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Long-Term Environmental Effects of Conifer Removal to Achieve Aspen Release in Near-Stream Areas Within the Northern Sierras

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ANNUAL PROGRESS REPORT

January 2004 through May 2005

For the project

LONG-TERM ENVIRONMENTAL EFFECTS OF CONIFER REMOVAL TO ACHIEVE ASPEN RELEASE IN NEAR-STREAM AREAS WITHIN THE NORTHERN SIERRAS

Submitted to

USFS Region 5 Fish Habitat Relationships Program
Lassen National Forest

Submitted by

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1. EXECUTIVE SUMMARY

The advanced state of conifer encroachment in aspen stands in the Sierra Nevada and southern Cascades is retarding aspen regeneration, putting an estimated 70 plus percent of stands at immediate risk of extinction with a significant percentage of stands already lost. The negative effects of conifer encroachment are often amplified by excessive grazing by domestic and in some cases sometimes native herbivores. Following the adaptive management framework, several USFS Districts and Forests in the region have begun to implement prescriptive conifer removal in heavily encroached aspen stands to conserve the stands, stimulate aspen regeneration, and eventually achieve full stand restoration. The purpose of the project detailed in this progress report is to provide the monitoring framework to assess the impacts of conifer removal from encroached riparian aspen stands on aspen recruitment, stream water quality, streamflow, stream canopy, stream temperature, aquatic macroinvertebrate community and aquatic habitat, and riparian soil quality. This project is a collaborative effort between USFS, UC Davis, and the interagency Aspen Delineation Program. Support has been provided as funding and in kind contributions from the USFS Region 5 Fish Habitat Relationships Program, the Lassen National Forest, and the Department of Plant Sciences at UC Davis. Over the past 3 years this collaborative venture has fostered the development of several complementary projects, greatly expanding the current scope of applied research focused on aspen conservation, restoration and management in the region. We have made significant progress during this reporting period, building upon and complementing progress made during 2003. Progress of specific note includes: 1) winter 2003/04 conifer removal was implemented on 2 stands at Pine and Bogard Creeks and before and after (1 year) soil quality and stream data collection was accomplished; 2) publication in the prestigious peer-reviewed journal *Restoration Ecology* of our research establishing prescribed conifer removal as an effective aspen conservation and restoration initiation technique, and 3) completion of all pre-treatment data collection and laboratory analysis from all 4 sites as planned. These accomplishments are benchmarks in the project assuring us of the effectiveness of prescribed conifer removal, providing our first chance to evaluate potential impacts of conifer removal on riparian resources, and providing a baseline by which to evaluate all future planned treatments. Initial analysis of pre and post-treatment data collected relative to the winter 2003/04 treatment on Pine and Bogard Creeks is the most novel result from this reporting period and forms the bulk of progress discussed in this report. Preliminary results for the first year following conifer removal at Pine and Bogard Creeks indicate the detrimental impacts to riparian were slight, with likely no ecological or hydrological significance. There was no statistically significant or apparent degradation of water quality (temperature, chemistry, sediments), stream channel morphology (pool size, substrate composition, channel width to depth) or soil nutrient pools (N, P, C). There was a 10 to 33% reduction in stream vegetative canopy cover over stream reaches adjacent to conifer removal, which did increase solar radiation reaching the stream's water surface, particularly for the months June and July. However, there was no associated increase ion stream temperature through these reaches, perhaps due to remaining canopy levels in excess of 50% cover, and/or the short length of the Bogard reach (<500 m). Soil surface bulk density (0 to 3 inches in depth) was increased from ~ 0.90 to ~1.05 g/cm^3. Bulk density was not changed at depths from 3 to 6 inches. Soil surface cover was also not changed with an average of 2 to 3 inches of duff available to protect the soil surface from rain drop energy, retard overland flow and surface contaminant transport, and conserve soil moisture. It is very likely that this slight soil surface compaction will be short lived, in light of reversal processes such freeze thaw, wetting and drying, and burrowing rodent/insect activity. Mean organic matter levels in this soil zone (0 to 3 in) exceed 6%. During the next reporting period (2005) we will obtain significant additional data from newly implemented conifer removal projects on Pine and Bogard Creeks. We will evaluate this data to confirm, refute, or modify preliminary results described here. We have focused additional data collection efforts on soil bulk density as well as stream cover and solar radiation, allowing a more mechanistic evaluation of the relationships between management and these variables. Overall, results suggest the potential for immediate negative impacts to riparian resources are slight compared to the significant benefit of conserving and restoring riparian aspen communities and habitat.

2. BACKGROUND

Trembling aspen (*Populus tremuloides* michx.) occurs in the montane zone of California's Sierra Nevada/Cascade range. It is a keystone species providing critical habitat to support plant and animal biodiversity in the region. Declines in the health and distribution of aspen stands across the region have been observed over the past century. That decline continues today. Much of this decline is attributable to conifer encroachment stimulated by the absence of natural fire regimes, as well as historic and current heavy browsing by domestic and in some cases native herbivores. A 2000-2002 assessment of the health of 557 aspen stands (90% of known stands) totaling 1,278 ha on the Eagle Lake Ranger District, Lassen National Forest documented that 77% of stands were at immediate risk of being lost, and that at least 39 stands have expired with no living aspen present and no means of recruitment. If broad scale conservation and restoration action is not implemented aggressively in the near term, the majority of existing stands on that district will be lost. Conifer encroachment was the major risk factor for the loss and poor health of most stands, with over 90% of inventoried stands encroached by conifers. These ELRD data reflect the condition of most aspen stands in the region, and support a credible argument for immediate and aggressive release of conifer encroached aspen stands followed by subsequent restoration actions such as controlling excessive grazing.

The advanced state and sheer scale of conifer encroachment induced aspen decline in the northern Sierra Nevada and southern Cascade dictates that: 1) aggressive conservation actions must occur sooner rather than later if the ecological services of aspen are to be preserved in the region; and 2) significant planning and implementation costs will be associated with conservation and subsequent restoration of degraded aspen stands. Logically and practically, prescriptive conifer removal has the potential to conserve a large number of conifer encroached aspen stands in the region which would otherwise transition to coniferous forest. Prescriptive conifer removal also has the potential to generate revenue to defray costs and fund additional restoration efforts such as protection from grazing. Jones at al. (2005) used prescriptive conifer removal in four extremely degraded aspen stands, liberating the stands to actively recruit and establish several new cohorts of aspen, thus conserving the stands. Additional research is required to quantify ecological service potentials (*e.g.*, herbaceous plant diversity, avian habitat structural complexity) and site constraints determining potential (*e.g.*, precipitation, elevation) so that achievable restoration targets can be set (are we there yet?).

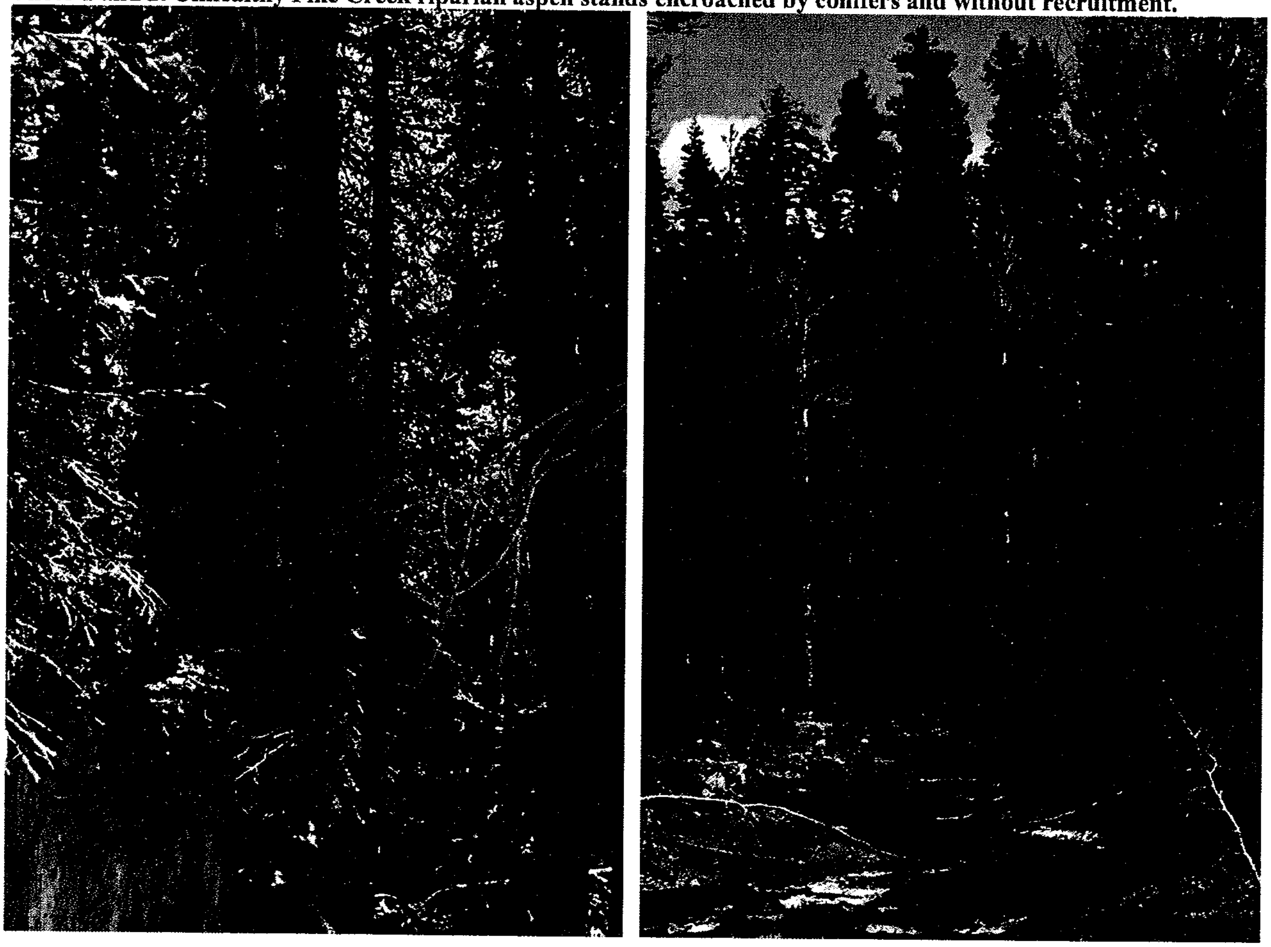
Broad scale implementation of prescriptive conifer removal in the region is an issue because a significant number of degraded stands are associated with riparian areas such as streams (Photos 1 and 2). Protection of riparian areas from silvicultural activities has justifiably strong legal and social support. However, conifer encroached riparian aspen stands that are not released will expire and overall riparian and landscape habitat complexity and biodiversity will continue to decline. Two causes as worthy as the protection of riparian areas and the conservation of aspen are surely not mutually exclusive, rather one could reasonably hypothesize that the restoration of riparian aspen stands would actually enhance overall riparian health. So, what are the negative impacts to riparian resources associated with aspen restoration initiated by prescriptive conifer removal? Which components of riparian resources are susceptible to negative impact: soils, water quality, aquatic habitat? If there are negative impacts, are they short or long-term? Will the ecological services a restored aspen stand provides to the riparian area and the landscape out-weigh short or even long-term negative impacts to riparian resources? Answering these core questions is crucial to initiating an informed, broad-scale conservation and restoration of riparian effort for aspen stands in the region.

