stream Type	Slope Class		
	0–15% (feet)	15%–25% (feet)	Greater Than 25%
Ephemeral	25	50	No mechanical
Meadows and Wetlands	25	50	No mechanical

Extend the equipment restriction zones to 25 feet beyond the outer or upslope extent of the "green line" (actual or potential extent of riparian vegetation) or the inner channel slope break, where these features are present and these widths would exceed the above-listed widths. Also, exclude equipment from unstable slopes (landslide-prone areas or unstable mined lands) outside the riparian equipment restriction zones.

The following project design elements are to further ensure compliance with PNF LRMP and Sierra Nevada Framework and address concerns that arose during the analysis process:

- Tractor limitations listed above in design features apply to excavators and fellerbuncher harvesters in addition to skidders and forwarders.
- Harvesting and removal of products within equipment restriction zones would require direction felling and end-lining.
- Allow low ground pressure equipment to travel into the outer RHCA (outside of the equipment restriction zone) to retrieve harvest trees and bring them to skid trails.
- Locate skid trails at angles acute or perpendicular to stream channels to minimize erosion into the channel and allow skidders to enter the outer RHCA on these skid trails.
- Space trails at no less than 50 feet. Though larger spacing is typically recommended, the 50 foot spacing may actually reduce off trail harvest traffic.
- To minimize soil displacement, no equipment would be permitted to turn around while off a skid trail in RHCAs.
- Limit tractor operation to either dry season or frozen/snow covered soils to lessen compaction risk. Though most landforms are well drained and rocky sloped, the riparian bottoms have high wet soil and thus compaction risk.

1.1.1.4 Monitoring

The PNF LRMP sets out objectives and protocols for monitoring of plan standards and guidelines, BMP compliance and effectiveness, and soil productivity parameters. Random sampling of project units will be performed as part of the Forest's annual monitoring for BMP implementation and effectiveness. For analysis watersheds that exceed the ERA threshold of concern and that have project activity, forensic monitoring shall be performed annually as required by the CA Regional Water Quality Control Board, Central Valley Region Resolution #R-5-2005-0052, "Conditional Waiver of Waste Discharge Requirements for Discharges Related to Timber Harvest Activities." This monitoring requires at least two inspections over the first winter after timber operations to monitor the condition of erosion control measures and to ascertain whether sediment discharges have resulted from failed management measures or general timber harvest activities. At least two inspections are required after November 15, both occurring within 12 hours following a 24-hour storm event of at least 2 inches, with one inspection occurring after the precipitation season has produced a total of 5 inches of precipitation and another inspection after a total of 15 inches has been produced. Additional photo-point monitoring is required if a noticeable significant discharge of sediment is observed at any time in any Class I or Class II watercourse.

In-channel monitoring following Stream Condition Inventory (SCI) protocols (USDA Forest Service, 2002) provides a second tier of evaluation, the first being monitoring of BMP compliance and effectiveness described above. The purpose of SCI monitoring of beneficial uses is to determine whether BMPs collectively are effective in protecting water quality at the watershed scale. Effectiveness will be assessed by monitoring trends in channel characteristics that affect beneficial uses. Two SCI sites would be located, one below a treated (salvage log) watershed and one below a burned but untreated watershed. Sites will be selected on basis of similar valley segment and stream reach characteristics.

1.1.1.5 Climate

The analysis area ranges from 3,600 feet to 7,800 feet in elevation. Annual precipitation occurs mostly between the months of October and May, although late summer thunderstorms can produce localized high rainfall intensities. Total annual precipitation varies from about 40 inches in the western side of the project to 24 inches on the east. The winter snow line occurs in late December above 6500 feet. Generally from the end of October to mid/late-November most storms occur as rain. Below 6,500 feet elevation precipitation may occur as rain or snow (Faust 2007).

1.1.1.6 Geology

The project area is underlain by various rock types that are in the main (71 percent of the total area) Cretaceous granitics, and Jurassic meta-volcanics and meta-sedimentaries. Most of the remainder of the area (23 percent of the total) is tertiary volcanics that are pyroclastic andesites and rhyolites. Some 6 percent of the total area is sedimentary, either tertiary or younger gravel deposits, including the Auriferous river channel deposits of the Eocene or Pliocene/Pleistocene, and Pleistocene to Holocene slump debris (Wopat 2007).

1.1.1.7 Watershed Sensitivity

Project area watersheds are rated as moderately sensitive by Forest staff when evaluated for use of the ERA method. Rating variables include erosion potential, slope steepness, amount of alluvial channels, risk of rain-on-snow and/or thunderstorm events, and re-vegetation potential. Using these ratings, a Threshold of Concern (TOC) value is assigned for each watershed in order to assess risk from proposed activities. The project watersheds have moderate risk ratings of 12 through 14 percent ERA. Most of the project area watersheds are above TOC because of wildfire effects, recent salvage removal on private lands, and past management on Forest lands.

1.1.1.8 Beneficial Uses

Existing beneficial uses of surface waters in the project area are found in the Central Valley Region Water Quality Control Plan (California Central Valley Regional Water Quality Control Board 2007). The project area drains to the North Fork Feather River. The North Fork Feather watershed comprises 55% of the approximately 2.2 million acre basin that feeds Lake Oroville, the primary reservoir for the California State Water Project. Existing beneficial uses include municipal and domestic supply, hydropower generation, recreation, freshwater habitat, habitat suitable for fish reproduction and early development, and wildlife habitat. Specific uses of water in the vicinity of the fire are irrigation (Indian Valley and North Arm of Indian Valley), cold water fisheries (Management Indicator Species Report, Chris Collins and Kristina Van Stone Hopkins, May 2008), and Antelope Lake reservoir for storage, domestic supply, and recreation (Faust 2007). There are, however, no specific monitoring data of these water bodies to support any conclusions regarding compliance with state regulatory criteria on beneficial uses.

On May 5, 2009, following heavy rainfall in the project area (1.9 inches 5/1/09-05/04/09 at Greenville weather station; California Department of Water Resources website: http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=TAY), technicians from Feather River Coordinated Resource Management (unpublished data, 2009) took grab samples of flow in Indian and Lights Creek in Indian Valley below the project area. Values of Nephelometric Turbidity Units (NTU), were 222 and 98 for Lights and Indian Creek, respectively. Specific NTU values for North Fork Feather River tributaries are not provided in state water quality standards (California Central Valley Regional Water Quality Control Board 2007), but general guidelines for natural waters given suggest values for Lights Creek, for example, are 2-30 times above thresholds for turbidity due to controllable factors.

1.1.1.9 Stream Channel Conditions

There are 790 miles of channel in the project area, including 604 miles of ephemeral, 80 miles of intermittent, and 106 miles of perennial according to Forest GIS records. The fact that listed perennial miles are greater than intermittent probably points more to the difficulties in determining flow regime than in actuality.

About 27 miles of channel, mostly ephemeral and intermittent in nature, have been surveyed previously by Forest staff for indication of flow regime and function, such as bank stability and amounts of large woody debris (LWD). Most of the survey reaches are in Pierce and Upper Indian creeks drainages with minor amounts in Cold Stream, Middle Lights Middle Creek, Moonlight, and Moonlight Valley (Forest GIS records). About 6 percent of the total surveyed reaches or 1.6 miles had prevalent or extensive bank instability, primarily in Upper Indian Creek, and almost entirely within ephemeral and intermittent channels. About 1.4 miles of channel, all intermittent or ephemeral in nature were listed in the survey as having poor, inadequate amounts of LWD in terms of habitat structure. All these reaches were in Middle and Upper Indian creek drainages.

Moonlight Creek received an overall condition rating of good. Both the percentage of sediment in pool tails and the percentage of unstable banks were low, and these were also rated as good. Shade was also rated as good, with conditions of 96 percent. Hungry Creek was rated as good overall, with both shade and unstable banks rating as good. Sediment in pool tails however, was more than 15 percent, and rated as poor. Pierce Creek at Wheeler Sheep Camp and Boulder Creek at Hallett Meadow rated at moderate to poor. Sediment in pool tail fines was high in both reaches, which rated at very poor and poor, respectively. Historic grazing activity has occurred around both reaches, and has contributed to bank instability.

Fire likely burned out the LWD in most channels, particularly first and second order streams. Sediment previously stored by LWD may be released, as well as new deliveries of sediment including ash may be freer to transport downstream (Faust 2007). In the larger channels LWD was only partially consumed. Burned trees on the banks have fallen into streams creating flow deflector that will divert water into stream banks creating more erosion as well as destabilizing the banks themselves (Rosel et al. 2007). Observation during field visits for this report was that those reaches within meadow areas were relatively untouched, and the burn was light on the meadow floodplain. Reaches in gorges such as lower Lights Creek with large areas of out cropping were also only lightly burned. Amounts of LWD in RHCAs in tons per acre are measurement indicator for stream morphology and aquatic habitat.

Mining in or near the streambeds of Cooks, Moonlight, Lights, and Indian Creeks has disturbed riparian areas and channels creating over-steepened and unstable stream banks.

There is a confluence of many streams to form the main stem of Lights Creek: West Branch Lights Creek, upper Lights Creek, Bear Valley Creek, Morton Creek, Smith Creek, Fant Creek and East Branch Lights Creek. The channels in this area are broad and mobile with cobble/boulder dominate beds. Channels upslope of the confluence are steep with unstable banks. Prominent terraces have developed along Morton Creek immediately upstream of its confluence with East Branch Lights Creek. These features indicate that accelerated post-fire erosion and sedimentation is likely to increase channel instability and bank erosion in this area. The main channel of Lights Creek is likewise unstable with high sediment loading and a braided cobble-dominated channel for approximately one mile downstream of the confluence area. Abundant mine tailings and debris are present on the banks and in the channel. Channel form and instability, as well as large bed particles may be the result as well from a very wide range of annual peak flows in area streams (USGS records, http://waterdata.usgs.gov/nwis/sw). The tributary channels of Upper Lights Creek watersheds by contrast are steep and dominated by cobbles and boulders and appear to be stable. Mastication and mulching treatments were proposed in the hydrology report for the Moonlight Fire BAER to moderate the expected increase in sediment delivery to the streams (Faust 2007).

The Willow Creek channel and its tributary channels appear to be stable, armored as they are by large substrate or vegetation. Similarly, the main channel and tributaries of Pierce Creek, and Indian Creek are composed mostly of cobbles and boulders and appear stable. The channels of Moonlight Creek and its tributaries were fairly stable, though some areas of Moonlight Valley appear degraded. Middle Lights Creek is dominated by placer mining activity and the channels are degraded, and tailing piles cover banks and floodplains (Faust 2007).

1.1.1.10 Soil condition

The defining soil characteristic is the current condition after the fire. Much of the burned area has sparse groundcover and LWD. The BAER team found that the Moonlight and Antelope Complex fires burned mostly at moderate and high burn severity (Rosel et al 2007). The sparse "moonscape" conditions together with highly erodible soils, in particular the granitics, create a high hazard for soil erosion. The worst area is at the confluence of Middle Lights Creek with several lower order watersheds, including East Branch Lights Creek, Smith Creek-Fant Creek, Morton Creek, and West Branch Lights Creek. These areas have large contiguous areas of high and very high burn severity on highly erodible soils. In addition, the burned area has a high probability for a rain on snow event that would trigger flooding. The implication for soil productivity would be soil losses from debris flows and mudflows. Though these mass wasting events are not documented for the project area, at least some level of risk stems from a post burn environment where substantial storm events could occur. Erosion risk will be sustained for at least 2 years after the fire while hill slopes revegetate, then reduce quickly during years 3 through 5 (Rosel et al. 2007).

