Watershed Response and Recovery from the Will Fire: Ten Years of Observation[1]

Kenneth B. Roby[2]

Abstract: Watershed response and recovery from a wildfire which burned 95 percent of the Williams Creek watershed in 1979 were monitored. Ground cover reduced to 11 percent by the fire increased to 80 percent by 1983. Grasses seeded for erosion control provided less than 10 percent cover until 3 years following the fire, and no significant difference in ground cover was found between seeded and unseeded transects. The average area of three channel cross sections on Williams Creek increased by 20 percent 4 years after the fire, but had returned to immediate postfire conditions by 1985. Benthic invertebrate sampling indicated the fire had a substantial impact on water quality for several years after the fire, and that recovery was incomplete through 1987. Comparable findings of incomplete recovery are presented for four additional California watersheds burned up to 23 years ago.

INTRODUCTION

A monitoring program was carried out with the objectives of (1) assessing short- and long-term impacts of a wildfire on water quality, and (2) determining the effectiveness of grass seeding as an emergency watershed rehabilitation measure. The results of the program are summarized here.

SETTING

The 825 ha Williams Creek watershed ranges between 1100 and 1800 m in elevation and is situated within the boundaries of the Plumas National Forest just north of the town Greenville, California. Soils are of the Kinkle and Deadwood families, derived from Paleozoic metavolcanic parent material, and typically support west side Sierra Nevada coniferous forest. The soils are moderately to highly erosive depending upon ground cover and slopes, which range from 20 to 70 percent.

Precipitation averages 100 cm annually (mostly as snow above 1750 m) and supports a perennial stream. The stream channel is steep and cascading, dominated by bedrock above 1450 m. Lower stretches of the creek are alluvial.

On the afternoon of September 18, 1979, a wildfire began to burn in the drainage. Pushed by strong winds, fire moved at rates of 2000 m per hour, and was not controlled until approximately 95 percent of the watershed had been burned. Fire intensity was rated as high on two-thirds of the burned area. Emergency watershed rehabilitation measures included seeding a mixture of orchard grass, slender wheatgrass, tall fescue and timothy with fertilizer on 390 ha of the burn.

METHODS

Ground Cover

Eight locations were selected within the seeded portions of the fire to represent a range of elevations and aspects. At each location, a 100-foot (30.48 m) tape was stretched in each of the four cardinal compass directions. At 1-foot (30.5 cm) intervals along the tape ground cover was classified as being bare, dead organic material, live pioneer vegetation, live grass seeded vegetation, or rock. Results were expressed in terms of percent of ground surface represented by each cover category.

Four additional transects were placed on each of two sub-basins located at 1100 m elevation within the fire. Each of these 0.2 ha watersheds had been intensely burned, and the two were nearly identical in natural characteristics. One watershed was seeded, the other was left unseeded, All ground cover transects were surveyed annually from 1979 to 1983, and in 1985.

Channel Cross Sections and Sediment Catches

Three straight reaches of alluvial channel were located on Williams Creek and Water Trough Creek. Water Trough Creek lies northwest, and was simular to Williams Creek before the wildfire.

Monumented reference points were established along each stream reach. Cross sections were determined by stretching a nylon tape between the fixed endpoints and determining channel width,

[1]Presented at the Symposium on Fire and Watershed Management, October 26-28, 1988, Sacramento, California.
[2]Supervisory Hydrologist, Plumas National Forest, Forest Service, U.S. Department of Agriculture, stationed at Greenville, California.

and channel depth at six-inch (15.24 cm) intervals Cross sections were measured in 1979, 1980, 1981, 1983, 1985, and 1987, and results plotted. Areas were planimetered and expressed in square meters.

To estimate sediment loss from surface erosion, sediment catches were constructed at the base of the small paired watersheds described above. Sediment captured behind each of the catches was estimated volumetrically in both 1980 and 1981.

Benthic Invertebrates

A standard 1 ft^2 Surber Sampler was used to collect invertebrates from both Williams and Water Trough Creeks in 1979 (2 weeks after the fire), 1980, 1981, 1982, 1983, 1985, and 1987. Samples were located in the lower elevation alluvial stretches of the creeks. At each station six samples were collected, and care taken to collect from areas with simular substrate size, water depth and velocity. Samples were concentrated in a #30 standard soil sieve and preserved in 95 percent ethanol. Invertebrates were sorted from rocks and detritus and keyed, usually to the family level.

Results were expressed in terms of number organisms per square meter, and number of taxa collected. Shannon Diversity (Pielou 1975) was calculated for the data from all six samples, for each year. Dominant organisms were expressed as a percentage of the total population.

