EP53A-0722. Response of Step-pool Mountain Channels to Wildfire Under Changing Climate-fire Regimes

Anne Chin[1], Laura Laurencio[1], Anna Parker[1], Jonathan Key[1], Rune Storesund[2], Alison O'Dowd[3]

[1]University of Colorado Denver, [2]Storesund Consulting, [3]Humboldt State University

I. Overview

Mountains of the western U.S. are becoming more susceptible to wildfire as a result of warming climates. These trends have growing impacts on human society, evidenced in increasing number of structures destroyed by wildfire and related costs of damages and firefighting (Figure 1; Table 1). Changing climate-fire regimes have significant indirect effects on hydrologic and geomorphologic processes. Because of the acute reduction of vegetation and organic matter, soils burned by fire are greatly altered, leading to elevated runoff, erosion, and flood potential years after fire. This contribution illustrates how wildfire affects the stability and functioning of mountain streams characterized by step-pool morphology. Step-pools are stable features adjusted to the prevailing flow and channel morphology, serving important functions of energy dissipation in high-energy environments. Steps and pools are also important ecologically, providing diverse habitats for sensitive organisms. Whereas step-pool channels are typically restructured by flows with recurrence intervals often exceeding 50 years, these flows are reached more frequently under changing climate-fire regimes. Following the Waldo Canyon Fire of June/July 2012 along the Colorado Front Range, we track the stability, destruction, and re-development of step-pool systems using ground surveys including terrestrial LiDAR technology. We document how the first geomorphologically significant event on 1 July 2013 obliterated the step-pool structure in Williams Canyon, widened river channels and lowered channel beds by more than one meter. Changes in ecological character accompanied the conversion of channel morphology, including a reduction in species abundance and number of sensitive organisms. Changing fire regimes have potential effects of "resetting the clock" more frequently in the development of stable and diverse geomorphic and ecologic mountain landscapes.