The project area soils have moderate productivity with ample moisture of 24 to 40 inches annual precipitation. Soils are differentiated based on geology. Soils on granitics are thin, have sandy loam textures and marginal productivity. The granitics are classically infertile with risk to erosion from sheetwash and dry ravel (Megahan 1992), though resistant to compaction because of a lack of clay (Gomez et al. 2002). These soils are textbook examples of decomposed granite "DG" soils with excessively drained conditions. Figure 1 shows the proximity of these granitic soils on which roughly a third of the proposed units occur.

Another indicator of productivity is potential wood volume mapped as the forest survey site class (FSSC). Forest survey site class (FSSC) is a measure of site productivity in cubic feet of wood per acre per year. Site class 1 is the most productive, while FSSC 7 is the least. Site class 7 lands are considered non-productive, and occur largely along ridge tops and steep rocky slopes. Both site class 5 and 6 lands are interpreted as having low productivity (USDA Forest Service 1999). Using this indicator, the project area has low potential for wood volume with mostly site classes 5 and 6 classes mapped.

All other project soils developed in either metamorphic rocks or volcanic parent material. These soils are very rocky, with very gravelly loam soil textures. Drainage is less than the granitics though appreciable. Productivity is higher with moderate soil development. Erosion risk is reduced from the high amounts of surface rock that break up erosive overland flows. Toe slopes and old landslide features will have deeper soils with higher clay content.

Burn severity for the Moonlight and Antelope Complex fires perimeter was 38 percent high severity, 37 percent moderate, 18 percent low and 7 percent unburned (Rosel et al. 2007). Ground observations of the high burn severity areas found soils still have good structure and intact fine roots, but soil cover and canopy was completely consumed. In limited areas hydrophobicity was found at 2 to 6 inches depth. Degraded root structure was also found in the top soil (Rosel et al. 2007).

Fire severity directly relates to burn residency time and is tied to the amount and condition of cover, depth of hydrophobic conditions that can interfere with soil drainage, and changes to soil structure and overall hydrologic function. In contrast, fire intensity translates to vegetation canopy burned. Not all high intensity burns typical of crown fires burn with high severity since flames sweep across the forest without downward radiant heating (Hartford and Fransden 1992). High severity burns can be long-term impairments to productivity from the excessive heating eliminating all surface organics and burning vegetative seed source in the upper horizons (DeBano et al. 1998). The bared soil is subject to erosion, though this is site specific and particularly tied to the risk for high intensity rainfall (Spigel and Robichaud 2007).

The high severity conditions observed by the BAER team are due to the complete removal of vegetation cover. Hydrophobic layers only developed on metamorphic and volcanic soils and were from 2 to 6 inches deep (Rosel et al. 2007). However, hydrophobicity is a temporary condition lasting 1 to 2 years (Shakesby et al. 2000) and not a substantial issue for soil drainage, especially on the prominently rocky metamorphic soils that are more robust to erosion. The extent of hydrophobic soils was estimated to be 797 acres on the 64,991 acre Moonlight Fire (less than 2%) and 7% of the Antelope Complex.

Recovery potential depends on erosion after wildfire as groundcover re-establishes with vegetation growth. Erosion risk reduces dramatically as groundcover returns, estimated at 3 to 5 years from the Moonlight BAER report (Rosel et al. 2007). Two complicating factors are limited natural regrowth within the high severity burned areas and the high chance for flooding events, mainly rain on snow events during January and February (Hydrology section below). Though rainfall intensity is a primary driver for erosion, especially in a burned area landscape (Spigel and Robichaud 2006), the saturated conditions are likely to produce shallow surface movement of soil from extreme rain on snow events. Also, delayed regrowth in adjacent burned areas was observed (Rosel et al. 2007).

Modeling soil erosion on high severity slopes found an average of 46 tons/acre following the wildfire compared to natural rates of 1-2 tons/acre (Rosel et al. 2007). Modeling used Water Erosion Project (ERMiT) to estimate soil erosion (Ibid). Generally, WEPP modeling has +/-50 percent accuracy.

Given the setting for heightened erosion risk after the fire, erosion risk was mapped to illustrate the most problematic areas. Mapping used the ERA model and followed the logic of the Moonlight BAER team post fire assessment (Rosel et al. 2007). The model uses soil survey information together with climate, slope metrics, and groundcover data. Figure 2 gives a general overview of the erosion risk in relation to the proposed harvest units. Table 2 shows the split of erosion risk within proposed units. Erosion risk is greatest on the steep sloped areas that had high burn severity; most notably on granitic soils. Other soils that are mapped as very high soil erosion risk include Rock Outcrop-Deadwood-Clallam families complex with 70-100 percent slopes and the Wapi-Chaix families complex with 50-85 percent slopes (red areas in Figure 2 outside granitic soils). Risk may be overstated in these areas since these steep rocky slopes do not have as much sediment available to lose.

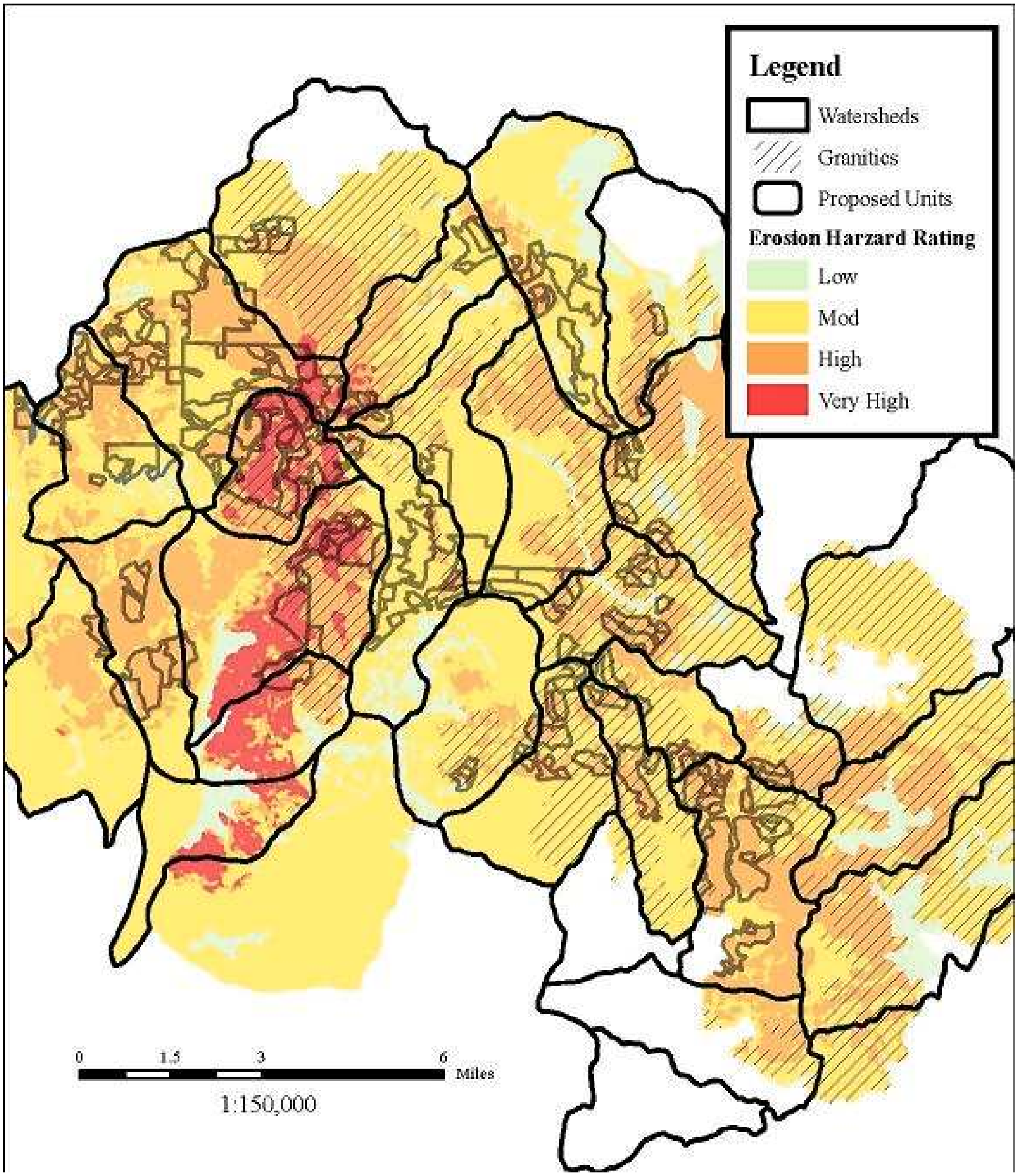


Figure 2. Granitic soils within the project area.

Table 2. Erosion risk across the project units for the Moonlight and Wheeler Fires project treatment units using the Erosion Hazard Rating System. Values shown are acres.

Erosion Hazard Rating				
Alternative	**Low**	**Moderate**	**High**	**Very High**
A	558	5878	6749	1758
C	515	5019	2737	264
D	515	3306	1754	169
E	508	2455	1265	157

Despite the high risk for erosion as indicated by the mapping, signs of erosion during the fall 2007 reconnaissance for this report were very rare. Overt signs of either overland flow or rilling was observed in very small portions (<<1 percent in extent of unit area) in 3 units (8, 67 and 76b), of the 30 units surveyed for soil disturbance in November, 2007. The lack of observed erosion is likely because of the well drained soils that limit erosive overland water flow.

The 2007-2008 precipitation season was well below normal and no significant rain-on-snow events occurred over that winter. Little or no overland erosion was expected to have occurred within the burned areas because winter and spring runoff was dominated by slow, steady snowmelt that did not have much erosive power. This expectation was verified on a limited scale by a two-day monitoring reconnaissance in June 2008 of BAER treatments and areas proposed for further treatment within the Moonlight Fire, performed by five R5 hydrologists and soil scientists. Of the half dozen sites without treatment visited, all within DG soils, none exhibited evidence of accelerated surface erosion over the winter (Hoffman 2008).

Current conditions in respect to soil management guidance are listed below. Mandatory soil quality standards and guidelines are provided from the amended PNF LRMP. The regional soil quality analysis standards provide threshold values for analyzing or evaluating soil condition. Soil quality indicators that are near or above threshold conditions include effective soil cover, soil compaction, and down woody material, based on the November, 2007 field visit. Observations and summaries are listed below.

