



December 2019

WILDLAND FIRE

Federal Agencies' Efforts to Reduce Wildland Fuels and Lower Risk to Communities and Ecosystems

Why GAO Did This Study

Wildfires have been increasing in size and severity, exacerbated by abnormally dense vegetation, drought, and other climate stressors. Development in and around wildlands also continues to increase, placing more people at risk from wildfires. To reduce vegetation that can fuel such fires, federal land management agencies implement fuel reduction projects on public lands.

GAO was asked to examine the federal government's preparedness, response, and recovery efforts following the wildfires and other natural disasters of 2017. This report describes (1) methods federal agencies use to reduce fuels to help protect communities and ecosystems, (2) information the agencies considered in allocating fuel reduction funds in fiscal year 2018, and (3) factors affecting agency efforts to implement fuel reduction projects.

GAO examined laws, regulations, and agency policies and budget documents; interviewed federal agency officials at headquarters, as well as in eight regional offices and 10 field units selected based on their locations' high wildland fire hazard potential; and interviewed officials from nonfederal entities, including representatives from the state forestry agencies for the seven states where selected field units were located (three field units were in California and two were in New Mexico).

View [GAO-20-52](#). For more information, contact Anne-Marie Fennell at (202) 512-3841 or fennella@gao.gov.

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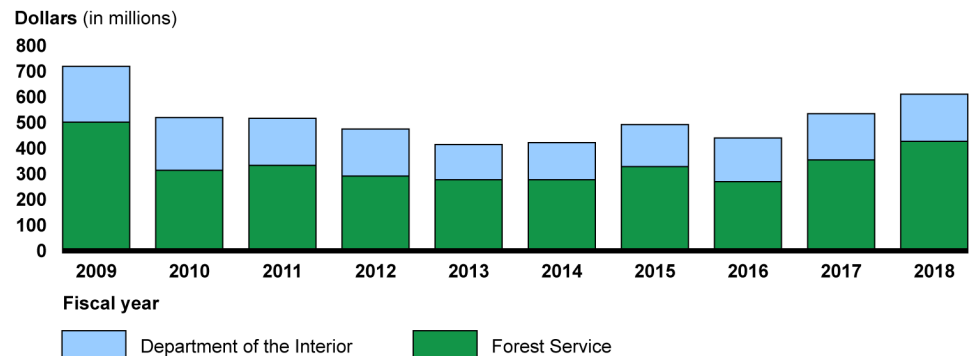
What GAO Found

Five federal land management agencies—the Department of Agriculture's Forest Service and the Department of the Interior's Bureau of Indian Affairs, Bureau of Land Management, Fish and Wildlife Service, and National Park Service—use several methods to reduce fuels (vegetation) to help lower the intensity of wildland fires on lands they manage or administer. These methods primarily include mechanical treatments, which use equipment to cut and remove vegetation, and prescribed burns, which are deliberate, planned fires set by land managers. The agencies have long-standing research programs designed to further develop their understanding of how to implement effective fuel reduction projects, including conducting assessments to evaluate project effectiveness. Officials said the research helps the agencies to improve how they design and implement fuel reduction projects to address site-specific conditions.

In fiscal year 2018, when allocating fuel reduction funds, the agencies considered information on wildfire hazard potential, the location of communities, and ecosystem health and the location of natural resources. Total fuel reduction appropriations exceeded \$5 billion in fiscal years 2009 through 2018 (see figure).

Officials from the five agencies cited several factors affecting implementation of fuel reduction projects. A key factor officials cited is that the number of acres needing treatment is significantly larger than the agencies can treat annually. The agencies have estimated that over 100 million acres they manage or administer are at high risk from wildfire, but, for example, in fiscal year 2018 they treated approximately 3 million acres. The agencies are developing risk assessments to help identify areas to prioritize for fuel reductions.

Forest Service and Department of the Interior Fuel Reduction Appropriations, Fiscal Years 2009 through 2018



Source: GAO analysis of Forest Service and Department of the Interior data on appropriations enacted by Congress. | GAO-20-52

Note: Dollar values are not adjusted for inflation. Fiscal year 2009 funding was partially based on a single year supplemental appropriation under the American Recovery and Reinvestment Act of 2009.

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Abbreviations

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
Cohesive Strategy	2014 Cohesive Wildland Fire Management Strategy
FWS	Fish and Wildlife Service
NPS	National Park Service
WUI	Wildland-urban interface

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December 19, 2019

Congressional Requesters

Wildfires are both natural and inevitable, and they play an important ecological role in maintaining healthy ecosystems on our nation's wildlands. Over time, however, fire suppression and other land management practices have disrupted the normal frequency of wildfires in many ecosystems, resulting in abnormally dense accumulations of vegetation. According to a multi-agency federal research effort, this altered landscape, combined with drought and other climate stressors, has contributed to larger and more severe wildfires.¹ At the same time, development in and around wildlands—an area called the wildland-urban interface (WUI)—continues to increase, placing more communities and infrastructure at risk from wildfire.² In recent years, wildfires have demonstrated the potential for devastating consequences to communities. For example, in 2018, the Camp Fire destroyed or damaged over 18,000 structures and resulted in 85 deaths in and around Paradise, California, and the Mendocino Complex Fire was the largest fire in state history, burning over 410,000 acres in northern California.³

Damage from wildfires has led to a growing awareness of the importance of increasing communities' resilience to such disasters, as well as to other natural disasters, such as hurricanes and floods.⁴ Promoting community resilience is one of the goals of the United Nations Sendai Framework for

¹U.S. Global Change Research Program, *Climate Change Impacts in the United States: The Third National Climate Assessment* (Washington, D.C.: May 2014).

²Department of Agriculture and Department of the Interior, *2001 Federal Wildland Fire Management Policy* (Washington, D.C.: January 2001). Federal agencies define the WUI as the geographical area where structures and other human development meet or intermingle with wildlands and vegetative fuels.

³In 2017, the Tubbs Fire in northern California destroyed or damaged over 5,500 structures and resulted in 22 deaths, and the Thomas Fire in southern California burned over 280,000 acres, destroyed or damaged over 1,000 structures, and resulted in two deaths.

⁴The National Research Council defines resilience as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. National Research Council, *Disaster Resilience: A National Imperative* (Washington, D.C.: 2012).

Disaster Risk Reduction 2015-2030.⁵ Likewise, promoting the nation's resilience to disasters is one of the goals of both *The 2014 Quadrennial Homeland Security Review* (an interagency report that includes information on federal disaster preparedness) and the 2017 U.S. National Security Strategy.⁶ Consistent with the framework, review, and strategy, reducing vulnerability to threats such as wildfires helps to build community resilience by reducing the amount of risk facing the community exposed to the threat.⁷

Federal wildland fire management is guided by, among other things, the 2014 Cohesive Wildland Fire Management Strategy (Cohesive Strategy).⁸ The Cohesive Strategy's goals include both building fire-adapted communities and restoring and maintaining fire-adapted ecosystems, which can help communities prepare for wildfires and can promote ecosystem health, respectively. The primary federal agencies responsible

⁵The goal, as presented in the framework, is to "Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience." The Sendai Framework is a 15-year, voluntary, non-binding agreement. UNISDR, *Sendai Framework for Disaster Risk Reduction 2015-2030* (Geneva, Switzerland: March 2015).

⁶Department of Homeland Security, *The 2014 Quadrennial Homeland Security Review* (Washington, D.C.: June 2014) and Executive Office of the President, *National Security Strategy of the United States of America* (Washington, D.C.: December 2017).

⁷The Department of Homeland Security's Federal Emergency Management Agency uses the following risk equation: risk = (threat) x (vulnerability) x (consequence).

⁸Department of Agriculture and Department of the Interior, *2014 National Strategy, The Final Phase in the Development of the National Cohesive Wildland Fire Management Strategy* (Washington, D.C.: April 2014). The Federal Land Assistance, Management, and Enhancement Act of 2009 required federal land management agencies to develop a national cohesive wildland fire management strategy consistent with our previous recommendations. Pub. L. No. 111-88 § 503, 123 Stat. 2971 (2009). The Cohesive Strategy provides a nationwide framework designed to integrate fire management efforts across jurisdictions; manage risks; and protect firefighters, property, communities, and landscapes. For additional information, see GAO, *Wildland Fire Management: Federal Agencies Have Taken Important Steps Forward, but Additional, Strategic Action Is Needed to Capitalize on Those Steps*, [GAO-09-877](#) (Washington, D.C.: Sept. 9, 2009) and *Wildland Fire Management: Update on Federal Agency Efforts to Develop a Cohesive Strategy to Address Wildland Fire Threats*, [GAO-06-671R](#) (Washington, D.C.: May 1, 2006). Also, in August 2018, the Forest Service issued a report on its plans to work more closely with states to set landscape-scale priorities for targeted fuel reduction projects in areas with the highest returns on investment. See Forest Service, *Toward Shared Stewardship Across Landscapes: An Outcome-Based Investment Strategy* (Washington, D.C.: August 2018).

for wildland fire management are the Department of Agriculture's Forest Service and the Department of the Interior's Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), and National Park Service (NPS). One approach the five agencies use to implement the goals of the Cohesive Strategy is fuel reduction—reducing the amount of brush, trees, and other vegetation that can fuel fires. Reducing these fuels—for example, by using chainsaws and other machines to cut and remove vegetation—is intended to lower the potential for severe wildfires, lessen the damage caused by fires that occur, and restore and maintain healthy ecosystems.

Federal agencies have estimated that tens of millions of acres they manage or administer are at high risk of wildfire. Recognizing that reducing the risks from wildfires on those lands may take decades, the agencies have acknowledged the importance of setting priorities for selecting fuel reduction projects that may be the most effective at reducing the overall risk posed from wildfire. We have previously reported on the agencies' fuel reduction programs, including how the agencies identify and set priorities for lands needing fuel reduction and their efforts to track their accomplishments.⁹ To help the Forest Service and Interior better understand the effectiveness of their approach to wildland fire management, in our 2015 report we recommended that the agencies develop specific criteria for selecting wildfires to review and revise their policies to align with the criteria developed. The Forest Service and Interior implemented these recommendations.¹⁰

⁹See, for example, *Wildland Fire Management: Agencies Have Made Several Key Changes but Could Benefit from More Information about Effectiveness*, [GAO-15-772](#) (Washington, D.C.: Sept. 16, 2015); *Wildland Fire Management: Better Information and a Systematic Process Could Improve Agencies' Approach to Allocating Fuel Reduction Funds and Selecting Projects*, [GAO-07-1168](#) (Washington, D.C.: Sept. 28, 2007); and *Wildland Fire Management: Additional Actions Required to Better Identify and Prioritize Lands Needing Fuels Reduction*, [GAO-03-805](#) (Washington, D.C.: Aug. 15, 2003).

¹⁰The Forest Service amended its policy to reflect its determination that it would review a statistically significant sample of large wildfires, including incidents that exceed \$50 million in suppression costs or incidents that involve 100,000 acres or more of Forest Service–managed land. Interior issued a policy memorandum stating that its agencies would review wildfires when the combined federal suppression costs were projected to meet or exceed \$15 million and more than 50 percent of the burned acres are managed by one or more Interior agencies.

You asked us to examine the federal government’s preparedness, response, and recovery efforts following the natural disasters of 2017, including wildfires. This report describes (1) methods the five federal agencies use to reduce fuels to help protect communities and ecosystems, (2) information considered and approaches the agencies used in allocating fuel reduction funds in fiscal year 2018, and (3) factors the agencies identified as affecting their efforts to implement fuel reduction projects.