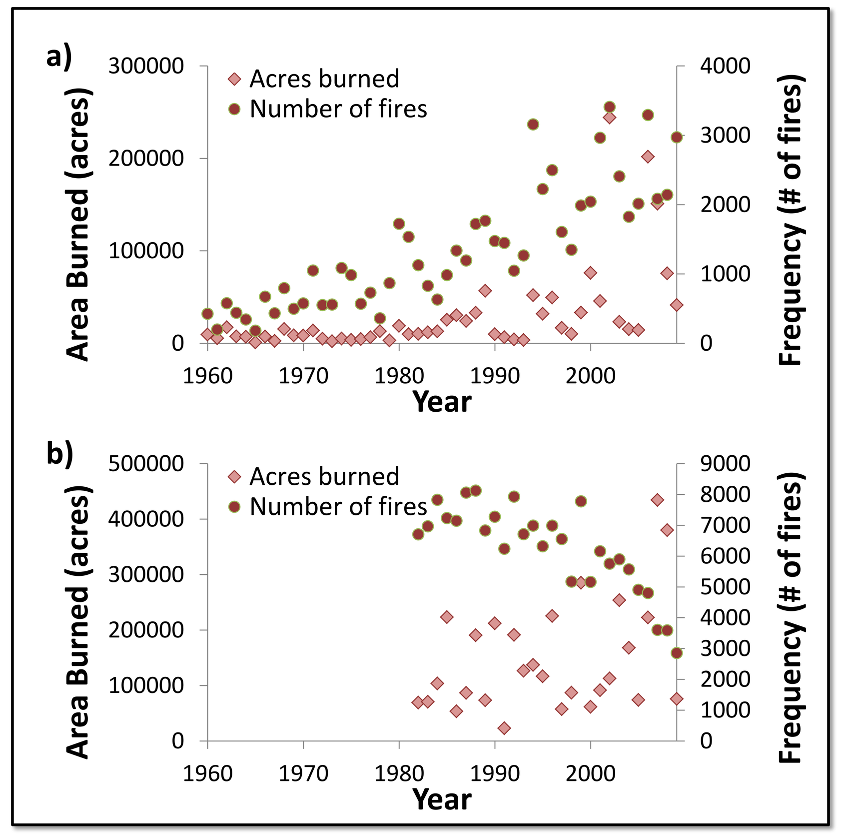


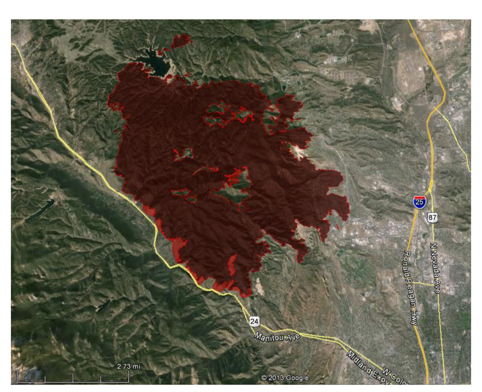
Figure 1. Annual acres burned by wildfire and annual number of fires (fire frequency) from: (a)1960 to 2010 in Colorado and (b) 1980 to 2010 in California. (Source: Dept. of Interior Federal Wildland Fire Occurrence 2013)

Table 1. Number of structures damaged by historically significant wildland fires in the western states of the U.S.[1], 1900-2012. (Source of data: National Interagency Fire Center)

Decade	Number of historically significant fires	Structures damaged
1900	1	0
1910	1	0
1920	1	624
1930	4	0
1940	2	0
1950	2	0
1960	2	0
1970	4	616
1980	5	325
1990	11	4045
2000	11	3970
2010	5	4188

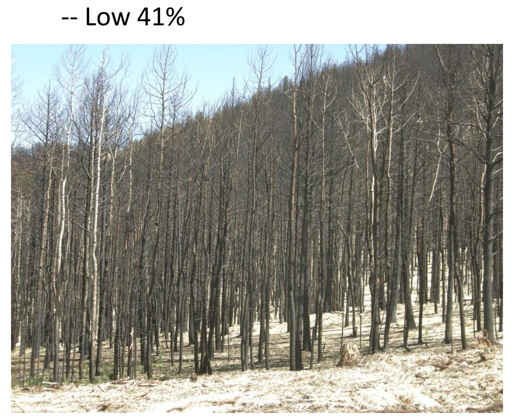
[1]Western states include Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming.

II. Study Sites

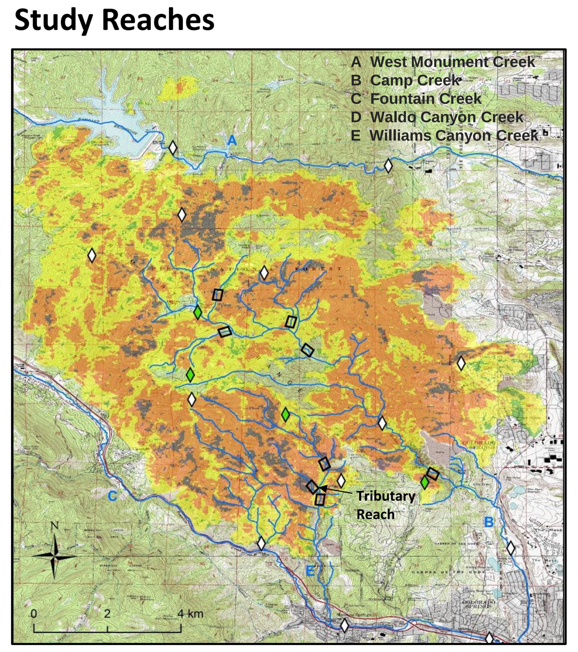


WALDO CANYON FIRE

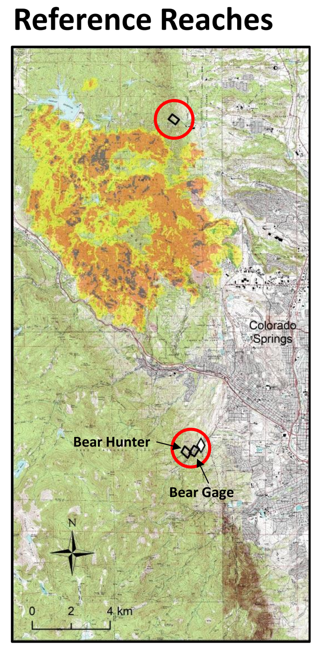
- Began 23 June 2012
- Contained 10 July 2012
- Acres burned 18,247
- Severity of burn
  - -- High 19%
  - -- Moderate 40%
  - -- Low 41%