Adaptive management is an iterative, quantitative process to identify and refine management to achieve defined natural resources objectives. It is founded upon active, not passive management. Conservation and subsequent restoration of aspen stands will require active, adaptive management. Adaptive management provides the manager, as well as other stakeholders, with the quantitative evidence that either: 1) tangible progress is being made towards natural resources objectives at an acceptable rate and appropriate management practices are in place; or 2) tangible progress towards natural resource objectives is not being made at an acceptable rate and management needs to be adapted. Central to this process is establishment of clear and measurable objectives, flexibility in management paradigms and implementation, and a data-based monitoring and evaluation framework to inform management of progress towards objectives. The management challenge we are facing is to design and implement prescriptive conifer removal strategies sufficient for conservation and initiation of restoration of encroached riparian aspen stands with minimal short-term (<3 years) and no long-term (>3 years) negative impacts on riparian resources. The overall goal of this project is to provide the monitoring and evaluation framework to assess impacts on riparian resources and progress towards aspen stand conservation and restoration.

Our specific monitoring objectives are to:

1) Evaluate the effectiveness of conifer removal as a means of successful aspen recruitment and stand establishment. **Completed ✓**
2) Conduct pre- and post- conifer removal monitoring of key stream attributes to evaluate effects on water resources. **On-Going**
3) Conduct pre- and post- conifer removal monitoring of soil attributes to evaluate effects on soil quality in riparian areas. **On-Going**
4) Extend and report the findings of this project to improve our ability to achieve Riparian Conservation Objectives as part of the Aquatic Management Strategy. **On-Going**

Photo 1 and 2. Unhealthy Pine Creek riparian aspen stands encroached by conifers and without recruitment.

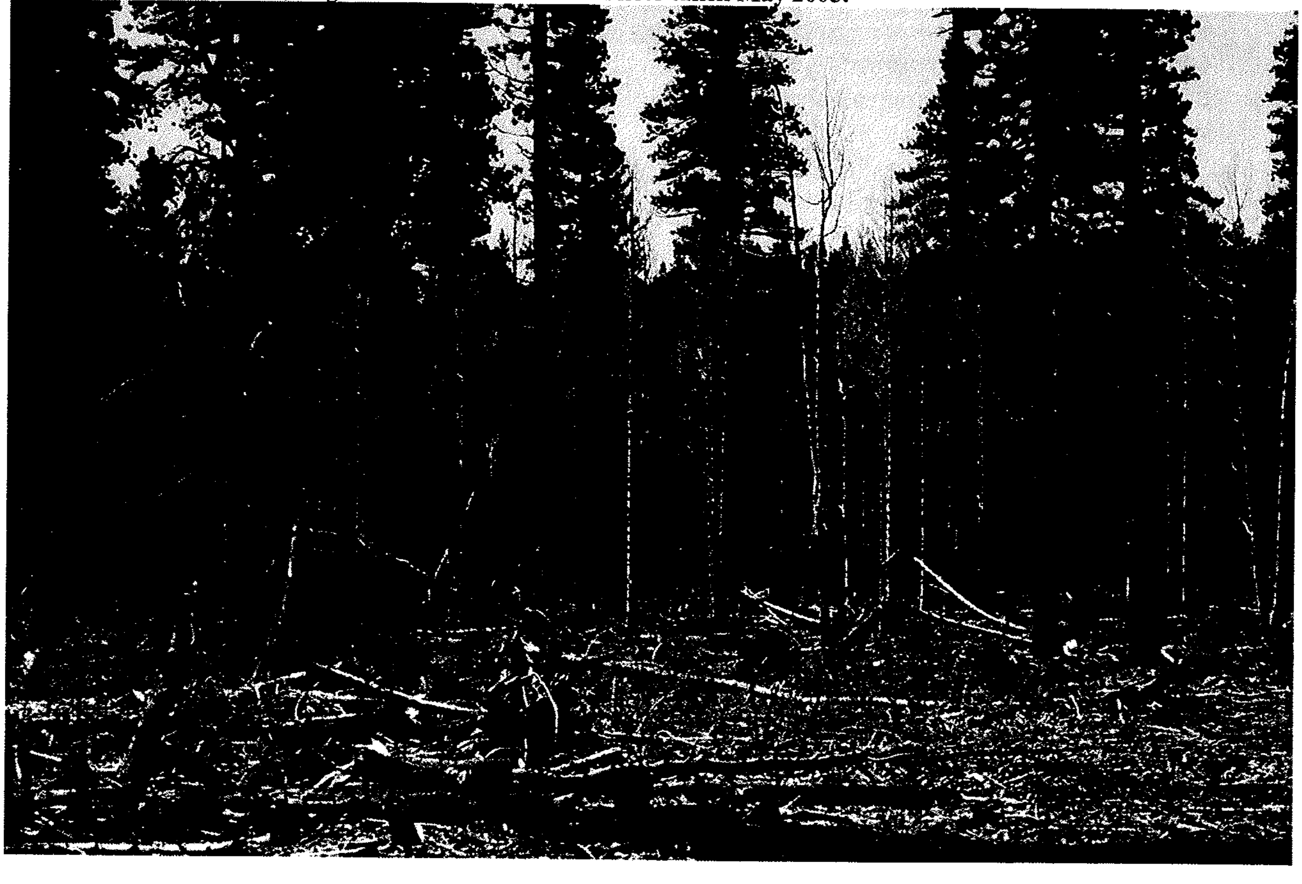


3. Treatment and Study Unit Definitions

A few definitions are provided here for clarity and consistency. The <u>treatment</u> is the removal of conifers from within degraded aspen stands located within stream riparian areas. The conifer removal strategy is designed to fully release aspen from conifer dominance, and may include a combination of commercial harvest, service contract and hand-thinning (Photo 3). The method and season in which conifers are removed will vary because each stand has different opportunities and constraints. Recent experience on the Lassen National Forest (LNF) indicates that the treatment should emphasize whole tree removal of conifers, of both pre-commercial and commercial size. Typically, all conifers less than 30" will be removed, except for conifers directly contributing to streambank stability or other site-specific benefits. Hand-felling of small diameter conifers may occur post-harvest. As a control, allowing evaluation of the impacts of treatment, we selected degraded riparian aspen communities in the vicinity of each aspen stand scheduled for treatment implementation (e.g., Photo 1).

There are two study units in this project, as illustrated in Figure 1. For the purposes of examining aspen recruitment and soil quality parameters (Objective 1 and 3), the study unit is the area within each degraded aspen stand (treatment and control study stand). For the purposes of examining stream parameters (Objective 2), the study units are stream reaches (treatment and control study reach) adjacent to treatment and control aspen stands as defined by stream monitoring stations located above and below adjacent study stands. Discrete sampling stations, plots, and transects (experimental units) have been established within aspen stand and above and below stream reach study units to allow collection of appropriate pre- and post treatment data to achieve the project objectives. For instance, stream monitoring stations are situated to monitor changes in stream flow and water quality through study reaches. Soil sampling stations are situated to provide a representative sample of the whole study stand.

Photo 3. Encroached aspen stand liberated from conifer encroachment by an over-snow winter conifer removal project (Jan 2004) on Pine Creek, Eagle Lake National Forest. Photo taken May 2005.



4. Monitoring Design and Analysis Overview

The study design is based upon consistent, simultaneous monitoring before and after treatment application of treated and control study stands and adjacent stream study reaches (Figure 1). Statistical analysis is applied to this data to determine the magnitude and significance (statistical, not ecological) of response(s) of treated stands/reaches relative to control stands/reaches before v. after treatment implementation. For instance, stream temperature is collected above and below both control and treatment reaches both before and after conifer removal from the adjacent treatment stand. With this data set we can statistically test if say the treatment resulted in increased stream temperature gain through the treatment reach following treatment. The pretreatment data from the control and treatment reaches serves as a benchmark, quantifying the increase in temperature through the treatment reach relative to the control reach prior to our treatment application. To determine if there is an increase in stream temperature through the treatment reach following treatment, we analyze all the data (before and after, above and below) to determine if there is a significant interaction between the factors location (above v. below conifer removal study site) and time (before v. after treatment). We are employing a linear mixed effects analysis to conduct this analysis to account for repeated measures introduced in the data set due to repeated sampling of the sample stations. A detailed, basic explanation of this analysis approach applied as a case study to stream temperature can be found at the following website, (Tate et al., 2005 http://californiaagriculture.ucop.edu/0503JAS/toc.html).

The basic form of this linear model is:

$y = b_0 + b_1*(\text{time}) + b_2*(\text{location}) + b_3*(\text{time X location})$

y = water temperature, soil organic matter level, etc.
time = before or after treatment
location = treatment or control, above or below

The terms b_0, b_1, b_2, and b_3 are coefficients estimated by a commercial statistical package (S-Plus 6.0) using a best fit approach known as restricted maximum likelihood. The significance of each coefficient ($b \neq 0$) is determined via a conditional t-test. For our purposes of determining treatment effect, we are mainly interested to determine if b_3 is significant. We use this model to test the hypothesis that the relative difference in y between treatment and control, or above and below, changed from before to after treatment by testing the significance of b_3 ($b_3 = 0$, $b_3 \neq 0$). If b_3 is significant ($b_3 \neq 0$), then the change in stream temperature above v. below the treatment stand changed significantly from before to after treatment implementation.

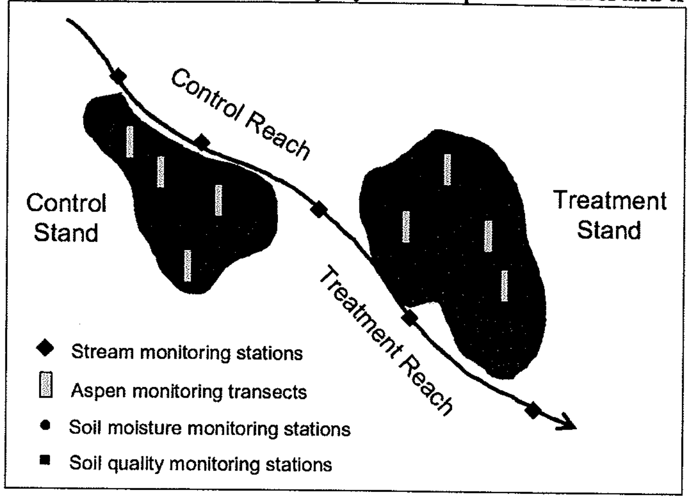
This approach does not assume above and below, or treatment and control, are originally identical (*i.e.*, replicates), but it does assume that the only major change during study period was in the treatment unit (conifer removal) and that the control was in a stable state throughout the time of comparison (before and after treatment). The same fundamental design and analysis approach described above for stream temperature is being applied for all variables of interest (e.g., stream canopy, water quality, soil bulk density).

