Day 2 Speakers: May 21, 2024

Where Practitioners & Scientists meet: Helping each other navigate the challenges and opportunities in post-fire hazard communication

Speaker: Katherine Rowden; US Army Corps of Engineers

Preparing for, responding to, and recovering from post-fire debris flows is a complex problem that relies on research in many disciplines to make advances in public safety. As interest in this topic has grown, so have the benefits and challenges of rapidly emerging science and technology. This talk – from a practitioner's perspective - will cover suggestions on how researchers can leverage existing interdisciplinary and interagency groups to have better interactions and outcomes with practitioners and communities, while also sharing some of the top research needs identified through interagency post-fire debris flow preparedness and response. Examples of successful partnerships between researchers and practitioners will be shared, alongside efforts that had some unintended consequences.

Variability in hydrogeomorphic responses to fire across snow zones

Speaker: Stephanie Kampf; Colorado State University

Co-authors: Megan Sears, Quinn Miller, Shelby Weder, Peter Nelson, Dave Barnard

2020, a year that changed most of our lives, was also a year of extreme wildfires. The two largest wildfires in Colorado history, Cameron Peak and East Troublesome, burned vast areas of forest stretching from the foothills up to the continental divide. These fires were unique in that they burned large areas at high elevation, where snow is usually present most of the year. Our research explores whether the effects of these fires on streamflow, hillslope erosion, and channel geomorphic change vary between snow zones. In each fire we monitor rainfall, streamflow, and topographic changes within catchments along a snow persistence gradient. Results to date indicate that low snow catchments experienced higher peak flows and greater geomorphic changes compared to higher elevation, higher snow catchments in each fire. Similarly, debris flows were more common at the lower elevations in each fire. High peak flows and debris flows were generated during summer rain storms in the first two years post-fire at Cameron Peak. In contrast, the stream responses to summer rains were still high during the 3rd year post-fire at East Troublesome. Although the Cameron Peak catchments experienced higher rainfall intensities, the extent of debris flow activity and magnitude of channel geomorphic change has been greatest in East Troublesome. Findings so far indicate that higher hydrogeomorphic responses in low snow catchments compared to higher snow catchments relates to greater topographic connectivity. Higher hydrogeomorphic responsiveness in the East Troublesome fire compared to Cameron Peak may relate to lithologic differences; East Troublesome sites have highly erodible sedimentary bedrock, whereas Cameron Peak sites have metamorphic/granitic bedrock. We continue to explore the causes of these differences in post-fire hydrogeomorphic responses between snow zones and fires.

Rainfall as the primary driver of post-fire flooding and debris flow: Key insights from a decadal review

Speaker: Natalie Collar; Wright Water Engineers, Inc.
Co-authors: John Moody, Brian Ebel

Increasingly severe wildfire activity highlights the need for improved post-fire flooding and debris flow prediction capabilities. Because rainfall is a primary input to prediction models, recent efforts have emphasized interdisciplinary work between meteorology and post-fire hazard science that develops more accurate rainfall estimates with longer lead times. In this work, we identified critical knowledge gaps for developing such estimates and attempted to fill those gaps by reviewing recent literature and with novel synthesis of pre-existing datasets. Gap areas were organized into the following general topics: a) rainfall characterization, b) the link between rainfall intensity and spatial scale, c) the physical interpretation of rainfall intensity-duration relations, d) time-varying rainfall, e) spatially varying rainfall, f) rainfall regimes, and g) modeling spatial rainfall.

Our presentation provides a high-level overview of findings from each topic area. Key advances include research-oriented deployments of rain gages in concert with observed flood and debris flow responses, matching the temporal discretization of rainfall to the time scale of response dictated by basin size and slope, increasing availability of gridded quantitative precipitation estimates, expanding the use of distributed hydrologic and erosion models that can incorporate spatial and temporal variability in rainfall, and linking of concepts and modeling from the atmospheric and climate sciences with post-fire hazard science. We close with a more detailed discussion of our rainfall regime meta-analysis. Results demonstrate that precipitation regimes can be meaningfully regionalized using a schema that captures self-similar properties of rainfall intensity (k, the maximum rainfall intensity) and temporal scaling (n, the decay rate). This rainfall regime schema, defined by k-n relations, could serve as a framework for organizing, interpreting, and predicting post-fire hydrologic and erosional responses.

Use of weather radar for monitoring rainfall over burnscars

Speaker: Jonathan Gourley; National Oceanic and Atmospheric Administration (NOAA)/National Severe Storms Laboratory

Co-authors: Jorge Duarte, Braden White

NOAA/National Weather Service operates and maintains 160 S-band weather radars across the US. In recent decades, they have transformed operational capabilities for real-time monitoring and short-term prediction of severe weather hazards including severe storms, wind, hail, tornadoes, winter weather, and flash flooding. The Multi-Radar Multi-Sensor system (MRMS) ingests all the NEXRAD radar data, mosaics them in 3D, and then generates a suite of real-time products for severe weather monitoring. One of the flagship product suites includes quantitative precipitation estimates (QPEs), available at resolutions as high as 1 km with updates every 2 min. Since the early development of the QPE algorithms, a great deal of progress has been made especially in response to the upgrade of the radar network with dual-polarization capabilities. Nevertheless, challenges remain for flash flood/debris flow monitoring over burn scars due to incomplete radar coverage in complex terrain, spatial/temporal resolution, and algorithmic deficiencies.

This presentation will provide an overview of MRMS relevant to the flash flooding/debris flow problem and then highlight challenges and potential solutions to address them. Finally, the presentation will introduce mobile and transportable instruments that can be deployed to specific burnscars for enhanced real-time monitoring and for generating research-grade datasets for improved understanding of the transformation of rainfall to extreme hydrologic responses on burnscars. Results obtained from field instrumentation placed on and nearby the Spring Creek burnscar in CO will be highlighted.

A fire ecology primer for debris-flow scientists

Speaker: Hugh Safford; University of California, Davis; Vibrant Planet

I outline the basic tenets of fire ecology and discuss how and why a better understanding of fire ecology is important for scientists and managers working with erosional processes. Certain fire-vegetation-landscape syndromes tend to accelerate rates of geomorphic change, but human-driven changes to fire regimes are expanding the footprint and quickening the cadence of catastrophic mass wasting. I provide a few examples of direct fire impacts on geomorphology and erosional processes, and I describe a number of tools and concepts integral to ecological restoration after fire that could help to better understand and predict debris flow probabilities and impacts.

Day 2 Poster Session: May 21, 2024

1. NWS Post-Fire Hydrology Operations and Challenges

Presenter: Tim Bardsley; National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Reno
Co-authors: Tony Anderson, Kate Abshire

Post-Fire flooding and debris flows present numerous challenges to National Weather Service (NWS) operations and communications. The NWS Weather Forecast Offices bear the responsibility of warning for weather and flood hazards, and post-fire events are among the most difficult events for NWS operations. These post-fire concerns continue to grow due to the combination of increasing acres burned at high intensity, and expanding community vulnerability. The heightened sensitivity of burned areas and rapid onset of flooding and debris flows often result in a disproportionate number of warnings relative to the unburned areas of NWS service areas, requiring significant attention and resources from before the fire is fully contained and sometimes lasting years after the burn. The NWS Post-Fire Hydrology Working Group is focused on advancing the NWS mission for providing services for post-fire hydrologic hazards, and works to build connections with our partner agencies and the research community to provide data, tools and modeling that support NWS in more timely and accurate warnings and communications for the protection of life and property. This poster will discuss these challenges from the NWS perspective and highlight gaps and science needs.