Study Reaches



Reference Reaches



III. Response of Step-pool Channels

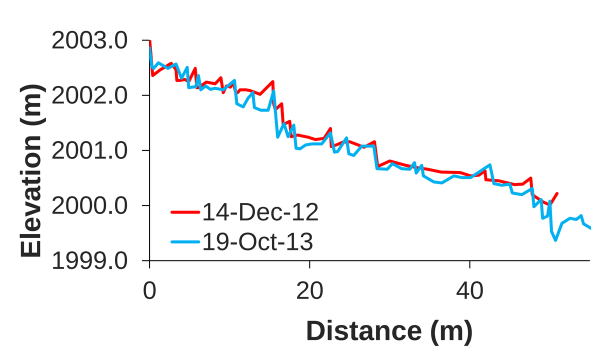
Table 2. Major precipitation events following Waldo Canyon Fire

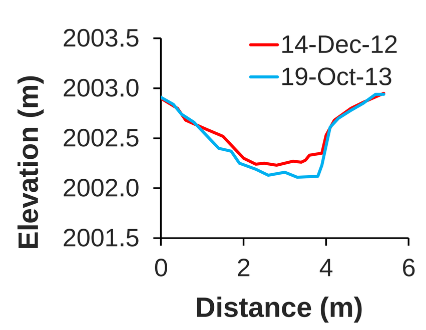
Location	Name	Storm 1: July 1, 2013 Duration	Depth (mm)	Avg. Intensity (mm/h)	5-min peak Intensity (mm/hr)	R.I.	Storm 2: July 10, 2013 Duration	Depth (mm)	Avg. Intensity (mm/h)	5-min peak Intensity (mm/hr)	R.I.
N 38.90965 W 104.92740	UCD-USGS-2	15min	8.1	33.5	76.2	< 2yr	25min 31min	1.0 13.7	2.4 26.0	6.1 39.6	< 2yr < 2yr
N 38.89344 W 104.91378	Upper Williams	10min	15.0	89.9	131.1	5 – 10yrs	25min	13.2	31.7	73.2	< 2yr
N 38.94436 W 104.93261	Upper Queens Canyon	10min	4.8	29.0	45.7	< 2yr	35min	10.9	18.7	36.6	< 2yr
N 38.8225 W 104.88806	Bear Creek	55min	12.2	13.3	51.8	< 2yr	Negligible rain				
		Storm 3: August 9, 2013					**Storm 4: September 11-12, 2013**				
N 38.90965 W 104.92740	UCD-USGS-2	2hrs	21.8	11.0	67.1	< 2yr	2 days	184.9	3.6	70.1	100 – 200 yr
N 38.89344 W 104.91378	Upper Williams	2hrs	39.9	19.9	131.1	5-10yrs	2 days	184.9	3.9	94.5	100 – 200 yr
N 38.94436 W 104.93261	Upper Queens Canyon	90min	7.1	4.7	24.4	< 2yr	2 days	170.9	3.6	70.1	100 – 200 yr
N 38.8225 W 104.88806	Bear Creek	1hr 15min 1hr 50min	8.4 10.2	6.7 5.5	24.4 42.7	< 2yr < 2yr	2 days	244.6	5.1	51.8	500 – 1000yrs

Initial surveys in Fall 2012 established baseline conditions before significant post-fire geomorphological changes occurred. Throughout summer 2013, following the first post-fire summer thunderstorms (Table 2), longitudinal profiles and cross sections of study reaches documented the response of step-pool channels. The graphs below compare the channel response within reference reaches (Bear Gage and Bear Hunter) and highlight changes within one of the burned reaches (Tributary in Williams Canyon). The storms of July 1, July 10, and August 9 had recurrence intervals (R.I.) of less than 10 years. The September 11-12 storm had a recurrence interval of up to 1,000 years. In burned reaches, the first event on July 1 obliterated step-pool sequences, whereas in reference reaches, the step-pool morphology remained intact through the significantly larger September event. Average sizes of step clasts are not significantly different between Hunter's Run and Tributary Reach (p = 0.6696).

