Air Quality Summary Report for the 2015 Pacific Northwest Fire Year

USDA Forest Service

September 2016

Acknowledgements

The report was written by Richard L. Graw, Janice L. Peterson, and James A. Miller of the USDA Forest Service Pacific Northwest Region. The authors wish to express their appreciation to Isaiah Hirschfield and Mike Powell of the Northwest Interagency Coordination Center for providing the fire statistics and information about structures lost. Roger Ottmar and Susan Prichard of the Fire and Environmental Research Application (FERA) team of the Pacific Wildland Fire Laboratory provided the methodology to calculate emissions from the fires. Susan determined the fuel types and fuel bed for each fire perimeter in both states. Roger provided the emissions for the wildfires in Washington. Air quality monitoring data for the permanent monitors in Washington was provided by Ranil Dhammapala of the Washington Department of Ecology and in Oregon by Anthony Barnack of the Oregon Department of Environmental Quality. Prescribed fire information in Washington was provided by Steve Freidenberg of Washington Department of Natural Resources and in Oregon by Nick Yonker of the Oregon Department of Forestry. Fuel Treatment Effectiveness Monitoring results were contributed by several individuals including Jeff Bouschor of the Okanogan-Wenatchee National Forest, Laura Mayer of the USDA Forest Service Pacific Northwest Regional Office and Paul Keller of the USDA Forest Service Wildland Fire Lessons Learned Center.

Cover Photo: *An eerie orange glow enveloped Portland on the morning of August 22, 2015 as low-level easterly winds brought wildfire smoke from the interior Pacific Northwest into the Willamette Valley causing low visibility and high concentrations of particulate matter that lasted for two days. Photo by James Miller, USDA Forest Service.*

Executive Summary

The 2015 Pacific Northwest wildfire season was one in which more than a million acres was burned in Washington and approximately two-thirds of a million acres burned in Oregon. Tragically, three wildland firefighters lost their lives. Additionally, 634 homes and other structures were destroyed by wildfire. More than 3800 fires occurred on the landscape; 102 of which met the large fire criteria. Fire suppression efforts cost more than $560 million.

The air pollution emissions from these fires was equally large. In Washington, approximately 130,000 tons of fine particulate matter (PM2.5) and 26.5 million tons of greenhouse gases were released from the fires. In Oregon, the fires released approximately 90,000 tons of PM2.5 and 14.2 million tons of greenhouse gases. The greenhouse gas emissions alone were equivalent to more than 8.5 million passenger vehicles driven for a year or heating 3.7 million homes.

Nearly everywhere in the Pacific Northwest was affected by smoke. In Washington, Nespelem, Republic and Omak were hardest hit where people experienced two to three weeks of unhealthy air quality. Nespelem was impacted the hardest with 10 of these days ranked “hazardous”. Even the west-side of the state was impacted by the fires; these areas experienced at least one day of unhealthy air attributable to wildfire smoke.

In Oregon, the southwestern portion of the state was impacted the most, with between two and three weeks of unhealthy air quality. Areas in Eastern Oregon such as Baker City and Enterprise also experienced at least a week of unhealthy air. Shady Cove had the worst smoke impacts when air quality deteriorated to the “hazardous” level for a day.

In response to the severe smoke events, federal, state, and local government agencies collaborated in anticipation of the needs of the public. States and incident management teams monitored air quality in near real time. Health authorities provided guidance to the public on how to protect one’s self from smoke. Air quality forecasts were provided by the Oregon Department of Forestry, the US EPA, the Washington Department of Ecology, and the US Forest Service. Air quality alerts were issued through a number of venues including news releases, postings on state and county websites, posts on the state smoke blogs, and National Weather Service websites.

However, wildfires aren’t the only cause of smoke. Prescribed fire (also known as controlled burning) also causes smoke emissions and air quality impacts. Land managers conducted 5,513 controlled burns, in the two-state region in 2015. These burns helped restore and maintain resilient ecosystems in their desired states. In Oregon, approximately 180,000 acres were burned using prescribed fire. In Washington, approximately 63,000 acres were burned using controlled fire. Emissions from prescribed burning in Washington were equivalent to approximately 2% emitted by wildfire.

Land managers have long recognized the need for fire on the landscape to fulfil its ecological role as a natural decomposer of wood. Without fire on the landscape, fuels buildup to unnatural levels and forests become overcrowded. This led to forests being more susceptible t to insects and disease outbreaks, but also to unnaturally large fires on the landscape.

Currently, the Forest Service as well as state and private land managers have expressed a need to increase the pace and scale of restoration on the landscape, especially through the use of fuel treatments. Mechanical treatments are helpful in reducing stand density and opening up forests to allow shade-intolerant species to reproduce. However, because most wildfires spread through surface fuels such as grasses and shrubs, prescribed burning is also needed. Thus the combination of mechanical treatments followed by prescribed burning is needed to improve forest health and reduce risk of the spread of wildfires.

