Erosion and Sediment Control: Preventing Additional Disasters after the Southern California Fires

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Introduction

Wildfires are a common occurrence in Southern California and much of the State's biologic and geologic character is a direct result of a cycle of fire, flood, and regeneration of plant communities, many of which have adapted to this disturbance. However, while the impact of fires might be considered a natural phenomenon in wild lands and left largely unattended, where human population and resources are affected by the fire cycle, mitigation activities designed to reduce the potential for flooding and mud flows must be included as part of that cycle.

In the fall of 1993, 20 separate fires burned over 186,000 acres of Southern California, extending from northern Los Angeles County to southern San Diego County and the Mexican border. Nearly 1,200 homes were destroyed and four people lost their lives. Unlike the 1991 East Bay Firestorm in Oakland, California where 3,100 structures were destroyed in an 1,800 acre densely populated urban area, the majority of acreage on which the 1993 fires occurred was in wild lands, or away from urban centers. However, at the urban interface where wild lands and development meet, the hazard from post-fire flooding, erosion, sedimentation, and mud flows can directly impact human populations. In the crucible that constitutes post-fire disaster planning and implementation, it is the potential occurrence of this second disaster which challenges federal, state, and local government entities to allocate human and financial resources and focus them into immediate and effective actions.

This article presents information on the post-fire hazard assessment and mitigation planning conducted by Woodward-Clyde Consultants (WCC) for the California Office of Emergency Services (OES) and its implementation in the communities of Malibu, Thousand Oaks, Laguna Beach, and Orange County.

The Post-Fire Hazard

Considerable information is available on post-fire sediment production rates and debris flows in California, particularly in Southern California, including studies by Wells, the Handbook of Applied Hydrology by Ven Te Chow, and the Los Angeles County Hydrology Manual. These studies show that fire accelerates erosion rates in California chaparral to such an extent that it must be considered the major factor which drives sediment production on these lands. The surface processes of dry ravel and rill network formation are major contributors to this accelerated erosion, and debris flows are a common occurrence. These flows move most of the sediment produced after a fire, and can occur following very little rainfall.

The incidence of fire temporarily reduces the beneficial effects that plants provide in reducing soil erosion. Plants provide cover that intercepts and reduces rainfall impact, the primary mechanism for soil erosion. Vegetation also increases the infiltration of water into the soil, reduces runoff velocities, filters out sediment, and provides plant roots to hold the soil together. Without vegetation and its benefits, sediment production and runoff in fire-affected areas and more important, its delivery down slope increases.

Burned watersheds erode in different ways, depending on soil type, climate, vegetation, burrowing and grazing animals, topography, and human activity. Dry creep, or dry ravel, is the downhill movement of soil and debris during dry periods, and is caused by gravitational forces. Where fire burns the vegetative cover, the mechanical resistance to gravitational forces decreases, and the soils become more susceptible to this type of erosion. Dry ravel is a major erosional force in post-fire conditions. Soil and debris accumulates at the base of slopes and remains stored until mobilized by intense runoff. This is known as channel loading. Intense runoff often occurs after a fire and can be the result of the development of soil hydrophobicity.

Hydrophobic, or water-repellent soils can develop from substances in the soil which are vaporized during the burning of surface litter, particularly on sandy soils. Hydrophobic soils are created as the fire breaks down organic matter and chemicals in the soils, releasing a gas which coats soil particles and reduces water penetration. This condition reduces water infiltration rates and moisture storage capacity resulting in increased runoff and erosion rates. After fire, soils are no longer protected by vegetative cover from turbulent air. Wind is an erosive force in these conditions, blowing slopes clean of loose soil particles. The windblown soils are usually deposited down slope and in stream channels for later movement during storms.