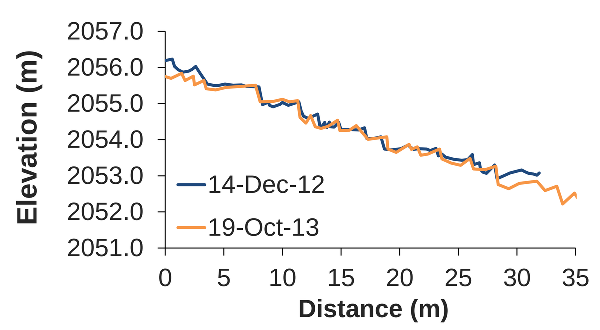
Reference Reaches

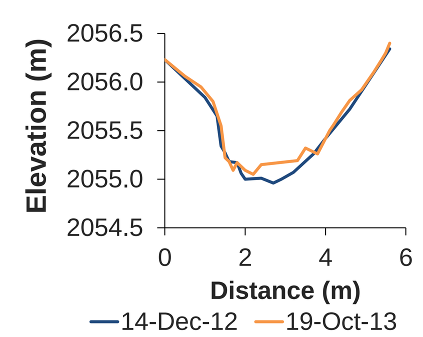
Bear Gage

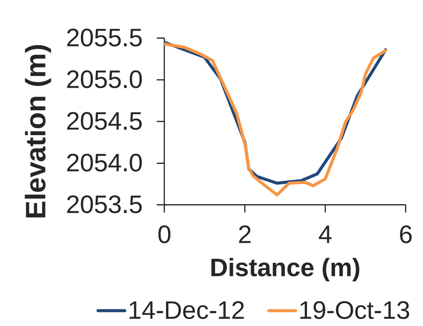




Bear Hunter

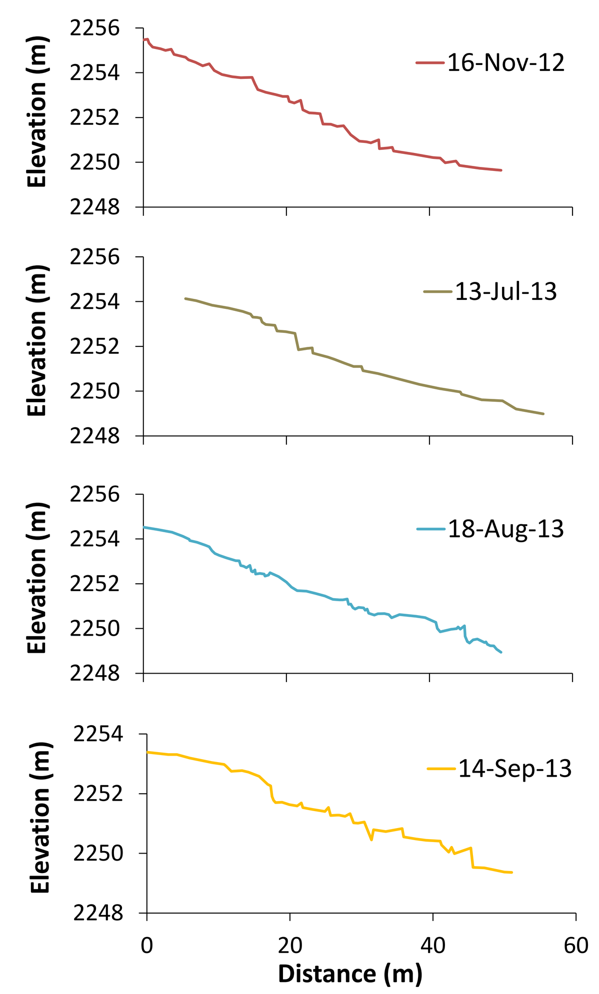


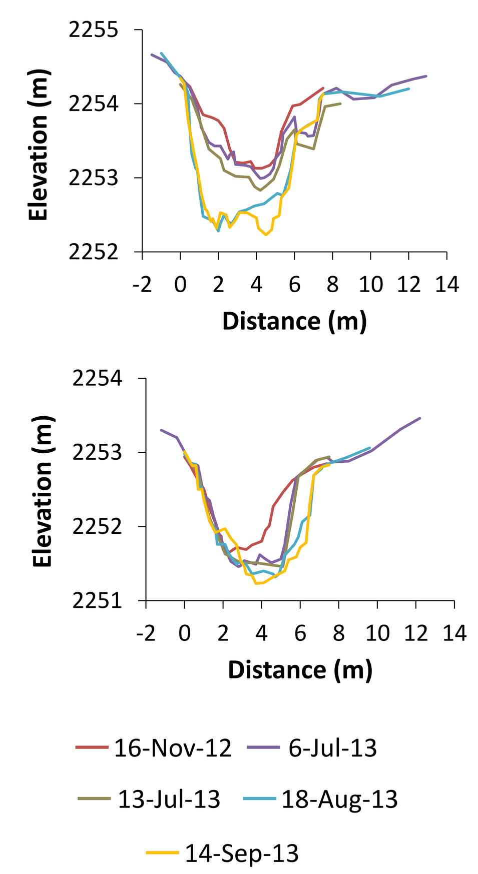




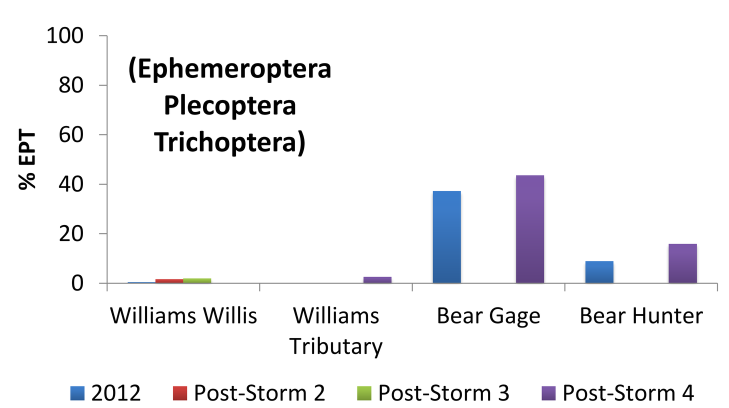
Bear Gage Reach

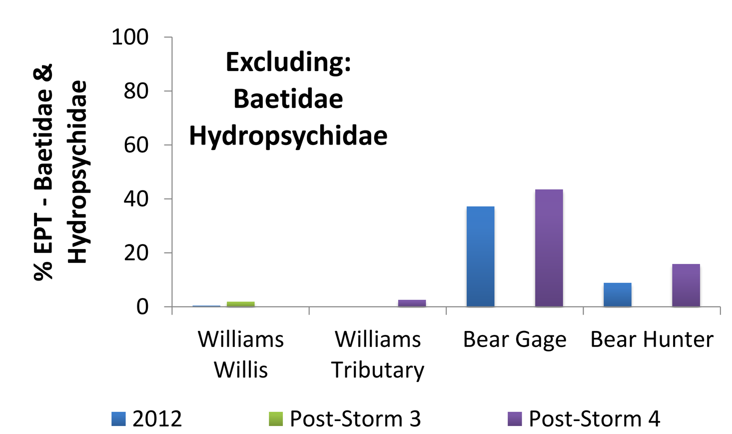
Burned Site: Tributary Reach





Ecological changes occurred along with the altered channel morphology. Burned reaches exhibited drastic reduction in the