MOKELUMNE WATERSHED AVOIDED COST ANALYSIS:

Why Sierra Fuel Treatments Make Economic Sense

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Appendix H: Bibliography on Wildfire, Fuels Reduction Treatment, and Prescribed Fire Effects on Runoff and Erosion

H.1 Wildfire effects on hillslope runoff and erosion

H.1.1 Badia, D., and Marti, C., 2008, Fire and rainfall energy effects on soil erosion and runoff generation in semi-arid forested lands: Arid Land Research and Management 22:93-108.

http://frames.nacse.org/ttrs/22000/22651.html

A study of artificial wildfire effects was conducted using sprinkler experiments in a semiarid forest in Spain. Only the litter layer was burned. Sediment yield increased between by factors ranging from 18.5 to 33.6 after wildfire. Runoff increased by a factor of 1.6 after wildfire owing to reduced infiltration.

H.1.2 Carroll, E.M., Miller, W.W., Johnson, D.W., Saito, L., Qualls, R.G., and Walker,R.F., 2007, Spatial analysis of a large magnitude erosion event following a Sierran wildfire: Journal of Environmental Quality 36(4):1105-1111.

https://www.agronomy.org/publications/jeq/tocs/36/4

The 2002 Gondola Fire near Lake Tahoe was followed within two weeks by an intense rain and hail storm. Erosion from the burned area (8,900 to 10,000 g/square meter, or 1,800 to 6,700 g/square meter/mm rainfall) was more than 4 orders of magnitude larger than erosion rates reported in previous studies of wildfires. Most of the sediment and ash was deposited in a low-gradient riparian zone.

H.1.3 Lanini, J.S., Clark, E.A., and Lettenmaier, D.P., 2009, Effects of fire-precipitation timing and regime on post-fire sediment delivery in Pacific Northwest forests: Geophysical Research Letters, vol. 36, L01402, 5 pp.

http://www.agu.org/journals/gl/gl0901/2008GL034588/2008GL034588.pdf

Modeled sediment delivery for a forested watershed on the east slope of the Northern Cascades was about 10 times higher for high-severity fire than no fire.

Excerpt from Conclusions:

"Post-fire increases in sediment generation were primarily related to slope failures, and were strongly controlled by the interactions of post-fire loss of root cohesion with spring snowmelt. Spring snowmelt changes in turn were closely linked to reduction in overstory LAI, which reduced winter ablation and hence increased spring snow accumulation, and increased peak spring melt rates due to reduction in canopy attenuation of solar radiation.

High sediment generation was critically dependent on interactions of high snow accumulation years during the period when post-fire root cohesion was at its lowest."

H.1.4 Mayor, A.G., Bautista, S., Llovet, J., and Bellot, J., 2007, Post-fire hydrological and erosional responses of a Mediterranean landscape: Seven years of catchment-scale dynamics: Catena 71: 68-75.

http://frames.nacse.org/ttrs/22000/22482.html

Runoff was 35 mm in burned catchment, 0.03 mm in unburned. Sediment yield was 4,563 kg/ha in burned catchment, 0.12 kg/ha in unburned. Effects of fire persisted at least 5 years.

Excerpt from abstract:

"We studied medium-term dynamics of fire effects on catchment runoff and sediment yield in a dry-Mediterranean area in Alicante, E Spain. The study area was a mixed forest and agricultural terraced landscape that was affected by a wildfire in August 1998. We measured runoff and sediment yield in two catchments – burned and unburned – during the first seven years after the wildfire. Post-fire vegetation cover dynamics were also monitored. Total runoff and sediment yield in the burned catchment (35 mm and 4563 kg ha-1, respectively) were considerably greater than in the unburned catchment (0.03 mm, and 0.12 kg ha-1). Annual runoff and sediment yield increased with time after fire until the third post-fire year, and then decreased progressively. However, even five years after the wildfire, differences in annual runoff and sediment yield between the burned and the unburned catchments were still about two orders of magnitude. Post-fire vegetation cover increased very slowly during the initial post-fire years, and differences between burned and unburned areas persisted six years after the wildfire. Most studies on post-fire hydrology and erosion have identified the first one or two post-fire years as the critical period for high runoff and erosion risk, indicating short-term ecosystem resilience to wildfire. However, we found that wildfire impact on catchment runoff and sediment yield in Mediterranean drylands may be amplified by drought periods that delay plant recovery, and thus wildfire impacts may be still of great importance several years after the fire."

