COLORADO
Colorado Water Conservation Board
Department of Natural Resources

What to Expect After a Wildfire?

Frequently Asked Questions About Soil Erosion and Impacts to Water Resources and Infrastructure

Introduction

This document provides a high-level summary of recent literature from post-wildfire studies in Colorado and provides answers to some common stakeholder questions. The Colorado Department of Natural Resources Water Conservation Board's mission is to conserve, develop, protect, and manage Colorado's water for present and future generations. Supporting post-wildfire recovery efforts through technical assistance and funding is one of many critical endeavors that the Colorado Water Conservation Board undertakes.

What Type of Issues Will Affect Our Stream Corridors and Reservoirs?

Wildfires change soil characteristics and vegetative cover resulting in profound changes to hillslope and channel erosion and sedimentation processes. After a wildfire, runoff and erosion can increase dramatically, often times by several orders of magnitude over pre-fire conditions - leading to extreme flooding, erosion, and sediment deposition that can damage infrastructure and may endanger human lives. Even if not extreme, increased erosion and sedimentation following a wildfire can impact water quality and quantity, reduce capacity of reservoirs, affect water delivery infrastructure, erode or clog transportation infrastructure such as roads and crossings, and degrade aquatic habitat. Predicting where and how much sediment erosion and deposition will happen, what the effects will be on downstream landscapes, and identifying actions to reduce the impact of these processes on infrastructure and natural resources is important information for pre- and post-wildfire planning and response.

There are three primary sources of sediment that natural resource and emergency response managers should be concerned with after a wildfire: 1) surface erosion (e.g., rill, inter-rill, and gullying) from hillslopes; 2) debris flows; and 3) sediment inputs from stream channel banks, bed, and floodplains due to erosion and scour caused by excess runoff. This document is primarily focused on surface erosion from hillslopes.

How Long Do Wildfire-Related Issues Persist?

High variability in site characteristics exist in burn areas and thus pinpointing how long fire-affected watersheds take to "stabilize" is very site dependent; for example, one Rocky Mountain-specific study found that post-fire recovery of vegetation and ground cover occurs within 1-6 years after the initial burn, while recovery of infiltration capacity of the soil typically occurs 2-3 years after burning (Wilson, 2018). These numbers correspond to the time needed for sufficient vegetation regrowth and litter accumulation to allow infiltration capacities of soils to accommodate typical summer events. Once infiltration capacity of soil is restored, surface runoff, and thus impacts to downstream water resources, are reduced. While fire-related sediment production from hillslopes and stream beds will decline as the watershed recovers, eroded sediments initially deposited into the downstream river systems can reside in those systems for over 300 years. The legacy of erosional and depositional features may affect landscape evolution and water quality by acting as a new set of conditions for subsequent wildfire and flood sequences (Moody and Martin, 2001). Further events may also be at play in recovery. In the Poudre River watershed, for example, the 2013 rain event that led to flooding following the High Park Fire caused a net improvement in water quality as problematic sediment deposits left behind following the wildfire were mobilized and moved downstream. The flood also reportedly shortened the watershed recovery timeline by elevating groundwater tables and accelerating postfire vegetation regrowth (RMRS, 2017).

A general rule of thumb is that for the first 2-3 years following a wildfire the flood and debris risk will be essentially the same as right after the burn. Then, recovery happens very quickly up until about year 6 or 7 (or sometimes sooner), at which point it slows down. Long-term 100% recovery to pre-fire hydrology and soil-sediment stability (and sediment production potential for that matter) may never occur as changing forest structure (e.g., reduced regeneration or composition shift) because of the burn and/or in combination with climate change. Such a shift can have lasting implications for communities and infrastructure located downstream of a burn scar.

How Much Hillslope Erosion Will Occur Post-Fire?

Land managers often need to predict watershed-scale erosion rates after disturbance or other land cover changes. Wilson et. al., (2018) identifies that there is a threshold by which rainfall precipitation overwhelms that ability of soil to allow water to infiltrate thereby resulting in overland (surface) flow and that the threshold varies with fire severity, time since burn, and the soil type. This surface flow is responsible for most of the hillslope soil erosion that causes problems as it enters stream corridors and reservoirs.

Post-fire emergency response teams have developed excellent tools for determining what parts of the landscape are most vulnerable to hillslope soil erosion, but quantifying sediment yield has remained problematic (although new data and models are improving our understanding and predictive skills). Current erosion models are relatively consistent at identifying areas with low and high erosion potential, but the wide range of predicted sediment yield and poor prediction of observed sediment yield highlight the need for better field observations and model calibration to obtain more accurate simulations (Kampf, 2020).