2. Comparing remote and field-based burn severity assessments across pyro-ecozones of British Columbia

Presenter: Yanik Nill; Simon Fraser University
Co-authors: Brendan P. Murphy, Jorrin Lenton, Tom Millard

The USGS post-fire debris flow hazards models rely on the creation of accurate soil burn severity (SBS) maps following large wildfires. These maps, typically produced in the western US by Burned Area Emergency Response (BAER) teams, require a multi-step process involving both remote sensing (dNBR) and field-based assessments of SBS to determine fire-specific dNBR thresholds used for creating classified, fire-wide SBS maps. While this is now standard protocol in the US, there is no agency in Canada responsible for this critical work and published emergency assessment severity maps often rely on default (or at best regional) thresholds. Given the rise in both extreme wildfire and post-fire hazards in western Canada, the lack of field-calibrated SBS maps is a serious concern and will significantly impact capabilities for predicting post-fire hazards. Moreover, it is not known whether the same protocols will even be appropriate in Canada's different ecosystems. In particular, British Columbia (BC) is home to 14 different biogeoclimatic ecosystems, and there has been almost no research on SBS across this diverse landscape. Here, we present severity data from remote sensing and plot-scale field assessments collected across the burn severity gradient in recent wildfires in BC's three major "pyro-ecozones". In each plot, we assessed: SBS using the BAER protocol, vegetation severity using the Composite Burn Index, soil hydraulic properties (see Lenton et al.), and collected samples to analyze changes in soil organic matter. From this analysis, we aim to advance our understanding of the relationships between burn severity metrics across BC forests and assess the viability of USFS protocols for SBS mapping for hazard assessment in western Canada.

3. Probabilistic assessment of postfire debris-flow inundation in response to forecast rainfall

Presenter: Alexander Prescott; Department of Geosciences, University of Arizona
Co-authors: Luke A. McGuire, Kwang-Sung Jun, Katherine R. Barnhart, Nina S. Oakley

Emergency hazard assessments conducted immediately after wildfire have included the likelihood and size of potential debris flows sourced from burnt basins, but they generally contain limited information on the spatial distribution of downstream impacts. An understanding of where postfire debris flows are likely to travel as well as the range of potential travel paths in response to uncertain future rainfall is critical for protecting people and property. To this end, we introduce a methodological framework to generate probabilistic predictions of postfire debris-flow inundation in response to forecast rainfall that links together existing models for debris-flow likelihood, volume, and runout with a distribution of 15-minute rainfall rates. We tested this framework by conducting a retroactive forecast for the destructive debris flows induced by extreme rainfall on the Thomas Fire scar upstream of the community of Montecito, CA, USA, on 9 January 2018. Peak 15-minute rainfall rates were extracted from an ensemble of 24-hour lead time high-resolution weather models. The resulting forecast captured 94% of the observed inundated area with predicted inundation probabilities greater than 1%. When debris-flow volumes are well constrained, the calibrated model framework is both reliable (i.e., forecast probabilities of inundation match the observed inundation frequencies) and sharp (i.e., predicted probabilities are mostly near zero or one). However, in the forecast simulation where debris-flow volumes were computed from weather model ensemble predictions of 15-minute rainfall rates, the model under-forecasted the observed inundation because the observed rainfall rates lie in the upper-most tail of the ensemble distribution. We found that additional constraints on debris-flow volume prediction will result in the greatest reduction in forecast uncertainty. This study takes a step toward a debris-flow inundation hazard assessment product that may be useful to postfire emergency management as well as prefire community preparedness.

4. Post-wildfire dry ravel loading and its relationship to debris flow initiation following the 2020 Apple, Bobcat, and El Dorado fires in Southern California

Presenter: Brandon Fong; Pennsylvania State University
Co-author: Roman A. DiBiase

Post-wildfire debris flows in southern California are often associated with the loading of channel networks with fine sediment transported by dry ravel, which is accelerated during and immediately following the burning of steep hillslopes. However, the magnitude of dry ravel loading in channels varies dramatically across geologic, climatic, and topographic settings in ways that are poorly constrained by existing hillslope sediment transport models. Here, we use multitemporal, high-resolution (<1 m) aerial lidar to track dry ravel loading following the 2020 Apple, Bobcat, and El Dorado Fires in Southern California, USA. Postfire dry ravel deposits were identified using automated point cloud change detection, hand mapping on post-fire slopeshade maps, and high-resolution (4-10 cm) orthoimagery. Estimates of catchment-averaged dry ravel yields were then compared against metrics of burn severity and topographic and geologic factors. We found that slope was the dominant control on dry ravel loading in channels, but for the same mean slope, dry ravel yield can vary by nearly an order of magnitude. We also mapped spatial patterns of debris flow scour following Tropical Storm Kay in 2022. Although debris flow scour correlated with spatial patterns of dry ravel loading in lowland regions, debris flows were also initiated in steep headwater channels with no dry ravel loading and in unburned catchments, due to localized high-intensity rainfall. Our results highlight how multitemporal change detection using airborne lidar enables tracking large scale (>100 km2) patterns in sediment routing following wildfire to better understand the controls on dry sediment loading following fire, the relationship to debris flow generation, and implications for improving postfire debris flow volume models.

5. Introducing the Watersheds & Wildfires Research Collaborative

Presenter: Brendan Murphy; Simon Fraser University
Co-authors: Patrick Belmont, Scott David, Larissa Yocom, Belize Lane, Jon A. Czuba, Muneer Ahammad, Justin Stout, Sara Wall, Alec Arditti, Haley Canham, Kipling Klimas, Paxton Ridgway, Jorrin Lenton, Casey Langstroth, Yanik Nill

The Watersheds & Wildfires Research Collaborative is an interdisciplinary, multi-university academic research group of faculty members, postdoctoral researchers, and students from Utah State University, Simon Fraser University, and Virginia Tech focused on advancing our understanding of the myriad, interconnected ways in which wildfires influence watershed processes, geohazards, and ecosystem services across western North America. The members of WWRC have experience and expertise in the disciplines of geomorphology, hydrology, fire ecology, climate science, and engineering with skillsets that include environmental monitoring and assessment, sediment transport mechanics, geospatial analysis, coding and software development, machine learning, and computational modelling. To date, the WWRC has received funding from the National Science Foundation, Joint Fire Science Program, US Forest Service, US Geological Survey, both Utah and Colorado Departments of Transportation, and others to advance our diverse, wildfire-focused research projects and the development of tools to support practitioners in the assessment and prediction of post-fire risks. Here, I will introduce recent and ongoing projects and research directions in our group, including field-based studies investigating: fire-induced soil hydraulic alteration (see Lenton et al.), predicting post-fire debris flow grain sizes (Wall et al., 2023), identifying controls on post-fire sediment connectivity (Arditti et al., in prep), the influence of channel dynamics on the evolution of post-fire sediment deposits (Lane et al., in review), and controls on the long-term erosion of debris flow deposits (Langstroth et al., in prep; Ridgway et al., in prep). Additionally, I will share about ongoing projects to develop novel approaches, models, and tools aimed at advancing capabilities in pre-fire risk assessment, including: analysis and prediction of post-fire rainfall-runoff response (Canham et al., in review), machine learning models to predict burn severity (Kipling et al., in review), and watershed-scale modeling frameworks to predict post-fire erosion and downstream sedimentation risks (see David et al.).

