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Post-Wildfire Debris Flows: Federal Role in Assessment and Warning

July 10, 2023

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SUMMARY

R47618

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Post-Wildfire Debris Flows: Federal Role in Assessment and Warning

A *debris flow* (also known as a mudflow or mudslide) is a type of landslide that involves a slurry of water, soil, rock, vegetation, or other debris moving down a slope. Often a debris flow may encounter a stream channel that may speed up the flow, thus carrying the debris faster and farther. Wildfires can leave a burned landscape particularly susceptible to debris flows triggered by intense rainfall for up to three years after the fire. These events are called *post-wildfire debris flows*. Post-wildfire debris flows have caused fatalities, injuries, property damage, and environmental degradation. In the future, more people and property may be in the path of potential debris flows in the United States due to the potential for more wildfires and more intense rainfall events attributed to climate change and projected increases in development near forested areas.

Various federal and nonfederal agencies may develop hazard assessments and warnings to try to reduce post-wildfire debris flow risks. After some wildfire events, the U.S. Geological Survey (USGS) may prepare a post-fire debris-flow hazard assessment that includes rainfall threshold amounts that could generate a debris flow for the area. The National Oceanic and Atmospheric Administration's National Weather Service (NWS) monitors for and forecasts rainfall on the burned landscape; a forecast may include debris flow watches and warnings based on the expected rain and rainfall threshold.

In 2021, Congress passed the National Landslide Preparedness Act (NLPA; P.L. 116-323), which directed the Secretary of the Interior (Secretary), through the USGS Director, to establish a National Landslide Hazards Reduction Program (NLHRP; 43 U.S.C. §3101-3102). NLPA authorized activities include identifying, mapping, assessing, and researching landslide hazards; responding to landslide events; and coordinating with state, local, territorial, and tribal entities to reduce landslide risks. The act did not specify how much funding should be devoted to debris flow assessments, but the act did specifically call for the expansion of a debris flow early warning system. The act directed the Secretary, with the interagency committee established under the law and in coordination with existing activities of the USGS and other federal agencies, to assess landslide hazards, including for debris flows, among other activities. The act also called for the Secretary, with the Secretaries of Commerce and Homeland Security, to "expand" a debris flow early warning system.

Congress may be interested in post-wildfire debris flows and reducing the risk of these flows to communities. As of June 2023, the Secretary had not submitted a NLPA required interagency plan to Congress, nor have agencies fully implemented the debris-flow-specific tasks called for in the NLPA. Agencies with directives from the act indicated that they need more time, staff, and resources to carry out debris flow tasks and that carrying out some tasks may be delayed for two or more years beyond FY2024. Congress may examine the NLPA's implementation, which may include requesting the status of the required interagency plan and more information about implementation of debris flow tasks. In addition, Congress may consider whether annual appropriations are sufficient or necessary to implement NLPA, whether to authorize appropriations beyond FY2024, and whether to direct agencies to support other debris-flow-related activities with existing appropriations.

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Introduction

A *debris flow* (also known as a mudflow or mudslide) is a type of landslide that involves a slurry of water, soil, rock, vegetation, or other debris moving down a slope. Often a debris flow may encounter a stream channel that may speed up the flow, thus carrying the debris faster and farther.[1] Debris flows may harm people and damage property because they can move quickly, pick up or create additional debris, and travel long distances.

A *wildfire* may create a burned landscape that is more susceptible to debris flows.[2] Changes to vegetation and soil due to a wildfire can increase the probability of runoff and erosion in a watershed during a rainfall event, and thus the likelihood of a debris flow triggered by a rainfall event.[3] Debris flows may damage natural resources, property, and infrastructure and may lead to injuries and fatalities. Communities downslope of burned terrain may be vulnerable to damage from debris flows, such as that which occurred in Montecito, CA, in 2018 (see text box).

During and after a wildfire, various federal agencies coordinate with nonfederal agencies to assess the potential for debris flow hazards on the steep slopes of a burned landscape. The U.S. Geological Survey (USGS) may provide post-fire debris flow assessments to federal and nonfederal agencies responding to a wildfire. These assessments can inform communities downslope of burned terrain about the potential debris flow risks following a wildfire. In addition, the National Oceanic and Atmospheric Administration's National Weather Service (NWS) forecasts or monitors for rainfall on a burned landscape. If warranted, an NWS forecast may include debris flow information within broader flood watches and warnings based on the expected rain and available USGS assessments (for example, see text box).

Debris Flows in Montecito, CA, After the Thomas Fire

In January 2018, a series of large and devastating debris flows descended the steep and burned terrain of the Santa Ynez Mountains into Montecito, CA, causing 23 fatalities, more than 167 injuries, and damage to more than 408 structures. These post-wildfire debris flows were triggered by an intense rainfall event on steep slopes of burned soil from the Thomas Fire that were susceptible to increased runoff and erosion.

