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Development and Application of the Fireshed Registry

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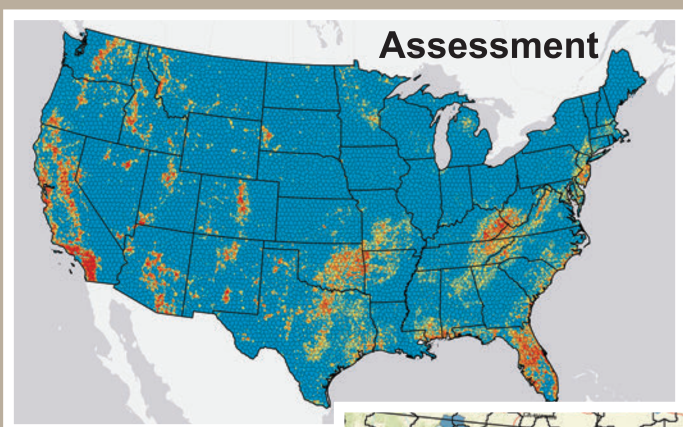

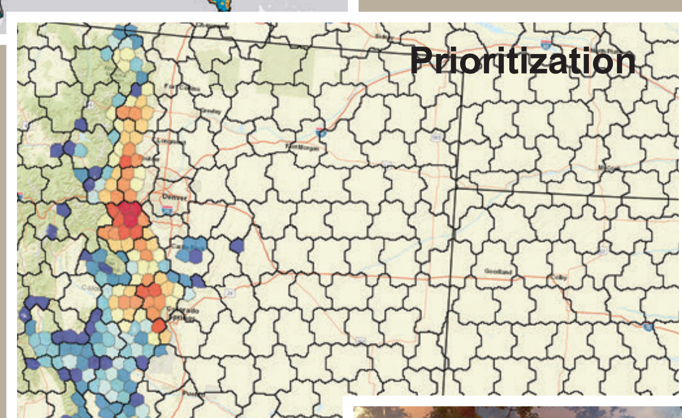

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Abstract

The Fireshed Registry is an interactive geospatial data portal providing access to data describing past, present, and future trends regarding wildfire exposure to communities and forest and fuel management. The registry employs a nested spatial framework that organizes landscape variation in wildfire risk to developed areas into containers or "firesheds" and displays these data on a background of maps on management and disturbances, including past and predicted wildfire events and their potential impacts. It was built in close cooperation with USDA Forest Service staff and establishes a nationally consistent, all-lands, scalable framework for classifying fireshed conditions in terms of underlying wildfire transmission and the potential to mitigate exposure and risk. Foremost, the framework provides a foundation for communication and coordination with external agencies and partners for cross-boundary collaboration and can potentially improve agency national reporting and monitoring of programs. The registry provides the Forest Service with a planning framework for tracking changes in fireshed conditions with respect to wildfire exposure at forest, regional, and national scales. We describe the process of building the system, sources of data, and its application within the agency for decision support and reporting for multiple ongoing programs related to forest and landscape management.

Keywords: collaborative forest planning, wildfire risk, scenario planning, fuel management, wildland urban interface

Cover photo

The Fireshed Registry incorporates an exposure "Assessment" using a national map of the 7,688 firesheds created from community wildfire transmission data with areas in red/orange representing hotspots of modeled sources of fire transmission to buildings in adjacent or nearby communities; and "Prioritization" through scenario planning to identify areas for "Treatment" within priority firesheds, such as the example prescribed fire hazardous fuels "Treatment" on the Finley National Wildlife Refuge (USFWS photo by Brent Lawrence, licensed under CC BY-ND 2.0).

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Contents

Introduction

The impacts of the 2020 fire season on people, property, natural resources, and fire suppression budgets have stimulated wide-ranging policy discussions about the role of active forest management to reduce hazardous fuels on federal and private wildlands. Wildfire impacts to developed areas are increasing in frequency, driven by multiple social and biophysical factors including the expanding wildland urban interface (WUI, Radeloff et al. 2018), increasing fire occurrence from human ignitions (Abatzoglou et al. 2018; Balch et al. 2017; Nagy et al. 2018), and changing climate (Abatzoglou and Williams 2016; Littell et al. 2018; McKenzie and Littell 2017). In the western United States, the buildup of forest fuels on public lands from fire exclusion in fire-adapted forests, coupled with regional droughts (Littell et al. 2016) and high-wind events (Abatzoglou et al. 2018), are catalyzing large pyro-convective fire events that spread to developed areas and consume housing subdivisions despite local fire hazard efforts within and around them (e.g., 2018 Carr Fire). These fire events increasingly challenge risk governance systems at multiple administrative and jurisdictional scales owing to their uncertainty in time and space, overlaid by fragmented risk governance across the boundaries that fires burn and the fuels they consume (Fischer et al. 2016; Steelman 2016).

As in other natural disasters, managing wildfire risk is a multiscale, cross-boundary problem that requires spatial planning frameworks to organize location-specific mitigation measures and efficiently allocate finite resources for both predisaster planning and postdisaster recovery (Greiving and Angignard 2014; Sapountzaki et al. 2011). Here, spatial containers are designed and scaled with the process at hand considering both the source of risk and what is at risk. Spatial planning frameworks exist for many other contexts (e.g., airsheds, watersheds, flood control districts, fire suppression). Within these containers, mitigation planning uses localized assessments to design site-specific mitigation programs to reduce impacts (e.g., floodplain mapping, development and building codes, dams). However, in the case of community disaster planning for wildfire, mitigation planning has been organized around individual community boundaries (e.g., community wildfire protection plans) (Jakes and Sturtevant 2013; USDA-USDI 2013), rather than spatial containers that delineate the scale of wildfire risk to them. Mitigation plans are thus decoupled from landscape efforts to manage fuels and ignitions on the larger landscape of public and private wildlands, creating a scale mismatch (Ager et al. 2016; Cumming et al. 2006; Turner et al. 2002). Communities are also inefficient spatial units for organizing and prioritizing federal assistance from public land management agencies. Developed areas in the western United States that are most exposed to wildfire risk often occur outside of formal community boundaries or are artificially grouped together based on historical factors unrelated to fire risk, thereby rendering community distinctions cloudy for anything other than city scale governance or access to federal funding. Moreover, in the larger wildland landscape, a single land parcel can contribute risk to multiple communities and, thus, the priority for fuel management should be based on the sum of the projected effect rather than any one community that it exposes.

Wildfire disaster planning can be improved with an assessment framework that connects social (ownership, jurisdictions) and biophysical (wildfire risk) conditions at scales meaningful in terms of large fires and forest and fuel management (Ager et al. 2016). Beyond assessments, spatial planning frameworks are required to ingest assessments and analyze how scarce financial resources can be allocated for forest and fuel management to target high leverage landscapes in terms of reducing wildfire risk. Linking assessment and planning systems provides a clear path to make progress towards the goals of the cohesive strategy (i.e., fire resilient communities fire adapted landscapes, safe and effective response [USDA-USDI 2013]). Widespread use of spatial planning models to explore fundamental questions about tradeoffs, outcomes, and spatial allocation efficiencies (Borges et al. 2017; Kline and Mazzotta 2012; Schroder et al. 2016) to respond to the escalating fire problem remain in a discussion phase in most federal land management agencies (Ager et al. 2017).

In this paper we describe the development and application of a geospatial information system that organizes landscape risk to developed areas into a planning framework. The system provides the first spatial assessment framework to specifically address wildfire risk to developed areas (Ager et al., in review). The Fireshed Registry is an ArcGIS Online dashboard that organizes the source of community exposure into hierarchical management containers, and it attributes these containers with information about past, present, and future plans with respect to management and disturbance. Just as watersheds are functional geographic delineations to manage water resources and airsheds are delineated to manage air quality, firesheds provide an organizing principle to manage wildfire risk to communities. In this paper, we describe the process of building the system, the sources of data, and its application within the agency to provide decision support and reporting capability for multiple ongoing agency initiatives.

Methods

Geographic Extent of the Registry

Firesheds were delineated and attributed for all lands in the continental United States and include 192 million ha of forest land (USGS 2011). National Forest System lands cover over 69 million ha. Delineations of firesheds did not consider administrative, jurisdictional, or other anthropogenic boundaries.

Estimating Wildfire Exposure to the WUI

We used wildfire simulation data from the national FSim library (Short et al. 2020a; fire perimeters not publicly available) with 79.4 million simulated fires for the continental United States. FSim consists of modules for weather generation, large-fire occurrence, growth, and suppression (Finney et al. 2011; Short et al. 2020a). For the most recent simulations (Short et al. 2020a), fuel conditions circa 2014 were used (LANDFIRE 2017), and weather was based on a national gridded dataset from the North American Land Data Assimilation System (NLDAS), a contemporary surface weather data assimilation system (Abatzoglou 2013). The NLDAS data were analyzed to produce daily spatiotemporal realizations of a fire danger index (Energy Release Component) retaining the spatial covariance structure and temporal auto-correlation of weather inputs (Grenfell et al. 2010), maintaining synchrony across weather scenarios used among independently simulated geographic areas. The geographic units used in simulations by Short et al. (2020a) were regions of relatively homogenous contemporary fire regimes called "pyromes" (Short et al. 2020b) with 128 pyromes across the continental United States. Between 10,000 and 100,000 hypothetical fire seasons were simulated for each pyrome, depending on the historical large fire frequency. The processes of calibrating and validating FSim area burned outputs and fire-size distributions from prior CONUS simulations are presented in Finney et al. (2011), with advances described by Short et al. (2020a). For each simulated fire, we obtained the ignition location and associated perimeter for each fire as output in shapefiles, along with the burn probability raster at 270-m resolution.

Building locations were obtained from the vector building dataset created by the Bing Maps team at Microsoft (Microsoft 2018). The dataset includes housing units, apartments, and farm, storage, and industrial buildings, etc. We extracted the 124,828,569 footprints for the continental United States. The data were converted to points where each point represents a single building. The data represent building locations in 2015 (table 1; Appendix A). We then intersected simulated fire perimeters with the building footprints and used the outputs to attribute each fire ignition with the number of buildings exposed (within the fire perimeter) by a given ignition.

Table 1—Spatial data descriptions, sources, and vintages used in the Fireshed Registry and prioritization process listed by dashboard tab. See Appendix A for non-spatial data sources.

				Dashboard tab					
Spatial layer	Description	Source	Data vintage	Overview	Ownership and fuels	Historic fires and treatments	Simulated fires	Planned/proposed treatments	Communities
USFS Regions	USFS Regional boundaries	AGOL/USFS	Current	X	X	X	X	X	X
USFS national forest boundaries	USFS administrative boundaries	AGOL/USFS	Current		X	X	X	X	X
Firesheds	Fireshed boundaries	Evers et al. (2020)	2019	X	X	X	X	X	X
Project areas	Project area boundaries	Evers et al. (2020)	2019	X				X	
Building locations	Building footprints	Microsoft (2018)	2015	X	X	X	X	X	X
Fire perimeters	Historical fire perimeters	AGOL/USFS; MTBS Data Access (2020)	2017	X		X		X	X
Prioritized treatment locations	Treated stands output from scenario planning	Ager et al. (In review)	2019	X				X	
WUI	WUI interface & intermix	SILVIS Lab (2012)	2010		X		X	X	X
Ownership	Major ownership groups	Protected areas database (USGS 2016, 2019)	2016: Western United States; 2019: Eastern United States	X				X	X
Fuel types	40 Scott and Burgan Fire behavior fuel models	LANDFIRE (2017)	2014		X				X
Historic fuels treatments—prescribed fire	Prescribed fire treatments completed within the fireshed	MTBS Data Access (2020); LANDFIRE (2014); FACTS (USDA FS 2020)	2010–2017 (MTBS); 2010–2014 (LANDFIRE); 2010–2019 (FACTS)			X			
Historic fuels treatments—thinning	Canopy thinning treatments completed within the fireshed	LANDFIRE (2014); FACTS (USDA FS 2020)	2010–2014 (LANDFIRE); 2010–2019 (FACTS)			X			

(continued on next page)

Table 1 (continued)—Spatial data descriptions, sources, and vintages used in the Fireshed Registry and prioritization process listed by dashboard tab. See Appendix A for non-spatial data sources.

				Dashboard tab					
Spatial layer	**Description**	**Source**	**Data vintage**	**Overview**	**Ownership and fuels**	**Historic fires and treatments**	**Simulated fires**	**Planned/proposed treatments**	**Communities**
Historic fuels treatments—mastication	Mastication treatments completed within the fireshed	LANDFIRE (2014), FACTS (USDA FS 2020)	2010–2014 (LANDFIRE); 2010–2019 (FACTS)			X			
Planned fuel treatments	Planned USFS treatments	FACTS; Region 2 CFLRP, Joint Chiefs, Forest Focus Areas, RMRI	2020–2030			X			
Thinning volume	Potential merchantable timber volume from treatments (MBF) for the western United States	Forest Inventory and Analysis imputed tree list data 2014 (Riley et al. 2016)	2017; data do not account for recent disturbance			X		X	
Building exposure index	Interpolated / smoothed building exposure raster	Ager et al. (in review)	2015 (MS footprint)				X	X	
Top five simulated fire perimeters by fireshed	Top five simulated fires igniting within each fireshed (in terms of building exposure)	FSim (Short et al. 2020a); MS footprints (Microsoft 2018)	2015 (MS footprint)				X		
Top five simulated fire perimeters by community	Top five simulated fires igniting within each community (in terms of building exposure)	FSim (Short et al. 2020a); MS footprints (Microsoft 2018)	2015 (MS footprint)						X
Community zones	Community zones based on 45-minute drive time from U.S. Census designated places.	Bunzel et al. (2021)	2010						X
Firewise communities	Firewise USA sites in good standing (n = 1,689)	NFPA (2015)	2020						X

Ignitions attributed with building exposure were then used to create a smoothed building exposure map using inverse distance weighting in ArcGIS using a search radius of 2,500 m, a power of 0.5, and a cell size of 90 m. This resulted in a map of building exposure given a fire occurs. To correct for the probability of ignition, an ignition probability raster was created (ignitions/acre/yr) using the ArcGIS point density tool with a 2,500-m circular search radius, area units as acres, and the population field set to ignitions per year. The building exposure raster described above was multiplied by the ignition probability raster to create a smoothed building exposure raster where each cell represents the number of buildings affected by fires igniting in the surrounding acre in 1 year. Units are buildings exposed/acre/year. Thus, the outputs represent expected exposure, calculated as the product of likelihood and total exposure given a fire occurs. This formulation is similar to expected loss (risk) except that exposure only predicts the juxtaposition of wildfire and buildings, and excludes prediction of effects.