The development of rill networks and gully erosion increases post-fire loss during the rainy season when soils are wet or saturated. Infiltration rates are decreased on bare slopes, and therefore, runoff, or overland flow increases and the sediment carrying capacity increases. The result of this type of erosion is the movement of sediment and debris into stream channels, causing clogged drainage ways, mud flows, and debris flows. Since the rate of runoff is higher and the sediment and debris load is higher, the potential for flooding is also increased. Soil slippage can occur during heavy rains when the amount of water entering the soil layer exceeds the capacity of the parent rock to transport water. This leads to supersaturated soils, and soon the stress on the soil exceeds its strength, resulting in sloughs and slumps. After fires, even moderately heavy rainfall can supersaturate soils denuded of vegetation.

There is generally a higher flooding risk as a result of a fire. This increased risk may arise from increased watershed runoff due to changes in the surficial soil and vegetation characteristics as previously described; diversion and/or overflow of conveyance facilities due to increased sediment loads from the barren watersheds, and the possibility of additional flooding from ineffective sediment basins. Post-fire conditions can also result in reduced-stability landslides and other geologic hazards. Examples include: erosion of supporting rocks or soil at the toe of a pre-existing slump or landslide; damage to a landslide stabilization measure (such as a drainage or dewatering system); and damage to earth retaining structures or other slope stabilization measures.

Issues and Concerns

Erosion, flooding mud flows, and debris flows following fires are considered by some geologists and geomorphologists as naturally occurring phenomena that don't require man's intervention. Government officials and the people in their jurisdictions who are directly impacted from post-fire hazards tend to think of them as anything but natural, and demand effective and immediate mitigation measures. Three of the questions that arise after a fire are: "Should we do anything at all?," "What should we do?," and "How much is enough?." Although the technical answers associated with appropriate response following fires may be years away from resolution, i.e., whether to mitigate, revegetate, or evacuate, the realities of the hazards and impacts on human populations require some type of action.

It might be instructional to consider the agricultural concept of "T," or tolerable soil loss. Tolerable soil loss is considered to be that amount of soil which can be lost on an annual basis without affecting a site's productivity, or its ability to support a multitude of uses. A certain amount of erosion might be permissible in an agricultural setting, with losses offset by adjusting management inputs, and erosion of outlying wild land areas is offset by natural soil formation over time. But, when the effects of accelerated erosion from fires affect people's lives, property, and community infrastructure, there is no tolerable soil loss. If 99 percent reduction in erosion still results in 1 percent of the sediment filling up someone's living room to the ceiling, then there is no soil loss which is tolerable in the urban environment.

In the case of the Southern California, logic dictated that remediation could not be pursued on all of the areas affected by the fires. Not only were the costs prohibitive, but natural regeneration in the extensive area of affected wild lands occurs at a rate much more rapid than man's effort to augment it. Limited economic and human resources were then directed, as they should have been, towards the affected communities of Laguna Beach, Malibu, Altadena, Thousand Oaks, and parts of Orange County.

Hazard Assessment

The planning and implementation of post-fire hazard mitigation measures require a documentable process wherein the effort is phased to allow the highest hazard areas to be identified and addressed first, followed by the next most urgent hazard areas. During and immediately following the fires, available information was gathered and reviewed for identification of potential hazards. This information included storm drain maps, topographic maps, geologic maps, hydrologic information, and aerial photographs. Both aerial and ground site reconnaissances were performed with two-person field teams to assess the damage and gather information on the potential hazards caused by the fire, including mud flows, debris flows, and high sediment loads; flooding; rockfalls; retaining structure damage; and landslides.

Based on the gathered information, the potential for post-fire hazards was evaluated and tabulated for various sites within the burned areas, Next, the impacts of those potential hazards were evaluated. Impacts of the post-fire hazards included public health and safety; public and private property damage; damage to infrastructure (such as the storm drain system); transportation route damage (such as key artery loss); or damage to receiving waters. Based on an assessment of the likelihood of the hazard together with the severity of its impact, an overall judgment was made as to which sites, if any, should have the highest priority for mitigation. This evaluation was a particularly valuable tool for allocating resources. An example of a hazard assessment matrix is presented in Table 1.