5. Study Sites and Treatment Timeline

At the outset of this project in early 2003, aspen stands and associated stream reaches selected for inclusion into the project: 1) were either scheduled or expected to be scheduled for implementation of a conifer removal treatment in the next 1 to 3 years; 2) had sufficiently similar stands and stream reaches in the vicinity to serve as controls; and 3) represented the range of precipitation regime found on LNF. Study stands and stream reaches at locations on Pine-Bogard Creeks, Butte Creek, and Brokeoff Meadow were enrolled in the study (Figures 2a&b, 3, and 4). We selected sites near the confluence of Pine and Bogard

Creeks on the Eagle Lake Ranger District due to treatment application scheduled for the winter of 2003-04 (Figure 2b "Bogard Units") and fall/winter 2005-06 (Figure 2b "Aspen_Enhance_Summer" and "Aspen_Enhance_Winter"). We selected stands and stream reaches on Butte Creek (at the boundary of ELRD and the Hat Creek Ranger District) and Brokeoff Meadow (HCRD) because both timber sales are expected to be scheduled for implementation in the within next few years. Butte Creek is a dry site, Pine-Bogard Creeks represents wet eastside conditions, and Brokeoff Meadow is located on the west-slope representing the highest precipitation regimes of LNF.

Figure 1. Illustration of study layout for a paired control and treatment aspen stand and associate stream study reach.



During this reporting period (1/04 – 5/05) the winter treatment along segments of Pine and Bogard Creeks was completed (Figure 2b). We are very confident that the fall/winter 2005-06 treatment for the remainder of Pine and Bogard Creeks will be completed as scheduled. We anticipate that the Brokeoff Meadow and Butte Creek treatments will occur in the next 2 to 3 years.

Figure 2a. Pine and Bogard Creek stream sampling locations and names.

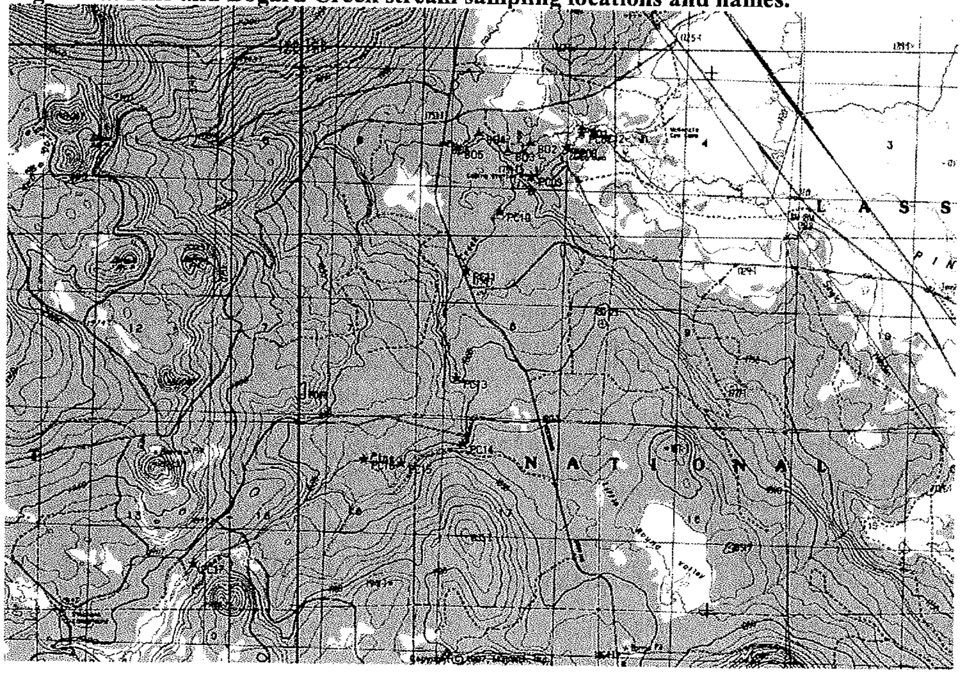


Figure 2b. Pine-Bogard Creek study location with monitoring stations and treatment areas marked.

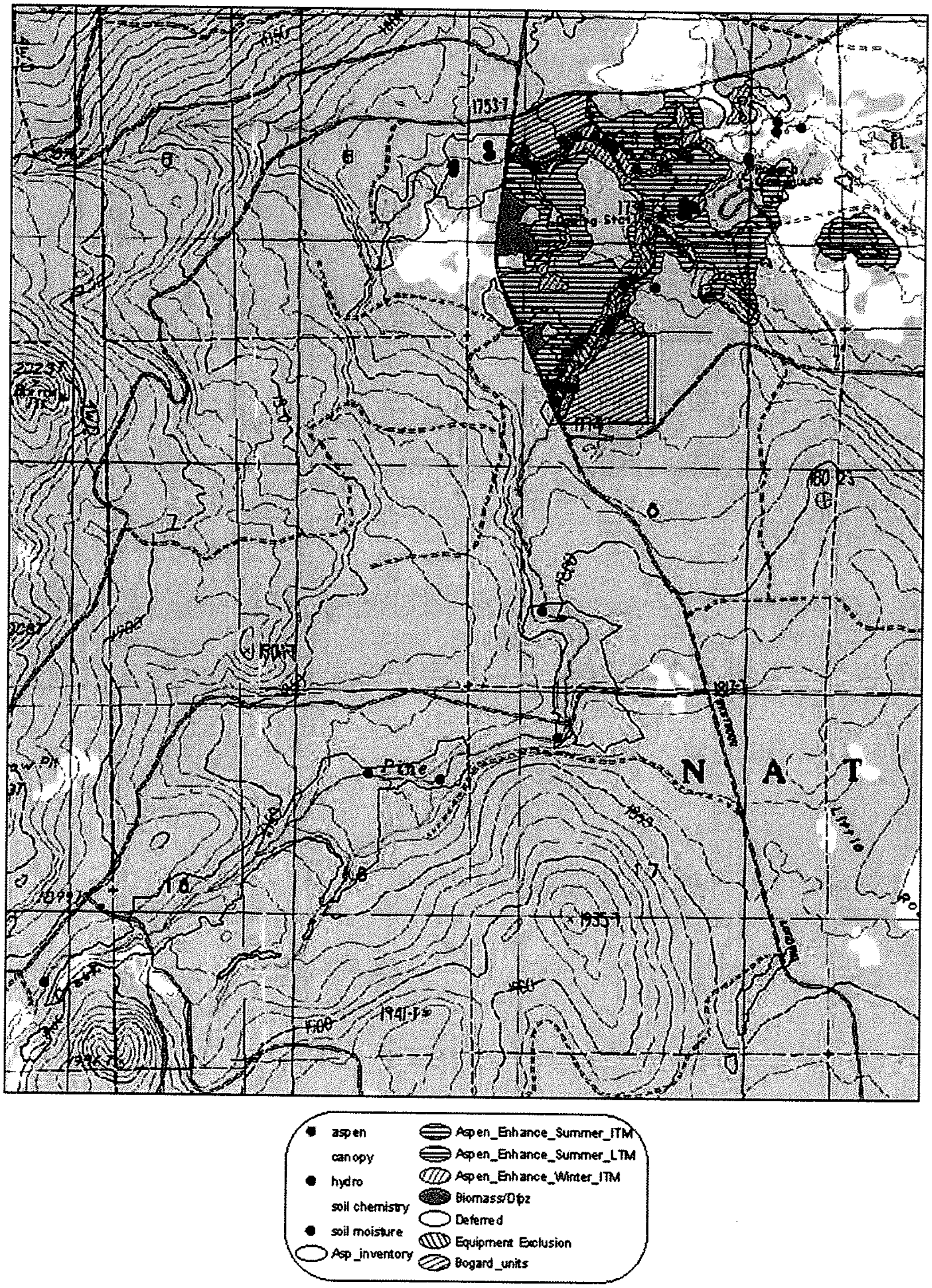


Figure 3. Butte Creek study location with stream monitoring stations marked.