Delineating Firesheds

Firesheds within the registry are accounting units that are delineated based on a smoothed building exposure map of the continental United States created from the building exposure map described above.[1] The fireshed boundaries were created by dividing up the landscape into regular-sized units that represent similar source levels of community exposure to wildfire (described above). To account for the fact that wildfire risk and risk mitigation efforts occur at multiple scales, exposure at stand-, project-, and fireshed-level scales was assessed (fig. 1). These layers were created in such a way that a finer-scale was nested within a coarser-scale, in much the same way as a drainage

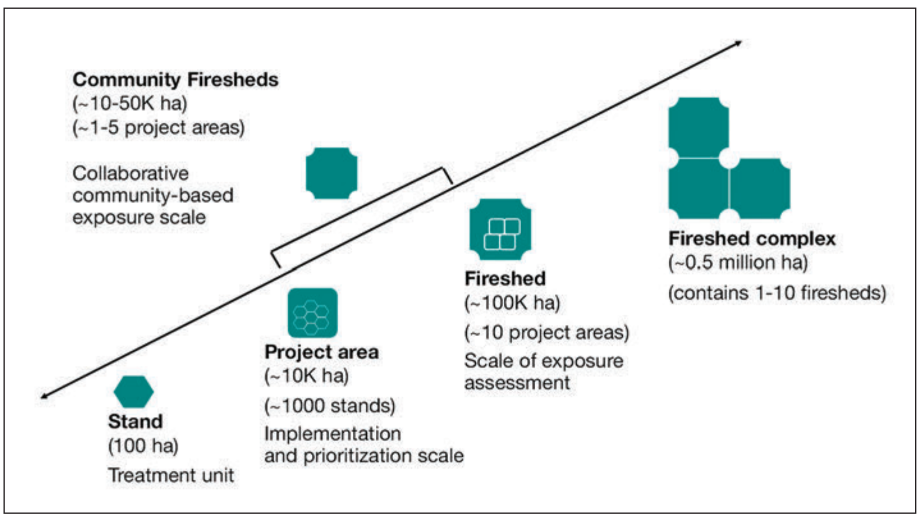

Figure 1—Nested spatial framework for firesheds. Each scale has specific functionality in terms of the planning processes. Firesheds are the broad scale unit of prioritization, but planning areas within them are also prioritized as part of implementation of treatments. Planning areas are roughly the size that national forests use for conducting vegetation and fuel management projects. The relative variation among firesheds compared to variation within them controls the relative emphasis on selecting firesheds versus individual planning areas. Figure modified from Ager et al. (in review).

[1] The original fireshed boundaries were based on a smoothed structure exposure map based on SILVIS wildland urban interface housing unit density data (SILVIS Lab 2010) as described in Ager et al. (2019b).

is nested within a larger watershed. The exposure grid developed above was first log10-transformed and then smoothed using focal statistics with a 10-km radius moving window in ArcMap. The transformed exposure grid described above was divided into roughly equal-sized mapping units (firesheds) using an optimized version of Simple Linear Iterative Clustering (SLIC; Achanta et al. 2012), an image segmentation algorithm based on a modified form of K-means clustering that includes an adaptive parameter controlling the compactness of the resulting segments. The algorithm was applied using the OpenImageR package. Starting points for clusters were placed on a hexagon grid, the total count of which was adjusted such that the image segments had a mean value centered on the desired scale (e.g., 10,000 ha, 100,000 ha). To ensure the segments from the fireshed and planning area scales were perfectly nested, we assigned each planning area (i.e., 10,000 ha) to a parent fireshed (i.e., 100,000 ha) based on where a majority of its area fell. Once assigned, we reconstructed the boundaries of the larger firesheds by merging planning areas sharing the same parent. The stands level of the hierarchy was created by intersecting a polygon layer of 100 hectare hexagons with a land tenure layer, which created stand polygons that represented a single ownership and manageability status. Finally, each stand was assigned to both a planning area and a fireshed based on where the majority of its area fell. As such, each stand belonged to a single planning area, and each planning area belonged to a single fireshed, with the unit area of each scale centered at the desired sizes of 100 ha, 10,000 ha, and 100,000 ha respectively. The delineation process resulted in 7,688 fireshed polygons for the continental United States (fig. 2), 77,112 planning areas, and 9,726,460 stands (stands ranged in size from 5 ha to 117 ha; mean = 80 ha) (Evers et al. 2020). The average area is 101,325 ha for the firesheds and 10,102 ha for the planning areas.

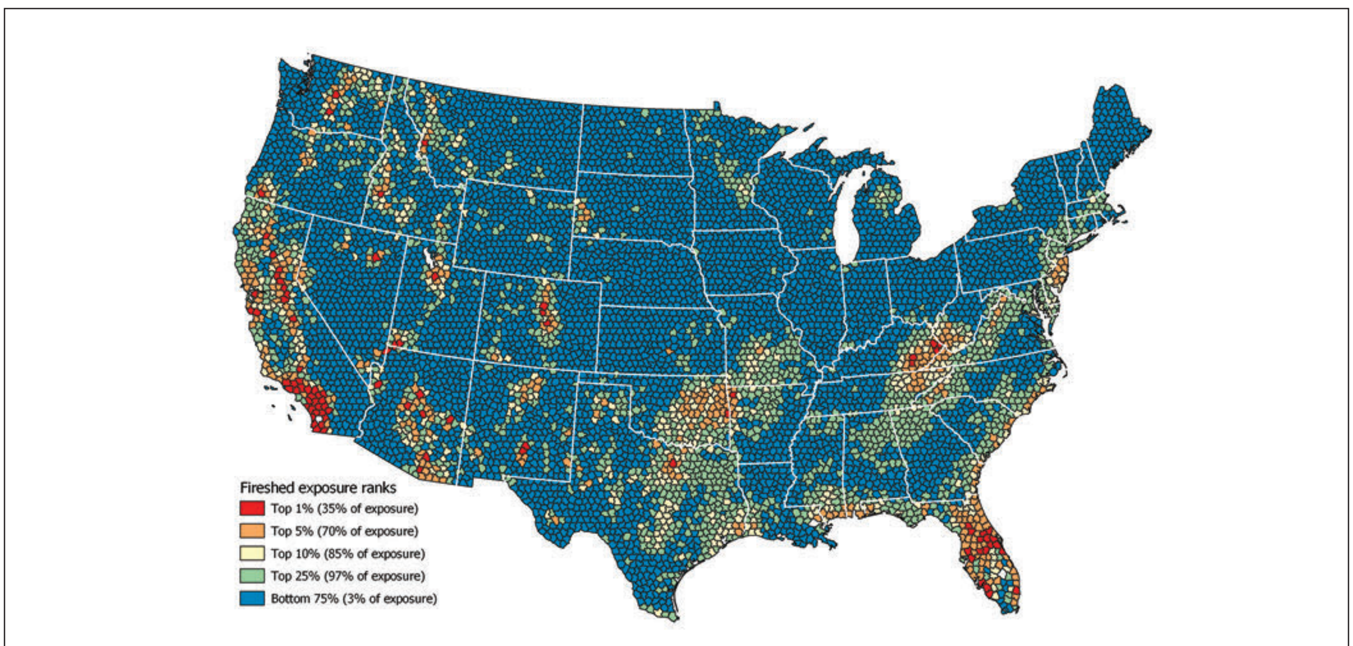

Figure 2—National map of the 7,688 firesheds created from community wildfire transmission data (Evers et al. 2020). The fireshed boundaries were created with a process that delineates hotspots of fire transmission to buildings in adjacent or nearby communities. See the Methods section for details on delineating firesheds.

Delineating Communities

We created community boundaries that included both core areas defined by the U.S. Census populated places data (U.S. Census Bureau 2016) and the adjacent WUI as defined by the SILVIS Lab (2012) (Ager et al. 2019c; Bunzel et al. 2021). The U.S. Census data identifies 28,816 settlements and communities in the continental United States in the place names database. These communities are identified as polygons or points and map the locations of incorporated and unincorporated towns, cities, and settlements. To create a map of discrete communities that included the surrounding WUI, we aggregated the core communities in the U.S. Census Bureau data with the SILVIS WUI. We attached SILVIS WUI polygons (SILVIS Lab 2012) to the core communities (U.S. Census Bureau 2016) using road networks (ESRI 2012) and minimum travel time from the community's core to each WUI polygon. Travel speed was used to create a cost raster that was input into the Cost Allocation ArcGIS tool with a maximum distance equal to 45 minutes driving time. The process organized 98.3 percent of WUI polygons into 28,816 communities, representing 300 million people and 129 million buildings as estimated by SILVIS. For specifically delineating communities (versus estimating exposure by WUI category), we removed SILVIS WUI polygons that were smaller than 0.1 ha or had building density less than two housing units per km^2; thus, our definition of WUI includes lower density census blocks than Radeloff et al. (2005) and includes no thresholds for wildland vegetation. To create the driving time cost raster, first the North America Detailed Streets dataset was converted to a 30-m raster using the speed field as the value, and then reclassed so that values equaled the number of minutes to cross the cell. This was done by reclassifying the raster where values = 1 were converted to 10 for 4-wheel drive, and No Data were converted to 3 for walking speed. A new raster with values of 1.11 was created and divided by the speed raster to create the time or cost raster in minutes. LANDFIRE Scott and Burgan fuel model data were used to correct for water bodies. Where fuel model = 98 (water), the cost raster was set to No Data.

Data Describing Fireshed Conditions

Stands in the registry were attributed with data compiled from numerous public and agency geospatial data sources (table 1; Appendix A tables A1 and A2) in addition to data on exposure and communities we generated above. A portion of the data cover all lands, whereas some information is only available for National Forest System lands. Data are briefly summarized below, with additional details provided in table 1 and Appendix A.

Wildfire Transmission to Developed Areas

To attribute the stand layer with building exposure, we first excluded nonburnable pixels using the 30-m Scott and Burgan (2005) standard fuel model grid downloaded from LANDFIRE. Specifically, we cleared from the grid the nonburnable fuel pixels including developed areas, agricultural or irrigated lands, open water, and bare ground. The exposure value for each stand was calculated as the sum of the pixel values in the underlying exposure raster. Finally, we locally adjusted the stand values so that the sum was equal to the total exposure within the fireshed (i.e., number of exposed buildings per year). This correction was conducted using the exposure results from all fire ignitions within each fireshed. In this way, we preserved the complex spatial pattern of the smoothed grid as well as the landscape-scale contribution of highly stochastic extreme fires.

Current Conditions

Spatial and tabular data on ownership composition, wildland urban interface area, number of communities and buildings, and fuels composition assessed at the fireshed scale were obtained from sources listed in table 1 and Appendix A and used to describe current fireshed conditions (fig. 3). This information provides a context for users to assess the contribution to total risk by different landowners and the potential for active management to reduce wildfire impacts on developed areas.

Wildfire and Treatment History

Historical fire perimeters from MTBS (MTBS Data Access 2020) and hazardous fuels treatment polygons from FACTS (USDA FS 2020) are provided to describe the fireshed in terms of disturbance history (table 1; Appendix A; fig. 4). Summary statistics on area burned and acres treated are provided at the fireshed scale as well as the percentage of the fireshed disturbed by type. In the interactive portal, information is available by individual fire perimeter and individual treatment polygon.

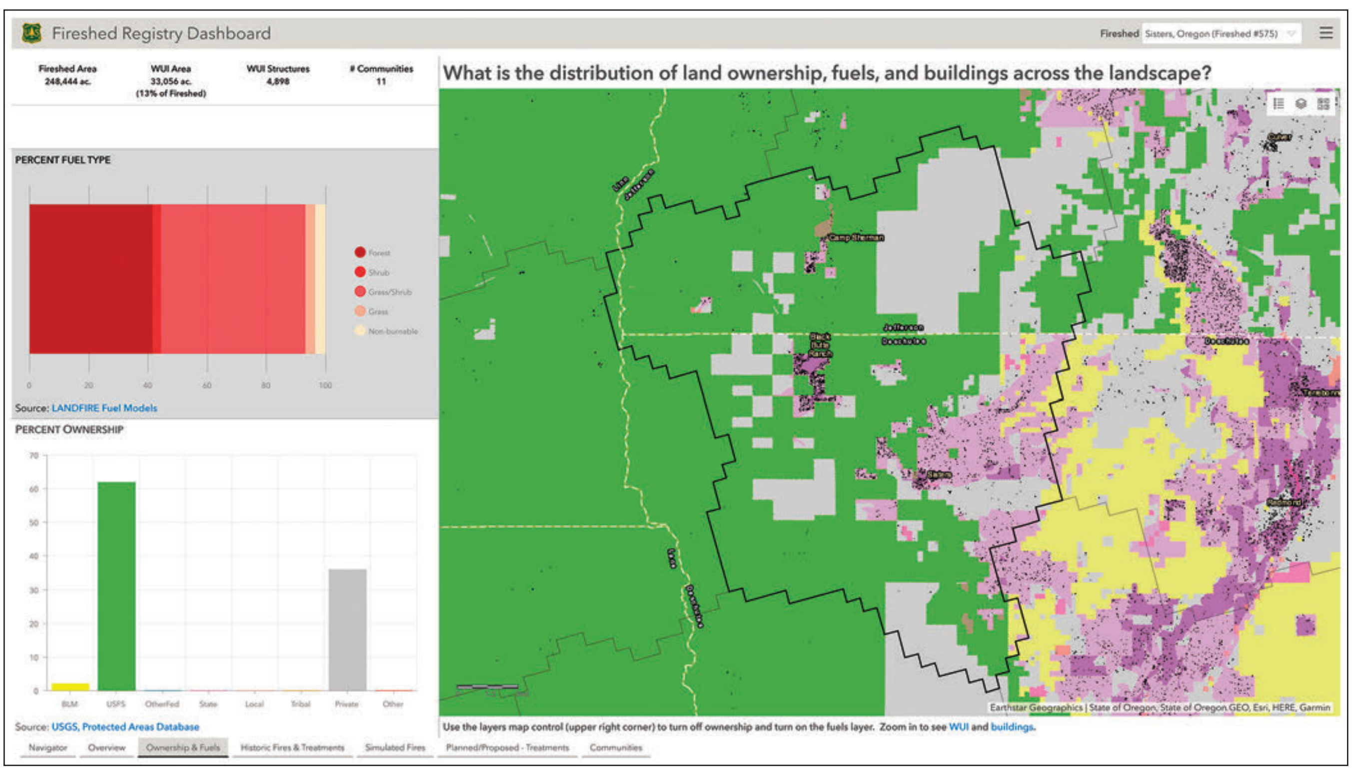

Figure 3—Screen display of the Fireshed Registry showing current conditions in terms of ownership, fuel composition, and buildings for Sisters, Oregon. See table 1 for information on data sources and vintages.

