California Fish and Wildlife, Fire Special Issue; 52-56; 2020

ESSAY

Caltrans' efforts to reduce the frequency and severity of wildfires while protecting California's valuable resources

KEVIN CHURCH, ALEX ARÉVALO, AND LORNA McFARLANE*

California Department of Transportation–District 1, North Region Environmental Engineering, 1656 Union Street, Eureka CA 95501, USA

**Corresponding Author: lorna.mcfarlane@dot.ca.gov*

Key Words: fuel reduction, National Pollutant Discharge Elimination System, total maximum daily load, water quality, wildfire

---

The California Department of Transportation's (Caltrans) mission is to provide a safe, sustainable, integrated, and efficient transportation system to enhance California's economy and livability. Recognizing the important role California's natural environment plays in the State's economy and livability, and during this time of unprecedented climate change, Caltrans Division of Environmental Analysis is motivated and committed to proactively turning innovative ideas into sustainable solutions.

While the history of water issues in California is long and convoluted, one thing is clear—clean, fresh water is undoubtedly one of the State's most precious and vulnerable resources. As wildfire has a measurable impact on water quality, Caltrans performs wildfire fuel reduction activities to reduce the intensity and severity of wildfire events. While Caltrans' existing vegetation management program reduces wildfire fuel within the highway right of way (area adjacent to highway owned by Caltrans), there is potential for a separate and additive effort if Caltrans is able to earn compliance credits as mandated under the National Pollutant Discharge Elimination System (NPDES) Statewide Storm Water Permit (State Water Resources Control Board (SWRCB) Order Number 2012-0011-DWQ, NPDES Number CAS000003), for TMDL (Total Maximum Daily Load) waterways by funding expanded fuel reduction efforts to off-highway projects. TMDLs within the permit are written by the State and Regional Water Quality Control Boards, and/or the U.S Environmental Protection Agency (EPA) (https://www.waterboards.ca.gov/water_issues/programs/tmdl/). A TMDL is the maximum amount of a specified pollutant that can enter a waterbody and have the waterbody meet water quality objectives. TMDLs cover a wide variety of pollutants including trash, temperature, sediment, and toxins such as mercury. Watersheds that feed a waterbody with a TMDL designation are often held to the same standards as the affected waterbody.

The Caltrans Stormwater Program works to ensure compliance with the NPDES Permit through implementation of the Storm Water Management Plan (SWMP). The SWMP provides the framework and guidance to ensure compliance with the permit, including monitoring and reporting, and ensures TMDL compliance.

Caltrans owns over 1,750 km^2 (434,000 acres) of right of way and maintains approximately 15,000 center-line miles of highway. Many highway facilities are located in TMDL watersheds and Caltrans is often assigned a waste load allocation for TMDL constituents ranging from temperature and dissolved oxygen, to sediment and specific pollutants like mercury. Fire science has demonstrated that wildfires and the associated runoff is a significant source of pollution, including those covered by TMDLs (Smith et al. 2011). In addition to Best Management Practices (BMPs), including low impact development and bioswales already used to treat roadway runoff, Caltrans proposes fuel reduction activities in TMDL watersheds in high fire-severity zones to provide water quality benefits by reducing the severity and intensity of a wildfire (Caltrans 2017). As these activities are supplementary and offer an opportunity to reduce devastating impacts to water quality after a high severity wildfire, Caltrans proposes earning TMDL compliance credits for these fuel reduction activities.

WILDFIRE IMPACTS TO WATER QUALITY

The first impact of any wildfire is modification of the ecosystem substrate (USFS 2005). After a high severity wildfire, grasses, forbs, and shrubs no longer protect stable sediments from the destructive impact of rainfall. Litter composed of dead leaves, thatch, twigs, and underbrush (duff) is destroyed and no longer cushions the soil surface from rainfall nor filters suspended material from runoff after a wildfire. Under the right circumstances, wildfires can turn into catastrophic high intensity events in the presence of ladder fuels (high density thickets of trees and brush), allowing fires to spread vertically and horizontally, damaging or killing mature trees. In many cases, high intensity wildfires, more than low intensity wildfires, generate more ash and charred vegetation while degrading soil structure and water quality. The biological component of surface soil is linked to the soil physical properties. After a wildfire, some or all roots that bind fine sediments are damaged or destroyed and sediments are more easily eroded. Additionally, high intensity wildfires radically alter the physical properties of soils, creating a hydrophobic layer approximately 15 to 30 centimeters below the soil surface (DeBano 1981; DeBano 1990; Robischaud 2000; USFS 2005; Weiting et al. 2017). This hydrophobic layer reduces infiltration, greatly increases runoff and destabilizes the surface soil, all of which increase sediment transport and magnify impacts from high intensity rainfall runoff (USFS 2005; Paige and Zygmunt 2013).