6. Reducing Post-Wildfire Debris Flow Risk Through Alluvial Fan Inventories and Outreach

Presenter: Brogan Kellermann, Cora Siebert; Washington Geological Survey
Co-authors: Kate Mickelson, Cora Siebert, Brogan Kellermann, Kara Fisher, Josh Hardesty, Emilie Richard, Mitch Allen

The Washington Geological Survey's Post-Wildfire Debris Flow Program conducts landslide hazard analyses in wildfire-prone counties of Washington in the form of lidar-based alluvial fan mapping and education outreach material. By mapping the extent of alluvial fans prior to wildfires, we can identify areas where property and lives may be at increased risk to debris flows and flash floods from future burn scars. Those living on or adjacent to alluvial fans are often unaware of the hazards and potential consequences associated with these landforms. As the size, frequency, and severity of wildfires increase, so do the hazards associated with alluvial fans. An inventory of alluvial fans provides critical information and awareness to planners, emergency managers, public works departments, and those who live or work where these hazards could impact their daily lives. Additionally, these inventories aid local governments, emergency responders, and residents in making educated decisions about their assets, hazard mitigation efforts, and growth management utilizing the best-available science. This poster highlights our alluvial fan mapping projects, ways our inventories are being utilized, and our novel approach to sharing our mapping and educating people about post-wildfire debris flow and flooding hazards (see our interactive story map outlining wildfires and alluvial fans in Klickitat County: https://experience.arcgis.com/experience/9202f7d5e81c427a85fdbc019bdfc0df/).

7. Estimating characteristic debris-flow discharge using channel geometry scaling relationships from steeplands

Presenter: Caleb Ring; University of Nevada, Reno
Co-authors: Scott W. McCoy, David B. Cavagnaro

Studies of fluvial systems around the world have demonstrated that river channel geometries increase with discharge and drainage area according to power laws. While it is understood that debris flows pose hazards to downslope communities and impact landscape evolution, little work has been done to develop similar scaling relationships for steep valley networks where debris flows are thought to be important. Using high-resolution satellite imagery, aerial imagery, and lidar differencing, we measured scoured channel widths of rainfall-runoff-generated debris flows at four recently burned areas across California, as well as from landslide-generated debris flows in Oregon, North Carolina, and southern California. When plotting scoured channel width versus upstream drainage area for study sites with runoff-generated debris flows, we observe a power law relationship with an exponent similar to that of fluvial systems. For debris flows initiated from landslides, scoured channel width does increase with drainage area, but at slower rate than runoff-generated debris flows. While there is variation between study sites, the multiplicative constant is notably larger than fluvial systems, indicating that debris flows scour channels that are systematically wider than their fluvial counterparts. We also examined the relationship between width and depth for cross-sections measured in the field or by lidar. We observe a relatively constant width-to-depth ratio for both initiation mechanisms, suggesting a characteristic width-to-depth ratio of self-formed debris-flow channels. With measurements of width, a relationship between width and depth, we assume a Froude-critical velocity and estimate the characteristic channel-forming discharge as a function of width. Using our width-drainage area scaling, we can estimate discharge as a function of drainage area and what the characteristic channel-forming discharge may be for a given landscape. Our results provide a new empirical description of key upper-network channel geometries that will be useful for modeling event-scale hazards and quantitative landscape evolution.

8. Comparisons between post-fire flood risk modeling and flood event observations - Lessons learned and potential ways to improve post fire flood risk modeling in Arizona.

Presenter: Chandler Adamaitis, JE Fuller; Joseph Loverich, JE Fuller Hydrology and Geomorphology, Inc.
Co-authors: Joseph Loverich, Michael Kellogg, Karlie Kessel, Gabrial Harju

The 2022 Pipeline Fire near Flagstaff burned approximately 26,000 acres, much of which was a reburn of the 2010 Schultz Fire. JE Fuller performed detailed flood risk modeling using FLO-2D to assess the post fire flood risk in the downstream drainages and developed areas. In addition, JE Fuller installed a dense network of rain gages, stream gages, and cell cameras on the primary drainages to monitor and collect runoff event data. Post-fire flood events were documented through Coconino County drone footage, field observations and remote sensing equipment. Using these observations and the rainfall event data, experienced inundation limits were compared to modeled inundation limits. These comparisons help to inform improvements in immediate post-fire hydrologic and hydraulic modeling as well as provide insight into why flow patterns may have been different than modeled results. Some of those reasons include watershed saturation, debris flow to flood event transitions, channel incision and debris flow deposits, and sediment and debris content of the flood waters.

9. Investigating effects of terrain and recent fire history on sediment yield from burned watersheds using repeat airborne lidar

Presenter: Corey Crowder; University of Arizona
Co-authors: Luke McGuire, Francis Rengers, Ann Youberg

Mountain watersheds burned by wildfires experience higher rates of erosion relative to similar unburned areas and are more susceptible to debris flows. Increases in debris flow activity and sediment yield following fire can have negative impacts on people, infrastructure, and aquatic habitat. Quantitative relationships between postfire sediment yield, terrain attributes, soil burn severity, and rainfall can be used to inform postfire hazard assessments and improve our ability to mitigate negative impacts of fire. In this study, we quantified the volume of sediment eroded from 22 small watersheds (0.12 km 2 to 3.8 km2) during the first rainy season following the 2022 Pipeline Fire in northern Arizona. The majority of the area was also burned by the 2010 Schultz Fire allowing us to examine differences in sediment yield among watersheds that burned only in 2022 relative to those that burned in 2010 and 2022. We quantified the sediment volume eroded from each watershed using digital elevation models derived from airborne lidar taken before (16 August 2019) and after (12 October 2022) the Pipeline Fire. We found that substantial volumes of sediment were mobilized in the first four months following the Pipeline Fire. There was substantial variability in the sediment volume eroded among the 22 watersheds, with 900 m3 being eroded from one watershed with an area of 0.12 km2 and 300,000 m3 being eroded from a watershed with an area of 3.8 km2. Volume eroded increased as a power law function of watershed area with an exponent of approximately 1.2. Ongoing efforts focus on exploring how rainfall, terrain, and recent fire history effect sediment yield.

10. Post-fire soil response and recovery of chaparral ecosystems in Northern California (USA)

Presenter: Corina Cerovski-Darriau; U.S. Geological Survey
Co-authors: Kimberlie Perkins, Courtney A. Creamer, Jeffrey P. Prancevic, Tyler Doane, Jonathan D. Stock, Allegra Baird, Nikka Pauline Pacifico, Lauren Holzman

Wildfires can create novel soil conditions by altering soil hydrological and biogeochemical processes. In the spatially extensive and fire-prone Northern California chaparral it is unclear how belowground processes are impacted by severe wildfire. Here we seasonally quantifying soil infiltration, soil organic matter, and soil biota since the 2020 LNU Lightning Complex and the 2021 Dixie Fires across multiple lithologies (intrusive and extrusive volcanics, metamorphic and sedimentary). By comparing burned soils to nearby unburned refugia through time, we aim to characterize the short and long-term impact of wildfire on soil infiltration and biogeochemical process rates within geologically diverse chaparral ecosystems. We used a variety of repeat hydrologic conductivity measurements, including sprinkling, tension disk, and falling head. After several seasons of post-fire hydrological observations, we found, compared to unburned test sites, chaparral sites mostly showed increased infiltration rates immediately post-fire and progressively return to unburned rates within ~2 years. Soil biogeochemistry was measured by total carbon (C) and nitrogen (N) content as well as two proxies of organic matter process rates—dissolved organic matter and microbial biomass. Although total C and N were similar between burned and unburned soils, the biota as measured by dissolved organic matter and microbial biomass were strongly impacted by wildfire. Instead of a progressive recovery through time, these organic carbon pools followed seasonal variations in soil moisture, with distinct relationships between water content and organic carbon in burned and unburned soils. The higher initial infiltration rates at the burned sites, further suggests that changing soil moisture may be a critical component of biogeochemical cycling after wildfire in these ecosystems. Understanding the interaction between rocks, microbes, and water is key to identifying areas of elevated risk post-fire and helping prioritize post-fire mitigation using scarce resources.