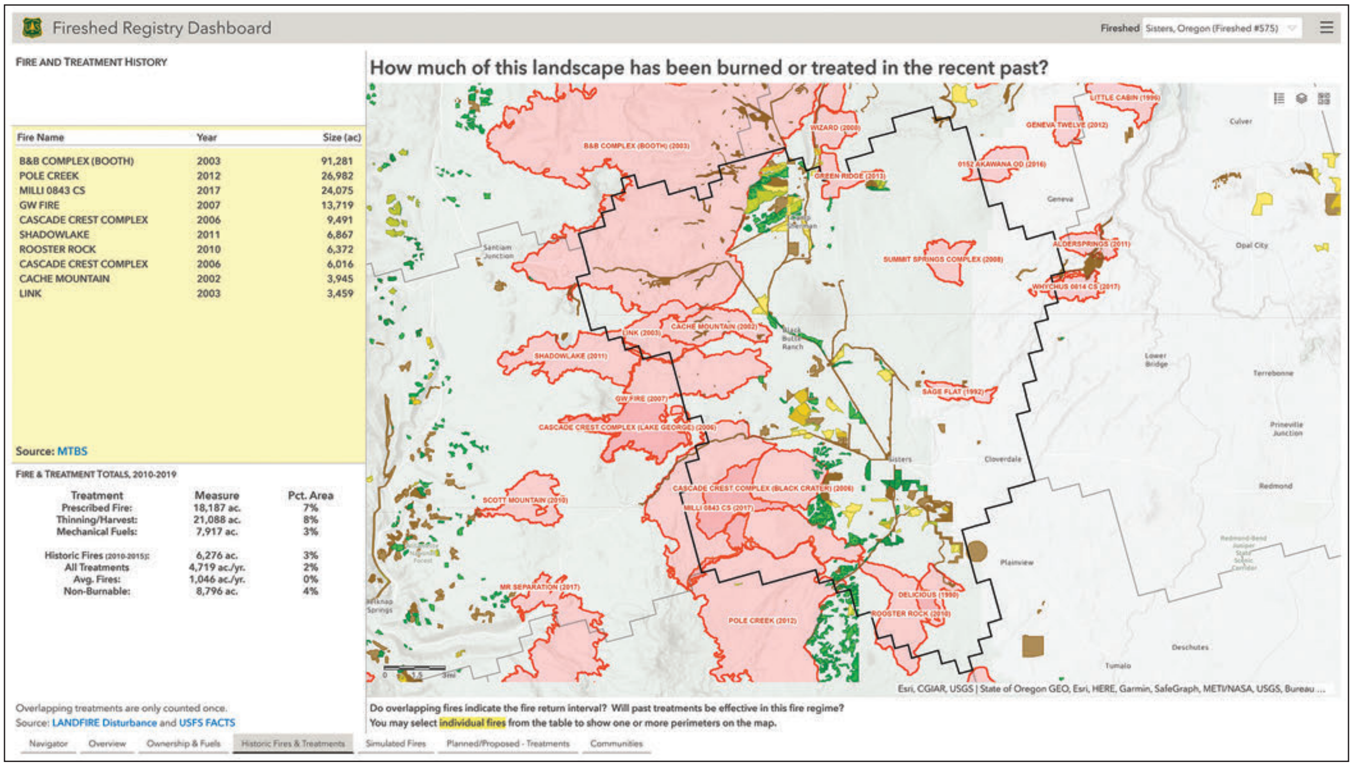

Figure 4—Screen display of the Fireshed Registry showing wildfire and treatment history. Users can select individual historical fire perimeters and treatment polygons for more detailed information. Information on area burned and acres treated is summarized for the entire selected fireshed. See table 1 for information on data sources and vintages.

Fireshed Exposure Profiles

In order to assess the effects of extreme wildfire events, we extracted simulated wildfires that started within a given fireshed and exposed the largest number of buildings in adjacent communities (table 1; Appendix A; fig. 5). Communities may be located within or outside the fireshed if a fire ignited in the fireshed and spread to adjacent areas. Total building exposure and area burned are reported for each of these extreme events.

At the community scale, the registry reports total building exposure by simulated fires ignited within a fireshed by community, with average exposure across all fire season scenarios that impacted each community, and maximum exposure from a single wildfire season (Appendix A). Building footprints are included as a spatial layer that can be overlaid with the smoothed exposure map described above to provide exposure at the scale of individual buildings.

Planned Treatments

We obtained data from FACTS (USDA FS 2020) on individual national forests that mapped future proposed treatments (2010–2019) (table 1). We found these data for roughly half of the national forests, and thus the data are incomplete and included for demonstration purposes.

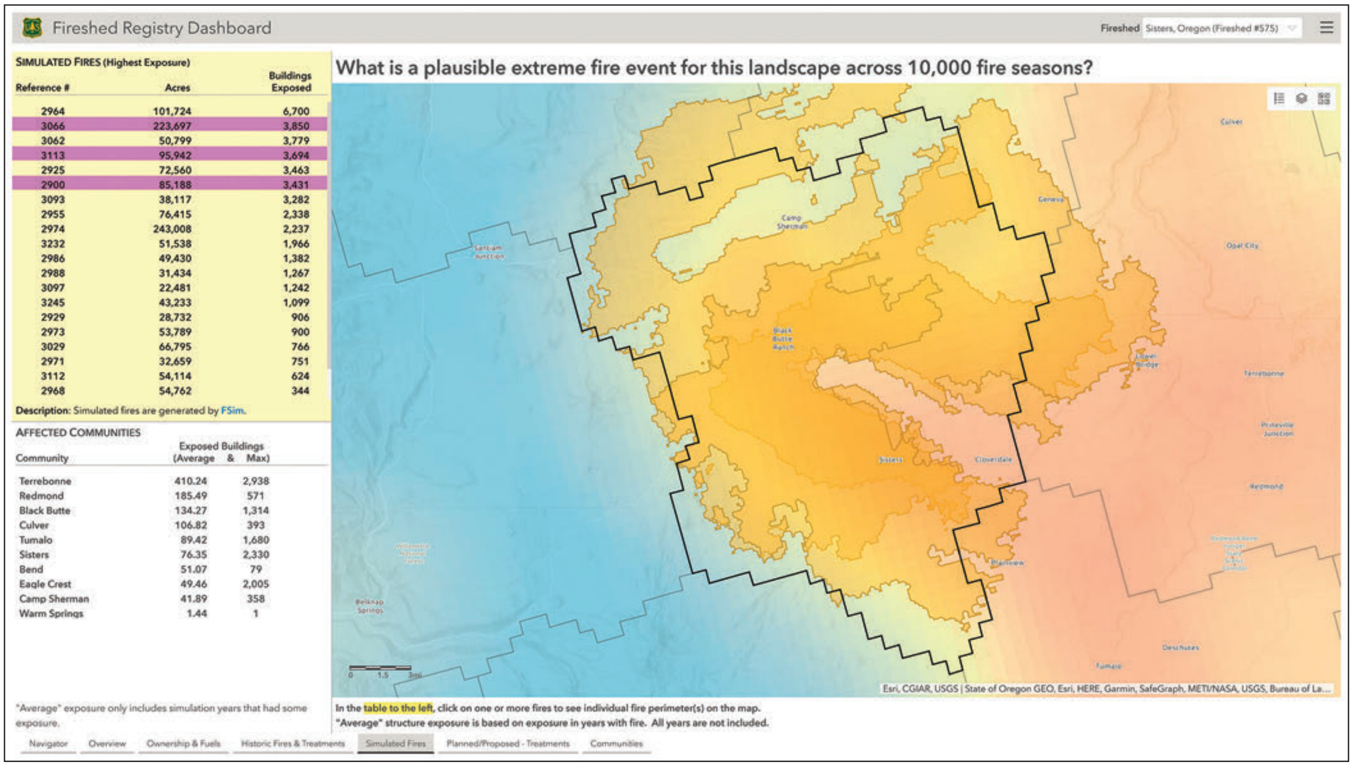

Figure 5—Screen display of the Fireshed Registry showing the fireshed exposure profile for the Sisters, Oregon fireshed. Users can select individual simulated fire perimeters and see building exposure and area burned by perimeter. Building exposure by ignitions within the fireshed for the most affected communities are summarized with average and maximum building exposure. See table 1 for information on data sources and vintages.

Prioritized Treatment Locations

We used results from a single prioritization scenario using the R version of the scenario planning model, ForSys, to simulate a 10-year forest management plan for the continental United States (Ager et al. 2019b). The western and eastern United States were analyzed and prioritized separately to eliminate scale effects. The land base was filtered to only prioritize stands classified as conifer (west) or forested (east) based on Forest Vegetation Simulator (Crookston and Dixon 2005) forest types. Stands were also filtered to only include those (1) available for mechanical treatment according to the USGS Protected Areas Database (USGS 2019) corrected with Forest Service Roadless and Nationally Designated Areas (USDA FS 2017a,b), and (2) undisturbed by recent wildfire and mechanical treatments, as determined in MTBS (MTBS Data Access 2020) and FACTS (USDA FS 2020), respectively (table 1; Appendix A).

The effect of land administration and vegetation filters was to remove 64 percent and 30 percent of the exposure to developed areas available to treat from the western and eastern U.S. Forest Service land bases, respectively (fig. 6) (table 2). Note that the total exposure was based on simulations completed with the 2014 fuels data, and the removal of lands disturbed since then by wildfire and management activities reduced the total exposure by

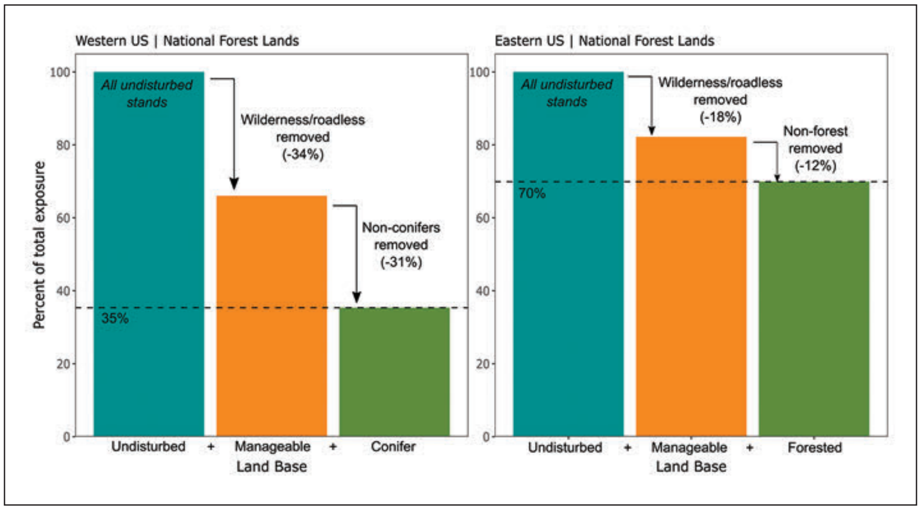

Figure 6—Percent of total building exposure by progressive land base filters on national forest lands in the western and eastern United States. Each column is a subset of the column to its left within each panel. The final columns (in green) represent the land base filter used in the scenarios in the Fireshed Registry: conifer or forest stands available for mechanical treatment that have not been recently disturbed by wildfires or treatments (including wildfires as of October 2020). Note that the treatment target only treats 6.8 percent and < 1 percent of the total exposure from all undisturbed lands in the west and east, respectively, versus national forest lands only.

16 percent and 23 percent for west and east, respectively, resulting in the starting amount of exposure (left bars; fig. 6). The removal of wilderness and roadless, where only nonmechanical treatments (e.g., fire) are allowed, reduced treatable (i.e., undisturbed stands) exposure from 100 percent to 66 percent and 82 percent for west and east, respectively. Restricting fuel

Table 2—Total area within each land base and the number of buildings exposed by ignitions within each land base considering progressive filters that exclude more area with each filter. Note that the smallest land base was used in the scenarios presented in this report.

		National Forest only		All lands	
Region	Progressive land base filter	Area (million acres)	Exposure (buildings/yr)	Area (million acres)	Exposure (buildings/yr)
West	All stands	145.0	5,177	954.9	24,520
	Undisturbed	131.0	4,359	921.8	22,530
	Undisturbed + Manageable	64.6	2,879	792.1	20,054
	Undisturbed + Manageable + Conifer stands	40.3	1,542	96.1	3,970
East	All stands	26.2	211	967.4	18,136
	Undisturbed	22.2	163	956.7	17,927
	Undisturbed + Manageable	15.6	134	919.3	17,450
	Undisturbed + Manageable + Forest stands	12.9	114	281.4	5,003

management to commercial conifer (west) or forested (east) stands reduced treatable exposure an additional 31 percent and 12 percent, leaving 35 percent and 70 percent of the estimated total for treatment in the west and east, respectively (fig. 6). The rationale for these specific filters is discussed below, and scenarios that assume treatments in some of these areas are part of ongoing work (see Discussion section).

Stands within projects were prioritized based on building exposure from fires that originated in that stand and added to each solution based on the total amount of exposure treated. ForSys ranks project areas for each scenario and reports building exposure treated. We assumed that treatments will be implemented using the mix of treatment types historically used on each national forest according to FACTS. We did not estimate reduction in exposure, only exposure treated. Stands were treated until 80 percent of the building exposure was treated within each planning area. This particular scenario was simulated and included into the registry to illustrate its use to examine future potential scenarios relative to planned activities and past wildfire impacts. We envision a system where a linked scenario planning model can be used to load scenarios into the registry by agency planners and stakeholders.

Community Exposure Profiles

Our previous work focused on estimating exposure at the scale of individual communities (Ager et al. 2019a; Ager et al. 2019c). To build a comprehensive portal for understanding wildfire exposure, we included those community results in the registry. In this way we provide for the assessment of both the larger landscape source of risk and the target (community). As part of this we included the worst five fire events in the FSim library in terms of exposure to each community. Major land ownership and fuel types are also provided for the area within the community boundary. Locations of Firewise communities (table 1) are also mapped.

Geospatial Registry

After organizing the above data and creating a series of tabular reports for each fireshed, we used an ArcGIS online dashboard to provide interactive viewing (ESRI 2019). The dashboard was organized into five main screen tabs that tied the map display and tabular reports to five key questions: (1) How is exposure distributed among ownerships? (2) How much of this landscape has been burned or treated in the recent past? (3) What are the spatial patterns of exposure to developed areas including plausible extreme fire events? (4) Where are future management efforts planned? (5) How are communities exposed to extreme fire events? A range of other questions can be addressed with these data, with the intent of the questions to create a flow for a basic fireshed assessment. In addition, a Navigator tab directs users to select the fireshed of interest, and an Overview tab (fig. 7) summarizes information from all elements of the registry.

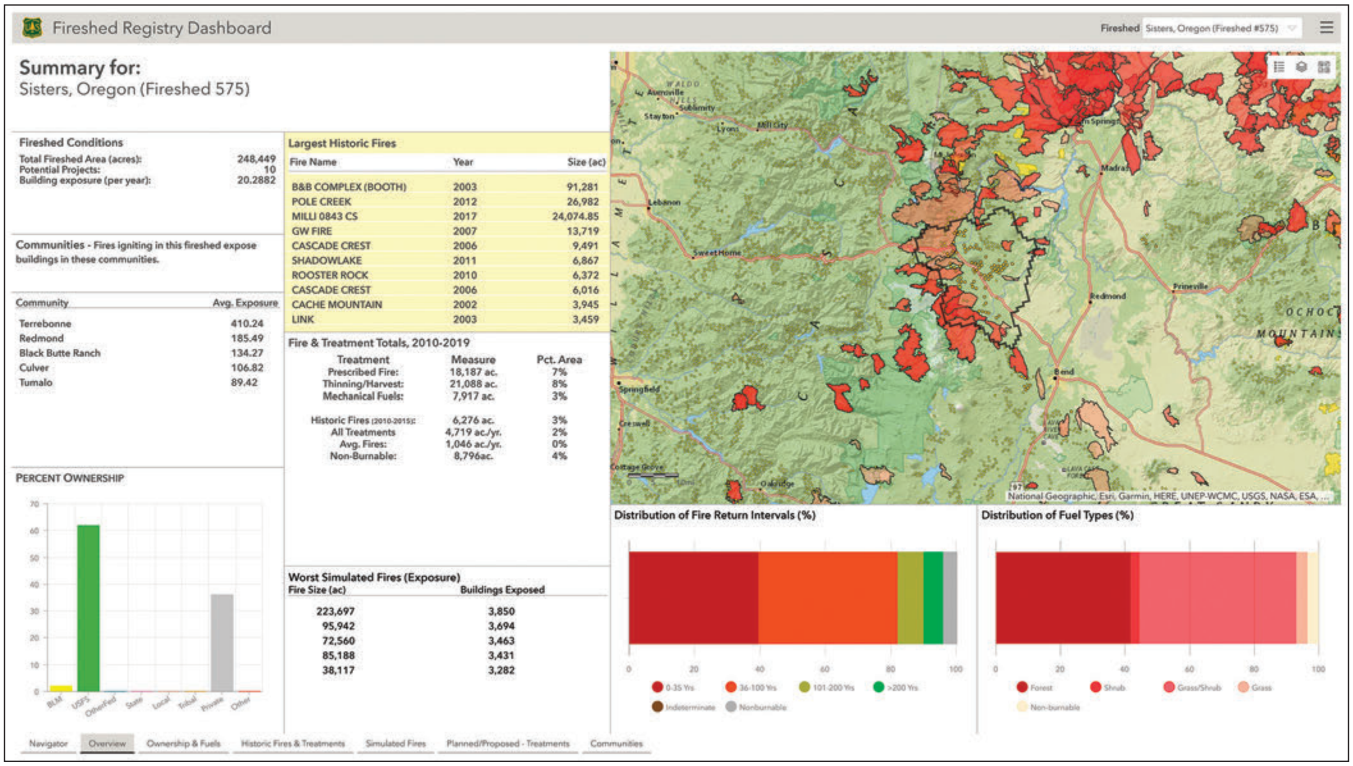

Figure 7—Screen display of the Fireshed Registry showing the overview page for the Sisters, Oregon fireshed. See table 1 for information on data sources and vintages.