The Thomas Fire started on December 4, 2017, and lasted nearly a month, burning about 281,893 acres (about 181,411 acres of U.S. Forest Service [FS] lands, 98,663 acres of private lands, and 2,891 acres of other lands) across Ventura and Santa Barbara counties. It was among the largest wildfires recorded in California.

The USGS conducted post-fire debris flow hazard assessments after the Thomas Fire. These assessments indicated a high likelihood of debris flows in many stream channels and drainage basins on steep, burned slopes for a modeled rainfall event with a duration of 15 minutes and one-quarter inch of rainfall accumulation.

The NWS forecast a rainfall event of one-half to one-and-a-half inches of rainfall per hour over the Thomas Fire area for the evening of January 8, 2018, and morning of January 9. In light of the expected rain amounts, the NWS issued flood watches and warnings, with information about debris flows, for communities downslope of the Thomas Fire area, including Montecito. The Santa Barbara County Office of Emergency Management issued mandatory and voluntary evacuation orders for Montecito on January 8.

Early on the morning of January 9, 2018, a 200-year storm (a storm with a 0.5% chance of occurring in any given year), with rainfall intensities of as much as 6 inches per hour, initiated debris flows on the steep slopes of burned

[1] U.S. Geological Survey (USGS) Landslide Hazards, "Landslides 101," at https://www.usgs.gov/programs/landslide-hazards/landslides-101.

[2] The Federal Emergency Management Agency (FEMA) describes wildfires as "unplanned, unwanted fire burning in a natural area, such as a forest, grassland, or prairie." See FEMA, "Wildfire," at https://community.fema.gov/ProtectiveActions/s/article/Wildfire-What.

[3] Dennis M. Staley et al., "Prediction of Spatially Explicit Rainfall Intensity-Duration Thresholds for Post-Fire Debris-Flow Generation in the Western United States," *Geomorphology*, vol. 278 (2017), pp. 149-162, at http://dx.doi.org/10.1016/j.geomorph.2016.10.019 (hereinafter Staley et al., 2017).

soil above Montecito. These debris flows inundated parts of Montecito, causing fatalities, injuries, and damage to property and other structures, as shown in the photographs below.

Sources: Forest Service, *Thomas Burned Area Report*, FSH 2509.13, January 16, 2018, at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd573382.pdf; and Jason W. Kean et al., "Inundation, Flow Dynamics, and Damage in the 9 January 2018, Montecito Debris-Flow Event, California, USA: Opportunities and Challenges for Post-Wildfire Risk Assessment," *Geosphere*, vol. 15, no. 4 (June 7, 2019), p. 1140, doi: 10.1130/GES02048.1.

Notes: USGS photographs of debris flow damage in Montecito, CA. **(A)** Debris flow damage to a bridge over Cold Spring Creek. **(B)** Debris flow plugging a 2.5-meter (8.2-foot) diameter culvert on Buena Vista Creek. **(C)** House constraining part of a debris flow along San Ysidro Creek. **(D)** Debris flow damage to a house along Buena Vista Creek.

The National Landslide Preparedness Act (NLPA; P.L. 116-323) authorized a National Landslide Hazards Reduction Program (NLHRP; 43 U.S.C. §3101 and 3102) to reduce landslide risks, including from debris flows. The act directs the Secretary of the Interior (Secretary), with an interagency committee and in coordination with existing activities of the USGS and other federal agencies, to assess landslide hazards. Assessing landslide hazards includes assessing debris flows. The act also called for the Secretary, with the Secretaries of Commerce and Homeland Security, to "expand" a debris flow early warning system.

This report summarizes the coordination, data, and modeling used to develop post-wildfire debris flow hazard assessments and warnings. This report also briefly discusses issues for Congress related to these efforts.

Post-Wildfire Debris Flow Hazard Assessments

The USGS Landslide Hazards Program (LHP) conducts post-fire debris flow hazard assessments (PFDFAs).[4] The PFDFAs estimate the chance of a debris flow for a specific *design storm*.[5] The PFDFAs display estimates of the likelihood of a debris flow, potential volume of a debris flow, and combined relative debris flow hazard (based on the likelihood and potential volume for specific watersheds or stream channels). The PFDFAs consist of six maps: three showing likelihood, flow volume, and overall hazard at the scale of the watershed, and another three at the scale of the stream channels. **Figure 1** shows an example of a PFDFA for watersheds, where the first panel shows debris flow probabilities (likelihood model), the second panel shows potential flow volumes (volume model), and the third panel shows the relative hazard (low, moderate, high; combination of the likelihood and volume models).[6] The assessments only estimate debris flow potential on a burned landscape (within the mapped extent of the wildfire).