To address these objectives, we reviewed relevant laws and regulations and agency strategy, policy, and budget documents. We conducted semi-structured interviews with officials from the Forest Service, Interior, BIA, BLM, FWS, and NPS, including headquarters officials in Washington, D.C. and at the National Interagency Fire Center in Boise, Idaho;¹¹ regional officials from a nonprobability sample of eight regional offices (four regional offices from the Forest Service and one from each of the Interior agencies);¹² and local officials from a nonprobability sample of 10 field units (e.g., a national forest or a BLM district office) located within the selected regions, including at least one field unit in each of these regions for each agency. The 10 field units were located in seven states (three field units were located in California and two were located in New Mexico). To better understand how field units selected and implemented fuel reduction projects, we visited four of the 10 field units (the Cibola and Santa Fe National Forests in September 2018 and the Shasta-Trinity National Forest and Whiskeytown National Recreation Area in April 2019). The results of these interviews cannot be generalized to all the agencies’ regional offices and field units but provide examples of fuel reduction projects and officials’ experiences with these projects.

To select offices, we reviewed the wildland fire hazard potential for each region, based on the Forest Service’s 2018 estimates, to identify the regions within the Forest Service and each of the four Interior agencies

¹¹The National Interagency Fire Center is the nation’s federal coordination center for wildland firefighting. It was created in 1965 when the Forest Service, BLM, and National Weather Service determined the need to work together to reduce duplication of services, cut costs, and coordinate national fire planning and operations. BIA, FWS, and NPS joined in the 1970s. The agencies at the center share firefighting supplies, equipment, and personnel to help enable efficient and cost-effective incident management. They also establish interagency policy, exchange information, and train personnel.

¹²The Forest Service, BIA, FWS, and NPS have regional offices, while BLM has state offices. For the purposes of this report, we refer to these as regional offices when we discuss the agencies collectively.

with the greatest hazard potential.¹³ For each agency, we judgmentally selected from among the high hazard potential regions that also generally received higher fuel reduction funding. Because we were also interested in geographic diversity, and associated diversity in vegetation types, we chose from among the high hazard potential regions but did not necessarily always choose the region with the highest hazard potential. In making our selections, we also considered suggestions from agency headquarters' officials. We then asked officials from the regional offices we selected to identify several field units in their regions that met characteristics we identified: high wildfire hazard potential, relatively larger fuel reduction program funding levels, challenging fuel conditions to address, having developed innovative approaches to reducing fuels, or a combination of these. We judgmentally selected from these field units, while considering geographic diversity and associated diversity in vegetation types.

In addition, we interviewed several nonfederal agency partners, including officials from the state forestry agency for each of the seven states where the federal field units we selected were located, as well as representatives from the National Association of State Foresters and the Western Governors' Association—given their involvement with federal wildland fire policy issues. We also interviewed a local government official and representatives from nongovernmental organizations during our site visit in New Mexico who were working with federal agencies in that state to design or implement fuel reduction projects. For a list of the agencies, field units, and nonfederal entities included in our review, see appendix I.

To address our first objective, we reviewed agency documents and interviewed agency officials to describe the various methods the agencies use to reduce fuels and how implementing fuel reduction projects help the agencies lower the risk to communities and ecosystems. Additionally, to describe examples of agency fuel reduction projects, we asked officials at the 10 field units selected to identify and describe fuel reduction projects their unit had completed during the previous 3 fiscal years (i.e., fiscal years 2016 through 2018). We also reviewed agency documentation related to these projects.

¹³The Forest Service defines wildfire hazard potential as the relative potential for a fire that would be difficult for suppression resources to contain. For more information on how the Forest Service estimates wildfire hazard potential, including data sources, see <https://www.firelab.org/project/wildfire-hazard-potential>.

Regarding our second objective, we reviewed applicable laws, regulations, and agency policies and guidance to determine the information the agencies considered and approaches the agencies used in fiscal year 2018—the most recently completed fiscal year at the time we began our review—when allocating their fuel reduction funds. We also interviewed agency headquarters officials and officials from the selected regional and field offices about the information they considered and the approaches they used when allocating their fuel reduction funds.

To address our third objective, we developed a preliminary list of potential factors that might affect agency efforts to implement fuel reduction projects based on initial discussions with agency headquarters officials and our previous work related to federal wildland fire management.¹⁴ We then interviewed agency officials from the selected regional and field offices to determine the extent to which they viewed the preliminary factors, or other factors, as affecting their implementation of fuel reduction projects. We also asked officials about any steps the agencies had taken, or planned to take, to address the factors. For various factors identified, we obtained supplemental documentation and data when available. Specifically, for one factor, the scope and scale of the need for fuel reduction, we analyzed data from the National Fire Plan Operations and Reporting System for fiscal years 2009 through 2018 to describe the average number of acres annually treated for fuel reductions in the United States.¹⁵ To assess these data for reliability, we reviewed national-level data reported by the agencies and discussed the data's completeness, accuracy, and consistency with officials at the Forest Service and Interior. We determined the data were sufficiently reliable for our purposes.

We conducted this performance audit from March 2018 to December 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

¹⁴See, for example, [GAO-15-772](#) and [GAO-07-1168](#).

¹⁵The National Fire Plan Operations and Reporting System is an interagency database designed to assist field personnel in managing and reporting accomplishments for work conducted under the National Fire Plan.

Background

Wildfires play an important ecological role on the nation's landscapes but various management practices over the past century—including fire suppression, timber harvesting, and grazing—have altered the normal frequency of fires in many forest and grassland ecosystems and have reduced these ecosystems' resilience to wildland fire.¹⁶ This history of fire exclusion and changes in forest management have resulted in a buildup of surface fuels—burnable material found on or near the ground—and the overstocking of some forests with trees and other fuels. In addition, the reduced frequency of wildfire in some ecosystems has resulted in increased amounts of vegetative debris (e.g., dead trees, branches, leaves, and grasses) accumulating on the ground, which serves to increase fuel quantities and can create more continuous fuels. When this occurs, surface fires—fires that occur on the ground—may ignite more quickly and burn with greater intensity, causing fires to spread more rapidly and extensively than they may have in the past.

The arrangement of living vegetation also affects the way wildfires burn. For example, an increase in the density of small trees creates a layered forest structure with fuels going from the forest floor into the forest's canopy. These layers are sometimes referred to as ladder fuels. This arrangement may allow fire that previously would have remained on the ground to climb the ladder fuels and spread into the trees' crowns, becoming a high-intensity crown fire. In addition, reducing the frequency of fire in fire-adapted forests and other ecosystems can result in changes to the plant species that make up the forest or ecosystem, which may cause the vegetative composition to shift toward species that are not well adapted to fire, including non-native invasive species. For example, many areas with sagebrush ecosystems—that historically had fires only once every few decades—have been invaded by cheatgrass that when dried

¹⁶As we found in [GAO-07-1168](#), most lands in the United States evolved with fire, and each ecosystem has a characteristic "fire regime" that describes the role fire plays in that ecosystem, including typical fire frequency, scale, intensity, and duration. The roles are based on certain characteristics, such as the average number of years between fires and the typical severity of fire under historic conditions. Fire regimes are categorized I through V. Fire regime I is characterized by low-severity fires that historically occurred every 35 years or less. Fire regime V is characterized by high-severity fires that historically occurred every 200 or more years.

creates large swaths of fuels that increase rates of fire spread, intensity, and frequency.¹⁷

Approximately 70,000 communities nationwide are considered to be at risk from wildfire, according to the National Association of State Foresters, *Communities at Risk, Fiscal Year 2018 Report*.¹⁸ Communities face different levels of risk from wildfires depending on such factors as the flammability of vegetation in and around the community, the flammability of materials used in constructing structures, and the location of the structures in relation to vegetation. Structures not located immediately adjacent to wildland vegetation can also be vulnerable to wildfire because winds can transport flaming embers that can ignite homes more than a mile away from a wildfire. In addition to residential housing, other valuable assets and infrastructure that support communities may be located in the WUI, including power lines; highways; and natural resources that provide economic benefits, such as timber, oil and gas wells, and recreational areas. According to the Cohesive Strategy, reducing fuels can help reduce a wildland fire's intensity, which in turn can help lower the risk fires pose to communities, structures, and other valuable assets and infrastructure.

Federal Agencies Involved in Fuel Reduction Projects

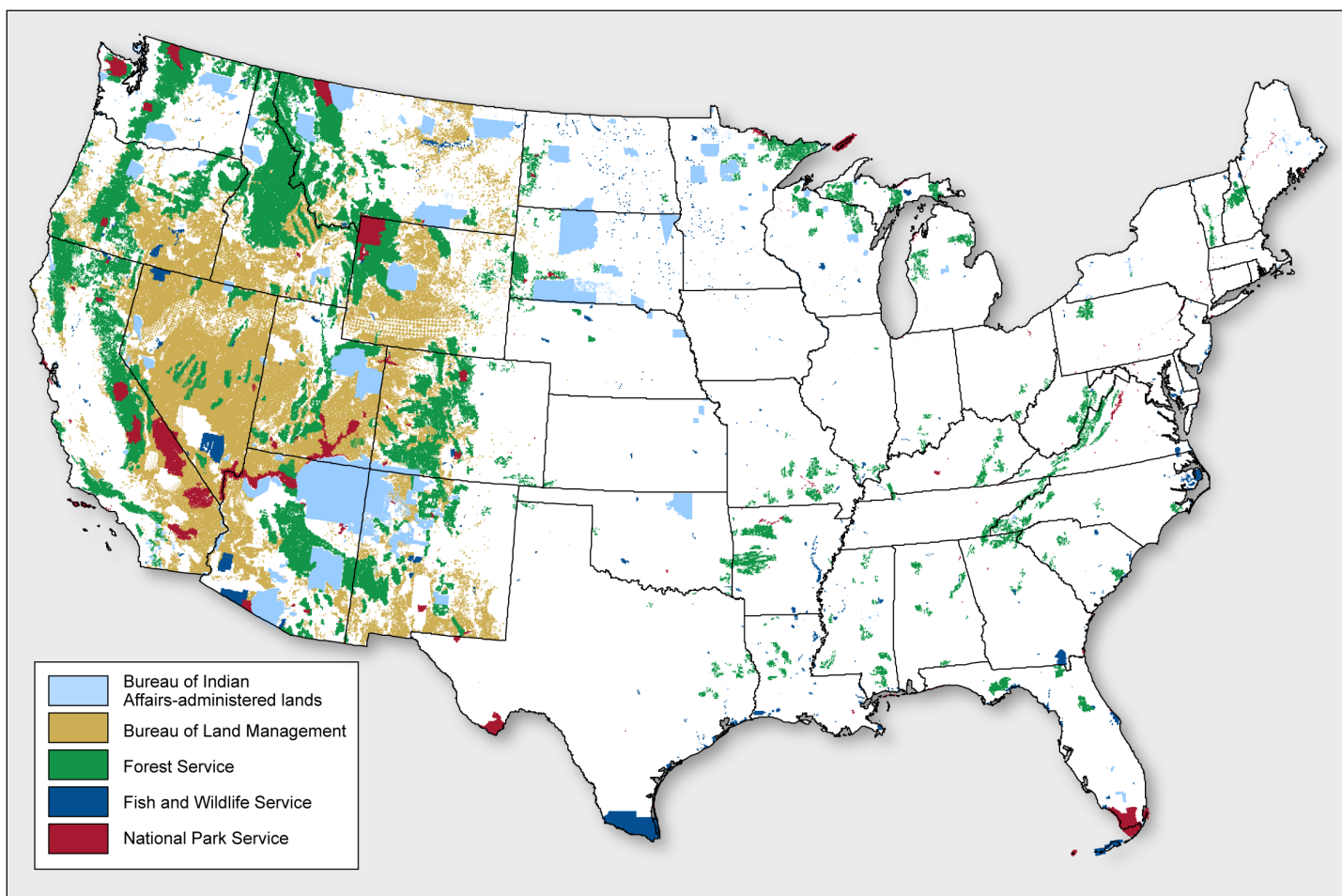
The Forest Service, BLM, FWS, and NPS manage more than 670 million acres of federal land across the country. In addition, BIA is responsible for administering approximately 55 million acres of lands held in trust by the United States for Indian tribes, individuals, and Alaska Natives. Figure 1 shows the lands that these five agencies managed or administered in the

¹⁷According to a recent U.S. Geological Survey report, cheatgrass is an invasive plant common to the southwestern United States. An early emerging annual grass native to southern Europe, northern Africa, and southwestern Asia, it was first identified as having been introduced into the United States in 1861, is now found throughout all 50 states, and is widely distributed across the western United States. U.S. Geological Survey, *A Conservation Paradox in the Great Basin—Altering Sagebrush Landscapes with Fuel Breaks to Reduce Habitat Loss from Wildfire* (Reston, VA: 2018).

