



**NAVAL
POSTGRADUATE
SCHOOL**

MONTEREY, CALIFORNIA

THESIS

**AMERICA WILDLAND-URBAN INTERFACE
BURNING: A MODERN APPLICATION OF A
HISTORIC SUCCESS**

by

Erik Litzenberg

March 2020

Co-Advisors:

Jeffrey E. Kline

Lauren S. Fernandez (contractor)

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE March 2020	3. REPORT TYPE AND DATES COVERED Master's thesis	
4. TITLE AND SUBTITLE AMERICA WILDLAND–URBAN INTERFACE BURNING: A MODERN APPLICATION OF A HISTORIC SUCCESS			5. FUNDING NUMBERS	
6. AUTHOR(S) Erik Litzenberg				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) In 2018, the Camp fire, a conflagration in the wildland–urban interface (WUI), destroyed Paradise, California, killing nearly 90 residents. Reports of the disaster focused on risk reduction in the structural or wildland environments; a comprehensive, collaborative look at the WUI, where the built environment and wildland or “outdoors” meet, has yet to be produced. In the 1970s, statistics on the number of fires and on persons killed or injured in fires, showed alarming growth, and in 1973 a report (America Burning) was ordered by Congress to present ways of reversing these trends. Subsequent core documents guided federal response and preparedness in general, but fires in the WUI zone were little discussed. This research makes policy recommendations for the WUI as a domain characterized by unique circumstances that require tailored plans. Data is analyzed through a strategic framework developed by the military to assess operational environments. The commissioning of an updated national report that reflects contemporary developments in firefighting, community awareness, and technologies is urged, and specific policies are recommended for implementation.				
14. SUBJECT TERMS wildland-urban interface, community risk reduction, firefighting, wildland, cohesive strategy, America Burning, America Burning Revisited, America Burning Recommissioned, national fire plan, fire adapted communities			15. NUMBER OF PAGES 103	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

**AMERICA WILDLAND–URBAN INTERFACE BURNING:
A MODERN APPLICATION OF A HISTORIC SUCCESS**

Erik Litzenberg
Fire Chief, Santa Fe County
BA, University of Colorado at Boulder, 1994
MPA, University of New Mexico, 2007

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
March 2020**

Approved by: Jeffrey E. Kline
Co-Advisor

Lauren S. Fernandez
Co-Advisor

Erik J. Dahl
Associate Professor, Department of National Security Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

In 2018, the Camp fire, a conflagration in the wildland–urban interface (WUI), destroyed Paradise, California, killing nearly 90 residents. Reports of the disaster focused on risk reduction in the structural or wildland environments; a comprehensive, collaborative look at the WUI, where the built environment and wildland or “outdoors” meet, has yet to be produced. In the 1970s, statistics on the number of fires and on persons killed or injured in fires, showed alarming growth, and in 1973 a report (America Burning) was ordered by Congress to present ways of reversing these trends. Subsequent core documents guided federal response and preparedness in general, but fires in the WUI zone were little discussed. This research makes policy recommendations for the WUI as a domain characterized by unique circumstances that require tailored plans. Data is analyzed through a strategic framework developed by the military to assess operational environments. The commissioning of an updated national report that reflects contemporary developments in firefighting, community awareness, and technologies is urged, and specific policies are recommended for implementation.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	THE PROBLEM.....	1
B.	OBJECTIVE AND APPROACH	4
1.	Research Question	4
2.	Research Design	4
II.	THE CORE DOCUMENTS.....	7
A.	AMERICA BURNING	7
1.	Content and Findings	8
2.	The Collaborative Process.....	8
B.	AMERICA BURNING REVISITED	9
1.	Content and Findings	9
2.	The Collaborative Process.....	11
C.	AMERICA AT RISK: AMERICA BURNING RECOMMISSIONED	11
1.	Content and Findings	11
2.	The Collaborative Process.....	12
D.	THE NATIONAL FIRE PLAN	12
1.	Content and Findings	13
2.	The Collaborative Process.....	15
E.	THE COHESIVE STRATEGY	15
1.	Content and Findings	16
2.	The Collaborative Process.....	18
III.	RECOGNIZING THE WUI	21
A.	THE WUI DEFINED.....	21
B.	THE THREAT	22
C.	A CALL TO ACTION.....	26
1.	The Nation’s Fire Problem.....	27
2.	Victims	30
3.	Evacuation	30
D.	THE FIRE SERVICES.....	36
1.	Firefighter Casualties	37
2.	Factors in Effectiveness	38
E.	BUILT VS. WILDLAND EFFORTS	39
F.	FIRE PREVENTION	40
1.	Mitigation.....	41

2.	Structural Preparation	43
G.	PROGRAMS FOR THE FUTURE	43
1.	Data Collection and Application.....	44
2.	Community Wildfire-Protection Plans	45
3.	Fire-Adapted Communities.....	48
4.	Situational Awareness	50
IV.	ANALYSIS: THE POESII-PT STRATEGIC FRAMEWORK	53
A.	THE PMESII-PT ANALYSIS TOOL.....	53
1.	POESII-PT: Political Factors	55
2.	POESII-PT: Organizational Factors.....	56
3.	POESII-PT: Economics.....	58
4.	POESII-PT: Social Factors	59
5.	POESII-PT: Information	60
6.	POESII-PT: Infrastructure.....	62
7.	POESII-PT: The Physical Environment.....	64
8.	POESII-PT: Time	65
V.	FINDINGS AND CONCLUSIONS	67
A.	A REPORT FOR THE WUI.....	67
B.	NINE RECOMMENDATIONS.....	68
C.	DISCUSSION	73
D.	LIMITATIONS	75
E.	FUTURE RESEARCH.....	76
	LIST OF REFERENCES	77
	INITIAL DISTRIBUTION LIST	85

LIST OF TABLES

Table 1. Hazard Ignition Zones.....50

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CPAT	candidate physical-ability test
CS	<i>National Cohesive Wildland Fire Management Strategy</i>
CSOC	Cohesive Strategy Oversight Committee
CWPP	community wildfire-protection plan
DMC	data-management committee
DOD	Department of Defense
DOI	Department of the Interior
EMS	emergency medical services
EPA	Environmental Protection Agency
FAC	fire-adapted community
FEMA	Federal Emergency Management Agency
FLAME	Federal Land Assistance, Management, and Enhancement
FSRS	fire-suppression rating system
FWS	Fish and Wildlife Service
GDP	gross domestic product
GIS	geographic information system
GPS	Global Positioning System
HIZ	home ignition zone
HOA	homeowners association
IAFC	International Association of Fire Chiefs
ICS	incident command system
IRWIN	integrated reporting of wildland fire information
ISO	Insurance Services Office
NASF	National Association of State Foresters
NFIRS	National Fire-Incident Reporting System
NIFC	National Interagency Fire Center
NIMS	National Incident-Management System
NIST	National Institute for Standards and Technology

NPS	National Park Service
NWCG	national wildfire coordinating group
NWS	National Weather Service
OE	operational environment
PMESII-PT	political, military, economic, social, information, infrastructure, physical environment, and time
POESII-PT	political, organizations, economic, social, information, infrastructure, physical environment, and time
<i>QFR</i>	<i>Quadrennial Fire Review</i>
RPL	recognition of prior learning
RS	remote sensing
RSC	regional strategy committee
SA	situational awareness
SDLE	stay and defend or leave early
SE	strategic environment
TNC	The Nature Conservancy
USDA	United States Department of Agriculture
USFA	United States Fire Administration
WFI	Wellness Fitness Initiative
WFIT	wildland fire information and technology
WUI	wildland–urban interface
WFEC	Wildland Fire Executive Committee
WFLC	Wildland Fire Leadership Council

EXECUTIVE SUMMARY

As America’s population and metropolitan areas grew in the 1970s, national statistics showed a rapid increase in “outdoor” or “wildland” fires and death or injury by fire. A 1973 report by the National Commission on Fire Prevention and Control, *America Burning*, formulated ideas for combating fire-related trends, primarily in the built environment,¹ providing guidelines for government at all levels to combat property loss and casualties. Follow-up reports—*America Burning Revisited*, in the 1980s, and *America at Risk: America Burning Re commissioned*, in the early 2000s²—expanded on the original by encouraging comprehensive building codes and standards, public education, and prevention. A subsequent reduction in civilian deaths, to 2,855 in 2012, was cited in a 2017 United States Fire Administration report.³

These reports mainly concerned building fires; yet since the start of fire-data collection, outdoor fires have constituted approximately half of reported calls, and the number of injuries and deaths in these fires has grown, even as incidents in the built environment declined. Recognizing these trends, Congress commissioned a report, the *National Cohesive Wildland Fire Management Strategy (CS)*, issued in 2010, to update a report that had guided federal response and preparedness for a decade, the *National Fire Plan*.

Wildland fires (also known as outdoor, brush, tree, or bush fires)⁴ are especially critical at the wildland–urban interface (WUI), where the built environment mingles with

¹ National Commission on Fire Prevention and Control, *America Burning* (Washington, DC: National Commission on Fire Prevention and Control, 1973), III, <https://www.usfa.fema.gov/downloads/pdf/publications/fa-264.pdf>.

² Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited* (Washington, DC: Government Printing Office, 1990), <https://www.hSDL.org/?view&did=446407>; Federal Emergency Management Agency, *America at Risk - America Burning Re commissioned* (Washington, DC: Government Printing Office, 2002), <https://www.hSDL.org/?abstract&did=745307>.

³ U.S. Fire Administration, *Fire in the United States: 2006–2015*, 19th ed. (Washington, DC: Federal Emergency Management Agency, 2017), 12, <https://www.hSDL.org/?view&did=806524>.

⁴ International Association of Fire Chiefs, *Wildland–Urban Interface: Chief’s Guide* (Chantilly, VA: International Association of Fire Chiefs, 2018), 3, <https://www.iafc.org/topics-and-tools/resources/resource/WuiChiefsGuide>.

natural land.⁵ As communities press into open space, the WUI continues to expand. One need not look far to learn what catastrophe this environment may bring. In 2018, the Mendocino Complex fire was the biggest in California history, at 459,123 acres; the Carr fire was the eighth most destructive in the state, with eight deaths, insurance losses of \$1.5 billion, and 1,600 structures destroyed; and the Camp fire obliterated a town and killed 88 residents.⁶

Despite a wealth of available data and reports focused on either the wildland environment or the built environment with the WUI as an afterthought, a comprehensive, collaborative look at the WUI as a unique problem requiring a dedicated plan has been lacking. The time has come to emulate the successful focus of *America Burning* and collaborative approach of the *CS* where the built and natural environments meet.

This research recommends policies for managing the WUI, reviews foundational strategic documents, and identifies a framework for a comprehensive new report on the WUI. A literature review is conducted to inform policy recommendations for preparedness, mitigation, response, and recovery in the WUI. Recommendations for future research are included.

This study urges that a comprehensive report be issued in which the WUI is treated as a distinct and clearly defined area requiring independent consideration. This report must be the product of a formal commission, with cooperative buy-in among agencies and stakeholders. It should begin with a specific, agreed-upon definition of the WUI; its scope should include emerging issues such as the effects of utility shutdowns on fire response and the uses of sensor and data-gathering technologies in promoting situational awareness. The remaining policy recommendations of this research fall into nine categories: risk management, emerging technology, evacuation and return, workforce issues and safety, community planning, data, communication, economic impacts, and forest health.

⁵ V. C. Radeloff et al., “The Wildland–Urban Interface in the United States,” *Ecological Applications* 15, no. 3 (June 2005): 799–805, <https://doi.org/10.1890/04-1413>.

⁶ “Facts + Statistics: Wildfires” Insurance Information Institute, accessed September 6, 2019 from <https://www.iii.org/fact-statistic/facts-statistics-wildfires>.

ACKNOWLEDGEMENTS

I am extremely appreciative of the understanding and support from my wife and kids—this journey could not have been completed without them. I am also grateful to my extended family, teammates and co-workers, and the team at CHDS, for being understanding of my crazy life. This thesis is the product of an incredible team effort.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. THE PROBLEM

As America's population and cities grew in the 1970s, the number of fires and deaths and injuries by fire were also rapidly growing. The National Commission on Fire Prevention and Control was created to formulate ideas to combat fire-related trends in the United States, which included skyrocketing property loss and casualties. The commission's report to Congress, *America Burning*, estimated that fires cost the United States \$11 billion in resources, 6,200 lives, and tens of thousands of injuries each year.¹ The report provided guidelines for efforts at all levels of government to reduce these disturbing statistics and presented technical, organizational, and social recommendations for reducing losses, mainly from structural fires. The report emphasized fire prevention, better training and education in the fire services, improved public fire-safety education, better design, materials, and protective features in buildings, and increased applied research.² Follow-up publications—*America Burning Revisited (1980)* and *America at Risk: America Burning Re commissioned (2000)*³—confirmed the findings and importance of the initial report.

Approximately fifteen years after *America Burning*, a group of cross-disciplinary professionals reexamined the national fire problem and issued a follow-up report in 1990. In the interim, annual averages for civilian and firefighter deaths had decreased slightly. Death by clothing fire had fallen drastically, and stricter mattress and furniture standards had reduced casualties, while fires from smoking grew as a percentage of total fires. Fire loss in dollars had risen, but at a moderate rate.⁴ *America Burning Revisited* and *America at Risk: America Burning Re commissioned* contributed to the positive changes, repeating *America Burning's* call for better codes, standards, and public education. A 2017 United

¹ National Commission on Fire Prevention and Control, *America Burning*, III.

² National Commission on Fire Prevention and Control, X–XI.

³ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 1 ; Federal Emergency Management Agency, *America at Risk—America Burning Re commissioned* (Washington, DC: Government Printing Office, 2002), <https://www.hsdl.org/?abstract&did=745307>, 7.

⁴ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 8–12.

States Fire Administration report estimated that civilian deaths reached a low in 2012 (2,855),⁵ and the trends for fires per million and dollar loss per capita were both down.⁶

While these reports provided effective guidance in reducing deaths, their focus was mostly building fires. Relatively unaddressed were outdoor fires, a source of destruction that had constituted about half of reported calls since fire-data collection began and was increasing in number annually. While the value of property losses in outdoor fires showed a slight decrease between 2006 and 2015, injuries and deaths showed a slight increase.⁷ Massive outdoor fires may be outliers, but they exact staggering costs. The Valley and Butte fires in California, for example, cost almost \$2 billion in fire loss alone, or fourteen percent of the total loss reported for 2015. By contrast, all other outdoor fires combined equaled two percent of total loss that year.⁸ The “October fire siege” of 2017 racked up \$10 billion in damages, and the Hill and Woolsey fires of 2018, an estimated \$5 billion.⁹ Recent National Interagency Fire Center reports have shown decreases in the number of outdoor fires per year, from approximately 80,000 in 1985 to 60,000 in 2018. During that period, however, the number of acres burned increased from three to eight million per year and total federal costs rose from \$240 million to over \$3 billion per year.¹⁰ There has been a noticeable uptick in high-dollar-loss fires and those burning over 100,000 acres—more of these fires occur per year, on average.¹¹

In response to these trends, Congress commissioned a study group in 2009, which in 2010 returned a report, the *National Cohesive Wildland Fire Management Strategy (CS)*.

⁵ U.S. Fire Administration, *Fire in the United States: 2006–2015*, 12.

⁶ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 1–2.

⁷ U.S. Fire Administration, *Fire in the United States: 2006–2015*, 65–66.

⁸ Marty Ahrens, *Trends and Patterns of U.S. Fire Loss* (Quincy, MA: National Fire Protection Association, 2017), 12, <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osTrends.pdf>.

⁹ Insurance Information Institute, “Facts + Statistics: Wildfires.”

¹⁰ National Interagency Fire Center, “Federal Firefighting Costs (Suppression Only)” (Boise, ID: National Interagency Fire Center, 2018), https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf.

¹¹ National Interagency Fire Center, “Wildfires Larger Than 100,000 Acres,” National Interagency Fire Center, accessed July 6, 2019, https://www.nifc.gov/fireInfo/fireInfo_stats_lgFires.html.

A follow-up to the *National Fire Plan* (2010), the *CS* was a collaborative work of the Department of the Interior (DOI), Department of Agriculture (USDA), National Association of State Foresters (NASF), and International Association of Fire Chiefs (IAFC), among other entities.

Wildland fires (also known as outdoor, brush, tree, or bush fires)¹² are especially critical at the wildland–urban interface (WUI), where the built environment mingles with natural land.¹³ The authors of the *CS* recognized that wildland fire is an issue not only of operations, fire management, and protecting the WUI, but also of land management and socioeconomics. The report identifies three areas of focus: “1) restoring and maintaining resilient landscapes, 2) creating fire-adapted communities, and 3) responding to wildfires.”¹⁴

As communities continue to press into the rural environment, the WUI continues to expand. Between 1990 and 2010, the number of dwellings in the WUI grew by 41 percent, and the land mass considered WUI increased by 33 percent.¹⁵ This was the fastest-growing land type in the decade—and the trend continues.

In 2018 alone, the Mendocino Complex fire was the biggest in California history, at 459,123 acres; the Carr fire was the eighth most destructive in the state, with eight deaths, insurance losses of \$1.5 billion, and 1,600 structures destroyed; and the devastating Camp fire killed 88 residents.¹⁶

Despite a wealth of available data and reports focused on either the wildland environment or the built environment, with a subsection on the WUI, a comprehensive, collaborative look at the WUI as a unique problem requiring a dedicated plan has been lacking.

¹² International Association of Fire Chiefs, *Wildland–Urban Interface: Chief’s Guide*, 3.

¹³ V. C. Radeloff et al., “The Wildland–Urban Interface in the United States,” 799–805.

¹⁴ Wildland Fire Leadership Council, *A National Cohesive Wildland Fire Management Strategy* (Washington, DC: Department of the Interior and Department of Agriculture, 2011), 12–14.

¹⁵ Volker C. Radeloff et al., “The 1990–2010 Wildland–Urban Interface of the Conterminous United States: Geospatial Data” (Washington, DC: U.S. Forest Service, 2015), 12, <https://doi.org/10.2737/RDS-2015-0012-2>.

¹⁶ Insurance Information Institute, “Facts + Statistics: Wildfires.”

The time has come to combine the successful focus of *America Burning* and its sequels with the collaborative approach of the *CS* to mitigate fire risk where the built and natural environments meet. The WUI is a unique but little-studied zone, with the burning characteristics of a wildland and the human and infrastructure vulnerability of a built environment. The devastation of WUI fires and their toll on the nation's resources and communities make them a significant homeland-security concern.

B. OBJECTIVE AND APPROACH

The objective of this research is to recommend national and local policy on the WUI.

1. Research Question

This research investigate the following question: What policy recommendations can be made to mitigate fire risk in the wildland–urban interface?

2. Research Design

This research examines the core national fire-strategy documents and related literature to identify successful fire prevention and response and concepts that can be applied to future efforts. *America Burning*, *America Burning Revisited*, *America at Risk: America Burning Recommissioned*, the *National Fire Plan*, and the *CS* are reviewed with an eye toward planning processes, implementation, metrics, collaborations, and strategic implications.

Literature related to the U.S. WUI was examined to evaluate the problem, review the efficacy of collaborations, and provide a range of possible solutions to the WUI conundrum. Documents that shaped, were cited by, or that resulted from the core documents are included, especially those that regard the WUI as a distinctive environment requiring separate treatment.