abundance and diversity of benthic macroinvertebrates. The graphs at right display change over time in the proportion of sensitive taxa found in burned (Williams Willis and Tributary) and unburned (Bear Gage and Bear Hunter) reaches.





IV. Terrestrial LiDAR Scanning

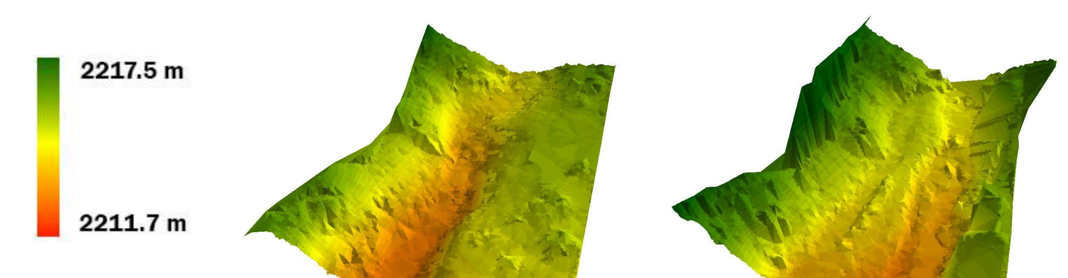


Figure a. elevation profile of Tributary Reach, Williams Canyon. Left: April 2013 (before summer storms); Right: September 2013 (post-floods) showing overall lowering and widening of study channel