Where Will the Eroded Sediment Go?

While detailed studies are useful for predicting erosion thresholds and production rates from certain hillslopes, impacts at the watershed scale may be more difficult as longer flow paths allow for more opportunities for water infiltration and sediment storage possibly reducing the distance sediment and water travel away from a hillslope (Wilson, 2018). In other words, a rain event may predictably mobilize sediment on a hillslope carrying it downhill but predicting where that sediment gets deposited and whether it will affect downstream infrastructure such as reservoir storage capacity can be very complex. One significant clue related to sediment transport delivery may be found in understanding whether the hillslope has the ability to transport sediments into a stream channel or whether they will fall out of transport at the toe of the valley. Rathburn et al. (2017) recommended focusing treatment priorities on areas of where hillslopes and stream channels are found to be highly connected.

How will the Fire Affect Flooding?

Intense heat from fire can make the soil repel water, a condition called hydrophobicity. Hydrophobicity decreases infiltration and initial rainfall losses and increases direct runoff from a watershed. Similarly, the more intense a fire, the deeper it will burn into the soil column, and the deeper it burns into the soil column, the longer it takes for vegetation to re-establish itself on the canopy floor. These changes to soil structure and vegetation cover combine to dramatically affects the hydrologic response of the watershed to rainfall events, significantly increasing runoff and flows in stream corridors even for small storm events that typically occur each summer. These changes in runoff response increase the size and proportion of downstream flood hazards, affecting flood flows, flood depths, the velocity of water, and the river systems ability to erode channel banks and beds while also transporting more sediment and debris. Legacy floodplain maps no longer represent the post-fire flood risk that results from the increases in hydrology, meaning that infrastructure within the watershed such as stream crossings (culverts and bridges), utility scour protection, and flood protection are no longer adequate for the increased size and frequency of flooding.

While moderate and severe burns may result in similar initial hydrologic changes, severe burns are likely to cause hydrologic changes over a longer time. Pinpointing specific expectations for change to watershed hydrology, similar to sediment erosion, is challenging as specific anticipated results are linked to a wide variety of physical deterministic and stochastic factors. The CWCB is available to assist in providing guidance for predicting changes in post wildfire hydrology and help prepare communities for flooding scenarios downstream of fire impacted areas.

Will Stream Corridors Change?

The short answer is, it depends. Brogan et al. (2019) found that wildfires with high and moderate burn severity can trigger significant changes to the shape and location of stream channels, but that unusually long or intense rainstorm or runoff events, such as those that resulted in the September 2013 Colorado Flood, create more persistent morphological changes regardless of whether a catchment has burned. Rathburn et al. (2017) found following the 2012 High Park Fire that intense rain events evacuated sediment in stream channels but that valley morphology, particle size, vegetation reestablishment, and the amount of time that has passed since the fire were also primary controls on whether a stream corridor experienced significant change.

Regardless of the size of the rainfall event, natural fluvial processes (those relating to the erosion, transport, and deposition of sediment and debris by moving water) can cause significant changes not before seen in our recorded history. Erosion of the channel bed and banks can significantly widen and deepen channels. Channels that were thought to be "stable," both in horizontal location and vertical gradient, can rapidly adjust during a post-fire flood event and relocate themselves to a new position on the valley bottom. Where valley slopes rapidly flatten or natural or human-made constrictions in the channel or floodplain occur (e.g., culverts, bridges, floodplain fill and armoring) sediment and debris is likely to fall out of transport leading to deposition which can force water and debris out of the channel and into areas that were once thought to be safe from flooding.

What Actions are Most Effective to Prevent Soil Erosion and Flooding?

A study of the 2012 High Park Fire in Northern Colorado (Schmeer et al., 2018) found that percent bare soil (or inverse ground cover) was the strongest control on annual sediment yield from burned hillslopes (this is consistent with numerous other studies in the literature). ***Because mulching immediately decreases the amount of bare soil, the study found that mulched hillslopes had a four-fold reduction in sediment yield in the first year after the fire.*** The effectiveness of mulch in reducing erosion declined over time (the largest difference between the two happening in the first year following the fire) and by the third year after the fire, mulched and unmulched hillslopes had similar erosion rates (although because of the effects of the reduction in the first and second years *the total sediment yield from mulched hillslopes was 3-4 times less than unmulched hillslopes*). Total rainfall and rainfall erosivity (uncontrollable events) were both highly correlated with annual sediment yield, whereas topographic variables such as hillslope length and slope (also uncontrollable variables) were only weakly correlated.