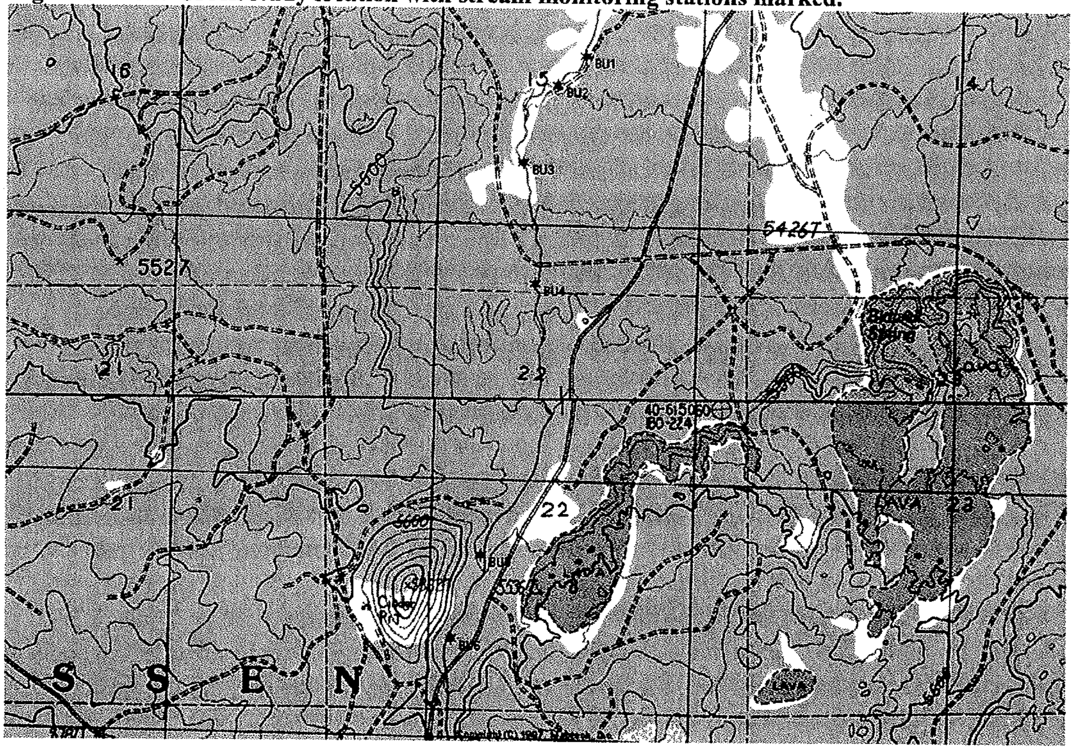
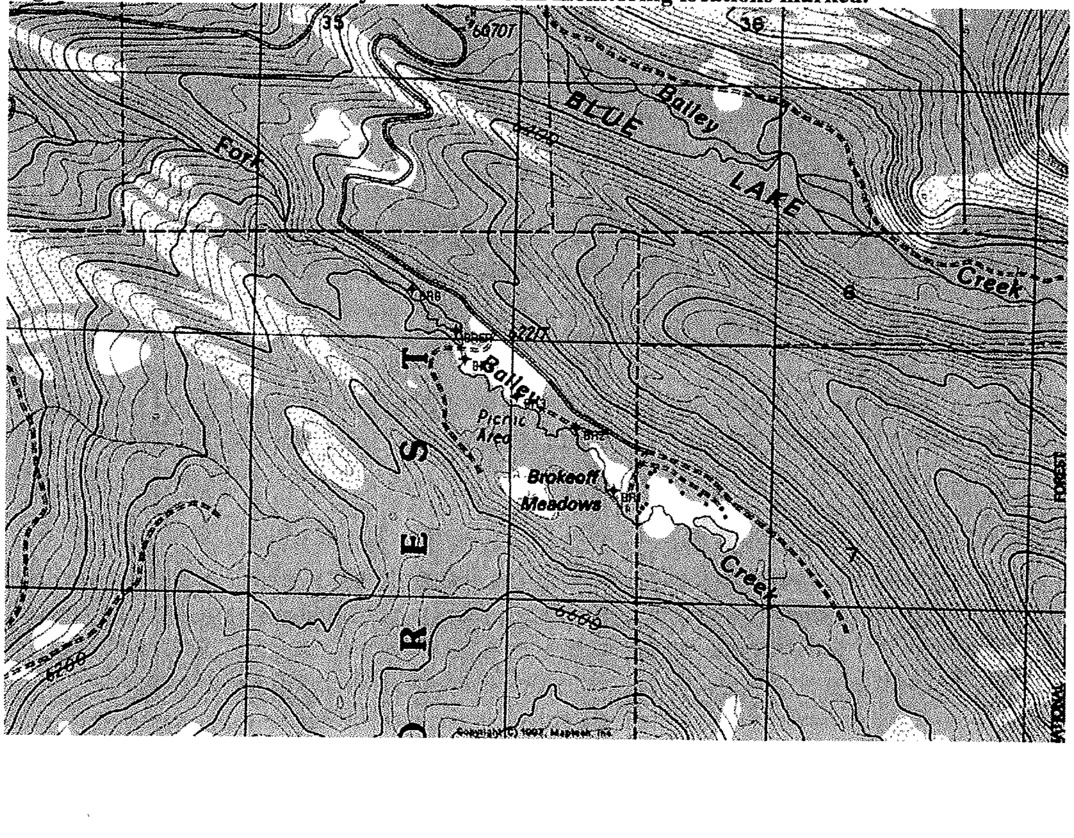


Figure 4. Brokeoff Meadow study site with stream monitoring locations marked.



6.0 Overall Progress

We have made significant progress during this reporting period, building upon and complementing progress made during 2003. Progress of specific note includes: 1) winter 2003/04 conifer removal was implemented on Pine-Bogard Creeks and before and after (1 year) soil quality and stream data collection was accomplished; 2) publication in the prestigious peer-reviewed journal *Restoration Ecology* of our research establishing prescribed conifer removal as an effective aspen conservation and restoration initiation technique, and 3) completion of all pre-treatment data collection and laboratory analysis from all sites as planned. These accomplishments are benchmarks in the project assuring us of the effectiveness of prescribed conifer removal, providing our first chance to evaluate potential impacts of conifer removal on riparian resources, and providing a baseline by which to evaluate all future planned treatments. Initial analysis of pre and post-treatment data collected relative to the winter 2003/04 treatment on Pine and Bogard Creeks is the most novel result from this reporting period, so will be discussed in greater detail in the next section. In this section we offer a simple report of general progress.

Continued Collaboration and Outreach

The strong cooperative relationship between USFS and UC Davis upon which this project was founded has continued the flourish. The project has increased exposure and credibility at the local, state, and national level with multiple stakeholder groups. Reports and updates on this project have been made to USFS staff at the district, forest and region level. Stakeholders and interested parties such as Quincy Library Group, Pine Creek CRMP, Point Reyes Bird Observatory, CDF&G, and LNF-PNF-MNF grazers. Feedback is consistently positive and supportive of the goals and approach of the project. The positive working environment this project generates has allowed for significant interaction between UC faculty, staff, students and USFS professional land managers and specialists. This interaction is building capacity within both organizations and has already instigated new investigations of aspen and grazing management dynamics as well as the importance of aspen stands for landscape plant community diversity and richness. Although difficult to quantify (even with a linear mixed effects analysis) benefits such as professional growth and improved cross-agency cooperation will lead to integrated, defensible natural resources research, management and restoration.

Objective 1 Completed and Published

Objective 1 of this project has been accomplished. Within 3 to 4 years, the conifer removal activities conducted on LNF are conserving aspen stands and initiating restoration by stimulating significant recruitment of aspen in all four size classes. The data, analysis, and results supporting this conclusion are contained in a paper published in the journal *Restoration Ecology.*

Jones, B.E., T.H. Rickman, A. Vasquez, Y. Sado, and K.W. Tate. 2005. Removal of Competing Conifers to Regenerate Degraded Aspen Stands in the Sierra Nevada. *Restoration Ecology*. 13:373-379.

Annual Data Collection and Laboratory Analysis

All data collection objectives for this year were achieved. Data collection began in May and continued through September. Tables 1 through 3 report parameters monitored for each study location. All sample locations have been GPSed and permanently marked to allow accurate repeated measurement in following years of the study and protection during treatment implementation. All laboratory analysis of water, soil, and macroinvertebrate samples collected were completed. In addition to field data collected by Eagle Lake Range District staff, Hat Creek Ranger District staff collected instream habitat and channel data following USFS Stream Condition Inventory protocol.

Table 1. Pine – Bogard Creek sample stations and data collection conducted during May – September 2005

Factor	Parameters Measured	Sample Stations	Data Collection Yr 2
Water	Streamflow, water and air temperature, pH, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, sulfate.	17 monitoring stations which define 10 stream reaches	Temperature continuously collected, other parameters sampled every 2 weeks.
Aquatic Macroinvertebrates	Samples will be identified to family and various metrics of richness, diversity, and composition determined.	Samples collected at 8 water monitoring stations.	Samples collected once.
Stream Canopy Cover	Canopy density and percent of available solar radiation reaching the stream each month.	5 readings for each reach defined by 17 water monitoring stations (n=50)	Samples collected once.
Soil Moisture	Soil moisture at 6 and 18 inches depth.	16 monitoring stations (8 controls and 8 treatment fall/winter 2005).	Sampled every 2 weeks.
Soil Quality	Soil samples have been collected at 0-3 and 3-6 inches depth for the following analysis: bulk density; total N, nitrate, ammonium, phosphate, total C, organic C, and organic matter.	80 monitoring stations (40 controls and 40 winter 2003/04 treatment).	Sampled once.
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment fall/winter 2005)	Sampled once.
Stream Condition Inventory	LWD, substrate size distribution, channel gradient, entrenchment, W:D, residual pool depth, pools formed by wood, % pool tail surface fines, % shade, stream shore depth, bank angle, % undercut banks.	Winter 2003/04 treatment reach on Pine Creek	Sampled once.

Table 2. Butte Creek sample station establishment and data collection conducted during May – September 2005

Factor	Parameters Measured	Sample Stations	Data Collection Yr 2
Water	Streamflow, water and air temperature, pH, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, and sulfate.	6 monitoring stations which define 5 stream reaches (3 control, 2 treatment).	Temperature continuously collected, other parameters sampled every 2 weeks.
Aquatic Macroinvertebrates	Samples are being identified to family and various metrics of richness, diversity, and composition determined.	Samples were collected at 3 water monitoring stations.	Samples collected once.
Soil Moisture	Soil moisture at 6 and 18 inches depth.	14 monitoring stations (5 controls, 5 treatment, and 4 already treated).	Sampled every 2 weeks.
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment)	Sampled once.

Table 3. Brokeoff Meadow sample station establishment and data collection conducted during June – September 2005

Factor	Parameters Measured	Sample Stations	Data Collection Yr 2
Water	Streamflow, water and air temperature, dissolved oxygen, electrical conductivity, turbidity, total suspended solids, total N, total P, nitrate, ammonium, phosphate, potassium, and sulfate.	6 monitoring stations which define 5 stream reaches (1 control, 4 treatment).	Temperature continuously collected, other parameters sampled every 2 weeks.
Aquatic Macroinvertebrates	Samples are being identified to family and various metrics of richness, diversity, and composition determined.	Samples were collected at 3 water monitoring stations.	Samples collected once.
Soil Moisture	Soil moisture at 6 and 18 inches depth.	16 monitoring stations (8 controls and 8 treated).	Sampled every 2 weeks.
Soil Quality	Soil samples have been collected at 0-3 and 3-6 inches depth for the following analysis: bulk density; total N, nitrate, ammonium, phosphate, total C, organic C, and organic matter.	40 monitoring stations (20 controls and 20 treatment).	Sampled once.
Aspen	Aspen density by 4 size classes and total.	10 transects (5 controls and 5 treatment)	Sampled once.
Stream Condition Inventory	LWD, substrate size distribution, channel gradient, entrenchment, W:D, residual pool depth, pools formed by wood, % pool tail surface fines, % shade, stream shore depth, bank angle, % undercut banks.	Treatment reach.	Sampled once.

Pre-Treatment Data Collection Complete Across all 3 Study Sites

This year we completed collection of pre-treatment data from all sites for water quality, stream temperature, stream flow, soil moisture and aquatic macroinvertebrates. We essentially have a complete 2 season dataset for these parameters, with multiple samplings throughout each season. The exception being soil moisture which was not collected for the Winter 2003/04 treatment on Pine and Bogard Creeks. There was insufficient time between the start of this project and that particular treatment implementation to capture a useful pretreatment dataset. We do have pretreatment soil moisture data for all other scheduled treatments (Pine-Bogard Fall/Winter 2005, Butte Creek, and Brokeoff Meadow). Pre-treatment data has been collected for soil quality (*e.g.*, bulk density, N, C, organic matter) at all sites where treatment implementation appears eminent within 1 to 2 years (Pine-Bogard Fall/Winter 2005, Brokeoff Meadow). Stream canopy and solar radiation input has been measured at all sites.