Study reaches were scanned in April 2013, before significant geomorphological changes occurred, to establish a baseline for tracking the stability of step-pool channels. The terrestrial LiDAR process consisted of establishing study bounds in the field, scanning the study areas and registering the point clouds with survey control (UTM 13N). Point cloud data were then analyzed using Maptek's ISITE Studio v4.0 to extract bare earth points (for volumetric analyses) ,as well as subset points for analysis of step-pool sequences and point cloud cross sectional views.

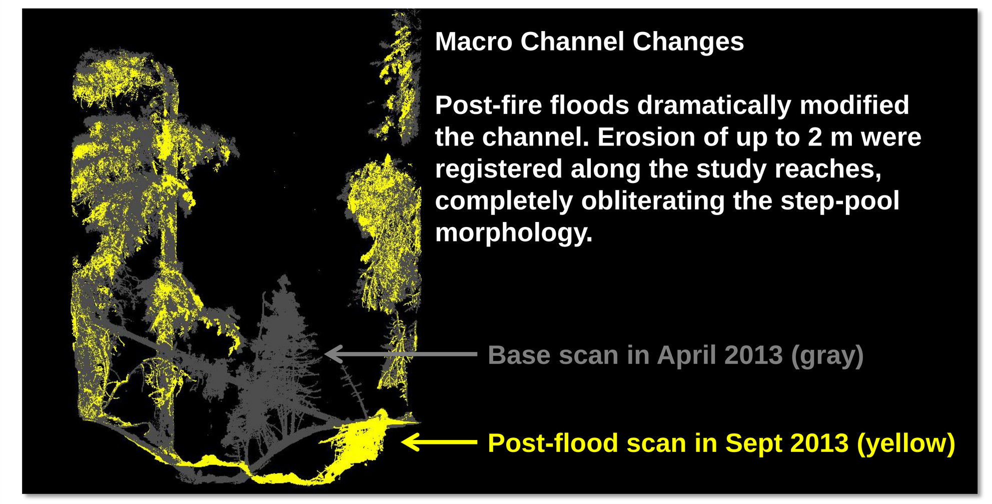


Figure b. View of macro channel changes

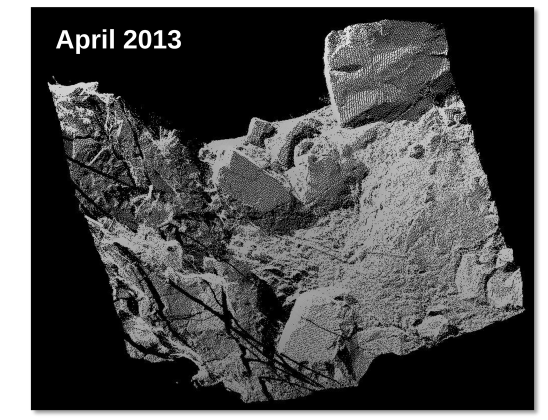


Figure d. Step-pool sequence from baseline scan April 2013

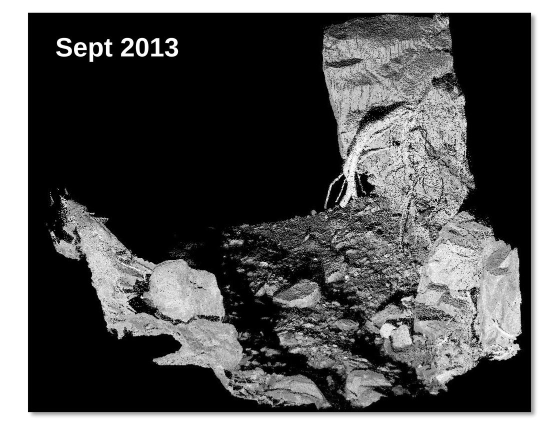


Figure e. Same location scanned after summer floods Sept 2013

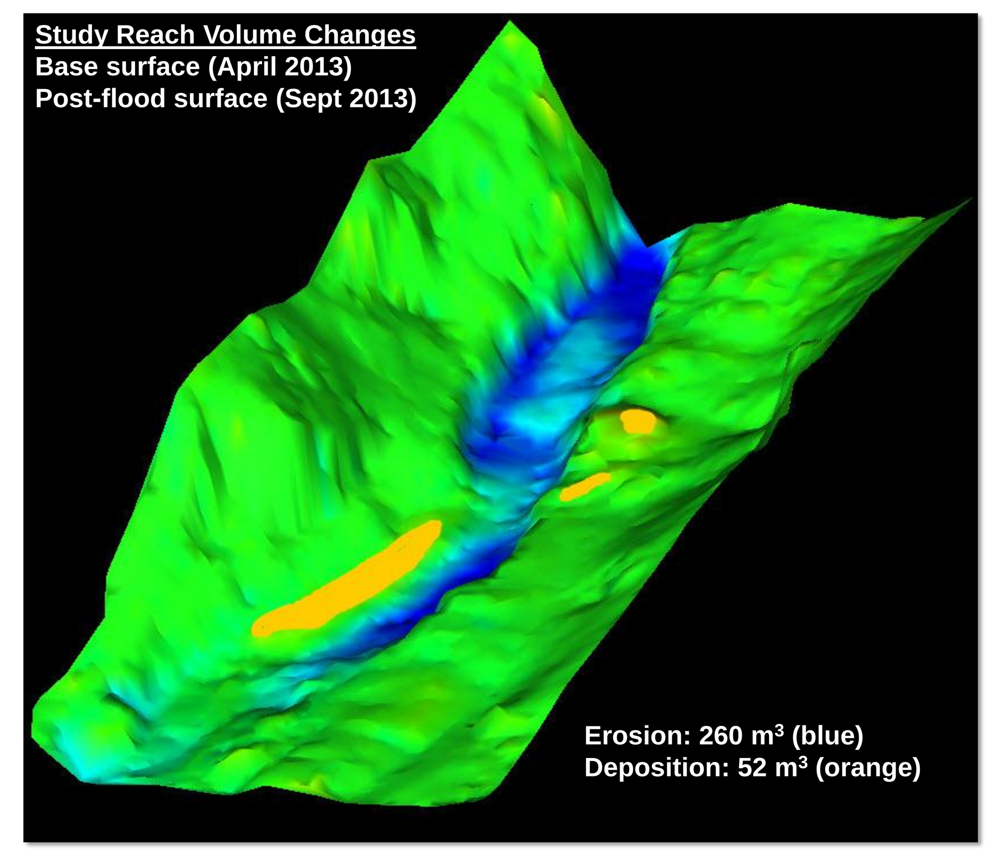


Figure c. Volumetric channel changes