H.1.5 Miller, M.A., MacDonald, L.H., Robichaud, P.R., and Elliot, W.J., 2011, Predicting post-fire hillslope erosion in forests lands of the western United States: International Journal of Wildland Fire 2001, 20: 982-999

http://www.publish.csiro.au/?act=view_file&file_id=WF09142.pdf

Abstract:

"Many forests and their associated water resources are at increasing risk from large and severe wildfires due to high fuel accumulations and climate change. Extensive fuel treatments are being proposed, but it is not clear where such treatments should be focused.

The goals of this project were to: (1) predict potential post-fire erosion rates for forests and shrublands in the western United States to help prioritize fuel treatments; and (2) assess model sensitivity and accuracy. Post-fire ground cover was predicted using historical fire weather data and the First Order Fire Effects Model. Parameter files from the Disturbed Water Erosion Prediction Project (WEPP) were combined with GeoWEPP to predict post-fire erosion at the hillslope scale. Predicted median annual erosion rates were 0.1–2Mg/ha/year for most of the intermountain west,10–40Mg/ha/year for wetter areas along the Pacific Coast and up to 100Mg/ha/year for north-western California. Sensitivity analyses showed the predicted erosion rates were predominantly controlled by the amount of precipitation rather than surface cover. The limited validation dataset showed a reasonable correlation between predicted and measured erosion rates (*R*-squared = 0.61), although predictions were much less than measured values. Our results demonstrate the feasibility of predicting post-fire erosion rates on a large scale. The validation and sensitivity analysis indicated that the predictions are most useful for prioritizing fuel reduction treatments on a local rather than interregional scale, and they also helped identify model improvements and research needs.

H.1.6 Moody, J.A., and Martin, D.A., 2004, Wildfire impacts on reservoir sedimentation in the western United States: Proceedings of the Ninth International Symposium on River Sedimentation, October 18-21, 2004, Yichang, China, p. 1095-1102

http://wwwbrr.cr.usgs.gov/projects/Burned_Watersheds/Files/fire_reservoir_sedimentatio n.pdf

Potential for postfire sediment deposition in reservoirs was found to be related more strongly to fire frequency, soil erodibility, channel slope, and rainfall intensity than to tectonic setting and underlying bedrock geology. Potential reservoir sedimentation rates were estimated to be high both for the tectonically active Coast and Transverse Ranges and the relatively stable Sierra Nevada.

H.1.7 Moody, J.A., Martin, D.A., Haire, S.L., and Kinner, D.A., 2008, Linking runoff response to burn severity after a wildfire: Hydrological Processes 22: 2063-2074.

http://water.usgs.gov/nrp/proj.bib/Publications/2008/moody_martin_etal_2008.pdf

Fire effects on runoff/rainfall ratio depends on spatial distribution of burn severity, near-channel areas exert more influence than ridge areas.

H.1.8 Pierson, F.B., Robichaud, P.R., Moffet, C.A., Spaeth, K.E., Hardegree, S.P., Clark, P.E., and Williams, C.J., 2008, Fire effects on rangeland hydrology and erosion in a steep sagebrush-dominated landscape: Hydrological Processes 22: 2916-2929.

http://ddr.nal.usda.gov/bitstream/10113/31594/1/IND44082838.pdf

Burned area 3-year cumulative runoff in northwestern Nevada was 298 L vs. 16 L on unburned control. Burned area 3-year cumulative sediment yield was 20,400 g/sq m vs. 6

g/sq m on unburned control. Fire effects were still evident, though reduced, 3 years postfire.