6.1. Winter 2003/04 Conifer Removal Treatment Applied to Pine and Bogard Creeks

Over snow conifer removal occurred during winter of 2003-04 between sites PC10 and PC11 (Figure 2a), and BO4 and BO6 (Figure 2b) on Pine and Bogard Creeks, respectively (Figure 2b "Bogard Units", Photo 3 and 4).

When combined with data collected in 2003 (before), the data collected in 2004 (after) at sites PC10, PC11, BO4 and BO6 allow for complete analysis of before and after, above and below treatment differences for all water and aquatic macroinvertebrate variables listed in Table 1. Stream Condition Inventory data as well as stream canopy cover data were collected 2003 and 2004 along each treatment and control reach (all reaches except PC10 to PC 11 and BO4 to BO6). Soil quality samples (see Table 1) were collected before (June 2003) and after (June 2004) treatment along permanent transects within the 2 treatment stands and within 2 control stands. Data from both years has been entered, checked for accuracy, and significant statistical analysis conducted. Results of this analysis are reported below for key variables of concern.

Photo 4. Aspen stand north of sample stations BO4 and BO6 on Bogard Creek which received prescriptive conifer removal during Winter 2003/04. Left side illustrates post treatment, right side illustrates initial conifer encroachment level. Bogard Creek lies ~ 30m to the right of treatment boundary. Photo taken May 2005.

Stream Canopy Response

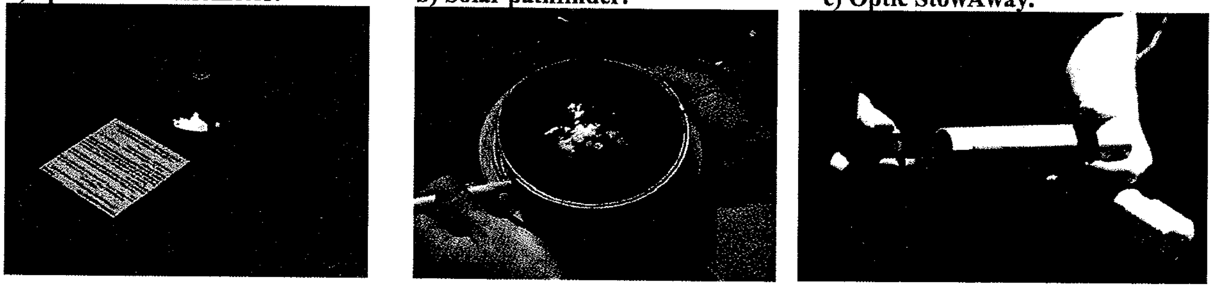
Stream canopy cover (%) was measured with a spherical densiometer and represents the amount of sky above a point on the stream channel which is blocked from view by vegetation (Photo 5a). It is a proxy for the amount of vegetative shade over a stream reach. In the arid, hot regions of northern California, vegetative canopy has been demonstrated to block solar radiation reaching the stream water surface and thus moderate water temperature (Tate et al. 2005, http://californiaagriculture.ucop.edu/0503JAS/toc.html). Stream temperature is a major habitat factor for cold water fish species in the region. Vegetative canopy also serves as an input of nutrients and organic matter to stream systems, influences in stream primary production, and macroinvertebrate assemblages (*e.g.*, shredders v. grazers). Percent of available solar radiation reaching the stream water surface was measured with a solar pathfinder (Photo 5b). This reading reflects the integrated effects of vegetative canopy, topographic shading, and stream channel aspect to block some portion (0 to 100%) of available solar radiation reaching a site at a given latitude for each month of the year. We concern ourselves with the months June through September which represent the warmest period in the region, when elevated stream water temperatures might be of concern.

There was a significant ($P<0.05$) reduction in vegetative canopy cover over the treatment reaches of both Pine and Bogard Creeks following conifer removal in adjacent aspen stands. Pine Creek canopy was reduced 10% and Bogard stream canopy was reduced 33%. Mean canopy cover before v. after treatment on Pine Creek was 70 and 60%, respectively. Mean canopy cover before v. after treatment on Bogard

Creek was 82 and 49%, respectively. Figure 5 reports available solar radiation during the months June, July, August, and September received at the water surface for each stream before and after treatment. A significant increase in solar radiation reaching Bogard Creek was realized June through August as a result of the 33% reduction in canopy cover. The increase was not significant for September (P>0.05). The 10% reduction in canopy cover on Pine Creek resulted in somewhat greater solar radiation reaching the water surface in June. No significant difference existed for July through September before or after treatment along Pine Creek. The magnitude of error bars are a function of inherent variation in replicating solar radiation readings from year to year. To overcome this in future treatments we are significantly increasing the number of readings taken from each stream reach.

Variation in the magnitude of canopy cover reduction and increased solar radiation between streams is potentially due to several factors. First, Bogard Creek and it's riparian area is narrow (<3 m) compared to Pine Creek (>10 m) (Photo 6 and 7). Treatment guidelines excluded conifer removal from within the stream's riparian area, but allowed tree removal up to the defined edge of the riparian area. Given the narrow nature of Bogard Creek's riparian area, it is reasonable to expect that a large percentage of stream canopy cover is provided by near stream upland trees (BO4 to BO5 in particular). Whereas, it is our observation that the majority of stream canopy cover on Pine Creek (PC10 to PC11) is provided by trees rooted in the riparian area. Second, the aspect of conifer removal was north on Bogard Creek and south on Pine Creek. While this should not effect canopy reduction measurements, solar radiation measurements do integrate aspect. The potential influence of aspect of conifer removal to stream orientation (E-W, N-S) should receive some consideration in development of prescriptive conifer removal plans. We will soon have significantly more canopy and solar radiation data from additional reaches of Pine and Bogard scheduled for treatment Fall/Winter 2005, and will attempt a more complete evaluation of how aspect and riparian area width effect canopy cover and solar radiation following conifer removal.

Photo 5. Equipment used to measure stream canopy (a), solar radiation (b), and water temperature (c).



a) Spherical densiometer. **b) Solar pathfinder.** **c) Optic StowAway.**

Stream Temperature Response

Stream temperature was collected at each sampling station using Onset Optic StowAway temperature dataloggers (Photo 5c), set to record temperature every 0.5 hours. Temperature loggers were deployed ~May 15 and retrieved ~Sept 30 each year at each station. We examined several metrics of stream water temperature above and below treatment reaches before (2003) and after (2004) conifer removal in adjacent aspen stands. Daily maximum and mean water temperatures, as well as 7-day running average daily maximum and mean water temperatures were calculated. For all metrics examined, the difference in temperature between above and below stations was not different before v. after conifer removal in adjacent aspen stands. This preliminary result is based upon the lack of significance (P>0.65 in all cases) of an interaction between location (above v. below) and year (before v. after). While temperatures below the treatment reach did increase from temperatures above the reach, the magnitude of increase was not significantly different between years. Figures 6 and 7 report 7-day running average daily maximum water temperatures above and below treatment reaches for both 2003 and 2004 on Pine and Bogard Creeks, respectively. It is important to note that maximum temperatures above and below treatment reaches on both streams remain well within optimal levels for all cold water fish species in the region (<67 °F).

This initial result indicates that although there was a reduction in stream canopy (10% on Pine, 32% on Bogard) which resulted in variable increases in solar radiation during the summer period, there was not a significant increase in stream temperature as a result. There are several possible reasons for this lack of response. First, there was minimal increase in solar radiation contributed to Pine Creek, particularly in July and August which are the warmest months in the region (Figure 5). Thus, it is not that surprising to see no stream temperature response on Pine Creek. However, Bogard Creek did sustain a relatively significant reduction in canopy cover (33%) and increase in solar radiation (Figure 5). Despite the reduction in canopy cover along the treatment reach of Bogard, there is still significant canopy cover (49%) following the treatment which may be providing sufficient shading to continue to moderate stream water temperature. It is also important to note that the Bogard Creek treatment reach is relatively short (<500 m). It is likely there is a relatively short residence time for water to pass through this reach. A short residence time would lessen the potential for water passing through the reach to be influenced by solar radiation arriving to the reach. We will soon have significantly more stream temperature data from additional, longer reaches of Pine and Bogard scheduled for treatment Fall/Winter 2005, and will attempt a more complete evaluation of how stream reach length and residence time effect stream temperature following conifer removal.

Photo 6 (left) and 7 (right). Photo 6 is Bogard Creek looking down stream from sampling station BO5 after conifer removal in aspen stand to the left side of picture. Photo 7 is Pine Creek looking up stream from sampling station PC10 after conifer removal in aspen stand to the left side of picture.

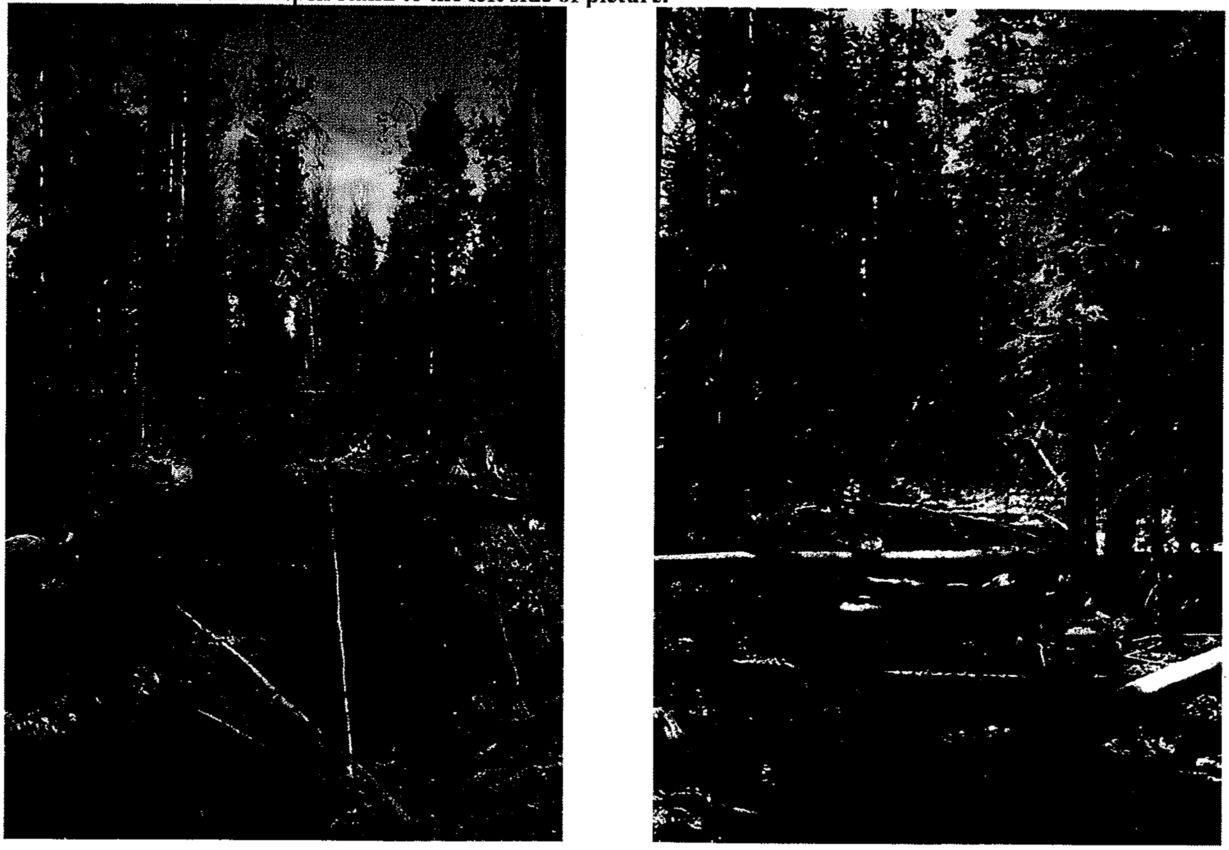


Figure 5. Available solar radiation received at water surface of treated reaches of Pine and Bogard Creek before (2003) and after (2004) conifer removal in adjacent aspen stands.