¹⁸Additionally, according to a report developed on behalf of the Forest Service and Interior, there are approximately 46 million single-family homes in the WUI in the United States. Booz Allen Hamilton, *2014 Quadrennial Fire Review Final Report* (Washington, D.C.: May 2015).

contiguous United States. The agencies have estimated that over 100 million of these acres are at high risk from wildfire.¹⁹

Figure 1: Lands Managed by the Bureau of Land Management, Fish and Wildlife Service, Forest Service, and National Park Service and Administered by the Bureau of Indian Affairs in the Contiguous United States



Sources: GAO analysis of U.S. Geological Survey's National Atlas website data; MapInfo (map). | GAO-20-52

¹⁹In 2018, the Forest Service estimated that there were approximately 63 million acres of national forest lands at high to very high risk from uncharacteristic wildfire. In July 2019, Interior officials estimated that 54 million acres of the lands its agencies manage or administer were at high or very high risk from wildfire.

Each agency has a unique mission that shapes how it manages or administers its associated lands. Specifically:

- The Forest Service manages land for multiple uses, such as grazing, timber, recreation, and watershed protection, and to sustain the health, diversity, and productivity of the nation's forests and grasslands. The agency operates through nine regional offices that manage 154 national forests and 20 national grasslands.
- BIA provides services, directly or through contracts or compacts, to federally recognized tribes comprising approximately 1.9 million American Indian and Alaska Natives, many of whom live on BIA-administered lands.²⁰ Tribal forests provide a source of revenue and jobs for many tribal governments and their members, and play an important role in sustaining tribal cultures and traditions, according to BIA documents. The agency operates through 12 regional offices that manage 83 BIA field units.
- BLM manages land for multiple uses, such as recreation, mining, grazing, timber, and natural scenic values. The agency operates through 12 state offices that manage subsidiary district and field offices.
- FWS manages the National Wildlife Refuge System, a network of lands and waters that provides for the conservation; management; and, where appropriate, restoration of fish, wildlife, and plants and their habitats, as well as opportunities for wildlife-dependent recreation, including hunting, fishing, and wildlife observation. The refuge system includes approximately 585 refuges. The agency operates through eight regional offices that manage the refuges.
- NPS manages the National Park System to conserve the scenery, natural and historic objects, and wildlife therein and to leave them unimpaired for the enjoyment of future generations. Individual park units have varied designations corresponding to the natural or cultural features they are to conserve, including national parks, monuments, lakeshores, seashores, recreation areas, preserves, and historic sites.

²⁰Federally recognized tribes have a government-to-government relationship with the United States and are eligible to receive certain protections, services, and benefits by virtue of their status as Indian tribes. The Secretary of the Interior is required by law to publish annually in the *Federal Register* a list of all Indian tribes that the Secretary recognizes as Indian tribes. As of August 7, 2019, there were 573 federally recognized tribes.

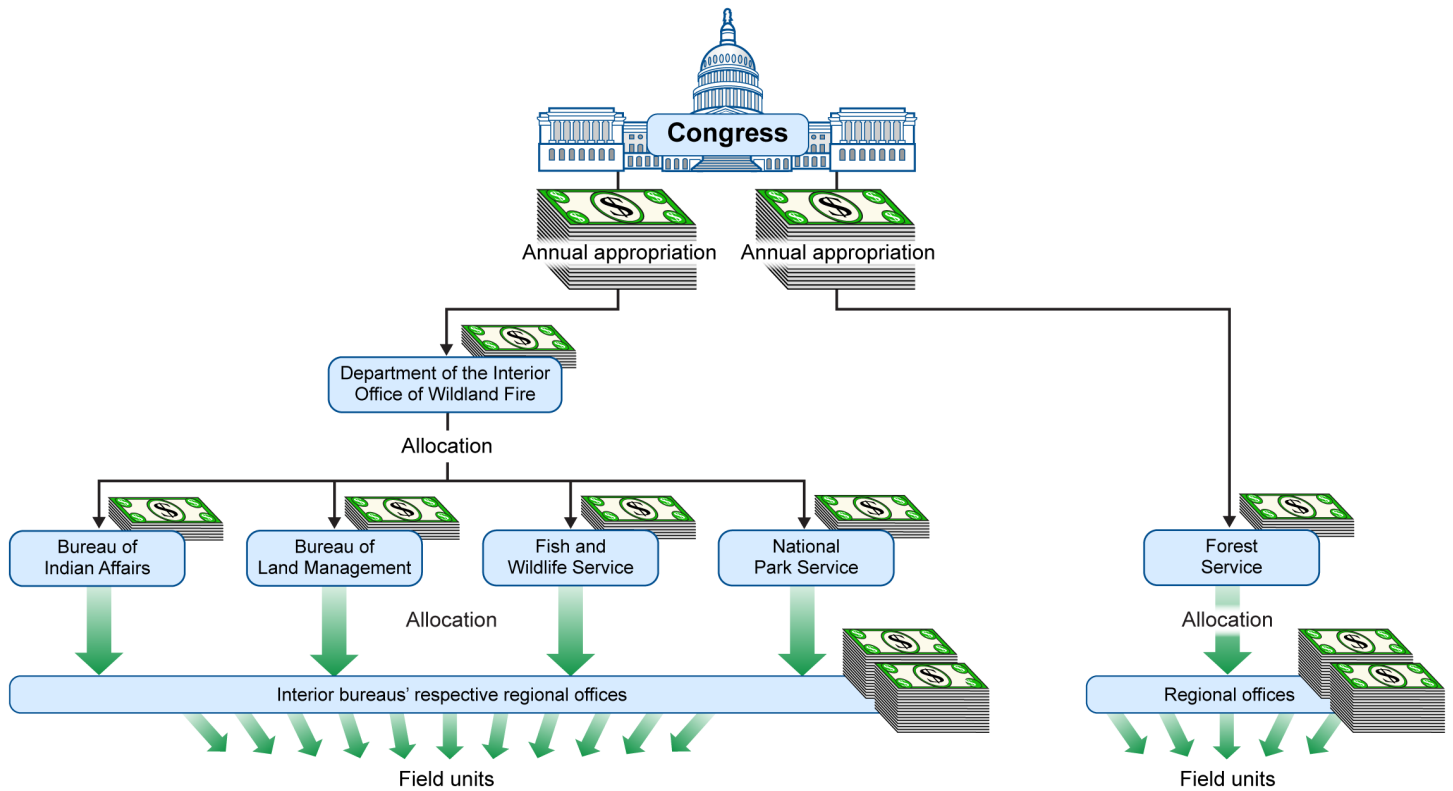
The agency operates through seven regional offices that manage 419 individual park units.

Federal Agencies' Appropriations and Allocations of Funds for Fuel Reduction

Generally, after receiving its annual appropriation, the Forest Service allocates its fuel reduction funds to its nine regional offices, which in turn allocate the funds they receive to individual field units (e.g., national forests and grasslands). Interior, upon receiving its annual appropriation, allocates its fuel reduction funds through its Office of Wildland Fire to BIA, BLM, FWS, and NPS.²¹ These agencies then allocate the funds to their regional offices, which, in turn, allocate the funds to individual field units, such as national parks or wildlife refuges. Once the field units receive their allocations, they select fuel reduction projects to implement during the fiscal year. For fiscal years 2009 through 2018, the Forest Service and Interior implemented fuel reduction projects that treated, respectively, approximately 1.4 million and 1.1 million acres per fiscal year on average. Figure 2 illustrates the annual appropriation and allocation processes for fuel reduction funds.

²¹Interior's Office of Wildland Fire organizes the activities of the four Interior agencies that manage and operate wildland fire programs. Specifically, it manages, oversees, and coordinates the department's wildland fire management program, as well as associated policies, budgets, information technology systems, and decision support tools. For fiscal years 2012 through 2018, the Office of Wildland Fire allocated Interior's annual appropriation for fuel reduction to its agencies, on average, approximately as follows: BLM, 47.1 percent; BIA, 21.6 percent; NPS, 14.8 percent; and FWS, 13.2 percent. In addition, the Office of Wildland Fire retained about 2.4 percent of the annual appropriation for its operations, and Interior retained 1.0 percent and carried it over into the following fiscal year for allocation.

Figure 2: Process for Annual Appropriations and Allocations of Funds to Federal Agencies for Wildland Fire Management, Including Fuel Reduction

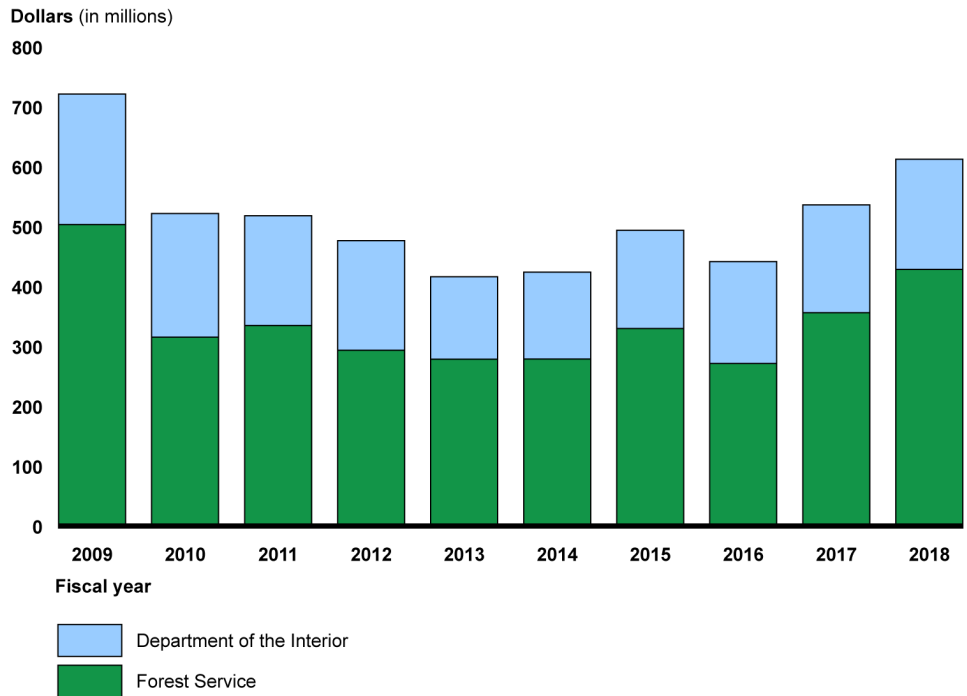


Source: GAO. | GAO-20-52

Note: Congress appropriates Interior's wildland fire management funding as part of Interior's department-wide programs. Interior's Office of Wildland Fire then allocates these funds to its bureaus. Congress appropriates the Forest Service's funding directly to the agency, not as part of any department-wide program of the Department of Agriculture.