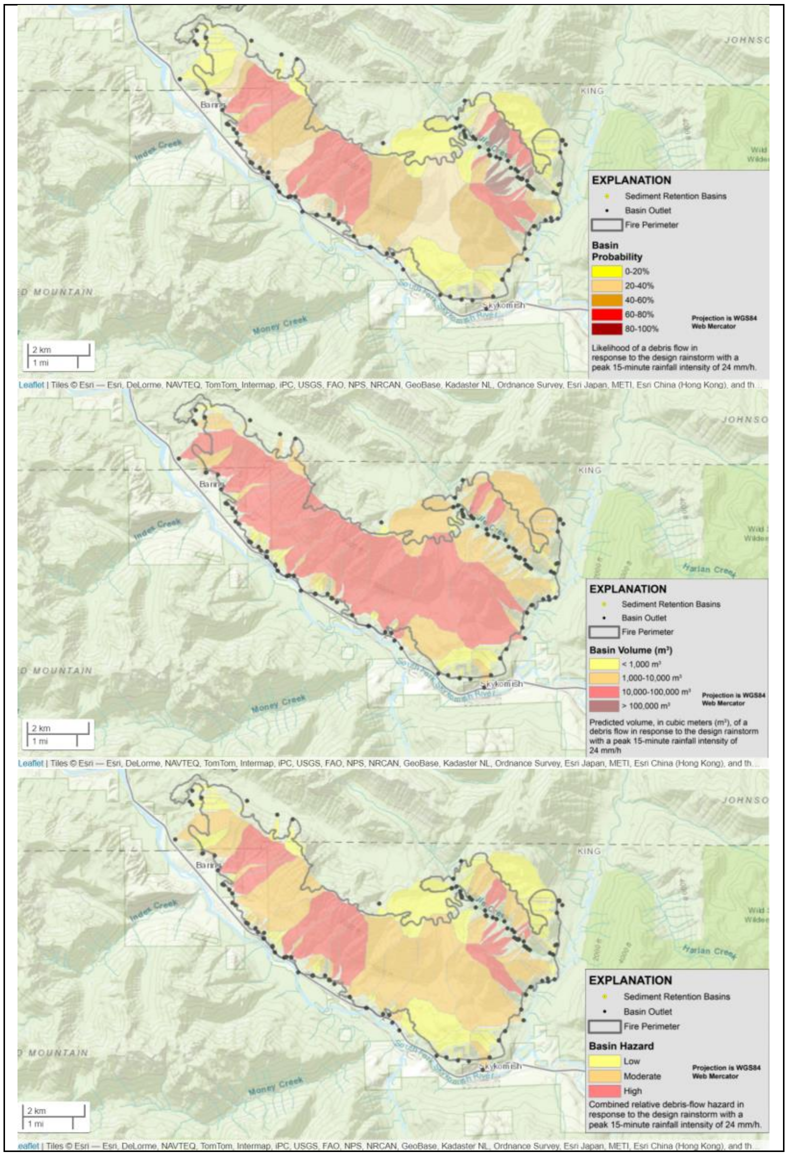
[4] USGS Landslide Hazards Program, "Emergency Assessment of Post-Fire Debris-Flow Hazards," at https://landslides.usgs.gov/hazards/postfire_debrisflow/.

[5] A *design storm* refers to a model of a storm with a specific amount of rainfall over a specific duration and area. The USGS uses a 15-minute duration yielding one-quarter inch of rain as their design storm. Staley et al., 2017. See also USGS, "Scientific Background," at https://www.usgs.gov/programs/landslide-hazards/science/scientific-background. The USGS provides assessments for other design storms in the geospatial data available for download. USGS, "Post-Fire Debris-Flow Hazards Assessments," at https://www.usgs.gov/programs/landslide-hazards/science/emergency-assessment-post-fire-debris-flow-hazards (see FAQ—Frequently Asked Questions).

[6] **Figure 1** is shown as an example of a post-fire debris flow assessment and only the three maps for watersheds are displayed for brevity in this product. The post-fire debris flow assessments available online allow the user to select which of the six maps to view (an icon that shows layers on the map legend allows the user to choose which map to display) and to enlarge or reduce the size of the map to view the details of different areas on the map at different scales. In addition, the data and metadata for the maps are available for download below the map display. USGS, "Emergency Assessment of Post-Fire Debris-Flow Hazards," at https://landslides.usgs.gov/hazards/postfire_debrisflow/. This online site will be supported only until October 1, 2023, because the USGS is migrating its post-fire debris flow assessments to a new online portal, called the USGS Post Wildfire Debris Flow Hazard Assessment Viewer, available at https://usgs.maps.arcgis.com/apps/dashboards/c09fa874362e48a9afe79432f2efe6fe.

