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Debris flow and debris basin management impacts on water quality

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Technical Completion Report
Project period: March 1, 2016 – February 28, 2018

Overall project summary/statement: *1) Context and importance of the project*: This study investigates the impacts of debris flows on water quality in southern California by focusing on two recently burned headwater catchments along the southern urban/wildland interface of the San Gabrielle Mountains and one in the Box Springs Mountains. Debris flows are fast moving masses of solids and water that occur when steep terrain cloaked in unstable sediments are exposed to high intensity rainfall. Expansion of urban populations and infrastructure in southern California has progressed beyond surrounding mountainous fronts, exposing large populations to the direct hazards of debris flows and their concomitant impacts on water quality.

2) Research and outreach during the reporting period: A third study watershed in the Box Springs Mountains was instrumented to monitor rainfall and sediment transport, and sampled to characterize sediment composition during this period. Additional sediment samples and monitoring was conducted in the previously instrumented study watersheds along the southern San Gabrielle front. These data are being used to investigate how the interactions of atmospheric, wildfire and hydrologic events result in the triggering and propagation of debris flows, and to examine the impacts of these phenomena on downstream water quality (Fig. 1). High resolution (mm to cm scale) 3-dimensional surveys of subbasins and channel reaches were performed using terrestrial laser scanner as well as unmanned aerial vehicle (UAV) and structure for motion technology to directly examine erosional processes. Hillslope, colluvial, channel, debris basin and outlet channel sediment and water samples were collected to investigate sediment composition and redistribution dynamics.

3) Project outcomes, impacts, and benefits to date: Preliminary findings on debris flow production include a) the identification of increasing rainfall intensity-duration (R I-D) thresholds over time, b) discovery of fine-scale storm features related to R I-D, c) evidence for dominant hillslope erosional processes, and d) characterization of changes the composition of sediment redistributed in and exported from burned watersheds over time.

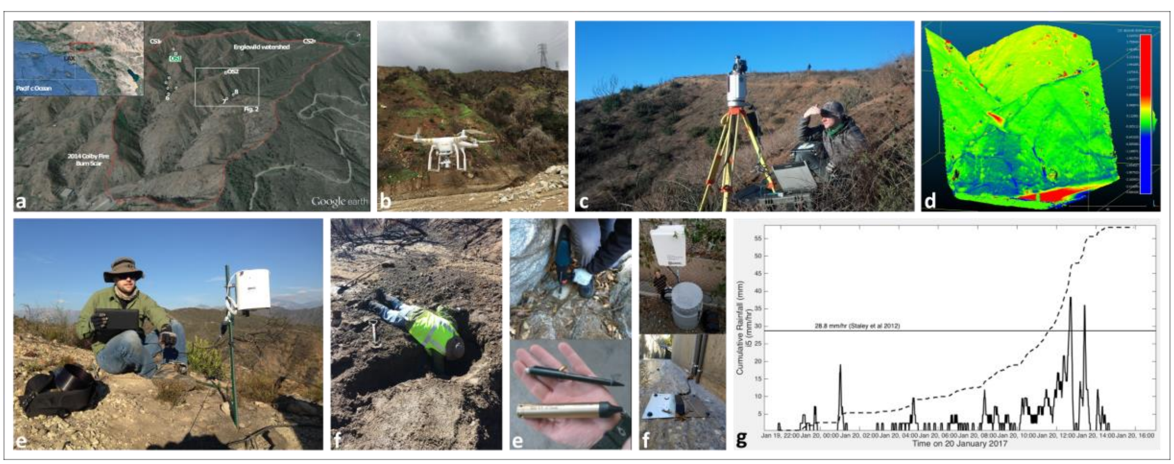

Figure 1. (a) Englewild Canyon field site, (b-d) 3-D surveying and DEM development, (e-g) hydro-meteorological monitoring and sediment sampling (images from R. Leeper, N. Barth and A. Gray).

Research program: Little is known about the quality and quantity of sediments exported from burned areas instrumented with debris basins. The research plan to approach this knowledge gap was to employ integrating hydro-meteorological monitoring of debris flow events with debris basin operations and suspended sediment monitoring to develop a better understanding of the changing conditions required to initiate debris flows with system rebound after wildfire, and to characterize the effects of debris flows on sediment mediated water quality. Research was conducted in the watersheds of the Englewild and Las Lomas canyons: steep headwater catchments situated above the cities of Glendora and Duarte, CA that experienced the Colby (1/2014) and Fish (6/2016) wildfires, respectively. In August, 2017 a 400 ha fire burned a large portion of the western slopes of the Box Springs Mountains adjacent to the UCR campus. At 15 ha headwater catchment located in this burn area was added to our study in September, 2018 (Fig 2a).

To examine the timing and intensity of precipitation events required to trigger debris flows, both study regions were instrumented with multiple high-resolution rain gauges and self-contained pressure transducers installed in bedrock channel beds. The Englewild debris basin drainage channel was outfitted with a hydrologic gauging and sampling station to monitor water and sediment export from the basin, which included instrumentation to measure stage, average flow velocity, turbidity, and an automated water sampler. Gauging and sampling from the Las Lomas debris basin drainage pipe was not possible due to access issues. The Box Springs catchment was outfitted with pressure transducers and a time lapsed camera to record channelized flow events, as well as multiple high resolution rain gages and soil moisture sensors. Subbasins of all three catchments were surveyed at high resolution (10^{-1} to 10^{1} cm scale) using TLS and UAV technologies. In the Box Springs catchment subsection of the TLS scan areas were outfitted with silt fences to capture eroded sediments (Fig. 2b). Resurveying in the Las Lomas study area was performed after each significant (i.e. debris flow triggering) storm. Hillslope, channel and exported sediments were characterized for particle size distribution, carbon content, and fallout radionuclide (^{210}Pb, ^{137}Cs, and ^{7}Be) abundance.