From fiscal years 2009 through 2018, Congress appropriated approximately \$5 billion in fuel reduction funds to the Forest Service and Interior, with the Forest Service and Interior annually receiving on average about \$339 million and \$177 million, respectively (see fig. 3).

Figure 3: Forest Service and Department of the Interior Fuel Reduction Appropriations, Fiscal Years 2009 through 2018



Source: GAO analysis of Forest Service and Department of the Interior data on appropriations enacted by Congress. | GAO-20-52

Note: Dollar values are reported without adjustment for inflation. The Forest Service's and Interior's fuels reduction funding in fiscal year 2009 was in part based on an additional single year supplemental appropriation under the American Recovery and Reinvestment Act of 2009.

The Role of Nonfederal Entities

Most development in the WUI occurs on nonfederal lands. Accordingly, state and local government agencies, as well as property owners, play a major role in protecting communities and other development from wildfire.²² The Forest Service and the National Institute of Standards and Technology have developed publicly available resources that describe ways communities can adapt to wildfire. Specifically, two critical actions

²²For example, the Forest Service's State Forestry Assistance program under the Cooperative Forestry Assistance Act of 1978 provides financial and technical assistance to states and communities for wildland fire management. State foresters are to allocate State Forestry Assistance program funds according to the priorities identified through State Forest Action Plans—strategic plans for all forests in each state that include an analysis of forest conditions and trends and that identify priority forest landscape areas. See GAO, *Wildland Fire Risk Reduction: Multiple Factors Affect Federal-Nonfederal Collaboration, but Action Could Be Taken to Better Measure Progress*, [GAO-17-357](#) (Washington, D.C.: May 10, 2017).

for protecting structures from wildfires are (1) reducing vegetation and flammable objects within an area of 30 to 100 feet around a structure, referred to as creating defensible space, and (2) using fire-resistant roofing materials and covering attic vents with mesh screens to block embers from entering the structure.²³ Individuals and communities can also take steps to mitigate fire risk by avoiding development in higher-risk areas.²⁴ To help protect structures, state and local agencies may conduct, or help fund, fuel reduction projects to protect communities and other nonfederal lands from wildfire. For example, a rural fire department in Montana funds a crew to reduce fuels around private residences to create defensible space for those homes. In addition, individual property owners may reduce fuels around their homes. In previous reports, we found that state and local agencies have adopted laws or ordinances that require homeowners to maintain a specified level of defensible space or have adopted building codes that require the use of fire-resistant building materials in fire-prone areas.²⁵ For example, in our May 2017 report, we found that under an Oregon law, property owners in certain at-risk areas must reduce excess vegetation around structures and along driveways.²⁶

²³Forest Service, *Fire Adapted Communities*, <https://www.fs.fed.us/managing-land/fire/fac> and National Institute of Standards and Technology, *Improving WUI Community Fire Protection- Fire Resistant Building Design and Materials*, <https://www.nist.gov/programs-projects/improving-wui-community-fire-protection-fire-resistant-building-design-and>. For more information, see also GAO, *Technology Assessment: Protecting Structures and Improving Communications during Wildland Fires*, [GAO-05-380](https://www.gao.gov/products/2005-05-380) (Washington, D.C.: Apr. 26, 2005).

²⁴For more details, see [GAO-17-357](https://www.gao.gov/products/2017-07-357).

²⁵For more information, see [GAO-17-357](https://www.gao.gov/products/2017-07-357) and [GAO-09-877](https://www.gao.gov/products/2009-09-877).

²⁶Under the Forestland-Urban Interface Fire Protection Act, the Oregon Department of Forestry established criteria for identifying at-risk areas in each county. See [GAO-17-357](https://www.gao.gov/products/2017-07-357) for additional information.

Agencies Use Various Fuel Reduction Methods to Help Lower Risk to Communities and Ecosystems

According to Forest Service and Interior documents and officials, the Forest Service and the four Interior agencies use various methods to reduce fuels, which have advantages and disadvantages under different conditions. For example:

- **Mechanical treatments.** This method entails using equipment such as chainsaws, masticators, bulldozers, or mowers to cut and remove vegetation.²⁷ Mechanical treatments reduce tree density where there are abnormally dense groups of trees or ladder fuels to help reduce the risk of a wildfire becoming severe. Interior officials said that mechanical treatments are also widely used for removing shrubs and other vegetation in rangeland ecosystems. However, mechanical treatments may also increase the amount of smaller fuels on the ground, including treetops and limbs (referred to as slash) and other debris from thinning, which can in some cases increase a fire's intensity or rate of spread.
- **Prescribed burns.** This method entails using deliberate, planned fires set by land managers to restore or maintain desired ecosystem conditions and reduce fuels. Prescribed burning under specified fuel and weather conditions is designed to enable a fire to burn at a relatively low intensity level within a confined area.²⁸ Prescribed burns typically work best when combined with previous prescribed burns or mechanical treatments because they are effective in removing smaller vegetation that can fuel a fire—such as grasses, leaves, pine needles, and twigs—which can reduce a fire's intensity and rate of spread, but are not as effective in removing larger fuel, such as trees. Smoke produced from prescribed burns and the risk of a prescribed burn spreading into other areas can limit the use of prescribed burns around communities, according to the Forest Service's *Fuels Technical Guide*.²⁹
- **Herbicides and targeted grazing.** Herbicides can be used to reduce fuels or when needed to kill fast growing vegetation to maintain an existing fuel reduction project. However, herbicide kills vegetation but does not remove it, potentially increasing an area's susceptibility to

²⁷Mastication uses machines to grind or shred trees or other types of vegetation on-site.

²⁸Prescribed burning includes broadcast burns, wherein an area of several acres or more is ignited, and pile burning, which involves collecting material left over following mechanical treatments into piles and burning them.

²⁹Forest Service, *Fuels Technical Guide* (Washington, D.C.: July 2018). This guide is designed to provide technical knowledge for field-level fuel reduction technicians.

fire if further action is not taken to remove the dead fuel.³⁰ Targeted grazing—the intentional use of cows, sheep, or goats to eat vegetation in a specified area—can also be used to reduce grasses and other smaller fuels that can fuel fires. One advantage of such methods is that they often can be applied with a greater level of control over the location, timing, and desired outcome of the treatment. These methods can be particularly helpful in removing smaller fuels in areas where prescribed burning is undesirable, such as in proximity to structures. With grazing, however, it may take multiple years before there is a noticeable difference in the fuels, and according to agency officials, moving livestock to different areas for grazing is labor-intensive and can potentially increase the spread of invasive plants if livestock movement is not controlled.

While some fuel reduction projects may be completed with a single treatment method, other projects may require multiple treatment methods and may span several years. For example, a project may first use mechanical treatment to thin accumulated vegetation, followed by a prescribed burn to remove remaining slash and litter on the ground. Moreover, once a project is completed, it needs to be maintained over time to retain its effectiveness as vegetation grows back. Depending on the ecosystem, fuels treatment effectiveness can vary in length from only a few years to over a decade. For example, fuel reduction projects are generally effective for 3 to 5 years in southeastern U.S. pine forests given the high rate at which vegetation grows in that region. In contrast, projects are generally effective for 8 to 12 years in dry conifer forests in the western United States.

The most appropriate fuel reduction method or methods—as well as how they are applied (i.e., how much vegetation is removed)—depends on the outcomes desired (e.g., protecting communities, restoring ecosystems); the type of forest or other vegetation present; and site-specific factors, such as topography and proximity to communities, according to the Forest Service's *Fuels Technical Guide* and agency officials.³¹ The Forest Service and Interior have long-standing research programs that are designed to support agency managers' understanding of how to

³⁰BLM officials said that in some cases herbicide use does not leave dead vegetation because it can be applied as a growth inhibitor before the vegetation has become established.

³¹Forest Service, *Fuels Technical Guide*.

implement effective fuel reduction projects.³² As of November 2019, Forest Service research priorities included refining the scientific understanding of how wildfire burns across landscapes and the effects of fuel reduction projects conducted at different scales.³³ In addition, the agencies conduct assessments, known as fuel treatment effectiveness monitoring reports, in cases where a wildfire either starts within or burns into a fuel reduction project area to evaluate the project's effect on fire behavior and fire suppression actions. Officials believe that such research helps their agencies continue to improve how they design and implement fuel reduction projects to account for site-specific factors.

Regardless of the method used, the purpose of fuel reduction projects is to reduce the intensity of future wildfires to help protect communities, restore ecosystems, or both, according to agency documents. The following examples illustrate various fuel reduction methods that the agencies have used to help protect communities and ecosystems:

- Officials from BIA and the San Carlos Apache Tribe said that they perform prescribed burns and mechanical treatments annually on approximately 1,000 to 1,600 acres of the San Carlos Apache Indian Reservation in Arizona to remove rapidly growing grasses, which could quickly carry a wildfire into the community. The officials said that they primarily use prescribed burns as this allows them to inexpensively treat the most acres. The officials said that they perform these treatments close to the community, to help keep fires from reaching structures and to provide space for firefighters to work more safely in the event of a fire (see fig. 4).

³²For example, the Forest Service and Interior jointly fund the Joint Fire Science Program, a research program that Congress established in 1998. The Forest Service also operates several fire research facilities, and Interior's wildfire science program is implemented within the department by the U.S. Geological Survey.

³³For more information, see <https://www.fs.fed.us/research/priority-areas/> and <https://www.usgs.gov/special-topic/fire/science>.