11. Environmental controls on regional postfire soil hydrology and runoff response across the Western U.S.

Presenter: Danica Roth; Colorado School of Mines
Co-authors: Cornelis Reijm, Caroline Bedwell, Matthew A. Thomas, Scott W. McCoy, David B. Cavagnaro

Prolonged drought conditions in the Western U.S. have increased wildfire occurrence since the 1980s and intensifying rainstorms have exacerbated the associated hydrogeomorphic hazard potential. Previous research demonstrates regional differences in postfire hydrogeomorphic hazard processes, often attributed to variation in climate, vegetation, or soil characteristics. However, hazard models currently do not account for the mechanistic effects of these variables. In arid regions like Southern California, some studies have shown that fire can create short-lived surface hydrophobicity, which increases runoff-driven erosion and runoff-generated debris-flow hazards during intense rainfall soon after fire. Models calibrated using data from these arid climates may overpredict runoff-generated postfire hazards in the humid Pacific Northwest, where debris flows more commonly initiate several years after fire, when root decay leaves soils vulnerable to shallow landsliding. As modern wildfire and drought regimes shift, these regional reference frames may also evolve. Here, we use uniformly reanalyzed field measurements and remote sensing data from over 30 fires across the Western U.S. to investigate environmental controls on regional postfire soil hydrology and runoff response. We use principal component analyses to examine regional differences in pedological, lithological, climatic, and biotic variables, as well as their correlations with postfire soil hydrology. These insights inform a reduced complexity rainfall partitioning model parameterized with key environmental variables and field-measured soil-hydraulic properties.

12. The spatial distribution of debris flows in response to observed rainfall anomalies: insights from the Dolan Fire and three other fires in California

Presenter: David Cavagnaro; California Geological Survey

Co-authors: Scott W. McCoy, Matthew A. Thomas, Jaime Kostelnik, Don N. Lindsay

A range of hydrologic responses can be observed in steep, recently-burned terrain, but predicting the type of flow that will debouch from any particular basin is challenging. Studies of mass-movement processes in unburned areas indicate that the location of events is well-predicted by rainfall anomaly maps, in which peak event rainfall is normalized by local climatological metrics. In this study, we use the 2020 Dolan Fire, which burned ~520 km2 across a sharp climatological gradient in coastal California and saw widespread flooding and debris flows during a subsequent rainfall event, as a natural experiment to test the applicability of short-duration rainfall anomaly in explaining postfire debris-flow location. We demonstrate that rainfall anomaly predicts debris-flow location more effectively than peak rainfall across the diverse hydroclimates of the Dolan Fire burn area. Furthermore, combining this workflow with existing models in a logic-based framework, in which an existing predictive model is only applied in areas which received anomalously high rainfall, improves model accuracy. We also test the rainfall anomaly workflow at three other fires to demonstrate its utility across diverse climates. To provide further context for the utility of rainfall anomaly calculations, we analyze the hydroclimatic variability within individual fires across four decades of historic fire perimeter data and suggest that intra-fire differences in climate should be considered when forecasting debris-flow hazard, especially as climate change continues to increase the size and geographic scope of severe wildfire.

13. A catalog of field-verified postfire debris flows in California

Presenter: Derek Cheung; California Geological Survey

Co-authors: Nina S. Oakley, Donald N. Lindsay

Postfire debris flows threaten life, property, and infrastructure throughout California. Mitigation of postfire debris-flow hazards requires knowledge of where and when they are occurring as well as their characteristics and impacts. Previously, this information was spread across disparate sources such as scientific publications, agency reports, and media accounts. To address this issue, we are developing a catalog that aggregates field-verified postfire debris-flow events in California from these various sources from the year 2000 to present. In this first phase of catalog development, we identify storm events that triggered postfire debris flows and basic characteristics of the event such as fire name and location, event date, debris flow initiation times, number of debris flows, impacts, and rainfall intensities when available. We use this information to explore the spatial and seasonal distribution of postfire debris flows across the state, and how impacts vary regionally. In future phases of the catalog, we will identify the location of each individual debris flow, further constrain triggering rainfall intensities where possible, and include more detailed analyses of flow characteristics. Based on the challenges we experienced developing this catalog, we provide recommendations for documentation of postfire debris-flow events to facilitate their inclusion in catalogs.

14. The use of High Frequency Ground Penetrating Radar (HFGPR) to enable the evaluation of watershed recovery rates associated with post-fire changes in water repellent (hydrophobic) soil layers in burnt watersheds in Southern California

Presenters: Frank A. Weirich Weirich Imaging, and Frank H. Weirich, University of Iowa
Co-author: William Neumann

It has long been recognized that the development of fire-related hydrophobic (water repellent) soil layers can lead to significantly increased rates of storm runoff and erosion in a wide range of environmental settings and directly contribute to increase risk of debris flows. Moreover, the effects of water repellent soil layers can also persist for three to five years or longer. Our capacity to assess changes in the presence, depth, spatial extent, and persistence of the hydrophobic soil layer over time using conventional methods such as the WDPT, and MIDI, while useful, have proven to be logistically and operationally challenging. The limitations of these methods have constrained the efforts to effectively evaluate and model recovery rates and the associated debris flow risks. In order to address some of these limitations, we have developed an approach that involves the use of High Frequency Ground Penetrating Radar (HFGPR). The HFGPR method is non-invasive, efficient, site-specific and repeatable and images a wider area of the soil subsurface than other conventional approaches. The resulting radargrams document the depth, continuity, persistence and spatial variability of the hydrophobic soil surface and have been used to document these changes over time. The resulting data can be presented in the form of a high resolution 2D or 3D image of the hydrophobic surface with a sample density on the order of 1000 sample points per square meter. Some example imagery collected at a variety of post-fire sites in Southern California are presented.

15. Modeling Compositional Influence on Debris-Flow Runout

Presenter: Hayden Jacobson; Colorado School of Mines
Co-authors: Gabriel Walton, Katherine R. Barnhart, Francis Rengers

In high-relief regions prone to debris-flow activity, predicting debris-flow runout is a key component of hazard assessments. There is evidence of variability in debris-flow runout due to parameters such as volume and composition (e.g., grain size distribution, water content). These parameters not only vary with geographic location, but with the mechanism of debris-flow initiation.

To evaluate the hazard presented by debris flows, numerical models may be used to simulate debris-flow runout. One current limitation is the lack of a formal connection between field-measurable quantities (e.g., grain size distribution) and runout model parameters. This limitation may hamper application to areas without historical observations.

To advance model representation of debris-flow hazards, we used a numerical model to recreate a series of debris-flow flume laboratory experiments in which composition and volume were varied. We conducted these numerical experiments with D-Claw, a finite-volume model capable of representing both solid and fluid material fractions. In this model, variable grain size fractions were represented by up to two species of material with different permeabilities. As the solid volume fractions of the mixture varied during flow, the hydraulic permeability and granular dilation rate evolved as functions of the volume fractions. This influenced the co-evolving pore-fluid pressure and flow resistance. The flow behavior was therefore dependent on the initial composition of material.

The results of these experiments provide insight on how to best represent grain size distribution in future debris-flow runout analyses. We also use the calibrated models to explore the effect of debris-flow compositions outside of those originally conducted in the laboratory and explore scaling impacts related to flow depth by considering dimensionless parameter combinations that describe the flow regime. These results have important implications for improving model calibrations for postfire debris flows.