RESULTS AND DISCUSSION

Ground Cover

The results of the vegetation transects (table 1) show that seeded vegetation did not contribute substantial cover until 3 years after the fire. Before that time, protective ground cover was provided primarily from dead organic matter. Data from the paired watersheds (table 2) also show that on the Will fire, seeding provided little ground cover for the first two winters following the burn. There was no significant difference (Mann-Whitney Rank Test 95% significance level) in the ground cover of the seeded and unseeded watersheds for any year. The paired watersheds showed little difference in terms of sediment collected in the catch basins in 1981-82. The seeded and unseeded drainages produces sediment at rates of 0.122 m^3/ha and 0.149 m^3/ha, respectively. Basins were vandalized in the summer of 1982, and no further sediment data was collected.

Table 1. Percent ground cover following wildfire in Williams Creek watershed

Year	Bare Soil	Dead Organic	Pioneer	Seeded Grass	Total Vegetation	Total Ground Cover[1]
1979	53	11	0	0	0	11
1980	35	17	7	6	13	30
1981	21	21	16	9	25	46
1982	11	19	24	36	60	79
1983	12	20	26	32	58	80
1985	15	20	33	21	54	74

[1]Bare soil + ground cover + rock (not shown) = 100 per.

The pioneer vegetation component was highest in 1982. Cheat grasses *Bromus* sp. composed a substantial portion of this cover, and probably did not provide quality cover for erosion prevention. Cheat grass had largely disappeared by 1983, when cover was provided primarily by *Ceanothus* sp. and oaks (*Quercus* sp.).

There has been considerable debate about the merits of grass seeding as an emergency measure following wildfire, though most of the research directed at assessing its effectiveness has focused on chaparral ecosystems of the southern California Coast Ranges. Data from higher elevation forested watersheds are far more limited. Results from the work of Dyrness (1976), Lyon (1976), Viereck and Dyrness (1977) and Helvey (1980), which are compareable studies of the effects of fire in forested watersheds, are summarized in Table 3.

Compared to the earlier studies the ground cover provided by vegetation on the Will Fire was comparatively high, but in line with the rate of regrowth after fire in these other forested watersheds. Grass seeding for erosion control was employed as a rehabilitation measure on all the watersheds compared in Table 3.

From a practical standpoint, sparse groundcover in the first few years following these wildfires is a significant result. Given the short growing seasons found in many forested areas, such as Williams Creek (55 frost free days), this response (especially in the first year following wildfire) is not surprising. No

Table 2. Percent ground cover (estimated from 8 transects) from seeded and unseeded sub-drainages burned by wildfire within the Williams Creek watershed

Year	Bare Soil	Dead Organic	Pioneer	Seeded Grass	Total Vegetation	Total Ground Cover[1]
SEEDED						
1980	67	15	6	0	6	21
1981	46	20	14	10	24	44
1982	16	20	24	41	65	75
1983	16	21	23	31	54	75
1985	22	24	29	15	44	68
UNSEEDED						
1980	63	14	7	0	7	21
1981	50	19	27	0	27	46
1982	20	21	54	0	54	75
1983	32	22	37	0	37	59
1985	35	19	34	0	34	53

[1]Bare soil + ground cover + rock (not shown) = 100 percent

Table 3- Cover (percent) by years following wildfire in forested watersheds

Researcher	1	2	3	4	5	6
Dyrness[1]	13.0	20.5	25.2	28.2	24.9	29.6
Helvey[2]	10.8	23.0	25.3	32.2	48.8	-
Lyon[1]	4.1	17.7	31.8	35.7	44.5	50.5
Viereck & Dyrness	9.0	14.9	37.4	37.4	-	-

[1]Vegetal cover, [2]Total cover

evaluation is made here of the selection of seed mixtures to local site conditions for either Williams Creek or the referenced studies, a factor which certainly plays a large role in the success or failure of revegetation efforts. My results indicate these factors deserve not only close scrutiny by wildfire rehabilitation planners, but detailed research to document results for future efforts.

The downward trend in total cover displayed in Tables 1 and 2 is noteworthy. It would appear seeded vegetation competed with pioneer species in the seeded areas. The decline in vegetation over time also suggests that neither the seeded or pioneer species were well adapted to the Williams Creek site, and encouragement and application of well adapted native species would probably provide the best vegetation erosion control. Given the limited groundcover provided by grass seeding on the Will Fire and the four other studies referenced, managers should also consider alternative erosion control methods (such as contour pole falling or mulching) during rehabilitation planning.

Channel Cross Sections

The changes in the channel cross, section from transect #1 on Williams Creek are shown in figure 1. Data were collected in 1979 soon after the fire and before any runoff events, and are therefore taken to represent the pre-fire channel condition. The changes in this transect are typical of those which occurred along most of the alluvial portion of Williams Creek, and represent the median condition of the three monitored transects. The channel response was the result of a combination of factors. Peak flows were probably increased following the fire (as documented by Schindler and others (1980) and other workers). 1982-83 was a rather severe winter with several high intensity storms; and the channel had lost both its dead organic and live vegetal stabilizers. As the figure depicts, there was slight channel widening following the winters of 1979 and 1980 and considerable widening and deepening following the severe winter of 1982. The channel had nearly returned to its pre-fire cross sectional area by 1985, though the channel profile was slightly wider and shallower than in 1979.

