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GROUP PROJECT BRIEF

POST-FIRE SEDIMENTATION AND FLOOD RISK POTENTIAL IN MISSION CREEK WATERSHED, CALIFORNIA

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ON THE WEB AT http://fiesta.bren.ucsb.edu/~hydro
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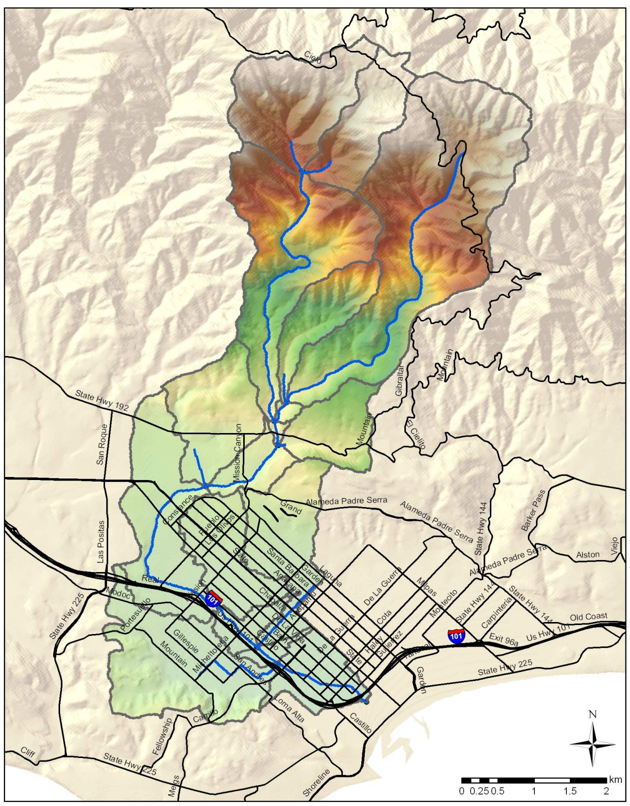
INTRODUCTION

Wildfires pose a threat to life and property, especially in vulnerable areas such as Southern California. However, hazards persist even after the fire is extinguished. Burned hillslopes are bare with unprotected soils, greatly increasing the risk of flooding, sedimentation, and debris flows in the succeeding winter rains. This project examines potential post-fire flood and sedimentation risk in Mission Creek watershed (Santa Barbara, California) with the goal of providing short and long-term mitigation recommendations.



Mission Creek watershed. (Data Sources: USGS, ESRI)

Mission Creek begins in steep, chaparral-covered slopes of the Los Padres National Forest and flows to the Pacific Ocean after winding through downtown Santa Barbara. Mission Creek floods overbank in the low-gradient urban reaches with a frequency between two and forty years. Upper Mission Creek watershed last burned in the Coyote Fire of 1964. As chaparral ecosystems typically burn every 30-70 years, accumulation of fire-prone vegetation makes Mission Creek watershed vulnerable to wildfire in the near future.

MAIN POINTS:

- ***Upper Mission Watershed has a high potential for wildfire based on fire history and fuel accumulation.***
- ***Fire in the upper watershed greatly increases runoff and sedimentation, increasing risk to downstream urban areas.***
- ***Pre-fire analysis improves understanding of risk and streamlines post-fire mitigation efforts.***
- ***Risk of flooding in Mission Creek after a fire is 55 - 400% greater than before a fire.***
- ***After a fire, sedimentation can increase up to 385%, overwhelming existing sediment basins during even a moderate rainstorm.***
- ***Sediment accumulation in lower Mission Creek may decrease channel capacity by 10% and increase the risk of flooding.***
- ***Clearing Sediment Basins, removing debris from the channel, and applying hydromulch, are effective in reducing risk.***

The July 2008 Gap Fire burned approximately 9,500 acres of chaparral vegetation nine miles west of Mission Creek. The fire consumed over 60 percent of San Pedro Creek. The fire consumed over 60 percent of San Pedro Creek watershed, an 18.5 km² watershed that is comparable in topography, geology, hydrology and climate to the Mission Creek watershed. These similarities provide an opportunity to refine predictions of post-fire hydrologic and sedimentation response in the Mission Creek watershed by observing the changes in the San Pedro watershed after the Gap Fire. Furthermore, local fires present an opportunity to assess current mitigation strategies and emergency response to the risk of flooding.