Table 1. Assessment of burn area hazards

	Hazard					**Impacts**					**Overall Rating**
Fire/site	**L**	**M**	**F**	**R**	**S**	**H**	**P**	**I**	**T**	**W**	
Fire 1											
Site 1	L	H	H	M	N	H	H	M	H	L	H
Site 2	M	H	H	H	M	H	H	M	L	L	H
Site 3	L	M	H	L	M	L	H	L	M	L	M

Legend: H=High M=Medium L=Low N=None

L=landslides; M=mudflows/debris flows/high sediment loads; F=flooding; R=rockfalls; S=retaining structure damage; H=public health and safety; P=public and private property damage; I=damage to infrastructure; T=transportation route damage (artery loss); W=damage to receiving waters.

In both the Oakland and Southern California Fires, this technique was used, and resulted in mitigation efforts being focused on those hazards that would have a high impact on public health and safety, public and private property damage, infrastructure damage, transportation route damage, and damage to receiving waters. In all cases, these hazards occurred at the urban interface areas. Where there were potential hazards with a medium or high likelihood of occurring, but the potential impacts were low, then no mitigation of the hazards was recommended or implemented. Typically, this occurred in the more open, undeveloped areas.

Development of Plans

The first step in mitigating the identified high priority post-fire hazards was to develop Early Action Plans that provided for immediate sediment control to reduce the impact of flooding and mudflows on developed areas. Early action measures should be identified to implement immediately if rains are imminent. Both the Oakland and Southern California fires occurred in late October at the start of the rainy season, and in both cases Early Action Plans were prepared and being implemented within a week of the fires being put out. These early action measures were intended to provide as much preliminary protection as is practical in critical areas while the more comprehensive Phase I Mitigation Plans were being prepared.

Early action measures were usually those measures that could be implemented using available work force crews (manual labor primarily), and focused on sediment and debris control. They included removal of debris from drainages; cleaning out storm drains; protection of storm drain inlets; construction of temporary velocity reduction measures, check dams, and sediment traps; and construction of sand bag diversions.

The project authority had at least four sources of labor for immediate action and response: the California Conservation Corps (CCC), work release program crews, local maintenance crews, and volunteer organizations. The project authority needed to develop a program of orientation, training, and oversight. This resulted in the timely and safe implementation of early action measures. These early action measures typically were not intended to eliminate, only reduce, damage from rainfall-induced flooding and mud, rock, and debris flows. It was recognized that the first significant rainfall after the fire would result in unexpected problems with increased flooding and mud and debris flows, so trained personnel were in the field to help citizens and assess needed repairs and improvements in the early action measures.

The next step in the process was to develop Phase I Hazard Mitigation Plans, which are comprehensive plans for a given area designed to address the short-term mitigation of geologic, erosion, and flood hazards caused by or exacerbated by the fire. These short-term mitigation measures were designed to address immediate threats to public health and safety, including ash, debris, sediment, and flood damage to public and private property. The measures provided for both erosion and sediment control. The Phase I Plans included provisions for operating and maintaining the installed systems throughout the rainy season.

The essential steps taken in developing the mitigation plans were: (1) Identify the Issues and Concerns; (2) Develop Goals and Objectives; (3) Perform Post-Fire Hazard Evaluation; (4) Develop Best

Management Practice (BMP) Selection Criteria; (5) Nominate and Evaluate Alternatives; (6) Screen and Select Alternatives; (7) Design the Hazard Mitigation Plan; (8) Implement the Plan; and (9) Operations and Maintenance. Since the fires occurred during the rainy season, Steps 1 through 8 had to be implemented as quickly as possible. Typically, this took a week to ten days. Based on the knowledge and local experience of the project authority's hazard mitigation team, some analyses and screening detail could be reduced. For example, clearly, areas where flooding and other geologic problems were present before the fire were likely to be worsened. However, a rational, well-documented decision process was essential to help with local, state and federal disaster funding.