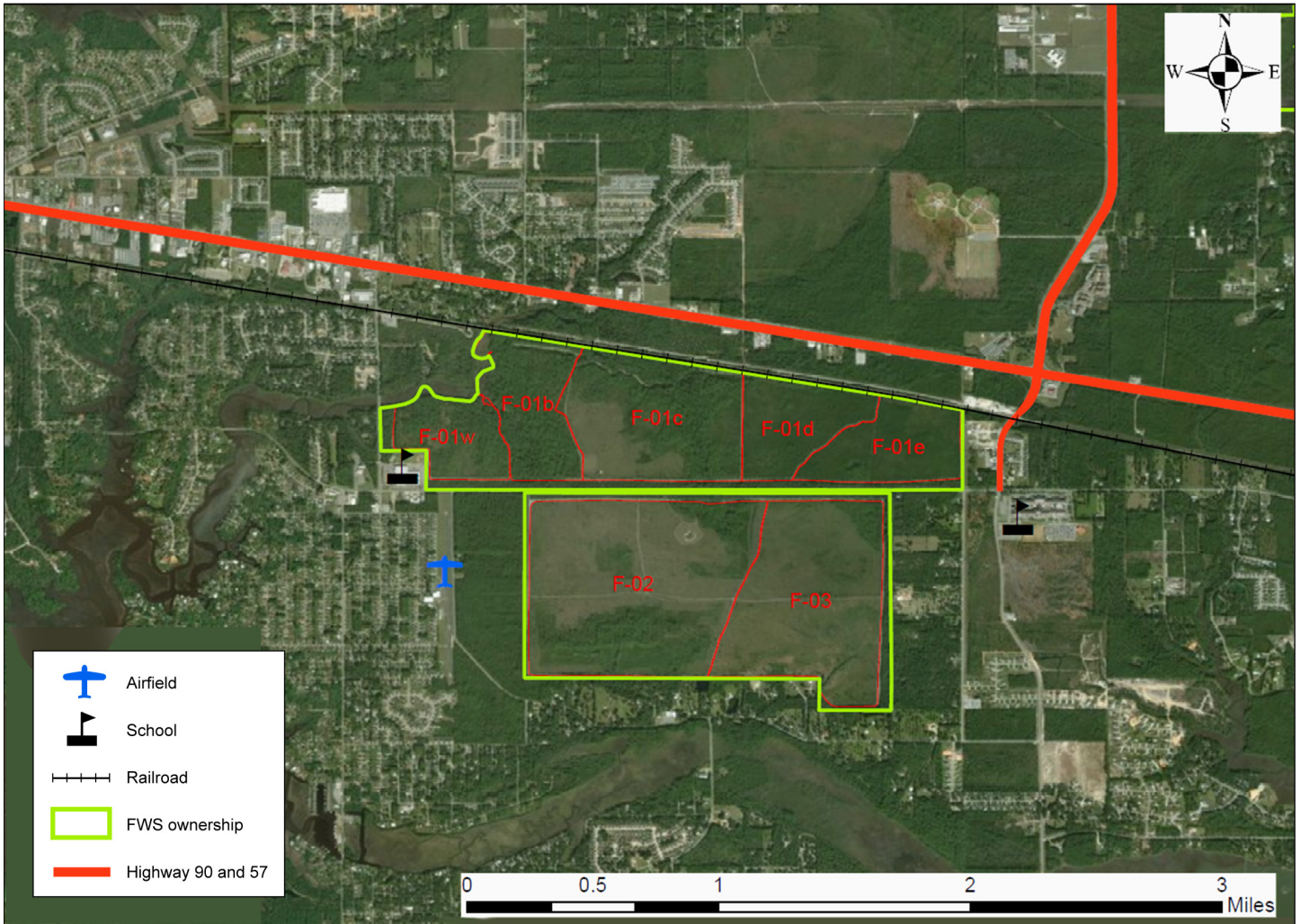
Figure 4: Prescribed Burn in the Wildland Urban Interface, San Carlos Apache Indian Reservation in Arizona (August 2019)



Source: San Carlos Apache Forest Resources Program. | GAO-20-52

- An FWS official at the Mississippi Sandhill Crane National Wildlife Refuge said that the refuge uses prescribed burns and mechanical treatments to reduce the wildfire risk to several nearby communities. For example, for a 1,000-acre area near Ocean Springs, Mississippi, the refuge has been doing fuel reduction projects for decades in an effort to protect nearby residential and commercial areas, as well as a highway, railroad, and other infrastructure (see fig. 5). The official said that because the dominant tree species on the refuge is slash pine, which grows very quickly, they have to treat the area every 3 to 5 years to maintain the effectiveness of the project. The official also said that the refuge uses more mechanical treatments than prescribed burns in this area because of concerns about smoke drifting into nearby communities but that they also use prescribed burns when weather conditions are favorable.

Figure 5: Fuel Reduction Project Area in the Mississippi Sandhill Crane National Wildlife Refuge That Is Close to Communities and Infrastructure (August 2019)



Source: Fish and Wildlife Service (FWS). | GAO-20-52

Note: Sections labeled with the letter F and a number indicate areas of the refuge in which FWS officials conduct fuel reduction projects.

- Santa Fe National Forest officials said that since the early 2000s, they have partnered with the New Mexico State Forestry Division and the New Mexico Department of Game and Fish to conduct a series of fuel reduction projects, including mechanical treatments and prescribed burns, covering 8,000 acres in the Jemez Mountains of New Mexico. These projects were designed to reduce both the likelihood of a fire

reaching nearby communities and potential ecosystem damage. The officials said that given the proximity to development and the large accumulation of fuels in that area, they used mechanical treatments first because a prescribed burn would be hazardous until fuel levels were reduced. After the mechanical treatments were completed, they used prescribed burns to remove as much of the remaining fuels as possible. Officials told us that the utility of these projects was demonstrated in July 2018 when the Venado Fire burned from an untreated into a treated area and changed from a high-intensity fire burning the crowns of the trees to primarily a low-intensity fire burning on the ground (see fig. 6).³⁴ The officials said that while they do not know what the Venado Fire would have done without the fuel reduction projects, they believe that the projects slowed the fire sufficiently to provide firefighters with time to contain the fire before it spread to populated areas and also helped reduce ecosystem damage.³⁵

³⁴A Forest Service video about this project is posted at <https://m.youtube.com/watch?feature=share&v=K329543iUp0>.

³⁵A postfire assessment of the Venado Fire, completed by the Forest Service in October 2018, noted that 2,945 acres of the fire's total 4,064 acres burned at low enough severity to meet the agency's resource objectives for that area.

Figure 6: Fuel Reduction Project in the Santa Fe National Forest in New Mexico (September 2018)



A wildfire burned from an untreated (left) into a treated area (right) and changed from a high-intensity fire burning the crowns of the trees to primarily a low-intensity fire burning on the ground, according to Forest Service officials.

Source: GAO. | GAO-20-52

- NPS officials at the Whiskeytown National Recreation Area near Redding, California, said that many of the fuel reduction projects they undertake are designed to reduce risk to local communities and restore ecosystem health. For example, the officials said that in 2013 they began a 1,000-acre project, consisting primarily of prescribed burns but also some mechanical treatments, located adjacent to privately owned houses and timber land. The officials said that they primarily use prescribed burns because the lower cost of the burns allows them to treat more acres. The project was intended to reduce fire risk to adjacent private property and to help improve the ecological health of old-growth Douglas-fir stands within the recreation area. The officials said that they believed the project helped to reduce the intensity in some areas burned by the 2018 Carr Fire but also noted

that the fire was too intense for the treatments to be effective in other areas, as shown in figure 7.³⁶

Figure 7: Fuel Reduction Project in the Whiskeytown National Recreation Area, California (April and July 2019)



The left photograph shows an area where the National Park Service had completed a fuel reduction project that reduced the intensity of a 2018 wildland fire, according to agency officials. The right photograph shows another treated area where agency officials said that the intensity of the fire was too high for the fuel reduction project to be effective.

Sources: National Park Service (left photo); GAO (right photo). | GAO-20-52

- Officials at the BLM West Desert District office in Utah said that they have been working on a 4,680-acre fuel reduction project since 2017. The primary purpose of this project is to improve breeding and winter habitat for the greater sage-grouse by removing juniper and other vegetation that pose a wildfire risk to the sagebrush habitat the bird

³⁶The 2018 Carr Fire burned 229,651 acres and destroyed at least 1,800 structures. Of the area burned by the fire, 4,318 acres had been treated by fuel reduction projects. National Park Service, *Carr Wildfire Fuel Treatment Effectiveness Report* downloaded from <https://iftdss.firenet.gov/fitem/#/fitemreport/81744/wildfire/NPS> by NPS officials on July 25, 2019.

relies on.³⁷ The project area is home to the largest population of greater sage-grouse in the state. The officials said that they mostly use mechanical treatments, including mastication, because mastication, unlike other fuel reduction methods, allows for the selective removal of juniper trees while still preserving sagebrush. Figure 8 shows the project area before and after treatment, with juniper trees removed and sagebrush remaining.

Figure 8: Bureau of Land Management Fuel Reduction Project in Utah Where Juniper Trees Have Been Removed (July 2016 and July 2018)



Source: Bureau of Land Management. | GAO-20-52

³⁷In 2010, FWS determined that listing the greater sage-grouse under the Endangered Species Act was “warranted but precluded” due to higher priorities. In September 2015, BLM and the Forest Service adopted land management plan amendments revising 98 BLM and Forest Service plans across 10 western states. In the same month, FWS determined that the greater sage-grouse did not warrant listing under the Endangered Species Act in part because the revised plans provided enhanced regulatory mechanisms to protect it. In 2019, in response to the Secretary of the Interior’s orders emphasizing energy independence and cooperation with western state governments, the relevant land management plans were further amended. Environmental groups challenged the 2015 amendments in federal court, and subsequently the 2019 amendments, arguing that these improperly relax restrictions on oil and gas developments on federal lands to the detriment of the greater sage-grouse. The court recently issued a preliminary injunction prohibiting BLM from implementing the revised management plans in seven western states. *Western Watersheds Project v. Schneider*, Civ. No. 16-83 (D. Idaho), slip op. at 7 (Oct. 16, 2019).

Agencies Considered
Similar Information on
Potential Wildfire
Damage to
Communities and
Ecosystems and
Used Different
Approaches to
Allocate Fuel
Reduction Funds

Agencies Considered
Similar Types of
Information in Allocating
Funds in Fiscal Year 2018

Agency officials told us that in deciding how to allocate their fuel reduction funds in fiscal year 2018, they primarily considered information related to the wildfire hazard potential on lands they manage or administer, the proximity of communities and infrastructure to those potential fires, and ecosystem health.³⁸

- **Wildfire hazard potential.** To allocate their fuel reduction funds, officials from the five agencies said they considered information regarding the likelihood and severity of wildfires that may occur across the areas they manage and administer. For example, officials said they generally used information incorporated into a national geospatial database that the Forest Service developed to estimate the relative probability a given area faces of experiencing a wildfire that would be difficult for suppression resources to contain and therefore may cause damage to communities or ecosystems.³⁹ To produce this database, the Forest Service used, among other things, satellite imagery to identify fuel conditions across the landscape. The Forest Service then ran computer models that used this fuel condition information to

³⁸Agency officials said they also considered factors related to program management in allocating fuel reduction funds, such as seeking to maintain relative funding stability from year to year to allow field staff to more effectively plan their programs and facilitate multi-year project planning efforts.