RESEARCH QUESTIONS

1. How would a fire in the upper Mission Creek watershed affect hydrologic and sedimentary processes in the following rainy season?

2. What risks must be addressed to prepare downstream communities and what are the magnitudes of those risks?

3. How can early predictions of post-fire flood and sedimentation risk inform mitigation strategies?

APPROACH

Three modeling programs were used to calculate post-fire changes in hydrology, erosion, and debris-flows risk:

1. The ***Hydrologic Modeling System*** (HEC-HMS, U.S Army Corps of Engineers) was used to estimate post-fire storm runoff to Mission Creek.

2. The ***Erosion Risk Management Tool*** (ERMiT, U.S. Forest Service) was used to predict sediment delivery rates from surface erosion after a fire.

3. The ***Shallow Landslide Stability Model*** (SHALSTAB, UC Berkeley) was used to identify areas of the watershed that may be sources of sediment from landslides or debris flows.

Increased flood risk from sediment accumulation in lower Mission Creek was analyzed by combining estimates of post-fire sediment delivery (from ERMiT) and discharge predictions (from HEC-HMS) with calculated sediment transport capacities for the creek.

San Pedro watershed after the Gap Fire, 2008.

SCENARIO DEVELOPMENT

To accurately assess risk of post-fire flooding and sedimentation, calculations were made for various combinations of realistic fire and precipitation scenarios. These scenarios fall between a most likely scenario (a small fire followed by a small storm, represented by the green box in the figure below) and a worst case scenario (a large fire followed by a large storm, represented by the red box). Very small storms that occur with a frequency of two years or less were not considered, as they would create a low magnitude of hazard.

Rainstorm Duration and Intensity

Fire Size and Intensity	Small Storm	Large Storm
Large Fire	Mid-range likelihood & magnitude of hazard	Lower likelihood, Higher Magnitude of Hazard
Small Fire	Higher likelihood, Lower Magnitude of Hazard	Mid-range likelihood & magnitude of hazard

Conceptual model of scenario development, Risk is determined by the size and intensity of fire and precipitation. The combinations of events that have the lowest likelihood have the highest risk and vice versa.

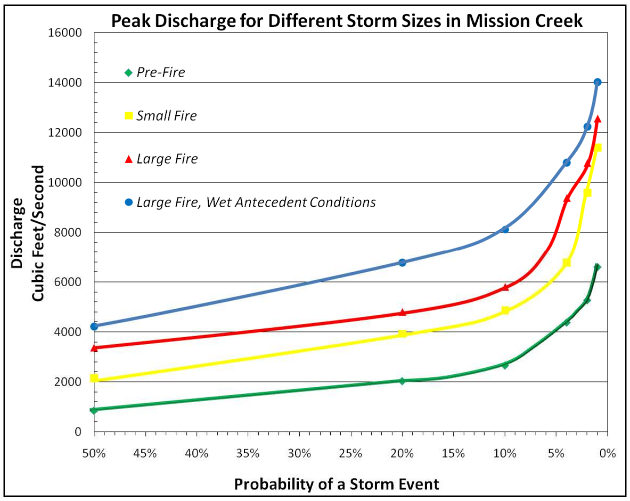
The small fire scenario is assumed to burn only the uninhabited areas of the Los Padres National Forest, while the large fire scenario would enter the residential area of Mission Canyon and burn approximately down to Foothill Rd. The small fire scenario (25 percent of watershed burned) is considered to have a higher likelihood than the large fire (50 percent of watershed burned), considering contemporary fire suppression techniques when lives and property are at risk.

This project modeled design storms of various sizes to mimic a range of storms that could occur within the rainy season following a wildfire. Smaller storms (e.g. 2-year recurrence interval) have a greater likelihood of occurring than larger storms (e.g. 100-year storms). Storms with recurrence intervals of 2, 10, 25, 50, and 100 years (probability of occurring is 50, 10, 4, 2, and 1 percent, respectively) were used in this project.