Excerpts from abstract:

"The greatest impact of fire was on the dynamics of runoff once overland flow began. Reduced ground cover on burned hillslopes allowed overland flow to concentrate into rills. The 3-year cumulative runoff from concentrated flow simulations on burned hillslopes (298 l) was nearly 20 times that measured on unburned hillslopes (16 l). The 3-year cumulative sediment yield from concentrated flow on burned and unburned hillslopes was 20,400 g/square meter and 6 g/square meter respectively. Fire effects on runoff generation and sediment were greatly reduced, but remained, 3 years post-fire. The results indicate that the impacts of fire on runoff and erosion from severely burned steep sagebrush landscapes vary significantly by microsite and process, exhibiting seasonal fluctuation in degree, and that fire-induced increases in runoff and erosion may require more than 3 years to return to background levels."

H.1.9 Reneau, S.L., Katzman, D., Kuyumjian, G.A., Lavine, A., and Malmon, D.V., 2007, Sediment delivery after a wildfire: Geology 35(2): 151-154.

http://geology.gsapubs.org/content/35/2/151.full.pdf+html

In the first year following the Cerro Grande Fire in New Mexico, sediment delivery to a downstream reservoir was 140 times larger than pre-fire delivery. Delivery of ash and fine-grained sediment to the reservoir peaked within a year of the fire, while transport of coarser sediment did not approach pre-fire levels until the 5th year after the fire.

H.1.10 Rulli, M.C., and Rosso, R., 2007, Hydrologic response of upland catchments to wildfires: Advances in Water Resources 30(10): 2072-2086.

[not available via internet]

Probability of flooding can increase by a factor of 10 in first year after fire.

H.1.11 Smith, H.G., Sheridan, G.J., Lane, P.N.J., Nyman, P., Haydon, S., 2011, Wildfire effects on water quality in forest catchments: A review with implications for water supply, Journal of Hydrology, Volume 396, Issues 1–2, 5 January 2011, Pages 170-192.

http://www.sciencedirect.com/science/article/pii/S0022169410006748

Reviews wildfire effects on sediment and dissolved constituents.

H.2 Wildfire effects on landslides and channel erosion and deposition

H.2.1 Benda, L., Miller, D., Bigelow, P., and Andras, D., 2003, Effects of post-wildfire erosion on channel environments, Boise River, Idaho: Forest Ecology and Management 178(2003):105-119.

http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/FireScienceResearch/Post-fireEffects/Postfire-Benda03.pdf

Sediment eroded from burned forests in Idaho resulted in substantial changes to the morphology of major river channels. An increase in sediment supply resulting from wildfire followed by rainstorms aggraded an entire 4th order valley floor and rejuventated alluvial fans at tributary confluences.

H.2.2 Canfield, H.E., Wilson, C.J., Lane, L.J., Crowell, K.J., and Thomas, W.A., 2005, Modeling scour and deposition in ephemeral channels under climate change; rates, implications, and feedback: Catena Giessen 61(2-3):273-291.

http://www.mendeley.com/research/modeling-scour-deposition-ephemeral-channels-after-wildfire-soil-erosion-under-climate-change-rates-implications-feedbacks/

The HEC6T model was successfully used to model sediment erosion and deposition in ephemeral channels following fires in Arizona.

H.2.3 Cannon, S. H., 2001, Debris-flow generation from recently burned watersheds: Environmental & Engineering Geoscience 7(4): 321-341.

http://pubs.er.usgs.gov/publication/70022812

Evaluation of the erosional response of 95 recently burned drainage basins in Colorado, New Mexico and southern California to storm rainfall provides information on the conditions that result in fire-related debris flows. Debris flows were produced from only 37 of 95 (similar to 40 percent) basins examined; the remaining basins produced either sediment-laden streamflow or no discernable response. Debris flows were thus not the prevalent response of the burned basins. The debris flows that did occur were most frequently the initial response to significant rainfall events. Although some hillslopes continued to erode and supply material to channels in response to subsequent rainfall events, debris flows were produced from only one burned basin following the initial erosive event. Within individual basins, debris flows initiated through both runoff and infiltration-triggered processes. The fact that not all burned basins produced debris flows suggests that specific geologic and geomorphic conditions may control the generation of fire-related debris flows. The factors that best distinguish between debris-flow producing drainages and those that produced sediment-laden streamflow are drainage-basin morphology and lithology, and the presence or absence of water-repellent soils. Basins underlain by sedimentary rocks were most likely to produce debris flows that contain large material, and sand- and gravel-dominated flows were generated primarily from terrain underlain by decomposed granite. Basin-area and relief thresholds define the morphologic

