RAPID ASSESSMENT AND TREATMENT OF POST-FIRE EROSION HAZARDS USING INNOVATIVE DATA COLLECTION AND ASSESSMENT TOOLS*

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Southern California was devastated in the fall of 2003 with a series of sweeping wildfires, which blackened in excess of 1500 km^2 of land and destroyed over 2500 homes. The risk posed by potential mud and debris flows in some ways exceeded impacts from the fire itself. The monumental task of rapidly assessing post-fire erosion hazards involved identification of hazards such as mudflows, debris flows, landslides, rock fall, and flooding, identification of the values at risk, and developing mitigation measures to help protect public health, damages to personal property, and infrastructure (roadways, surface water conveyance systems, and reservoirs). Data was collected from field teams employing GPS enabled ruggedized PDAs. This data was then assimilated directly into a Database/GIS system. To assess the overall potential for increased erosion response, ESRI's Spatial Analyst extension (ESRI, 2002) was used to integrate slope, soil type, and burn severity data to produce a Post-fire Hazard Index of Relative Erodability (PHIRE) map. This paper provides an overview and site specific examples of the tools and techniques applied as well as a summary of lessons learned and a discussion of the appropriateness of the technologies and debris flow models as a function of the magnitude and complexity of the task at hand.

1 Introduction

In the days and weeks following the devastating October 2003 Cedar, Paradise, and Otay wildfires in southern California which blackened in excess of 375,000 acres, San Diego County and the City of San Diego separately undertook the tasks of conducting assessments of post-fire hazards and mitigating potential impacts. The process of rapid assessment of post-fire hazards and the emergency mitigation of primary and secondary impacts required efficient collection, processing, and analysis of field data and conditions. Both the County and the City contracted with GeoSyntec to assist with these monumental efforts.

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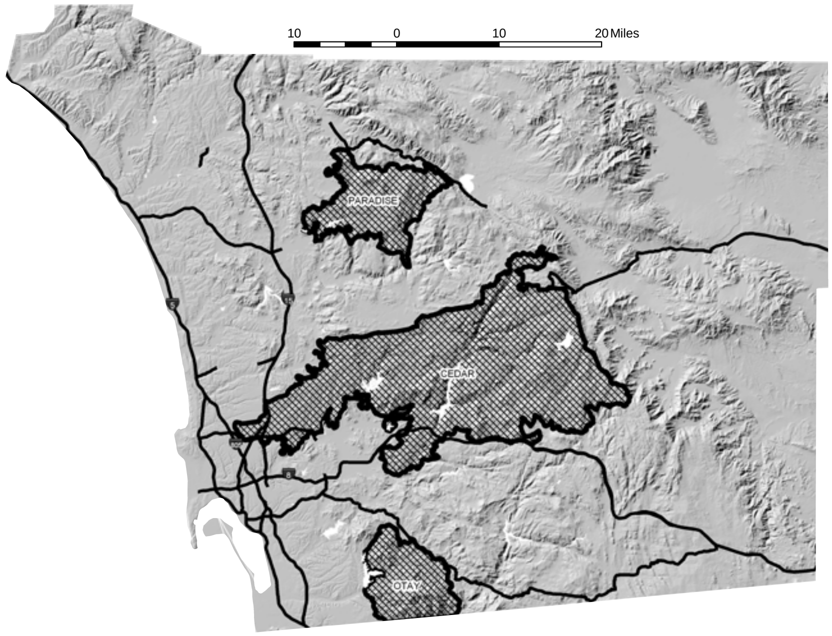

Figure 1. Extent of Paradise, Cedar, and Otay fires within San Diego County, CA.

GeoSyntec used a number of recently developed tools and techniques during the post-fire hazard assessment, mitigation, and implementation process to improve the efficiency of the collection of field data during the assessment and improve the ability to make time-critical engineering decisions due to the imminent onset of winter rains. These tools included: deployment of ruggedized personal digital assistants (PDAs) equipped with integral global GPS and multi-spectral satellite imagery; and automated feature analysis of post-fire imagery to delineate burn areas based on satellite imagery and to refine estimates of burn severity and watershed response.

2 Erodibility Index Derivation

The increased potential for post-fire hazards and impacts was qualitatively evaluated using 1 meter pan-chromatic and 2.4 meter multi-spectral satellite imagery and the Spatial Analyst extension of ArcView 8.3. Factors considered in the model were slope steepness, soil erodibility, and burn severity, which were combined to form a relative erodibility index. Due to the enormous size of the burned watersheds, this analysis allowed a rapid assessment of the hazards and impacts to Values at Risk (VARs).