METHODOLOGY AND RESULTS

Flood Risk

HEC-HMS was utilized to simulate fire's effects on peak discharge in Mission Creek. Each of the design storms was modeled for pre-fire conditions and the small and large fire scenarios. The effect of existing soil moisture from previous rainfall, or antecedent moisture, was also considered.



Peak Discharges fir varying recurrence intervals under four fire and antecedent moisture scenarios

The effects of a small fire on the watershed increase runoff peaks from 155 to 250 percent of pre-fire conditions. A 2-year recurrence interval storm that would create peak discharge of 850 cubic feet per second (cfs) when the watershed is unburned results in 2,000 cfs discharge after a small fire. This is a similar discharge to what would occur in a 10-year recurrence interval storm before a fire.

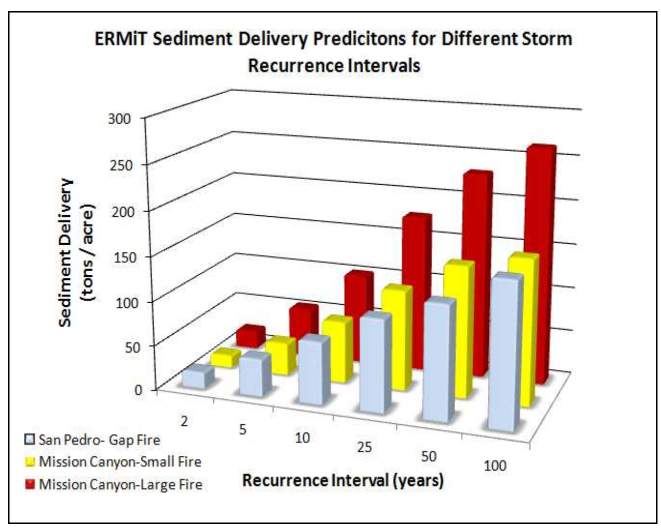
As would be expected, the large fire has a more pronounced impact on peak discharge than the small fire. For a 10-year recurrence interval storm, peak discharge increased 80 percent from pre-fire conditions for the small fire scenario and 120 percent for the large fire scenario. A 10-year storm after a large fire creates discharge peaks nearly as great as a 100-year storm on an unburned watershed. This shows an approximately tenfold increase in the risk of the hundred year flood when half of the upper watershed is burned.

When soils are wet, peak discharge increases by 24 to 28 percent for each of the fire scenarios when compared to dry antecedent moisture. For example, a 100-year recurrence interval storm occurring on a large fire with dry antecedent conditions has a predicted peak discharge of 12,600 cfs, compared to 14,000 cfs when the same storm occurs on soils that are already wet.

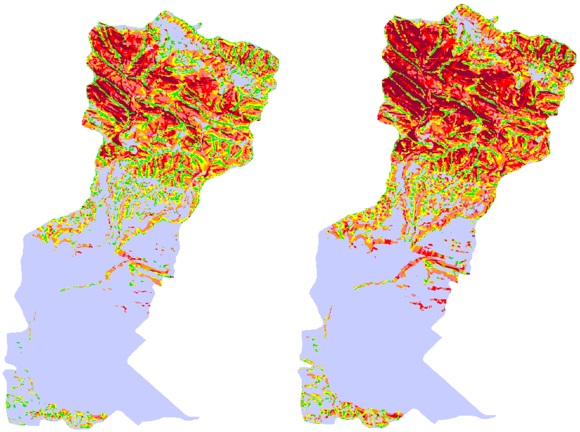
Sedimentation Risk

Analysis of post-fire sedimentation included the quantification of surface erosion and spatial assessment of areas of possible debris flow production. ERMiT was used to predict surface erosion and SHALSTAB was used to identify areas of the watershed where sediment may be prone to mobilization in collapse events such as debris flows.