16. Evaluation of Post-Fire Debris Flow Hazards for Salvage Logging Following the Labor Day Fires of 2020 in Western Oregon

Presenter: Jason Hinkle, Rachel Pirot; Weyerhaeuser
Co-authors: S.C. Shaw, R. Pirot, T.R. Turner, T.E. Justice

The historic Labor Day Fires of September 2020 burned over 850,000 acres in western Oregon. Four of the fires burned 125,000 acres owned by Weyerhaeuser. The timber company promptly initiated a massive salvage operation to harvest dead and dying trees within a two-year window before the wood began to rot. Company geologists provided guidance for managing and mitigating potential fire-related soil erosion and debris flow hazards.

Geologists utilized USDA soil burn severity maps, USGS debris flow models, USFS Burned Area Incident Reports, post-fire imagery, and preexisting LiDAR-based topographic data to conduct office-based evaluations and focus field investigations. Basins were qualitatively ranked based on the hazards and associated risk to residential structures and public roads, forest worker safety, and sediment delivery to streams. Geologists made recommendations regarding logging methods and timing, including avoiding timber salvage on some of the highest risk sites. Salvage operations in many basins were deferred during the first winter to see how burned slopes would respond to wet season conditions.

Increased soil erosion and debris flow activity were anticipated within the first two years post-fire. Loss of organic soil horizons, localized pockets of hydrophobic soils, and the widespread emergence of groundwater pipes created by burned-out root systems and buried logs were observed. Few debris flows were noted during that timeframe. Debris flow activity has since increased, primarily associated with road failures due to fire-related debris clogging ditches and culverts. The minimal debris flow activity initially observed might have resulted from a lack of high-intensity or long-duration storms, persistent drought since 2015 and correspondingly low antecedent soil moisture conditions, and the behavior of permeable loamy soils prevalent in the region. More research is needed to understand the post-fire response of the western Oregon landscape and calibrate debris flow models using physical parameters specific to the region.

17. Potential of smartrocks for understanding debris flow transport mechanics, and fire forecasting from climate models

Presenter: Joel Johnson; Dept. of Earth and Planetary Sciences, The University of Texas at Austin
Co-author: Danielle Touma

I will present work relevant to two aspects of post-fire debris flows. First, instrumented tracer clasts—“smartrocks”—can measure unique and otherwise difficult-to-measure data sets from Lagrangian reference frames from within surface transport events. Data from both natural snowmelt floods in field settings, and also from debris flow experiments in a rotating drum flume, show the potential of this approach to constrain grain interactions. At the same time, many challenges (battery life, downloading from smartrocks after events, cost) limit their widespread applicability. Their use in controlled settings, including field experiments, can provide useful constraints and calibrations for indirect monitoring methods such as environmental seismicity. Second, I highlight work by collaborator Dr. Danielle Touma using climate models to predict how forest fire probabilities will change with anthropogenic climate change. We are beginning a project to combine climatological fire forecasting and surface process models to evaluate future “hot spots” where both climatic factors and geomorphic characteristics of landscapes combine to increase risks of cascading hazards from wildfires, including debris flows.

18. Assessment of a Post-Fire Debris Flow Impacting El Capitan Watershed, Santa Barbara County, California, U.S.A.

Presenter: Jonathan Yonni Schwartz; U.S. Forest Service
Co-authors: Nina S. Oakley, Paul Alessio

In the summer of 2016, the Sherpa Fire burned 30.2 km^2 in steep terrain in western Santa Barbara County, California. Rainfall events in the subsequent wet season produced damaging post-wildfire flooding and debris flows. This poster presents a case study along a watershed within the burned area, El Capitan Creek, that (1) describes the events and conditions that led to the post-wildfire flooding and debris flow events, and (2) documents the debris flow deposits and inundation zone impacted by the events. Observations compiled after three post-wildfire precipitation events indicate that three distinct flow processes impacted El Capitan Creek between 19 and 22 January 2017. These flow processes included watery flows, hyper-concentrated flows, and debris flows. The velocity and concentrated nature of these flows caused overbanking and channel avulsions that resulted in damaged roads, bridges, pipelines, and major infrastructure damage to the El Capitan Canyon Resort.

These events occurred only 1 year prior to the devastating Montecito debris flows of 2018 and call attention to the conditions that produced these impactful flows and highlight the timing and conditions that generate post-wildfire debris flows. Information from case studies such as this can guide decision makers and emergency managers to understand the hazards and risks those floods, and debris flows pose on communities below steep mountain drainages and support the development of sound protocols to help reduce the threat to life, property, and infrastructure in downstream communities.

19. Post-fire Debris Flow Monitoring and Observations from 2022 and 2023 in Washington State

Presenter: Josh Hardesty, Kara Fisher; Washington Geological Survey
Co-authors: Emilie Richard, Mitch Allen, Kate Mickelson

Until recently, little research on post-fire debris-flow processes has been done in Washington State. Initial work in other areas of the Pacific Northwest shows that current models used for emergency post-fire debris-flow hazard assessment, which were developed with data from outside the region, may be less accurate for Washington's geology and climate. The Washington Geological Survey (WGS) is working to better understand post-fire debris-flow processes in Washington State to (1) improve models for hazard assessment in the region, and (2) refine estimates of triggering rainfall thresholds that are used for early warning in the years following a fire. To accomplish this work, WGS is currently building an inventory of debris flow activity in recent burn areas in Washington State and collecting associated weather data. We monitored 13 burn scars during 2022 and 2023. In our first year of monitoring, we recorded 26 debris flows and 29 hyperconcentrated flows on 6 of the burn scars. The following year, we observed 18 debris flows, and 4 hyperconcentrated flows over 5 burn scars. We plan to continue monitoring these areas for several years post-fire to better determine the window of increased debris flow risk following a burn.

20. Evaluation of debris-flow building damage forecasts

Presenter: Katherine Barnhart, U.S. Geological Survey
Co-authors: Christopher R. Miller, Francis K. Rengers, Jason W. Kean

Reliable forecasts of building damage due to debris flows may provide situational awareness and guide land and emergency management decisions. Application of debris-flow runout models to generate such forecasts requires combining hazard intensity predictions with fragility functions that link hazard intensity with building damage. In this study, we evaluated the performance of building damage forecasts for the 9 January 2018 Montecito postfire debris-flow runout event, in which over 500 buildings were damaged. We constructed forecasts using either peak debris-flow depth or volume flux as the hazard intensity measure and applied each approach using three debris-flow runout models (RAMMS, FLO-2D, and D-Claw). Generated forecasts were based on combining multiple simulations that sampled a range of debris-flow volume and mobility, reflecting typical sources and magnitude of pre-event uncertainty. We found that only forecasts made with volume flux and the D-Claw model could correctly forecast the observed number of damaged buildings and the spatial patterns of building damage. However, the best forecast only predicted 50 % of the observed damaged buildings correctly and had coherent spatial patterns of incorrectly forecast building damage (i.e., false positives and false negatives). These results indicate that forecasts made at the building level reliably reflect the spatial pattern of damage, but do not support interpretation at the individual building level. We found the event size strongly influences the number of damaged buildings and the spatial pattern of debris-flow depth and velocity. Consequently, future research on the link between precipitation and the volume of sediment mobilized may have the greatest effect on reducing uncertainty in building damage forecasts. Finally, because we found that both depth and velocity are needed to forecast building damage, comparing debris flow models against spatially distributed observations of building damage is a more stringent test for model fidelity than comparison against the extent of debris-flow runout.