Data obtained from the literature review was synthesized to support a new focus—the WUI—and applied to the PMESII-PT (political, military, economic, social, information, infrastructure, physical environment, and time) analysis framework, which is

used for the strategic analysis of wartime and military-conflict operational environments. This framework was adapted as “POESII-PT” by swapping in “organizational” for the “military” element. Data and strategies are applied to this framework to identify areas for prevention, mitigation, and emergency response and to generate insights for policy- and decision making at all levels. Recommendations for practical actions and follow-up research conclude the thesis.

THIS PAGE INTENTIONALLY LEFT BLANK

II. THE CORE DOCUMENTS

Of the five national fire-response planning documents—*America Burning*, *America Burning Revisited*, *America at Risk: America Burning Recommissioned*, the *National Fire Plan*, and the *CS*, only the latter two consider the WUI in detail. This chapter summarizes these reports.

A. AMERICA BURNING

America Burning was presented to President Richard Nixon in 1973 as the culmination of two years' work by the National Commission on Fire Prevention in Control. The commission consisted of the secretary of commerce, the secretary of housing and urban development, and eighteen experts in fire control, prevention, safety, and research. The report provides guidelines for policy making at all levels of government and technical, organizational, and social recommendations for reducing property loss (mainly structural) and casualties. It strongly recommends that fire prevention and control remain primarily the responsibility of local government. Increases in resource allocation and improved codes, laws, and programs, and the use of built-in detection and fire-suppression devices are prescribed. The commission recommended that the federal government offer technical and educational assistance to local firefighting entities, collect and analyze fire data, regulate the flammability of materials for building and manufacturing, conduct fire research, and provide funding. This report led to the creation of the United States Fire Administration (USFA). General recommendations are

- an emphasis on fire prevention;
- better training and education for fire services;
- fire-safety public education;
- preventive design and materials engineering;

- improved fire-protection features in buildings; and
- more applied research.¹⁷

1. Content and Findings

Hundreds of witnesses testified and dozens of experts filed 130 positions papers to frame the fire-related problems and conclusions expressed in *America Burning*. The commission reviewed construction techniques, inspections, and technological advances; government-driven risk reduction in existing housing and planned developments; recruitment, training, suppression, communication, and equipment standards; and the optimal distribution of responsibility among government and private entities.¹⁸ Nevertheless—despite a chapter on forest and grassland protection, in which it is observed that, of the two billion acres constituting the United States, more than half are forest and grasslands, a quarter farmlands and small wooded lots, and the remainder cities and infrastructure—there is no recognition of the WUI zone.

2. The Collaborative Process

The twenty-member National Commission on Fire Prevention and Control included federal, state, and local representatives, academics, and interested trades and industry. The commission had four bipartisan advisory members, two each from the House and Senate. The duties of the commission were to investigate the fire problem, evaluate measures for reducing destruction, and report to the president and Congress.¹⁹ The report was informed by expert testimony, representing a variety of sectors and organizations, including the fire services, that was received in hearings over a total of seven days, beginning in February 1972.²⁰

¹⁷ National Commission on Fire Prevention and Control, *America Burning*, 10–11.

¹⁸ National Commission on Fire Prevention and Control, *America Burning*, 4–9.

¹⁹ National Commission on Fire Prevention and Control, *America Burning*, 160–162.

²⁰ National Commission on Fire Prevention and Control, *America Burning*, 163–165.

B. AMERICA BURNING REVISITED

America Burning Revisited was released in 1987 following a three-day workshop on the state of the fire problem since the founding report fourteen years before. The workshop was convened by the USFA and the Federal Emergency Management Agency (FEMA), and attended by original participants, Congressmen, and interested organizations. The group sought consensus on the nature of the problem, discussed *America Burning* in retrospect, and recommended further ways to reduce losses. Participants proposed no major changes to programs and organizations, but identified changes in the environment and the responsibilities assumed by the fire services. They noted increasing risk to firefighter health and safety and a greater need for public education and awareness.²¹

The general purpose of *America Burning Revisited* was to

- evaluate the progress made in achieving the report's original goals;
- revise past recommendations;
- provide new guidelines for the government and private sectors, based on environmental and societal changes; and
- reach consensus on the status of the U.S. fire problem.

The workshop was organized into task groups for fire-services operations, management, and administration; fire and the built environment; fire and rural wildlands; prevention; and preparations for the 21st century.²²

1. Content and Findings

America Burning Revisited reports that fire loss and incidents had generally declined since *American Burning* and fire departments were handling greater call complexity, volume, and variety. Changes in Fair Labor Standards Act regulations were a

²¹ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 1.

²² Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 3–6.

new concern. The NFA and USFA had been operating fifteen years, as had the Center for Fire Research, the precursor of the National Institute for Standards and Technology (NIST). Many federal organizations had improved their fire-safety education, and protective systems, codes, and standards had been improved. The increased use of exotic materials had worsened the release of toxic smoke and gases in fires, and attention to firefighter health had improved.²³ The report did not address the WUI at any depth.

Annual fire-death averages had fallen by 23 percent to 6,200 in 1985, firefighter deaths had decreased slightly, clothing-fire deaths fell 73 percent, and children's clothing-fire deaths decreased 90 percent. Fires from residential smoking continued to grow as a percentage of total cause, and fire losses in dollars continued to rise at a somewhat controlled rate.²⁴

Significant changes in the fire-service profession included less demand for fire suppression and more demand for emergency medical services (EMS), specialized response, and local resources.

America Burning Revisited acknowledges that more structures were being built at the frontiers of human habitation and natural land, but—oddly—claimed that this would reduce the number of wildland acres at risk, observing that firefighters would be forced to choose between protecting wildland or structures. There is no suggestion of resources designed for both. The report notes an increased demand for regional control, to promote efficiency and effectiveness,²⁵ and explores fire as a socioeconomic and political issue.²⁶

²³ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 7.

²⁴ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 8–12.

²⁵ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 12–20.

²⁶ Federal Emergency Management Agency and U.S. Fire Administration, *America Burning Revisited*, 30–32.

2. The Collaborative Process

The public process behind the new document was much shorter than that of its predecessor, consisting of a three-day workshop overseen by the USFA. Its sessions focused on the past, present, and future of *America Burning*, the formation of task forces to study seven issues and issue reports, to be compiled as *America Burning Revisited*.

C. AMERICA AT RISK: AMERICA BURNING RECOMMISSIONED

The third core document—*America at Risk: America Burning Recommissioned*—was begun in 1999 in response to a blue-ribbon-panel report on the USFA that asserted that reductions in fire losses and a new vision for the fire service were required to safeguard evolving communities. The panel’s theme of risk management was reflected in the title of the ensuing report.²⁷ The commission reached two main conclusions: first, fire risk and severity were increasing, in part because known reduction strategies were not funded and applied. Responsibility lay mostly with state and local government, and federal funding and technical support were needed. Second, because fire responders had increasingly become all-risk responders, a thorough look at risks other than urban fires should be made.

1. Content and Findings

America Burning Recommissioned found that the implementation of loss reduction and prevention strategies had been effective in reducing structural-fire risks. Nevertheless, the USFA and other advocacy groups were seen as insufficiently aggressive, and Congress inadequately generous. The committee recommended that Congress fully fund the all-hazard prevention programs in the original report, consistent with the Federal Fire Prevention and Control Act of 1974.²⁸

The commission urged public education, data consolidation, stronger communication among fire professionals and researchers, tougher codes and standards, and national accreditation and certification for training and licensure, among other measures.

²⁷ Federal Emergency Management Agency, *America at Risk: America Burning Recommissioned*, 6.

²⁸ Federal Emergency Management Agency, *America at Risk: America Burning Recommissioned*, 16–17.

The USFA was advised to work with the USFS to evaluate educational efforts, it was noted that these organizations had teamed with the NFPA, DOI, and NASF to create the national Firewise program for communities. The committee supported the Council of State Governments' 1975 program of developing state laws for adoption and recommended that the National Weather Service (NWS) improve fire-support operations for wildland fires.²⁹

2. The Collaborative Process

America at Risk: America Burning Recommissioned began with a blue-ribbon panel organized by the FEMA director in 1998 to evaluate the USFA and recommend ways to implement its goals. The panel advised an update of *America Burning* to reflect changes in the emergency-response world, especially large-scale-disaster response, the emergence of EMS, and the new all-risk range of duties. A diverse commission of governmental and private-industry stakeholders was assembled³⁰ and four two-day meetings were held. Between gatherings, the commission solicited input from stakeholders by mail and online. Besides directing their report to the FEMA director, the commissioners released an initial version in a May 2000 meeting of the congressional fire-service caucus.³¹

D. THE NATIONAL FIRE PLAN

The *Federal Wildland Fire Management Policy and Program Review* (known as the *National Fire Plan*) provides a working definition of the WUI (“the line, area, or zone where structures and other human development meet or intermingle with undeveloped or vegetative fuels”)³² and provides a WUI problem statement: “managing wildland fire in the United States is increasing in complexity and magnitude. Catastrophic wildfire now threatens millions of wildland acres, particularly where vegetation patterns have been

²⁹ Federal Emergency Management Agency, *America at Risk: America Burning Recommissioned*, 44.

³⁰ Federal Emergency Management Agency, *America at Risk: America Burning Recommissioned*, 47–55.

³¹ Federal Emergency Management Agency, *America at Risk: America Burning Recommissioned*, 6–8.

³² US Department of the Interior and US Department of Agriculture, “Federal Wildland Fire Management Policy & Program Review” (Boise, ID, December 18, 1995), https://www.forestsandrangelands.gov/documents/strategy/foundational/1995_fed_wildland_fire_policy_program_report.pdf, 21.

altered by past land-use practices and a century of fire suppression.”³³ The report advocates a policy for all federal responses and unified collaboration. It provides an umbrella policy for federal agencies that accommodates specific agency-related policies.

1. Content and Findings

Key guiding concepts in the *National Fire Plan* include

- recognition of the vital ecological role of fire;
- basing policy on sound modern science and public and environmental health;
- developing applications to deliver tools and knowledge to policymakers;
- promoting a leadership structure for response and research that encourages coordinated action for all stakeholders;³⁴
- standardized policies and procedures among federal partners;
- assignment of responsibility for WUI firefighting, fuel reduction, fire prevention, and technical assistance to federal agencies;
- relegation of structural protection to other governmental agencies; and
- allowances for exterior structural protection where specific contractual agreements are in place.³⁵

The *National Fire Plan* promotes the integration of fire-management practices into land management and community planning, including the reintroduction of fire into

³³ U.S. Department of the Interior and US Department of Agriculture, “Federal Wildland Fire Management Policy & Program Review,” iii.

³⁴ Baldwin V. Jr. Clark, “Accomplishing and Applying National Fire Plan Research and Development from 2001-2005” (Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2007), 42–44, <https://doi.org/10.2737/RMRS-GTR-187>.

³⁵ U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire*, 4–6.

landscapes as a WUI safety measure.³⁶ Federal responsibility for the WUI is argued, because federal lands pose a risk to adjacent communities and community encroachment into wildlands is a widespread national phenomenon. The WUI's emergence as a hotspot is described as taxing resources and budgets at every level, with zoning, codes, legal mandates, firefighting infrastructure, insurance and rating systems, and environmental concerns adding layers of complexity.

Values-at-risk analysis in both preplanning and suppression is presented and protection priorities are ranked as “(1) human life, (2) property, and (3) resource values.”³⁷ Shifting budgets from suppression to pre-positioning of resources is recommended. As a report summarizes, “(t)here is no one simple solution. Leadership and cooperation are essential.”³⁸

Problems explored include passive community attitudes towards fires as an issue for professionals only, ambiguous rules for FEMA funding, and the inability of insurance companies to reimburse catastrophic WUI losses.

Partnerships and cooperation are heavily emphasized in recommendations for fire-protection agreements, funding, and the qualification and training of collaborative responders. The report calls for data-collection mechanisms, to be shared by all agencies, cost-share and granting mechanisms, upgraded fire-hazard and mapping systems, and the formalizing of cooperative relationships and processes.³⁹ New analyses, including economic, legal, risk, data, and logistical, are prescribed.

In other highlights, resource standardization, inventory, and tracking through the National Wildfire Coordinating Group (NWCG) and the NIFC, and the use of the Incident Command System (ICS) to integrate resources on fires is recommended. Budgeting

³⁶ U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire*, 10–12.

³⁷ U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire*, 18.

³⁸ U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire*, 22.

³⁹ U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire*, 25–27.

guidance calls for an increase of over \$1.5 billion dollars for federal resources, with \$897 million and \$682 million more for the USFS and DOI, respectively.⁴⁰

The *National Fire Plan* includes computer modeling of alternatives in post-burn restoration and the economic effects of fuel reduction. A ten-year comprehensive strategy is proposed for wildland fire-management planning, including accountability via reporting and monitoring to prevent misplaced or suboptimal deployment of funding.⁴¹

2. The Collaborative Process

The *National Fire Plan* was less collaborative than its predecessors and decidedly federal in focus. While the steering group comprised members of the USFS, DOI, NWS, Environmental Protection Agency (EPA), and FEMA, the core team hailed solely from the USDA and DOI. Expert teams, primarily from federal agencies,⁴² focused on wildland fire in resource management, the use of wildland fire, preparedness-and-suppression coordinated program management, WUI protections, and public involvement and support. Despite the committee's strong urging of joint action, it was narrowly staffed, which presumably limited its scope and depth.

E. THE COHESIVE STRATEGY

While the *National Fire Plan* focused on wildlands, it paid little attention to the built margins or WUI. The *Cohesive Strategy (CS)* brings these realms together. Written in response to the Federal Land Assistance, Management and Enhancement Act (FLAME), which directed the secretaries of the USDA and DOI to report to Congress on the wildland-fire problem, the report was issued in three phases, beginning with the *National Cohesive*

⁴⁰ Department of Agriculture and Department of the Interior, *Managing the Impact of Wildfires on Communities and the Environment* (Washington, DC: United States Department of Agriculture and Department of the Interior, 2000), 30.

⁴¹ Forests and Rangelands, *Wildland Fire Management: The National Fire Plan (2007 Budget Justification)* (Washington, DC: Department of the Interior and Department of Agriculture, n.d.), 12, https://www.forestsandrangelands.gov/documents/resources/reports/2007/nfp2007_budget_justification.pdf.

⁴² U.S. Department of the Interior and U.S. Department of Agriculture, *Federal Wildland Fire Management Policy & Program Review*, 39–45.

Wildland Fire Management Strategy and progressing to the *Development of Regional Strategies and Assessment* and *National Trade-Off and Execution*.⁴³

The CS acknowledges the pertinent findings of earlier documents, especially the need to integrate science and data and consider social and political factors in the creation of strategy. New emphases include

- early planning in anticipation of national challenges;
- community and individual buy-in on responsibility for effecting fire adaptation and resistance measures through local codes;
- creating resiliency in landscapes compromised by weather changes, fire exclusion, suppression, disease, non-native species, and land-use pressures from development; and
- reconciling disparities among agencies in capabilities, roles, responsibilities, scopes, and missions.⁴⁴

1. Content and Findings

The objectives of the CS are risk reduction, managerial resiliency grounded in experience and science, capacity building, and the devolution of WUI responsibility to individuals and communities, as feasible. Prevention and planning receive cross-jurisdictional treatment featuring accommodation of the disparate missions and goals involved. It is held that aggressive initial attack is often desirable and may be possible through proper planning and agreements, and that investments and programs must be commensurate with the values to be protected.⁴⁵ The CS asserts that the nation must learn to use and “live with wildland fire.”⁴⁶

⁴³ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 2.

⁴⁴ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 2–5.

⁴⁵ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 6.

⁴⁶ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 1.

In Phase I, it is recognized that wildland fire is not just a matter of conflagrations per se, but a land-management and social issue. The report cites climate change, fuel-management problems, expanding WUI zones, and mission change as vexatious factors that require an engaged public, clear roles and responsibilities, and informed assumptions.⁴⁷ While the CS formulates a national strategy, local and regional priorities and needs are integrated as well.

The document's starting point for strategy is a wildfire risk assessment that is based on science, linked to risk maps, geographically and temporally scalable, and useful to policymakers and planners at all levels. Input from regional strategy committees (RSCs) concerning environmental and social values in specific localities, regional and local risks and opportunities, and multi-jurisdictional accomplishments is employed. The strategic exercise was intended to demonstrate a scientific approach to collaborative decision making.⁴⁸

Phase II of the CS evaluates work done by the RSCs in developing a governance structure for their processes, defining their analyses and alternatives, and providing a list of goals and objectives to stakeholders and the national analysis team. Phase III contains a national trade-off analysis, conducted with the regional data provided by the RSCs. The initial results were to be shared with stakeholders and inform further analysis and, ultimately, recommendations for national strategic priorities and alternatives. This process was to be repeated after five years.⁴⁹

The CS grapples with risk management in wildland and WUI fires, but fails to identify solutions commensurate with the scope of the problem. While sound efforts to reduce risk were proceeding nationally, it became clear that only landscape-scale modifications of built-up fuels could reduce the risk of catastrophic loss from WUI infernos. Actions and consequences versus costs and losses are weighed, and improved

⁴⁷ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 2–7.

⁴⁸ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 10–11.

⁴⁹ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 11–12.

simulation and modeling using geospatial data is employed to demonstrate informed-risk decisions and trade-offs.

Four risk-reduction strategies are proposed for WUI loss reduction of loss:

- wildland fire-prevention education, which might lower the number of preventable ignitions by 80 percent, and acres burned by 10 percent;⁵⁰
- investment in fuel-reduction and -management projects (a complex topic for further study);
- increased response capacity to enable safe and rapid initial attack;⁵¹ and
- fire-loss prevention by individuals applying wildfire and risk-reduction techniques on their own properties. This assumption of responsibility would free funding for national parks, cultural and historical centers, and areas of economic value to a community.

2. The Collaborative Process

The 2009 FLAME Act requires a revision of the *CS* every five years. The DOI and USDA have ultimate responsibility for the document, with development assigned to the WFLC's Wildland Fire Executive Council (WFEC), a group of intergovernmental fire-program leaders. Ancillary regional strategy committees (RSCs) representing the Northeast, Southeast, and West provided representation from local and regional experts and stakeholders.⁵²

A cross-jurisdictional *CS* oversight committee (CSOC) was formed to make technical and scientific assessments, set research priorities, collect reports and comments, and formulate goals, options, and trade-offs. CSOC membership included 24 members from local, state, federal, and non-governmental agencies with a cross-section of interests.

⁵⁰ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 21.

⁵¹ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 24.

⁵² Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 9.

The CSOC held fourteen regional forums with about 450 total attendees and received data and comments from 500 individuals.⁵³

The CSOC first created a draft report, which was updated as input was received.⁵⁴ The resulting document was comprehensive and collaborative. The use of RSCs was found successful in regionalizing CS processes and results.

⁵³ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 40.

⁵⁴ Wildland Fire Leadership Council, *Cohesive Wildland Fire Management Strategy*, 40.

THIS PAGE INTENTIONALLY LEFT BLANK

III. RECOGNIZING THE WUI

America Burning and the other core documents rely heavily on statistics and trend analyses derived from contemporary and historical studies, including *Fire in the United States 1986–1995*⁵⁵ and NFPA reports. Combining these hard numbers with an understanding of the WUI as a discrete problem in fire science ultimately revealed the nature of the risk crisis at the frontiers of human development and natural spaces.