Channel enlargement for the three transects (1983 data) ranged from 0.17 m^2 to 0.54 m^2, representing an increase of 10 to 27 percent in channel cross section over pre-fire conditions. The transects on Water Trough Creek (unburned) showed little change in area or width for any year including 1983, when the maximum enlargement was less than 5 percent.

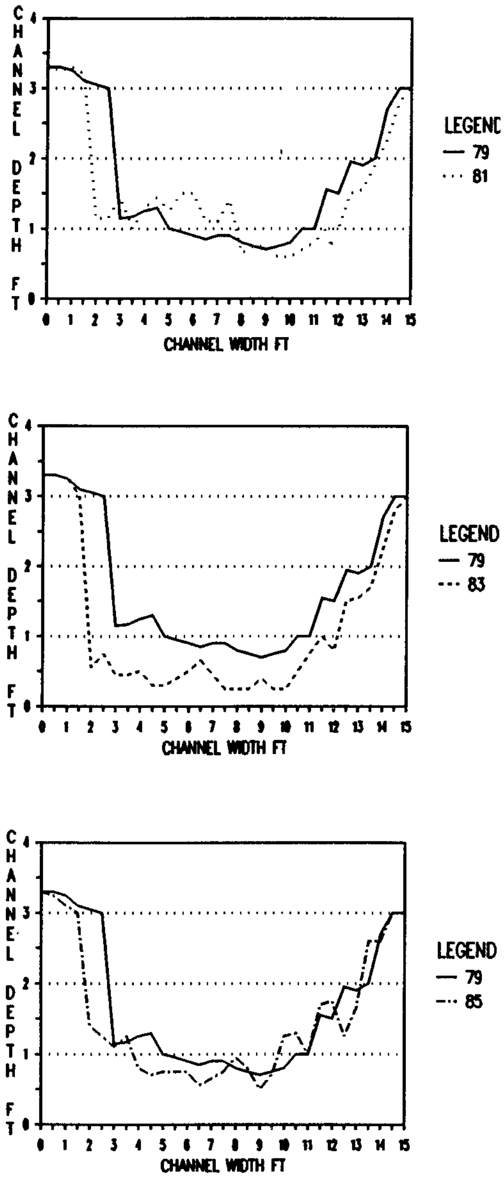

Figure 1--Channel cross sections from Williams Creek immediately (1979) and two, four, and six years following wildfire.

Significant change in the channels of burned watersheds seems a likely response to such a catastrophic event, but such changes have been poorly documented. Helvey (1980) found substantial changes in channel morphology, debris torrents and sediment production following an intensive forest fire in Central Washington. Rich (1962) investigated post fire changes in a ponderosa pine-dominated Arizona watershed. Both attributed a high percentage of post fire sediment production to channel sources, a conclusion consistent with the findings for Williams Creek.

Contributions of sediment from surface and channel sources following the fire in Williams Creek can be compared if the limited data is assumed to represent average conditions. If the sediment basin results are taken to represent an average surface erosion rate from Williams Creek, then the watershed would have produced approximately 113 m^3 of sediment from this source. If channel enlargement of 0.35 m^2 (the 1983 average) is applied to all of the alluvial channel within the fire (approximately 2430 m), then an estimate of 850 m^3 of sediment from channel cutting is derived. The subdrainages were on gentler slopes than much of the watershed, and therefore have lower erosion rates. The sediment production rates include that from the cutting of the ephemeral channel in these basins, so on balance the estimate may be representative.

By any estimate, sediment contributions from channel sources following wildfire are very important, and should receive emphasis at least equal to upslope erosion in the planning of emergency rehabilitation measures. Channel rehabilitation measures could include replacement of large organic material lost to the fire, use of structures to replace natural stabilizers, and planting of riparian species along channel banks.

Benthic Invertebrates

Benthic invertebrate data (table 4) provides an indication of water quality conditions. The invertebrates collected in 1979 (only a few weeks following the wildfire) show reduced taxa and density of organisms as compared with Water Trough Creek. Unfortunately, no pre-fire data was collected, but this apparent decline in the number of organisms was possibly the result of lethal fire-caused water temperature increases, and ash input to Williams Creek.