Identification of Priority Firesheds

We used the registry to address prioritization of forest and fuel management investment as part of multiple agency initiatives (table 3). We first filtered the stands as described in the Prioritized Treatment Location section to remove areas that are unlikely or infeasible to receive active forest management.[1] Then we further filtered the stands to select only Forest Service stands. The 7,688 firesheds were then ranked using a scenario planning model (Ager et al., in review) based on predicted building exposure from ignitions on Forest Service lands within the fireshed. The top 10 firesheds for each region were identified and loaded into the simplified companion “fireshed investment portal” for use by the field units. This portal displayed estimated total building exposure by landowner and building exposure from USFS-managed stands. In addition, the planning areas (~10,000 hectares) within these firesheds were also ranked by building exposure and included in the portal.

[1] Initial scenario runs to identify the top 10 priority firesheds by region filtered stands based on NLCD (USGS 2011) definitions of forested vs. nonforested rather than FVS forest type as described in the Prioritized Treatment Location section.

Table 3—Application of the Fireshed Registry for prioritization to inform agency initiatives and reporting requests.

Application	Description	Citation
USDA Forest Service National Investment Strategy for Reducing Fire Risk	A multiyear, focused investment in large, cross-boundary critical landscapes for fire risk reduction.	USDA FS (2018)
Response to Executive Order 13855, “Promoting Active Management of America’s Forests, Rangelands, and Other Federal Lands to Improve Conditions and Reduce Wildfire Risk”	Requires identification of DOI- and USDA FS-administered lands where there is a high probability that wildfires would threaten people, structures, or other high-value assets.	Executive Order 13855 of Dec. 21, 2018 (Federal Register 2018)
FY2021 Hazardous Fuels Allocation	The Forest Service anticipates allocating up to $1 million for priority projects including risk-based hazardous fuels and fire management.	USDA FS (2018)
Development of USDA FS Shared Stewardship Performance Metrics	The USDA FS Shared Stewardship Performance Framework includes identifying specific indicators related to wildfire risk reduction in priority firesheds.	USDA FS (2018)
Prioritization of USDA Forest Service and NRCS Joint Chiefs’ Restoration Partnership Projects	FY2021 project proposal evaluation criteria include a wildfire risk reduction objective.	USDA FS (2019)

Fiscal Year 2021 National Fuels Investment Strategy

In 2020, the Forest Service initiated a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas. The plan specifically earmarked about $5.1 million in hazardous fuels funding in the initial allocation to two priority firesheds. The plan included a provision that as additional funding became available during FY2021, additional priority firesheds will be identified. For this initiative, the registry was used to identify the top 10 firesheds in each Forest Service region that were predicted to contribute to the highest level of building exposure originating from lands available for active forest and fuels management (fig. 8). Ten priority firesheds in each Forest Service Region accounted for between 3 percent and 53 percent of the total exposure within the western or eastern United States (based on stands available for treatment). Spatial data including priority fireshed boundaries, exposure estimates, and related information

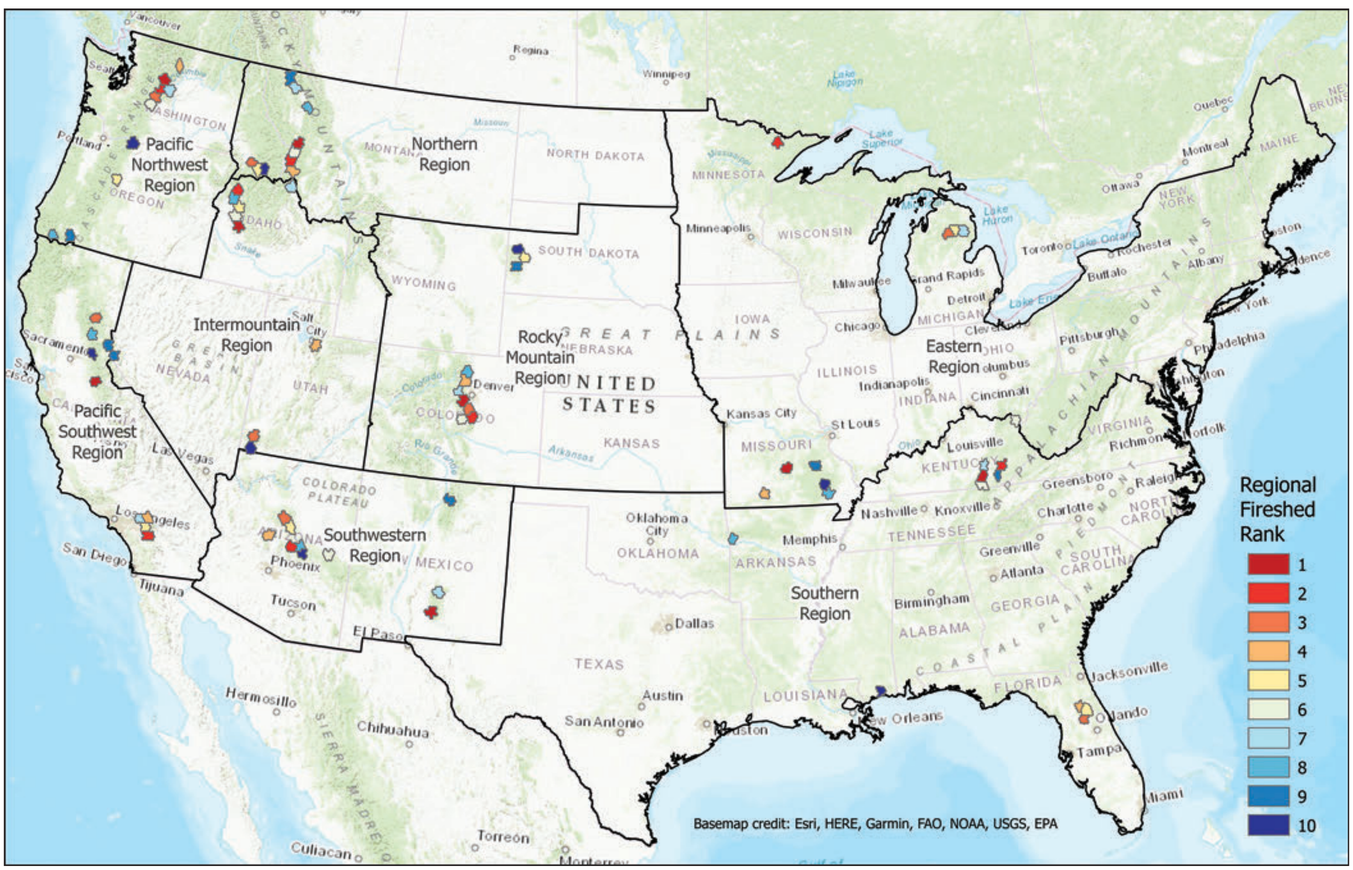

Figure 8—Map of CONUS showing the top 10 firesheds in each Forest Service Region identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities. See Appendix B for higher resolution maps by region.

were loaded into the Fireshed Investment Portal (fig. 9) to provide regions with a simplified online viewing system to review the results. The use of both portals (Registry and Investment Portal) facilitated downscaling and interpreting the prioritization results in terms of where and how much treatment was recommended to the eight regions and 112 national forests.

Executive Order (EO) 13855

Data from the registry were used in response to the December 2018 Executive Order (EO) 13855, “Promoting Active Management of America’s Forests, Rangelands, and Other Federal Lands to Improve Conditions and Reduce Wildfire Risk, Section 5 Wildfire Strategy” subsection. Subsection 5(b)(i) requires the USDA Forest Service and the Department of Interior (DOI) to: “Identify DOI- and USDA FS-administered lands with the highest probability of catastrophic wildfires, as well as areas on those lands where there is a high probability that wildfires would threaten people, structures, or other high-value assets, in order to direct and prioritize actions to meet land management goals and to protect communities” (Federal Register 2018).

Data in the registry on fire transmission to buildings originating on national forests and DOI lands were summarized into five levels of exposure and used to generate a series of map products that were included in the response to the EO. The results of this assessment predicted 8,475 buildings are potentially exposed annually by ignitions on DOI and Forest Service administered lands. The highest 40 percent of building exposure originated from simulated wildfires ignited on a mere 1 percent of Forest Service and DOI administered lands (2,853,455 acres). The latter land base accounted for 3,389 buildings

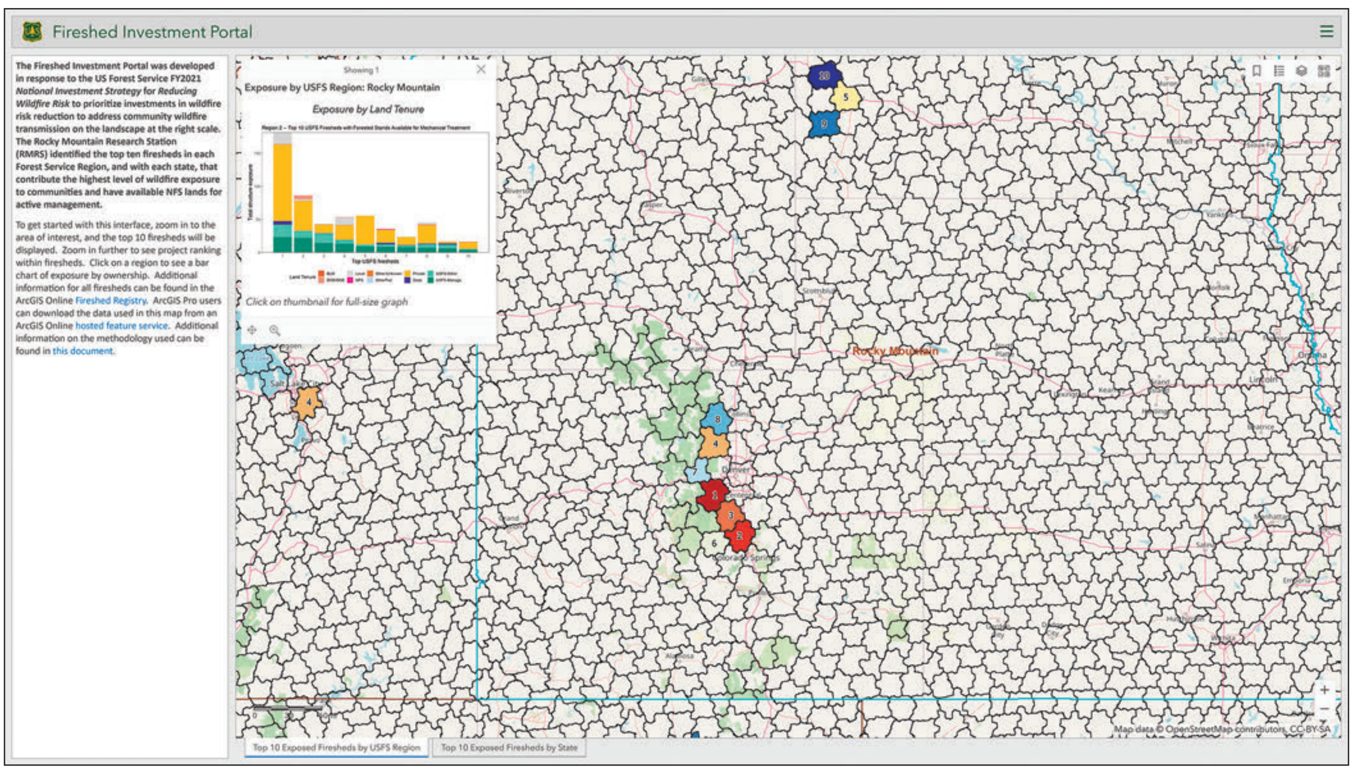

Figure 9—Forest Service Fireshed Investment Portal ArcGIS Online dashboard for viewing priority firesheds based on Forest Service forested stands available for mechanical treatment and not recently disturbed by wildfire or mechanical treatments.

exposed per year (table 2). High exposure areas were distributed across the United States with concentrations in southern California, central Arizona, and Washington (fig. 10). Scattered locations of high exposure were predicted throughout the West, as well as in western Virginia and Florida. Pockets of moderate exposure were mostly concentrated in the 11 western U.S. States. The lowest 15 percent of total exposure was predicted on 87 percent of the land base (313,565,960 acres) and was classified into the very low and low exposure categories (table 4). Within these categories an estimated 847 buildings are exposed per year.

Scenarios for Revision of the National Fire Plan

As stated in the wildland fire section of the 2018 Omnibus bill, "despite more than $5,000,000,000 in investments in hazardous fuels mitigation since the development of the National Fire Plan following the 2000 fire season, the [Forest Service] has not been able to keep pace with the challenges caused by previous management decisions, a changing climate, ever-increasing costs, and an expanding wildland urban interface, all of which exacerbate the risk of catastrophic wildfire. The Committees direct the [Forest Service] to work with the Office of Management and Budget and the Department of the Interior, as well as other relevant agencies, to review and update the National Fire Plan, as needed" (U.S. House of Representatives 2018 pages 1174–75).