conditions under which both types of debris flows occur. Debris flows containing large material are more likely to be produced from basins without water- repellent soils than from basins with water repellency. The occurrence of sand-and gravel-dominated debris flows depends on the presence of water-repellent soils.

H.2.4 Cannon, S. H., Gartner, J.E., Rupert, M.G., Michael, J.A., Rea, A.H., and Parrett, C., 2009, Predicting the probability and volume of postwildfire debris flows in the intermountain western United States: Geological Society of America Bulletin 122(1-2): 127-144.

http://gsabulletin.gsapubs.org/content/early/2009/09/24/B26459.1.full.pdf+html

Empirical models to estimate the probability of occurrence and volume of post-wildfire debris flows can be quickly implemented in a geographic information system (GIS) to generate debris-flow hazard maps either before or immediately following wildfires. Models that can be used to calculate the probability of debris-flow production from individual drainage basins in response to a given storm were developed using logistic regression analyses of a database from 388 basins located in 15 burned areas located throughout the U.S. Intermountain West. The models describe debris-flow probability as a function of readily obtained measures of areal burned extent, soil properties, basin morphology, and rainfall from short-duration and low-recurrence-interval convective rainstorms. A model for estimating the volume of material that may issue from a basin mouth in response to a given storm was developed using multiple linear regression analysis of a database from 56 basins burned by eight fires. This model describes debris- How volume as a function of the basin gradient, aerial burned extent, and storm rainfall. Applications of a probability model and the volume model for hazard assessments are illustrated using information from the 2003 Hot Creek fire in central Idaho. The predictive strength of the approach in this setting is evaluated using information on the response of this fire to a localized thunderstorm in August 2003. The mapping approach presented here identifies those basins that are most prone to the largest debris-flow events and thus provides information necessary to prioritize areas for postfire erosion mitigation, warnings, and prefire management efforts throughout the Intermountain West.

H.2.5 Cannon, S.H., and Gartner, J.E, 2005, Wildfire-related debris flow from a hazard perspective: Chapter 15 in: Jakob, M., and Hungr, O. (eds.), Debris flow hazards and related phenomena, Praxis Springer, no pagination.

http://landslides.usgs.gov/docs/cannon/Cannon_Gartner_Springer_2005.pdf

This chapter provides an overview of debris-flow hazards related to wildfires in the mountainous areas of the western United States. Information on peak flows, frequencies, and size of flows is summarized.

H.2.6 Carroll, E. M., Miller,W.W., Johnson, D.W., Saito, L., Qualls, R.G., and Walker, R.F., 2007, Spatial analysis of a large magnitude erosion event following a Sierran wildfire: Journal of Environmental Quality 36(4): 1105-1111.

http://frames.nacse.org/ttrs/22000/22323.html

High intensity wildfire due to long-term fire suppression and heavy fuels buildup can render watersheds highly susceptible to wind and water erosion. The 2002 "Gondola" wildfire, located just southeast of Lake Tahoe, NV-CA, was followed 2 weeks later by a severe hail and rainfall event that deposited 7.6 to 15.2 mm of precipitation over a 3 to 5 hour time period. This resulted in a substantial upland ash and sediment flow with subsequent down-gradient riparian zone deposition. Point measurements and ESRI ArcView were applied to spatially assess source area contributions and the extent of ash and sediment flow deposition in the riparian zone. A deposition mass of 380 Mg of ash and sediment over 0.82 ha and pre-wildfire surface bulk density measurements were used in conjunction with two source area assessments to generate an estimation of 10.1 mm as the average depth of surface material eroded from the upland source area. Compared to previous measurements of erosion during rainfall simulation studies, the erosion of 1800 to 6700 g m(-2) mm(-1) determined from this study was as much as four orders of magnitude larger. Wildfire, followed by the single event documented in this investigation, enhanced soil water repellency and contributed 17 to 67% of the reported 15 to 60 mm per 1,000 years of non-glacial, baseline erosion rates occurring in mountainous, granitic terrain sites in the Sierra Nevada. High fuel loads now common to the Lake Tahoe Basin increase the risk that similar erosion events will become more commonplace, potentially contributing to the accelerated degradation of Lake Tahoe's water clarity.