Data from Williams Creek since 1980 reveals higher number of organisms and reduced number of taxa relative to Water Trough Creek. In combination these factors result in lower diversity values, and indicate an enriched stream system. Enrichment was probably in response to shade reduction and increased nutrient input. The benthic community of Williams Creek also undoubtedly responded to unquantified changes in channel substrate. After the fire, sand, and silt increased at the expense of gravels and cobbles and provided habitat for the Chironomidae which dominated the post fire invertebrate community.

Diversity values from Williams Creek remained consistently below those from Water Trough Creek, indicating incomplete recovery from wildfire impacts nine years following the fire. Though the number of organisms collected from Williams Creek declined after 1981 (possibly lower production in response to canopy recovery) the density remained 1.3 (in 1985) to 2.1 (in 1987) times higher than Water Trough Creek. The number of taxa from Williams Creek was consistently about

Table 4. Results of benthic invertebrate sampling from a burned (Williams Crk) and unburned (Water Trough Crk) watershed 0-9 years following wildfire.

Year	number/ m^2	Taxa	Shannon Diversity	Dominant Taxa (percent total)
Williams Creek (burned)				
1979	420	15	2.03	Cinygmula sp. (37)
1980	1539	28	1.78	Chironomidae (42)
1981	6359	31	2.21	Chironomidae (32)
1982	4732	32	2.06	Chironomidae (34)
1983	3432	31	2.21	Chironomidae (27)
1985	1259	31	2.46	Chironomidae (33)
1987	1937	30	2.50	Chironomidae (21)
Water Trough Creek (unburned)				
1979	1528	31	2.85	Chironomidae (13)
1980	452	24	2.91	Hydropsychidae(18)
1981	1334	37	2.85	Chironomidae (16)
1982	731	34	2.65	Chironomidae (17)
1983	904	32	2.78	Hydropsychidae(15)
1985	947	34	3.06	Chironomidae (12)
1987	936	34	2.84	Hydropsychidae(16)

10 percent lower than Water Trough Creek.

There is very little data available on long-term recovery of watersheds from wildfire, and essentially none which has used benthic invertebrates. During the summer of 1987, I had the opportunity to sample several California watersheds which had been burned by wildfire. The Shannon Diversity of the benthic invertebrate samples and time since the watershed burned are as follows:

Watershed	(National Forest)	Years Since Fire	Diversity
Hot Springs	(Plumes)	7	2.55
Coyote	(Tahoe)	9	3.01
Jaw Bone	(Stanislaus)	12	2.57
West Hayfork	(Shasta-Trinity)	23	2.42

The Coyote Creek watershed was unique in that it possessed a very stable bedrock channel, and because most of the perennial stream channel was not burned by the fire. The benthic diversity of each of the other three watersheds was lower (range 8 to 18 percent) than the unburned streams to which they were compared.

Little work on the benthic invertebrate response to wildfire is available for comparison. Lotspeich and others (1970) found essentially no change in the invertebrate community following an Alaskan wildfire. Albin (1979) compared a burned and an unburned watershed tributary to Yellowstone Lake, and found higher diversity in the burned watershed. In both studies, sampling stations were some distance downstream of the burns.

When compared to research employing benthic invertebrates as indicators of water quality on similar watersheds, the reduction in diversity following wildfire in Williams Creek can be seen as a substantial impact. Erman and others (1977) studied the impacts of logging on northern California streams. Those streams most severely affected had average benthic diversity values 25 percent lower than comparison control streams. Erman and Mahoney (1983) studied recovery of the same logged streams, and found substantial but incomplete improvement in conditions 6-10 years after logging, as indicated by benthic diversity. In comparison, the Williams Creek data shows substantial recovery between 1980 and 1981, but very little recovery in the subsequent six years. The data from three of the four burned watersheds sampled in 1987 suggest similar, incomplete recovery.

There are several explanations that might account for the slow or incomplete recovery of benthic communities of burned watersheds. The first is that wildfire represents a truly catastophic event, one that changes flow regimes and sediment production for years. Sediment produced from surface and channel sources might not be passed through the system immediately. When the sediment is transported, the response of benthic invertebrates might be reflected in lower diversities. There is also the possibility that the benthic community has undergone a change in structure due to repeated, significant physical changes. The data from Williams Creek (and the other burned watersheds) do not indicate taxa replacement has occurred, so if a change in structure has occurred, it is subtle.

SUMMARY

Results from vegetation transects indicate seeding of grass species was of little value on the Will Fire, and that in critical watersheds managers should consider alternate ground cover protection measures such as mulching or contour falling of available material.

The nine years of data following the Will Fire on the Plumes National Forest indicate that intense wildfires may have a substantial and long lasting impact on the water quality of the watersheds in which they burn, as indicated by stream invertebrate diversity. When fires remove both live and dead organic channel stability components, significant sediment production from channel sources can be expected, and managers should consider use of in channel (check dams, recruitment of woody debris, etc.) as well as upslope rehabilitation measures following wildfire.

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