GeoSyntec developed the post-fire hazard index of relative erodibility (PHIRE) to aid in rapidly narrowing the areas of greatest risk related to geologic and erosion hazards resulting from the fire. Topographic data consisted of 30 meter resolution digital elevation models (DEMs) and was obtained from the San Diego Association of Governments (SANDAG) geospatial information server (www.sandag.cog.ca.us). Slope steepness was then derived from these topographic data and categorized into four discrete intervals (Table 1). Soil erodibility was evaluated using existing Natural Resources Conservation Service (SCS) soil maps for the greater San Diego County area. Digital soil type maps were obtained from SANDAG, erodibility data was cross referenced with SCS hydrologic soil groups (HAAN, 1994). The mapped surface soil was assigned values based on the hydraulic soil group classification and the anticipated relative erosion rates of slight, moderate, or severe (Table 1). The third key component of PHIRE was the burn severity mapped by the Federal Burn Area Emergency Response (BAER) team's Burn Area Reflectance Classification (BARC) maps. These maps can be viewed at: http://frap.cdf.ca.gov/socal03/baer/burnseverity-maps.html. Soil burn severity was assigned an increasing integer value for increasing burn severity (Table 1). As a final step, the values for the slope, burn severity and erodibility were summed using a 1.5 meter grid across the entire extent of the burned area (Figure 2).

PHIRE values were checked to make sure that there was no change in PHIRE for unburned areas within the study boundaries.

Table 1. Input values used to generate PHIRE maps.

Slope	Weighted Slope Value	Burn Severity	Weighted Severity Value	Erodibility	Weighted Erodibility Value	Total PHIRE Index	PHIRE Rating
0-5	0	Low	1	Low	2	0-4	Low
5-10	1		2	Moderate	4	5-8	Moderate
10-15	2	Moderate	3	High	6	9-12	High
15-20	3		4			13-16	Severe
20-30	4	High	5				
30+	5						

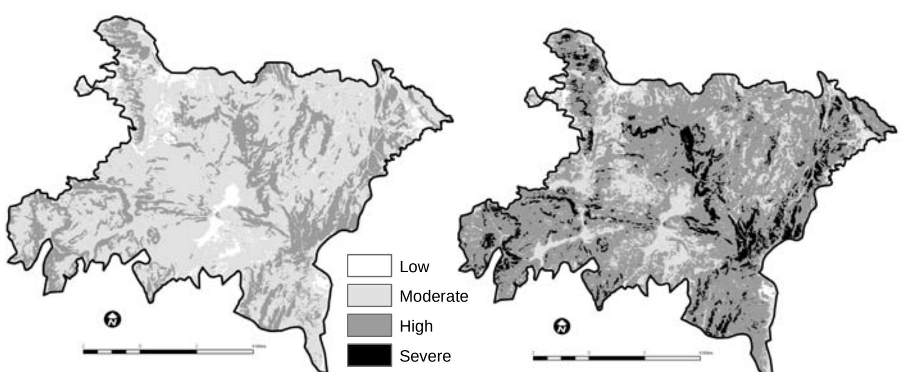

Figure 2. Pre-burn PHIRE analysis Paradise fire

Post-burn PHIRE analysis Paradise fire

3 Implementation of PHIRE analysis

3.1 Aerial Surveys

PHIRE analysis of the post-fire satellite imagery allowed GeoSyntec to focus the fixed wing aircraft and helicopter over flights on the most critical areas. The fixed wing over flights (at 4,000 - 5,000 feet) and helicopter over flights (at 500 feet) further narrowed the areas to be covered on the ground with field assessment teams. This rapid multi-level approach to post-fire hazard assessment which went from satellite imagery to fixed wing aircraft to helicopter to ground surveys saved the City and County considerable time and money and facilitated the rapid deployment of site-specific mitigation measures to the most critical areas.

3.2 Ground Surveys

The ground survey teams employed ruggedized personal digital assistants (PDAs) equipped with integral global positioning systems (GPS) running the rapid development relational database engine Jetstream™ for consistent data gathering (Figure 3). Information was gathered on drainage features, surviving vegetation, hydrophobic soils, burn severity, receiving waters, infrastructure, and surviving homes. The PDAs were downloaded every night into a whole-project field data management system and correlated with the aerial and site photographs.

Figure 3. Jetstream equipped PDA for consistent field data gathering.

Concurrent with development of a comprehensive hazard mitigation plan, the City and County initiated early action measures which included public assistance (erosion control materials and guidance to homeowners), cleaning out storm drains, cleaning out sediment retention structures, and protecting storm drain inlets.