High intensity wildfires followed by high-intensity rainfall can lead to catastrophic mud and debris flows which can impact the entire watershed. An example of the connection between high intensity wildfire followed by high intensity rainfall occurred in southern California in December 2017 (Thomas Fire). In January 2018, a flash flood passed through an urban area of Montecito CA to the Pacific Ocean, resulting in 20 different debris flows which added more than a million cubic yards of sediment to the surrounding waters. The debris flows overwhelmed Highway 101 (impassable for 10 days), left 23 people dead, 80 homes destroyed, 500 structures damaged, 20 bridges damaged, and more than 50 miles of highway impacted (SB OES 2018). Caltrans alone spent $26 million and replaced three bridges, based on a Directors Order (executed as an emergency contract, Public Contract Code §1102).

Even when catastrophic mud or debris flows do not occur, high intensity wildfires increase surface water sediment loading approximately 10 to 10,000 times, depending on the location, timing and rainfall intensity (Burke et al. 2013; Ice et al. 2004; McNabb and Swanson 1990; Paige and Zygmunt 2013). As climate change and drought worsen, plants can become weaker and more susceptible to wildfire, generating more erosion and sediment impacts on surface water (Sankey et al. 2017).

All wildfires have a measurable impact on water quality (USFS 2005), however high intensity wildfires significantly increase the potential for soil erosion, generating sediment transport that increases turbidity, pH, temperature and reduces dissolved oxygen in surface water (Burke et al. 2013). Post-wildfire runoff not only contains suspended charred organic material, but ash and sediment. Increases in suspended sediment loading also result in increased concentrations of dissolved nutrients, metals, salts, alkalinity and organic compounds, further degrading water quality (USFS 2005; Smith et al. 2011; Paige and Zygmunt 2013; Sham et al. 2013). High temperatures transform hydrated minerals (calcium and magnesium carbonates, gypsum) into dehydrated alkaline oxides that increase pH in runoff (Abraham et al. 2017). Metals, including iron, manganese, mercury, and selenium, are transformed (oxidized) by high-temperature, high-intensity wildfires (USFS 2005; Smith et al. 2011; Burton et al. 2016; Ogidie and Flegal 2017).

Virtually all metals retained by organic matter chelation (cobalt, copper, nickel, lead, zinc) become soluble when organic matter is destroyed, which impacts receiving waters (USFS, 2005; Smith et al. 2011; Abraham et al. 2017). Nitrogen loading to surface water increases by a factor of 5 to 10 times (Chorover et al. 1994; Mast and Clow 2008; Murphy et al. 2008; Smith et al. 2011; Stein et al. 2012; Abraham et al. 2017) and sulfate loading after a wildfire can be as high as 100 times the pre-wildfire levels (Chorover et al. 1994).

Given it takes two to five years after a wildfire for water quality impacts to diminish (Tecle and Neary 2015; Abraham et al. 2017), preventing further degradation is key—thus these findings support the concept of offering TMDL compliance crediting for wildfire-reduction activities by Caltrans in TMDL watersheds. Currently, Caltrans wildfire fuel reduction activities are somewhat limited to existing vegetation control and removal programs in the right of way. If Caltrans were able to earn TMDL compliance credits for fuel reduction activities, more comprehensive off highway fuel reduction efforts could be developed, while also increasing Caltrans' ability to fund external agencies' fuel reduction activities in TMDL watersheds.

MOVING FORWARD

The solution to improving water quality is complex; however, there is clear proof that high intensity wildfires degrade water quality. Managing fuel loads and fuel breaks is achievable through partnerships, funding and prioritization. To lead such efforts to protect our State's valuable aquatic resources, and to support and present a unified voice, Caltrans needs the partnership and expertise of departments such as the California Natural Resources Agencies (CNRA), including the Department of Fish and Wildlife (CDFW) and CAL FIRE, as well as the CalEPA (State and Regional Water Quality Control Boards).

Caltrans has begun a collaborative dialogue with other state agencies to 1) establish support for the TMDL compliance crediting based on wildfire fuel reduction activities, and 2) find the most appropriate, region-specific fuel reduction methods. Fuel reduction is typically accomplished by several methods, including application of fire control strips adjacent to the roadside shoulder, tree removal, thinning/felling trees in place, often followed by mastication and/or mowing. From a technical perspective, scientists, ecologists, firefighters and engineers support more frequent, less intense wildfires, however implementing this approach is costly, time consuming and will require a broad multiagency effort. Ultimately, the public must weigh in as well through the CEQA process for each individual project.

Caltrans aims to take a collaborative approach working with the various departments that have expertise in this field within the California Natural Resource Agencies such as CDFW and CAL FIRE, and the CalEPA.

LITERATURE CITED

Abraham, J., K. Dowling, and S. Florentine. 2017. Risk of post-fire metal mobilization into surface water resources: a review. Science of the Total Environment 599–600:1740–1755.