1.1.1.10.1 Effective soil cover

As stated above, soil cover was removed from the wildfire and ranged from 0 to 60 percent for the surveyed units (Table 3). Most of the units in high burn severity areas have sparse groundcover. Only one unit, unit 15, had adequate amounts of ground cover. Ground cover was provided mostly by rock fragments greater than 3 inches on the intermediate axis, with minor amounts of basal vegetation. PNF LRMP standards and guidelines direct that adequate ground cover for disturbed sites is to be determined for each Plumas NF project on a case-by-case basis. The PNF LRMP offers suggested guides for effective ground cover that vary by the soil erosion hazard rating (EHR). Effective ground cover should be maintained at 60 percent for soils with a high EHR, and 50 percent for soils with a moderate EHR. Given that 65 percent of the treatment area soils have EHR of high or very high (Table 2), effective ground cover should be considered no less than 60 percent in all units. Those units with ground cover ≥ 20 percent were underlain by Jurassic metamorphic and Tertiary volcanic rocks, which are more resistant to mechanical weathering than the granites, had large extents of outcrops, and are stony. The remaining units in question were mostly in Cretaceous granites which weather relatively quickly into sandy textured, highly erodible soils. Effective ground cover overall in the project is well below the suggested guidelines virtually throughout the project area and will remain so until basal vegetation can re-establish within 3 to 5 years. The PNF ground cover standard for this project is to utilize project materials, such as scattered top and limb slash material, to improve existing ground cover where possible until basal vegetation can be re-established.

1.1.1.10.2 Soil compaction

Residual harvest accounts for 6679 acres within the preferred alternative, whereby roughly half is slated for tractor based harvest. PNF LRMP soil standards state that, to avoid land base productivity loss due to soil compaction, no more than 15 percent of a timber stand is to be dedicated to landings and permanent skid trails. Permanent skid trails and landings are not dedicated within the proposed project area. Region 5 soil analysis standards have a threshold in soil porosity reduction of 10 percent, at which point it is assumed detrimental compaction may occur, but this guideline does not in itself consider extent of compaction. A threshold of 15 percent extent of detrimental effects to soil productivity, over an activity area, is recommended. Table 3 shows that of the field reconnaissance proposed units, of which roughly half had signs of past harvest, no indication of past harvest impacts exceeding threshold for detrimental disturbance were found. The area of detrimentally compacted ground found during the survey was almost exclusively skid trails and landings, although not all skids and landings were deemed detrimentally compacted. The lack of residual harvest effects was surprising given the level of past harvest activities within the planned fire area.

1.1.1.10.3 Down woody material

The PNF LRMP as amended states that down woody material retention should be determined on individual project basis. For this project, retention levels for down woody material (where available) will be 5-10 tons per acre of large woody debris greater than 3 inches in diameter and a minimum of 3 logs greater than 12 inches diameter per acre. Regional soil analysis standards suggest that forest specific guidelines be according to local ecological type. The forest type in the analysis area is east side or within the transition zone from west side vegetation type to east side, favoring the east side (Tompkins and Moghaddas 2008). Recommended levels for east side vegetation types should be an average of 3 large down logs per acre a minimum of 12 inches diameter at mid point (USDA 2004a, page 69). The average number of large down logs per acre in the surveyed treatment units as might be expected was very low (Table 3). LWD in units of tons per acre are a measurement indicator for soil productivity. Recommended numbers and diameter of down logs works out to about 1 ton per acre for ponderosa pine and Douglas fir types, using conversion factors found in Brown et al. (2003).

In fire salvage and green timber harvest areas, much attention has focused on large woody debris as a viable indicator for ensuring soil productivity (Harvey et al. 1989; Graham et al. 1994). The coarse wood debris creates microsites that moderates soil moisture, temperature and biota. Graham et al. (1994) recommends retention of 5-10 tons per acre of LWD (defined as greater than 3 inches in diameter) on dry ponderosa pine types (Brown et al. 2003). Given the proportion of the burn within the project area that is very high and high severity, it is likely that current down CWM is below desired amounts.

Decaying material needed to support organisms and return nutrients to the soil will be formed as standing dead trees fall in the project area and come into contact with the ground. As the downed wood decays, the old logs become sites for biological activity with mineral nutrients and higher moisture. The ecto and endomycorrhizae that take advantage of downed wood as substrate are important for vegetation including shrub, forb, and grass species. The moisture content in adjoining soils will also remain at elevated levels and provide areas of accelerated vegetative recovery**.** Burned logs that where charred may not function readily as nutrient sinks per se, though the charcoal can moderate mineral nitrogen abundance in the long term by alleviating inhibitory compounds that interfere with nitrification (DeLuca et al. 2006).

1.1.1.11 Fine organic matter

The Region 5 guidance provides a threshold for surface fine organic matter, recommending retention of 50 percent cover in all stands. Organic cover helps maintain site fertility and prevent soil loss from erosion. Fine organic matter consists of plant litter, duff, and woody material less than three inches in diameter. None of the units surveyed had any appreciable fine organics. There were significant areas in many units with a thin ash layer, on order of a few millimeters thickness. Although in some cases partially burned litter and duff existed, ash, when dried, may not present a sufficient buffer to rainfall and was not counted as effective cover.

Table 3. Results of disturbance survey

Unit #	Soil Cover %	Detrimental Compaction %	Down Logs per Acre	Canopy Cover %
11	28	0	<<1*	21
5a, 55b`	16	0	<1	15
15	60	5	<<1	19
16	38	0	~1	23
113c	50	0	<<1	20
113e	40	0	<1	11
22	25	5	~1	20
24	20	0	~1	6
26, 26f	12	6	~2	4
28	10	7	<1	13
26i	45	5	<1	24
31, 31c	5	5	<1	26
38a	0	0	<<1	3
76b	25	3	<1	11

Unit #	Soil Cover %	Detrimental Compaction %	Down Logs per Acre	Canopy Cover %
52	5	0	<<1	8
54, 134	20	0	<1	28
59, 59b	0	0	<<1	9
96, 61a, 61b	5	0	<1	14
8	3	0	<1	21
79b, 92a	10	0	<<1	19
67	20	0	<<1	14
69	5	5	<<1	49

*--no downed wood within sample transects.

1.1.2 Environmental Consequences

1.1.2.1 Alternative A (Proposed Action), C, D, and E

Alternative C is inclusive of all tractor harvest in proposed Alternative A. It also retains 92% of the temporary road construction (12 of 13 miles). It drops from Alternative A the helicopter and skyline cable logging, as well as the need to construct 11 helicopter landings.

Alternative D is inclusive of the roadside hazard tree removal and 31% of the tractor harvest, those units or sub-units of tractor harvest which essentially requires no temporary road construction. Only 3 miles of temporary roads are proposed with Alternative D. As with Alternative C, D drops the helicopter and skyline cable units.

Alternative E is inclusive of the roadside hazard tree removal component of Alternative A. No temporary roads or landings are proposed with this alternative. Amount of harvest in RHCA is not substantially different than the other alternatives (Table 36). This simply points up that most of the RHCA harvest entries are along already existing forest roads.

Table 4. Comparison of actions in project alternatives.

Type Action*	Alternatives				
	A	B	C	D	E
Temp Road*	19	0	18	3	0
Ground-based Harvest	8,536	0	8,536	5,656	4,389
Skyline Harvest	872	0	0	0	0
Helicopter Harvest	5,347	0	0	0	0
Roadside Hazard	4,389	0	4,389	4,389	4,389
Reforestation	16,006	0	9,306	16,006	16,006
Snags Retention	1,060	0	580	174	0

*--temporary road values are miles, all others are acres.

These reductions in project activities in Alternatives C, D and E, from Alternative A, do not alter substantially the condition for any of the analyzed watersheds (Table 11). The amount of harvest within RHCA's in Alternatives C, D and E are similar and not substantively different from Alternative A, considering the much larger disturbance impacts of ground-base harvest methods.

The wildfire left the landscape in a very risky condition for flooding and slope erosion within the next two to three years as slopes revegetate. The effects of the action alternatives are difficult to measure compared to the larger issue of recovery after the wildfire. The main effect will be delayed recovery for 1 to 3 years from soil disturbance associated with tractor yarding activities. Long-term effects to soil productivity are less certain, particularly on the 8536 acres where biomass removal is planned. Granitic soils are the most at risk for long term impairments to productivity because they are relatively infertile. There are 2425 acres of biomass removal planned on granitic soils. No piling or burning of slash or biomass will occur in the tractor harvest units.

Reforestation activities, while beneficial for timber recruitment, will not alleviate the disturbance hazard of tractor harvest activities. The highest risk is in the Lights Creek valley. Soils on the main stem stream and major contributing streams are naturally highly erodible and were predominately burned at a high severity.

The confluence of similar third order watersheds at the top of the Middle Lights Creek project watershed creates in itself a heightened risk for flooding on and downstream of this watershed. An aggravating circumstance is the heavy logging on Sierra Pacific lands in the headwaters of Upper Lights, West and East Branch Lights, and Smith Creeks, the principle contributors to Lights Creek. Altogether these factors create a "perfect storm" condition for flooding during the occurrence of a warm southwester in mid winter that brings heavy rains and warm winds on a thick blanket of snow.

1.1.2.1.1 Direct and Indirect Effects

1.1.2.1.1.1Soil Erosion and Detrimental Disturbance

Current predicted rates of erosion are well above natural erosion rates of between 1 and 2 tons/acre. Erosion is upwards of 30 tons/acre the first year following fire, dropping to 5 tons/acre within 5 years. (Rosel et al. 2007). The impact of all action alternatives would not be higher than that of the wildfire, though the salvage activities would prolong natural recovery from 2 to 5 years on ground disturbed by harvest activities. The steep slopes, though more erosive, would return to rates similar to wildfire within two years. These steep slopes would be unaffected under alternatives C, D and E., The shallow slopes where ground-based systems are used would return to natural fire recovery within 3-5 years. Slope restrictions for ground based harvest under 25 percent slope, which include areas within granitic soils, RHCA, and roadside hazard removal, would variously lower erosion potential for all action alternatives. Difference in erosion potential from steep (>25%) and shallow slopes is illustrated in figure 3 below. The graph for skyline and tractor harvest shows that harvest technique in early years after a fire is not as significant as the burned condition itself.

Detrimental disturbances within helicopter yarding treatment units are incidental to hand falling of trees and insignificant in extent.

Use of heavy equipment in ground base units for felling and yarding will compact and displace topsoil, particularly along principle trails and landings. The degree of soil compaction depends on the number of passes by heavy equipment, and also the texture of soil (Powers 2002). Coarser, sandy soils typically resist compaction better than finer grain soils (Gomez et al. 2002), but most soil compaction occurs within the first three or four passes (Williamson and Neilson 2002). In general, project soils are resistant to compaction due to sandy granitic soils in a third of the tractor units and otherwise from the high rock content. However, the additional tractor use from biomass removal of unmerchantable trees increases ground based traffic.

Further effects of ground base yarding are decreased infiltration capacity, either because of the removal of the organic ground cover and exposure to high intensity rainfall, or reduced porosity through compaction. The former condition is the most probable because of heightened risk for surface erosion by sheet wash and rilling. Additional erosion modeling was done to frame the recovery with the predicted effects. Theoretically, tractor yarding would have the greatest impact with removal of cover from 15 to 30 percent across treatment units due to machine travel on bare soils. Further loss, albeit small, would be through removal of trees with some needles left. Needlecast on the burn slopes is an important first component to soil cover recovery. On severe burn areas, loss of cover would be smaller but salvage harvest during the first year of harvest would set back recovery none the less. Steep areas would have groundcover reductions of 3 to 10 percent depending on the harvest system. Helicopter yarding usually leads to less than 3 percent detrimental disturbance and skyline yarding averages 10 percent detrimental disturbance (McIver and Starr 2000).