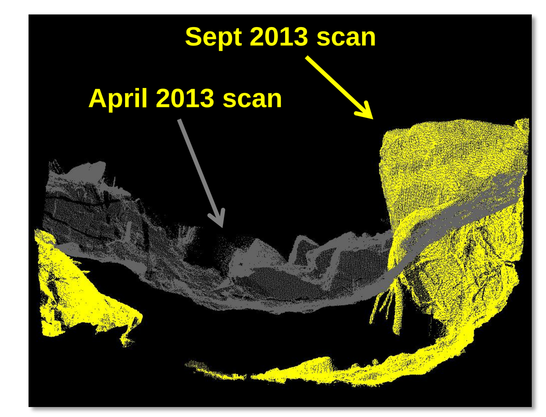


Figure f. Comparison of pre- and post-flood cross section showing scouring and destruction of step-pool sequences

Previously stable step-pool channels were exceptionally susceptible to erosion following the wildfire. Macro channel changes were dramatic (Figure b), with scouring of 1 m to 2 m common. Total erosion from Tributary Reach in Williams Canyon was 260 m^3 (Figure c).

Figures d-f document the movement of step-pool sequences in detail through post-fire floods. The average size of the step clasts in Figure d (April 2013) was 280 mm, shown to have been transported by Sept 2013 (Figure e). Figure f illustrates a comparison between the pre- and post-flood step pool morphologies, with the original sequence completely destroyed. The original grade decreased by 0.7 m as a result of scour from the post-fire runoff events.

EAR1254989

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