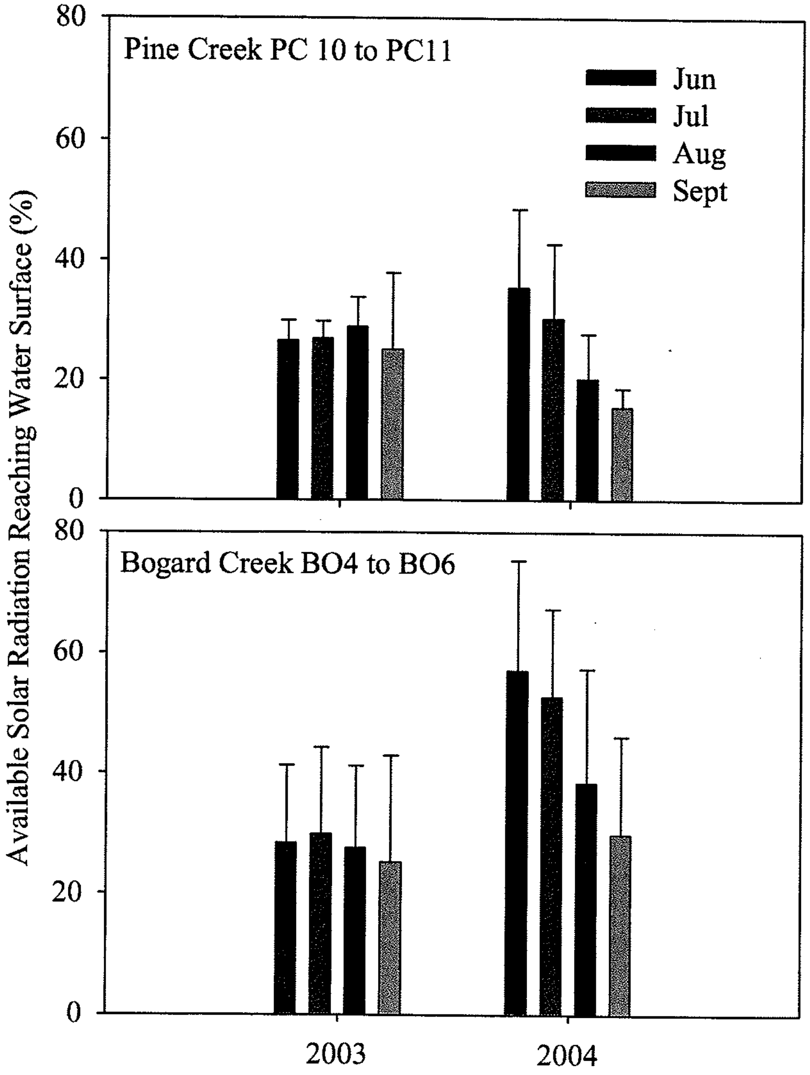


Figure 6. Seven day running daily maximum water temperature (F) on Pine Creek above (PC11) and below (PC10) the stream reach (PC10 to PC11) before (2003) and after (2004) conifer removal from an adjacent aspen stand.

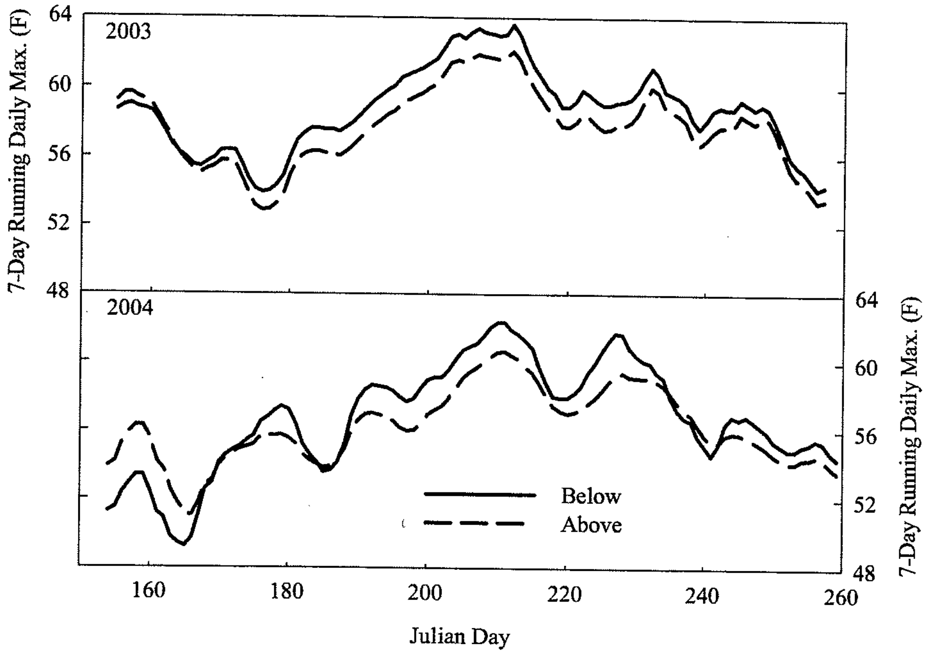
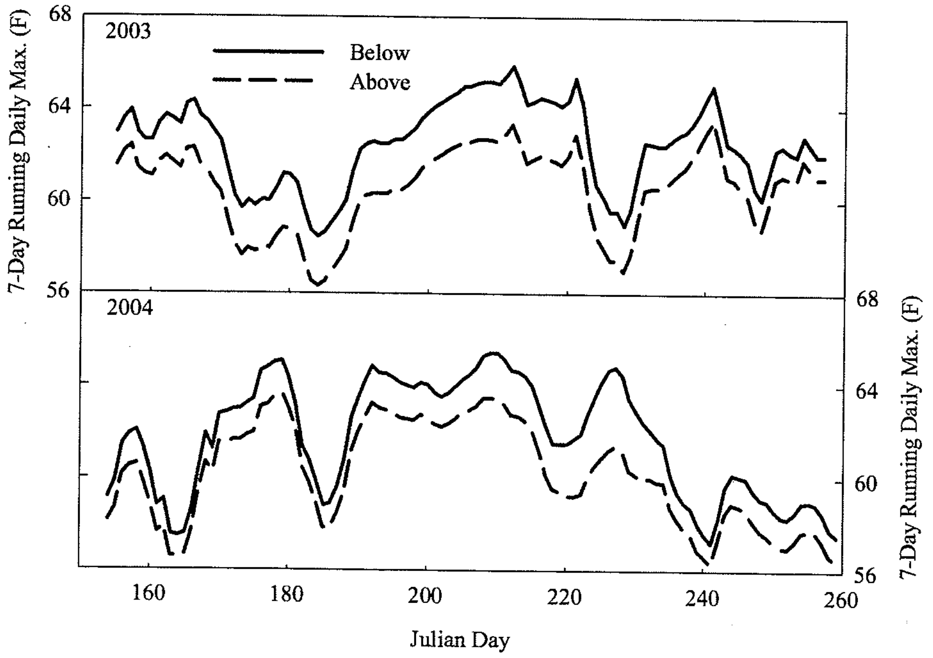


Figure 7. Seven day running daily maximum water temperature (F) on Bogard Creek above (BO6) and below (BO4) the stream reach (BO4 to BO6) before (2003) and after (2004) conifer removal from an adjacent aspen stand.



Stream Chemistry and Sediments

Stream water samples were grab sampled every 2 weeks from ~May 15 to ~September 30 above and below as well as before (2003) and after (2004) treatment on each stream (Photo 8a). Stream discharge (cfs) was measured at the same time as the grab sample was collected using the area velocity method (Photo 8b). Dissolved oxygen (mg/L) and electrical conductivity (dS/m) were determined at the time of grab sample collection and discharge measurement using standard field meters (Photo 8c). Grab samples were refrigerated (4 °C) and transported to UC Davis where they were analyzed for total suspended solids, electrical conductivity, pH, turbidity, and major anions and cations. Electrical conductivity (conductivity cell), pH (potentiometrically) and turbidity (turbidity meter) were measured on a non-filtered subsample. A separate aliquot of each sample was passed through a 0.45 μm membrane filter. Total suspended solids (g/L) were determined as change in mass of filter pre and post filtration on an analytical balance accurate to 0.001 g. The filtrate was analyzed for major cations (Na, Mg, K, Ca, & NH_4) and anions (Cl, SO_4, NO_3 & ortho-PO_4) by ion chromatography.

Tables 4 and 5 report discharge and water quality data collected from Pine and Bogard Creeks for 2003 and 2004. Examination of the mean concentrations below treatment reaches for both streams in both years indicates exceptionally high water quality. Concentrations of nutrients and sediments are low, while average dissolved oxygen readings are well within the optimal range for cold water fish species in the region. As Table 6 reports nitrate, ammonium, and phosphate (primary nutrients of concern) are below our detection limit (0.01 ppm or mg/L) for the majority of samples collected from Pine and Bogard Creeks (data shown are downstream of treatment reach). The low levels of nutrients and sediment below treatment reaches (Tables 4 and 5) following treatment is in itself enough to demonstrate that there were no significant water quality impacts of the conifer removal.