21. Investigating Changes in Erosivity Along the Path of Post-Wildfire Debris Flows

Presenter: Lauren Guido; Colorado School of Mines
Co-author: Paul Santi

Combining remote sensing with spatial and statistical analyses, we investigate changes in the yield rate, or erosion, along the path of post-wildfire debris flows. Previous research has identified threshold locations where yield rate can suddenly increase by over 100%, substantially increasing the final debris-flow volume and hazard. The primary objectives of this research include (1) using remote sensing data to identify and quantify yield rate thresholds in post-wildfire settings, (2) evaluating the role of topographic, hydrologic, and fire parameters in the occurrence of yield rate thresholds using satellite and aerial data, and (3) assessing the impact of these parameters on modeled physical flow properties (i.e. velocity, viscosity, density) to better quantify the governing processes of yield rate threshold occurrence and inform hazard assessment and mitigation decisions. The work presented here focuses primarily on the methods and results of high resolution intra-channel remote sensing change detection and their comparison to yield rates observed in field data, as well as initial results of the evaluation of topographic and fire parameters on the occurrence of yield rate thresholds.

The scope of this research includes change detection and geometric channel analyses of debris flows across burn areas in the western United States identifying the locations of yield rate thresholds. The locations of yield rate thresholds are correlatively compared with topographic, hydrologic, and fire parameters of the site, as well as their variation within the channel. Ongoing work includes developing working hypotheses based on correlation data and the physical understanding of debris flows to develop proposed causal relationships for the occurrence of yield rate thresholds. Using these causal relationships, we assess the importance of the site factors identified on modeled physical flow derivatives, including velocity. Broader implications of this work include a deeper knowledge of hazard magnitude and mitigation options in the western Unites States.

22. Wildfire burn severity and post-fire debris flow runout modeling for highway resiliency planning

Presenter: Madeline Hille; BGC Engineering
Co-authors: Joseph Gartner, Gemma Ferland, Sai Siddhartha Nudurupati, Suyog Chaudhari, Karen Williams, Mark Vessely, Thomas Walsh, Becky Rude

Transportation agencies can improve the performance of critical highways exposed to post-fire debris-flow hazards by incorporating resiliency into infrastructure improvement plans. Modeling potential volumes and runout extents of post-fire debris flows can inform decisions to change roadway alignments, conveyance structure size and location, and operations such as maintenance and emergency response. The Northeast Entrance Road (NER) in Yellowstone National Park is both a critical year-round travel route for communities and a high-volume tourist destination. Following the 2022 flooding event, and to build resiliency into the corridor, BGC Engineering and Jacobs Engineering were tasked with identifying areas that could be susceptible to both pre and post wildfire debris flows. The analysis included modeling wildfire likelihood, burn severity, and post-fire debris-flow volumes and runout for 13 catchments along the NER. Wildfire likelihood and burn severity were forecasted by Jacobs Engineering for the years 2040 and 2070, considering two Representative Concentration Pathways (RCPs) following Vilar et al. (2021). Post-fire debris-flow volumes were modeled by BGC Engineering following Gartner et al. (2014) for each of three scenarios representing low, moderate, and high hazard represented by RCP 4.5 in 2070, RCP 8.5 in 2040, and an assumption that 90% of each watershed burns at moderate to high severity, respectively Runout extents were modeled using the Progressive Debris-Flow routing and inundation model (ProDF) (Gorr et al, 2022) and calibrated with field observations and dendrochronology of debris-flow deposits. Modeled post-fire debris-flow extents fall within the bounds of mapped alluvial fans and in most cases, beyond recent (<100 years) observed deposits, suggesting that the post-fire scenario is consistent with expected volumes and runout of low-frequency debris flows in this terrain. Results from this study are informing roadway design and resilience planning for debris-flow hazard that are not typically considered in standard hydrological and geotechnical design practices for highways.

23. Geologic and wildfire controls on debris flow hazard in steep volcanic catchments

Presenter: Maryn Sanders; University of Oregon
Co-authors: Josh Roering, William Burns, Nancy Calhoun, Ben Leshchinsky

Hazards occur on rapid timescales within landscapes that have evolved over geologic timescales, and our capacity to predict hazards depends on marrying these timescales to understand how geomorphic processes shape terrain. The western Columbia River Gorge (WCRG) is historically (<150 years) infamous for destructive debris flows initiated by high-intensity precipitation events, and debris flow fans from these basins suggest continued activity throughout the Holocene. In September 2017, the Eagle Creek Fire burned nearly 50,000 acres in the WCRG at variable intensity and differential lidar mapping revealed an increase in debris flow frequency following the fire. Here, we quantify the extent to which variable climate disturbances (i.e. storms, fire) and pre-historic geologic events affect sediment yields in ten small catchments near Nesmith Point, a Cascade range volcanic edifice, by calculating erosion rates over intervals ranging from 10^0 to 10^6 years. We quantify rates by reconstructing the Nesmith Point edifice since the last eruption (~0.923 Ma), quantifying volumes of fans accumulating since the Missoula Floods (~13 kya), and using differential lidar to map pre- and post-fire debris flow volumes (1-9 years). Erosion rates since the Missoula Floods range from 2.0 to 12 mm per year and vary nonlinearly with basin-averaged slope. The long-term fan rates exceed the 10^6 edifice reconstruction rate by >1 order of magnitude. Post-fire debris flow erosion rates are of similar order of magnitude to the fan volume rates, while pre-fire erosion rates are similar to the edifice reconstruction rate. Further analysis of debris flow events occurring in 2021 show a doubling of event volume an unburned to a burned catchment for the same storm. Although the region may be predisposed to regular debris flows due to its geologic history, fire may increase the likelihood of catastrophic events via volume increase.

24. San Francisco Peaks Pre-Wildfire Assessment of Post-Fire Risk

Presenter: Michael Kellogg; University of Arizona/Arizona Geological Survey
Co-authors: Joseph Loverich, Karlie Kessel

Coconino County has experienced numerous catastrophic fires within the last 13 years on the San Francisco Peaks (SF Peaks) and Mount Elden. Post-fire flooding originating from the burn scars has caused significant damage to neighborhoods within the City of Flagstaff and unincorporated Coconino County. A portion of the Rio de Flag Watershed is within the planning area of the Four Forest Restoration Initiative (4FRI) and forest treatment is currently scheduled for numerous units.

To better understand the potential post-fire flood risks to the Rio de Flag floodplain and its tributaries that originate from the Peaks, JE Fuller has performed a pre-wildfire assessment of post-fire flood risk using different fire burn scenarios that affect the watershed. Results from this study have identified areas that have the highest risk for post-fire flooding. These results can be used to develop mitigation strategies to reduce the risk of life and property from post-fire flows, as well as aid the U.S. Forest Service (USFS) in determining key areas for targeted fuel reduction treatments.

Many initial post-fire events can carry significant sediment and debris loads which bulk runoff volumes and can influence flow patterns and levels of risk. The volume of debris can change from storm to storm and once deposited it will affect the flow patterns of the next runoff event. Modeling hyper-concentrated and debris flow events are challenging given the current state of the science, and communities are often reluctant to map these types of risks due to the uncertainty in the analyses. Bulking of flow can be a reasonable proxy for the additional volume of sediment and debris but may not accurately simulate the non-Newtonian behavior. One approach to meet this challenge is to model multiple storm and burn scenario events and overlay all the results to establish a “combined probability” risk product.