The third step in the plan development process was to prepare Phase II Hazard Mitigation Plans that were designed to address the longer term mitigation of fire impacts relative to geologic, erosion, and flood hazards. These were optional plans, but where deemed necessary, included the next level priority areas after the Phase I Plans were implemented, site disturbance from debris removal and the reconstruction process, and/or semi-permanent drainage design modifications necessitated by changed post-burn conditions.

Mitigation Measures

The wide range of conditions encountered following a fire in an urban or urban-wild land interface area require a variety of Best Practical and Available Technology (BPAT) solutions designed to address hazards under site-specific circumstances. These solutions are commonly referred to as Best Management Practices (BMPs). The BMPs selected for implementation in potential hazard areas were evaluated utilizing the following selection criteria: effectiveness; implementation cost; long-term (maintenance) cost; environmental impacts; regulatory acceptability; public acceptability; risk/liability; aesthetics; suitability for site; feasibility; and durability or longevity.

No numerical equation presently exists whereby an emergency mitigation planner can establish the most appropriate solution to a post-fire problem. In almost all cases, successful erosion and sediment control involves a variety of techniques and materials which are pulled together to form a complementary and composite system of BMPs. Above all, post-fire hazard mitigation must been done quickly... and be effective.

Twenty BMPs were selected for implementation in the urban-interface areas of Laguna Beach, Orange County, Malibu and Thousand Oaks. Not all of the BMPs were used on sites, and in some areas, specific practices were relied on more than others. With all revegetation BMPs, the seed mixtures were specified by the Soil Conservation Service (SCS) as part of their technical assistance provided to affected communities through the Emergency Watershed Program. These seed mixtures were composed primarily of native plant materials selected to complement indigenous plant re-establishment. SCS field engineers also worked with contractors hired by the communities, assisting in the coordination of work activities and inspecting applications.

It is important to note that neither re-establishment of native plant materials (from root or seed which survived the fire) nor introduced vegetation (through hydraulic or broadcast seeding) appears to provide enough soil protection in the first year following a fire to prevent erosion. For this reason, a two-pronged strategy was employed which included: first, sediment control, detention and diversion; and second, temporary cover practices to hold the soil in place until vegetation is established.

The sediment control practices were used in the immediate response to reduce the down-slope impact of sediment until soil stabilization measures could be implemented. These aggressive, source control practices provided an immediate, temporary cover that reduced the erodibility of soils until permanent, soil-stabilizing vegetation was re-established. Although all of these revegetation practices were used on the fire-affected areas to some degree, primary emphasis was placed on the use of hydraulic practices due to cost, timeliness, topographic, environmental compatibility, and safety concerns.

Conclusions

It should be recognized that of the 186,000 acres affected by the fires of 1993, less than 1 percent of the area (<1,800 acres) received the comprehensive erosion and sediment control treatments described in this paper. These were the urban and urban-interface areas of highest priority identified in the Hazard Assessment provided to the California Office of Emergency Services. Orange County, Laguna Beach, Thousand Oaks, and the Big Rock area of Malibu received individual plans prepared for each community by Woodward-Clyde, and to a large degree, when implemented, these plans were effective in mitigating the erosion and sedimentation impacts from winter storms.

Much needs to be learned about post-fire emergency erosion and sediment control in the urban interface and not just from a technical standpoint about which practices should be used to mitigate impacts. We should accept the fact that the cycle of wildfires and the resulting erosion and sedimentation is a natural phenomena in Southern California and other western states as well. But to the people who are affected by these processes, those living at the urban-wildland interface, questions on whether or not to use any mitigation practices at all are moot: Do-nothing alternatives are not politically, technically, economically, or socially acceptable. People and their activities are as much a part of the post-fire environment as are native plants and animals, and any approach that does not incorporate human resources and values as part of a mitigation strategy fails to appreciate the practical interface between humans and their environment.