H.2.7 Gartner, J. E., Cannon, S.H., Santi, P.M., and DeWolfe, V.G., 2008, Empirical models to predict the volumes of debris flows generated by recently burned basins in the western US: Geomorphology 96(3-4): 339-354.

http://www.journals.elsevier.com/geomorphology/

Recently burned basins frequently produce debris flows in response to moderate-to- severe rainfall. Post-fire hazard assessments of debris flows are most useful when they predict the volume of material that may flow out of a burned basin. This study develops a set of empirically-based models that predict potential volumes of wildfire-related debris flows in different regions and geologic settings. The models were developed using data from 53 recently burned basins in Colorado, Utah and California. The volumes of debris flows in these basins were determined by either measuring the volume of material eroded from the channels, or by estimating the amount of material removed from debris retention basins. For each basin, independent variables thought to affect the volume of the debris flow were determined. These variables include measures of basin morphology, basin areas burned at different severities, soil material properties, rock type, and rainfall amounts and intensities for storms triggering debris flows. Using these data, multiple regression analyses were used to create separate predictive models for volumes of debris flows generated by burned basins in six separate regions or settings, including the western U.S.,

southern California, the Rocky Mountain region, and basins underlain by sedimentary, metamorphic and granitic rocks. An evaluation of these models indicated that the best model (the Western U.S. model) explains 83% of the variability in the volumes of the debris flows, and includes variables that describe the basin area with slopes greater than or equal to 30%, the basin area burned at moderate and high severity, and total storm rainfall. This model was independently validated by comparing volumes of debris flows reported in the literature, to volumes estimated using the model. Eighty- seven percent of the reported volumes were within two residual standard errors of the volumes predicted using the model. This model is an improvement over previous models in that it includes a measure of burn severity and an estimate of modeling errors. The application of this model, in conjunction with models for the probability of debris flows, will enable more complete and rapid assessments of debris flow hazards following wildfire.

H.2.8 DeGraff, J., Wagner, D., Gallegos, A., DeRose, M., Shannon, C., and Ellsworth, T., 2011, The remarkable occurrence of large rainfall-induced debris flows at two different locations on July 12, 2008, Southern Sierra Nevada, CA, USA: Landslides 8(2011):343- 353.

http://www.springerlink.com/content/f88568301m244650/fulltext.pdf

Two very large debris flows in the southern Sierra Nevada occurred on July 12, 2008, on recently-burned watersheds. Wildfire appears to have been a factor in at least one of the debris flows.

H.3 Wildfire effects on in-stream woody debris

H.3.1 Berg, N.H., Azuma, D., and Carlson, A., 2002, Effects of wildfire on in-channel woody debris in the Eastern Sierra Nevada, California: USDA Forest Service General Technical Report GTR-181, p. 49-63

Recruitment of large woody debris was higher in a burned watershed relative with an unburned control watershed within one year of a fire in the eastern Sierra Nevada. However, the burned watershed produced fewer debris jams owing to the generally smaller size of the remaining debris.

http://www.fs.fed.us/psw/publications/documents/gtr-181/006_Berg.pdf

H.3.2 Bragg, D.C., 2000, Simulating catastrophic and individualistic large woody debris recruitment for a small riparian system: Ecology 81(5):1383-1394.