A. THE WUI DEFINED

The definition of the WUI has been argued since the term was coined. A common definition is the geographic area where homes and other structures are close to flammable natural fuels.⁵⁶ Some definitions are more specific, adding, for example, that the WUI begins 30 or 600 feet away from a structure.⁵⁷ Some experts see the WUI primarily as a set of conditions, reflecting a fire-management community’s familiarity with specific issues that influence policy.⁵⁸ Others bring a natural-resource perspective, citing a set of conditions in which human interactions affect natural-resource production, health, and management tactics. A sociopolitical perspective may define the WUI as an area in which differing views of management techniques create conflict and agreement; a more-traditional spatial perspective might differentiate between urban sprawl, where suburban areas push into open spaces, and intermix, in which houses are intermittently distributed in an area transitioning from agricultural use. Between these alternatives are open-space

⁵⁵ U.S. Fire Administration, *Fire in the United States: 2006–2015*, 1–2.

⁵⁶ Paul Summerfelt, “The Wildland/Urban Interface: What’s Really at Risk?,” *Fire Management Today* 63, no. 1 (Winter 2003): 4; Susan I. Stewart et al., “Defining the Wildland–Urban Interface,” *Journal of Forestry* 105, no. 4 (June 2007): 202, <https://doi.org/10.1093/jof/105.4.201>; U.S. Fire Administration, *Your Role in Fire-Adapted Communities* (Washington, DC: Federal Emergency Management Agency, 2012), 1, https://www.usfa.fema.gov/downloads/pdf/publications/fire_adapted_communities.pdf; L. Annie Hermansen-Baez, Jennifer Seitz, and Martha C. Monroe, “Wildland Urban Interface: Varied Definitions” (Gainesville, FL: IFAS Extension, University of Florida, July 2009), 1, <https://edis.ifas.ufl.edu/pdf/FR/FR28700.pdf>; International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?,” Ready, Set, Go!, accessed July 17, 2019, <https://www.wildlandfirersg.org/About/Wildland-Urban-Interface>; International Association of Fire Chiefs, *Wildland–Urban Interface*.

⁵⁷ Summerfelt, “The Wildland/Urban Interface: What’s Really at Risk?,” 4.

⁵⁸ Stewart et al., “Defining the Wildland–Urban Interface,” 202.

islands amid urbanized areas and isolated interfaces in remote areas interspersed with structures.⁵⁹

Whichever the definition selected, it is important to frame and limit the area of focus. “Wildland” has many definitions, and wildland fires may involve grass, forest, brush, range, or outdoor fires.⁶⁰ WUI may not be so much a place as a set of conditions that may exist anywhere and that includes the amount, distribution, and type of natural resources; the flammability of structures and their proximity to burnable natural fuels; and weather, climate, and topography, among other factors.⁶¹ As the definition of WUI evolves, there remain three constants: a human presence, flammable wildland vegetation, and a definable distance that represents the potential for interaction to occur.⁶² Perhaps the cleanest, most concise definition is “An area in and adjacent to a neighborhood or community where the immediate or secondary effects of a wildland fire threaten at-risk values and will be a serious detriment to the area’s overall health and sustainability.”⁶³ Regardless of terminology, the WUI is an increasingly popular place for recreation, beauty, and rural living, with new landscaping often planted for privacy.⁶⁴

B. THE THREAT

The irony of wildland firefighting is that the suppression tactics used in the past to prevent fire catastrophes have in fact guaranteed that these fires will occur. Historically, wildland fire suppression has had a 95–98 percent rate of effectiveness.⁶⁵ At the same time,

⁵⁹ Hermansen-Baez, Seitz, and Monroe, “Wildland Urban Interface: Varied Definitions,” 1–2.

⁶⁰ International Association of Fire Chiefs, *Wildland–Urban Interface*; International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?”; U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 1.

⁶¹ International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?”

⁶² Stewart et al., “Defining the Wildland–Urban Interface,” 202.

⁶³ Summerfelt, “The Wildland/Urban Interface: What’s Really at Risk?,” 6.

⁶⁴ International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?”

⁶⁵ Hylton Haynes, Angela Garcia, and Rachel Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities* (Quincy, MA: National Fire Protection Association, 2015), 1, <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/WUI/osWUIPhase1.ashx?la=en>.

the statistics also show a growing trend of large-scale fires and staggering fire loss. In short, “Business as usual is not working.”⁶⁶

The problem, like the definition, depends on the frame of reference. Indisputably, more people are living within the WUI, fires are growing larger and more damaging, climate patterns are increasing fire severity, and the fire season is expanding. For a federal land manager, the problem is treating and managing a growing land mass despite declining financial and operation resources, increasing mission creep, and the demands of competing programs. For other responders and levels of government, a perfect storm has emerged, in which resources for response and preparedness are overworked and overwhelmed.

The threat of WUI fires is worsening, if number of structures or acres burned may be taken as indicators.⁶⁷ Over the past few decades, the U.S. has suffered increases in extreme WUI fires, risks to responders and the public, property and structural damage, and threats to communities.⁶⁸ A number of causes for these trends have been proposed, including hotter drier conditions, overabundant fuel, climate change, insects and disease, housing growth, population shifts, and misguided management practices.⁶⁹ The growing frequency and severity of wildfires perpetuates the problem—increased fire activity increases forest vulnerability and mortality, contributing to reduced overall air quality, greater pressure to use suppression, and consequent budget shortfalls. It is estimated the human activity and population changes since the 1970s precipitated climate and fuels changes that, from 1985 to 2016, doubled the expected fire-burned area per year.⁷⁰

⁶⁶ Western Governors’ Association, “A Call to Action” (Western Governors’ Association, January 23, 2009), 1.

⁶⁷ Haynes, Garcia, and Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*, 3.

⁶⁸ Wildland Fire Leadership Council, *The National Strategy: The Final Phase in the Development of the National Cohesive Wildland Fire Management Strategy* (Washington, DC: Departments of Interior and Agriculture, 2014), 1.

⁶⁹ Stewart et al., “Defining the Wildland–Urban Interface,” 201; Kristiane Huber, *Resilience Strategies for Wildfire* (Arlington, VA: Center for Climate and Energy Solutions, 2018), 1.

⁷⁰ John T. Abatzoglou and A. Park Williams, “Impact of Anthropogenic Climate Change on Wildfire Across Western Us Forests,” *Proceedings of the National Academy of Sciences* 113, no. 42 (October 18, 2016): 11770, <https://doi.org/10.1073/pnas.1607171113>.

The seeds of these developments were planted after the fires of 1910, when the USFS adopted a policy of full suppression. This approach persisted until the 1960s, when policy makers recognized that the financial and economic costs of full suppression were untenable. Nature is rhythmical, as are fire regimes—many fire-prone landscapes are supposed to burn, and this forces decision makers to consider historical trends, making blanket policies difficult.

This research discovers three anthropogenic forces at work in the fire issue:

1. We now burn fossilized biomass in the form of gas and oil, rather than the original live biomass, and the impacts of industrial combustion have an effect.
2. The movement of settlers as the West was opened, and sometimes the exodus of native populations, has contributed to the overall effect.
3. National trends of overgrazing, the movement of previously dispersed or nomadic populations into reservations, and the creation of protected parks and open spaces have changed how we use and manage land.⁷¹

These factors are the result of policy decisions that would be difficult or impossible to undo, even if desirable. They represent significant overall risk, from structural and infrastructure threats to public panic in emergencies and epidemics. Risks to firefighter safety are a primary concomitant of increased wildland and WUI fire; secondary effects include financial and economic losses, transportation disruption, curtailed recreation and health-related activities, high costs of rebuilding, and environmental costs such as lost habitats, species, soil, and watersheds. Not to be discounted are deleterious effects on public confidence in the fire system and personal emotional fallout.⁷²

In the 1970s, the growth of non-urban populations outstripped urban growth, and the latter has experienced steep decline in ensuing decades. While this trend switched in

⁷¹ Stephen J. Pyne, “The Fires This Time, and Next,” *Science* 294, no. 5544 (November 2, 2001): 1005.

⁷² Summerfelt, “The Wildland/Urban Interface: What’s Really at Risk?,” 5.

the 1980s, it again became the norm in the 1990s, and has remained so. A number of factors made this possible, including technological progress, economic changes, and transportation improvements. In the Midwest, for example, housing grew 146 percent between 1940 and 2000 (by over 14 million units). Approximately a third of this growth was in non-metropolitan areas.⁷³ WUI is found in all 49 continental US states, with the greatest concentration along the east coast, surrounding the Great Lakes, and around the metropolitan areas of the Southwest and Rocky Mountains. Intermix is most frequent in the West, which contains just over half of WUI intermix homes nationwide.⁷⁴ Overall, about 175 million acres in the US are classified as WUI, or about 9.3 percent of the land mass. While the Northeast and Southeast have the greatest extent of WUI, North Carolina had the highest proportion of WUI land (41 percent). Washington contains the West's highest proportion, at 9 percent.⁷⁵ The number of dwellings in the WUI increased 30 percent between 1990 and 2010, from 31 million to 43 million.⁷⁶ California is often seen as having the worst WUI issues. The number of California properties in the WUI has increased 1000 percent since 1940, to 7 million. Fifteen percent of these properties are in high- or extremely high-risk areas. Owing to urban expansion and growth in these zones, California fires tend to be deadlier and costlier than ever. In 2017, the federal government spent \$3 billion on suppression in the state, and damages from two major California fires reached an estimated \$19 billion.⁷⁷ The true costs of these fires are far greater however, predicted as 30 times the immediate costs when economic, resource, and environmental losses are factored in.⁷⁸

⁷³ Volker C. Radeloff, Roger B. Hammer, and Susan I. Stewart, "Rural and Suburban Sprawl in the U.S. Midwest from 1940 to 2000 and Its Relation to Forest Fragmentation," *Conservation Biology* 19, no. 3 (June 2005): 795, <https://doi.org/10.1111/j.1523-1739.2005.00387.x>.

⁷⁴ Stewart et al., "Defining the Wildland–Urban Interface," 205.

⁷⁵ Hermansen-Baez, Seitz, and Monroe, "Wildland Urban Interface: Varied Definitions," 2.

⁷⁶ Huber, *Resilience Strategies for Wildfire*, 2–3.

⁷⁷ Laignee Barron and Mahita Gajanan, "Why California's Fires Are Bigger, Deadlier, and More Costly," *Time*, November 13, 2018, <https://time.com/4985252/california-wildfires-fires-climate-change/>.

⁷⁸ Western Governors' Association, "A Call to Action," 1.

C. A CALL TO ACTION

Wildland fire is not only a fire-management problem; it is bound together with WUI fire and operational, land management, and social issues. Though the risk of wildland fire can never be wholly eliminated, it can be minimized by collaboration and cooperation among governmental, community, and business partners—even under constrained resources—if solutions also come from the public.⁷⁹

An NFPA report containing statistics on the three decades since *America Burning* showed that reported fires per capita decreased 79 percent in this period. The death rate per million population fell 70 percent. While total fire damages had been increasing over this period, they showed a slight decrease when adjusted for inflation.⁸⁰ This report notes a generally decreasing trend in number of outdoor fires, though data on deaths, injuries, and property loss in these fires was poorly collected.⁸¹ Statistics show that the number of firefighters killed in wildland firefighting duties has stayed somewhat constant, if rising slightly. 485 firefighters were killed in action between 1990 and 2017, an average of 17 deaths per year. In 2017, there were 87 total firefighters killed, six of them from wildland firefighting agencies.⁸²

The cost of large outdoor fires is an outlier worthy of consideration. The Valley and Butte fires, for example, represented almost 2 billion dollars in fire loss alone, which was 14 percent of the total loss reported for 2015. In contrast, all other outdoor fires made up 2 percent of the total.⁸³ The NIFC keeps statistics on wildland fires as well. Recent reports show decreases in fires per year from approximately 80,000 in 1985 to 60,000 in 2018. During this time there were increases in many other important categories, such as acres burned (from 3 million to 8 million per year), and total federal costs (from 240 million to

⁷⁹ Western Governors' Association, "A Call to Action," 2.

⁸⁰ Ahrens, *Trends and Patterns of U.S. Fire Loss*, 1.

⁸¹ Ahrens, *Trends and Patterns of U.S. Fire Loss*, 8.

⁸² U.S. Fire Administration, *Firefighter Fatalities in the United States in 2018* (Washington, DC: Federal Emergency Management Agency, 2019), 8–9.

⁸³ Ahrens, *Trends and Patterns of U.S. Fire Loss*, 12.

over 3 billion dollars).⁸⁴ There is also a notable upturn in high-dollar-loss fires and fires consuming over 100,000 acres—more of these fires occur per year, on average, as time goes on.⁸⁵

1. The Nation’s Fire Problem

Fire departments in the United States responded to an estimated 35 million calls for service in 2017. 1,319,500 of these calls for assistance involved fires, or 4 percent of the total. There were 3,400 reported civilian deaths and 14,670 civilian injuries in these fires, and the fires caused an estimated direct property loss of \$23 billion. \$10 billion of this loss was due to fires in the Northern California WUI.⁸⁶ Higher estimates of the losses from the Woolsey and Camp fires have reached \$18 billion. These fires not only caused financial losses, they also forced the evacuation and displacement of hundreds of thousands of residents and claimed over 40 lives. WUI fires tend to be costlier and deadlier because they represent urban expansion into high-risk areas. Insurance costs are predicted to rise by as much as 18 percent by 2055, with California seeing an increase of 77 percent of area burned by 2100 if things go unchanged.⁸⁷ The 7,000 fires reported in CA in 2017 caused total costs of \$180 billion.⁸⁸ Approximately 623,000 of the nation’s fires were outdoor fires, a decrease of 6 percent from 2016, according to NFPA reports. This represents an outdoor fire every 51 seconds in the U.S. Fires per year peaked in 1977 at 1,658,500, decreased steadily to just over a million in 1983, and hit a low of 564,500 in 2013.⁸⁹

Costs can be used to evaluate a problem across the U.S.—total cost is determined to be all losses due to fire plus net expenditures for fire protection. In 2014, the total cost of fire was measured at \$328.5 billion. \$273.1 billion of this was expenditure related and \$55.4 billion was fire loss. The greatest portion of the 83.1 percent of the total related to

⁸⁴ National Interagency Fire Center, “Federal Firefighting Costs (Suppression Only).”

⁸⁵ National Interagency Fire Center, “Wildfires Larger Than 100,000 Acres.”

⁸⁶ Ben Evarts, *Fire Loss in the United States During 2017* (Quincy, MA: National Fire Protection Association, 2018), 13.

⁸⁷ Barron and Gajanan, “Why California’s Fires Are Bigger, Deadlier, and More Costly.”

⁸⁸ Huber, *Resilience Strategies for Wildfire*, 1.

⁸⁹ Evarts, *Fire Loss in the United States During 2017*, 6.

expenditures was for fire safety in building construction; this generally fits into the category of fire prevention. Since 1980, the total cost of fire has increased by 50.3 percent. However, the cost expressed as a percentage of U.S. gross domestic product (GDP) declined from 7.6 percent to 1.9 percent.⁹⁰ Expenditures included active protection, such as local fire-department expenditures, the value of volunteer donated time, and donations, insurance, and passive-protection expenditures (e.g., building construction responsive to fire safety, the use of fire-grade products, and disaster and emergency planning).⁹¹ The NFPA states that “Building codes could be one of the key determinants of the total cost of fire, contributing to both expenditure as well as losses.”⁹² Apparently, the value of codes in the built and the wildland environment cannot be overstated. Unfortunately, wildfires are not considered in the most recent NFPA cost report, because the suppression and prevention of wildfires is poorly compatible with the structural modeling of their report.

The NFPA tracks fires with multiple deaths (i.e., “catastrophic” fires). In 2018, 29 catastrophic fires killed a total of 215 people. This represents 5.9 percent of total fire deaths, while the number of incidents is only 0.002 percent of the total number of fires. The deadliest and most damaging fire in California history, the Camp fire, ignited November 8, 2018, killed 85, injured twelve (five of whom were firefighters), and left three missing. This was the most catastrophic WUI fire of 2018, but not the only example—three other catastrophic fires occurred in California in 2018, with a total of 96 fatalities. By contrast, there were two WUI fires and 47 related deaths in 2017.⁹³

NFPA tracks large-loss fires, defined as those causing at least \$10 million in property damage. In 2017, there were 22 large-loss fires, which cumulatively wreaked \$12.5 billion in losses. The two largest, measured in loss, were WUI incidents in California. The first, known as the October fire siege, burned 335 square miles (245,000 acres), forced

⁹⁰ Jun Zhuang et al., *Total Cost of Fire in the United States* (Quincy, MA: Fire Protection Research Foundation, 2017), 1.

⁹¹ Zhuang et al., *Total Cost of Fire in the United States*, 8.

⁹² Zhuang et al., *Total Cost of Fire in the United States*, 40.

⁹³ Stephen Badger, “Catastrophic Multiple-Death Fires and Explosions in the United States in 2018,” *NFPA Journal*, October 2019, <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2019/September-October-2019/Features/Catastrophic>.

the evacuation of over 100,000 persons and killed 44, destroyed 9,000 structures, and caused \$10 billion in damages. The December fire siege required the evacuation of 230,000 and destroyed 307,000 acres and 1,355 structures. In this inferno, 12 firefighters and seven civilians were injured and a firefighter and civilian were killed. 2017 marked the eighth time in ten years that a WUI fire was at the top of the large-loss list.⁹⁴

Looking at other large fires U.S. fires over the past few decades, the story is telling: the Oakland Hills fire of 1991 caused \$2.5 billion in losses, destroyed over 3,000 structures, and killed 25 persons, while Southern California fires caused \$2 billion in losses, 5000 evacuations, and seven deaths; the 2000 Cerro Grande fire in New Mexico caused \$1.3 billion in losses and the destruction of 500 structures; the 2003 Cedar fire in California caused \$1.3 billion in losses and fifteen fatalities; the Old fire in California, also in 2003, created \$1.2 billion in losses and six deaths; the 2008 Southern California fires caused \$0.9 billion in losses and 13 lives in a siege of 4,000 fires; and the Laguna Beach fire of 1993 brought losses of \$0.5 billion and destroyed 400 homes.⁹⁵

While the focus of this thesis is U.S. WUI fires, there is a grim international history as well. The 2016 Fort McMurray fire in Alberta, Canada, caused \$7 billion in loss. 3,600 structures were destroyed, 88,000 persons were evacuated, and two persons were killed. Fires in British Columbia in 2003 caused \$0.5 billion in loss, the destruction of 334 homes, 36,000 evacuations, and three fatalities. The 2006 Slave Lake fire left \$0.6 billion in losses, the evacuations of 15,000 persons, and the one death.

The environmental impacts of WUI fires take many forms. Carbon emissions from combustion and non-carbon emission in smoke plumes are generally significant, and particulate matter is also released.⁹⁶ Contaminants and toxic byproducts may be released in water runoff in the aftermath of fires as well. Smoke, air and other environmental

⁹⁴ Stephen G. Badger, *Large-Loss Fires in the United States 2017* (Quincy, MA: National Fire Protection Association, 2018), 1–2.

⁹⁵ Enrico Ronchi et al., *E-Sanctuary: Open Multi-Physics Framework for Modelling Wildfire Urban Evacuation* (Quincy, MA: Fire Protection Research Foundation, 2017), 14.