Results of WEPP analysis on an acre of disturbed ground under average conditions of slope gradient, length etc., using the ERMiT module (Robichaud et al. 2006), are shown in figure 3 below. In addition, the Disturbed WEPP module was used to ascertain the increase on erosion potential with reductions in groundcover. Recovery rates were assumed to follow the same trends as after the wildfire. Slope lengths were 300 feet for shallow slopes, less than 35 percent, and 500 feet for steep slopes averaging 50 percent. Though erosion on granitics is problematic, the WEPP software shows markedly lower rates of erosion on these hillslopes conflicting with field observations and soils mapping risk interpretations. Thus, soils on metasedimentary rocks were used to contrast erosion rates between wildfire and wildfire with salvage harvest.

The modeling illustrates the very high erosion potential in the first two years following wildfire. Erosion rates could be as high as 50 tons/acre, which is in the same order of magnitude as those found by the Moonlight Fire BAER team (Rosel et al. 2007) who reported an average rate of 46.2 tons per acre for all watersheds 1 year after the fire. Within the second year, potential erosion is just over half the initial year’s rate with almost a five fold drop with five years regrowth.

Using skyline yarding system, the third year would have double the erosion potential with the relatively small reductions in groundcover since early in the recovery period slopes have little regrowth. However, within five years, burned area and skyline areas would have similar risk for erosion potential, albeit still at high levels of risk at 12-15 tons/acre.

Using tractor yarding systems, the third year would be 2.5 times the erosion over the normal recovery after the wildfire. The higher disturbance on tractor ground would take longer to recover. Forecasted rates would mirror wildfire recovery at years 7 to 10. Thus, tractor harvest, would delayed recovery compared to skyline systems when compared to natural wildfire recovery rates.

The skyline curve starts with higher erosion rates and continues so through harvest activities because of the steep slopes associated with this method. Slope gradient is strong driver of erosion and a dominant factor, along with slope length, in WEPP analysis.

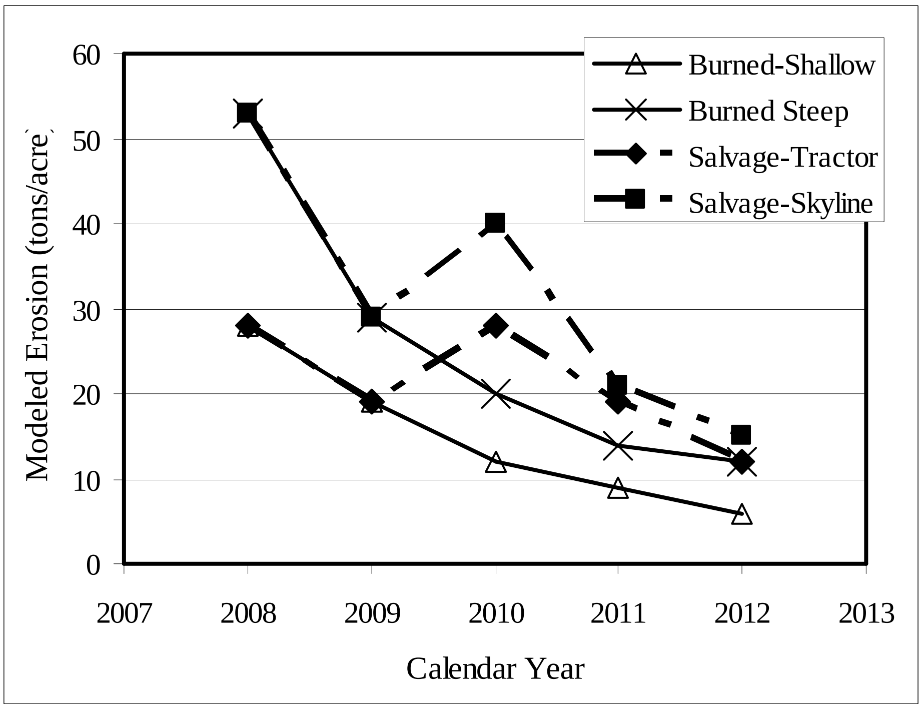


Figure 3. Potential erosion in time for burned slopes versus planned skyline and tractor salvage. Modeling assumes salvage harvest is completed during year 2009.

Biomass harvest could also impact the erosion rates. All of the planned tractor units have biomass removal. Trees over 24” dbh in the tractor units would be limbed and topped. This debris would then be lopped and scattered. All trees harvested in the helicopter and skyline units would be limbed and topped and the debris scattered. It is expected that the resultant ground cover would be approximately 10%. Skyline and helicopter salvage harvest would leave all non-merchantable material within the units. Though mixed results are found with contour logging effectiveness (Robichaud et al. 2000), leaving this material would intuitively provide some level of protection. Table 5 below shows that LWD component of cover will increase many times over across the helicopter and skyline units. Some soil cover gained since the fire, due to vegetative recovery however, would be lost by disturbance during harvest. Also, in monitoring of downed wood debris after harvest, data from the Rocky Mountain Research Station indicates roughly 13-56 tons/acre material after salvage harvest using tractor systems (Page-Dumroese 2008, personal communication).

To further temper discussion, erosion either could or could not happen. Somewhat minor blowouts along roads and skid trails are expected. However, a storm with enough intensity to drive overland flow is beyond the order of a 10 year storm. Localized thunderstorms are common, though not in the same magnitude as summer monsoonal influences of the southwest. The real risk for flooding is from the heavy mid winter rain or rain on snow events but these would not necessarily move the hillslopes.

While it is reasonable to assume there is some observable effect of activities on burned slopes, in the event of a storm sufficient to initiate overland flow, those effects would be relatively localized and in terms of delivery of sediment to channels it would be difficult if not impossible to differentiate from the sediment load derived from the rest of the watershed’s burned if untreated slopes. The main effect is the prolonged exposure of 2 to 3 years where natural recovery would be delayed from the salvage harvest activities.

Application of BMPs will be used to lower incidence of surface erosion and sediment delivery. Since 1992, the Plumas NF has conducted over 600 evaluations of BMP effectiveness per the approved R5 protocol. The most recent summary of this monitoring was produced following the 2007 field season (USDA 2008a). That summary listed 441 evaluations of BMPs for the type of activities proposed under the action alternatives. BMPs were rated as effective for 79.8% of those evaluations. Other sources for soil erosion are from temporary road construction where native surfaces are exposed to rainfall. Within units, these areas will likely have short-term increases of soil erosion above the recommended 2 tons/acre. Effects will decrease as roads are obliterated immediately following project completion by subsoiling, which will break up compaction and increase infiltration capacity. Erosion risk is for less than 10 years as groundcover returns to 50 percent or over.

1.1.2.1.1.2 Soil Organic Matter and Large Woody Debris

Regional standards are to maintain organic matter both of fine and large size in amounts sufficient to prevent significant short or long-term nutrient deficits.

Fine surface organic matter includes plant litter, duff, and woody material less than three inches in diameter that occurs over at least 50 percent of the activity area. This condition is not met in very high and high burn severity areas, nor would it be for up to 3 years or more after the fire.

Limbs and tops used for lop and scatter in helicopter and skyline units, breakage during harvest in all units, and scattering of tops and limbs of trees over 24” dbh in ground-based units would contribute to total LWD greater than 3 inches diameter in the immediate post-harvest condition. It is expected that the resultant ground cover would be approximately 10%. Fire ecology models (Tompkins and Moghaddas 2008) give estimates of over 7 tons per acre on average immediately after harvest, which exceeds the current and no action condition (Table 5). Increase is also due to fire-damaged trees dying within 3 to 5 years of the fire. Other areas that will contribute LWD, outside of treated ground but within the treatment units, are snag retention areas for wildlife and equipment exclusion zones within RHCAs.

Table 5. LWD values in tons per acre average in treatment units—summarized from fire ecology modeling and stand exam data (Tompkins and Moghaddas 2008).

Term	All Action Alternatives	All Action Alternatives	Alt. A Only	RHCAs	
	Tractor and/or Roadside Hazard Units LWD > 3" diameter	Tractor and/or Roadside Hazard Units, LWD > 12" diameter	Helicopter and Skyline Units LWD > 3" diameter	Tractor and/or Roadside Hazard Units LWD > 3" diameter	Helicopter and Skyline Units LWD > 3" diameter
Post-Harvest	7.3	1.1	7.3	7.8	10.4
10 years after harvest	6.7	1.0	14.7	12.4	17.3
20 years after harvest	6.2	0.9	18.8	12.8	23.1
30 years after harvest	5.6	0.8	18.5	11.8	22.8

Because all standing dead trees under 16 inches dbh are left in the helicopter and skyline cable units in alternative A, recruitment for LWD is greatest, and in the long term (10-30 years) LWD is estimated to be from about 15 to 19 tons per acre in those units.

Because of biomass removal of standing dead trees below 16 inched dbh, and harvest of standing dead trees above 16 inches dbh, LWD amounts in tractor units are estimated to decrease in time from 7.3 tons per acre on average to 5.6 tons per acre on average 30 years after the fire. The reason is that removal of most standing dead trees from the treatment units eliminates LWD recruitment. There will be some recruitment from those fire damaged trees that will die 3 to 5 years after the fire.

According to the fire ecology modeling for alternative A presented in Table 5, in the treated areas of tractor units, aside from wildlife snag retention stands and equipment exclusion zones in RHCAs, total LWD amounts greater than 3 inches dbh would be on low side of range of 5 to 10 tons per acre recommended for long term soil productivity (Graham et al., 1994; Brown et al., 2003). Project design elements require retention of 5 to 15 tons of down woody material per acre for alternatives A and C and 10 to 20 tons of large down wood per acre for alternative D.

Converting east side eco-type standards for 3 large logs a minimum of 12 inches dbh into tons per acre gives about 1.0 tons for ponderosa and Douglas fir type cover, using conversion factors from Brown et al. (2003). Therefore total tonnage of LWD greater than 12 inches dbh in the tractor units would be marginal or below levels set by standards

(Table 47). However, since implementation of any action alternative would occur in 2009, nearly 2 years after the fire events, a substantial amount of cull logs greater than 12 inches dbh will be left in the units, generally raising the log mass per acre well over 1.0 ton.

All units will be hand planted with conifer seedlings. Preparation for planting is hand scalping of ground cover, of approximately 2 feet in diameter. The density of planting will be between 100 and 200 seedlings per acre, depending on burn severity and plant association groups of burn area. The total disturbance from planting constitutes about 1 percent of the planted area. These totals are not considered to be a significant detriment to the eventual recovery of ground cover, nor are the treatment plots large enough to be considered as detrimentally disturbed ground (USDA Forest Service 1998).

In time, organic matter will gradually accumulate from litter, woody debris, forbs, and grasses. Nutrients will gradually accumulate due to inputs (in precipitation, dry deposition, throughfall, weathering of parent material, and nitrogen fixation) and retention. These processes will take decades.