Burke, M. P., T. S. Hogue, A. M. Kinoshita, J. Barco, C. Wessel, and E. D. Stein. 2013. Pre- and post-fire pollutant loads in an urban fringe watershed in Southern California. Environmental Monitoring and Assessment 185:10132–10145.

Burton, C., T. Hoefen, G. Plumlee, K. Baumberger, A. Backlin, E. Gallegos, and R. Fisher. 2016. Trace elements in stormflow, ash, and burned soil following the 2009 Station Fire in southern California. PLoS ONE 11(5):e0153372.

California Department of Transportation (Caltrans). 2017. Construction Site Best Management Practices (BMP) Manual. CTSW-RT-17-314.18.1. Available from: http://csgcwwwace.dot.ca.gov/hq/construc/stormwater/CSBMP-May-2017-Final.pdf

Chorover, J., P. Vitousek, D. Everson, A. Esperanza, and D. Turner. 1994. Solution chemistry profiles of mixed-conifer forests before and after fire. Biochemistry 26:115–144.

DeBano, L. F. 1981. Water repellant soils: a state-of-the art. USFS General Technical Report PSW-46. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA, USA.

DeBano, L. F. 1990. The effect of fire on soil properties. Pages 151–156 in A. E. Harvey, editor. Proceedings-management and productivity of western-montane forest soils, April 10-12, Boise, ID. Gen. Tech. Rep. INT-280. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT, USA.

Mast, M., and D. Clow. 2008. Effects of 2003 wildfires on stream chemistry in Glacier National Park, Montana. Hydrological Processes 22(26):5013–5023.

McNabb, D. H., and F. J. Swanson. 1990. Effects of fire on soil erosion. Pages 159–176 in J. D. Walstad, S. R. Radosevich, D. V. Sandberg, editors. Natural and Prescribed Fire in the Pacific Northwest Forests. Oregon State University Press, Corvallis, OR, USA.

Murphy, J. D., D. W. Johnson, W. W. Miller, R. F. Walker, E. F. Carroll, and R. R. Blank. 2008. Wildfire effects on soil nutrients and leaching in a Tahoe Basin watershed. Journal of Environmental Quality 35(2):479–489.

Neary, D. G., K. C. Ryan, and L. F. DeBano. 2005. Wildland fire in ecosystems: effects of fire on soils and water (Revised 2008). Gen. Tech. Rep. RMRS-GTR-42-vol.4. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT, USA.

Odigie, K., and A. R. Flegal. 2014. Trace metal inventories and lead isotopic composition chronicle a forest fire's remobilization of industrial contaminants deposited in the Angeles National Forest. PLoS ONE 9(9):e107835.

Paige, G., and J. Zygmunt. 2013. The science behind wildfire effects on water quality, erosion. Pages 31–34 in J. Thompson and S. L. Miller, editors. Living with Wildfire in Wyoming. University of Wyoming, Laramie, WY, USA.

Robichaud, P. 2000. Fire effects on infiltration rates after prescribed fire in Northern Rocky Mountain forests, USA. Journal of Hydrology 231:220–229.

County of Santa Barbara Office of Emergency Services (SB OES). 2018. Thomas Fire and 1/9 Debris Flow, After Action Report and Improvement Plan. Available from: https://www.countyofsb.org/asset.c/4550

Sham, C. H., M. E. Tuccillo, and J. Rooke. 2013. Report on the effects of wildfire on drinking water utilities and effective practices for wildfire risk reduction and mitigation. Water Research Federation, Denver, CO, USA.

Smith, H. G., G. J. Sheridan, P. Lane, P. Nyman, and S. Haydon. 2011. Wildfire effects on water quality in forest catchments: A review with implications for water supply. Journal of Hydrology 396:170–192.

Stein, E. D., J. S. Brown, T. S. Hogue, M. P. Burke, and A. Kinoshita. 2012. Stormwater contaminant loading following southern California wildfires. Environmental Toxicology and Chemistry 11:2625–2638.

Tecle, A., and D. Neary. 2015. Water quality impacts of forest fires. Journal of Pollution Effects & Control 3(2):1000139.

U.S. Forest Service (USFS). 2005. Wildland fire in ecosystems: effects of fire on soil and water. General Technical Report RMRS-GTR-42-Volume 4.

Sankey, J. B., J. Kreitler, T. J. Hawbaker, J. L. McVay, M. Miller, E. Mueller, N. Vaillant, S. Lowe, and T. Sankey. 2017. Climate, wildfire, and erosion ensemble foretells more sediment in western USA watersheds. Geophysical Research Letters 44(17):8884–88892.

Wieting, C., B. Ebel, and K. Singha. 2017. Quantifying the effects of wildfire on changes in soil properties by surface burning of soils from the Boulder Creek Critical Zone Observatory. Journal of Hydrology 13:43–57.

Submitted 25 June 2020
Accepted 28 August 2020
Associate Editor was C. Walters