Figure 1. Example of a Post-Fire Debris Flow Hazard Assessment for the Bolt Creek Fire, WA

(Maps are only for watersheds; stream channel maps are not shown here)



Source: USGS, "Bolt Creek (Mt. Baker-Snoqualmie National Forest, WA)," at https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=451. The interactive source map shows the watershed and stream channel maps.

Notes: The three panels display the probability of a debris flow (top), the potential volume of a debris flow (middle), and the relative debris flow hazard for individual watersheds: low, moderate, high (bottom). These assessments are for the Mount Baker-Snoqualmie National Forest in Washington. The assessments were prepared after the Bolt Creek Wildfire that started on September 10, 2022.

PFDFAs require mapping the impacts of a wildfire on vegetation, soil, and slope stability. Federal land management agencies assess the impact of a wildfire on federal lands,[7] while state and local

[7] The primary federal land management agencies that respond to wildfires are part of the U.S. Department of Agriculture (USDA) and the Department of the Interior (DOI). At USDA, the U.S. Forest Service (FS) is responsible (continued...)

agencies assess the impact of a wildfire on nonfederal lands.[8] For example, the USGS uses soil burn severity maps produced by federal and nonfederal agencies to prepare PFDFAs.[9] The extent of the fire and the soil burn severity are mapped using soil survey data from before the wildfire, field observations of fire damage and burn severity, and satellite observations before and after the fire.[10] The USGS prefers a soil burn severity map validated by field observations. If a field-validated map is not available, the USGS can use a soil burn severity map based only on satellite measurements.

The USGS has developed two models to estimate (1) the likelihood and (2) the volume of a post-fire debris flow for a given rainfall intensity event. The models are *empirical* and based on data from past events, including debris flow characteristics, rainfall, topography, soil conditions, and soil burn severity data.[11] The models use a *design storm* of 15-minute duration rainfall accumulating 0.24 inches of rain (about 1 inch of rain per hour).

In general terms, the likelihood model considers the amount of rainfall accumulation for the design storm over three areas: (1) moderate to severely burned soil on the steepest slopes, (2) soil burned to a certain severity based on satellite data, and (3) soil with a certain degree of erodibility.[12] The volume model estimates the potential volume of the debris flow based on the design storm averaged over a watershed, the maximum change in elevation in a watershed, and the amount of area in a watershed that was burned to a moderate to high severity. The results of the two models combined provide an estimated probability of a debris flow for watersheds or stream channels.[13]

The USGS produced 438 PFDFAs in western states in the conterminous United States between 2013 and 2022.[14] The USGS has provided assessments for an increasingly higher percentage of

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for wildfires on FS lands. At DOI, the Bureau of Land Management (BLM); Bureau of Reclamation (BR); Bureau of Indian Affairs (BIA); U.S Fish and Wildlife Service (FWS); and National Park Service (NPS) are responsible for wildfires on their respective federal lands. The Department of Defense has land management and wildfire response responsibilities on defense-related lands not discussed in this report. For more on federal wildland fire response, see CRS In Focus IF12384, *Federal Interagency Wildfire Response Framework*, by Katie Hoover.

[8] State laws governing wildfire management vary, and some states use cooperative fire protection agreements and contract with the federal government to handle their wildfire response activities. In addition, wildfire response may be managed jointly for comingled land ownership.

[9] USGS, "Post-Fire Debris-Flow Hazards Assessments," at https://www.usgs.gov/programs/landslide-hazards/science/emergency-assessment-post-fire-debris-flow-hazards (see Assessment Requirements topic).

[10] The soil burn severity data come from field observations of the soil burn severity by Burned Area Emergency Response (BAER) teams and from satellite data, primarily collected by the USGS Landsat Mission. USDA and DOI BAER, "BAER," at https://burnseverity.cr.usgs.gov/baer/. Imagery (primarily Landsat data) is provided to USDA and DOI BAER teams. Imagery for nonfederal BAER teams is considered on a case-by-case basis.

[11] *Empirical* means based on observations rather than theory or pure logic.

[12] The soil erodibility is given by the soil k-factor. G. Schwartz and R. Alexander, *Soils Data for the Conterminous United States Derived from the NRCS State Soil Geographic (STATSGO) Database*, USGS, U.S. Geological Survey Open-File Report 95-449, Reston, VA, 1995, https://water.usgs.gov/GIS/metadata/usgswrd/XML/ussoils.xml.