Salvage logging impacts soil recovery after wildfire by extracting remaining organic matter in form of tree boles. The greatest impacts are within high intensity burn areas. Where wildfire burned hot, forest floor is missing, and most of the trees are blackened. These areas are sensitive since live above-ground biomass is essentially removed. Site conditions are largely moderated with the remaining forest structure in the form of dead wood. Dead down and standing wood ameliorate site condition by forming micosites that shelter vegetation regrowth, harbor moisture, and augment soil temperature with shade (Harvey et al. 1987; Franklin et al. 2002). These attributes improve soil growth potential, especially in dry areas such as south facing slopes. As standing dead falls, this wood is further incorporated as brown cubicle rot that acts as a sponge for moisture.

1.1.2.1.1.3 Soil Biology

Impacts to micro-organisms and soil fauna, including endo- and ecto-mycorrhizae are not quantifiable. Impacts would be highest in high burn intensity areas. Ectomycorrhizae are most abundant in the organic soil components, including litter, humus, soil wood, charcoal, and organic enriched mineral horizons. Since the Moonlight and Wheeler fires reduced the soil organic component, it follows that the total number of ectomycorrhizae would be reduced. This occurs for a number of reasons including the reduction of habitat sites, chemical changes in the remaining organic matter, and the reduction of conifer needs for the added nutrient uptake capacity gained through ectomycorrhizal associations. Soil chemistry can change after fire, resulting in unfavorable conditions for some ectomycorrhizae species.

All action alternatives would theoretically have greater impact on ectomycorrhizae with the removal of wood products. Though likely immeasurable, the impacts would be greatest in the tractor based biomass and harvest removal units, where the most disturbances occurs with the least amount of organic material left. Alternatives A, C, D and E have similar level of these activities. Skyline and helicopter harvest units would likely not impact ectomycorrhizae with appreciable material left to ameliorate site conditions.

An indirect effect that can result in adverse effects to soil productivity is from introduction of noxious weed species. Noxious weed species are a threat where groundcover is sparse and soil resources are abundant. Typically, available nutrients spike following fire and greatly reduce over the following two years (Choromanska and Deluca 2002). Noxious weeds invasion is a risk since these species are more adept than natives at exploiting abundant soil resources after fire.

Noxious weed invasion can impact soil productivity by shifting plant species composition. The shift in composition has biodiversity implications. The assumption is less diversity can lead to less productivity (Perry and Amaranthus 1997). Aggressive exotic invader species such as cheatgrass *(Bromus tectorum*) influence below-ground soil function by changing soil nutrient status and water dynamics, creating legacy effects that favor opportunistic species (Norton et al. 2004; Thorpe and Callaway 2006; Gundale et al. 2007). The risk is highest where noxious weeds establish and hinder native plant recolonization, especially where the fire burned the hottest.

1.1.2.1.1.4 Roads

Proposed temporary road results in short term degradation of soil hydrology and long-term reduction in soil biological function. In this case the life-time of the road is the project implementation period of approximately 1 year. Obliteration and reclamation efforts improve soil hydrologic function over leaving roads in place. For the short term, reclamation improves soil infiltration adequately to address erosion potential, though reclaimed soil would have infiltration rates lower than natural forest rates (Luce 1997; Foltz and Maillard 2003). For the long term, infiltration rates improve over time as freeze/thaw and plant roots improve soil porosity though rates would likely remain lower than adjacent natural forest soil (Switalski et al. 2004). Soil biological function restores as forest floor and native plant communities returns. Moist areas in the lower to middle portion of the watershed have higher restoration potential. Also, most of the project area has a northeast aspect, and thus cool and wet conditions that promote vegetation growth. Degraded biological condition is predicted for greater than 20 years.

1.1.2.1.1.5 Hydrology: Surface Flow and Water Quality

Road prisms intercept overland and subsurface flow, conveying this water across the relatively impermeable running surfaces and ditches to concentrate at discrete discharge points. Skid trails and other temporary transport routes associated with treatment have a similar effect, though a lesser degree of compaction and total width, they are often on steeper gradients. Erosion from increased flow routing on trails is controlled with water bars, which dissipate water energy and allow water to infiltrate into the soil. Subsoiling of temporary roads and landings will improve infiltration and disrupt surface flow.

The effect of greater overland flow and routing by roads and trails may be great enough to accentuate surface flow peaks for small fall storms in the natural channels of small watersheds. Exacerbated flows, occurring with a frequency or duration that exceeds existing long-term conditions of flow, could affect channel stability by degrading beds and in turn undercut banks and valley side slopes in the confined channels. However, the project area’s channels and near-channel valley slopes are dominated by large alluvial/colluvial and bedrock outcropping. The generally good bank stability found in project surveys are an indication of the resiliency of the well armored mountain streams.

Temporary roads are to be constructed for the action alternatives, but will within the same year of harvest be closed and, along with landings subsoiled to a minimum depth of 18 inches. The overall effect of roads is expected to be similar to the long-term pre-fire condition. Maintenance of running surfaces and crossings may attenuate response to storms insofar as concentration of flow in rutted roads, plugged or damage culverts would be corrected. Erosion treatment on skidding trails will reduce or eliminate the hydrologic connectedness of the skid trial system to Forest roads and its drainage, hence to project streams.

Loss of ground cover due to harvest would normally be limited by BMPs and other design criteria such as lop and scatter of tops and limbs, so that on average it would be no less than 50 percent. Currently ground cover in the project area is well below this level. In the event of high intensity rainfall, over the short term of 3-5 years after the fire it is the effects of fire that are paramount, and likely will mask the effects of harvest. The recovery rate of the fire -no action alternative-would likely be faster than the action alternatives where groundcover is reduced and soils are slightly to moderately compacted by timber extraction.

Runoff response to harvest, and incidental road building is overwhelming only for small (<<1 year recurrence interval) fall storms in dry antecedent conditions and well within the range of annual variability of peak flows (Beschta 1978; Ziemer 1998; Jones 2000). Incidents of significant effects of harvest to large peak flows can usually be correlated only with very high road density, or the placement of roads in close proximity to channels (Rice et al. 1973; Jones and Grant 1996; Jones 2000). This effect of harvest and roads is also most significant in small watersheds of under 1,000 acres and tends to decrease to insignificance with larger watersheds (Beschta et al. 2000). Analysis watersheds are between 1600 and 7600 acres, and average 3800 acres.

Sediment production from harvest is also mostly tied to access roads with several fold increases (multiplicative factors of 2 and 3) measured from 1 to 5 years after completion of harvesting, before a return to near baseline or pre-activity condition (Krammes and Burns 1973; Rice et al. 1973; Beschta 1978; Keppeler and Ziemer 1990). Primary sources are running surfaces, cut banks, and fill slope failures, the latter which usually come a few years after road construction.

Burned watersheds with significant ground cover loss however, diverge from their pre-burned conditions of peak flow and sediment production in response to high intensity rainfall, particularly in small headwater drainage areas (Neary et al. 2005). Most importantly, peakflow responses from wildfire are typically well out of range of responses produce by harvest and road building, with measurements from 1 to 3 orders of magnitude (multiplicative factors of 10 to 1,000) over pre-fire conditions (Tiedemann et al. 1979; Neary et al. 2005), because of the much larger proportions of a burned watershed in condition to generate overland flow. These runoff events are capable of initiating debris flow in headwater areas, drastically altering channel morphology of alluvial channels (USDA 2004b). Sedimentation following a wildfire is also typically 1 and often 2 orders of magnitude greater than pre-fire conditions (Tiedemann et al. 1979). There is a high probability of impairment to water quality downstream of the project watersheds in the near term (2-5 years) because of the existing burned condition. Recent water samples in Lights and Indian Creeks by Feather River Coordinated Resource Management (unpublished data, 2009,), following rainfall in the project area during May 1 through May 5, 2009, showed NTU measurement of turbidity many times over thresholds of state water quality standards (California Central Valley Regional Water Quality Control Board 2007)

The predominance of large bed particles in area streams (Affected Environment, Stream Channel Conditions) and banks of woody species are typical of mountain streams and relatively resilient to flow and an indicator of high per annum variance of flow. In project area streams that were surveyed either by the Moonlight Fire BAER effort or in stream surveys by Forest staff of channel conditions prior to the fire, channel condition was good overall. The proposed action calls for harvest of Riparian Habitat Conservation Areas (RHCAs) to the extent outlined in design features section and in Table 6 below. Values in the table are distance in feet from channels that harvest would occur and equipment can travel. On slopes greater than 25 percent there is no equipment travel. Where riparian conditions or valley slope break exists at slopes greater than 25 percent but at a distance that exceed those values given in Table 11, equipment will be allowed to operate an additional 25 feet. Equipment is restricted to slopes of 35 percent in all areas except those with granite parent material, or in an RHCA as described below.

Table 6. Riparian Habitat Conservation Area parameters for logging equipment use.

Stream Type	0-15% (feet)	15-25% (feet)	> 25% (feet)
Perennial	100	150	No mechanical
Intermittent	50	100	No mechanical
Ephemeral	25	50	No mechanical
Meadows and Wetlands	25	50	No mechanical

About 40% of the treatment acres in Alternative A will be helicopter or skyline yarding of all material except snags to the extent of 4 to 6 per acre, over 16 inches dbh, over a landscape basis. Limbs and tops will be lopped and scattered to a depth of 18 inches or less. The other half of the treated ground will use ground based equipment. Most of the standing dead will be removed, except for snag retention, as sawlogs or as biomass. This harvest scheme will persist in the RHCA areas to the extent outlined in Table 6. The substantive difference between Alternative A and C, D and E is the elimination of skyline and helicopter acres from those alternatives. Alternatives D and E further reduce acreage of tractor harvest from A and C.

The equipment exclusion zones within the RHCA retain sufficient quantities of standing dead trees for future recruitment and within 10 years predicted LWD is greater than 10 tons per acre.

Planting of conifer seedlings will take place throughout the burn perimeters. Between 100-200 tress will be planted per acre spaced in clusters. Site preparation for each tree would be hand grubbing of about a 2 foot circle. Total disturbance would be about 1 percent of the area, in widely spaced patches.

There is no available method to quantify effects of harvest on burned slopes, except to point out the greatly magnified effects of a denuded slope compared to that of a typical green harvest. Whatever the added effects of harvest on burned slopes, burned over stream buffers are obviously much less likely to dissipate and disperse overland flow and transported sediment before it reaches a channel.

In the helicopter and skyline cable units, because of the lop and scatter of limbs and tops, and the leaving of trees under 16 inches dbh, the resultant ground cover immediately after harvest is likely to be better than the current, post-fire ground cover in any RHCA that these units may include. The same is not necessarily true for ground-based units which will transport most of the standing dead material out. Trees over 24" dbh in the tractor units would be limbed and topped and the debris then lopped and scattered. It is expected that the resultant ground cover would be approximately 10%. There will be some amount of breakage that will be left on the ground, but this volume would be far less and less predictive. In addition, because of biomass prescription, it is likely wheeled equipment would travel over most of a unit area. Table 100 shows that 53% of entries into RHCAs are in ground-base equipment tractor harvest or roadside hazard tree removal units. The substantive differences between the alternatives are those RHCA acres in Alternative A within helicopter and skyline cable units. Application of BMPs, such as water barring skidding trails, and project design features, such as lop and scatter of limbs to increase cover will mitigate some of the effects of harvest. The scope of the activity treatment area within the burned watersheds is between 5 and 18% (Alternative A through E). Detrimental ground disturbance, upwards of 30% in tractor base unit area and between 5 and 10% in helicopter and skyline units, would range between 1.6 and 3.6 % total for the project watershed's area, depending on action alternative. Given implementation of erosion control features in activity area, impacts to water quality from activity disturbed ground are not expected to be a significant factor in the event of precipitation that induces overland flow in the burned watersheds.