To confirm there were no real increases in concentration due to treatment we tested the data to determine if an interaction existed between location (above v. below) and year (before v. after) for each parameter. The lack of significant change in discharge above v. below indicates that changes in concentration would not be due to dilution effects. With the exception of total suspended solids and turbidity on Bogard Creek there was no significant change in concentration through treatment reaches after compared to before removal of conifers from adjacent aspen stands on either creek. On Bogard Creek, there was actually a filtering of sediments (and thus turbidity) in 2004. For some reason (*e.g.*, summer thunder storm, up-stream disturbance) there was a higher concentration of sediment and turbidity *above* (BO6) the treated reach on Bogard Creek in 2004 (after) compared to 2003 (before). This was not likely associated with the winter conifer removal which occurred below this point (BO6). There is a dirt road which crosses Bogard Creek at this point (BO6) and does contribute road runoff above BO6, if storms are sufficient to generate runoff (Photo 9a). Figure 8 reports the raw total suspended concentration data for this site (BO6) for both 2003 and 2004. It appears that the elevated total suspended solids concentrations occurred during mid to late summer. This pattern actually occurs both years, but is more pronounced in 2004. The significance of this result is that the treated reach of Bogard Creek (BO4 to BO6) was able to serve as a sink, or filter for sediment contributed to this reach as streamflow from an up stream source. Given that a small portion of this reach (BO5 to BO6) is meadow, this is not a surprising result (Photo 9b).

Collectively, these results indicate that there is not a significant negative impact on water quality as a result of prescriptive conifer removal from riparian aspen stands along Pine and Bogard Creek. Again, we will soon have significantly more water quality data from additional reaches of Pine and Bogard scheduled for treatment Fall/Winter 2005, and will conduct additional analysis to further support this preliminary result.

Table 4. Mean stream discharge and water quality for Bogard Creek below the treatment reach (BO4), as well as the difference between above (BO6) and below (BO4) the treatment reach before (2003) and after (2004) conifer removal in an adjacent aspen stand.

Parameter	2003 Below	2004 Below	2003 Change	2004 Change
Discharge (cfs)	0.86	0.87	-0.02	-0.16$^{n.s}$
Total Suspended Solids (mg/L)	7.81	16.29	0.87	-8.71*
Turbidity (ntu)	1.09	3.54	0.33	-2.28*
Nitrate-N (mg/L)	<0.01	<0.01	--	--
Ammonium-N (mg/L)	<0.01	<0.01	--	--
Ortho-Phosphate (mg/L)	0.10	0.04	-0.01	-0.03$^{n.s}$
Potassium (mg/L)	2.25	2.00	0.09	-0.09$^{n.s}$
Sulfate (mg/L)	0.08	0.53	0.01	0.01$^{n.s}$
pH	7.52	7.66	0.04	0.05$^{n.s}$
Electrical Conductivity (ds/m)	90.61	97.18	-0.85	1.27$^{n.s}$
Dissolved Oxygen (mg/L)	6.95	6.98	-0.41	0.61$^{n.s}$

* Significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), $P<0.05$.

n.s. No significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), $P>0.05$.

Table 5. Mean stream discharge and water quality for Pine Creek below the treatment reach (PC10), as well as the difference between above (PC11) and below (PC10) the treatment reach before (2003) and after (2004) conifer removal in an adjacent aspen stand.

Parameter	2003 Below	2004 Below	2003 Change	2004 Change
Discharge (cfs)	13.94	4.53	-0.73	-0.01$^{n.s}$
Total Suspended Solids (mg/L)	3.12	3.40	-2.74	0.31$^{n.s}$
Turbidity (ntu)	0.34	0.57	-0.08	0.31$^{n.s}$
Nitrate-N (mg/L)	<0.01	<0.01	--	--
Ammonium-N (mg/L)	<0.01	<0.01	--	--
Ortho-Phosphate (mg/L)	0.02	<0.01	0.01	--
Potassium (mg/L)	1.40	1.28	0.01	-1.28$^{n.s}$
Sulfate (mg/L)	0.04	0.29	0.01	-0.04$^{n.s}$
pH	7.48	7.62	0.07	0.02$^{n.s}$
Electrical Conductivity (ds/m)	60.65	66.18	2.93	2.92$^{n.s}$
Dissolved Oxygen (mg/L)	6.92	6.39	-0.39	0.62$^{n.s}$

* Significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), $P<0.05$.

n.s. No significant difference between above v. below water quality pre-treatment (2003) compared to post-treatment (2004), determined by linear mixed effects analysis for an interaction between year and location (above, below), $P>0.05$.

An interesting side note in the data reported in Table 6, is the order of magnitude greater levels of sulfate (SO4) found in Bailey Creek (Brokeoff Meadow) compared to the 3 east side streams. SO4 is not considered to be a major source of water quality impairment, rather in this case it is reflective of the geologic setting of a given stream. Note that the upper Bailey Creek watershed extends into the west slopes of Lassen Volcanic National Park, and that the high SO4 levels reflect this. It is interesting that Butte and Pine Creek, whose watershed extends up the eastern slope of Lassen Volcanic National Park do not display this SO4 signature. Otherwise, Table 6 indicates that water quality is relatively consistent across these streams, and uniformly clean, clear and cool.

Table 6. Mean discharge, water quality, and aquatic habitat values for all four streams enrolled in study. Data represent the lowest sample station on each stream and were collected May – September 2004.

	Pine		Bogard		Butte		Bailey	
Parameter	Mean[1]	%<dl[2]	Mean	%<dl	Mean	%<dl	Mean	%<dl
Discharge (cfs)	6.6	0	0.8	0	11.2	0	14.2	0
Daily Max. Temp. (F)	56.7	0	58.7	0	65	0	52.6	0
Daily Mean Temp. (F)	51.9	0	50.0	0	58.1	0	47.4	0
D.O. (mg/L)	8.1	0	9.9	0	7.4	0	7.9	0
TSS (mg/L)	5.2	0	8.9	0	5.1	0	5.3	0
Turb. (ntu)	0.9	0	1.7	0	0.7	0	0.9	0
pH	7.5	0	7.6	0	7.5	0	7.1	0
E.C. (dS/m)	65	0	95	0	52	0	41	0
NO_3-N (mg/L)	0.01	76	0.01	75	0.01	57	0.01	51
PO_4-P (mg/L)	0.03	79	0.08	18	<0.01	89	<0.01	82
SO_4-S (mg/L)	0.16	13	0.39	0	0.42	0	11.53	0
NH_4-N (mg/L)	0.3	98	<0.01	100	0.21	88	0.11	78
K (mg/L)	1.43	0	2.04	0	1.13	0	0.73	0

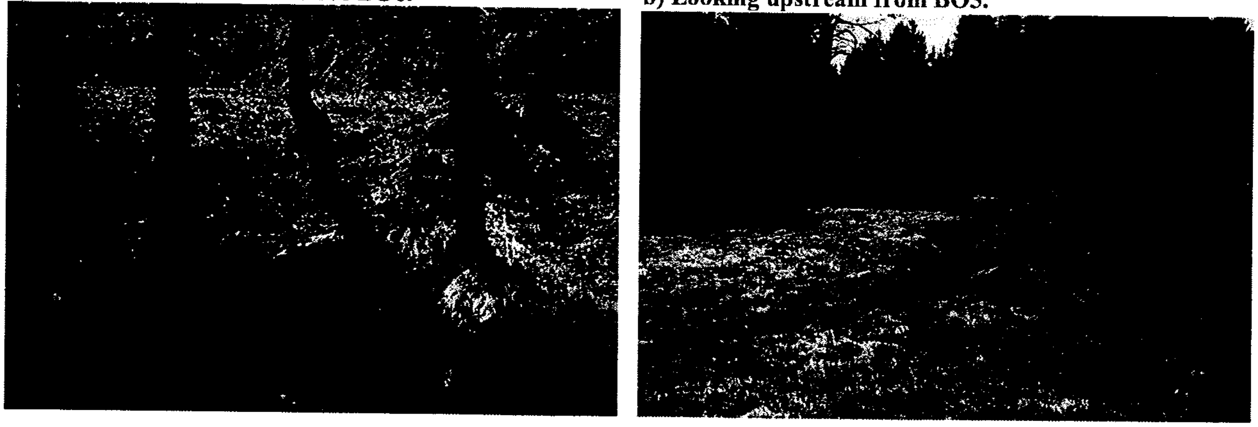
[1] Mean of all water samples above detection limit (0.01 mg/L for NO_3-N, PO_4-S, SO_4-S, and NH_4-N).

[2] Percent water samples collected which were below the detection limit.

Photo 8. Water quality and stream discharge data collection.

a) Grab sample collection. **b) Streamflow measurement.** **c) Dissolved oxygen measurement.**

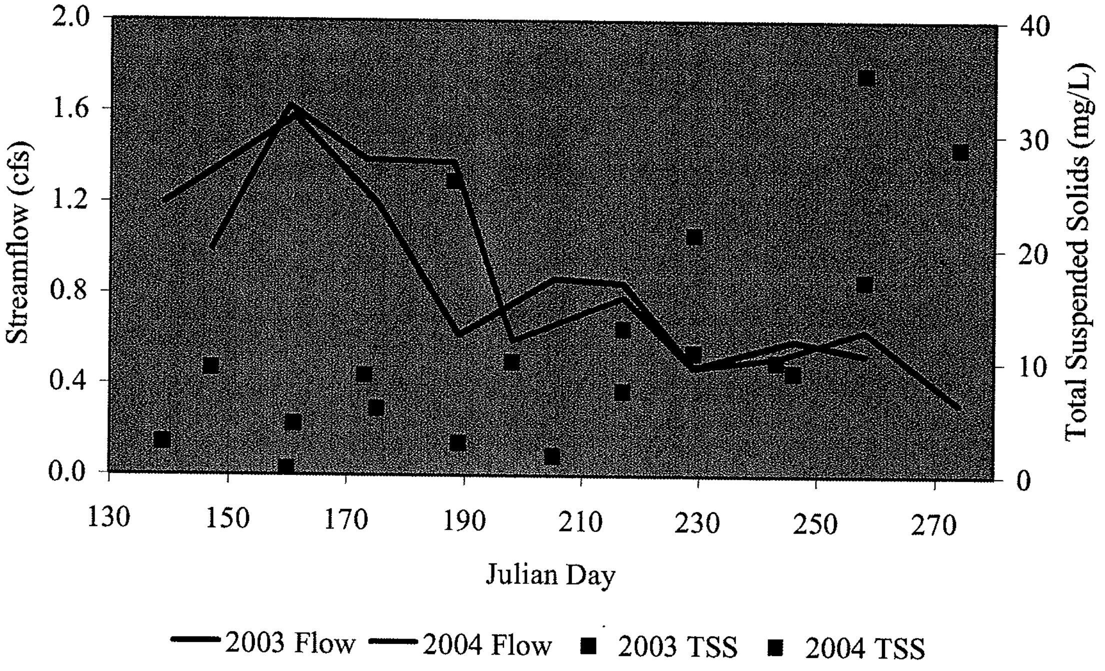
Photo 9. Bogard Creek showing road and culvert above sample station BO6 (a) and small meadow reach between BO5 and BO6 (b).



a) Road and culvert 10 m above BO6.

b) Looking upstream from BO5.

Figure 8. Stream discharge and total suspended solid concentrations above the treated reach (BO6) of Bogard Creek before (2003) and after (2004) removal of conifers in an adjacent, down-stream aspen stand.