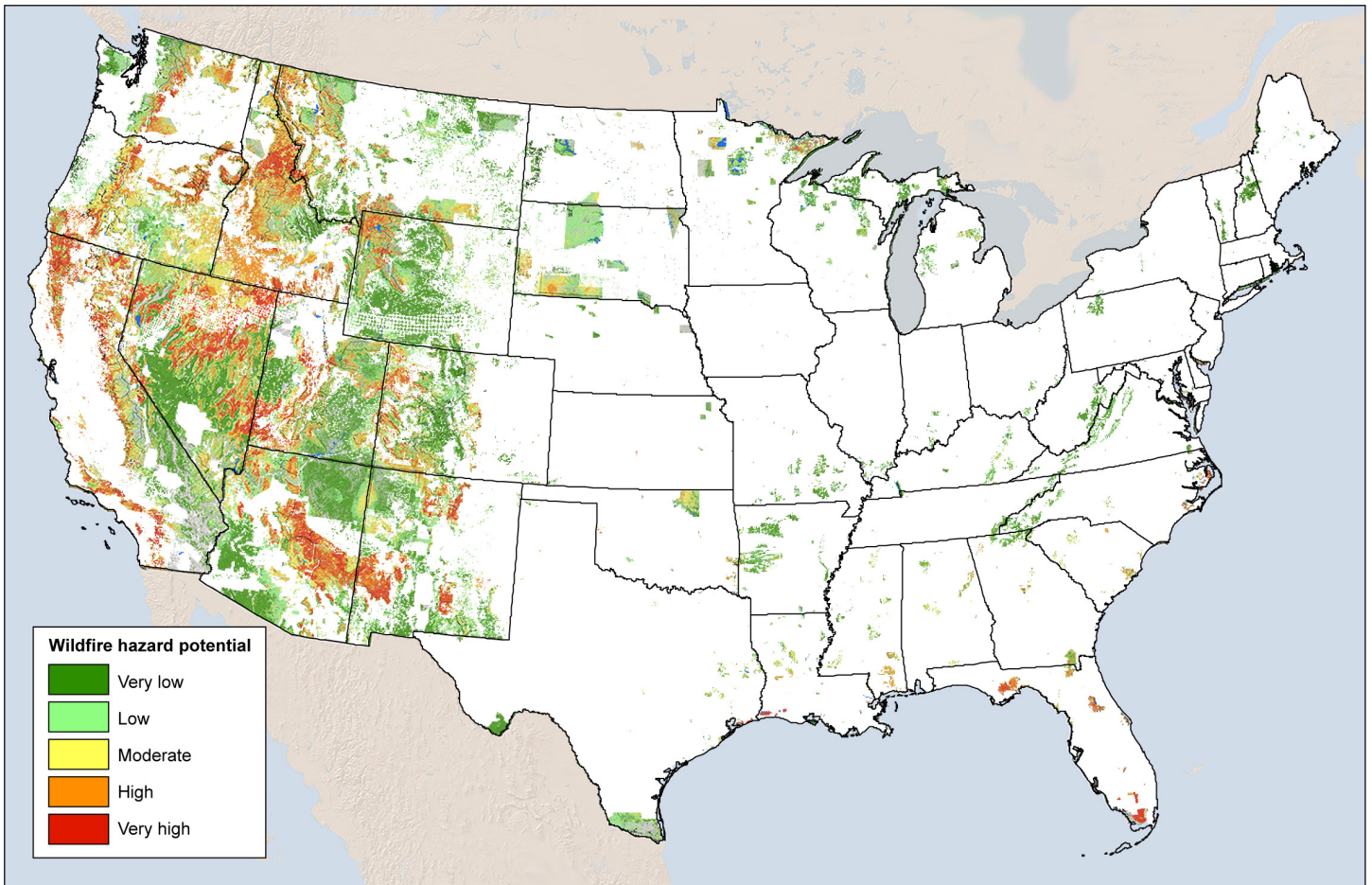
³⁹For more information on how the Forest Service estimates wildfire hazard potential, including data sources, see <https://www.firelab.org/project/wildfire-hazard-potential>.

estimate the potential intensity of future wildfires.⁴⁰ The Forest Service's identification of the likelihood and potential intensity of a wildfire in a given area helps the agencies compare the relative hazard potential different geographic areas face from such fire. The agencies also used information from another national geospatial database that the Forest Service developed on historical fire occurrence data to identify where fires have most frequently occurred, whether because of natural causes (e.g., lightning) or human causes (e.g., accidental ignitions or arson).⁴¹ Figure 9 shows the wildfire hazard potential, as assessed by the Forest Service in July 2018, on lands the five agencies managed and administered in the contiguous United States.

⁴⁰For more information on the federal interagency LANDFIRE program, which produces geospatial data on wildland vegetation across the United States, see <https://www.landfire.gov/index.php>.

⁴¹For more information on the Forest Service's database of historical wildfire occurrence, see <https://www.fs.usda.gov/rds/archive/catalog/RDS-2013-0009.4>.

Figure 9: Wildfire Hazard Potential on Lands Managed by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service and Administered by the Bureau of Indian Affairs in the Contiguous United States



Sources: GAO analysis of U.S. Geological Survey's National Atlas website data; U.S. Forest Service Fire Modeling Institute, Wildfire Hazard Potential for the Conterminous United States (raster geospatial product); MapInfo (map). | GAO-20-52

Notes: Figure shows wildfire hazard potential as assessed by the Forest Service in July 2018. The Forest Service defines wildfire hazard potential as the relative potential for a fire that would be difficult for suppression resources to contain. Areas of the map showing higher hazard potential contain vegetation with a higher probability of experiencing torching, crowning, and other forms of extreme fire behavior. The map does not represent a forecast or fire outlook for any particular year or fire season. We developed this map—specifically for lands in the contiguous United States managed by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service and administered by the Bureau of Indian Affairs—using the Forest Service's nationwide wildfire hazard map.

- **Location of communities and infrastructure.** Officials from the five agencies told us that they considered the location of communities and

important infrastructure, such as municipal watersheds and electrical transmission lines, which could be damaged by wildfires.⁴² The officials said they used several information sources to help them identify the locations of these communities and infrastructure.⁴³ For example, the agencies used a national geospatial database that the Forest Service developed that maps the WUI as defined by the Forest Service and Interior in 2001.⁴⁴ Field unit officials said that they also considered local knowledge about areas that are important to protect in or near to a given community when selecting fuel reduction projects to prioritize and implement. For example, officials said that many communities had developed Community Wildfire Protection Plans—plans identifying areas the communities believe are important to protect—and that they would consider these local plans when selecting fuel reduction projects to implement.⁴⁵

- **Ecosystem health and location of natural resources.** Officials from four of the five agencies said that they considered information on the locations of particularly valued natural resources, such as rare or otherwise important plants, including those that provide habitat for

⁴²The Forest Service is working to more closely integrate its information related to wildland fire hazard potential and the location of communities across the contiguous United States based on requirements contained in the omnibus appropriations act for fiscal year 2018. The act directed the Forest Service to develop a geospatial map appropriate for community-level use that depicts wildland fire hazard severity. According to the act, the purposes of the map are to (1) inform evaluation of wildland fire risk, (2) prioritize fuels management needs, and (3) depict the relative potential for wildland fire that could be difficult for suppression resources to contain and that could cause ignitions of community infrastructure. Pub. L. No. 115–141, Div. O, Title II, § 210, 132 Stat. 1067 (2018). As of August 2019, the Forest Service had developed a prototype of the map for the state of Washington. The community-level map for the contiguous United States is to be completed by March 2020, according to Forest Service officials, to align with the statutory time frame.

⁴³According to BIA officials, tribal lands as a whole are essential contributors to the cultures of tribal communities and are considered to be of at least equal value and importance as the WUI on tribal lands.

⁴⁴66 Fed. Reg. 751 (2001). For more information on the database, see <https://www.fs.usda.gov/rds/archive/catalog/RDS-2015-0012-2>.

⁴⁵Community Wildfire Protection Plans are documents that outline ways individual communities plan to reduce their risk from wildfire, such as by identifying priority areas for fuel reduction projects. The Healthy Forests Restoration Act of 2003 called for the preparation of Community Wildfire Protection Plans or comparable plans to define the WUI and establish locally based strategic priorities for wildfire preparedness and hazardous fuel reduction work in these areas. For more information, see [GAO-17-357](#).

threatened or endangered species.⁴⁶ Using an interagency tool, they also considered information on the overall ecological condition of forests, grasslands, and other vegetation and how current conditions related to historical conditions in given locations.⁴⁷ The officials said that this information helped them identify areas where wildfires may be more damaging than they were in the past because of changes in the density, age, and species composition of the vegetation. For example, officials said that in part because of decades of fire suppression, many ponderosa pine forests currently contain more trees than they would have historically, and as a result, today's wildfires may burn hotter and cause more damage to those forests than fires did in the past.⁴⁸ Reducing fuels can help the agencies to restore an area closer to its historical conditions, which in some ecosystems may reduce the risk of wildfire damaging an ecosystem and the resources it contains, according to the Cohesive Strategy.

Agencies Used Different Approaches for Allocating Funds in Fiscal Year 2018

As they considered similar information on potential damage to communities and ecosystems, each agency used a different approach for allocating fuel reduction funds in fiscal year 2018, according to agency documents and agency officials. Officials from each of the agencies said that professional judgment plays an important role in making these decisions. The general approaches each agency used for allocating fuel reduction funds in fiscal year 2018 were:

- **Forest Service.** Forest Service headquarters officials said they allocated fuel reduction funds to their regions based primarily on the allocation levels from the previous fiscal year. However, they also said

⁴⁶FWS officials said that FWS does not consider ecosystem health when deciding how to allocate its fuel reduction funds, but that most of its projects designed to protect communities would also improve ecosystem health. The officials said that they also conduct fuel reduction projects whose primary purpose is to improve ecosystem health, but that they use funds from their National Wildlife Refuge System account, not their fuel reduction account, to do so.

⁴⁷The agencies assess the difference between current and historical conditions using an interagency tool known as Fire Regime Condition Class. For more information, see <https://landfire.gov/frcc/frchome.php>.

⁴⁸To reduce potential damage to such forests from wildfires, officials from one field unit we interviewed said they implemented several fuel reduction projects to reduce forest density and improve the ecological health of the ponderosa pine ecosystem, including areas that provide habitat for the threatened northern spotted owl. These officials said these projects helped to reduce the likelihood that wildfire would severely damage the areas treated, including areas the owls use for nesting and foraging.

they considered information based on the best available science on the wildfire risk facing the regions and each region's contributions to meeting the agency's acreage targets for fuel reduction projects in the previous fiscal year. According to a 2017 Forest Service manual, the agency was to develop national and regional risk assessments to help inform their approach to allocation decisions, but the national assessment had not been finalized for use in fiscal year 2018.⁴⁹ Forest Service officials initially allocated approximately 70 percent of the agency's total fuel reduction funds to the regions, withholding about 30 percent to make available to regions and national forests on a competitive basis later in the fiscal year. The regions and forests then competed for additional fuels funds for projects aligned with specific national priorities as determined by Forest Service headquarters.⁵⁰

- **Interior.** Interior's Office of Wildland Fire officials said they allocated fuel reduction funds to the Interior agencies based primarily on allocation levels from fiscal year 2017. However, late in the third quarter of fiscal year 2018, Interior officials began testing an approach for reviewing each of the four Interior agencies' planned fuel reduction projects for consistency with the Secretary of the Interior's priorities for the fiscal year. The agencies' plans for such projects were to be updated each quarter to keep Interior officials informed on the implementation status for projects underway and of changes to planned projects, according to Interior documents.⁵¹
- **BIA.** BIA headquarters officials told us they allocated fuel reduction funds to their regional offices based on an allocation model that the agency adopted around fiscal year 2012. The model analyzes wildfire hazard potential and agency staffing levels across BIA regions, among other factors. According to a BIA document, the model

⁴⁹Forest Service, *Forest Service Manual 5100 – Wildland Fire Management, Chapter 5140 – Hazardous Fuels Management and Prescribed Fire* (Washington, D.C.: Aug. 25, 2017).

⁵⁰According to Forest Service headquarters officials, in fiscal year 2019 they discontinued the practice of withholding funds for competitive application later in the fiscal year by the regions and national forests. They instead allocated all of their fuel reduction funds directly to the regions.

⁵¹Department of the Interior, *Office of Wildland Fire Policy Memorandum 2019-002 – Preliminary Guidance for FY2019 Funds Execution and Wildland Fire Budget Allocations under Continuing Resolution* (Washington, D.C.: Oct. 11, 2018), and *Office of Wildland Fire Policy Memorandum 2019-003 – Fuels Management Program Priorities and Spend Plan Guidance for FY 2019* (Washington, D.C.: Oct. 11, 2018).

includes information that captures risk-related information for wildfires on BIA-administered tribal lands.⁵² It also captures information on performance and fiscal management for each BIA regional office's fuel reduction program during the previous fiscal year and each BIA regional office's contributions to the total number of acres treated overall by the BIA fuel reduction program.⁵³ BIA officials said the comparative scores for each regional office derived from the model served as a starting point for discussions with BIA senior leadership when determining the fuel reduction allocations to the regions.