Table 7. RHCA acres in high/very high EHR soils.

Logging Systems	Alternatives							
	A		C		D		E	
	Int.*	Per.**	Int.	Per.	Int.	Per.	Int.	Per.
Helicopter	388	289	0	0	0	0	0	0
Skyline cable	67	186	0	0	0	0	0	0
Tractor/Roadside	406	635	406	635	358	586	297	565
Total	930	1041	406	635	358	586	297	565

*--Intermittent streams, **--Perennial streams

1.1.2.1.2 Cumulative Effects

1.1.2.1.2.1Soils

An activity area is any impacted site feasible for sampling. Sale contract units are typically considered as individual activity areas for the purpose of soils monitoring

(USDA Forest Service 1998). Current rates of compaction or detrimentally disturbed ground in units surveyed are low (Table 3).

Cumulative effects of the proposed harvest are best characterized in the context of recovery after the wildfire. Natural recovery would be set back from 2 to 5 years from an erosion standpoint. Longer term effects are more difficult to discern with poor understanding of long term effects. Generally, over snow logging will have much less impact than summer logging (McIver and Starr 2001; Page-Dumroese et al. 2006a). However, implementation varies across forests and cover types with long term implications uncertain.

The Moonlight and Wheeler project area has moderately productive soils on metasediments and poor soils on granitics. Page-Dumroese (2006) alludes to poor productivity sites as having more critical needs for organic matter. Further, in an exhaustive catalogue of organic stores on sites throughout Idaho, Montana, and somewhat in Oregon, Page-Dumroese and Jurgensen (2006) found that surface organic matter on poor sites is a larger portion of the overall nutrient base and thus has implications for overall productivity. In regards to the proposed project, these findings suggest that the biomass removal together with timber harvest on the granitics would hinder recovery. This effect would occur on 2425 acres, roughly a third of the planned tractor biomass acres for Alternatives A and C. Tractor biomass would occur on 2002 acres of granitic soils for Alternative D and 1384 acres of granitics for Alternative E, roughly one half and one third of the total acreage for the alternatives, respectively.

In tractor units, and outside of the RHCAs and wildlife snag retention areas, estimates of LWD greater than 12 inches in diameter for east side vegetation types would be marginal or slightly under standards over the long term (30 years), because of lack of recruitment.

The scientific community has conflicting viewpoints on the long term effects of fire salvage on soils. James McIver, a professor at Oregon State who has actively participated in describing effects, provides a great overview. In his Forest Service briefing paper, McIver suggests that viewpoints by Beschta et al. (2004) offers a protection approach in the face of uncertain effects on severely burned soils as opposed to a more utilitarian approach with economics as a factor. In a rebuttal to Beschta, Evers (2002) argues that salvage within the context of site specific conditions is reasonable. However, without specific long term monitoring of salvage harvest within this ecosystem, long term effects are still uncertain.

1.1.2.1.2.2 Hydrology

As Table 11 above shows (Affected Environment, Hydrology) the largest effect to hydrologic function to hill slopes in the project are is from the wildfire itself. Although the ERA method is not quantitatively predictive it may be used to show relative effects of different sources to watershed runoff. For instance the fact that alternative C retains the ground base harvest, but drops the helicopter and skyline cable units has little effect on overall results, as ground base methods are by far the most disturbing to ground cover, which is the most important factor to hydrologic function of forested slopes. Figure 4 which classify project watersheds ERA percentage relative to TOC for alternative A would essentially be the same for alternative C, D and E as Table 8 shows.

Table 8. Summary of Equivalent Roaded Acre analysis for determining cumulative watershed effects.

Watershed	ERA% Alternative				Total ERA %				
	Alt. A	Alt. C	Alt. D	Alt. E	Existing*	Alt. A	Alt. C	Alt. D	Alt. E
Bear Valley	0.0	0.0	0.0	0.0	23.0	23.0	23.0	23.0	23.0
Cold Stream	1.1	0.9	0.3	0.3	13.6	14.7	14.5	13.9	13.9
East Branch Lights C.	3.0	2.9	1.9	1.8	16.6	19.5	19.4	18.4	18.4
Freds C.	0.2	0.0	0.0	0.0	12.5	12.7	12.5	12.5	12.5
Indian C. blw Antelope-Babcock	1.9	1.0	0.2	0.0	19.7	21.5	20.7	19.9	19.7
Indian C. blw Antelope-Dam	0.5	0.4	0.0	0.0	14.6	15.1	15.0	14.6	14.6
Lonesome Canyon	0.4	0.2	0.1	0.0	26.7	30.1	29.9	29.8	29.7
L. Cooks C.	0.3	0.3	0.2	0.2	5.9	6.2	6.2	6.1	6.1
L. Indian C.	1.6	1.6	1.6	1.2	15.8	17.4	17.4	17.4	17.0
L. Lights C.	0.6	0.1	0.1	0.1	17.4	18.0	17.5	17.5	17.5
L. Lone Rock C.	1.4	1.0	0.8	0.5	15.4	16.7	16.4	16.2	15.9
Middle C.	0.9	0.6	0.3	0.3	12.3	13.2	12.9	12.6	12.6
Mid. Hungry C.	1.1	1.0	0.6	0.4	8.8	9.9	9.8	9.4	9.2
Mid. Lights C.	3.0	1.5	1.0	0.9	19.9	22.9	21.3	20.9	20.8
Moonlight C.	1.2	0.7	0.6	0.6	14.5	15.7	15.2	15.1	15.1
Moonlight Pass	0.1	0.0	0.0	0.0	22.8	22.9	22.9	22.9	22.9
Moonlight Valley	1.9	1.7	1.4	0.8	18.0	19.9	19.8	19.5	18.8
Morton C.	1.0	0.9	0.6	0.4	21.8	22.8	22.8	22.5	22.3
North Arm Indian Valley	0.1	0.1	0.1	0.1	4.7	4.8	4.8	4.8	4.8
Pierce C.	0.8	0.8	0.8	0.6	9.6	10.3	10.4	10.4	10.2
Smith C.	1.4	1.3	0.9	0.3	25.3	26.7	26.6	26.2	25.6
Up. Hungry C.	1.4	1.4	1.3	1.3	12.2	13.6	13.6	13.5	13.5
Up. Indian C.	1.5	1.4	0.8	0.5	10.2	11.6	11.5	11.0	10.7
Up. Lights C.	0.3	0.1	0.1	0.1	14.1	14.3	14.2	14.2	14.2
Upper Peters Creek	0.5	0.5	0.5	0.5	10.5	11.1	11.1	11.1	11.1
West Branch Lights C.	3.5	2.7	1.2	1.1	21.2	24.7	23.9	22.4	22.3

*--assumes proposed harvest on private land, see Total ERA% Table 4 below.

Roads, though a steady and non-diminishing source of runoff effect are a minor one in the project area, accounting for 1 to 2 percent ERA across the watersheds. The ERA method is not spatial, so the true effect of roads may be greater or less than the value given, relative to their position on the valley slopes. Roads in steep slopes, with high cuts, tend to capture a degree of ground interflow particularly during storm events. Conveyance of this water through drainage ditches to low order draws are the primary means by which forest roads advance the timing and/or increase runoff. Roads on the ridge lines obviously capture little except what precipitation falls directly on their running surfaces. Roads in the valley bottom may capture interflow, but at point where it was to daylight into the valley channel at any rate. Roads at mid-slope, particularly if there are multiple segments across a slope have the greatest potential for capturing storm flow and conveying to natural surface channels. It is at these crossings of roads and natural channels where the most significant resource damage occurs, typically by scour and bank erosion downstream, where accelerated velocities caused by crossing pipes and increased volume from the road conveyance degrades a channel.

With the proposed Alternative A, 19 of 26 project area watersheds are over ERA% thresholds set by the Forest, for management impacts that affect runoff. All but four watersheds over threshold are due to the effects of the fire (Table 11). Two of the exceptions, Bear Valley and Moonlight Pass are due to fire salvage harvest on private land completed in 2008, or expected by 2009. Salvage harvest in private lands is mostly upslope of Forest Service managed land, in the headwaters of analysis watersheds. The other two watersheds potentially over threshold are Middle Creek and Upper Hungry. Both watersheds are very near threshold conditions currently (Table 11) and given the proposed alternative Middle Creek could exceed thresholds by 0.2 ERA% points and Upper Hungry Creek by 0.6 ERA% points. Actually all action alternatives would result in an ERA% over threshold in Upper Hungry Creek, but only Alternative A would cause an over-threshold condition in Middle Creek. The increase ERA% of Alternative A is accounted entirely by ground-base and helicopter harvest. Eleven of the watersheds are in excess of 30 percent over TOC and it is reasonable to expect that under conditions of intense precipitation significant increases in runoff would occur. One more watershed, East Branch of Lights Creek, is 30% over TOC with this alternative compared with existing condition, see Table 11, which is due to the proposed action, although existing harvested land has actually a greater effect to runoff in most watersheds than the proposed action.

Potential erosion from harvest slopes, and subsequent sediment delivery to channels is expected to be elevated over normal conditions because of lack of ground cover. But in the event of precipitation that initiates erosion the overall lack of ground cover on burned slopes will be the greater source. Harvesting creates areas of compaction and displacement of soils that may lead to localized incidences of overland flow, but BMPs, PNF LRMP standards, and regional soil productivity guidelines would limit detrimental disturbances to soil to 15 percent or less of a treatment unit. The treatment units do not constitute the majority of slope area. Therefore actual harvest effects are a relatively minor proportion of the watershed, as shown in Table 8. This point is illustrated in table 104 which shows that between 4 and 18% of project watershed's area are rendered comparable to forest road surface by fire effects (column ERA%). Compare that to values in table 101 which shows that effected area by alternative to be between 0.0 and 3.5% of project watershed's area.