Catastrophic events such as wildfires increased the amount of large woody debris in small streams in Utah.

http://www.esajournals.org/doi/abs/10.1890/0012-9658(2000)081%5B1383:SCAILW%5D2.0.CO%3B2

H.4 Fuels treatment effects on hillslope runoff and erosion

H.4.1 Benavides-Solorio, J., and MacDonald, L.H., 2001, Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range: Hydrological Processes 15(15):2931-2952.

http://warnercnr.colostate.edu/~leemac/publications/PostFireRunoff_ErosionFromSimulatedRainfallonSmallPlotsColoradoFrontRange.pdf

Runoff increased only by 15-30%. Sediment yields from recent high-severity fires were 10 to 26 times higher than yields from unburned and low severity areas. Sediment yields from older high-severity burns about the same as unburned areas.

Abstract:

"Wildfires in the Colorado Front Range can trigger dramatic increases in runoff and erosion. A better understanding of the causes of these increases is needed to predict the effects of future wildfires, estimate runoff and erosion risks from prescribed fires, and design effective post-/ire rehabilitation treatments. The objective of this project was to determine whether runoff and sediment yields were significantly related to the site variables of burn severity, percent cover, soil water repellency, soil moisture, time since burning, and slope. To eliminate the variability due to natural rainfall events, we applied an artificial storm of approximately 80 mm h-1 on 26 I m2 plots in the summer and fall of 2000. The plots were distributed among a June 2000 wildfire, a November 1999 prescribed fire, and a July 1994 wildfire. For 23 of the 26 plots the ratio of runoff to rainfall exceeded 50%. Nearly all sites exhibited strong natural or fire-induced water repellency, so the runoff ratios were only 15-30% larger for the high-severity plots in the two more recent fires than for the unburned or low-severity plots. The two high-severity plots in the 1994 wildfire had very low runoff ratios, and this probably was due to the high soil moisture conditions at the time of the simulated rainfall and the resulting reduction in the natural water repellency. Sediment yields from the high-severity sites in the two more recent fires were 10-26 times greater than the unburned and low-severity plots. The plots burned at high severity in 1994 yielded only slightly more sediment than the unburned plots. Percent ground cover explained 81 % of the variability in sediment yields, and the sediment yields from the plots in the 1994 wildfire are consistent with the observed recovery in percent ground cover."

H.4.2 Benavides-Solorio, J.D., 2003, Post-fire runoff and erosion at the plot and hillslope scale, Colorado Front Range: Ph.D. Dissertation, Department of Earth Resources, Colorado State University, Fort Collins, Colorado.

http://frames.nacse.org/6000/6366.html

This study evaluated plot and hillslope scale effects of prescribed fires and wildfires. Effects on runoff were minor. High burn severity plots had increases of 16 to 33 times

background sediment yields. High-severity wildfire sediment yield was 10 Mg/ha/yr. High-severity prescribed fire sediment yield was 0.1 to 4 Mg/ha/yr.

H.4.3 Berg, N.H., and Azuma, D.L., 2010, Bare soil and rill formation following wildfires, fuel reduction treatments, and pine plantations in the Southern Sierra Nevada, USA: International Journal of Wildland Fire 2010: 478-489.

http://www.publish.csiro.au/?act=view_file&file_id=WF07169.pdf

A plot study of wildfire and fuels treatments effect on rill and bare soil formation showed that wildfires increase both rilling and bare soil, but differences between burned and undisturbed reference plots disappear after 4 to 6 years. Rill formation on plots affected by fuels reduction treatments was minimal, and bare soil on plots within fuels treatments did not differ significantly from reference plots.

H.4.4 Cram, D.S., Baker, T.T., Fernald, A.G., Madrid, A., and Rummer, B., 2007, Mechanical thinning impacts on runoff, infiltration, and sediment yield following fuel reduction treatments in a southwestern dry mixed conifer forest: Journal of Soil and Water Conservation 62(5):359-366.

http://frames.nacse.org/ttrs/22000/22338.html

Heavy mechanical use on steep slopes resulted in fourfold increase in runoff and an increase in sediment yield by factor of 22.

Excerpt: "Significantly, the results of this study indicated light to moderate disturbance from mechanical operations did not significantly increase erosion over undisturbed control areas, even on steeper slopes."