- **BLM.** BLM headquarters officials said they allocated fuel reduction funds to their state offices based on the results of the 5-year allocation model the agency adopted in 2015.⁵⁴ The model analyzes the location of communities, critical infrastructure, and sagebrush habitat, among other factors, as well as wildfire fire hazard potential for the area covered by each BLM state office. According to BLM officials, the model provides a relative ranking for each BLM state office based on acreage at risk, which helps determine the state offices' respective fuel reduction allocations.⁵⁵ For example, BLM state offices that manage more sage-grouse habitat that is at high risk for wildfire received larger allocations than offices in states without such habitat or where the sage-grouse habitat was at lower risk for wildfire.

⁵²The model's risk-related inputs include geospatial information on wildfire hazard potential; the location of WUI and critical infrastructure; and the location, size, and frequency of previous wildfires. These inputs constitute approximately 70 percent of the score that BIA headquarters gives to each BIA region.

⁵³The model's performance and fiscal management inputs include information on a 10-year rolling average percentage for the number of acres that received fuel reductions versus the number of acres that had been targeted for fuel reduction projects, information on the percentage of fuel reduction funds that were not spent within the fiscal year and were carried over into the next fiscal year, and information on the average number of acres that received fuel reductions in a given year. Together, these inputs constitute approximately 30 percent of the score for each BIA region.

⁵⁴BLM, *Information Bulletin No. FA IB-2015-019 – 5 Year Fuels Allocation Plan* (Washington, D.C.: June 16, 2015). The BLM allocation model is detailed in this 5-year plan. BLM established a 5-year allocation plan, in part, to respond to its state offices requests for stable funding over time.

⁵⁵BLM's 5-year allocation plan identifies allocation amounts for each state office for fiscal years 2016 through 2020 that were derived from the agency's allocation model. The plan is scheduled to be revisited in fiscal year 2020 in anticipation of developing the allocation amounts for each BLM state office for fiscal years 2021 through 2025. BLM officials said that they do not expect the allocation amounts to change significantly.

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- **FWS.** FWS headquarters officials said they allocated fuel reduction funds to their regional offices based on the results of an allocation system—the Fuels Management Allocation and Accountability System—that they have used since fiscal year 2016.⁵⁶ This system generates a risk profile for each FWS region based on, for example, the location of infrastructure, population density, and how fuel conditions may affect wildfires that occur on FWS-managed land. According to FWS officials, this system provides a relative ranking for each FWS region based on acreage at risk, which helps determine the regions’ respective fuel reduction allocations. In general, the FWS regions with the most acreage at risk receive the largest percentage of FWS’s fuel reduction funds.⁵⁷
 - **NPS.** NPS headquarters officials told us that they allocated fuel reduction funds to their regions based primarily on historical allocation levels from fiscal year 2017. Headquarters officials said they are considering ways to improve their allocation process, such as potentially adopting a model developed in one of their regions.⁵⁸ Specifically, officials from the NPS region in our review said that they had developed a model to help analyze the relative risk facing the field units in their region when making allocation decisions. This model is designed to identify highly valued assets in the national parks and other NPS-managed lands in the region and provide relative rankings for those assets requiring protection through fuel reduction projects, according to the officials.

⁵⁶FWS, *Fuels Management Allocation and Accountability System – FY16-FY18* (Washington, D.C.: September 2016). FWS officials said the system will be updated in fiscal year 2020 to identify allocation amounts for each FWS region for fiscal years 2020 through 2022.

⁵⁷According to a Fuels Management Allocation and Accountability System document, FWS officials used professional judgment to determine that a fixed 3.3 percent of fuel reduction funds is to be allocated each fiscal year to FWS’s region covering Alaska. The remaining funds are allocated to FWS’s regions in the contiguous United States. The system did not include FWS field units in Hawaii, Puerto Rico, or U.S. territories in the Pacific because of data limitations for those locations.

⁵⁸Managed Business Solutions, *Fuels Reporting and Prioritization for the National Park Service: Alternatives Analysis* (Washington, D.C.: July 16, 2018). This report details an analysis of alternatives for seven different approaches NPS may potentially adopt for determining fuel reduction allocations in fiscal year 2020 or later years.

Agency Officials Cited a Variety of Factors Affecting Their Efforts to Implement Fuel Reduction Projects

Officials we interviewed from the five federal agencies cited a variety of factors affecting their efforts to implement fuel reduction projects.⁵⁹ The officials also identified steps they were taking to help mitigate some of the factors.

Scale of problem. Officials from all five agencies we interviewed said that the number of acres needing fuel reductions is significantly larger than the number of acres the agencies are able to treat in any given year. As previously noted, the Forest Service estimated in 2018 that there were approximately 63 million acres of national forest lands at high to very high risk from uncharacteristic wildfire, and Interior officials estimated in 2019 that 54 million acres of the lands that they manage or administer were at high or very high risk from wildfire. In fiscal year 2018, the Forest Service and Interior implemented fuel reduction projects that treated approximately 1.7 million and 1.3 million acres, respectively, of lands they manage or administer.⁶⁰

Agency officials told us that they recognize that their efforts will not allow them to reduce fuels on all high-risk lands needing treatment but said that in addition to the projects they undertake to reduce fuels, wildfires also serve to reduce fuels in areas burned by such fires. In some circumstances, officials said, wildfires may provide similar fuel reduction benefits as prescribed burns and other fuel reduction methods. To the extent that wildfires reduce fuels in areas that the agencies would otherwise plan to implement fuel reduction projects, such wildfires would

⁵⁹Forest Service headquarters officials also noted that the practice of “fire borrowing” negatively affected their efforts to implement fuel reduction projects. To pay for wildfire suppression costs when the funds appropriated are insufficient, the Forest Service and Interior transferred funds from other programs—including fuel reduction programs. In 2009, we found that while the agencies received additional appropriations to cover, on average, about 80 percent of the funds transferred, the transfers resulted in the agencies cancelling or delaying some projects and not fulfilling certain commitments to their nonfederal partners. See [GAO-09-877](#). The 2018 omnibus appropriations act included a new approach for suppression funding in the form of an adjustment to the discretionary spending limit, which is commonly referred to as the wildfire funding fix. Beginning in fiscal year 2020, this fix allows Congress to provide additional funding above a specified baseline level for suppression that is effectively outside of the discretionary spending limits, up to a specified annual maximum. Congressional Research Service, *National Forest System Management: Overview, Appropriations, and Issues for Congress*, R43872 (Washington, D.C.: Sept. 5, 2019).

⁶⁰For fiscal years 2009 through 2018, the Forest Service and Interior implemented fuel reduction projects that treated an average of approximately 1.4 million and 1.1 million acres, respectively, per fiscal year of lands they manage or administer.

serve to reduce fuels on more acreage than they would otherwise be able to treat.⁶¹

Agency officials also said, as previously discussed, that they are working to improve their ability to identify areas to prioritize for treatment. For example, scientists at the Forest Service's Rocky Mountain Research Station are helping the agency refine its methods for identifying areas most at risk from wildfire and the communities closest to those areas by expanding and updating agency risk assessments to more accurately depict where fuels reduction projects on national forest lands could provide the most protection to communities. This may also allow Forest Service officials to reduce the total number of acres needing treatment through better targeting of the highest-risk acres. According to Forest Service officials, the agency intends to consider this research to help inform its budget requests and funding allocations for fuel reduction efforts in future fiscal years. The Forest Service and Interior are also working to improve their existing fuel reduction project computer simulation software—called the Interagency Fuels Treatment Decision Support System—so that it can be used to model and quantify the risk reduction effects of potential projects across larger geographic areas. Officials said these improvements would help them prioritize areas to treat by allowing agency officials to explore how different combinations of locations and types of treatments affect predicted future wildfire behavior.⁶²

Operating under continuing resolutions. Officials we interviewed from all five agencies said that operating under continuing resolutions negatively affected their ability to implement fuel reduction projects. Specifically, agency officials said that they tend to budget conservatively

⁶¹For example, the Forest Service reported that 636,000 acres and Interior reported that 191,000 acres burned during wildfires in fiscal year 2018 in a manner that reduced fuels similar to how the agencies would have done so had they implemented a fuel reduction project in the area. In addition, Forest Service officials said that if acres treated from all sources were counted toward their fuel reduction efforts, a total of approximately 3.4 million acres in fiscal year 2018 were treated—a total that included approximately 1.1 million acres treated by fuel reduction projects under a variety of Forest Service programs, such as the agency's state fire assistance program.

⁶²Interior officials stated that the system allows officials to perform analyses of alternatives among various fuel reduction projects at the landscape scale in order to identify those projects that will yield the greatest expected risk reduction. In past iterations, the system was only able to perform analyses of alternatives at the local scale for projects in a more limited geographic area. For more details on the Interagency Fuels Treatment Decision Support System, see https://iftdss.firenet.gov/landing_page/.

until they receive their regular appropriation and therefore implementation of planned projects may be delayed.⁶³ For example, Forest Service officials said that the weather for doing prescribed burns is often better in the fall and winter and that receiving their annual appropriation later in the fiscal year can reduce their ability to perform these burns in a given year. In addition, the officials said they had delayed hiring and training staff in previous years when the agencies were operating under continuing resolutions, reducing the number of staff available to implement projects.

The Forest Service has taken some steps to mitigate the effects of operating under continuing resolutions. For example, officials in one region said they recently adopted an approach that allows them to more readily shift funding from one planned fuels project to another, either within the same national forest or to other national forests in the region, to complete projects as weather conditions and budgets allow. Officials from one national forest in this region said that this approach has facilitated sharing fuels reduction staff among neighboring national forests to plan additional projects, thereby leading to a broader array of projects being ready for implementation when the agency receives its regular annual appropriations.

Balancing fuels projects in new areas with maintaining past treatments. Officials from all five agencies said that it can be difficult to balance conducting fuel reduction projects in new areas with maintaining areas that have already had initial fuel reduction projects completed. Some agency officials said that while it is important to conduct projects to reduce wildfire risk in new areas, they also need to conduct projects in previously treated areas to maintain the effectiveness of past treatments.

Agency officials said that in balancing their investments between new and previously treated areas, they consider the relative costs of projects. Conducting fuel reduction projects in new areas can be more expensive

⁶³When action on regular appropriation bills is not completed before the beginning of the fiscal year, a continuing resolution may be enacted in a bill or joint resolution to provide funding for the affected agencies for the full year, up to a specified date, or until their regular appropriations are enacted. GAO, *A Glossary of Terms Used in the Federal Budget Process*, [GAO-05-734SP](#) (Washington, D.C.: September 2005). In the 10 fiscal years from 2009 through 2018, the five agencies on average received their annual appropriation about 130 days, or approximately 4-1/2 months, into the fiscal year. During that timeframe, they received their annual appropriations within the first month of the fiscal year once, in fiscal year 2010. For more information on continuing resolutions, see GAO, *Budget Issues: Continuing Resolutions and Other Budget Uncertainties Present Management Challenges*, [GAO-18-368T](#) (Washington, D.C.: Feb. 6, 2018).

than conducting maintenance projects because of the type of treatments that need to be done, according to officials. For example, officials from one national forest said that initial mechanical treatments may cost from \$300 to \$1,500 per acre, depending on the area where the treatment is located, while conducting prescribed burns to maintain a previously treated area may cost from \$25 to \$100 per acre.