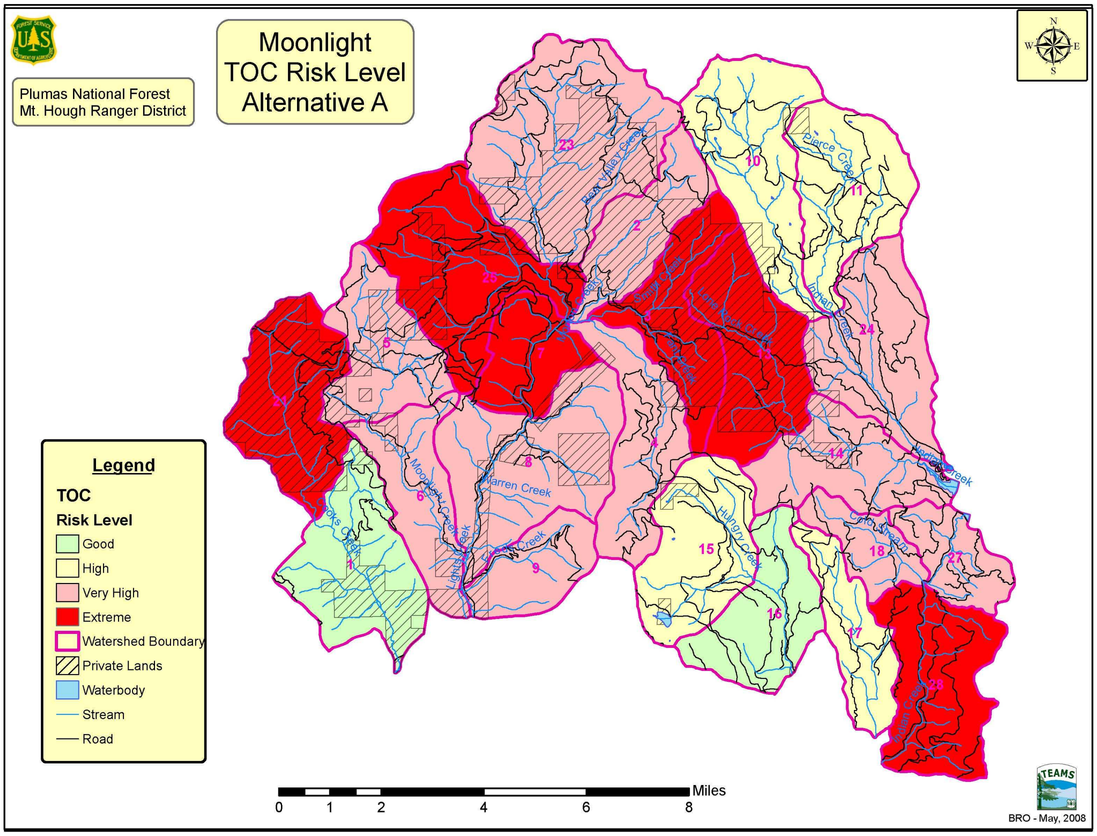
Effects of proposed actions would ameliorate fuel loading and potential fire behavior within the treatment units themselves. However, given the limited scope of the treatment units it is unlikely that the treatment would significantly alter the effect of future wildfire, in a given watershed, on hydrologic response or erosion. The action alternatives are designed to *exclude* harvest activities entirely from 78 percent (under alternative A) to 94 percent (under alternative E) of public lands within the analysis area (and 5 to 18% of project watershed's area). Consequently, large areas of unsalvaged and untreated areas would exist under all action alternatives. In addition, there are snag retention areas within salvage harvest units, equipment restriction zones, and further snag retention guidelines within RHCAs, all of which would reduce effectiveness of treatment.

There have been few recorded fires that extend across more than one of the analysis watersheds. The largest fire in the Lights Creek drainage was in 1959 of 1400 acres in the

Morton and Smith Creeks watersheds. The next largest was 1100 acres in 1996 in the Cooks Creek watershed, a steam that confluences with Lights Creek well downstream of the project area. Therefore, a thoroughly unique situation exists in regards to runoff for Lights Creek, particularly within and below the Middle Lights Creek sub-watershed. Two of three important variables that could drive a very large runoff event occurred in the winter of 2007-2008. First, the fact of the fire and its most significant effect, the catastrophic loss of forest ground cover across virtually the entire landscape. Second, there was an early and heavy snowfall. The third factor would have been heavy rainfall in the mid winter months of January and February of 2008, a happenstance of 12 of 21 years during the period of record on the Indian Creek gage, which drove the 7 largest flood events recorded at the site. The occurrence of heavy rain and warm and breezy conditions in mid-winter is popularly referred to as the "pineapple express" because of the point of origin of these systems in the South Pacific Ocean near the Hawaiian Islands. These conditions can be present during El Nino episodes, but the latitude of the project area puts it between El Nino and La Nina influenced zones, and makes the correlation somewhat problematic (Barkhuff 2008, personal communication). Most importantly is the frequent occurrence of warm and moist tropical air from the southwest moving over the Sierra Nevada Mountains in mid-winter when a thick blanket of snow may be already present. The 2007-2008 precipitation season, in fact, proved to be well below normal and no significant rain-on-snow events occurred over that winter. Little or no overland erosion was observed to have occurred within the burned areas because winter and spring runoff was dominated by slow, steady snowmelt that did not have much erosive power. However, rain-on-snow event potential remains for 2008-2009 and beyond. A further condition that certainly exaggerates this effect locally, and perhaps is a very significant factor, is the southwest aspect of the Lights Creek headwaters area roughly above the 5,000 foot elevation that is also the principle catchment area for the stream.

Therefore, over the next 3 to 5 years until sufficient ground cover is re-established there is a high risk of a large floods downstream of the project area, particularly within the Lights Creek drainage. Because of the effective lack of ground cover a flood could be potentially much larger than previous to the fire, with the same return interval of rainfall. It is the conclusion in this report that the Moonlight Fire BAER Hydrology Report very probably underestimated the magnitude of potential runoff from the fire area. However, as also stated above, the peak flow increases due to burned area effects calculated in the BAER report are likely conservative.

Figure 4. Action alternatives level of risk for exceeding watershed threshold of concern. Values listed in Table 81 above.



1.1.2.2 *Alternative B – No Action*

1.1.2.2.1 Direct and Indirect Effects

1.1.2.2.1.1Soil Erosion and Detrimental Disturbance

Groundwater will be elevated in the burn area due to reduced evapo-transpiration and thereby elevating the risk of mass wasting. However, active or recent landslides were only observed in units 26a and 26b. They were low angle slumps from low ridges dissected with deep V-shape first order draws. Some draws had flow on the order of a few gallons per minute during time of field visit in November, 2007.

Typically in conditions of forest canopy and floor cover overland flow is a rare occurrence limited to areas of outcrops, or disturbance whether natural or due to activities. However, in the 30 units surveyed soil cover ranged from 0 to 60 percent with an average of 20 percent, and canopy cover ranging from 3 to 49 percent (Table 3). Given these low groundcover and overstory canopy conditions, overland flow could occur with high rainfall rates or rapid snowmelt over the larger part of the analysis area.

Raindrop impact is a severe source of initial erosion on bare soil. Shear stress imparted by raindrops on bare soil has been measured as much as four times the critical shear stress of cohesive soils and 100 times the shear stress created by thin sheet wash (Julien 2002). Critical shear stress is the point of initiation of movement of a particle. Fine particles transported by raindrop impact or sheet wash can plug pores in the mineral soil surface and thereby reduce infiltration capacity (Biswell 1989; Powers 2002). Overland flow can be initiated when surface infiltration capacity is drastically reduced. The effect of wildfire in the event of high intensity rainfall is comparably much higher than roads or harvest, because of the much greater proportion of watershed area that is affected.

Aerial mulching to re-establish cover in high-vegetative burn severity areas was recommended in the Moonlight BAER hydrology report (Faust 2007). Mulch areas were approximately 700 acres in Middle Lights Creek, west of Forest Service road 28N36, within portions of sections 7, 8 and 18, Township 27 North, Range 11 East, and sections 12 and 13, Township 27 North and Range 10 East. An additional 40 to 80 acres were mulched in the Fred's Creek watershed over a portion of sections 29 and 30, Township 27 North and Range 11 East. Mulch areas were selected in order to protect a residence in Fred's Creek and water quality in the main stem Light's Creek.

1.1.2.2.1.2Soil Organic Matter and Large Woody Debris

Dead and downed wood is well recognized as a critical element for soil productivity (Harvey et al. 1987; Graham et al. 1994). Recommendations for minimal coarse wood levels to sustain productivity are outlined in Graham et al. (1994), and are between 5 and 10 tons per acre for drier ponderosa pine forest cover. Preliminary data gathered in fall, 2007, in mostly high severity burn tractor units shows those units are well below the recommended range (Table 3). Estimates of LWD for the current and in the short-term are about 6.5 tons per acre on average across the treatment area (Tompkins and Moghaddas 2008). In the long-term, because of recruitment from standing dead trees, LWD estimates range from 16 tons per acre 10 years after the fire to 27 tons per acre 30 years after the fire (Table 5).

Brown et al. (2003) postulates where coarse wood (greater than 3 inches in diameter) reach 30 tons/acre; high severity fire could result in the event of a reburn. The greatest risk is within 10 to 30 years where logs are in contact with the ground and have not experienced much decay. However, recent findings suggest that reburn in plantations following salvage is not lower than in naturally regenerated stands (Thompson et al. 2007). Factors that may increase fire severity in managed areas are the close tree spacing in plantations, higher abundance of fine fuels (Donato et al. 2006), and homogenous stand structure that promotes high severity fire (Odion et al. 2004). Also, sclerophyllus shrubs common in both managed and unmanaged regenerating stands can increase fire severity (Odion et al. 2004; Thompson et al. 2007). Given the uncertainties of reburn occurring and risk from the no-action and action alternatives, no difference can be construed in regards to fire severity.

Alternative B, the no action alternative, would have no adverse effects on soil microbes, including ectomycorrhizae. Recovery of soil microbial communities would occur gradually as vegetative communities return. Ectomycorrhizae are commonly associated with conifers and thus would follow their succession.

1.1.2.2.1.3 Hydrology: Surface Flow/Water Quality

The overwhelming effect to hydrologic function, in any of the alternatives, is that of cover loss and the potential for widespread overland flow. An indication of just this occurrence may be reflected in recent water samples collected in Lights and Indian Creeks by Feather River Coordinated Resource Management (unpublished data, 2009,), following rainfall in the project area during May 1 through May 5, 2009. Turbidity measurements of water samples gave NTUs many times over thresholds of state water quality standards (California Central Valley Regional Water Quality Control Board 2007)

Peak flow increases were calculated for the Moonlight BAER report (Faust 2007). Regional runoff equations developed by Waananen and Crippen (1977) were used as a basis, with factors of 3, 1.5 and 1.1 applied to areas of high, moderate, and low severity burn, respectively. Runoff from wildfire areas, particularly high severity burns can be 1 to 3 orders of magnitude above normal or baseline peaks under comparable conditions (Tiedemann et al. 1979; Neary et.al. 2005). Therefore the calculated peak flow results from the BAER hydrology report are rather conservative.

The design storm chosen for the runoff computations was a 10 year 24-hour frequency and duration (4.5 to 5.0 inches total of precipitation in project area) as the event most likely to create a damaging flood to downstream beneficial uses (Faust 2007). The calculated effects of the fire was that runoff from the design storm is equal to that of a 30 year storm under unburned conditions. The ratio of increased runoff of post-fire to pre-fire conditions ranged from 1.01 in Boulder Creek which had only a few percent of its area within the fire perimeter, to 2.33 in West Branch Lights Creek, which was entirely within the fire perimeter. The mean ratio for all watersheds affected by the fire was 1.60 (Faust 2007).

A U.S. Geological Survey stream gage was operated on Lights Creek (Station # 114013) for six years between 1958 through 1963 (Table 9). While this period of record is less than adequate for statistical treatment of annual peak flows the record was useful for comparison to Moonlight Fire BAER modeling outputs.

Table 9. Comparison of USGS gage peaks on Indian and Lights Creek for period of record on Lights Creek. Values in cubic feet per second (cfs).