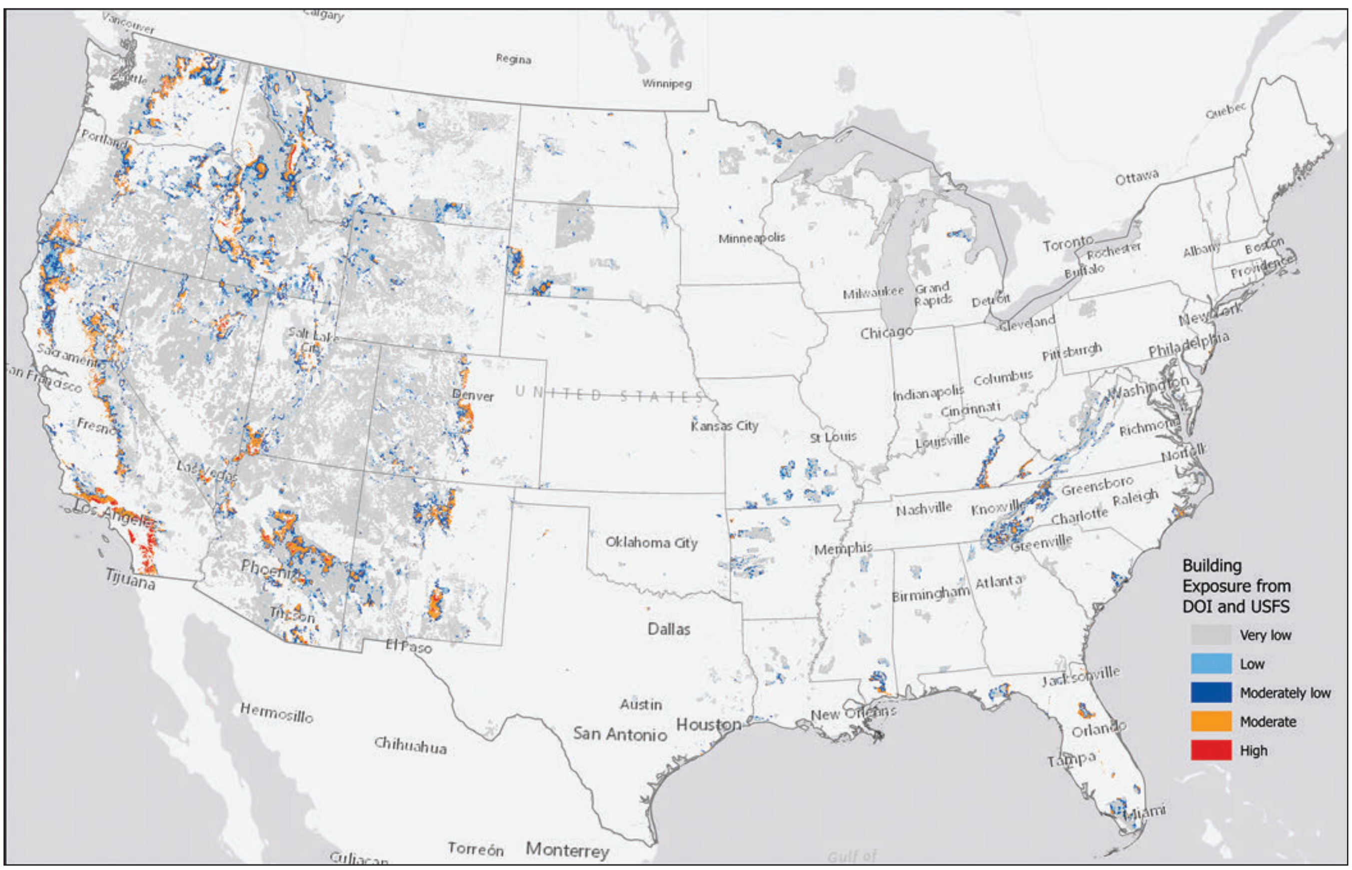

Figure 10—Department of Interior and Forest Service administered lands where fires have the potential to ignite and spread to communities and expose buildings by exposure class. See table 4 for details on each building exposure class. Map developed from data in the registry in response to December 2018 Executive Order (EO) 13855.

Table 4—Total area by agency where wildfires potentially ignite, spread, and expose buildings; and total number of buildings exposed.

Agency	Number of buildings exposed by agency ignitions (per year)	Total area where wildfires ignite and expose buildings (acres)[1]	Percentage (%) of agency area that is mapped to spread fires to buildings[2]
USFS	5,455	165,143,337	89
BLM	1,724	119,230,768	71
BIA	1,003	52,335,036	77
NPS	159	16,057,149	54
FWS	95	8,210,695	55
USBR	38	1,337,688	56

[1] Total area for all Forest Service and DOI lands (CONUS) is 469,318,394 acres.

[2] For example, 89 percent of all Forest Service lands have the potential for wildfires to ignite and spread to communities and expose buildings.

The Forest Service, in partnership with other agencies, recently initiated a revision to the 2000 Fire Plan, which included discussions on the feasibility of substantially accelerating fuels treatment from the current levels and potentially refocusing treatments to target wildfire transmission to developed areas.

As part of this effort, we used spatial and other data in the registry to develop a 10-year period of accelerated fuel management and investigated to what extent a national investment in hazardous fuels treatments can address community exposure from national forests given current management and fire regimes. Details of the scenario modeling are reported elsewhere (Ager et al., in review). We analyzed the scenario and its performance in terms of the rate at which the areas of high fire transmission are treated, the space-time scheduling dynamics among and within the 76 national forests in the western U.S., and the potential for future wildfire to alter the prioritization schedule during implementation (fig. 11). The plan treated 16.3 million acres in the western United States in 3,475 projects reducing building exposure from ignitions on national forest lands by 77 percent when considering exposure on conifer stands available for mechanical treatments. Building exposure treated relative to all national forest lands was 36 percent. We also examined the overlap between predicted wildfire events and treatments over time. The methods and results provide the agency with a strategic capacity to use both the registry and scenario planning models (Ager et al., in review; Ager et al. 2019b) to conduct fuel management planning by leveraging new technology and models to the problem of wildfire risk to developed areas.

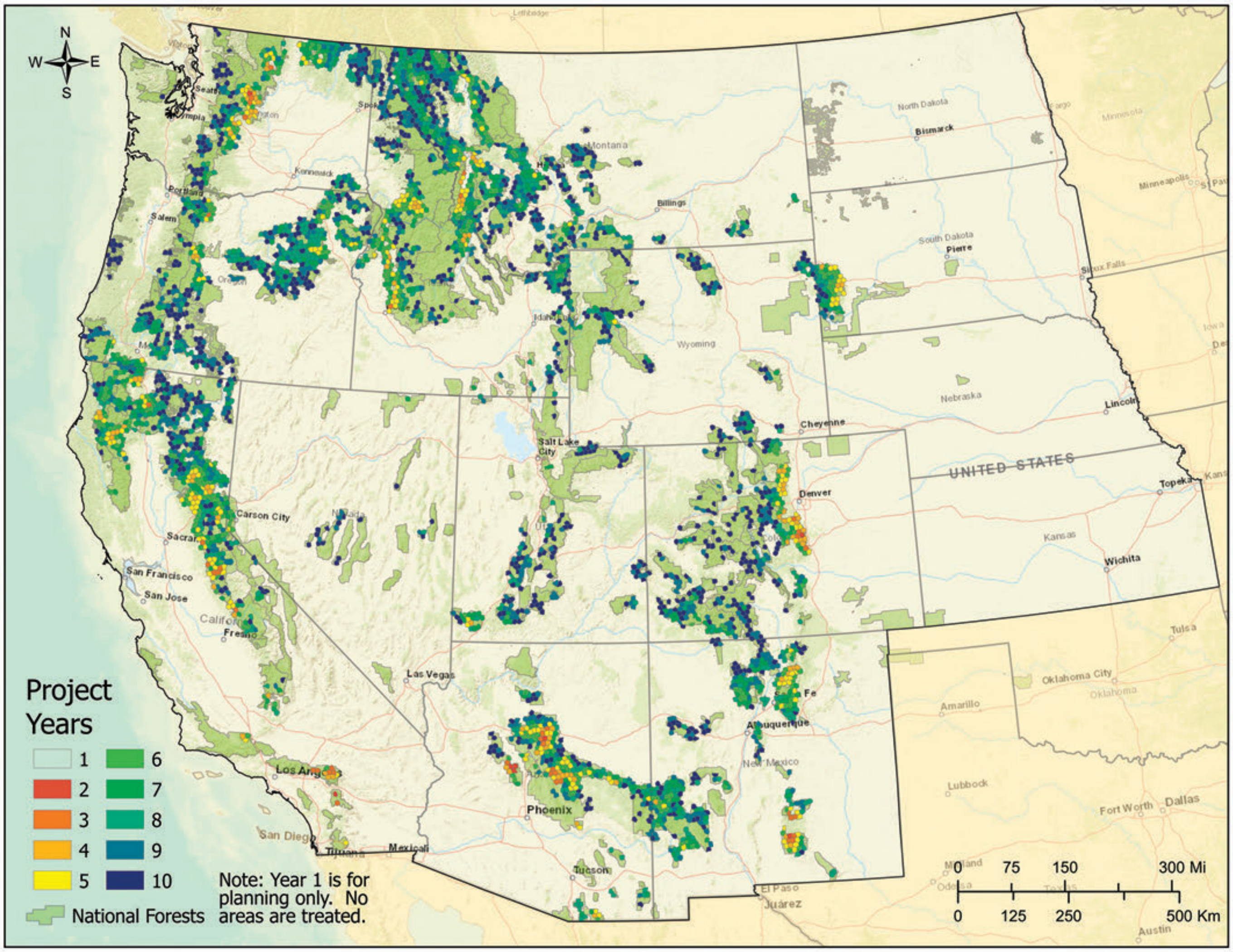

Figure 11— Map of 10-year national forest treatment plan in the western United States with Fireshed Registry project areas symbolized by treatment year with highest priority projects implemented in year 2. Year 1 is reserved for planning. Projects were prioritized to treat 80 percent of the wildfire exposure originating in each planning area on national forest lands available for mechanical treatments (e.g., excludes wilderness) and with conifer stands. Area treated is increased over the 10-year period. Note that entire planning areas are symbolized and not just area treated. Figure modified from Ager et al. (in review).

Performance Metrics for Shared Stewardship

The Shared Stewardship initiative was established in FY2019 to forge a network of cross-boundary collaborations between state and federal lands throughout the country (USDA FS 2018). The National Shared Stewardship performance team was subsequently tasked with developing a framework for performance evaluation for three specific elements of the Shared Stewardship program: wildfire risk reduction, generation of co-benefits (e.g., water quality improvement), and partnership capacity. The framework includes: (1) pilot projects in multiple States that represent the goals in Shared Stewardship memorandums of understanding (MOU), and (2) focused efforts to support agency investment in priority firesheds. The process is making use of the registry as an accounting framework for reporting wildfire risk reduction in priority firesheds as mapped and attributed in the registry. Specific indicators will be developed for FY2021 implementation to assess if and how our investments are causing significant reduction in wildfire risk in identified high-priority landscapes.

Although work is underway to develop specific performance metrics, multiple metrics specific to landscape condition reported in the registry are being considered in the Shared Stewardship Performance Framework. Some metrics of potential use include:

(1) change in area of predicted high severity fire in the fireshed;

(2) change in predicted wildfire risk to high-value resources;

(3) change in predicted wildfire transmission to communities; and/or

(4) change in an index related to water, carbon, or other ecosystem services.

Prioritization of Restoration Partnership Projects

The USDA Forest Service and NRCS Joint Chiefs' Restoration Partnership projects are designed to improve the health and resiliency of forest and rangeland ecosystems, while benefiting local communities. Projects leverage technical and financial resources between agencies and with Forest Service partners to complete on-the-ground accomplishments across jurisdictional boundaries. Successful projects utilize this program to focus investment by both agencies within a 3-year-long period and to coordinate and accelerate efforts within a shared landscape. The spatial and timing linkages of these projects enable cumulative impacts to be more beneficial and efficient. For FY2021, one of the criteria for project proposal evaluation, scoring, and selection is that proposals that include a wildfire risk reduction objective should describe the cross-boundary or community planning efforts used to prioritize the work (e.g., fireshed analysis, risk assessments).

Proposals for funding in FY2021 were required to include, at minimum, a combination of activities on private and public land. The Fireshed Registry and fireshed boundaries were used in the development of proposals, specifically to align state-level priority firesheds based on community wildfire transmission from ignitions on Forest Service forested lands that are available for mechanical treatments.

Evaluating Collaborative Forest Landscape Restoration Program Proposals

Congress created the Collaborative Forest Landscape Restoration Program (CFLRP) in 2009 to support large-scale forest restoration and benefit local communities through collaborative approaches. CFLRP has proven to be an effective tool for improving forest conditions, growing rural economies, and leveraging partner investments to improve the quality and scale of our work. Congress reauthorized CFLRP in the 2018 Farm Bill, doubling the authorized funding level to $80 million per year and creating the opportunity for new CFLRP projects. The Farm Bill also provides an opportunity for current CFLRP projects funded for 10 years to apply for an extension waiver to complete implementation.

In FY2020, fireshed boundaries were integrated into the CFLRP mapping portal, thus allowing national CFLRP staff to analyze how CFLRP prospective projects aligned with priority firesheds identified in the Fireshed Registry. The registry is being used by national CFLRP staff to help integrate priorities established in the registry with future proposed CFLRP projects.

Additional Applications of the Fireshed Registry

Regions, Forests, and staff at the national level used the Fireshed Investment Portal and the registry in a number of prioritization discussions and decisions for FY2021 (table 3). The portals were also used for the purpose of validation with local priorities identified in regional assessments, and national priorities identified in the modeled scenarios. Some of these were part of the annual budget process and others were one-time special programs or requests (table 3).

Discussion

The Fireshed Registry was created to advance spatial planning to manage wildfire risk to communities from both national forests and other state, federal, and private lands. The registry is a unique geospatial planning framework that stiches together a time window of information—past, present, and future scenarios—to describe risk trajectories on lands where destructive wildfires are likely to originate. The geospatial dashboard coupled with scenario planning models and investment portals creates a flexible system where each component can stand on its own or be used as an interlinked system to build and test management scenarios (fig. 12). The fireshed delineation organized spatial variation in areas that contribute (i.e., via wildfire spread) risk to communities into a hierarchical system of geographic units, similar to the hydrologic unit classification (USGS and USDA-NRCS 2013). The registry weaves together many different spatial data to provide a time portrait of land conditions, recent wildfire activity, simulated wildfires, exposure to communities, and treatment scenarios derived from 5- to 10-year action plans and the Scenario Investment Planning Platform.