Availability of staff. Agency officials from all five agencies said that fuel program staff may be involved in wildfire suppression efforts and therefore may not be available to plan or perform fuel reduction projects, leading to delays in completing such projects. Officials noted that this was largely an unavoidable result of the agencies' approach to suppression operations, whereby staff from many of the agencies' program areas, including fuels, are mobilized through temporary emergency assignments to respond to large wildfires across the country as they occur.

Agency officials said that they are used to working within staff availability constraints. However, some officials expressed concern about the potential for staff burnout. Specifically, fuel program staff may work many overtime hours when suppressing fires and additional overtime hours when they return to their field units to catch up with planned fuel reduction projects that were delayed because of the emergency suppression assignments.

Higher cost of treating WUI areas. Officials we interviewed from four of the five agencies said that costs are a factor when determining which projects to pursue and that it can be more expensive to conduct fuel reduction projects close to homes and infrastructure in the WUI. For example, officials at one national forest said that conducting prescribed burns close to communities in the WUI typically costs almost \$250 per acre, whereas it may cost \$60 per acre to reduce fuels further away from communities.

Agency officials told us that they try to balance their work between WUI and non-WUI areas to ensure treatment of high-risk areas. In balancing between WUI and non-WUI areas, some Forest Service field unit officials noted that Forest Service headquarters annually sets fuel reduction acreage targets for each region; each region then sets targets for each of its national forests and grasslands. Some officials said that as their annual targets for acres of fuel reduction increase, they may feel pressure to choose projects in locations where they can treat more acres to meet

their targets, even if those acres may not be located in the areas at highest risk from wildfire damage.⁶⁴ Forest Service headquarters officials said that they do not pressure field units to meet the targets but that they are aware that increasing the annual fuels targets, while budgets remain relatively flat, may incentivize field units to select lower cost areas, which may be at lower risk from wildfire. The officials added that the field units, consistent with Forest Service guidance, should be selecting their project locations based on their risk assessments, not cost.

Community acceptance of fuel reduction projects. Officials we interviewed from four of the five agencies said that community concerns about the effects of proposed fuel reduction projects have affected their ability to conduct some projects but that they are often able to work with communities to gain their acceptance. For example, the officials said that community members are frequently concerned that smoke from prescribed burns will have negative impacts on their health and quality of life, or that mechanical thinning of vegetation near their communities will be visually unattractive or have negative impacts on wildlife.

Agency officials said that they work to minimize these impacts. For example, Forest Service officials schedule prescribed burns at times when weather conditions are not expected to cause a significant volume of smoke to drift into communities. The officials also said that they work with community members to educate them about the benefits of reducing fuels, steps the agencies are taking to reduce negative impacts on the community and wildlife, and steps community members can take to help avoid some impacts. In other instances, agencies partner with various stakeholders to help mitigate negative effects of fuel reduction projects on communities. For example, the Forest Service in New Mexico is part of the Greater Santa Fe Fireshed Coalition, a group that loans air filters to community members who are sensitive to smoke to help them avoid negative health impacts from prescribed burns.⁶⁵

Limited economic value of biomass. Officials from three of the five agencies we interviewed said that, in contrast to commercial timber harvests in which contractors pay the agency for the material they

⁶⁴The Forest Service has identified its reliance on output-based performance measures as a concern. See Forest Service, *Toward Shared Stewardship Across Landscapes: An Outcome-Based Investment Strategy* (Washington, D.C.: August 2018).

⁶⁵The coalition includes the Forest Service, the City of Santa Fe, The Nature Conservancy, and the Santa Fe Watershed Association.

remove, fuel reduction projects often produce small trees and other biomass with limited economic value. As a result, fuel reduction projects are unlikely to generate revenues that the agencies could use to help offset the costs of completing such projects.⁶⁶

To help mitigate this issue, Forest Service officials said they are working to expand their use of a practice known as stewardship contracting. Through stewardship contracting, the agencies can trade goods—such as timber—for fuel reduction or forest restoration services that the agencies would otherwise pay for with appropriated dollars.⁶⁷ Officials we interviewed at two national forests said that the use of stewardship contracts had facilitated their ability to conduct fuel reduction projects, although officials at one of the forests also said they were concerned that the relatively long length of the contracts could slow the rate at which contractors completed the projects.⁶⁸ The Forest Service is also researching ways to increase demand for small trees and other biomass—for example, by expanding their use in energy production and building materials—which, if successful, could help to increase the economic value of the material.⁶⁹

⁶⁶Some Forest Service officials also noted that a long-term decline in federal timber harvest levels has led to many timber mills being closed. As a result, even when fuel reduction projects generate economically valuable material, contractors may be willing to pay less for it because they are faced with high costs to transport the material to more distant mills.

⁶⁷See also GAO, *Federal Land Management: Use of Stewardship Contracting Is Increasing, but Agencies Could Benefit from Better Data and Contracting Strategies*, [GAO-09-23](#) (Washington, D.C.: Nov. 13, 2008).

⁶⁸Stewardship contracts were originally limited to 10 years, but Section 207 of the 2018 Consolidated Appropriations Act included new authority to extend the length of stewardship contracts to 20 years in some cases. Pub. L. No. 115-141, Div. O, Title II, § 210, 132 Stat. 1065 (2018).

⁶⁹Since 1993, the Forest Service's Forest Products Laboratory in Madison, Wisconsin, has focused some of its research on characterizing small-diameter trees and other biomass, identifying potential uses, and providing technology that can help create businesses for the by-products of forest management, including fuel reduction projects. The laboratory's research projects include studying the potential of small-diameter wood as a structural material for use in building projects and other construction, and innovative ways to use underutilized woody biomass. See also GAO, *Wood Utilization: Federal Research and Product Development Activities, Support, and Technology Transfer*, [GAO-06-624](#) (Washington, D.C.: June 15, 2006).

Agency Comments

We provided a draft of this report to the Department of Agriculture and the Department of the Interior for review and comment. In comments reproduced in appendix II, the Forest Service, responding on behalf of the Department of Agriculture, generally agreed with our findings. In addition, the Forest Service and Interior provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Agriculture, the Secretary of the Interior, and other interested parties. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or fennella@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix III.



Anne-Marie Fennell
Director, Natural Resources and Environment

List of Requesters

The Honorable Michael B. Enzi
Chairman
Committee on the Budget
United States Senate

The Honorable Ron Johnson
Chairman
The Honorable Gary C. Peters
Ranking Member
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Marco Rubio
Chairman
Committee on Small Business and Entrepreneurship
United States Senate

The Honorable Rand Paul, M.D.
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Management
Committee on Homeland Security and Governmental Affairs
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The Honorable Al Green
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Subcommittee on Oversight and Investigations
Committee on Financial Services
House of Representatives

The Honorable Emanuel Cleaver, II
House of Representatives

The Honorable Michael McCaul
House of Representatives

The Honorable Gary J. Palmer
House of Representatives

The Honorable Ann Wagner
House of Representatives

Appendix I: Federal Agencies, Agency Units, and Nonfederal Entities Interviewed

Table 1: Federal Agencies, Agency Units, and Nonfederal Entities Interviewed

Agency	Regional office (geographic area covered by region)	Field unit (state in which unit is located)
Federal agencies		
Forest Service (Washington Office)	Southwestern Region (Arizona, New Mexico, Oklahoma, Texas)	Cibola National Forest (New Mexico) Santa Fe National Forest (New Mexico)
	Pacific Southwest Region (California, Hawaii)	Cleveland National Forest (California) Shasta-Trinity National Forest (California)
	Pacific Northwest Region (Oregon, Washington)	Deschutes National Forest (Oregon)
	Southern Region (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and the territory of Puerto Rico)	Francis Marion and Sumter National Forests (South Carolina)
Department of the Interior (Office of Wildland Fire)	N/A	N/A
Department of the Interior's Bureau of Indian Affairs	Western Region (most of Arizona, Nevada, Utah)	San Carlos Agency (Arizona)
Department of the Interior's Bureau of Land Management	Utah State Office (Utah)	West Desert District (Utah)
Department of the Interior's Fish and Wildlife Service	Southeast Region (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and the territories of Puerto Rico and the U.S. Virgin Islands)	Mississippi Sandhill Crane National Wildlife Refuge (Mississippi)
Department of the Interior's National Park Service	Pacific West Region (portions of Arizona; California; Hawaii; Idaho; portions of Montana; Nevada; Oregon; Washington; and the territories of American Samoa, Guam, and the Northern Mariana Islands)	Whiskeytown National Recreation Area (California)
State forestry agencies		
Arizona Department of Forestry and Fire Management	N/A	N/A
California Department of Forestry and Fire Protection	N/A	N/A
Mississippi Forestry Commission	N/A	N/A
New Mexico State Forestry Division	N/A	N/A
Oregon Department of Forestry	N/A	N/A

**Appendix I: Federal Agencies, Agency Units,
and Nonfederal Entities Interviewed**

Agency	Regional office (geographic area covered by region)	Field unit (state in which unit is located)
South Carolina Forestry Commission	N/A	N/A
Utah Department of Natural Resources—Division of Fire, Forestry, and State Lands	N/A	N/A
Nonfederal entities		
City of Santa Fe, New Mexico	N/A	N/A
Intertribal Timber Council	N/A	N/A
National Association of State Foresters	N/A	N/A
The Nature Conservancy	N/A	N/A
Western Governors' Association	N/A	N/A
Wildland Fire Leadership Council	N/A	N/A

Source: GAO. | GAO-20-52

Note: N/A = Not applicable

Appendix II: Comments for the Department of Agriculture, Forest Service



Forest Service
Washington Office

1400 Independence Avenue, SW
Washington, D.C. 20250

File Code: 1420
Date: DEC 11 2019

Ms. Anne-Marie Fennell
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G. Street, NW
Washington, DC 20548


Dear Ms. Fennell:

The U.S. Department of Agriculture Forest Service appreciates the opportunity to respond to the U.S. Government Accountability Office draft report "Federal Agencies' Efforts to Reduce Wildland Fuels to Lower Risk to Communities and Ecosystems." The Forest Service generally agrees with the report, and notes the report contained no recommendations. As a learning organization, we are always interested in engaging with our partners, stakeholders and the public.

The draft report was very thorough in its process of describing the methods Federal agencies use to reduce fuels to help protect communities and ecosystems and how they allocated fuel reduction funds in fiscal year 2018. We appreciate the Government Accountability Office's recognition of the challenges affecting agency efforts to implement fuel reduction projects such as the estimated 100 million plus acres at risk from wildfire and the uncertain budget allocations due to continuing resolutions. By including interviews with federal agency officials and representatives from State forestry agencies, the report was able to encompass a wide range of implementation perspectives.

We appreciate the Government Accountability Office's review as we constantly seek to make progress toward reducing wildfire risk to communities. Thank you again for the opportunity to review the draft report. If you have any questions, please contact Antoine L. Dixon, Chief Financial Officer, at (202) 205-0429, or by email at antoine.dixon@usda.gov.

Sincerely,


VICTORIA CHRISTIANSEN
Chief

Enclosure



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Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Anne-Marie Fennell, (202) 512-3841 or fennella@gao.gov

Staff Acknowledgments

In addition to the contact named above, Jonathan Dent (Assistant Director), David Lysy (Analyst-in-Charge), Aditi Archer, Kathryn Godfrey, Richard Johnson, Gwen Kirby, Anne Rhodes-Kline, Dan Royer, and Kyle Stetler made key contributions to this report.

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