⁹⁶ Drew Martin, Mai Tomida, and Brian Meacham, *The Environmental Impact of Fire* (Quincy, MA: Fire Protection Research Foundation, 2015), 5.

contaminants, and hazardous runoff and erosion from flooding are all significant negative effects of wildland fire.

2. Victims

America Burning had a strong indirect effect on preserving the lives of persons caught in fire emergencies. But fire also has victims who succumb. From 2013 to 2017, the annual number of U.S. deaths from fire-related causes was 3,170. The fire-related-death rate between 2013 and 2017 was two percent higher than numbers between 2008 and 2012.⁹⁷ There is large variability in the number of deaths per million population among the states. While the average is 9.9 deaths by fire per million population, the range is 4.6–23.5. Higher rates generally correlate with higher rates of disability, lower incomes, smoking rates, rural residency, and in certain cases, genetics. During this period all states had lower death rates by fire than was seen in statistics for 1981–1985, and all but three had fewer deaths by fire.⁹⁸

Of the top-ten states for death rates by fire from 2013 to 2017, nine were from the south and one from Alaska. Alaska Natives and Native Americans had the highest death rate, with the African-American rate slightly lower. Death rates generally increase with age. There is also a strong correlation between fire-death rates and rural living—five of the top-ten states are also among states with the highest proportion of residents living in areas classified as rural.⁹⁹

3. Evacuation

One risk-management tactic that specifically involves populations is evacuation—often with little warning or direction and for an unknown period. While there is not a single agency that tracks the number of evacuations, anecdotal evidence and some specific statistics can be staggering. Examples of fires in which thousands were moved are quickly

⁹⁷ Marty Ahrens, *US Fire Death Rate by State* (Quincy, MA: National Fire Protection Association, 2019), 2, <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osstate.pdf>.

⁹⁸ Ahrens, *US Fire Death Rate by State*, 1.

⁹⁹ Ahrens, *US Fire Death Rate by State*, 3–5.

found; one such occurred in 2005, when 4,000 people were moved in the Texan Panhandle fire. A series of Southern California fires in 2003 led to the evacuation of an estimated 100,000 people.¹⁰⁰ Fires in Southern California in 2007 involved the evacuation of over 300,000 and the destruction of 2,223 dwellings.¹⁰¹ Other estimates of evacuees during these fires are as high as 1,000,000.¹⁰²

A recent study in Canada reported that 20 percent of residents in fire-prone areas reported having received an evacuation alert, while only three percent had actually evacuated. Less than one percent lost their homes, and 19 percent witnessed firefighting or emergency-management activities.¹⁰³ The past ten years in Canada have averaged 7,084 fires per year, with 547 evacuations involving 200,000 people between 1980 and 2007. From 1980–2014, the average evacuation per year was 8,500, with a doubling trend every 30 years. In the 2016 Fort McMurray fire, 90,000 were evacuated. Overseas, in Italy and Portugal, 100 fatalities occurred in fires in July 2017. As people move into the WUIs of North America, Europe, Australia, South America, and Africa, they are increasingly at risk of fire. U.S. WUIs increased by 52 percent between 1970 and 2000, and this trend is mimicked elsewhere, owing to the appeal of rural living, proximity to recreation, and, potentially the opportunity for affordable dwellings. Evacuations happen whenever there is a WUI; and if the Canadian trend is indicative, the number of evacuees per year will quickly reach the millions.¹⁰⁴ Evacuations are troublesome emergency-management tools. Hurricanes Andrew, Floyd, and Katrina provide examples of the problems that arise before, during, and after an event. Flooding in Canada in 1997 exposed similar difficulties,

¹⁰⁰ Travis Paveglio, Matthew S Carroll, and Pamela J Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” *Journal of Forestry* 106, no. 2 (March 2008): 65–70.

¹⁰¹ Sarah M. McCaffrey and Alan Rhodes, “Public Response to Wildfire: Is the Australian ‘Stay and Defend or Leave Early’ Approach and Option for Wildfire Management in the United States,” *Journal of Forestry* 107, no. 1 (February 2009): 9–15.

¹⁰² Paveglio, Carroll, and Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” 66.

¹⁰³ Tara K. McGee et al., *Human Dimensions of Fire Management at the Wildland-Urban Interface in Alberta: A Summary Report* (Toronto, Canada: Institute for Catastrophic Loss Reduction, 2009), 7, http://epe.lac-bac.gc.ca/100/200/300/institute_for_catastrophic/iclr_research_paper-ef/no46/McGee_et_al_2009.pdf.

¹⁰⁴ Ronchi et al., *E-Sanctuary: Open Multi-Physics Framework for Modelling Wildfire Urban Evacuation*, 11.

especially in the timing of warnings. Whether the evacuation is triggered by floods, hurricanes, or wildfires, the issues remain the same—inadequate notification, disorganized logistics, terrified animals, poorly identified ingress and egress routes, and persons who refuse to leave.¹⁰⁵

Research on evacuation has focused on testing, modeling, and theoretical analysis and finds that identifying community trigger points may promote effective evacuation.¹⁰⁶ Emergency managers should provide more lead time and control traffic to evacuees, and scout subdivision exits in advance when possible. In social research, evacuees exhibit increased conflict due to disagreement over fire-management choices, access to information, and delayed repopulation of burned areas. Uncertainty is the greatest concern reported.¹⁰⁷

The most pressing focus has been on how to evacuate should need arise; but the deeper question of who has ultimate authority to order an evacuation and whether evacuations can be mandatory is unclear. Most response agencies direct residents to leave when asked, and some communities teach preparation, planning, and early evacuation to ensure a safe process.¹⁰⁸ Residents may be advised to be “ready” with an emergency plan, “set” to evacuate by packing a go kit and listening for instruction, and then to “go” promptly.¹⁰⁹

a. SDLE: An Australian Approach

Sheltering in place, an alternative to evacuation, has been proven to reduce injuries and deaths in short-lived emergencies. The Australian Fire Authorities Council’s stay-and-

¹⁰⁵ Pavaglio, Carroll, and Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” 68.

¹⁰⁶ Thomas J. Cova et al., “Setting Wildfire Evacuation Trigger Points Using Fire Spread Modeling and GIS,” *Transactions in GIS* 9, no. 4 (October 2005): 603–17, <https://doi.org/10.1111/j.1467-9671.2005.00237.x>.

¹⁰⁷ Pavaglio, Carroll, and Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” 69.

¹⁰⁸ Riverside County Mountain Area Safety Taskforce, *Evacuating to Safety: A Wildfire Evacuation Guide for Residents and Visitors of the Mountain Communities of Riverside County* (Riverside County, CA: Riverside County Mountain Area Safety Taskforce, 2005).

¹⁰⁹ International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?”

defend model acknowledges that some residents will ultimately prefer to stay in their homes than evacuate, and provides a number of safety rules.¹¹⁰ A variant is the “prepare, stay, and defend, or leave early” (SDLE) policy. In some cases, a well-defended structure may be the safest resort, and residents who stay behind are well positioned to help with ember control and other defensive efforts once the fire passes. These doctrines are regularly reviewed by the Bushfire Cooperative Research Centre.

Australians view bushfires as a normal and healthy part of the natural environment in the dry season. Government decision makers attempt to balance ecological and community needs against tolerable levels of risk, based on the values at risk.¹¹¹ Risk management is a shared responsibility. Fire-resistant construction and maintenance and mindful siting and fuel management are strongly encouraged. Land-management agencies and fire departments bear some statutory responsibility for managing risks, and responders will assist to the extent possible; but homeowners are educated to create refuges onsite, be self-reliant, and know when to leave.¹¹² Those dwellings most likely to succumb in an emergency are identified and deprioritized for protection, and their residents are asked to leave rapidly if advised.¹¹³

SDLE strategies are informed by broad research. Studies of the Cedar fire in California and a 100-year study in Australia, for instance, showed that over three quarters of fire deaths occurred as victims attempted to evacuate.¹¹⁴ In Australian fires from 1900 to 2008, a third happened during late evacuations.¹¹⁵ Studies of structural losses showed

¹¹⁰ Paveglio, Carroll, and Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” 69.

¹¹¹ Bushfire Cooperative Research Center, “The Stay and Defend Your Property or Go Early Policy” (East Melbourne, Victoria: Australasian Fire Authorities Council, October 2006), 1.

¹¹² Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 3.

¹¹³ Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 2.

¹¹⁴ McCaffrey and Rhodes, “Public Response to Wildfire: Is the Australian ‘Stay and Defend or Leave Early’ Approach and Option for Wildfire Management in the United States,” 10.

¹¹⁵ Shahrooz Shahparvari, Babak Abbasi, and Prem Chhetri, “Possibilistic Scheduling Routing for Short-Notice Bushfire Emergency Evacuation under Uncertainties: An Australian Case Study,” *Omega* 72 (October 2017): 97, <https://doi.org/10.1016/j.omega.2016.11.007>.

that buildings are more likely to survive if a trained and equipped resident remains to fight embers and small fires, because most structures ignite after the main fire passes.¹¹⁶ It is understood that not everyone should stay in every circumstance; and if not, leaving early is key. The destination need not be far—a neighboring property may have been identified, for example, as sufficiently well prepared to offer safety.¹¹⁷

The 2009 Black Saturday fires in Australia killed 173 and triggered a critical evaluation of the policy, which a commission concluded was sound. But the report exposed a number of weaknesses. First, there was no recognition of variation in fire severity and extremity owing to factors such as topography, density, and weather. Second, the planning aspect was insufficient to allow properly informed decision making. Third, the commission stressed that the advice given to residents must be consistent and regular, and information shared before an emergency must be timely and comprehensive. Finally, the concept of “shared responsibility” required greater emphasis to ensure compliance.¹¹⁸

b. The Decision to Evacuate

In ideal conditions, each person may decide whether to stay or leave. In extreme circumstances, the authorities may urge mass evacuation. But under no circumstance should a well-prepared resident be forced from a well-prepared home, and last-second evacuations are to be avoided at all costs. In general, mass evacuations cause panic and ineffective, unsafe movements. Ultimately, authorities are saddled with the responsibility to shelter, feed, and care for large numbers of stressed individuals. A better approach is to identify vulnerable populations well in advance and make sure evacuation plans are understood before the time of need.¹¹⁹

¹¹⁶ McCaffrey and Rhodes, “Public Response to Wildfire: Is the Australian ‘Stay and Defend or Leave Early’ Approach and Option for Wildfire Management in the United States,” 10; Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 2.

¹¹⁷ Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 2.

¹¹⁸ Victorian Bushfires Royal Commission, *2009 Victorian Bushfires Royal Commission: Final Report* (Melbourne, Victoria: Government Printer for the State of Victoria, 2010), 4–5.

¹¹⁹ Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 3.

To provide a sound basis for decision making, accurate and timely information must be freely available to residents. Australia fire authorities consider information sharing a vital task, and residents and communities are consulted in the drafting of emergency plans to encourage collaboration with response agencies.¹²⁰ In the SDLE model, informed choice begins with the following checklist:¹²¹

- cognizance of, adherence to, codes and fuel-reduction strategies
- community planning to reduce the ignitability of structures and promote safe arrangements, training, and equipping for appropriate action
- advance area-of-refuge preparation
- annual reviews and updates before fire season
- contingency plans for unexpected developments
- agreement on trigger points for the leave-or-stay decision
- well-developed follow-through plans

There should be a clear expectation that staying is an active responsibility and that those who stay passively are at great risk. It must be noted that while SDLE and the recently introduced prepare–act–survive approach are sanctioned by law, under extreme circumstance the government can mandate an evacuation,¹²² though unclear legislative definitions invite ambiguity.¹²³

¹²⁰ Bushfire Cooperative Research Centre, “The Stay and Defend Your Property or Go Early Policy,” 3–4.

¹²¹ McCaffrey and Rhodes, “Public Response to Wildfire: Is the Australian ‘Stay and Defend or Leave Early’ Approach and Option for Wildfire Management in the United States,” 11.

¹²² Shahrooz Shahparvari, Babak Abbasi, and Prem Chhetri, “Possibilistic Scheduling Routing for Short-Notice Bushfire Emergency Evacuation under Uncertainties: An Australian Case Study,” *Omega* 72 (October 2017): 96, <https://doi.org/10.1016/j.omega.2016.11.007>.

¹²³ Elise Loh, *What Does the “Prepare, Stay and Defend, or Leave Early” Policy Mean for Me?: Legal Liabilities of Emergency Workers and Emergency-Service Organisations in South Australia* (East Melbourne, Victoria: Bushfire Cooperative Research Centre, 2007), 12, http://www.bushfirecrc.com/sites/default/files/managed/resource/stay_or_go_legal_south_australia_jul-07.pdf.

D. THE FIRE SERVICES

NFPA reported 29,806 public fire departments in the United States in 2017.¹²⁴ Nevertheless, there are problems with WUI responsiveness. The WUI world accommodates neither the wildland nor the urban responder, and the two do not integrate seamlessly. Wildland firefighters and equipment are designed for mobility and prolonged performance. Urban forces are less agile, but pack a heavier punch. While most departments claim a demand for wildland response, 58 percent report no formal training or preparation.¹²⁵ Another review found that while 49 percent of departments have not trained all their personnel in structural firefighting, 63 percent reported a need for wildland fire training—with no formal training provided. These numbers were both up from a study five years earlier—from 46 percent and 58 percent, respectively.¹²⁶

Fire departments responded to a total of 26,880,800 calls in 2017, according to the NFIRS. This is five percent above the number in 2016. Only four percent of these calls were fire related, and 64 percent were EMS.¹²⁷ There were an estimated 1,056,200 firefighters in the United States in 2017; of these, 373,600 were career firefighters and 682,600, volunteer. This represents an increase of three percent for career firefighters and decrease of six percent of volunteers from 2016. In general, the number of career firefighters is increasing and the number per 1,000 residents remains steady, while the number of volunteer firefighters and of volunteers per 1,000 residents are in steady decline. Of the close to 30,000 departments in the U.S., 17 percent were career departments that protected 69 percent of the population in the country. Local fire-protection expenditures increased 179 percent from 1980 to 2015.¹²⁸

¹²⁴ National Fire Protection Association, *Fourth Needs Assessment of the U.S. Fire Service*, 1.

¹²⁵ Haynes, Garcia, and Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*, 2.

¹²⁶ National Fire Protection Association, *Fourth Needs Assessment of the U.S. Fire Service*, viii.

¹²⁷ U.S. Fire Administration, “Fire Department Overall Run Profile as Reported to the National Fire Incident Reporting System (2017),” *Topical Fire Report Series* 20, no. 1 (May 2019): 1.

¹²⁸ Ben Evarts and Gary Stein, *U.S. Fire Department Profile 2017* (Quincy, MA: National Fire Protection Association, 2019), 1, <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osfdprofile.pdf>.

Seventy-eight percent of fire departments report that they perform WUI firefighting, and about half that of those that serve communities of 250,000 or less said they could handle a WUI incident with two to five structures threatened. Sixty-eight percent of departments that serve populations greater than 500,000 said they could respond to a fire of up to 100 acres on their own. Of fire departments serving populations of 100,000–250,000, 41 percent stated they could handle incidents involving one to ten acres, and 20 percent said they could handle incidents between 11 and 50 acres. Departments in communities of 2,500 and less reported a 49 percent and 26 percent confidence in the same parameters.¹²⁹ Of departments covering all population sizes, the number-one ranked educational need was a wildfire-safety training program based on a nationally accepted model, with 84 percent reporting they had none. The WUI operational training needs for departments in populations over 500,000 was 15 percent, while that for departments serving under 2,500 was as high as 65 percent.¹³⁰

1. Firefighter Casualties

In 2018, 82 firefighters were killed in the line of duty, five less than in 2017. Records show a steady decline since 1973, with a seven percent decrease in on-duty fatalities since 2009. Of the 82 mortalities, 33 were career firefighters (five from rural departments, 28 from urban) and 44 were volunteers (27 from rural departments, 17 from urban). Five were from wildland agencies. Eleven died while performing activities that could be described as “wildland firefighting”; between 1990 and 2018, 495 were killed in such activities, with an average of 17 per year. The average over the past decade has been 14 per year; the highest toll was 31, spiked by the Yarnell Hill fire in which 19 firefighters were killed. There is also a ten-year average of one firefighter death per year attributable to wildland aircraft operations.¹³¹

The USFA provides detailed information on firefighter injuries and deaths. For example, between 2015 and 2017, an estimated annual average of 25,975 firefighters were

¹²⁹ National Fire Protection Association, *Fourth Needs Assessment of the U.S. Fire Service*, 208–9.

¹³⁰ National Fire Protection Association, *Fourth Needs Assessment of the U.S. Fire Service*, ix–xiii.

¹³¹ U.S. Fire Administration, *Firefighter Fatalities in the United States in 2018*, 2–12.

injured while performing operations and 4,525 while responding to or returning from an emergency. Eight-seven percent of these injuries occurred while working on structural-fire operations and 8.2 percent on outdoor fires. This means firefighters were 11 times more likely to be injured while working on fires in buildings. The vast majority of injuries are related to overexertion and strain, besides exposure, contact with objects, slips, falls, being struck or assaulted, and jumps.¹³²

Leading causes of firefighter deaths include aircraft and vehicle accidents, entrapment, and heart attacks. Since 2007, only three have died while performing the mandated annual work-capacity test for wildland firefighters, while eleven died between 1999 and 2006—this improvement likely reflects the addition of a mandatory physical exam with a new process. Since 2007, there were six fires in which more than one firefighter died: nine were killed in a helicopter crash in the 2008 Iron Complex Fire, three were killed in a 2008 aircraft accident, three died in a 2009 aircraft crash, and four were killed in an airplane accident while fighting the White Draw fire. Nineteen firefighters were entrapped and killed in the Yarnell Hill fire, and three were killed in the 2015 Twisp fire, in which 16 firefighters were entrapped.¹³³

2. Factors in Effectiveness

There are many actual and perceived issues surrounding fire-department effectiveness when it comes to the WUI. Apparatus design, personnel training and equipping, response configurations, communications, and qualifications and standards greatly determine the readiness of a fire unit. Indirect factors include communications with the public, relationships among partners and policymakers, and community preparedness and risk reduction in general. Effective communication with the public may include direct contact through programs such as Ready, Set, Go! and Firewise, traditional media such as newspapers, television, and community meetings, and social media targeted at

¹³² Federal Emergency Management Agency, “Fire-Related Firefighter Injuries Reported to the National Fire Incident Reporting System (2015-2017),” *Topical Fire Report Series* 20, no. 2 (July 2019): 1–4.

¹³³ National Wildfire Coordinating Group, *NWCG Report on Wildland Firefighter Fatalities in the United States: 2007-2016*, PMS 841 (Boise, ID: National Wildfire Coordinating Group, 2017), 3–7.

subgroups.¹³⁴ Twenty-two percent of departments reported community risk-reduction educated focused on the WUI, while 46 percent spent more time on structural work, and 30 percent invested equally in both.¹³⁵

E. BUILT VS. WILDLAND EFFORTS

In a recent survey, one quarter of departments reported spending more time on wildfire than on structural incidents. Forty-four percent reported more structural than wildland work, while 31 percent reported a more-or-less equal split.¹³⁶ Overall, the built environment occupies more reporting and data collection space than the wildland. Of the 22 large-loss fires evaluated by NFPA in 2017, 20 involved structures, and these accounted for \$747.7 million in property losses. The 20 accounted for only six percent of the total loss. Between 2007 and 2017, there were 26 fires that cost more than \$100 million in losses. Twelve were structure fires—eight percent fewer than in 2016.¹³⁷

From 2007 to 2017, 29 fires each accounted for direct property losses of at least \$10 million. Fourteen of these separately accumulated over \$100 million in direct property losses, and three independently accounted for more than \$1 billion in property losses each. The total loss from these fires is valued at \$17.7 billion, besides casualties of 499 injured and 80 dead.¹³⁸ In 2013, the NASF identified 72,000 communities at risk for WUI fires. Most are served by one or more of the 30,000 fire departments or fire districts nationwide, the majority of which claim the need for a wildland or WUI focus.¹³⁹

The 2014 *Quadrennial Fire Report*, provided a third follow-up to the *National Fire Plan* and *CS*. The report makes a baseline assessment based on the assumption that climate change is increasing temperatures, changing normal precipitation patterns, limiting water

¹³⁴ Haynes, Garcia, and Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*, 55–74.