A large fire is predicted to increase total sediment production in upper Mission Creek watershed by up to 385 percent from baseline values after the 2-year storm. Sediment production increases dramatically for larger storms, with a large fire and a 100-year storm producing an increase of as much as three orders of magnitude in sediment volume eroded. A 2-year event following a large fire in Mission yields on average 20 tons/acre, while a 100-year storm yields up to 265 tons/acre. Results for small fire scenarios are about 30 percent less than for large fires.



Sediment Delivery to Mission Creek under small and large fire scenarios and comparison San Pedro watershed after the Gap Fire.



Unstable slopes in Mission Creek watershed pre-fire (left) and post-fire (right). Areas where landslides and debris flows are most likely to occur are shown in dark red.

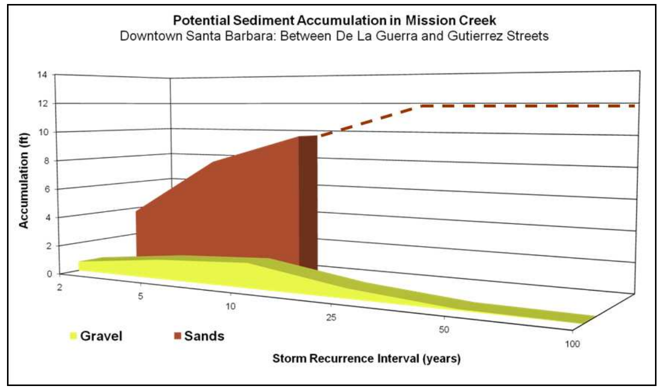
Unstable slopes with the potential to initiate debris flows increase by 53% after a fire that would reduce the reinforcement of soils by plant roots. Because of its remote location, the upper watershed does not pose a significant debris flow risk to the downstream community, but the failed debris would add to sedimentation problems in the lower Mission Creek. The middle watershed, however, contains some residential areas with scattered increases in soil instability, indicating the potential for small, localized landsliding.

Mission Creek Watershed has two sediment basins, the combined design capacity of which is 24,200 yd³, although only 7,100 yd³ is currently available. The estimated post-fire sediment production above both basins is 51,977 yd³ for a 2-year storm following a large fire in the upper watershed. The sediment basins may capture some of the increased sediment production, but most post-fire erosion will be carried downstream.

Synthesis of Results

Except for one constriction, Mission Creek is designed to carry discharges from the 15- to 20-year storm. One area of Mission Creek near the Montecito Street Bridge will flood with discharges greater than 1,500 cfs, but most reaches of the creek can contain up to 3,200 cfs. Every storm and fire scenario examined would create flooding in some part of Mission Creek.

Sediment accumulation may exacerbate flooding by decreasing channel capacity. Gravel accumulation was estimated using sediment transport calculations, and may reach 1-2 feet between De La Guerra and Gutierrez streets in downtown Santa Barbara. One foot of sediment accumulation would decrease channel capacity by 10 percent, increasing the risk of flooding.



Qualitative analysis representing potential gravel and sand accumulation risk in lower Mission Creek. Sand accumulation is unknown when predicted to exceed the depth of the channel.

RECOMMENDATIONS

Prioritizing post-fire risk mitigation actions improves emergency response plans and allows for pre-emptive mitigation to supplement emergency post-fire response. Recommendations focus on both specific actions to reduce run-off and sediment delivery and on coordinated emergency and long-range planning.

Emergency Post-Fire Actions:

1. Clear sediment basins to their maximum capacity to prepare for dirt and debris. This could occur well in advance of fire to ensure excavation to design capacity.

2. Clear the creek channel of debris and vegetation to increase flow velocity and prevent blockage from large debris

3. Reduce hillslope erosion by applying hydromulch. This may reduce sediment production by 90 percent.

Long Term Actions:

4. Permanently increase Mission Creek flow capacity through infrastructure improvements in lowest capacity reaches

5. Incorporate post-fire risk into city & county General Plans and Winter Storm Emergency Response Plans

6. Improve information dissemination by providing real-time information to citizens after a fire, such as through a publicized website.