Stream Condition Inventory

Stream Condition Inventory was conducted 2003 and 2004 on the treated reach of Pine Creek. The channel is moderate gradient (about 2 percent), and therefore probably moderately sensitive to change. Comparison of data collected in 2003 and 2004 is summarized in Table 7 indicate no increase in any measure of sediment in the channel (particle count, pool tail fines, residual pool depth) or change in channel morphology (W:D ratio, wood formed pools. In fact, surface fines and particle count percentage less than 2% size class decreased slightly, but within error of the measurements.

Table 7. Stream condition inventory data collected 2003 (before) and 2004 (after) on treatment reach of Pine Creek.

Pine Creek Aspen Site (below rd 32N22)	aggs	no in aggs	< 2mm	D_{50}	Entrenchment	W:D Ratio (Monuments)	W:D Ratio	Residual Pool Depth	Wood formed Pools	% Pool Tail Surf Fines	% Stable Banks	% Shade	Stream Shore Depth (m)	Bank Angle (degrees)	% Undercut Banks
Lower Pine 2004															
Mean				29.90	1.56	21.70	17.40	0.41		7.00		60.70	no data	144.00	16
Range					1.2-1.7	20.8-22.8	9.7-24	.28-1.17		0-54		34-100		45-176	
n			300		6	3	6	22		60	100	50		100	100
Count or %	10.00	125.00	1.70						5		65				
Lower Pine 2003															
Mean					2.1	19.7	no data	0.43		8.3	39	70	0.14	146	17
Range					1.7-2.8	19.2-24.2		.22-.1.16		0-60		24-95	0-0.45	55-175	
n			329.00		3	3		23		63	100	50		100	100
Count or %	11.00	74.00	15.50	15.90					5		39	0	17		

Soil Quality Response

The term soil quality, much like the term water quality, represents a suite of chemical and physical properties of soil. Within the treatment aspen stands at Pine and Bogard Creek and in adjacent control stands both before and after treatment implementation we sampled surface duff layer thickness, measured dry bulk density (g/cm^3), and collected a sample for nitrogen, phosphorus, and carbon analysis. Dry bulk density was determined via collection of intact cores (2 in diameter by 3 in depth) which were then dried in a forced air oven at 105 °C until a constant weight was achieved. Sample dry weight was then determined on an analytical balance accurate to 0.001 gm. Total nitrogen (N), nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), phosphate (PO_4-P), organic carbon (OC), organic matter (OM), and total carbon (C) were conducted by the University of California Division of Agriculture and Natural Resources Analytical Laboratory (DANR Lab) on the UC Davis campus following standard methods as described on their website (http://groups.ucanr.org/danranlab). Soil dry bulk density and samples for N-P-C analysis were collected at depths of 0-3 and 3-6 inches. Forty sample stations were established along permanent transects within each treatment and control stand (80 samples per stand, 40 stations at 2 depths). Samples were collected in late June/early July of 2003 (before treatment) and 2004 (after treatment).

Forest soil are notorious for their spatial variability, even at relatively small scales (<10 m^2). The soils at both treatment and control stands in the Pine-Bogard complex did not disappoint us. Formidable variation exists around mean calculations for almost all soil quality parameters presented in this section. Excessive variation is typically overcome with large sample size; however, with a sample size of 80 sample stations (160 samples total per year) we have pushed sample size to the practical limits of an adaptive management/monitoring project. Not to mention the fact that the field crew threatened to quit if we added more sample stations. Table 7 reports soil quality variables determined at the DANR Lab for control and treatment stands before (2003) and after (2004) conifer removal treatment. Figure 9 illustrates dry bulk density at control and treatment stands before (2003) and after (2004) conifer removal treatment. Figure 10 reports surface duff layer at control and treatment stands before (2003) and after (2004) conifer removal treatment.

We would not expect an immediate (1 year) response in soil N-P-C at either the 0-3 or 3-6 inch depth to conifer removal. Soil N, OM, OC, and C pools are quite large and thus are well buffered against short term change. Exceptions might be nitrate and phosphate, both plant and soil microbe available as well as soluble and subject to leaching. Table 8 indicates an apparent (but not significant, $P>0.05$) increase in these constituents post treatment. This apparent trend could be possible due to reduced conifer demand for these constituents. It could also be an artifact of spatial variation introducing excessive variation between years and stands. This baseline and immediate post treatment dataset provides a benchmark from which we can track changes in soil N-P-C pools as these aspen stands recover and potentially modify soil quality. We will continue to monitor these parameters on these sites in the future, but at a 3 to 5 year time step. Over time this dataset will have provide insight about nutrient cycling in aspen stands, carbon sequestration potential, and potential soil restoration targets for aspen restoration efforts.

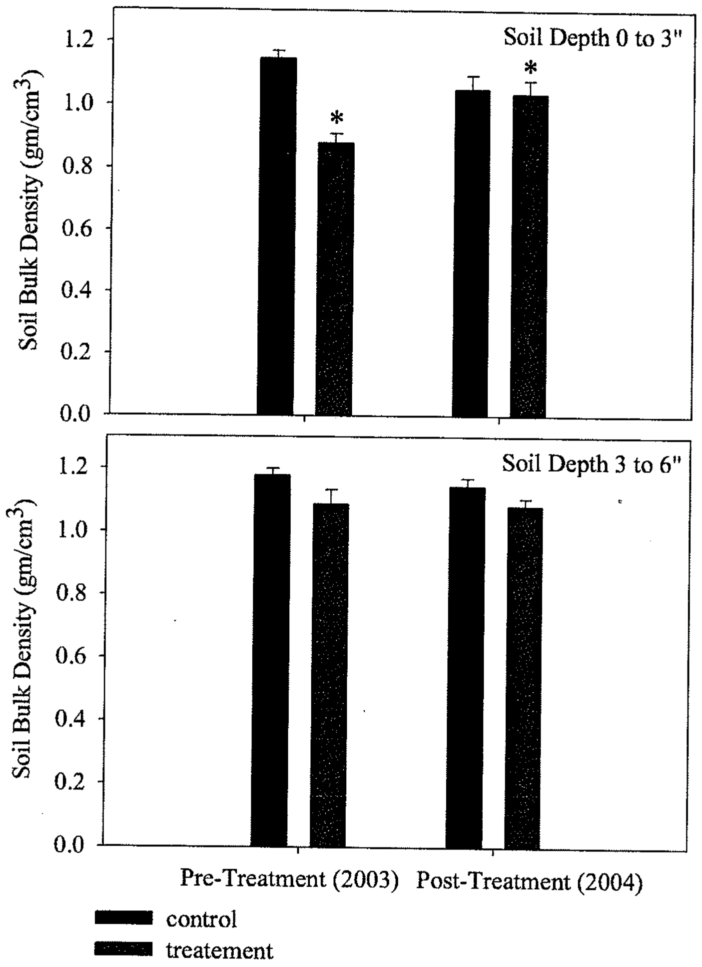
Table 8. Mean soil quality parameters for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.

		2003		2004	
Depth	Parameter	Treatment	Control	Treatment	Control
0 to 3 inch	N	0.30	0.26	0.15	0.16
	NH_4-N	10.3	10.9	9.6	8.0
	NO_3-N	0.34	0.24	0.92	0.68
	PO_4-P	24.7	29.7	20.7	13.7
	OM	9.9	8.3	6.5	6.8
	OC	5.7	4.8	3.8	4.0
	C	9.7	6.9	4.3	5.0
3 to 6 inch	N	0.13	0.13	0.10	0.11
	NH_4-N	7.4	7.5	7.4	6.7
	NO_3-N	0.23	0.13	0.61	0.51
	PO_4-P	8.8	4.4	11.1	9.1
	OM	3.9	4.2	3.9	4.4
	OC	2.2	2.5	2.3	2.6
	C	3.2	3.0	2.5	3.0

Soil bulk density is the soil quality parameter most likely to respond immediately to conifer removal treatments. Soil bulk density is a surrogate for direct measurement of soil compaction, a common impact of silvicultural practices such as skidding fallen logs to load landings. As a soil is compacted bulk density will increase. Figure 9 illustrates that a statistically significant increase in bulk density occurred in the o to 3 inch zone of the soil profile as a result of conniver removal activities. There was no change in bulk density in the 3 to 6 inch depth zone.

The question then is if this increase in bulk density translates to a tangible effect of infiltration, overland flow and erosion potential. Given the extremely low bulk densities (<1.10 g/cm^3), it is unlikely that this level of soil compaction would reduce soil surface infiltration capacity to the point where significant runoff would occur. Figure 10 illustrates that despite the moderate compaction of the mineral soil surface layer, there was no significant reduction in the 2 to 3 inches of duff layer covering the soil surface (Photo 10). This duff layer has a major capacity to absorb and retain rainfall, as well as to provide cover to protect soil surface integrity. It is also likely that the increased soil surface bulk density will be reversed within 1 to 2 years via freeze thaw action and the expansion of soil organic material with wetting and drying (>6% in this zone). Soil bulk density samples will be collected in 2005 to determine the longevity of this compaction event. In addition, we will soon have significantly more bulk density data from additional stands in the Pine-Bogard complex scheduled for treatment Fall/Winter 2005, and will attempt a more complete evaluation of how soil bulk density is impacted by 2 conifer removal strategies (fall-dry ground, winter over snow).

Figure 9. Mean soil dry bulk density for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.



* significantly different, P<0.05

Figure 10. Mean soil surface duff layer thickness for treatment and control aspen stands in the Pine-Bogard complex before (2003) and after (2004) conifer removal in treatment stands.

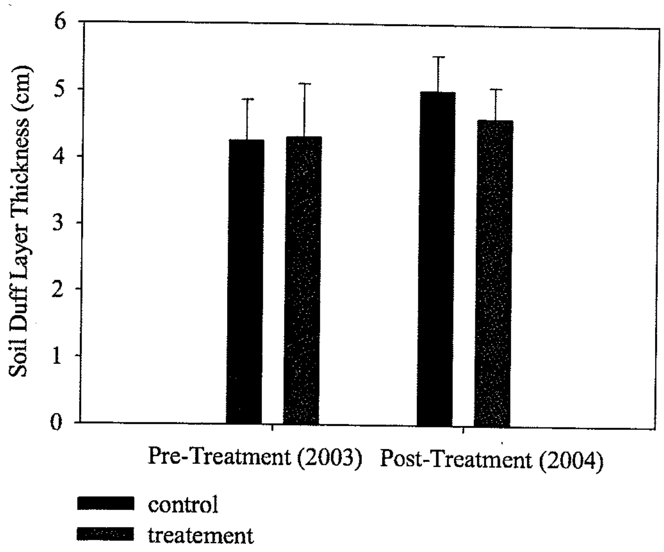


Photo 10. Soil surface duff layers average 2 to 3 inches in treatment stands following winter harvest over snow.