¹³⁵ Haynes, Garcia, and Madsen, *Wildland/Urban Interface*, 75.

¹³⁶ Haynes, Garcia, and Madsen, *Wildland/Urban Interface*, 10.

¹³⁷ Badger, *Large-Loss Fires in the United States 2017*, 2.

¹³⁸ Badger, *Large-Loss Fires in the United States 2017*, 2.

¹³⁹ Haynes, Garcia, and Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*, 2.

supply, encouraging overgrowth and making vegetation more fire prone, causing extreme fire behavior, and extending the fire season. Risk management had changed in previous decades, with prescribed burning reduced from 25–40 million acres in the 1940s to 5 million or fewer since the 1960s. Meanwhile, the WUI saw rapid expansion. A changing workforce affected the number of higher-level responders and incident leaders available. Technology gaps were evident in the collection and use of data and the use of emerging technology; these were seen as great opportunities to grow and improve.¹⁴⁰

In a study from 2017 to 2019, an evaluation of capability assessments of WUI response reached three conclusions and seven recommendations, especially singling out modern technologies such as remote sensing and detection as effective tools in reducing WUI damage. The study's recommendations are to

- employ remote sensors;
- improve public warning and alerting systems;
- increase public communications and social media use;
- use better fire forecasting and modeling;
- improve the resilience of infrastructure;
- improve public and responder situational awareness through existing and improved data; and
- enlist tracking technology.¹⁴¹

F. FIRE PREVENTION

A Florida study found a return of \$35 in total community benefits for every dollar spent on public fire-prevention education and community outreach. These activities

¹⁴⁰ Booz Allen Hamilton, “2014 Quadrennial Fire Review” (Washington, DC: USDA Forest Service Fire & Aviation Management and Department of the Interior Office of Wildland Fire, May 2015), ii, <https://www.forestsandrangelands.gov/documents/qfr/2014QFRFinalReport.pdf>.

¹⁴¹ U.S. Fire Administration, *Wildland Urban Interface Fire Operational Requirements and Capability Analysis* (Washington, DC: Federal Emergency Management Agency, May 31, 2019), i–vi.

increase public awareness and trust in government—public-safety benefits that are clear in time of emergency—and improve overall public health.¹⁴² Preparedness in general constitutes a large part of activities at the federal level as well. About 42 percent of the president’s Department of the Interior budget, and 51 percent of the president’s USFS budget relate to preparedness. Unfortunately, while most of this funding is for preparing operational resources, much is diverted to large-incident responses.¹⁴³

1. Mitigation

An emerging trend in prevention is mitigation—reducing loss of property and lives by decreasing the potential impact of wildland and WUI fires. Mitigation and prevention are not identical, but are conflated for the purposes of this thesis. Effective mitigation helps reduce the risk to firefighters and the public and reduces the ignition potential of structures. It creates resilient communities, speeds up recoveries, and minimizes post-disaster disruptions, reducing their financial impacts. These measures often contribute to other economic, ecological, and environmental factors, as well as landscape aesthetics. Basic practices include the promotion of fire-adapted communities (FACs) by means of outreach and public engagement, incentives, and assisting homeowners with the application of new research and modern approaches to the protection of their property. Components of a FAC should include a community wildfire-protection plan (CWPP), responder training and education, fuel treatments to reduce hazardous fuels and create fuel breaks, updated codes and ordinances, encouragement of cooperation and collaboration, evacuation planning, and prevention and preparedness.¹⁴⁴

A study in Washington state showed that in an area subject to mechanical thinning and prescribed burning, 57 percent of trees survived a wildfire, while only 19 percent survived when only thinning was done, and 14 percent with burning alone. Likewise, a California study determined that a return of \$1.90 to \$3.30 was recognized for every dollar

¹⁴² Huber, *Resilience Strategies for Wildfire*, 6.

¹⁴³ Booz Allen Hamilton, “2014 Quadrennial Fire Review,” 8.

¹⁴⁴ National Wildfire Coordinating Group, *Wildland Urban Interface Wildfire Mitigation Desk Reference Guide* (Boise, ID: National Wildfire Coordinating Group, 2019), 1–3.

spent on fuel reduction.¹⁴⁵ In a Canadian study, researchers found that nearly 61 percent of homeowners thought preparing for a WUI would significantly reduce damage to their homes should a fire occur, while nearly 10 percent thought WUI fires so destructive that preparation was useless. Preparedness constraints were also studied. Half of respondents thought that lack of funding was the ultimate constraint on preparedness. About a third said that personal factors such as time and expertise were the main constraint, and a large proportion thought that the perceptions of others were also inhibiting. Participants thought that the best ways to promote participation were insurance incentives, education, and free hazard assessments by professionals. The least effective mechanisms were identified as more stringent building restrictions, the proscription of problematic building materials, and strict community bylaws.¹⁴⁶

There are many resources in the U.S. to help with mitigation. The Fire Adapted Communities Coalition, for instance, helps people live with and reduce fire risk. The Fire Learning Network is a TNC program promoting public–private partnerships that plan and implement public-education programs and restore national lands. Fire-safe councils are community-led organizations to protect homes and the environment from the risks of fire through education and preparedness. While governmental representatives might participate, these grassroots councils are independent entities. Firewise Communities is a program that teaches residents to live with fire and work together as a community to prevent losses. Firewise promotes defensible space and home hardening through a nationally recognized program, workshops, on-line resources, and other support. Living with Fire is a mitigation program for homeowners that was launched in Nevada. The IAFC Ready, Set, Go! program promotes dialog between response agencies and members of the community on preparedness and risk reduction.¹⁴⁷

¹⁴⁵ Huber, *Resilience Strategies for Wildfire*, 4–5.

¹⁴⁶ McGee et al., “Human Dimensions of Fire Management at the Wildland-Urban Interface in Alberta,” 7–14.

¹⁴⁷ National Wildfire Coordinating Group, *Wildland Urban Interface Wildfire Mitigation Desk Reference Guide*, 4–6.

2. Structural Preparation

While many good practices are now commonplace in the U.S., there is still room for improvement. The updating of zoning and development codes is essential, with a focus on land conservation and encouraging smart growth and development. Codes should provide incentives to developers to conserve open space, install paths for recreation and commuting, and create natural fuel breaks. During plan reviews, the authoritative body should look for and require defensible space and mitigation practices, as well as an adequate water supply for suppression and preparation. Building practices should be consistent with safe principles. Materials should not include wood siding, shingles, or roofs. Vents and all openings should be covered and protected from embers, and all windows should be double paned to resist radiant heat and breakage that would allow ember exposure. Ignition-resistance should be the norm across the structure. Compliance may be ensured through approval reviews or waiving certain fees according to level of compliance.¹⁴⁸

G. PROGRAMS FOR THE FUTURE

A clear vision has been established through many attempts to jumpstart improved WUI management. It is generally agreed that ensuring effective partnerships, agreeing on clearly shared responsibility among all stakeholders, creating fire-adapted communities, and maintaining resilient landscapes will promote a safer future. A specific call to action, for example in “America’s Wildland Burning” is to set the stage for this collaboration, establish shared principles, and craft a collective strategic direction and framework for roles and responsibilities.¹⁴⁹ The shared vision of a new *America Burning* should, according to this research, advance the premises that we need to safely and effectively extinguish fire when needed, use fire where possible and warranted as a tool for mitigation and risk reduction, take a collaborative approach to resource management, and learn to live with fire. These actions would require support from top leadership at all levels. Specific tasks might include establishing roles and responsibilities for suppression and

¹⁴⁸ Huber, *Resilience Strategies for Wildfire*, 3.

¹⁴⁹ Western Governors’ Association, “A Call to Action,” 2.

preparedness; pursue vigorous and sustainable landscape-scale fuel reduction and management; restore healthy landscapes through pre-fire activities and post-fire rehabilitation; build community capacity through relationships with insurers, develop codes and standards and enforce them; and expect overall accountability.¹⁵⁰

1. Data Collection and Application

There is a growing trend in the fire service of creating a dynamic data collection and use environment for modern operations. Two main themes have emerged in this world: “the fire service recognizes the value of data” and “the fire service isn’t satisfied with the status quo.”¹⁵¹ Yet most fire data systems remain static and archaic, constrained by poor data quality and accuracy and inaccessible when needed. No single set of needs or single solution is recognized, but it does appear that fire-service partners are moving from static collection and paper reports to dynamic systems in which data is available in real time to manage operations and the organization in general. Modern computer-aided dispatch and records-management systems contribute more to decision-making than in the past.¹⁵²

The Wildland Fire Information and Technology (WFIT) program brings together many levels of government and agencies to support fire programs. WFIT works independent of organizational or agency limitations. One of its main programs is integrated reporting of wildland-fire information (IRWIN), which supports full-scale wildland-data collection and utilization. The goals of IRWIN are to consolidate all wildland-data entry systems into a single platform, identify the main data sources used nationally, and improve the availability and accuracy of data used for operations. Many studies over the past two years cite data inconsistency as impediment to safe operations.¹⁵³

¹⁵⁰ Western Governors’ Association, “A Call to Action,” 2.

¹⁵¹ Matt Hinds-Aldrich et al., *National Fire Data Survey: Findings on the State of the Existing American Fire Data Ecosystem* (Quincy, MA: National Fire Protection Association, 2017), 1, <https://www.nfpa.org/-/media/Files/News-and-Research/NFDS/osNFDSurvey>.

¹⁵² Hinds-Aldrich et al., *National Fire Data Survey*, 18–19.

¹⁵³ IRWIN Core Team, *Irwin Project Management Plan* (Department of Interior, July 30, 2018), 3, <https://www.forestsandrangelands.gov/documents/wfit/applications/IRWIN/IRWIN-ProjectManagementPlan-v51.pdf>.

Responsibility for NWCG data management rests with the data-management committee (DMC). The DMC attempts to develop and implement data standards where data has historically not been integrated and usable. The DMC data-management strategy is a key collaborative goal. The mission includes “assisting the wildland-fire community to identify, define, and standardize data that is reliable and accessible for planning, decision support, and research” and “developing programmatic guidance for wildland-fire data, including data requirements, data governance, and data architecture that support a data exchange environment and improved efficiency in operational work and communication processes.”¹⁵⁴

Data standardization is the first objective, beginning with the definition of data elements for all agencies and developing a data-management guide for NWCG collaborators. Other objectives are to manage the data throughout its lifecycle and to implement quality assurance and a governance model.¹⁵⁵

2. Community Wildfire-Protection Plans

Communities should be empowered and required to develop community wildfire-protection plans (CWPPs).¹⁵⁶ Though its CWPP, a community identifies areas at risk of and WUI fire and plans accordingly. Participants are drawn from all levels of government, local responders and response agencies, land-management agencies, and partners in the private, non-profit, and government sectors. A CWPP should address values at risk, land and forest conditions, and action priorities. The minimum requirements for an effective CWPP are broad collaboration, fuel reduction in all types of land, and individuals willing to take responsibility for hardening structures in their control.¹⁵⁷

The fire service has a responsibility and the authority to provide property and human protection in communities. Community actions to mitigate risk can aid this charge

¹⁵⁴ National Wildfire Coordinating Group, *NWCG Data Management Strategy*, PMS 940 (Boise, ID: National Wildfire Coordinating Group, 2018), 2.

¹⁵⁵ National Wildfire Coordinating Group, *NWCG Data Management Strategy*, 2–6.

¹⁵⁶ Stewart et al., “Defining the Wildland–Urban Interface,” 202.

¹⁵⁷ National Wildfire Coordinating Group, *Wildland Urban Interface Wildfire Mitigation Desk Reference Guide*, 2–3.

while also protecting at-risk populations, critical infrastructure, natural resources, and cultural sites, and supporting firefighter safety. CWPPs typically outline a mitigation, prevention, and preparedness plan; establish strategic relationships; document collaborative actions, project successes, and group decisions; and develop an operational plan. The goals and objectives of a CWPP must be clear and achievable.¹⁵⁸

The first step in developing a successful CWPP is to identify and bring together potential partners to provide well-rounded expertise, support, and political capital. Federal partners such as the USFS, the Bureau of Land Management (BLM) and the Bureau of Indian Affairs (BIA), the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), the DOD, and FEMA should be included, even if a community does not contain or border on federally owned land. Potential stakeholders may be divided into participants and notify-only groups, based, for example, on topics ranging from the potential effects of smoke on air quality to recreational concerns to water and infrastructure risks. Stakeholders may include, for example, homeowner associations, neighborhood champions, builders and realtor groups, non-profit foundations, the departments of public works and parks and recreation, utility companies, developers, and firefighters and law enforcement, among a number of parties.¹⁵⁹

CWPPs develop a risk map for their area. With the standard definitions of WUI as a point of departure, a community must define the WUI for itself. Criteria may be the degree of intermix, the proximity of homes and forested areas, infrastructure vulnerability, and the abundance of natural fuels in an area, among other factors.¹⁶⁰

Once a community has mapped its WUI risk, the next step is a community risk assessment based on input from all collaborators and resulting in a triage that establishes priorities. Considerations in a risk evaluation should include structure type and layout, fuel types and proximity, fire history, topographical features, and anything else that might affect the likelihood of, and susceptibility to, wildland fire. Fuel conditions and historical

¹⁵⁸ International Association of Fire Chiefs, “A Fire Service Leader’s Guide” (Chantilly, VA: International Association of Fire Chiefs, n.d.), 2.

¹⁵⁹ International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 2–3.

¹⁶⁰ International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 4.

considerations are weighed, including local data such as fire-return intervals and average fire size and spread. Preparedness takes the form of operational pre-planning; the training, equipping, and certification of responders; ensuring resources are available, including crews, heavy equipment, and aircraft; completing a mitigation project; drafting mutual-aid agreements; and ensuring overall readiness for response. It is important to remember, however, that a CWPP should never be considered an operational plan.¹⁶¹

CWPP leaders must check codes, ordinances, and grant opportunities and gauge community willingness in constructing a sequential, well-paced plan for achieving benchmarks. Hazard- and risk-reduction priorities should include the equitable distribution of mitigation funds and projects. A tracking mechanism to report to stakeholders and funders should be built in.¹⁶² While a CWPP is a living document, a five-year planning horizon is a reasonable start.

Finalizing a CWPP starts with distributing a draft plan to stakeholders. A public-comment period is scheduled, well advertised in all media and accommodating electronic and in-person input. Meetings should be hosted in a variety of locations to attract a range of feedback. The final draft of a CWPP should incorporate comments and be circulated physically to the signatories, who may include elected officials, department heads, planners, members of fire or law enforcement, delegates from local, state, and federal government, funding parties, and others, depending on the authorities required.¹⁶³

Planning for outreach and public education might include media choices, audience identification, and messaging. Evacuation planning can also be tackled. This may include identifying the parties in charge, setting trigger points and routes, staging exercises, sharing pet and livestock plans, and creating emergency kits. Post-fire response might cover safety considerations upon return and repopulation, re-entry hazard identification, damage

¹⁶¹ International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 5–7.

¹⁶² International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 7–8.

¹⁶³ International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 8–9.

assessment and reporting, and inspections for certificates of occupancy. A CWPP may make suggestions for code modifications as well.¹⁶⁴

3. Fire-Adapted Communities

There is a strong push for fire-adapted communities (FACs), a concept strongly encouraged in the *CS*. The aim of a FAC is to ensure that community-wide preparation and mitigation will allow whole populations and infrastructures to withstand WUI fire exposure. In a FAC, private parties, community groups, and government collaboratively adapt to fire through a widespread effort.¹⁶⁵ The concept was first proposed in the 2005 *Quadrennial Fire Review (QFR)*, with the objective of enabling communities to create a fire-safe environment for themselves. This idea was expanded in the 2009 *QFR* by proposing that knowledge sharing and individual commitment be used to heighten responsibility among homeowners, insurance companies, fire departments and districts, government at all levels, and stakeholders. Ultimately, the goal is to reduce reliance on the federal government and ease the financial burden of federal suppression.¹⁶⁶

FAC concepts explain how a community can coexist with wildland fire, reduce the large-scale threat of fires, and largely eliminate massive response needs through a set of practices and principles. A FAC is essentially a community of prepared citizens who live in a fire-adapted ecosystem. A FAC community is characterized by adequate local fire suppression for normal response and substantive agreements for mutual aid and assistance as needed. It has landscape-design, construction-design, and building-material standards, fire-resistance codes duly adopted and enforced, fuel-treatment plans, and an existing CWPP.¹⁶⁷

FAC partners take specific roles. The local government engages the public, ensures that fire-department personnel are proficient, follows building susceptibility and

¹⁶⁴ International Association of Fire Chiefs, “A Fire Service Leader’s Guide,” 10–13.

¹⁶⁵ International Association of Fire Chiefs, “What Is the Wildland-Urban Interface?”; U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 1.

¹⁶⁶ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 2.

¹⁶⁷ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 3–4; National Wildfire Coordinating Group, *Wildland Urban Interface Wildfire Mitigation Desk Reference Guide*, 2–3.

preparation principles, evaluates local fuel loads and associated risks, develops plans to protect at-risk populations, and monitors development and building plans. All responses are coordinated with emergency-management and response personnel.

Land managers of various types play an important role in a FAC. Private land managers, such as farmers, ranchers, and property owners, and public or formal land managers, such as open-space managers, utility owners, and government appointees, should understand the effects of their operations on other partners and surrounding owners and take responsibility for stewardship. The public has a responsibility to understand the risk to the community and prepare for it as a partner. Community groups should build relationships with the public sector in general to understand protocols for emergency management and response, concepts in home ignition and defensible space, the need for a preparedness plan and situational awareness (SA), and, ultimately, how to prepare for orderly evacuation when needed.¹⁶⁸

Federal and national partners play leading roles in a FAC. NFPA is one of the more significant partners in the FAC model. Relevant NFPA codes include *Fire Code*, (NFPA 1, Ch 17), *Standard for Fire Protection Infrastructure and Land Development in Suburban and Rural Areas* (NFPA 1141), *Standard on Water Supplies for Suburban and Rural Firefighting* (NFPA 1142), *Standard for Wildfire Management* (NFPA 1143), and *Standard for Reducing Structure Ignition Hazards from Wildland Fire* (NFPA 1144). Ensuring these codes are up-to-date and relevant is key. The International Code Council has a similar role in a FAC. The *International Building Code* and the *International Wildland–Urban Interface Code* should be monitored and modified frequently. The ISO fire-suppression-rating schedule (FSRS) should be updated to account for WUI conditions, and appropriate public-protection classifications issued accordingly.¹⁶⁹ ISO should work to ensure that the FSRS has been revised to appropriately include community risk reduction within its design.¹⁷⁰

¹⁶⁸ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 5–6.