25. Predicting potential postfire debris-flow hazards in California prior to wildfire

Presenter: Paul Richardson; California Geological Survey
Co-authors: Rebecca Rossi, David Cavagnaro, Stefani Lukashov, Mary Ellen Miller, Donald Lindsay

Wildfires and consequent postfire geohazards are a major threat to California communities. One of the more impactful postfire hazards is runoff-induced debris flows that are common in the first few years following fire and have caused significant damage to critical infrastructure, economic loss, and loss of life. To help prefire planning efforts in California, we identified areas that are most susceptible to postfire debris flows before fire occurs. Predicting postfire geohazards is complicated by our inability to accurately predict spatial patterns of fire severity. Due to these challenges, we used a simple burn severity model developed by the US Geological Survey (USGS) that relates existing vegetation type (EVT) to differenced Normalized Burn Ratio (dNBR) to predict the most common burn severity behavior for each EVT category. We used the resulting simulated dNBR values and corresponding simulated Burned Area Reflectance Classification (BARC) maps to inform a postfire debris-flow model developed by the USGS. In addition to the simulated burn severity values, the debris-flow likelihood model requires digital elevation and soil erodibility data—both known prior to wildfires—and precipitation intensity. We used a fixed 15-minute rainfall intensity rate of 24 mm/h, a commonly used triggering precipitation intensity threshold for debris flows in California. We split California into ten geomorphic regions and calibrated the burn severity model to each region using EVT, dNBR, and BARC data for wildfires that occurred during 2020 and 2021. We also explored how well the predicted debris-flow likelihoods with simulated dNBR match debris-flow likelihoods predicted with observed dNBR for 2020-2021 Californian wildfires. Although actual wildfire dNBR values and patterns are likely to vary from our simulated products, we show that applying a consistent methodology is useful for identifying areas that are likely to pose the greatest postfire hazards, which should help focus prefire mitigation in California.

26. River corridor response to post-wildfire Debris Flows in a mountain stream in the Upper Colorado Basin, USA

Presenter: Paxton Ridgway; Utah State University
Co-author: Belize Lane

Incidence of wildfire increases sediment input to rivers through many pathways, including via discrete perturbations such as post-fire debris flows. Since sediment supply is a dominant control on river morphology, understanding mountain river responses to sediment regime perturbations is critical to predicting and addressing downstream impacts on infrastructure, water security, and aquatic habitat. A growing body of literature explores the causes and characteristics of post-fire debris flows, but the morphological changes to downstream fluvial channel type, magnitude, and persistence - associated with these disturbances remain poorly studied. This study applied scripted spatial analysis toolsets to high-resolution pre- and post-fire DEMs, repeat cross-sectional surveys, time-lapse footage, and pebble counts to chronicle channel response to punctuated delivery of sediment supply to a burned mountain watershed in the upper Colorado River Basin, USA. We document the re-working of DF material deposits, the primary drivers of mobilization by spring snowmelt versus summer monsoon, and potential geospatial controls on geomorphic response. Initial categorical types of channel change along the entire 8-km study reach were correlated with corridor and valley-scale attributes, indicating the potential for predicting controls on these responses within other fire-prone watersheds. Following initial DF events, numerous DFs were initiated again three years post-fire, delivering another sediment pulse to the study reach from both new and repeat sub-drainages. While channel surveys following snowmelt peaks had suggested rapid corridor re-adjustment towards pre-fire geometry prior to the second major sediment input, continued monitoring following subsequent rounds of sediment disturbance emphasizes lasting vulnerability that extends the recovery timeline. These findings highlight the importance of long-term field and remote sensing-based channel analysis to improve understanding of mountain channel response to post-fire debris flows.

27. Assessing a novel flood mitigation strategy below the 2022 Pipeline burn area, Flagstaff, Arizona

Presenter: Rebecca Beers; Arizona Geological Survey at the University of Arizona
Co-authors: Ann Youberg, Luke McGuire, Peter Robichaud, Edward Schenk

Communities in the wildland-urban interface (WUI) are subject to significant impacts from wildfires and subsequent post-fire flooding. Indeed, past post-fire floods have resulted in fatalities and costly damage to property and infrastructure, prompting a need for enhanced community resilience through post-fire flood mitigation. Traditionally, mitigation efforts consisted of constructing detention basins in watersheds to retain sediment and water from runoff events. However, as post-fire flooding becomes more prevalent in WUI communities, new flood mitigation strategies are being evaluated.

Near Flagstaff, Arizona, WUI communities have experienced significant flooding following the 2022 Tunnel and Pipeline Fires, prompting the Coconino County Flood Control District (CCFCD) to construct eight novel food mitigation structures in watersheds upstream of impacted neighborhoods. The novel mitigation strategy reshapes existing alluvial fans and floodplains, creating broad, low-relief surfaces in an effort to slow flood-flow velocities and promote infiltration and sediment deposition upstream of vulnerable communities.

We assessed the efficacy of the novel mitigation strategy below the Pipeline burn area during the 2023 monsoon though repeat structure-from-motion surveys (SfM) and sediment analysis. During this period, two intense, short-duration rain events occurred over the Lenox mitigation structure headwaters. The first event on July 30th, 2023, had a peak 15-minute rainfall intensity (I15) of 93 mmhr-1, and the second event on September 2nd had a peak I15=53 mmhr-1, resulting in a debris flow and hyperconcentrated flow, respectively. Our SfM surveys show that while sediment deposition occurred on the upper third of the Lenox structure, erosion dominated the lower two-thirds, resulting in a net loss of 1,000 m3 of sediment following the July 30th event, and a net loss of 175 m3 after the September 2nd event. Our results indicate that the Lenox structure sourced more sediment than was deposited and the strategy may not be appropriate in this steep, relatively confined setting.

28. Expanding postfire debris flow monitoring in California to improve geohazard predictions

Presenter: Rebecca Rossi; California Geological Survey
Co-authors: Paul Richardson, Nina S. Oakley, David Cavagnaro, Kevin Callahan, Derek Cheung, Donald Lindsay

In many areas of California, postfire floods and debris flows pose a threat to life, property, and infrastructure downslope of steep, burned watersheds. The California Geological Survey's Burned Watershed Geohazards (BWG) Program is implementing postfire monitoring to expand our ability to predict postfire hazards and associated impacts. The monitoring consists of instrumenting recent burn areas with rain gages, pressure transducers, and stream gages to collect precise observations of flood and debris-flow triggering rainfall and to quantify rainfall and runoff conditions across a range of hydrogeomorphic regions throughout California. This will be paired with observations of inundation and runout to better calibrate hydraulic models used to identify hazard zones and inform strategies to mitigate the risk within the downslope built environment. Postfire hazards may persist several years after fire, with a transition from runoff-induced to landslide-induced hazards after the first 3-5 years. Through monitoring of vegetation recovery and soil infiltration and runoff characteristics, BWG will improve our understanding of how hazards change through time. These monitoring efforts are in collaboration with partners at academic institutions and local, state, and federal agencies with the goal of implementing consistent postfire monitoring methods statewide. Monitoring outcomes will support improved situational awareness and early warning of postfire hydrologic hazards.

29. The transition from post wildfire debris flow susceptibility mapping to tactical mitigation responses and strategies

Presenter: Richard Guthrie; Stantec
Co-authors: T. Wasklewicz, G. Knibbs, A. Buechi

This poster is a process map with specific examples that takes readers from the early post-wildfire debris flow susceptibility through to mitigation strategies. Using practical advice and case studies, we outline how to create debris flow scenarios (expected number of debris flows for given a precipitation event), model runout (including calibration) for the post wildfire setting using DebrisFlow Predictor, calculate inundation probabilities, volumes, and predicted velocities. We provide practical useable advice and strategies for monitoring and mitigation. We note that much of the work can be done immediately after a fire and before the debris flow hazards have materialized thereby increasing local resilience to wildfire hazards.