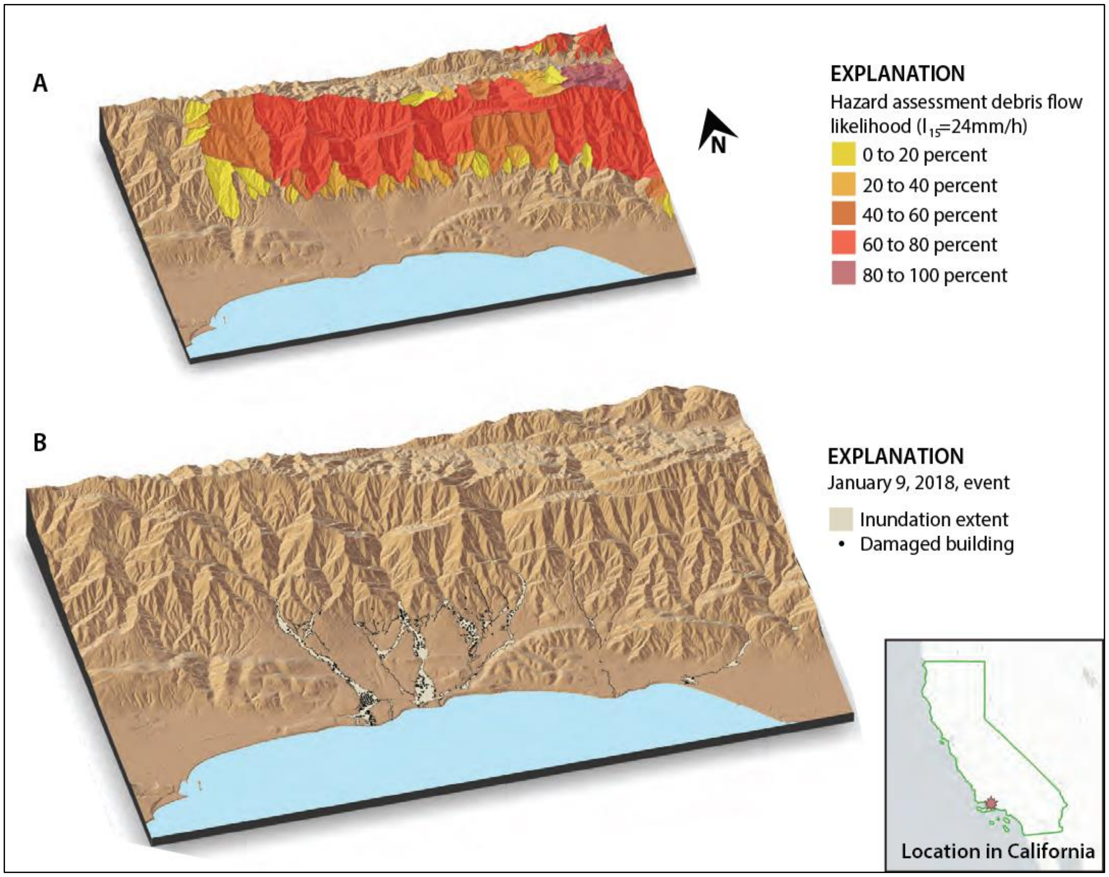
[13] For an example of a debris flow combined hazard map for streams for the Thomas Fire that led to damaging debris flows in Montecito, CA (see text box, "Debris Flows in Montecito, CA, After the Thomas Fire"), see USDA-Forest Service, *Thomas Burned Area Report*, FS-2500-8, January 16, 2018, at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd570172.pdf, p. 45.

[14] USGS, *Budget Justifications and Performance Information Fiscal Year 2024, USGS*, p. 71, https://www.doi.gov/sites/doi.gov/files/fy2024-usgs-greenbook.pdf-508.pdf (hereinafter USGS Budget Justifications FY2024). The western states include Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming. USGS, "Emergency Assessment of Post-Fire Debris Flow Hazards," at https://www.usgs.gov/programs/landslide-hazards/science/emergency-assessment-post-fire-debris-flow-hazards (see Disclaimer—Limitations of Hazard Assessment topic).

burned acres in western states. For example, assessments for 15% of burned acres in 2013 were in western states, whereas assessments for 75% of burned acres in 2021 were in western states.[15]

Commonly, most of the damage from a debris flow occurs downslope when a debris flow enters a community or another development (**Figure 2**). Therefore, the assessments are communicated not only to post-wildfire responders working within the extent of the fire (federal and nonfederal agencies), but also to community emergency responders who are responsible for hazards that extend beyond the fire's extent. In addition, the assessments are communicated through established coordination between the USGS and the NWS.

Figure 2. Post-Fire Debris Flow Assessment and Flow Runout Damage, Montecito, CA



Source: CRS modified the USGS figure from Katherine R. Barnhart, Veronica Y. Romero, and Katherine R. Clifford, *User Needs Assessment for Postfire Debris-Flow Inundation Hazard Products*, USGS, USGS Open-File Report 2023–1025, 2023.