¹⁶⁹ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 5.

¹⁷⁰ Haynes, Garcia, and Madsen, *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*, 2.

Funding for a FAC should be promoted through customary and innovative methods. FEMA grants such as assistance to firefighters, interoperable emergency communications, and staffing for adequate fire and emergency response should be continued. The hazardous-mitigation grant program and pre-disaster mitigation competitive grant should be re-funded and continued, as should reimbursement for firefighting on federal property and state, rural, and volunteer fire assistance.¹⁷¹ Federal representatives should provide coordination of all operational and preparedness resources.¹⁷²

Key concerns in a FAC include the home-ignition zone (HIZ), generally specified as 0–200 feet, in which high-hazard flammable areas should be cleared. It is expected that a homeowner create a “defensible space” buffer zone between buildings and fuels. The defensible space is generally categorized in zones as represented in Table 1. Likewise, structures should be hardened—fitted with fire-resistant roofs, eaves, decks, windows, doors, and vents—to forestall ignition by embers, a primary concern in WUI exposure.¹⁷³

Table 1. Hazard Ignition Zones

Zone	Distance from structure
1	0 to 30 feet
2	30 feet to 100 feet
3	100 feet and beyond

4. Situational Awareness

In the WUI, a dynamic environment with many variables and decision points, SA is difficult—and poor SA can be disastrous. For this research, SA is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.”¹⁷⁴ In other words, it is

¹⁷¹ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 9.

¹⁷² Stewart et al., “Defining the Wildland–Urban Interface,” 201.

¹⁷³ U.S. Fire Administration, *Your Role in Fire-Adapted Communities*, 7.

¹⁷⁴ Mica R Endsley, “Toward a Theory of Situation Awareness in Dynamic Systems,” *Human Factors* 37, no. 1 (1995): 36.

gathering and understanding information in real time and using it to predict developments and consequences.

Collective and individual SA are equally important. Team SA occurs when individuals connect their own SA with that of others to achieve a shared awareness.¹⁷⁵ Shared or team SA is discussed according to the degree to which this occurs.¹⁷⁶

Geospatial technology is used in many ways to plan, respond to, and manage tasks that increase SA in WUI firefighting and preparedness. Unfortunately, the geospatial data available is often sparse or unavailable to those who need it at the time needed. There is currently little training, funding, or protocol for the use of this tool. Efforts to make the use of geospatial data commonplace include the *Standard for Data Development and Exchange for the Fire Service* (NFPA 950).¹⁷⁷ Geographic-information systems (GIS), the Global Positioning System (GPS), and remote sensing (RS) to acquire and manage data, visualize space and distance, monitor fire activities and growth, distribute information, assess risk, create SA, and help predictive services.¹⁷⁸ There are many GIS applications in the wildland and WUI environments.¹⁷⁹ RS applications include active fire mapping, burned-area emergency response, monitoring of trends in burn severity, and national infrared operations.¹⁸⁰ GPS products include the ESRI ArcPad, Magellan and Garmin applications, and the Rockwell precision lightweight GPS receiver.¹⁸¹

¹⁷⁵ Endsley, 37.

¹⁷⁶ Cheryl A. Bolstad, Mica R. Endsley, and SA Technologies, "Measuring Shared and Team Situation Awareness in the Army's Future Objective Force," *Proceedings of the Human Factors and Ergonomics Society* 47, no. 3 (2003): 373, <https://doi.org/10.1177%2F154193120304700325>.

¹⁷⁷ Minchao Yin, "A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events" (Quincy, MA: The Fire Protection Research Foundation, December 2014), 2.

¹⁷⁸ Minchao, "A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events," 44.

¹⁷⁹ Minchao, "A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events," 10–35.

¹⁸⁰ Minchao, "A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events," 36–39.

¹⁸¹ Minchao, "A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events," 41–43.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. ANALYSIS: THE POESII-PT STRATEGIC FRAMEWORK

Strategic and operational environments are, in general, complex problems for policymakers. The Army defines a strategic environment (SE) as “the set of general conditions, circumstances, and influences throughout the world that can affect military operations.”¹⁸² The SE is composed of all the operational environments in which commanders perform operations that need decisive action. Operational environments (OE) are similarly defined as “a composite of the conditions, circumstances, and influences that affect employment and capabilities and bear on the decisions of the commander.”¹⁸³ The Army recognizes that OEs are dynamic and evolving, characterized by uncertainty, instability, complexity, and ambiguity. Human, infrastructure, social, natural, and urban effects that must be considered to “prevent, shape, and win” the conflicts encountered. The interactions of all of these variables and the actions taken by the decision makers, constitute the OE. Much emerging technology deals with the OE of the WUI, as pertains to response, prevention, public education, mitigation, communications, data collection, sensing and alerting, situational awareness, and recovery. There is a need for continual learning and awareness and the ability to discover technology and transfer it to a usable target. This is also part of the discovery of the OE.

A. THE PMESII-PT ANALYSIS TOOL

The Army has developed a flexible and scalable framework with which to analyze and understand strategic and operational environments. The framework can be applied at any level to influence operations, leader development, training and education, capability and capacity enhancement, and policy development. The framework, referred to as PMESII-PT because of the eight variables analyzed in the OE (political, military, economic, social, information, infrastructure, physical environment, and time) provides a structured approach to creating an action in the OE by analyzing the external environment,

¹⁸² Department of the Army, *Operational Environment and Army Learning*, TC7-102 (Washington, DC: Department of the Army, 2014), 1, https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/tc7_102.pdf.

¹⁸³ Department of the Army, *Operational Environment and Army Learning*, 1.

and organizes the massive information that can be gathered in such an environment. The utility of PMESII-PT extends to business applications as well.¹⁸⁴

Briefly, the PMESII-PT's political variable looks at the entire political structure of an OE, including governmental structures, unofficial but influential groups, and formal organizations. Power structures within the OE and among stakeholders are also considered. Important information analyzed might include the legitimacy and effectiveness of governments and agencies, political issues and subcultures in the OE, and attitudes. The military variable includes force composition, capabilities, and limitations. This might include all individual forces and their summative capability. For this study, this category is replaced with "organizations" to capture more closely the nature of the WUI. The economic variable views the production, distribution, and consumption of resources, the basis of the economy, and the nature of the investment and banking systems. The social variable examines ethnic, cultural, and religious viewpoints and the beliefs and values of the population involved. The first "I" variable, information, describes individuals, systems, and organizations that collect, process, deliver, and act on information, whether formal, informal, or media related. The infrastructure variable stands for the overall design and needs of the community, including advanced technological capabilities such as the internet and mobile networks. The physical environment, represented by "P", includes man-made structures, geography, climate, weather, and topography. Since time is a constant, the time variable stands for the duration and timing of activities and effects.¹⁸⁵ Thus, though designed for military application, the PMESII-PT tool can be applied profitably in other contexts and OEs, such as the WUI. As altered for this research, the tool is renamed "POESII-PT."

¹⁸⁴ Department of the Army, *Operational Environment and Army Learning*, 2; Ben Janse, "What Is PMESII-PT? A Powerful Strategy and Management Tool," *Toolshero* (blog), March 23, 2019, <https://www.toolshero.com/strategy/pmesii-pt/>.

¹⁸⁵ Department of the Army, *Operational Environment and Army Learning*, 4–6; Janse, "What Is PMESII-PT?"

1. POESII-PT: Political Factors

Wildland firefighting has been political from the beginning. *America Burning* stems from a congressional decision to explicitly involve major governmental jurisdictions and agencies, especially the USDA and DOD, in the wildland fire environment, and the USFA was created to assist political collaboration in this realm. Recognition of the fire problem and the need for federal funding and technological support grew in subsequent decades, but elected officials still tended to relegate the issue primarily to the states and local governments; Congress did not adequately fund fire-prevention efforts. As EMS emerged and local fire departments started providing emergency services, it became clear that federal agencies must play a leading role and work together more effectively. At the state level, it was suggested that the Council of State Governments develop example laws related to fire compacts and public education that could be adopted by state governments.

The *National Fire Plan* pointed out that ultimate authority in the WUI is unclear; federal agencies often consider it a local issue, and local authorities think it is federal. To get jurisdictions working together, the report establishes priorities for integrated management and preparedness, fuel reduction, and local outreach. For governance, the WFLC and a tool for research and information delivery for decision makers were created. The recommendations of the *CS* include the establishment of the WFEC, CSOC, and RSC agencies to oversee collaborative work, technical assessments, and research priorities and formulate goals and trade-offs for service delivery.

The full suppression of fires was a politically motivated policy changed by policymakers in the 1960s. Other historical issues, such as the deleterious effects of industrial combustion, the consequences of westward migration into the WUI, and land-management decisions such as overgrazing, derived from policy decisions.

A number of salient issues in the WUI are political in nature. First, there is a need for policies on key points such as prevention, mitigation, community planning, water, evacuation, etc. to be drafted and standardized among as many governments, partners, and collaborators as possible. Moreover, American politicians should look at Australian and other foreign doctrines for possible application in the U.S. WUI codes regarding building

style and materials, building and community planning and arrangement, and infrastructure should be standardized.

One emerging issue is the effectiveness and implications of power shutdowns as a response to high risk and red-flag warnings. Others are privacy in data collection and SA and the importance of funding policy and technological updating. Policies around specific and vulnerable populations should also be considered.

Some utility companies, most significantly Pacific Gas and Electric in California, have begun to shut down electrical power grids where high winds are predicted to reduce fire risk. While seemingly prudent, this practice has political and social implications. There is no broad agreement as to its value in risk reduction—some believe shutdowns actually add collateral risks as people attempt to operate without power and light, deploy home generators, detour into fire-prone rural areas, and experience delayed emergency response. Whether or not there is agreement on the efficacy of mandatory blackouts, all agree that they underscore the degree to which the power infrastructure is at risk.¹⁸⁶ Overall, these issues invite the question of who is ultimately responsible for risk reduction in the WUI, and who has solutions.

2. POESII-PT: Organizational Factors

Workforce responsibilities were a key topic in *America Burning*, which recommended that fire control remain the responsibility of local government and that all resources be directed locally to improve responder training and prevention programs. The USFA was created to help departments with this task by standardizing processes, organizing the NFA for responder education, and raising administrative capabilities. Additional roles for the federal government were technological and educational assistance, the collection of fire data, the regulation of materials and codes, research, and funding.

The recommendations from the original core report contributed to an improvement in fire data and response, and *American Burning Revisited* and *America at Risk: America*

¹⁸⁶ Abrahm Lustgarten, “Mandatory Blackouts,” *The New York Times Magazine*, October 22 2019, 22–23, <https://www.nytimes.com/2019/10/22/magazine/pge-california-blackouts.html>.

Burning Re commissioned supported these trends. As the changing complexity of the services precipitated a greater focus on large-scale disaster and emergency management, FEMA was created and the USFA was tasked with standards for response, staffing, equipment, physical capability, etc. It was recognized that the USFA and the USFS should combine their organizational strengths to work together (e.g., on public education).

The *National Fire Plan* recommended that the role for federal agencies in the WUI be to provide wildland firefighting resources and assistance, and coordination and standardization among agencies. Standardization was to occur through the NWCG and the NIFC, with ICS coordination. The *CS* continued the trend of agency devolution by stating the need to clearly define what local governments can provide for resources. The *CS* stated that looking to the closest appropriate unit for response services should be the norm.

Most agencies report that they cannot respond to WUI emergencies alone. For local organizations, existing resources are often fatigued and departments are unable to fill order requests. Replacing aging workforces is a problem in IMT succession planning. There is an emerging problem of behavioral health issues that needs to be addressed in the workforce. Considering the new yearly response paradigm, there is a need to truly evaluate impacts on responders and examine staffing models that consider the “fire year” instead of the “fire season” to determine safe shift lengths. Physical- and performance-testing standards should be created and accepted. While a “pack test” is commonly used to test annual physical ability in the wildland environment, and the CPAT in the cities, a standardized test is appropriate. Perhaps the need for reciprocity between the specific tests, and tools such as recognition of prior learning (RPL), are needed. Consistency would be useful. Moreover, qualification and certification standardization would be of benefit and in line with national direction based on the NIMS typing and concept. Tools such as RPL and the Crosswalk program will help gain this consistency if implemented and accepted. Finally, accountability in emergency operations is widely recognized for imperative for the safety of the workforce—it was never so starkly needed as when nineteen hotshots were killed in Arizona in 2013.¹⁸⁷ The move to year-long firefighting will test many factors,

¹⁸⁷ *Yarnell Hill Fire, June 30, 2013: Serious Accident Investigation Report* (Phoenix, AZ: Arizona State Forestry Division, 2013), 1.

among them the resiliency of the workforce, the practice of seasonal hiring by land-management agencies, and the calculation for safe shift lengths and assignments. These are all worthy of future study.

3. POESII-PT: Economics

America Burning recognized that improved codes and standards would impose costs to businesses and builders. To offset these burdens, the report suggested incentives, for example, insurance deductions, tax breaks, and system improvements. *America Burning Revisited* noted that some recommendations in the original had led to the use of exotic materials that in many cases made the fire problem worse, but that new codes had improved conditions generally. *America at Risk: America Burning Re commissioned* observed that there was insufficient risk-management funding allocated at any level of government to address the issue. It was recommended that Congress fully fund risk prevention, commensurate with national risks. The hope was that changes would be incentivized as well, technology costs would continue to drop, and noncompliant-building retrofitting would continue. The report also recommended funding for the standardization of policies, procedures, hiring, and assessing responders.

The *National Fire Plan* recognizes a need to reduce escalating costs, indicating that FEMA has granting authority to help local governments and that grants through federal land-management agencies had been useful. Increased use of state, rural, and volunteer fire-assistance grants was advised. The report stated that improved fire-hazard rating systems in the WUI were needed to help insurance company products and assessments.

In general, mission creep in all agencies has diminished the dollars that go to response. For example, nearly half of recent DOI and USFS budgets were for preparedness as budgeted, but much was moved into response based on emerging needs. Dollar loss continues to rise, while the need to focus on fire's effects on business, transportation, utilities, education, health of vulnerable populations, and critical infrastructure continues.

4. POESII-PT: Social Factors

Specifically social items that should influence WUI policy include demographics, population movements, languages spoken, crime, human rights, social power centers, and cultural norms and values. In the 1970s, there was growing concern over fire statistics. As city populations exploded, there was increased social risk indifference, and the density of at-risk populations in urban areas grew. *America Burning's* recommendations about materials and construction choices for furniture and clothing brought immediate reductions in related fires, and these successes led to building codes and standards that, where implemented, also made a difference. Public education and prevention efforts, especially those aimed at schoolchildren, the invalid, and the infirm, were also stepped up and proved effective nationwide.

While societal changes improved awareness, general public apathy tended to retard changes to risky behavior. Fire was perceived in large part as a socioeconomic issue, and public understanding of wildland fire risks was weak. *America at Risk: America Burning Re commissioned* focused on public education to anchor change. This report called for messages that were easy to grasp and emotionally stirring, starting with all-risk education in grade school. It was recommended that the fire-services workforce achieve diversity commensurate with the communities served. On a positive spiritual, emotional, and physical note for individuals and communities, the report noted that burn care had improved dramatically.

The *National Fire Plan* identified firefighter and public safety, and public health in general, as top needs. The *CS* confirmed these socially-related goals, recognizing that risk management should form the basis for all decisions, but that it is impossible to reduce risk to zero. It also stressed the need for communities and individuals to learn to live with fire as an essential part of nature. But troubling statistics revealed that most wildland fires were set by humans, reflecting their greater presence in the WUI than ever before. Technological changes, changes in the economy, and transportation improvements had contributed to this reality. The growing WUI issue revealed a number of interrelated problems, such as public health degradation from smoke and the airborne byproducts of fire, public panic in large-scale emergencies, economic losses, firefighter endangerment, environmental costs,

transportation interruptions, and losses in health and recreation opportunities and public confidence.

These changes revealed a number of needs and opportunities. First, the ways people are moved within and outside of fire areas and kept safe must be identified; this includes evacuation, escape routes, and safety zones. Next, standardized evacuation definitions and policies and return procedures should be created and shared. Alternatives to evacuation such as the Australian stay-and-defend model should be explored. Finally, there is a need to pinpoint the effects and risks of major emergencies to responders and the public. Risk management should be promoted through collaborative strategies to minimize damage, and mitigation, prevention, and fire-adaptation programming should be consolidated in a scalable fashion for nationwide delivery.

5. POESII-PT: Information

The information category links the other categories and is vital to future improvements. Informational factors include public communications, media collaborations, information warfare, data collection and dissemination, information management, intelligence, and SA. *America Burning* and *America Burning Revisited* noted the need to redefine the problems of fire and wildland fire to understand root causes and enable the deployment of reliable and valid data; NFIRS was created to fill that need. A subsequent recommendation was made to reconcile existing data with databases at the USFA, in collaboration with the NFPA and ISO. As more research was conducted and practical findings were confirmed, these results would be distributed through the NFA, trade journals, and national conferences.

The *National Fire Plan* stressed the need for federal promotion of high-level public education on fire, covering risks to life, property, and resources. Strong outreach was conducted at all levels to establish clear, shared, and well-communicated messages on (e.g., how to safely extinguish fires, fire as a management tool, and building resilience by improving building codes). Education of this sort would allow local regulators to grasp how codes relate to loss in wildland fires and how policies influence insurance pricing in the WUI. Community members would benefit from learning how to decrease community

losses and lower their premium costs.¹⁸⁸ In sum, a vision for creating communities that safely live with fire was articulated.

Modern studies have identified modern needs for information and built ways to acquire it—for example, remote sensors, improved alert and warning tools (including social media), better forecasting and SA through data collection and modeling, and tracking and accountability systems. A FEMA/DHS technology report recommended expanded use of the Integrated Public Alert and Warning System and forecasting tools to create timely WUI-specific models; improvements to SA by integrating data from open, private, and crowd-sourced data collection and dissemination; and support of real-time SA using tracking technologies.¹⁸⁹ These desiderata have been largely unfulfilled and remain needs today. Future improvements might include a WFIT program and the IRWIN data-consolidation effort. Collective SA is a sure wave of the future, aided by geospatial technology, GPS, GIS, and RS.

A recent FEMA/DHS study cited a need to “Implement and scale the use of state-of-the-art remote sensing assets to provide state and local stakeholders real-time, accurate, low-cost ignition detection and tracking information...”¹⁹⁰ Operational gaps that led to this finding include a dearth of updated resource and resource-status information, slow detection of ignitions, sluggish, inaccurate fire-perimeter tracking, and poor tracking of emerging fire characteristics. The report called for improving the “ability of available and adaptable public alert and warning technologies to deliver more targeted and effective message across the whole community, particularly to individuals with disabilities and others with Access and Functional Needs (AFN).”¹⁹¹ Shortfalls in this area include a lack of systems that deliver geographically targeted or functionally tailored messages,

¹⁸⁸ Verisk Analytics, “National Building Code Assessment Report” (Jersey City, NJ: Insurance Services Office, March 2019), v.

¹⁸⁹ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” vi.

¹⁹⁰ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” vii.

¹⁹¹ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” vii.

insufficient dedicated systems for delivering messages through social media, telecommunications-carrier limitations, and inconsistent warning terminology.