30. Post-wildfire sediment cascades and reservoir vulnerability

Presenter: Scott David; Utah State University

Co-authors: Brendan P. Murphy, Patrick Belmont, Jon A. Czuba, Belize A. Lane, Haley A. Canham, Larissa L. Yocum, Kipling Klimas, Casey Langstroth

Post-fire debris flows (PFDFs) may represent only the first in a cascade of hydrogeomorphic sediment-related hazards that can extend well beyond the boundaries of the fire and persist for years. In particular, when large magnitudes of sediment eroded by PFDFs are delivered to river networks, sediment will be transported downstream, potentially impacting transportation and utility infrastructure, aquatic ecosystems, and reservoir water storage capacity. To improve our ability to predict post-wildfire erosion and sedimentation, we present a new, comprehensive watershed-scale modeling framework, Fire-Watershed Assessment Toolkit for Erosion and Routing (Fire-WATER). Fire-WATER is a GIS-based framework that: 1) incorporates new watershed delineation tools, 2) predicts burn severity using a new machine-learning model, 3) integrates and links models that predict post-fire hillslope erosion, debris flow erosion, and river sediment delivery, and 4) models downstream sediment transport via Lagrangian, physics-based network sediment routing. We demonstrate the utility of Fire-WATER for identifying sub-catchments that represent persistently high sources of debris flow sediment to critical water-supply reservoirs in Salt Lake City, Utah, USA under a range of conditions. Our spatially-explicit modelling of watershed-scale sediment connectivity to downstream reservoirs across various scenarios of burn severity and post-fire hydrology is a critical step forward for developing more targeted pre-fire fuel treatments to mitigate reservoir sedimentation risks. Finally, we present a state-wide analysis for Utah’s 130 critical water supply reservoirs to assess vulnerability to post-wildfire sedimentation under low and high scenarios of potential burn severity and post-fire hydrologic conditions. The results indicate that 10% of Utah’s reservoirs could experience reductions in their constructed storage capacity of 10% or greater if their upstream catchments burn during more extreme fire weather conditions. Further, if these watersheds burn within the next 50 years, the added wildfire-related inputs could reduce projected reservoir capacity in the state by an additional 8% by 2060.

31. Rainfall thresholds for postfire debris-flow initiation vary regionally with hydroclimate

Presenter: Scott McCoy; University of Nevada, Reno
Co-authors: David B. Cavagnaro, Donald N. Lindsay, Luke A. McGuire, Jason W. Kean

The size, frequency, and geographic scope of severe wildfires are expanding across the globe, including in the Western U.S. Recently burned steeplands have an increased likelihood of debris flows, which pose hazards to downstream communities. The conditions for postfire debris-flow initiation are commonly expressed as rainfall intensity-duration thresholds, which can be estimated given sufficient observational history. However, the spread of wildfire across diverse climates poses a challenge for accurate threshold prediction in areas with limited observations. Studies of mass-movement processes in unburned areas show evidence that initiation thresholds vary with local hydroclimate, such that higher rainfall rates are required for initiation in wetter climates characterized by frequent intense rainfall. Here, we use three independent methods to test if postfire debris-flow initiation across the Western U.S. varies in a similar fashion. Through compilation of observed thresholds at various fires, analysis of the spatial density of observed debris flows, and quantification of feature importance at different spatial scales, we show that debris-flow initiation thresholds across the Western U.S. vary systematically with short-duration rainfall-intensity climatology. The predictive power of climatological datasets that are readily available before a fire occurs offers a much-needed tool for hazard management in regions that are facing increased wildfire activity, have sparse observational history, and/or have limited resources for field-based hazard assessment. Furthermore, if the observed variation in thresholds reflects long-term adjustment of the landscape to local hydroclimate, rapid shifts in rainfall intensity related to climate change will likely induce spatially variable shifts in postfire debris-flow likelihood.

32. Prefire Assessment of Postfire Debris Flow Hazards near Flagstaff, Arizona: Insights from Debris Flow Runout Modeling and Climate Change Implications

Presenter: Tanner Johnson; University of Arizona, University of Texas – Austin
Co-authors: Luke McGuire, Alexander Gorr

We use debris flow volume and runout models to conduct a prefire assessment of postfire debris flow hazards in an area near Flagstaff, Arizona. We calibrated model parameters through a back-analysis of a nearby debris flow that initiated after the 2022 Pipeline Fire. Estimating debris flow volume is a critical component of our analysis since flow volume influences runout potential. Debris flow volume increases with watershed relief, watershed area burned at moderate to high severity, and peak 15-minute rainfall intensity. Our hazard assessment included estimating the area inundated by debris flows under different rainfall and burn severity scenarios. For a rainstorm with a 2-year recurrence interval, we found that the area inundated varied from 0.26-0.42 km2 as watershed area burned at moderate-high severity increases from 20% to 100%. We observed an analogous trend for rainstorms with greater recurrence intervals (10, 25, 50, 100-year storms), though higher 15-minute rainfall intensities result in larger debris flows with greater inundation areas. An additional challenge in prefire assessments is estimating how the frequency and intensity of rainfall may unfold in the future due to climate change. We found that the area inundated by debris flows in response to a 2-yr recurrence interval rainstorm increases from 0.26-0.42 km2 under present day conditions to 0.41-0.64 km2 under the RCP8.5 scenario. Results demonstrate that prefire assessments of postfire hazards would benefit from accounting for the effects of rainfall intensification under future climate scenarios.

33. Variations in Debris Flow Risk During Wildfire Recovery – FEMA R8 Flood After Fire

Presenter: Thad Wasklewicz; Stantec Consulting Services Inc
Co-authors: Richard Guthrie, Graham Knibbs, Amelia Ochsenbein, Julia Ryherd, Jonathan Teboul

The likelihood of post-wildfire floods and debris flows can remain high for multiple years until vegetation, hydrology, and soils recover thereby reducing the runoff and stabilizing sediment. Therefore, it is critical to develop a framework to examine debris flow risks to infrastructure and communities in or adjacent to wildfires. We develop three phases of post-wildfire debris flow risk over the period of recovery: initial phase (0-3 years after the wildfire), transitional phase (estimated to be from 3-10 years after the wildfire) and later recovery phase (approximately >10 years after the wildfire). We examine three fires in FEMA Region 8 at various points of post-wildfire recovery and consider how the debris flow risk varies over the various phases. Debris flow risk at different receptors is determined under the conditions of the respective scenarios for each element at risk by multiplying hazard and consequence index values. Debris flow modeling is performed whereby varying return-interval rainfall conditions are simulated in the modeling for each of the locations. For the initial phase, known rainfall-events for debris flows occurring in some of the fires was an initial starting point for these fires and return intensities from published literature are used for fires were the remaining fire. Debris flow modeling is varied based on infiltration and rainfall intensity required for debris flow initiation in the later phases. Our findings show the risk profile increases significantly following the wildfire, but over time there is a potential for greater damage (despite the declining frequency of the event) as larger storms are required to produced debris flows. Risk at receptors (roads, houses, and occupants) in the various fires is unique with different receptors experience higher risks in different phases. Risk also varies depending on location of the receptor within a landscape or a debris flow fan.

34. Longevity of wildfire effects

Presenter: Tim Giles; SPIRE Geotechnical

How long do the effects of wildfire last? The adverse impacts of wildfires on the environment can persist for years after containment of the wildfire. Wildfires remove vegetative cover and consume soil layers which alter hydrologic processes such as runoff, peak streamflows and sediment transport. This drives geomorphic change, including debris flows, landslides, rockfall and floods. Moving from the immediate effects of fire on the landscape to 5 or 10 years after the fire is becoming more relevant as increasing areas of land are consumed by fire. Rebuilding or new development in or below burned areas frequently now comes with a requirement for a geohazard assessment to determine if it safe to develop. Property owners are responsible for completing these assessments, often in areas where the fire burn severity was relatively low and occurred several years previously.