Notes: (A) A small portion of the USGS post-fire debris flow assessment for the 2017-2018 Thomas Fire is overlayed on a three-dimensional topographic relief map. The assessment denoted by the different colors (yellow to purple) only covers the burned landscape. The darker red to purple colors indicate where a debris flow is most likely (greater than 60% chance) to occur for a specific minimum rainfall amount. (B) Shows the various debris flow runout pathways (called *inundation extent* in the figure legend) down different stream channels after debris flows started on the burned landscape due to an intense rainfall event on January 9, 2018 (see text box "Debris Flows in Montecito, CA, After the Thomas Fire"). As shown in the figure (black dots showing

[15] The USGS used the National Interagency Coordination Center's wildfire statistics, a national database of wildfire location, date, and acreage burned to calculate their assessment rate in western states. For more information on wildfire occurrence, see CRS In Focus IF10244, *Wildfire Statistics*, by Katie Hoover and Laura A. Hanson.

damaged buildings), most of the damage from post-wildfire debris flows occurs when the debris flow pathways run out along stream channels into communities below the burned landscape.

Debris Flow Outlooks, Watches, and Warnings

The Secretary of Commerce, through the NWS, is responsible for forecasting and issuing watches, warnings, and advisories for weather events.[16] The NWS Weather Forecast Offices (WFOs), which are responsible for a certain geographic area, work with communities and other partners before, during, and after wildfires to prepare for, anticipate, and monitor potential debris flow areas. After a wildfire, the NWS WFOs work with partners, including the USGS, to determine rainfall thresholds that could trigger a debris flow, help to evaluate burn scars, assist with establishing burn scar observation requirements, potentially obtain and install the observation equipment, and continue outreach with affected communities.[17] In advance of potentially significant rainfall or flood events, the NWS and its WFOs provide precipitation outlooks, forecasts, flood watch and warning services, and decision support services to federal and nonfederal partners.[18] The outlooks, forecasts, and services are based on real-time monitoring information from rain gauges, NWS Doppler radars, and satellites; and from numerical and statistical weather models.

The NWS WFOs integrate information about potential debris flows in a certain area into flood or flash flood watches and warnings for that area. For example, the NWS WFOs are required to issue flood watches if there is a 50% to 80% chance that "meteorological, soil, hydrologic, and/or burn area conditions will lead to debris flows within a 48-hour period," among other factors.[19] The NWS WFOs are expected to issue flash flood warnings for a geographical area when "precipitation as indicated by radar, rain gages, satellite and/or other guidance is capable of causing debris flows, particularly (but not only) in burn areas," among other reasons.[20] A flood watch or flash flood warning with the potential to initiate a debris flow will state as such.

Debris Flow Early Warning Systems

Some have suggested that debris flow early warning systems can help mitigate the risks to life and property posed by debris flows.[21] The USGS noted that the 2018 Montecito, CA, debris flow response included three components of a United Nations definition of an early warning system:

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[16] 15 U.S.C. §313.

[17] NOAA works with other partners in other ways as well, such as funding, land access, operations and maintenance, and data access (Email correspondence with NOAA Office of Legislative and Intergovernmental Affairs, November 2022).

[18] Email correspondence with NOAA Office of Legislative and Intergovernmental Affairs, November 2022.

[19] NOAA National Weather Service (NWS) Weather Forecast Offices (WFOs) may issue a flood warning after a flood watch "for any high flow, overflow, or inundation in a geographic area which threatens life and property" (NWS, Instruction 10-922, 2021, p. 64). NOAA, NWS, *Weather Forecast Office Water Resources Products Specification*, NWS Instruction 10-922, August 3, 2021, p. 12, at https://www.nws.noaa.gov/directives/sym/pd01009022curr.pdf (hereinafter NWS, Instruction 10-922, 2021).

[20] NWS may issue flash flood warnings for reasons unrelated to debris flows as well. NWS, Instruction 10-922, 2021, p. 31. Flash flooding is a flood caused by heavy or excessive rainfall in a short period of time (i.e., generally less than six hours); conversely, flooding is a longer-term event, and may last days to weeks (NOAA NWS, "Flood and Flash Flood Definitions," at https://www.weather.gov/mrx/flood_and_flash).

[21] For more information and examples, see F. Guzzetti et al., "Geographical Landslide Early Warning Systems," *Earth-Science Reviews*, vol. 200 (January 2020), at https://www.sciencedirect.com/science/article/pii/S0012825219304635; and USGS, "Post-Fire Debris Flow Early Warning," PubTalk, video presentation, October 20, 2018, at https://www.usgs.gov/media/videos/pubtalk-102018-post-fire-debris-flow-early-warning (hereinafter USGS, PubTalk, 2018).