Finding three of the report was also associated with the informational component of the OE, and represents an opportunity for change: “Improve the use of key public and private social media and internet resources and capabilities to appropriately share data and adapt existing applications to enable more efficient and effective evacuation....”¹⁹² There are unacceptable gaps in AFN data, crowdsourcing use, evacuation tracking and status, and public-private partnerships, and their fully deployment will help responders visualize, monitor, predict circumstances, distribute accurate information, and achieve individual SA. Modern decision-making must be data driven, and as that becomes increasingly possible, identifying the types of data worthy of collection, mechanisms for collection, and policies for safe and ethical collection are topics vital to resolve.

6. POESII-PT: Infrastructure

The infrastructure of the OE includes construction, building, and community planning, codes and standards, and components of the interface such as utilities, services, roads, and transportation architecture. In the 1970s, buildings were getting bigger and taller, and construction techniques and styles were changing. *America Burning* suggested that building codes be rewritten and fully implemented to prevent growing fire losses, and the success of this advice was a large part of the project’s success. The prescription was refined in both *America Burning Revisited* and *America at Risk: America Burning Recommissioned*. What emerges in the documents is a need for clear definitions of the WUI and better tools and infrastructure to fight fires. Answers such as Firewise, Ready, Set, Go!, the WUI Toolkit, and the *Homebuilder’s Guide to Construction in Wildfire* have promoted mitigation at many levels, fire adaptation, CWPPs, and smart growth and development in the interface. A consolidation of these examples into a single accepted standard might be useful for understanding and implementation.

¹⁹² U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis, vii.

The current OE invites codes and community plans that incentivize developers to create open space, paths, and fuel breaks. Establishing best practices in these and other mitigation vehicles would be useful, especially if scalable and modifiable, and communication of these plans should be simple, sharable, and open source ISO reframed the disaster-preparedness discussion in 2019, affirming that loss mitigation will require resiliency and that preparation means collaboration among property owners, government, businesses, insurance companies, and other partners. The building-code effectiveness-grading schedule rates communities on their commitment to code enforcement, because of its direct effects on insured losses after natural disasters. Wider use of this scale may increase resilience in the WUI. Incentivizing compliance is one option—dwellings built to meet or exceed code standards may enjoy a lower premium, reflecting lower losses.¹⁹³ A specific focus should be on critical-infrastructure protection for communication systems, data centers, and power utilities. Broader acceptance of building codes may be promoted through grants and best-practices education. Finally, superior management practices should be disseminated through conferences, workshops, and pilot programs,¹⁹⁴ and metrics should be usable by all agencies. These suggestions were fulfilled in the aftermath of *America Burning*.

The FEMA/DHS report called for increased infrastructure resilience, “especially critical infrastructure lifelines and support functions for wildland fire response.”¹⁹⁵ Resilient communication systems and dispatch centers, utility-company data sharing and connectivity, first responder connectivity, and data standards across response- and preparedness agencies are still needed.

¹⁹³ Verisk Analytics, *National Building Code Assessment Report: Building Code Effectiveness Grading Schedule*, 4.

¹⁹⁴ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” vi.

¹⁹⁵ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” ix.

7. POESII-PT: The Physical Environment

Attributes of the physical environment include terrain, topography, climate, weather, the WUI interface (if not considered as part of infrastructure), and hazards. The *National Fire Plan* recognized a need for more specific environmental considerations in policy making and fire management, discussing the environmental fallout of the USFS fire-exclusion doctrine and ecological role of fire.

WUI fires have altered landscapes, destroying forests, habitats, species, and watersheds. Fire also brings air-quality degradation, erosion, and soil damage. The 2014 *QFR* states that climate change is increasing temperatures, changing rain and moisture patterns, limiting water supplies, encouraging and then withering vegetation, and extending the fire season. Risk reduction in the natural environment can be improved by sound land management and mitigation throughout and within an adjacent community. Overall, there remains a need to streamline planning, funding, and approvals.

Recent research has focused on the types of communities that tend to suffer more structural burns. Kramer, Mockrin, Alexandre, and Radeloff note that close to one third of homes in the United States are built in proximity to wildland fuels, and that 50 percent of structures destroyed in the period of study were in interface WUI areas, in which structures are grouped in areas without vegetation, but near forests, grasslands, or brush. Intermix areas, where vegetation and structures are mingled, represented only 32 percent of total structures destroyed. While intermix numbers are lower, its fires are generally harder to manage. This suggests that wildfire policy is effective when focused on reducing building ignition through vegetation management close to structures and preventing structural ignition from firebrands. This is generally implemented at the local and state levels by regulating land use and planning. Policies should consider fuel styles and arrangements at the interface as well as the intermix, since most structures are destroyed at the interface. However, most fuel models do not consider this complexity. In sum, policy should consider

proper modeling, research on fire in dense areas, fuel reduction near structures, and strategies for communities, education, and planning.¹⁹⁶

8. POESII-PT: Time

Time as a POESII-PT factor includes perception, measurement, dates, periods, intervals, and events. As applied to the WUI, two facets must be considered: the short time available in responding to rapidly emerging WUI incidents, and season-based understanding of WUI risk. A recent FEMA and DHS Science and Technology Directorate research project discussed the speed at which WUI fires enter and devastate communities. Technology can extend these timeframes by realizing improvements to response, detection, and the speed at which decision making can occur. The report recommends the exploitation of RS assets such as aerial- and space-based systems and improvements to public warning and alert systems.¹⁹⁷

In general, the contemporary movement from the term “fire season” to “fire year” acknowledges the changing temporal context of fire risk. The season is now protracted, in part because snows may melt earlier and rain come later. Extended drought, aggravated tree mortality, and invasive tree, brush, and grass species have contributed to this change, as did early policies of exclusion. While organizations across the nation are planning year-round response, issues of year-round hiring, firefighter fatigue, and increased training, and maintaining qualifications and standards are a concomitant concern.¹⁹⁸ The implications of the fire year must be explored.

In reviewing the dates and times of major U.S. fires, discrete national trends appear. This is largely attributable to weather: extreme fire weather historically visits the Southwest in late spring and early summer, the Northeast in late summer and early fall, and California in the fall. Conditions in Florida and the rest of the Southeast are generally worse

¹⁹⁶ Heather Anu Kramer et al., “High Wildfire Damage in Interface Communities in California,” *International Journal of Wildland Fire* 28, no. 9 (2019): 1–10, <https://doi.org/10.1071/WF18108>.

¹⁹⁷ U.S. Fire Administration, “Wildland Urban Interface Fire Operational Requirements and Capability Analysis,” v.

¹⁹⁸ Deb Schweizer, “Wildfires in All Seasons?,” *USDA Blog* (blog), June 27, 2019, <https://www.usda.gov/media/blog/2019/06/27/wildfires-all-seasons>.

in the later and earlier months. Looking at California's ten deadliest fires, for example, most are in October or November. These trends are not difficult to follow and must be considered in planning.

V. FINDINGS AND CONCLUSIONS

The principal policy recommendation of this study is that a core report be issued that treats the WUI as a distinct and defined area demanding independent consideration.

A. A REPORT FOR THE WUI

A new report must be written for the WUI, with a call to action like those in preceding U.S. documents and an urgency reflecting the magnitude of conflagrations like the Camp fire and Australia's hellish 2019–2020 season. As in preceding documents, human behavior in and around WUI fires, fire dynamics, air quality and hazards, fire service and resource needs, prevention and mitigation should be covered. The report should be both minutely focused on building materials and fire resistance and globally focused on community preparedness and social change. Effects of the ISO and insurance issues should be thoroughly discussed.

The commissioning of new research and a new report is largely a political issue. The core documents pointed out a need for federal funding of prevention, mitigation, and response, and budgeting issues are squarely political in nature. Funding must be provided in categories other than response, and the political nature of this prescription becomes evident as the prospective roles of governmental, private, and non-profit players are outlined.

If the proposed report examines community planning; population movement out of urban environments; the economic effects of population trends; prevention and mitigation; water questions; access and egress; and evacuation and return, many parties will wish to participate. For this reason, a formal commission and cooperative buy-in are essential. Standardizing building and planning codes, for example, will trigger public reaction that study participants must be prepared to acknowledge. The study should investigate current issues such as the ramifications of electrical shutdowns and promote SA through sensing and data-gathering technologies.

B. NINE RECOMMENDATIONS

The remaining policy recommendations derived from this research require policy development and further research. The nine topics identified below were discussed and refined in an informal WFLC workgroup at the National Fire Academy in November 2019.

a. Risk Management

To some degree, every recommendation in this study is an exercise in risk reduction, just as the primary task of most the collaborators and allied professionals should be, in essence, risk reduction. WUI risk cannot be reduced to zero, but the ravages of wildland and WUI fire can be minimized through risk-reduction strategies. A policy that promotes collaborative risk-reduction strategies as the norm and formalizes the expectation that risk will always be present should be promulgated.

An academy should be developed that focuses on the WUI, with a curriculum that encourages groups interested in urban response and urban planning.

Incentives should be further explored. As in the code development and incentives that flowed from the *America Burning* series, builders and owners may be motivated to perform mitigations through insurance reductions, grant investments, and tax breaks. The research shows better compliance with a carrot than a stick. Incentives should be supported by a CWPP and programs such as Firewise, Ready, Set, Go!, and Living With Fire. In addition to the hardening of structures and fire-resistant community planning, incentivized fire adaptation should include the promotion of automatic sensing and detection, residential sprinklers, and external sprinkler systems in areas of extreme risk.

The core documents resulted in a number of oversight bodies to manage risk throughout the country, most prominently the USFA, NFA, FEMA, WFLC, WFEC, CSOC, and RSC. A single group should be formed to look at the WUI issue as a whole, perhaps synthesizing the WFLC, USFA and NWCG. In general, the WUI requires better governance and a better organizational strategy.

b. Emerging Technology

This research highlights some emerging technologies now applied to wildland and WUI fire-prevention processes and requirements. Fire policies should promote the invention and application of advanced technologies and encourage the broader employment of technologies currently underused. Awareness and continuous learning must be cultivated, and technology-transfer assistance must be available to get products to end users. Fire policies should promote the ubiquitous use of technologies that significantly improve intelligence and information collection for SA.

c. Community Planning

Establishing best practices for safer communities in the WUI is imperative, just as building codes and fire codes strengthened the urban/structural platform. Planning policies should be scalable to the necessary and appropriate level of utilization. The core documents cite public apathy and misunderstanding as powerful contributors to fire loss and casualties; policies for the WUI must overcome public inertia through better communications and incentives.

Regulations for the building and maintenance of fire-resistant infrastructure in the WUI must be written and enforced. Local CWPPs should routinely push mitigation, prevention, and preparedness efforts, while FACs should be formalized through all existing programs (e.g., Firewise). New development should adhere to codes that inform WUI ingress and egress and fire-resistant structures, and require allowances for safety zones to shelter those unable to evacuate. These policies should work in conjunction with any SDLE doctrines in place. Community codes should guarantee resilient infrastructure for utilities, water, and roadways and specify landscaping and natural materials that are resistant to fire and drought. The concept of fire adaptation and the creation of FACs should be formalized through policies that support their creation and maintenance.

d. Data/Modeling

Data-driven decision making requires the identification of desired data types, exploration of the methods and applications available, and employment of best technologies and

approaches. Policies should define the need and respond to the key issues that must be resolved in future policy making. NFIRS was a product of the *America Burning* series, but its success is still marginal because collaborative implementation has still not occurred.

Three general policies should be considered regarding data collection and use. First, a single platform for gathering information is necessary, similar to the NFIRS effort, but comprehensively accepted. Current practices make it very difficult to evaluate the full WUI situation, since data is not consolidated. WFIT and IRWIN have focused on this issue, but the solution should be formal and agreed upon by all partners. Second, a policy should be developed to use existing sources for incident information gathering and champion RS as a future strength. Finally, policies that mandate improved forms of public communications should be devised. Today's technologies can reach most people, and they should all be used.

e. Evacuation and Return

At all levels, we must explore better ways to communicate in regions and communities, define ways to move people rapidly and safely, and establish best and alternative strategies for evacuation. Ventura County, California, and Painted Rocks, Montana, are two examples of communities investigating this mandate; whatever their emphasis, all strategies or policies must be adaptable to local conditions and well communicated and understood.¹⁹⁹ Santa Fe, New Mexico, for instance, regards remaining in fire-hardened structures as a last resort, while Rancho Santa Fe, California, promotes shelter in place. Data on the results of these policies has yet to be collected—no communities have used these models in a wildfire event.²⁰⁰

Adopted policies must anticipate the most severe fires and worst days. Communication and warning systems should be boosted for timely and accurate sharing of emergency information. Refuges and assisted evacuation must be planned, and long-term

¹⁹⁹ McCaffrey and Rhodes, "Public Response to Wildfire: Is the Australian 'Stay and Defend or Leave Early' Approach and Option for Wildfire Management in the United States," 10.

²⁰⁰ Paveglio, Carroll, and Jakes, "Alternatives to Evacuation - Protecting Public Safety during Wildland Fire," 67.

community education programs should aim to improve public behavior and understanding. Shared responsibilities must be agreed to among all actors, whether individuals or agencies. Leaving a fire-threatened area early should be promoted as the best option, but staying to defend should also be discussed and provided for in less-extreme circumstances. Proper advice, sound preparation, and timely information are essential.²⁰¹

The specific policy topics that must be covered for success include

- trigger points, like those used in hurricanes, should be established for at-risk communities;
- agency understanding that a safe and effective model requires hardening of structures and a public well prepared through education and communication;
- cooperation in sharing and expanding knowledge;
- building high levels of social capital, based on a history of collaboration and trust, to encourage policy adoption and compliance;
- understanding the organizational culture of response and emergency-management agencies;
- including a wide variety of organizations;
- agency development and testing of methods for communicating new policies and their rationale. A communication plan is integral to any policy; and

²⁰¹ Victorian Bushfires Royal Commission, *2009 Victorian Bushfires Royal Commission: Final Report*, 6.

- collaborative frameworks for dissemination of accurate information to diverse populations. A shared vision will allow alternatives such as the SDLE model to be successfully implemented.²⁰²

f. Workforce Issues and Safety

Definitions are required for components of the organizational workforce that address the WUI. This research discovers several needs in this regard. First, there must be an emphasis on ensuring worker safety and wellness through resources such as aptitude and ability testing, annual physical examinations, behavioral-health assistance, and acknowledgement of post-traumatic stress disorders (PTSD) as a professional reality. Second, response and deployment standards for the WUI should be developed. Third, training and qualification standards should be adopted by all parties. The NWCG has made progress in this area, but collaborator agreements must be formalized.

A prime focus of the core documents was strengthening the national response system. Existing systems should be boosted through funding, oversight, and modernizing of collaborative interactions, response models, and capacity. The problem remains urgent, and policies to improve response are overdue.

g. Communications

Effective communication strategies can reduce risk during response operations and decrease the harm of fire in the WUI. In general, communications should be simple, consistent, and cohesive across all constituencies. Policies for communicating with the public before, during, and after incidents, and with partners in risk-reduction efforts, should be in place well before an emergency happens.

h. Economic Impacts

The economic consequences of wildland and WUI fires are ultimately related to historical policy decisions. Policymakers should be cognizant of the myriad financial

²⁰² Paveglio, Carroll, and Jakes, “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire,” 68.

repercussions of WUI incidents on the many public and private entities in a community. They should consider any new and alternative funding models available for WUI response, preparedness, and management.

The financial impacts of mitigation and fire-adaptation efforts on individual homeowners is a critical topic. Previous policy recommendations include providing incentives for owners to perform mitigation on their properties, through inducements such as insurance adjustments, tax breaks, and grant opportunities. The need continues, as does the solution.

i. Forest and Rangeland Health and Resiliency

It is important to educate WUI partners in a holistic approach to forest and rangeland health and resilience. While this question may preoccupy a fire chief in a local community, it is understood as vital by USDA and DOI land managers, because of its clear effects on risks in the WUI. Policies on risk reduction are greatly enhanced when adjacent land-management activities are coupled with mitigations within the community. Streamlining collaborative and cross-boundary project identification and planning is critical to the success of such policies, as are finding collective funding models, improving approval processes, and including multiple jurisdictions in discussions of non-federal land. The rehabilitation and restoration of fire-damaged lands was a topic of the *National Fire Plan*; to this should be added preparedness and mitigation through programs for hazardous-fuel reduction.

C. DISCUSSION

Among the findings of this study is a need for a practical standard definition of the WUI that accommodates regional variations and interpretations as necessary. A new definition—“the geographic area where structures and infrastructure interacts with burnable natural fuel”—is here proposed. Further, the term “fire season” should be abandoned for policy purposes; the “fire year” should be the norm.

Concerning responsibilities in prevention and control, the core documents clearly suggest that state and federal contributions center around technical and educational

assistance, data collection, regulation, research, and funding, with other duties relegated to local authorities. Clearly FACs should be promoted, especially the CWPP component. This research supports a policy that goes so far as to require communities to develop a CWPP as a prerequisite to community assistance.

A strong theme in the core documents is a need to formalize data collection and use. A single convening body should be assembled, and perhaps a series of groups formed to regionalize the results, as the RSCs did for the CS. Geographical differences in the WUI must be considered, and a structure should acknowledge this need.

POESII-PT analysis suggests that Australia's SDLE policy may translate well to U.S. policy-making. The SDLE approach was adopted in 2005; its most successful implementations have occurred in places of extreme risk, where residents likely seek alternatives to conventional approaches. The comparative ubiquity of wood shingles and siding in the U.S. would necessitate variations in SDLE policies, however, were the doctrine to be adopted in the U.S.²⁰³ Another potential difficulty is the variety and number of U.S. agencies that deal with wildland fire. In Australia, protection and prevention are consolidated among fewer agencies. Furthermore, while American agencies tend to handle both land management and response (with the exception of most local agencies, which focus on response), Australian agencies tend to specialize in one or the other.²⁰⁴ The mixed responsibility of U.S. agencies may dilute the focus required to plan an effective SDLE model. Australia is also helped by more centralized messaging and education, the importance of which cannot be overstated. This must be considered in any U.S. SDLE policy.²⁰⁵

The original *America Burning* saw the education of responders and the public as the first step in reducing losses. At the highest level, the federal government and response agencies should promote a stay-and-defend or leave-early policy for WUI fires. Most states

²⁰³ McCaffrey and Rhodes, "Public Response to Wildfire: Is the Australian 'Stay and Defend or Leave Early' Approach and Option for Wildfire Management in the United States," 11–12.

²⁰⁴ McCaffrey and Rhodes, "Public Response to Wildfire: Is the Australian 'Stay and Defend or Leave Early' Approach and Option for Wildfire Management in the United States," 12.

²⁰⁵ McCaffrey and Rhodes, "Public Response to Wildfire: Is the Australian 'Stay and Defend or Leave Early' Approach and Option for Wildfire Management in the United States," 13.

require that martial law be in force to mandate an evacuation,²⁰⁶ and the circumstances that might require martial law are exceptional. Response agencies might consider liability assessments in their preplanning and communications should a policy were to be considered.

A number of personnel-related issues are referred to in the core documents. The health and safety of personnel must always be primary, and standardized evaluation and testing processes and a comprehensive master plan would assist. RPL should be formalized as an avenue to achieving qualifications and developing a robust workforce. Finally, structuring workforce development around the concept of the fire year, rather than seasonal hiring, must be formalized, and a new paradigm for staffing devised. Part of the problem is that staff are generally all-risk responders now, which increases stress and requirements; additional resources must be supplied as expanded duties increase. Education and training should be standardized and certified, looking to colleges and universities for partnerships.