Year	Instantaneous Peak Flow	
	Lights Creek Gage	***Indian Creek Gage***
1958	2120	14000
1959	261	1020
1960	1300	6180
1961	180	464
1962	463	3090
1963	2440	30200

The location of the Lights Creek gage corresponds to the downstream end of the Middle Lights Creek watershed used in this project and also in peak flow analysis in the Moonlight Fire BAER hydrology report (Faust 2007). Table 10 below shows post-fire predicted values for 2, 5 and 10 year recurrence interval peak flows (Q2, Q5, and Q10) calculated in the BAER hydrology report (Faust 2007) and those from regression equation between Indian Creek gage data and Lights Creek data.

Table 10. Comparison of BAER and station data estimates of peak flow for Lights Creek

Source of data for estimation of Lights Creek Peak Flows	Return Interval of Flow (cfs)		
	Q2	Q5	Q10
BAER report; Regional Equations	291	789	1,200
Regression Equation. With Indian C. Data	644	1198	1857

Three of the annual six peak flows from the Lights Creek USGS record exceed the calculated Q5 flow from the BAER report and two of these exceed the calculated Q10 flow. Correlation of Lights Creek gage record with the USGS gage on Indian Creek near Taylorsville (Station # 114012), that has a period of record from 1958 to 1980, indicate that the years in question on Lights Creek are probably between the Q1.25 and Q20. The correlation was made by regression between the peak values of the two gage sites. This was considered reasonable since the peaks at both sites occurred on the same day in each year, obviously driven by the same storm event. The aspect and total relief of the watershed above the gages are similar. The R square value, a measurement of the degree correlation of the parameters used is high at 0.83, which indicates that those factors that combine to produce peak flow are similar in both drainages. Only Greenville climate records were available, but are at a location sufficiently close to clearly show the correlation between precipitation events and runoff at the gage site, and provide further evidence that the storms that drive the largest peaks are not localized to a single drainage.

While some of these flows were certainly channel forming events, or generally above the average set of yearly conditions that maintains active channel geometry, these flows are also well within long-term range of baseline conditions. It is important to note that at the Indian Creek gage with 21 years of record between 1956 and 1980, the range of peak flows is over four orders of magnitude (from 11.5 cubic feet per second (cfs) to 30, 200 cfs). Streams with these kinds of variation in peaks are considered very flashy, with markedly high variability. Also 12 of the 21 peaks of record, including the top 7 occur in the months of December through February indicating most likely that rain on snow is a frequent occurrence. The greatest peak flow on record at the Lights Creek gage on 10/13/1962, was 2,440 cfs, and was driven by two days of rain (10/12 to 10/13/1962), recorded at the Greenville station (COOP #043621) as 5.77 and 5.11 inches. Each day of rain was close to the 10-year, 24-hour storm. The flow at the Indian Creek gage peaked at over 11,000 cfs. Had this storm occurred later in the season when soil moisture was higher the flow undoubtedly would have been very much higher. As it is 2,440 cfs produced at the Lights Creek gage was more than double the project runoff calculated in the Moonlight Fire BAER Hydrology report for similar rainfall.

The braided channel form noted in the BAER hydrology report, for Lights Creek, and other evidence of instability on the higher order streams can be placed in a context of high relief, and wide variation of annual peaks due to heavy rain or rain on snow in early winter. Mining and grazing activities notwithstanding, a degree of channel instability, wide floodplain, and large substrate clast may be expected natural conditions for these channels.

1.1.2.2.2 Cumulative Effects

The Forest uses the ERA method to assess cumulative effect of activities that alter hydrologic function and result primarily in alteration of runoff in project watersheds. The ERA method is essentially an accounting of the past, present, and future impacts. It is used to index land use intensity, rather than to predict effects. Judgment of the effect of proposed actions is made in consideration of current conditions, as determined by field observations, and those environmental parameters that are deemed relevant to the response of watershed hill slopes and channels in the project area. ERA is commonly expressed in percent of watershed area. ERA percentage for watershed is a measurement indicator to address soil disturbance, runoff, and sediment delivery concerns.

A degree of activity within a watershed, beyond which an adverse effect might be expected is the TOC described previously in this report in units of ERA percent. An appropriate range for TOCs is 10 to 20 percent ERA (USDA Forest Service 1990). The TOC for a watershed is calculated by a numeration of sensitive ground within that watershed. The closer the calculated ERA value for the watershed is to the threshold value the greater risk of detrimental impact to the watershed and its beneficial uses. The effect of activities decreases over time although the contribution of permanent roads to ERA does not change. Given the broad assumptions built in the ERA method, TOCs are not absolute determinations of adverse impacts, but a point at which it is reasonable to expect measurable effects. Given the degree that many of the project watersheds exceed their TOC, it is especially appropriate to use the value as a yardstick of detrimental change.

Seventeen of 26 analysis watersheds are over thresholds set by the Forest, for management impacts that affect runoff. All but two of the watersheds over threshold are due to the effects of the fire (Table 11). The two exceptions, Bear Valley and Moonlight Pass are due to fire salvage harvest on private land completed in 2008, or expected by 2009. Most of the salvage harvest on private lands is upslope of the Forest Service managed land, in the headwaters of the analysis watersheds. Ten of the watersheds are in excess of 30 percent over TOC and it is reasonable to expect that under conditions of intense precipitation events, as discussed in preceding sections that significant increases in runoff would occur.

Table 11. Current ERA in project area watersheds.

Watershed	ERA% NFS*	ERA% PVT*	ERA% Roads	ERA% Fire	ERA% PVT Proposed	Total ERA%	ERA% TOC
Bear Valley	0.1	5.8	1.2	11.2	4.6	23.0	13
Cold Stream	3.5	0.0	1.2	8.9	0.0	13.6	13
E.B. Lights	1.6	0.2	1.6	12.8	0.3	16.6	14
Freds	1.8	0.1	0.9	9.3	0.5	12.5	13
Indian blw Antelope, Babcock	1.7	0.0	1.4	16.6	0.0	19.7	13
Indian blw Antelope Dam	3.9	0.0	1.8	9.0	0.0	14.6	13
Lonesome Cyn	0.2	5.5	1.1	17.7	5.1	26.7	13
L. Cooks	0.5	0.0	0.8	4.5	0.1	5.9	12
L. Indian	2.5	0.0	1.8	11.2	0.3	15.8	12
L. Lights	0.0	2.0	0.9	13.0	1.5	17.4	14
L. Lone Rock	2.5	0.0	1.2	11.2	0.5	15.4	13
Mid. Creek	2.1	0.0	1.1	9.0	0.0	12.3	13
Mid. Hungry	1.7	0.1	1.5	5.6	0.0	8.8	13
Mid. Lights	0.2	0.8	1.3	17.6	0.0	19.9	14
Moonlight	0.4	.1	0.8	12.0	1.2	14.5	13
Moonlight Pass	1.4	12.8	1.1	6.2	1.4	22.8	14
Moonlight Valley	0.8	2.5	1.6	11.7	1.5	18.0	13
Morton	1.0	3.9	1.3	11.8	3.8	21.8	14
North Arm Indian Valley	.1	0.0	0.7	3.8	0.0	4.7	13
Pierce	3.5	0.0	1.4	4.7	0.1	9.6	12
Smith-Fant	0.5	1.85	1.4	15.8	5.7	25.3	14
Up. Hungry	2.2	0.2	1.3	8.4	0.1	12.2	13
Up. Indian	2.4	1.0	1.0	5.8	0.0	10.2	12
Up. Lights	0.9	3.5	1.2	7.7	0.8	14.1	13
Upper Peters Creek	5.4	0.0	3.8	1.4	0.0	10.5	14
W.B. Lights	0.6	0.5	1.5	17.2	1.3	21.2	13

*--NFS = NFS lands; PVT = private land

1.1.2.3 Alternative C – Direct, Indirect, and Cumulative Effects

Alternative C is inclusive of all tractor and roadside hazard elements within alternative A, already described above. Most temporary road construction (Table 12) including RHCA entries crossings are retained from Alternative A, so that on the basis of the analyzed watersheds there is little substantive difference in impacts to hydrology (Table 8) and detrimental disturbance for soils. Eighteen miles of temporary roads are proposed compared to 19 miles with Alternative A, with 7 RHCA entries and crossings of channels, including 1 with perennial flow.

Excepting the RHCA harvest areas, LWD > 3” will decrease over time, out to 30 years after harvest, because biomass removal will also remove future recruitment (Table 5). Predicted levels from fire ecology modeling indicate that LWD is expected to be on the low end of the range for sustaining adequate soil productivity. A project design element requires the general retention of 5 to 15 tons of down woody material per acre. Harvest disturbance is expected to set back recovery (live and litter ground cover) 2 to 3 years at minimum.

Table 12. RHCA acres by alternative

Logging Systems	Alternatives							
	A		C		D		E	
	Int.*	Per.**	Int.	Per.	Int.	Per.	Int.	Per.
Helicopter	388	289	0	0	0	0	0	0
Skyline cable	67	186	0	0	0	0	0	0
Tractor/Roadside	406	635	406	635	358	586	297	565
Total	930	1041	406	635	358	586	297	565

*--Intermittent streams, **--Perennial streams

The only difference between Alternative A and C is the exclusion of skyline and helicopter logging in alternative C (Table 4). The steeper slopes associated with these latter harvest techniques have the greatest potential for erosion under the current conditions. That logging would not occur on these slopes under alternative C and therefore would not set back the timing of recovery, primarily of soil cover, substantially reducing potential erosion by a factor of two (see figure 3), on 6,219 acres (Table 4) when compared with Alternative A.

1.1.2.4 Alternative D – Direct, Indirect, and Cumulative Effects

Alternative D is inclusive of roadside hazard within Alternative A and a modified and decreased tractor harvest of 40 of the 187 units or sub-units, included in Alternative A, already described above (Table 4). Three miles of temporary roads are constructed for this alternative with a single channel crossing and entry into RHCA. The principle difference between ground base harvest of this alternative and those of Alternatives A and C is the eschewing of units not accessible by the existing forest road system. Regarding a watershed basis of runoff and detrimental soil impacts differences are not substantial between Alternative D and Alternatives A and C (Table 8). In terms of potential sediment delivery to channels, and given the greatly more disturbance associated with ground based harvest to other methods, and the degree of harvest within RHCA's (Table 12), this alternative again may not differ substantively from alternatives A and C.

Large woody debris component of the forest floor will decrease gradually out to thirty years, to marginal levels to maintain soil productivity. A project design element requires the general retention of 10 to 20 tons per acre of large down wood. Ground base harvest will set back recovery of forest floor by 2 to 3 years are a minimum.

1.1.2.5 Alternative E – Direct, Indirect, and Cumulative Effects

Alternative E is inclusive of the roadside hazard treatment element within Alternative A, already described above (Table 4). No temporary roads or landings are proposed with this alternative. These reductions, however, do not alter substantially the condition for any of the analyzed watersheds (Table 8). The amount of harvest within RHCA's is similar to tractor harvest in RHCA's in Alternatives C and D, and not substantively different from Alternative A (Table 12). This simply points up that most of the RHCA harvest entries are along already existing forest roads.

Over the next thirty years after harvest the LWD component of the forest floor will gradually decrease, due to lack of recruitment from proposed biomass removal, to levels that are marginal for soil productivity. It is expected that harvest will also set back recovery of the forest floor by 2 to 3 years.