(1) monitoring, forecasting, and prediction; (2) disaster risk assessment; and (3) communication and preparedness activities, systems, and processes.[22] NOAA and the USGS have developed and tested debris flow early warning systems in Northern and Southern California. For example, the NWS and the USGS established a demonstration flash flood and debris flow early warning system for burned areas in Southern California in 2005.[23] From 2005 to 2009, the WFOs involved in the demonstration system issued 104 debris flow warnings; 47 debris flows (45%) actually occurred following the warnings.[24] The NWS has issued guidance to WFOs to issue watches and warnings, with debris flow information, in these areas and others since the inception of the demonstration system.[25]

In a 2005 NOAA/USGS Debris Flow Task Force report, the task force concluded that while it would be possible to establish a debris flow early warning system broadly, the "human capital and financial resources required to successfully implement, operate, and advance such a system are beyond those available to either agency at this time."[26] In addition, demonstration system scientists noted the need for research in (1) improving multi-sensor precipitation estimates and the spatial and temporal resolution of precipitation forecasting, (2) developing high-resolution hydrologic models that account for soil moisture; and (3) developing methods to generate debris flow forecasts that integrate real-time hillslope and channel monitoring and precipitation forecasts and measurements.[27]

Considerations for Congress

Congress may examine several aspects of NLPA implementation related to debris flows, including the development of an interagency plan to implement the NLHRP national strategy; the creation, or expansion, of a debris flow early warning system; and whether appropriations are sufficient or necessary to complete debris-flow-related activities.

The NLPA directed the Secretary, in coordination with the Interagency Coordinating Committee on Landslide Hazards (ICCLH), to submit an interagency plan to implement a national strategy for NLHRP no later than January 5, 2022.[28] To date, the Secretary has not done so. The interagency plan is to include details about the programs, projects, and budgets needed to implement the national strategy. Such a plan may include program and budget details for debris flow assessments and warnings. The USGS submitted a "National Strategy for Landslide Loss

[22] USGS, PubTalk, 2018 and United Nations Office for Disaster Risk Reduction, "Early Warning System," at https://www.undrr.org/terminology/early-warning-system.

[23] "NOAA/USGS Demonstration Flash-Flood and Debris-Flow Early Warning System," at https://www.weather.gov/lox/debrisflow; and P. Restrepo et al., "Joint NOAA/NWS/USGS Prototype Debris Flow Warning System for Recently Burned Areas in Southern California," *Bulletin of the American Meteorological Society*, 2008, at https://journals.ametsoc.org/downloadpdf/journals/bams/89/12/2008bams2416_1.xml.

[24] P. Restrepo et al., "NOAA/USGS Demonstration Flash-Flood and Debris-Flow Early-Warning System," 2009, poster presentation at the European Geosciences Union General Assembly, at https://hydrology.nws.noaa.gov/pub/oh/Restrepo-et-al-EGU2009.ppt (hereinafter Restrepo, Demonstration Poster, 2009).

[25] For the 2021 guidance, see NWS, Instruction 10-922, 2021. For examples of NWS debris flow information in areas outside of Southern California, see NWS, Seattle/Tacoma, WA WFO, "Post Fire Burn Scar—Debris Flow and Flash Flooding," at https://www.weather.gov/sew/burnscar; NWS, Spokane, WA WFO, "Floods After Fires – Burn Scars," at https://www.weather.gov/otx/Postfireburnscars; and NWS, Western and Central Wyoming WFO, "Flash Flood Threat Within Fire Burn Scar," at https://www.weather.gov/riw/burn_scar_flooding.

[26] USGS, *NOAA-USGS Debris-Flow Warning System-Final Report*, Circular 1283, 2005, at https://pubs.usgs.gov/circ/2005/1283/pdf/Circular1283.pdf (hereinafter USGS, Circular 1283, 2005). NOAA NWS, p. 36.

[27] Restrepo, Demonstration Poster, 2009.

[28] 43 U.S.C. §3102 (b)(2).

Reduction" (National Strategy) to Congress in September 2022, but the strategy did not include an interagency plan.[29] According to the National Strategy, the "associated management plan that outlines the programs and costs associated with these strategic actions will be written separately and approved by the interagency coordinating committee on landslide hazards (ICCLH) once the committee is established."[30] Congress may consider requesting further information about the status and contents of the interagency management plan, including challenges to its development.