H.4.5 Elliot, W.J., 2010, Effects of forest biomass use on watershed processes in the Western United States: Western Journal of Applied Forestry 25(1):12-17.

http://ddr.nal.usda.gov/bitstream/10113/38922/1/IND44322342.pdf

Biomass removal can result in soil compaction and increased surface runoff on forested hillslopes. Implementation of appropriate Best Management Practices can mitigate these effects. Biomass removal can reduce erosion risks associated with wildfires.

H.4.6 Hatchett, B., Hogan, M.P., and Grismer, M.E., 2006, Mechanical mastication thins Lake Tahoe forest with few adverse impacts: California Agriculture 60(2): 77-82.

http://ucanr.org/repository/cao/landingpage.cfm?article=ca.v060n02p77&fulltext=yes

Mastication had little effect on soil compaction or erosion at an experimental site on the west shore of Lake Tahoe.

H.4.7 Johansen, M.P., Hakonson, T.E., and Breshears, D.D., 2001, Post-fire runoff and erosion from rainfall simulation: contrasting forests with shrublands and grasslands: Hydrological Processes 15:2953-2965.

http://onlinelibrary.wiley.com/doi/10.1002/hyp.384/pdf

Runoff from plots burned in a Ponderosa pine forest during the Cerro Grande Fire in New Mexico increased by a factor of 2. Sediment yield increased by a factor of 25.

H.4.8 Loupe, T.M., Miller, W.W., Johnson, D.W., Sedinger, J.S., Carroll, E.M., Walker, R.F., Murphy, J.D., and Stein, C.M., 2009, Effects of mechanical harvest plus chipping and prescribed fire on Sierran runoff water quality: Journal of Environmental Quality 38(2):537-547.

https://www.agronomy.org/publications/jeq/tocs/38/2

Mechanical (CTL) thinning, chipping, and prescribed fire had minimal effects on nutrient concentrations in post-treatment runoff.

H.4.9 Madrid, A., Fernald, A.G., Baker, T.T., and Vanleeuwen, D.M., 2006, Evaluation of silvicultural treatment effects on infiltration, runoff, sediment yield, and soil moisture in a mixed conifer New Mexico forest: Journal of Soil and Water Conservation 61(3):159-168.

http://www.jswconline.org/content/61/3/159.abstr
act

Partial thinning without burning in a New Mexico mixed-conifer forest did not significantly affect infiltration rates, runoff rates, or soil moisture. Sediment yield was very low in all cases.

Excerpt: "We conclude that southwestern mixed conifer forest may be partially thinned without risk of significant increases in hillslope runoff and sediment yield."

H.5 Fuels treatment effects on in-stream woody debris

H.5.1 Beche, L.A., Stephens, S.L., and Resh, V., 2005, Effects of prescribed fire on a Sierra Nevada (California, USA) stream and its riparian zone: Forest Ecology and Management 218(1-3): 37-59.

http://www.sciencedirect.com/science/article/pii/S0378112705004457

Prescribed fire had no effect on woody debris volume or recruitment.

H.5.2 Zelt, R.B., and Wohl, E.E., 2003, Channel and woody debris characteristics in adjacent burned and unburned watersheds a decade after wildfire, Park County, Wyoming: Geomorphology 57(3-4):217-233.

http://www.sciencedirect.com/science/article/pii/S0169555X03001041

Frequency of in-channel large woody debris was lower in a burned watershed than in an adjacent unburned control, but debris jams were more common in the burned watershed.

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Disclaimer

This report is rich in data and analyses and may help support planning processes in the watershed. The data and analyses were primarily funded with public resources and are therefore available for others to use with appropriate referencing of the sources. This analysis is not intended to be a planning document.

The report includes a section on cultural heritage to acknowledge the inherent value of these resources, while also recognizing the difficulty of placing a monetary value on them. This work honors the value of Native American cultural or sacred sites, or disassociated collected or archived artifacts. This work does not intend to cause direct or indirect disturbance to any cultural resources.

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