All future efforts should focus on spreading the fire-safe message and telling a compelling and persuasive story. Effective communications will go far in solving many WUI issues. The report recommended as a product of this research should be promulgated in all possible ways. A video clip should be produced for social media that talks about wildland and WUI risk, new technologies and tools, and other public-education points. Videos spread throughout the local social-media population would allow lifesaving messages to link fire departments and residents throughout the country with low logistical effort and cost. In general, the newest core documents must affirm the message of its predecessors: we must collaborative, all hands must be on deck, and non-traditional solutions are welcome.

D. LIMITATIONS

This research conducted data analysis based on historical data that is publicly available. It is intended as a starting point for future follow-up opportunities.

²⁰⁶ Encyclopedia.com. "Martial law," <https://www.encyclopedia.com/social-sciences-and-law/law/law-divisions-and-codes/martial-law>," n.d.

E. FUTURE RESEARCH

Additional research in many aspects of this thesis is warranted. First, for a new core document to sound a contemporary call to action, engagement sessions like those conducted previously will be necessary. These collaborative sessions should include all stakeholders in analyzing data on WUI problem and solutions.

Second, research on updated codes and standards, community planning and development, and landscape composition and arrangement is required.

Third, research should be performed on the ISO grading schedule and its relevance in suburban and rural environments. If insurance and funding decisions are based on this evaluation, further research should be examine results.

Fourth, research is needed in the deployment of communication strategies for emergency response, informing the public, social media as a preparedness and emergency-management tool, and the use of tracking devices for accountability. Up-to-the-minute communication technologies should be evaluated, along with promising systems such as FirstNet.

Fifth, future research should investigate testing and evaluation programs for firefighter ability, aptitude, and wellness. Studies should be done on the resiliency of the workforce, seasonal hiring, lengthening shifts, and increasing demands. Health and safety must continue to be a top focus, and this requires fresh data.

Finally, ongoing research is needed in the collection and use of data. The decision making of the future will be data driven, and further research will help prepare a platform that all can use effectively in defending the WUI.

LIST OF REFERENCES

- Abatzoglou, John T., and A. Park Williams. "Impact of Anthropogenic Climate Change on Wildfire Across Western Us Forests." *Proceedings of the National Academy of Sciences* 113, no. 42 (October 18, 2016): 11770–75.
<https://doi.org/10.1073/pnas.1607171113>.
- Ahrens, Marty. *Brush, Grass, and Forest Fires*. Quincy, MA: National Fire Protection Association, 2018.
- . *Trends and Patterns of U.S. Fire Loss*. Quincy, MA: National Fire Protection Association, 2017. <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osTrends.pdf>.
- . *US Fire Death Rate by State*. Quincy, MA: National Fire Protection Association, 2019. <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osstate.pdf>.
- Badger, Stephen. "Catastrophic Multiple-Death Fires and Explosions in the United States in 2018." *NFPA Journal*, October 2019. <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2019/September-October-2019/Features/Catastrophic>.
- Badger, Stephen G. *Large-Loss Fires in the United States 2017*. Quincy, MA: National Fire Protection Association, 2018.
- Barron, Laignee, and Mahita Gajanan. "Why California's Fires Are Bigger, Deadlier, and More Costly." *Time*, November 13, 2018. <https://time.com/4985252/california-wildfires-fires-climate-change/>.
- Bolstad, Cheryl A., Mica R. Endsley, and SA Technologies. "Measuring Shared and Team Situation Awareness in the Army's Future Objective Force." *Proceedings of the Human Factors and Ergonomics Society* 47, no. 3 (2003): 369–73.
<https://doi.org/10.1177%2F154193120304700325>.
- Booz Allen Hamilton. "2014 Quadrennial Fire Review." Washington, DC: USDA Forest Service Fire & Aviation Management and Department of the Interior Office of Wildland Fire, May 2015.
<https://www.forestsandrangelands.gov/documents/qfr/2014QFRFinalReport.pdf>.
- Bushfire Cooperative Research Centre. "The Stay and Defend Your Property or Go Early Policy." *Fire Note*, October 2006.

- Clark, Baldwin V. Jr. “Accomplishing and Applying National Fire Plan Research and Development from 2001-2005.” Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2007. <https://doi.org/10.2737/RMRS-GTR-187>.
- Conway, Geoff. “AIIMS Doctrine: Have We Got the Fundamentals Right?” 27, no. 2 (2012): 4.
- Cova, Thomas J., Philip E. Dennison, Tae H. Kim, and Max A. Moritz. “Setting Wildfire Evacuation Trigger Points Using Fire Spread Modeling and GIS.” *Transactions in GIS* 9, no. 4 (October 2005): 603–17. <https://doi.org/10.1111/j.1467-9671.2005.00237.x>.
- Department of Agriculture, and Department of the Interior. *Managing the Impact of Wildfires on Communities and the Environment*. Washington, DC: United States Department of Agriculture and Department of the Interior, 2000.
- Department of Agriculture, Forest Service. *National Fire Plan Research and Development 2001 Business Summary*. Saint Paul, MN: North Central Research Station, 2001. <https://www.nrs.fs.fed.us/pubs/misc/NFPR2001.pdf>.
- Department of Homeland Security, Federal Emergency Management Agency, and U.S. Fire Administration. *Wildland Urban Interface Fire Operational Requirements and Capability Analysis: Report of Findings*. Washington, DC: Department of Homeland Security Science and Technology Directorate, 2019.
- Department of the Army. *Operational Environment and Army Learning*. TC7-102. Washington, DC: Department of the Army, 2014. https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/tc7_102.pdf.
- Elsworth, Gerald, Kaye Stevens, John Gilbert, Helen Goodman, and Alan Rhodes. *Evaluating the Community Safety Approach to Bushfire: An Initial Theory-Based Synthesis of Research on Seven Australian Initiatives*. Melbourne, Australia: Bushfire Cooperative Research Centre and School of Global Studies, Social Science and Planning, RMIT University, 2008. <https://doi.org/10.13140/rg.2.1.3626.1207>.
- Endsley, Mica R. “Toward a Theory of Situation Awareness in Dynamic Systems.” *Human Factors* 37, no. 1 (1995): 32–64.
- Evarts, Ben. *Fire Loss in the United States During 2017*. Quincy, MA: National Fire Protection Association, 2018.
- Evarts, Ben, and Gary Stein. *U.S. Fire Department Profile 2017*. Quincy, MA: National Fire Protection Association, 2019. <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/osfdprofile.pdf>.

- Federal Emergency Management Agency. *America at Risk - America Burning Re commissioned*. Washington, DC: Government Printing Office, 2002. <https://www.hsdl.org/?abstract&did=745307>.
- . “Fire-Related Firefighter Injuries Reported to the National Fire Incident Reporting System (2015-2017).” *Topical Fire Report Series 20*, no. 2 (July 2019): 1–15.
- Federal Emergency Management Agency, and U.S. Fire Administration. *America Burning Revisited*. Washington, DC: Government Printing Office, 1990. <https://www.hsdl.org/?view&did=446407>.
- FireSmart Canada. “Firesmart Home Partners Program: Take Action on Your Property to Reduce Wildfire Risks.” Partners in Protection, n.d.
- Forests and Rangelands. *Wildland Fire Management: The National Fire Plan (2007 Budget Justification)*. Washington, DC: Department of the Interior and Department of Agriculture, n.d. https://www.forestsandrangelands.gov/documents/resources/reports/2007/nfp2007_budget_justification.pdf.
- Haynes, Hylton, Angela Garcia, and Rachel Madsen. *Wildland/Urban Interface: Fire Department Wildfire Preparedness and Readiness Capabilities*. Quincy, MA: National Fire Protection Association, 2015. <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/WUI/osWUIPhase1.ashx?la=en>.
- Hermansen-Baez, L. Annie, Jennifer Seitz, and Martha C. Monroe. “Wildland Urban Interface: Varied Definitions.” Gainesville, FL: IFAS Extension, University of Florida, July 2009. <https://edis.ifas.ufl.edu/pdf/FR/FR28700.pdf>.
- Hilbruner, Michael, and Susan Conard. *USDA Forest Service National Fire Plan: Research & Development*. Washington, DC: Department of Agriculture, Forest Service, 2004. https://www.forestsandrangelands.gov/documents/resources/overview/nfp_research/2003rdbusinesssummary.pdf.
- Hinds-Aldrich, Matt, Melissa Knight, Adele Nicolosi, and Benjamin Evarts. *National Fire Data Survey: Findings on the State of the Existing American Fire Data Ecosystem*. Quincy, MA: National Fire Protection Association, 2017. <https://www.nfpa.org/-/media/Files/News-and-Research/NFDS/osNFDSSurvey%20>
- Huber, Kristiane. *Resilience Strategies for Wildfire*. Arlington, VA: Center for Climate and Energy Solutions, 2018.

- Infoplease. "Worst U.S. Forest Fires." InfoPlease, February 11, 2017.
<https://www.infoplease.com/world/disasters/natural/worst-us-forest-fires>.
- Insurance Information Institute. "Facts + Statistics: Wildfires." Insurance Information Institute. Accessed July 6, 2019. <https://www.iii.org/fact-statistic/facts-statistics-wildfires>.
- International Association of Fire Chiefs. "A Fire Service Leader's Guide." Chantilly, VA: International Association of Fire Chiefs, n.d.
- . "What Is the Wildland-Urban Interface?" Ready, Set, Go! Accessed July 17, 2019. <https://www.wildlandfirersg.org/About/Wildland-Urban-Interface>.
- . *Wildland–Urban Interface: Chief's Guide*. Chantilly, VA: International Association of Fire Chiefs, 2018. <https://www.iafc.org/topics-and-tools/resources/resource/WuiChiefsGuide>.
- IRWIN Core Team. *Irwin Project Management Plan*. Boise, ID: Department of Interior, 2018.
<https://www.forestsandrangelands.gov/documents/wfit/applications/IRWIN/IRWIN-ProjectManagementPlan-v51.pdf>.
- Janse, Ben. "What Is PMESII-PT? A Powerful Strategy and Management Tool." *Toolshero* (blog), March 23, 2019. <https://www.toolshero.com/strategy/pmesii-pt/>.
- Kramer, Heather Anu, Miranda H. Mockrin, Patricia M. Alexandre, and Volker C. Radeloff. "High Wildfire Damage in Interface Communities in California." *International Journal of Wildland Fire* 28, no. 9 (2019): 641–50.
<https://doi.org/10.1071/WF18108>.
- Loh, Elise. *What Does the "Prepare, Stay and Defend, or Leave Early" Policy Mean for Me?: Legal Liabilities of Emergency Workers and Emergency-Service Organisations in South Australia*. East Melbourne, Victoria: Bushfire Cooperative Research Centre, 2007.
http://www.bushfirecrc.com/sites/default/files/managed/resource/stay_or_go_legal_south_australia_jul-07.pdf.
- Lustgarten, Abraham. "Mandatory Blackouts." *The New York Times Magazine*, October 27, 2019.
- Martin, Drew, Mai Tomida, and Brian Meacham. *The Environmental Impact of Fire*. Quincy, MA: Fire Protection Research Foundation, 2015.
- McCaffrey, Sarah M., and Alan Rhodes. "Public Response to Wildfire: Is the Australian 'Stay and Defend or Leave Early' Approach and Option for Wildfire Management in the United States." *Journal of Forestry* 107, no. 1 (February 2009): 9–15.

- McGee, Tara K., Bonita L. McFarlane, Lauren Harris, and Hillary Faulkner. *Human Dimensions of Fire Management at the Wildland-Urban Interface in Alberta: A Summary Report*. Toronto, Canada: Institute for Catastrophic Loss Reduction, 2009. http://epe.lac-bac.gc.ca/100/200/300/institute_for_catastrophic/iclr_research_paper-ef/no46/McGee_et_al_2009.pdf.
- National Commission on Fire Prevention and Control. *America Burning*. Washington, DC: National Commission on Fire Prevention and Control, 1973. <https://www.usfa.fema.gov/downloads/pdf/publications/fa-264.pdf>.
- National Fire Protection Association. *Fourth Needs Assessment of the U.S. Fire Service: Conducted in 2015 and Including Comparisons to the 2001, 2005, and 2010 Needs Assessment Surveys*. Quincy, MA: National Fire Protection Association, 2016. <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Emergency-responders/Needs-Assessment/OSFourthNeedsAssessment.ashx>.
- National Interagency Fire Center. “Federal Firefighting Costs (Suppression Only).” Boise, ID: National Interagency Fire Center, 2018. https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf.
- . “Wildfires Larger Than 100,000 Acres.” National Interagency Fire Center. Accessed July 6, 2019. https://www.nifc.gov/fireInfo/fireInfo_stats_lgFires.html.
- National Wildfire Coordinating Group. *NWCG Data Management Strategy*. PMS 940. Boise, ID: National Wildfire Coordinating Group, 2018.
- . *NWCG Report on Wildland Firefighter Fatalities in the United States: 2007-2016*. PMS 841. Boise, ID: National Wildfire Coordinating Group, 2017.
- . *Wildfire Prevention Strategies*. PMS 455. Boise, ID: National Wildfire Coordinating Group, 1998.
- . *Wildland Urban Interface Wildfire Mitigation Desk Reference Guide*. Boise, ID: National Wildfire Coordinating Group, 2019.
- Paveglio, Travis, Matthew S Carroll, and Pamela J Jakes. “Alternatives to Evacuation - Protecting Public Safety during Wildland Fire.” *Journal of Forestry* 106, no. 2 (March 2008): 65–70.
- Pyne, Stephen J. “The Fires This Time, and Next.” *Science* 294, no. 5544 (November 2, 2001): 1005–6.
- Radeloff, V. C., R. B. Hammer, S. I. Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. “The Wildland–Urban Interface in the United States.” *Ecological Applications* 15, no. 3 (June 2005): 799–805. <https://doi.org/10.1890/04-1413>.

- Radeloff, Volker C., Roger B. Hammer, and Susan I. Stewart. "Rural and Suburban Sprawl in the U.S. Midwest from 1940 to 2000 and Its Relation to Forest Fragmentation." *Conservation Biology* 19, no. 3 (June 2005): 793–805. <https://doi.org/10.1111/j.1523-1739.2005.00387.x>.
- Radeloff, Volker C., David P. Helmers, H. Anu Kramer, Miranda H. Mockrin, Patricia M. Alexandre, Avi Bar Massada, Van Butsic, et al. "The 1990–2010 Wildland–Urban Interface of the Conterminous United States: Geospatial Data." Washington, DC: U.S. Forest Service, 2015. <https://doi.org/10.2737/RDS-2015-0012-2>.
- Riverside County Mountain Area Safety Taskforce. *Evacuating to Safety: A Wildfire Evacuation Guide for Residents and Visitors of the Mountain Communities of Riverside County*. Riverside County, CA: Riverside County Mountain Area Safety Taskforce, 2005.
- Ronchi, Enrico, Steven Gwynne, Guillermo Rein, Rahul Wadhvani, Paolo Intini, and Albin Bergstedt. *E-Sanctuary: Open Multi-Physics Framework for Modelling Wildfire Urban Evacuation*. Quincy, MA: Fire Protection Research Foundation, 2017.
- Schoennagel, Tania, Cara R. Nelson, David M. Theobald, Gunnar C. Carnwath, and Teresa B. Chapman. "Implementation of National Fire Plan Treatments near the Wildland-Urban Interface in the Western United States." *Proceedings of the National Academy of Sciences* 106, no. 26 (June 30, 2009): 10706–11. <https://doi.org/10.1073/pnas.0900991106>.
- Schweizer, Deb. "Wildfires in All Seasons?" *USDA Blog* (blog), June 27, 2019. <https://www.usda.gov/media/blog/2019/06/27/wildfires-all-seasons>.
- Shahparvari, Shahrooz, Babak Abbasi, and Prem Chhetri. "Possibilistic Scheduling Routing for Short-Notice Bushfire Emergency Evacuation under Uncertainties: An Australian Case Study." *Omega* 72 (October 2017): 96–117. <https://doi.org/10.1016/j.omega.2016.11.007>.
- Society of American Foresters. *Preparing a Community Wildfire Protection Plan: A Handbook for Wildland–Urban Interface Communities*. Bethesda, MD: Society of American Foresters, 2004.
- Stewart, Susan I., Volker C. Radeloff, Roger B. Hammer, and Todd J. Hawbaker. "Defining the Wildland–Urban Interface." *Journal of Forestry* 105, no. 4 (June 2007): 201–7. <https://doi.org/10.1093/jof/105.4.201>.
- Summerfelt, Paul. "The Wildland/Urban Interface: What's Really at Risk?" *Fire Management Today* 63, no. 1 (Winter 2003): 4–7.

- U.S. Department of the Interior, and U.S. Department of Agriculture. *Federal Wildland Fire Management Policy & Program Review*. Boise, ID: National Interagency Fire Center, 1995.
https://www.forestsandrangelands.gov/documents/strategy/foundational/1995_fed_wildland_fire_policy_program_report.pdf.
- U.S. Fire Administration. “Fire Department Overall Run Profile as Reported to the National Fire Incident Reporting System (2017).” *Topical Fire Report Series* 20, no. 1 (May 2019): 1–10.
- . *Fire in the United States: 1986–1995*. 10th ed. FA-183. Washington, DC: Federal Emergency Management Agency, 1998.
- . *Fire in the United States: 2006–2015*. 19th ed. Washington, DC: Federal Emergency Management Agency, 2017.
<https://www.hsdl.org/?view&did=806524>.
- . *Firefighter Fatalities in the United States in 2017*. Washington, DC: Federal Emergency Management Agency, 2018.
- . *Firefighter Fatalities in the United States in 2018*. Washington, DC: Federal Emergency Management Agency, 2019.
- . *Wildland Urban Interface Fire Operational Requirements and Capability Analysis*. Washington, DC: Federal Emergency Management Agency, 2019.
- . *Your Role in Fire-Adapted Communities*. Washington, DC: Federal Emergency Management Agency, 2012.
https://www.usfa.fema.gov/downloads/pdf/publications/fire_adapted_communities.pdf.
- Verisk Analytics. *National Building Code Assessment Report: Building Code Effectiveness Grading Schedule*. Jersey City, NJ: Insurance Services Office, 2019.
- Victorian Bushfires Royal Commission. *2009 Victorian Bushfires Royal Commission: Final Report*. Melbourne, Victoria: Government Printer for the State of Victoria, 2010.
- Western Governors’ Association. “A Call to Action.” Western Governors’ Association, January 23, 2009.
- Wildland Fire Leadership Council. *A National Cohesive Wildland Fire Management Strategy*. Washington, DC: Department of the Interior and Department of Agriculture, 2011.

———. *The National Strategy: The Final Phase in the Development of the National Cohesive Wildland Fire Management Strategy*. Washington, DC: Departments of Interior and Agriculture, 2014.

Yarnell Hill Fire, June 30, 2013: Serious Accident Investigation Report. Phoenix, AZ: Arizona State Forestry Division, 2013.

Yin, Minchao. “A Collection of Geospatial Technological Approaches for Wildland and Wildland Urban Interface (WUI) Fire Events.” Quincy, MA: The Fire Protection Research Foundation, December 2014.

Zhuang, Jun, Vineet M. Payyappalli, Adam Behrendt, and Kathryn Lukasiewicz. *Total Cost of Fire in the United States*. Quincy, MA: Fire Protection Research Foundation, 2017.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California