The NLPA also directed the Secretary, in coordination with the Secretaries of Commerce and Homeland Security, to

> expand the debris flow early warning system by
>
> (A) expanding the early warning system for post-wildfire debris flow to include recently burned areas across the western United States;
>
> (B) developing procedures with State, territorial, local, and Tribal governments to monitor stormwater drainage in areas with high debris flow risk; and
>
> (C) identifying high-risk debris flow areas, such as recently burned land and potential lahar hazard areas.[31]

It is unclear what system Congress is referring to in the NLPA provision. As discussed in "Debris Flow Early Warning Systems," the USGS and NOAA have worked together to establish systems in certain areas in the past. As of June 2023, the USGS planned to work with NWS to "continue to build on recent scientific advances to expand the [2005 demonstration] project to other parts of California and the western U.S. to meet the intent of the [NLPA]."[32] The Secretary has not developed procedures to monitor stormwater drainage areas nor identified high-risk debris flow areas, as required under statute. The USGS, in its online description of NLPA, expressed uncertainty regarding the federal government's role in stormwater monitoring.[33] The National Strategy envisions improving and expanding PFDFAs, expanding landslide monitoring and alert systems in high-risk areas, and integrating these systems with satellite-based detection and weather forecasts as some of the ways to identify high-risk debris flow areas.[34] Without an interagency plan, the federal role for these activities remains unclear. Congress may consider requesting updates on the status of these tasks through its oversight activities.

Congress, through the NLPA, authorized appropriations for the USGS ($25 million annually) and NOAA ($1 million annually) for FY2021 through FY2024 to implement the NLHRP.[35] The act does not specify how much of these appropriations should be used for debris flow activities. In

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[29] USGS, *National Strategy,* 2022.

[30] USGS, *National Strategy,* 2022, p. 5. The ICCLH discussed a detailed interagency plan that would include projects, programs, and budgets to implement the NLHRP at its first meeting in February 2023, but such a plan has not yet been prepared. Personal correspondence between the USGS and CRS, April 2023.

[31] 43 U.S.C. §3102(b)(5).

[32] USGS, FY2024 Budget Justifications, p. 71. See also the USGS, *National Strategy,* 2022, pp. 13-15 and 27-28 for some plans and strategies for the USGS and NOAA to collaborate on early warning system expansion to meet the intent of NLPA.

[33] USGS Landslide Hazards Program, "National Landslide Preparedness Act," at https://www.usgs.gov/programs/landslide-hazards/science/national-landslide-preparedness-act. See also USGS, *National Strategy,* 2022, p. 28, where the USGS states, "Debris-flow risks are reduced greatly as local partners monitor stormwater drainage in high hazard zones," indicating that the USGS views stormwater drainage monitoring as a local responsibility, not a federal responsibility.

[34] USGS, *National Strategy,* 2022, pp. 27-28.

[35] 43 U.S.C. §3102(h). NLPA also authorized appropriations of $11 million annually for FY2021 through FY2024 for the National Science Foundation to provide grants to eligible entities for landslide research.

addition, from FY2021 to FY2023, Congress has not enacted appropriations that match the authorized levels for the USGS and has not appropriated funding specifically for NLPA to NOAA. In FY2023, Congress provided $14.4 million in annual appropriations for the USGS Landslide Hazards Program and directed $4.8 million of this total amount to actionable science.[36] The USGS describes actionable science as "actionable landslide hazard and risk modeling for vulnerable populations and high-risk settings with an emphasis on areas recently burned by wildfire."[37] Some of these actions include modeling and assessing the potential debris flow runout paths (called inundation models by the USGS) into communities (**Figure 2**).[38] In its FY2024 budget request, the USGS requested $11.8 million for the Landslide Hazards Program, a decrease compared to FY2023 appropriations. The USGS indicated that at this level, implementation of the NLPA would proceed at a slower pace in FY2024 and the development of debris path runout models (i.e., inundation models) would be extended by two or more years.[39] Congress may consider whether funding is sufficient or necessary to carry out the debris flow activities called for in the NLPA and envisioned in the USGS National Strategy. Congress may also consider whether or not to direct any funding to specific activities such as debris flow assessments or warnings.

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[36] P.L. 117-328 and H.Rept. 117-400.

[37] USGS, FY2023 Budget Justifications, p. 81. The Landslide Hazards Program (LHP) is a line-item program within the USGS Natural Hazards Mission Area. The USGS contribution to NLHRP are within the activities of the LHP. Activities of the NLHRP are overseen by the Secretary and carried out in coordination with other federal agencies as directed in the NLPA. The NLHRP emphasizes the development and execution of products and activities, such as an expanded debris flow early warning system, that supports risk reduction on a nationwide scale. Personal correspondence between the USGS and CRS, March 2023.

[38] For example, the USGS surveyed the community emergency responders and other post-wildfire response stakeholders about ways to expand the USGS post-fire debris flow hazard assessments, to include information about debris flow runout path hazards that directly impact communities. Katherine R. Barnhart, Veronica Y. Romero, and Katherine R. Clifford, *User Needs Assessment for Postfire Debris-Flow Inundation Hazard Products*, USGS, USGS Open-File Report 2023–1025, 2023.

[39] The USGS plans to delay the addition of debris flow inundation models (debris flow runout paths) to assessments and other technical capabilities by two or more years in FY2024. USGS, FY2024 Budget Justifications, p. 70.

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