While the registry was organized around fire risk to developed areas, the framework does not preclude integrated assessment of other resource management priorities such as protecting water, wildlife habitat, and recreation opportunities. The all-lands geography of the Fireshed Registry makes it a useful platform for planning cross-boundary, large-scale restoration projects as part of Shared Stewardship and the Collaborative Forest Restoration Program. In practice, coordinated cross-boundary efforts will be required to significantly reduce wildfire transmission in many planning areas. Cross-boundary forest and fuel management is facilitated

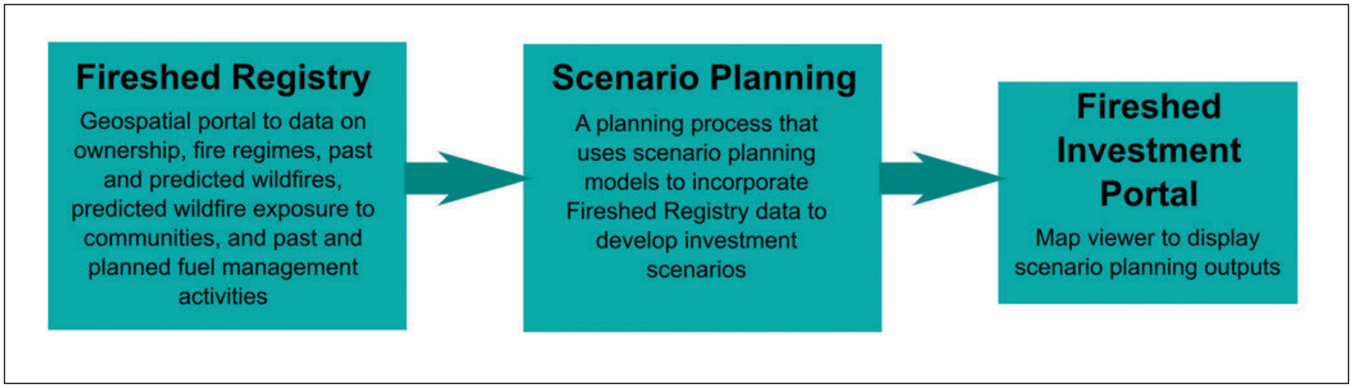

Figure 12—The Fireshed Registry (left) is a geospatial dashboard built to organize information about wildfire transmission to communities and monitor progress towards risk reduction from management investments. Scenario planning models use data from the registry to develop investment scenarios (middle), which are then loaded into a simple investment portal for viewing and review by field units.

by newer agency initiatives that have created a cross-boundary authorizing environment (USDA FS 2018). Heretofore, a national-scale system to organize landscape fire risk to developed areas does not exist as it does for other forest disturbance and ecological conditions (e.g., Land Type Associations, Ecological Units, and the Terrestrial Condition Assessment, or Hydrological Unit Codes and the Watershed Condition Framework) (Cleland et al. 2017; Omernik and Griffith 2014; USDA FS 2011). Moreover, the framework provides a foundation for communication and coordination with external agencies and partners and for national-scale reporting and monitoring of outcome-based performance measures related to community risk.

Wildfire risk to developed areas has received substantial attention from the research community. Researchers have developed various schemata to define and map the WUI (Bento-Goncalves and Vieira 2020; Lampin-Maillet et al. 2010; Modugno et al. 2016; Radeloff et al. 2005) and assess fire hazard in relation to biophysical factors and social vulnerability (Adams and Charnley 2018; Carroll and Paveglio 2016; Evers et al. 2019; Paveglio et al. 2015; Wigtil et al. 2016). However, most existing WUI classification schemes rely solely on in-situ factors such as structure location and surrounding vegetation cover (but see Price and Bradstock 2013) for measuring wildfire risk (Bar Massada et al. 2009; Bento-Goncalves and Vieira 2020; Chas-Amil et al. 2013; Lampin-Maillet et al. 2010). Prior efforts have focused on in-situ risk with risk assessments, while we have focused on identifying the source of risk. This approach allowed us to target the problem of prioritizing large areas of wildlands that are the source of fire to developed areas, rather than focusing on individual communities as has been the emphasis of many existing programs (Scott et al. 2020).

We also transcended typical risk assessments by describing potential extreme events in each fireshed, rather than average risk metrics. This is the first use of extreme event scenarios in a fire risk application and overcomes the limitations of contemporary risk maps (Dillon 2015; Scott et al. 2013) that show pixel-scale average burn probabilities and exposure levels averaged over thousands of fire seasons. The fireshed framework is more efficient for land management agencies to organize variation in wildfire transmission to communities. For instance, firesheds and project areas expose multiple communities to wildfire (fig. 13).

One appealing feature of firesheds is they facilitate efficient investment in hazardous fuels treatments. While the Forest Service has invested billions of dollars in hazardous fuels reduction and other active management activities for two decades, the cost of fire suppression continues to rise steeply (U.S. House of Representatives 2018). Longer fire seasons and the rising size and severity of wildfires, along with expanding risk to communities, natural resources, and the safety of firefighters, are of concern to all land management agencies. Since 2018, the agency has been especially focused on leveraging partnerships and collective efforts to address these concerns and manage Forest Service lands differently. Building on this Shared

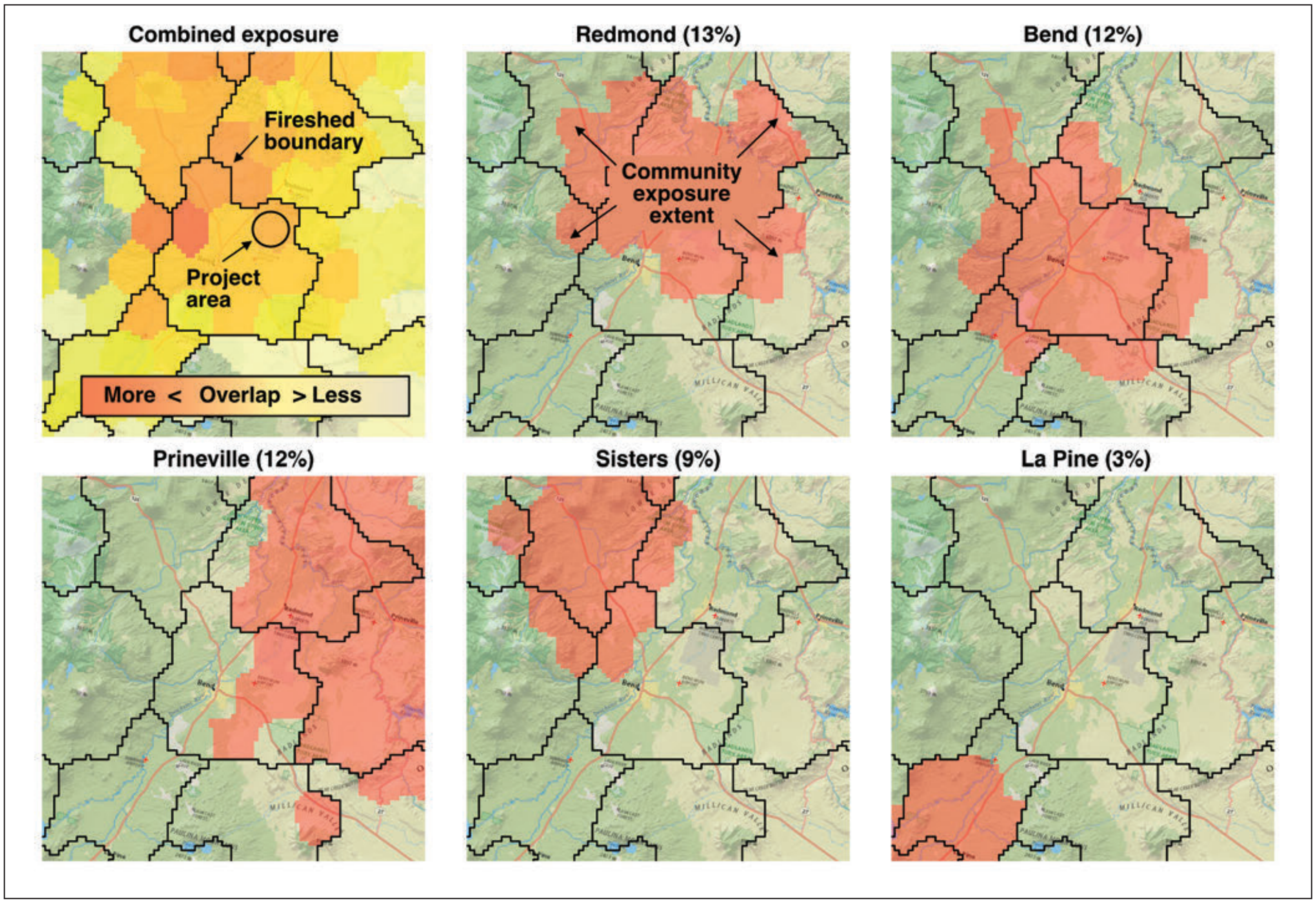

Figure 13—Wildfire exposure for Central Oregon showing how the zones of community exposure often overlap, thus highlighting the need for exposure containers (i.e., firesheds) that address the source of exposure and are not bounded by administrative community boundaries.. The combined exposure panel represents the number of buildings exposed (yellow = less, red = more) from ignitions at a given location. Firesheds are outlined in black. The remaining panels show the scale of exposure to five individual communities (i.e., community-scale firesheds as described in Ager et al. [2016], shown in red). The percentage of the area's exposure is reported in parentheses. The scale of exposure for many of the region's communities is equivalent to the firesheds (i.e., 100,000 hectares), although distinct in coverage.

Stewardship approach, the agency has been working to target our efforts on larger landscapes that are at high risk to communities. In FY2021, the agency refined how to direct work to the appropriate areas on the landscape at scales that more closely matched recent large wildfire events.

The development of a coupled planning system like the Fireshed Registry and scenario planning models directly addresses recommendations concerning the advancement of systems thinking, data analytics, and prescriptive intervention in the federal government, as issued in the recent National Academies of Sciences report "Science Breakthroughs to Advance Food and Agricultural Research by 2030" (NASCEM 2019). Specifically, the application and integration of data sciences, software tools, and systems within the scenario planning platform advance the data analytics maturity curve into the next stage of prescriptive analysis, thereby providing enhanced foresight into natural resource management outcomes (NASCEM 2019). The fireshed planning framework takes a systems approach to the wildfire problem by moving from a descriptive (assessments) to predictive (risk models) to prescriptive (scenario modeling) environment. To date, agency efforts have focused on the descriptive stage (e.g., USDA FS 2011) with the development of various performance metric systems and dashboard portals that are heavily weighted towards descriptive assessments. These dashboards use a wide assortment of information that may not have a statistically established link to desired outcomes. Predictive and prescriptive thinking needs to be incorporated into performance systems and dashboards that have been or are being developed in the agency for widespread use. The predictive ability of performance metrics that are hypothesized to derive (or are correlated with) outcomes need to be established with the help from management research programs tied to specific dashboards and performance metric systems. A systems framework can guide the development of performance metrics and help advance predictive and prescriptive thinking in the agency. As the agency moves forward with coordinated prioritization with States and partners, the numerous data sets, dashboards, and performance metrics created to track progress need to be implemented within a larger systems framework that will ensure the future development of predictive and prescriptive systems.

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Appendix A. Fireshed Registry Data Details

Table A1—Tabular and chart data descriptions, sources, vintages, and type used in the Overview tab of the Fireshed Registry. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Total fireshed area	Total area within fireshed	Evers et al. (2020)	2020	Tabular
Number of potential projects	Total number of projects within fireshed	Evers et al. (2020)	2020	Tabular
Building exposure per year, average	Total potential building exposure from fires ignited within the fireshed	FSim (Short et al. 2020); MS footprints (Microsoft 2018)	FSim: LF2014b; MS footprints: 2015	Tabular
Community building exposure	Average annual conditional structure exposure within the community from ignitions in the fireshed	U.S. Census Bureau (2016); FSim (Short et al. 2020); MS footprints (Microsoft 2018)	U.S. Census: 2018; FSim: LF2014b footprints: 2015	Tabular
Percent ownership	Percentage of fireshed within major ownership classes	Protected Areas Database (USGS 2016, 2019)	Western U.S.– 2016; Eastern U.S.– 2019	Graph
Largest historic fires	Ten largest historic fires intersecting the fireshed	MTBS Data Access (2020)	2017	Tabular
Historical area treated with prescribed fire	Prescribed fire treatments completed within the fireshed	MTBS Data Access (2020); LANDFIRE (2014); FACTS (USDA FS 2020)	MTBS: 2010–2017; LANDFIRE: 2010–2014; FACTS: 2010–2019	Tabular
Historical area treated with thinning/harvesting	Mechanical fuel treatments completed within the fireshed	LANDFIRE (2014); FACTS (USDA FS 2020)	LANDFIRE 2010–2014; FACTS 2010–2019	Tabular
Historical area treated with surface fuel mastication	Mastication treatments completed	LANDFIRE (2014); FACTS (USDA FS 2020)	LANDFIRE 2010–2014; FACTS 2010–2019	Tabular
Historical area burned by wildfire	Cumulative total area burned within the fireshed by fires ignited within the fireshed	Short (2017)	2010–2015	Tabular
Top five worst simulated fires: building exposure	Top five worst simulated fires based on structure exposure from ignitions within the fireshed and corresponding structure exposure (Note: buildings exposed may be located outside of the fireshed)	FSim (Short et al. 2020); MS footprints (Microsoft 2018)	FSim: LF2014b MS footrpints: 2015	Tabular
Distribution of fire return intervals	Percentage of fireshed in each of six fire return interval classes	LANDFIRE	2014	Graph
Percent fuel type	Percentage of fireshed within major fuel types	LANDFIRE (2017)	2014	Graph

Table A2—Tabular and chart data descriptions, sources, vintages, and type used in the Ownership and Fuels tab of the Fireshed Registry. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Total fireshed area	Total area within fireshed, generally ~250,000 acres	Evers et al. (2020)	2020	Tabular
WUI area	Area within fireshed classified as WUI (acres and percentage of fireshed)	SILVIS Lab (2012)	2010	Tabular
WUI buildings	Number of buildings within the fireshed/WUI	SILVIS Lab (2012)	2010	Tabular
# of communities	Number of communities defined as the U.S. Census populated place and associated WUI within a 45 minute drive time	U.S. Census Bureau (2016); SILVIS Lab (2012)	2018; 2010	Tabular
Percent ownership	Percentage of fireshed within major ownership classes	Protected Areas Database (USGS 2016, 2019)	Western U.S.–2016; Eastern U.S.–2019	Graph
Percent fuel type	Percentage of fireshed within major fuel types	LANDFIRE (2017)	2014	Graph

Table A3—Tabular and chart data descriptions, sources, vintages, and type used in the Historic Fires and Treatments tab of the Fireshed Registry. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Largest historical fire perimeters (up to 10)	Largest historical fires overlapping the fireshed	MTBS Data Access (2020)	2017	Tabular
Historical area treated with prescribed fire	Prescribed fire treatments completed within the fireshed	MTBS Data Access (2020), LANDFIRE (2014), FACTS (USDA Forest Service 2020)	MTBS: 2010–2017; LANDFIRE: 2010–2014; FACTS: 2010–2019	Tabular
Historical area treated with thinning/harvesting	Mechanical fuel treatments completed within the fireshed	LANDFIRE (2014), FACTS (USDA Forest Service 2020)	LANDFIRE: 2010–2014; FACTS: 2010–2019	Tabular
Historical area treated with mastication treatments	Mastication treatments completed within the fireshed	LANDFIRE (2014), FACTS (USDA Forest Service 2020)	LANDFIRE: 2010–2014; FACTS: 2010–2019	Tabular
Historical area burned by wildfire	Cumulative total area burned within the fireshed	Short (2017)	2010–2015	Tabular
Non-burnable	Acres of non-burnable landscape within the fireshed	National Land Cover Dataset (NLCD)(USGS 2011)	2016	Tabular

Table A4—Tabular and chart data descriptions, sources, vintages, and type used in the Simulated Fires tab of the Fireshed Registry. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Worst simulated fires intersecting the selected fireshed	Among the worst five simulated fires for each fireshed (in terms of building exposure), those that intersect the selected fireshed	FSim (Short et al. 2020); MS footprints (Microsoft 2018)	FSim: LF2014b; MS footprints: 2015	Tabular
Affected communities	Communities affected by simulated fires ignited in the fireshed, average and maximum buildings exposed	FSim (Short et al. 2020); MS footprints (Microsoft 2018)	FSim: LF2014b; MS footprints: 2015	Tabular

Table A5—Tabular and chart data descriptions, sources, vintages, and type used in the Planned/Proposed Treatments tab of the Fireshed Registry and prioritization process listed by dashboard tab. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Total fireshed area	Total area within fireshed	Evers et al. (2020)	2020	Tabular
Number of potential projects	Total number of projects within fireshed	Evers et al. (2020)	2020	Tabular
Building exposure per year	Total potential building exposure from fires ignited within the fireshed	FSim (Short et al. 2020); MS footprints (Microsoft 2018)	FSim: LF2014b; MS footprints: 2015	Tabular
Area treated	Total area treated (acres) in current treatment scenario	Ager et al., in review	2020	Tabular
Number of projects	Number of projects implemented in current treatment scenario	Ager et al., in review	2020	Tabular
Reduction in structure exposure posttreatment	Exposure treated in current treatment scenario	Ager et al., in review	2020	Tabular
Portion of fireshed treated	Proportion of the total area of the fireshed treated	Ager et al., in review	2020	Tabular
Harvest volume	Potential merchantable timber volume from treatments (MBF)	FIA imputed tree list data 2014 (Riley et al. 2016)	2017; data do not account for recent disturbances or forested stands. No data available for East.	Tabular
Project area treatments	Project-specific information from current treatment scenario implementation (Project Area total acres; acres treated; reduction in building exposure; treated volume)	Ager et al., in review	2020	Tabular

Table A6—Tabular and chart data descriptions, sources, vintages, and type used in the Communities tab of the Fireshed Registry and prioritization process listed by dashboard tab. See table 1 for spatial data.