Very little debris flow activity was observed in Englewild Canyon during water years 2016 and 2017, despite five minute duration rainfall intensities surpassing know post-fire debris flow initiation thresholds (Leeper et al., 2016). In contrast, the more recently burned Las Lomas catchment produced debris flows at even lower thresholds than previously established. Evidence from these portions of the study will be used to modify existing approaches to assessing debris flow risk potential in post-wildfire scenarios. Also as a result of system rebound, including breakdown of hydrophobic layers and increased vegetative effects, the Englewild Debris Basin drainage channel experienced only very low flow levels and minor episodes of sediment transport during water year 2017. In contrast, during the wet season directly after the Box Springs fire, our study catchment produced appreciable sediment or water export due to relatively little precipitation and low rainfall intensities. Las Lomas and Englewild and Box Springs surveying and sediment sampling results are in process, but show promising indications of new evidence to support the identification of dominant erosional regimes in these landscapes, and how they shift after wildfires.

Initial sediment composition analyses indicate that debris flow deposits are highly enriched in fallout radionuclides (Jumps et al., 2018). This suggests that surficial erosion processes such as sheetwash and rill erosion are responsible for much of sediment delivery that results in debris flows. Initial findings from high resolution topographic surveying show that our TLS methods can be used to accurately detect down to 1.5 cm of elevation change (Guilinger, 2018). Initial high resolution change detection in the Box Springs suggests that rill erosion may be an important component of the erosion regime during the kind of low magnitude, high frequency rainfall events that primarily produce internal redistribution of sediment rather than sediment discharge from the catchment (Fig. 2c).

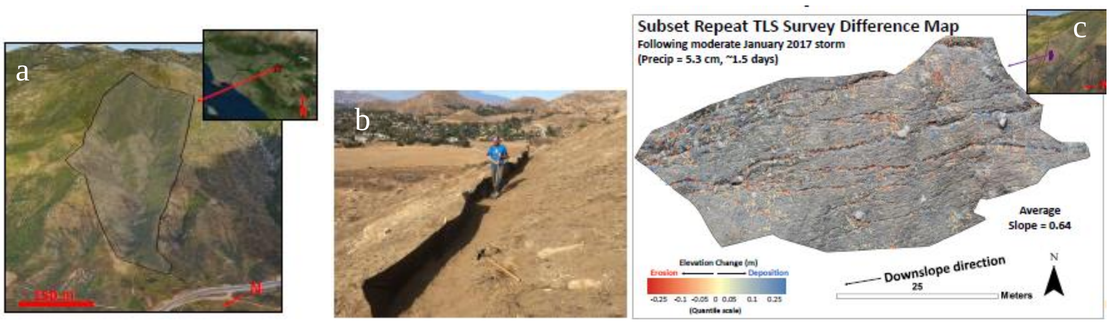

Figure 2. (a) Box Springs study catchment, (b) silt fence installation, (c) preliminary TLS change detection results. Note erosion concentrated in rills. (images from J. Guilinger).

1. **Information transfer/outreach program:** Preliminary results of this study have been communicated at the American Geophysical Union 2016 Fall Meeting (Leeper et al., 2016), at the UCR GIS Day Symposium (Guillinger et al., 2018a); at the 1st Annual SoCal Geomorphology Symposium (Guillinger et al., 2018b; Jumps et al., 2018), on the PI's website (Gray, 2018), and through coverage of our work by the UC ANR water sciences blog. Four journal articles are currently in preparation.

2. **Notable achievements:** A relationship with the LA County Department of Public Works has been furthered during the study period, which has facilitated access to the study watersheds, their debris basins, and some drainage structures. This relationship will help support further studies in the region, and facilitate future information transfer to operations personnel involved in debris flow management. Collaboration has been fostered between the PI and Assistant Professor Nicolas Barth, UCR Department of Earth Sciences through shared advising of Robert Leeper, the first graduate student funded in part by this project. A new collaborative investigation into the carbon dynamics of chaparral landscapes involving the PI and Associate Professor Jeff Hatten, Oregon State University Department of Forestry has been made possible by the sediment sampling efforts involved in this study. Another new collaborative investigation has also begun with Dr. Kingsley Odigie, a geochemist specializing in heavy metal stable isotopes. Our laboratories are working together to investigate the redistribution of lead derived from 'native' rock and leaded-gasoline combustion fallout in the context of shifting erosion regimes in catchments impacted by the Thomas Fire.

Supplemental Images

Sediment deposit excavation in the Las Lomas debris basin after the first flush following the 2017 Fish Fire in the Southern San Gabrielle front, CA. (image A. Gray).

Graduate student Robert Leeper downloads rainfall data with the Las Lomas debris basin below. (image: A. Gray)


Debris flow deposit in Las Lomas Canyon following the first rainfall events of the 2017 water year (image: A. Gray).

Scenes from direct aftermath of the 400 ha Box Springs Mountains wildfire in August, 2017.

Graduate student James Guilinger conducting TLS operations in the Box Springs burn area before the first rains hit in December, 2017. (image: A. Gray).

Graduate student Nathan Jumps revisiting Englewild Canyon to collect additional sediment samples for fallout radionuclide analyses April, 2018. (image: A. Gray).