What are Practical Strategies that may Help Reduce Erosion?

Targeted Mulching – Mulching can be a highly effective tool to reduce sediment yield from hillslopes as well as aid in the establishment of vegetation. Identification and prioritization of critical areas for mulching should be a primary strategy of recovery efforts. For example, slopes with anticipated high sediment yields, as determined though sediment yield modeling (e.g., WESTT), *and* that are highly connected to stream channels would rank high for priority. Wood straw and shred mulch are preferred over straw mulch due to the latter's propensity for introducing unwanted weed seeds and for being displaced by wind events (Robichaud, et al., 2013); furthermore wood mulch was found to be superior for tree seedling establishment (RMRS, 2017). Depending on the type (hydro, straw, wood shred, etc.), mulch is applied up to about 65% slopes, as mulching steeper slopes may have declining effectiveness with increased cost (Napper, 2006; Robichaud, et al., 2013). Flat slopes are not as problematic from an erosion standpoint but if the burn is high severity mulching is helpful and can be done at lower cost (e.g., hand-spreading with volunteers or using a small manure spreader behind an ATV). Slopes in the range of 25-45% are most likely to achieve overall effectiveness relative to cost for aerial mulching and are also good slopes for targeted seeding if that is also an identified strategy (Ekarius, 2021).

Targeted Seeding/Reforestation – Independent studies of the Bobcat and Hayman fires found no significant effect of seeding on vegetation growth or post-fire sediment delivery rates (Wilson et al., 2018) while other studies seem to imply a benefit (RMRS, 2017). If seeding and reforestation efforts are conducted, numerous factors should go into planning efforts to investigate such things as species selection and seed viability, natural regeneration capacity (e.g., litter and crown cover), soil and moisture conditions, timing and rates. Both positive impacts (reduced erosion and reduced invasive species) and negative impacts of seeding (limited long-term native vegetation establishment) must be weighed (RMRS, 2017).

Targeted Sediment Catchment/Capture systems—Sediment can be captured and stored in floodplains and other natural "sink" areas where water is forced to slow down. An analysis of valley geomorphology and/or other modeling data may help a recovery team identify where these areas naturally exist in the watershed and if they need additional improvements to act as sediment sinks. Popularity of use of contour-felled logs on hillslopes has gone down as studies have found most do not function due to undercutting, off-contour, or overtopping (RMRS, 2017).

Post-Fire Hazard Identification and Mapping in Critical Corridors – Identification of post-fire hazards is a critical step to protecting life and property. Following a fire, recovery stakeholders should work to pursue the development of post-fire hydrology (runoff), hydraulics (flood hazards), debris flow, sediment yield, and fluvial hazard (geomorphologic risk) identification and mapping. These hazard maps can be quickly and cost-effectively created to delineate areas vulnerable to water, sediment and debris impacts spurred by rainfall over the burn scar. Mapping these post-fire hazards may allow downstream residents to prepare by preemptively moving vehicles, storage units, and other items to safer locations and to develop evacuation plans.

What Wildfire Recovery Assistance Can the Colorado Water Conservation Board Provide?

The CWCB has some ability to readily deploy resources for post-fire and flood analysis, planning, and project prioritization. Technical assistance services we may be able to provide include:

- Review of emergency designs and projects by a team of multi-disciplined professionals including experts in engineering, geomorphology, vegetation, ecology, and biology.
- Data Collection and Baseline Conditions Assessment.
- Identifying where additional data and/or evaluations are needed to support decision making.
- Pre and post-burn hydrology and evaluation of changes by scale (HEC-HMS, GSSHA, etc.).
- Post-burn hydraulics (basin-wide) to determine flood risk (HEC-RAS 1D and 2D or RiverFlow2D). This analysis can include the addition of bulking factors to account for sediment and debris loading.
- Fluvial hazard zone delineation and assessing geomorphic risk.
- Sediment and debris flow modeling (FLO-2D and USFS and USGS methodologies).
- Assistance with identification of values at risk and project/area prioritization.
- Detailed Damage Survey Report (DSR) support with NRCS.
- Flood warning support including correlation to hydrology, hydraulics, and FHZ mapping.
- Watershed recovery plan development; technical analysis, prioritization, concept design, and implementation recommendations.

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