Variable	Description	Source	Data vintage	Type
Community name	Community name where community is defined as the U.S. Census populated place and associated WUI within a 45-minute drive time	U.S. Census Bureau (2016); SILVIS Lab (2012)	2018; 2010	Tabular
Community area	Total area of community (acres)	U.S. Census Bureau (2016); SILVIS Lab (2012)	2018; 2010	Tabular
Number of buildings	Number of buildings within the community	MS building footprints (Microsoft 2018)	2015	Tabular
Acres burned	Average annual acres burned within the community	U.S. Census Bureau (2016); FSim (Short et al. 2020); SILVIS Lab (2012)	U.S. Census: 2018; FSim: LF2014b; WUI: 2010	Tabular
Buildings exposed	Average annual building exposure within the community	U.S. Census Bureau (2016); FSim (Short et al. 2020); MS footprint (Microsoft 2018)	U.S. Census: 2018; FSim: LF2014b FSim; MS building footprints: 2015	Tabular
Percent fuel type	Percentage of fireshed within major fuel types	LANDFIRE (2017)	2014	Graph
Percent ownership	Percentage of community within major ownership classes	Protected Areas Database (USGS 2016, 2019)	Western U.S.–2016; Eastern U.S.–2019	Graph
Top five worst simulated fires: building exposure	Top five worst simulated fires based on buildings exposed within the community	FSim (Short et al. 2020); MS footprint (Microsoft 2018)	FSim: LF2014b MS building footprints: 2015	Tabular
Top five worst simulated fires: area burned	Area burned for the top five worst simulated fires based on buildings exposed within the community	FSim (Short et al. 2020); MS footprint (Microsoft 2018)	FSim: LF2014b MS building footprints: 2015	Tabular

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Appendix B. Top 10 Firesheds by Forest Service Region

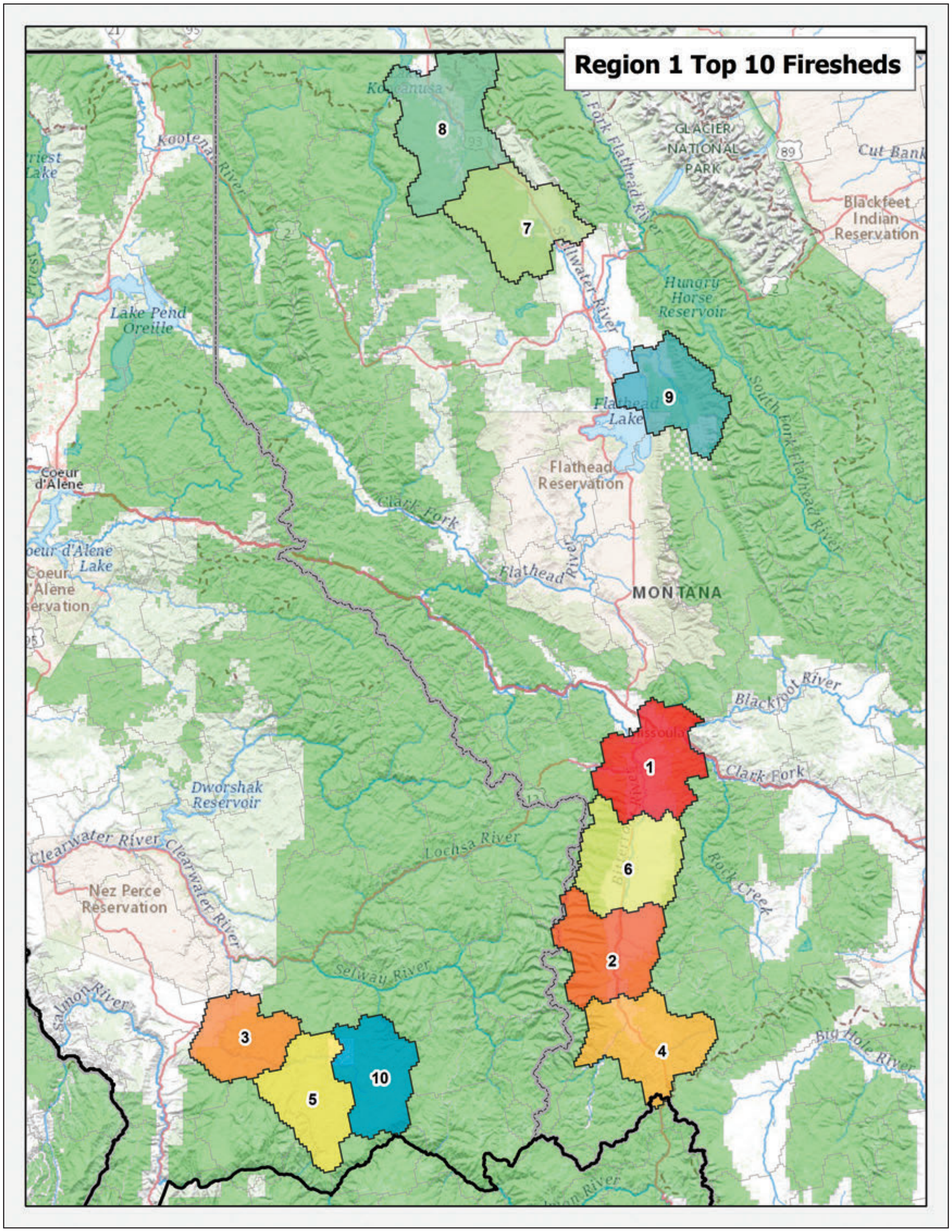

Figure B1—The top 10 firesheds in Forest Service Region 1 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

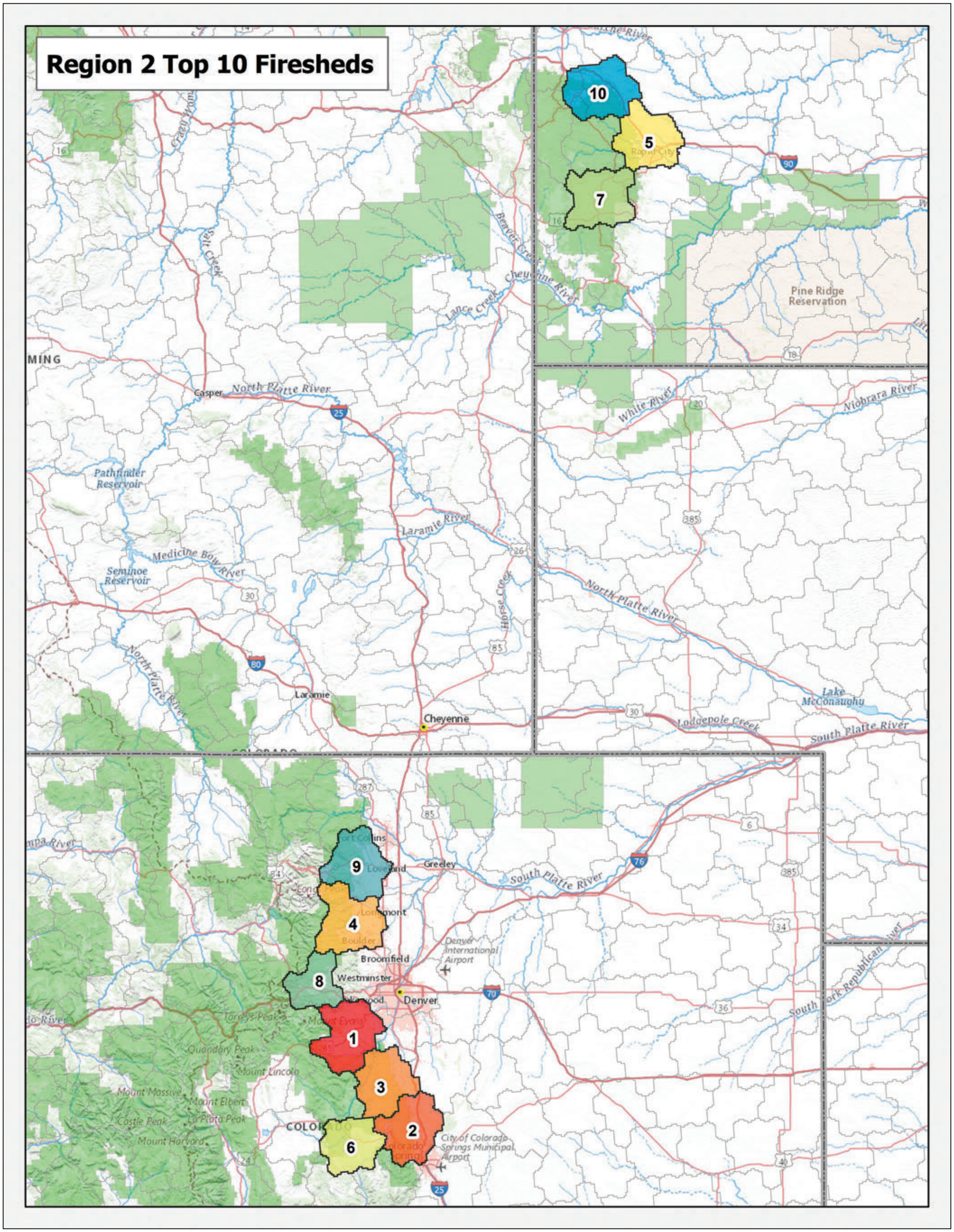

Figure B2—The top 10 firesheds in Forest Service Region 2 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

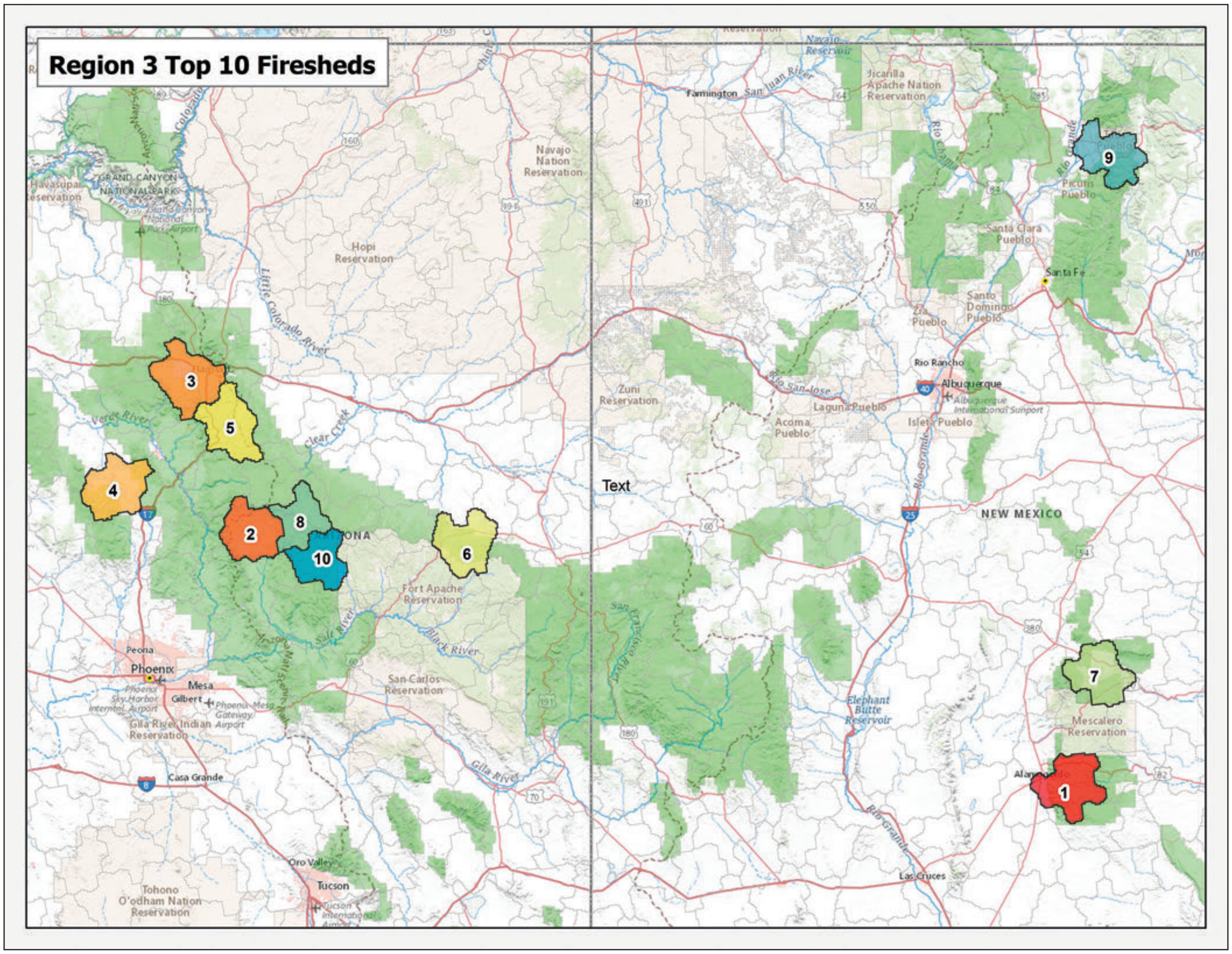

Figure B3—The top 10 firesheds in Forest Service Region 3 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