The hazard evaluation and priority establishment was performed in a manner that was consistent with the approach taken by GeoSyntec staff in previous fires, which was first to rate the hazards (e.g. landslides, mudflows/debris flows/high sediment loads, flooding, rockfalls, retaining structure damage), and then to rate the impacts of those hazards (e.g., public health and safety, public and private property damage, damage to infrastructure, transportation route damage, damage to receiving waters). Based on these assessments, each site was given an overall hazard rating, and the sites with the highest hazard rating became the high priority sites (HPS) for development of hazard mitigation plans.

4 Mitigation Measures

4.1 Selection Criteria

Selection criteria for mitigation measures included effectiveness, implementation cost, maintenance cost, environmental compatibility, regulatory acceptability, availability, suitability, and longevity. Specifications for candidate mitigation measures were developed, which in some cases included development of customized specifications for post-fire application. The mitigation measures included sediment control measures, erosion control measures, trash racks and debris flow devices, evacuations and warnings. Soil bacteria (mycorrhizal inoculum) were used in limited areas where native seeding (with nine native seed species) was applied to burnt slopes.

Mitigation measures were selected for the high priority sites, and hazard mitigation plans and specifications were developed, which utilized the satellite imagery as the base layer. GeoSyntec, on behalf of the City and County as applicants, coordinated with the Natural Resources Conservation Service (NRCS) under their Emergency Watershed Protection Program and FEMA for reimbursement of the eligible projects.

4.2 Implementation

As the mitigation plans were finalized, materials were ordered and labor forces were contracted. Labor forces included hand labor crews (e.g., California Conservation Corps and Urban Corps) who were trained to construct temporary grade control measures, barriers and diversions, and slope interrupter devices (Figure 4). Experienced hydraulic erosion control contractors were retained to apply hydraulic mulch (wood fiber, tackifier, native seed, and mycohhizae) and bonded fiber matrix (Figure 5). Construction contractors were retained to install trash racks and debris flow devices (e.g., k-rail).

Figure 4. California Conservation Corps installing fiber rolls.

Figure 5. Hydraulic mulch application.

Despite the mitigation measures some areas were still at risk of flooding (due to steep slopes and short times of concentration) and warranted development of an evacuation and warning system. This system included identification of the homes at risk, installation of additional rain gauges, development of a three-stage warning system, and issuance of pagers linked to the County's ALERT system to homeowners.

Another result of the October 2003 was the complete burning of the watersheds of three City of San Diego reservoirs, San Vicente, El Capitan, and Otay reservoirs. A rapid assessment was conducted to quickly identify values at risk (VAR) and mitigation measures to help protect public heath, water quality and infrastructure associated with the reservoirs. The reservoirs are used for non-contact recreation (boating and fishing) as well as their primary function to provide drinking water to the City of San Diego.

Erosion control methods on up-gradient slopes were not considered practical due to the vast size of the watersheds at each reservoir, so in-reservoir treatment systems were evaluated, selected, and designed. Mitigation measures included spillway debris booms, creation of sediment basins in tributaries using geotubes (geosynthetic tubes filled with dredged material), turbidity curtains deployed within the reservoir near the mouth of tributaries to partition sediment-laden runoff, and alum dosing to enhance settling of sediment particles.

5 Outcome of Predictions and Mitigation

The first test of the mitigation measures occurred on 25 December 2003 with a storm that brought approximately 17.78mm of rainfall to the County. This event triggered mudflows and debris flows in locations that were previously predicted by the PHIRE analysis. These debris flows caused the closure of some roads and affected some property, but did not damage any homes. Additionally, as predicted, there were high sediment and debris flows into the reservoirs.

Field engineering during implementation and changed conditions throughout the winter resulted in the need to update the plans. As-built plans and as-costs were also required for funding reimbursement. Since it will take years for the watersheds to recover, the City and County will face other issues including problems in subsequent winters with the next level of priority sites, site disturbance from debris removal and the reconstruction process, and possibly permanent drainage design modifications necessitated by changed post-burn site conditions.

Overall, GeoSyntec found that use of the recently developed tools and techniques during the hazard assessment, mitigation, and implementation process significantly improved the efficiency of the collection of field data during the assessment, and improved the ability to make time critical engineering decisions, which were vital given the magnitude and complexity of the task at hand. Although the repercussions of the fires will persist for quite some time, these tools, combined with a trained labor force, appropriate mitigation measure technologies, and a defensible plan, facilitated a timely and appropriate response.

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