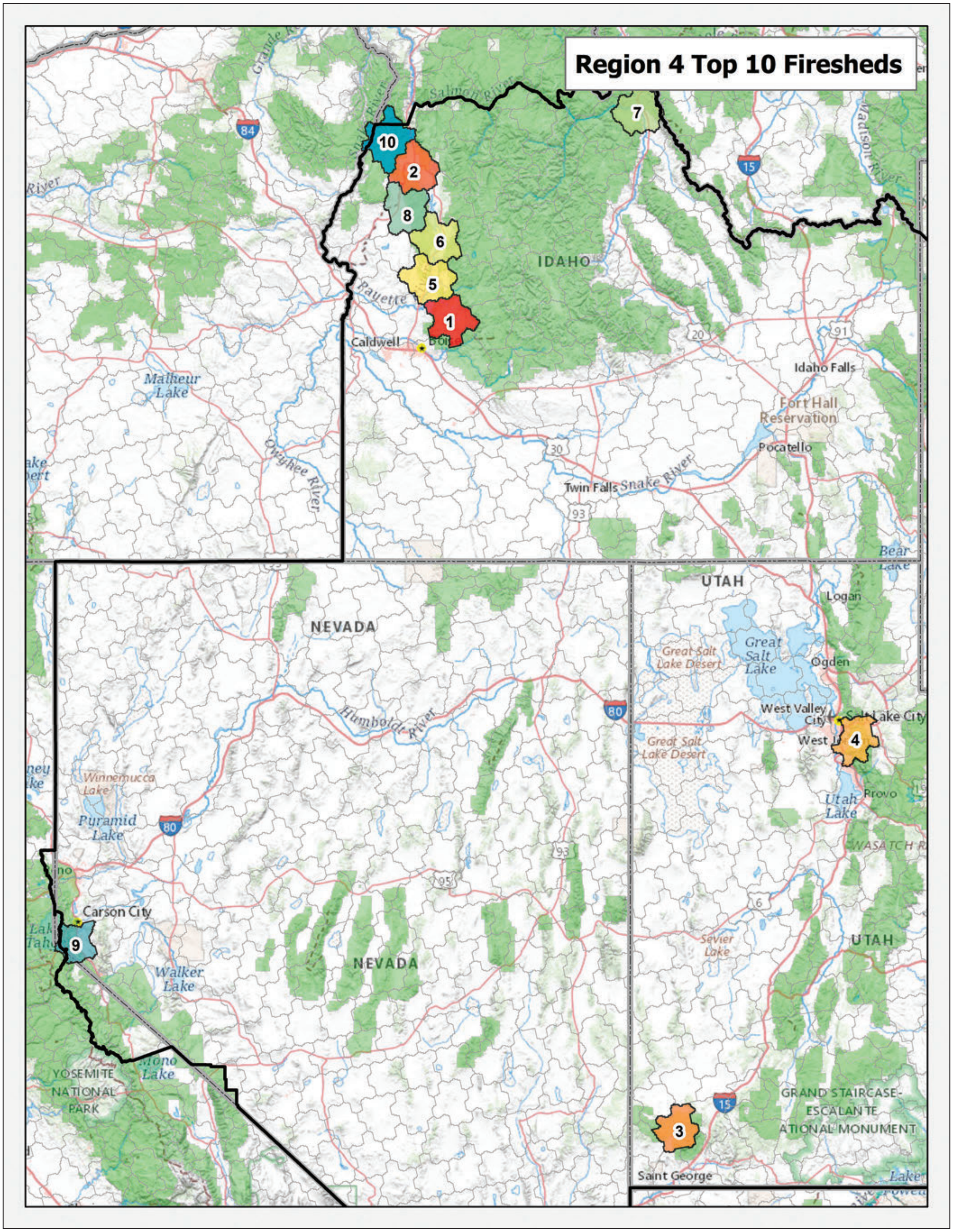

Figure B4—The top 10 firesheds in Forest Service Region 4 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

Figure B5—The top 10 firesheds in Forest Service Region 5 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

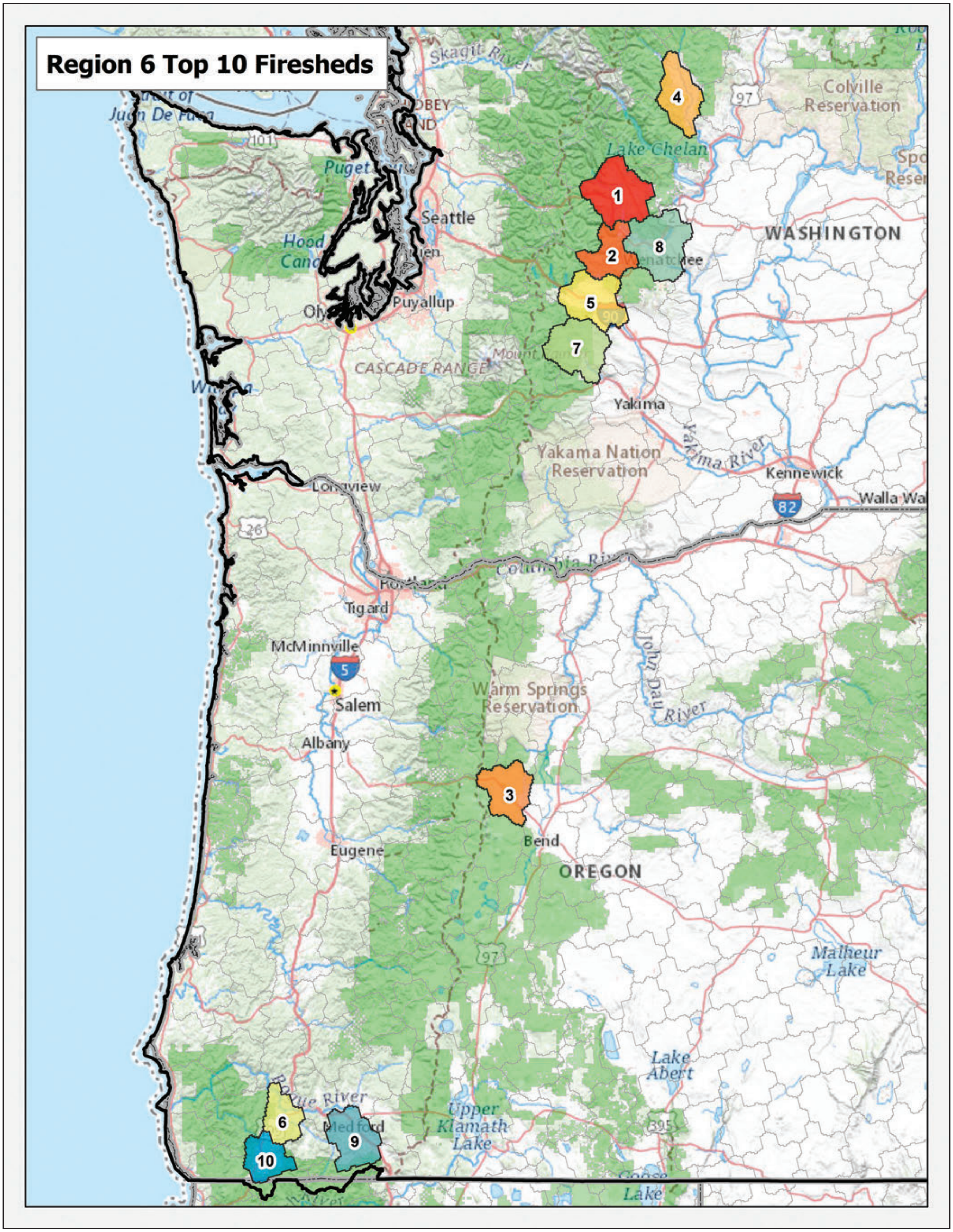

Figure B6—The top 10 firesheds in Forest Service Region 6 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

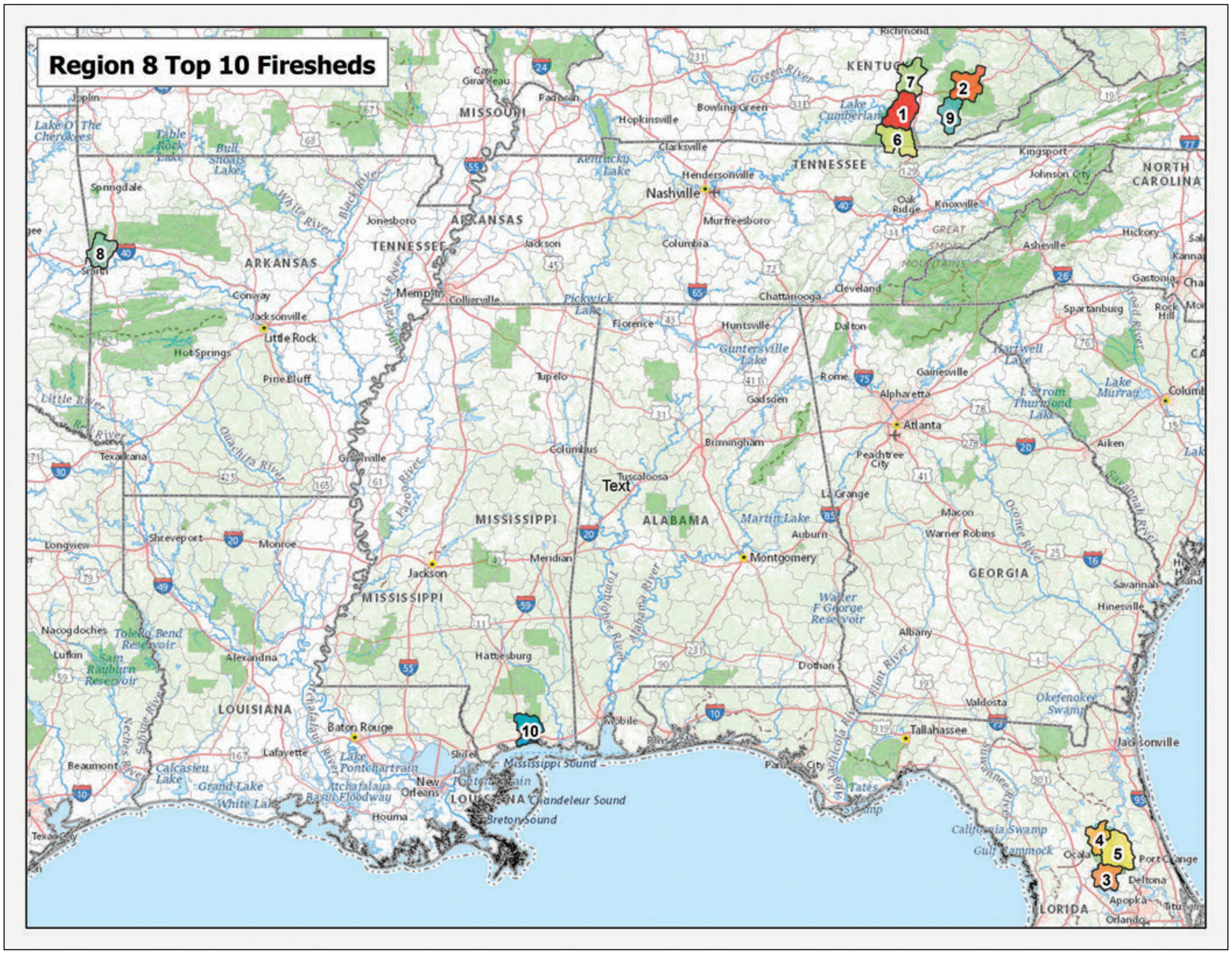

Figure B7—The top 10 firesheds in Forest Service Region 8 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

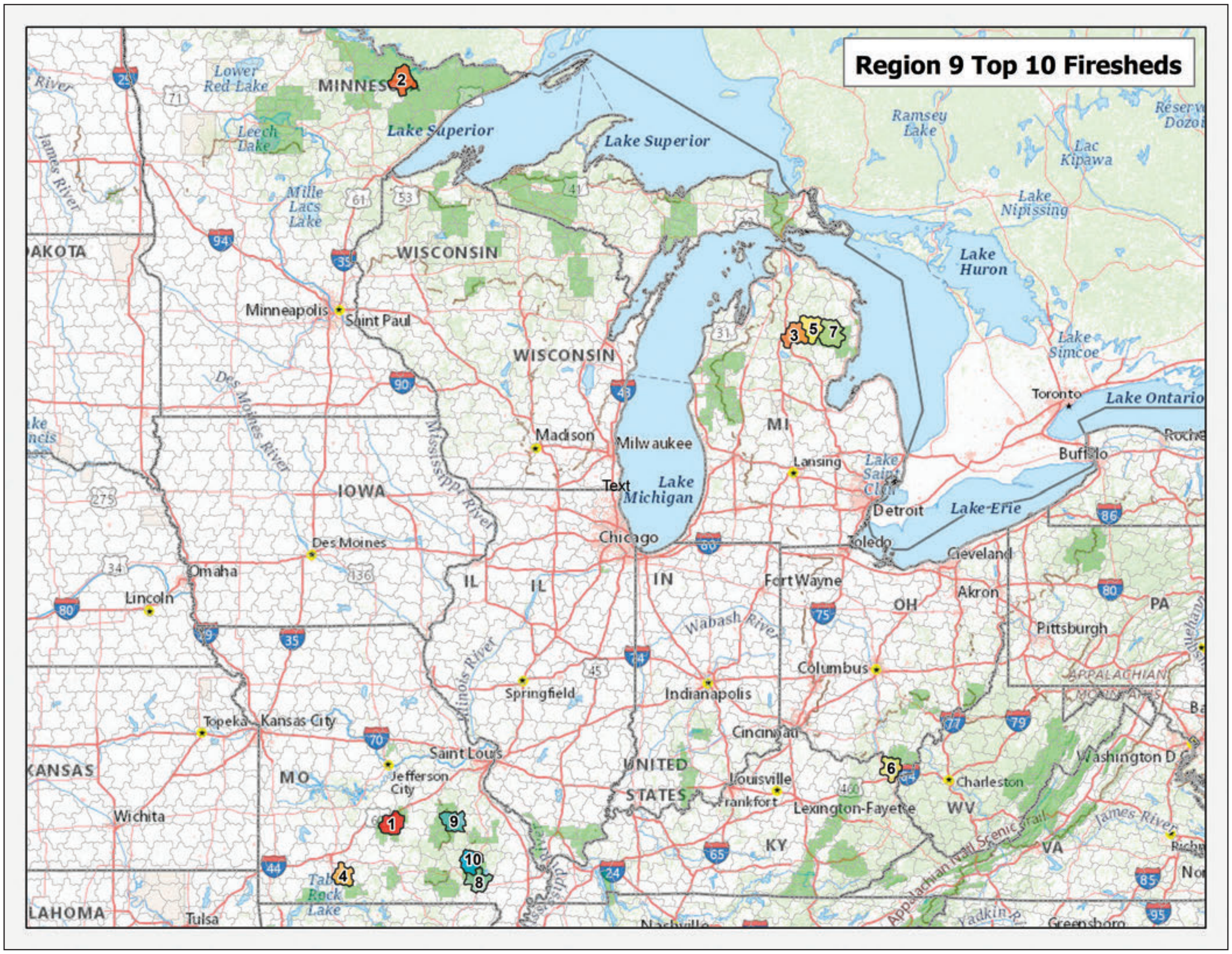

Figure B8—The top 10 firesheds in Forest Service Region 9 identified for a multiyear national investment strategy to target fuel management funding to reduce risk to developed areas (table 2). Firesheds were identified based on wildfires igniting on forested national forest land available for mechanical treatments (e.g., excludes wilderness) and exposing buildings in adjacent communities.

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