However, there are limitations to accomplishing the pace and scale of the desired treatments across the 10 million acres in need of forest restoration in Oregon and Washington. There are only a limited number of days each in which the fuel moisture and weather conditions are within prescription as needed to achieve the desired silvicultural objectives of each burn. Additionally, budgetary and resource availability constrain efforts to accomplish fuel treatments. Further, air quality regulations further limit opportunities to conduct prescribed burning.

As there is no single solution to this issue, all potential solutions must be examined and optimized. One aspect of this strategy is for land managers and air quality regulators to increase their collaboration by examining current policies and practices to improve upon the current situation.

This report, along with subsequent reports in the years to come, provides useful information to evaluate policy and adjust management actions to balance needs for forest restoration and air quality.

Introduction

Smoke from wildfires can cause serious health concerns to the public and fire personnel. Smoke can reduce visibility, impairing transportation safety and restricting the ability to use aviation resources for wildfire suppression. Impaired air quality, sometimes at levels deemed hazardous by EPA's National Air Quality Index, impacts public health, community cohesiveness, and local economies. When it gets too smoky; tourists stay away; community fairs, outdoor concerts and sporting events are cancelled; children are kept indoors; and many local residents leave town in search of clean air.

In the past few wildfire seasons, many federal, state, and local agencies in the Pacific Northwest have worked in partnership to provide near real-time information about air quality conditions and recommend actions needed to protect public health and welfare. These efforts include monitoring air quality, providing smoke dispersion and concentration forecasts, conducting daily coordination calls, and issuing public health advisories. This report documents the magnitude and duration of the wildfire smoke events of 2015, and the partnership efforts of the many agencies involved in helping to understand and communicate air quality impacts with the public and fire personnel. The analyses in this report are also useful for understanding the severity and geographic extent of the smoke impacts and comparing air quality conditions experienced during the 2015 wildfire season with other times of the year (such as during prescribed burning season) to help characterize tradeoffs. Additionally, wildfires emit tremendous amounts of greenhouse gases, a topic of great interest to a wide range of audiences.

This report is divided into nine sections.

- Section 1 provides a summary of the large wildfires that occurred in Oregon and Washington in 2015 and the type of vegetation burned.
- Section 2 presents information about particulate and greenhouse gas emissions from the fires, including the variations in emissions between vegetation types and fire severity.
- Section 3 presents a summary of monthly meteorology during the summer wildfire season. It highlights anomalies which occurred in June and presents a case study of the meteorology associated with the August smoke event which impacted Portland and surrounding areas.
- Section 4 presents information on air quality impacts associated with the fires. It illustrates the number of days which exceeded unhealthy conditions at each monitoring location and presents tables summarizing the number of days by Air Quality Index (AQI) category by monitoring location. It also quantifies the number of people exposed to unhealthy levels of air pollution by day throughout the summer.
- Section 5 presents a discussion of what actions were taken to inform the public of air quality conditions and recommended actions they could take to minimize exposure. It includes a discussion of the use of air resource advisors, smoke blogs, and other means in which information was distributed to the public.
- Section 6 presents information about prescribed fire including emissions and air quality impacts.
- Section 7 presents a discussion of fuel treatments. It highlights a few cases in which wildfires interacted with lands where fuel treatments had been applied and the results. A particularly interesting example from the Chelan Complex compares the fire interaction with untreated, thinned-only, and thinned and burned fuel treatments.
- Section 8 presents a discussion of the current trends in wildfire and air quality regulations and the challenges in increasing the pace and scale of forest restoration.
- Section 9 presents the conclusion from this report.

1.0 Wildfires

The 2015 fire season in the PNW was one of the most severe in modern history from a variety of metrics (USDA Forest Service, 2015). Table 1 presents summary statistics of the 2015 wildfire season for both Oregon and Washington and compares the values with the average from the previous 10 years. In 2015, Oregon and Washington experienced more than 3,800 wildfires that burned more than 1,775,000 total acres. While Oregon experienced less than the 10-yr average number of fires, the total acres burned was 55% higher than average. In Washington, the number of fires experienced was not only greater than the 10-year average, the total number of acres burned was 6 to 7 times greater than average. The Canyon Creek Complex was the largest fire in Oregon which burned more than 110,000 acres near John Day. The North Star fire was the largest fire in Washington, which burned more than 210,000 acres southwest of Republic. Tragically, three wildland firefighters lost their lives in the Twisp River fire in Washington. Additionally, 634 homes and other structures were destroyed.

Table 1. 2015 Northwest Wildfire Statistics

Metric	Oregon	Washington
Number of Fires in 2015	2273	1541
Number of Fires: 10-Yr Average (2005-2014)	2592	1355
Number of Large Fires*	43	59
Acres affected by wildfires	685,809	1,089,966
Acres Burned: 10-Yr Average (2005-2014)	442,963	152,281
Largest Fires by State	Canyon Creek Complex (110, 422 acres)	North Star (218,138 acres)
Homes and Structures Lost	135	499
Fatalities	0	3

**A large fire is at least 100 acres in timber or 300 acres in grass or brush.*

Figure 1 shows the locations of the large wildfires that burned in Oregon and Washington in 2015. In Washington, the majority of the fires occurred in the north central and north east portion of the State. In Oregon, the majority of the fires occurred in northeastern and southwestern portions of the state.

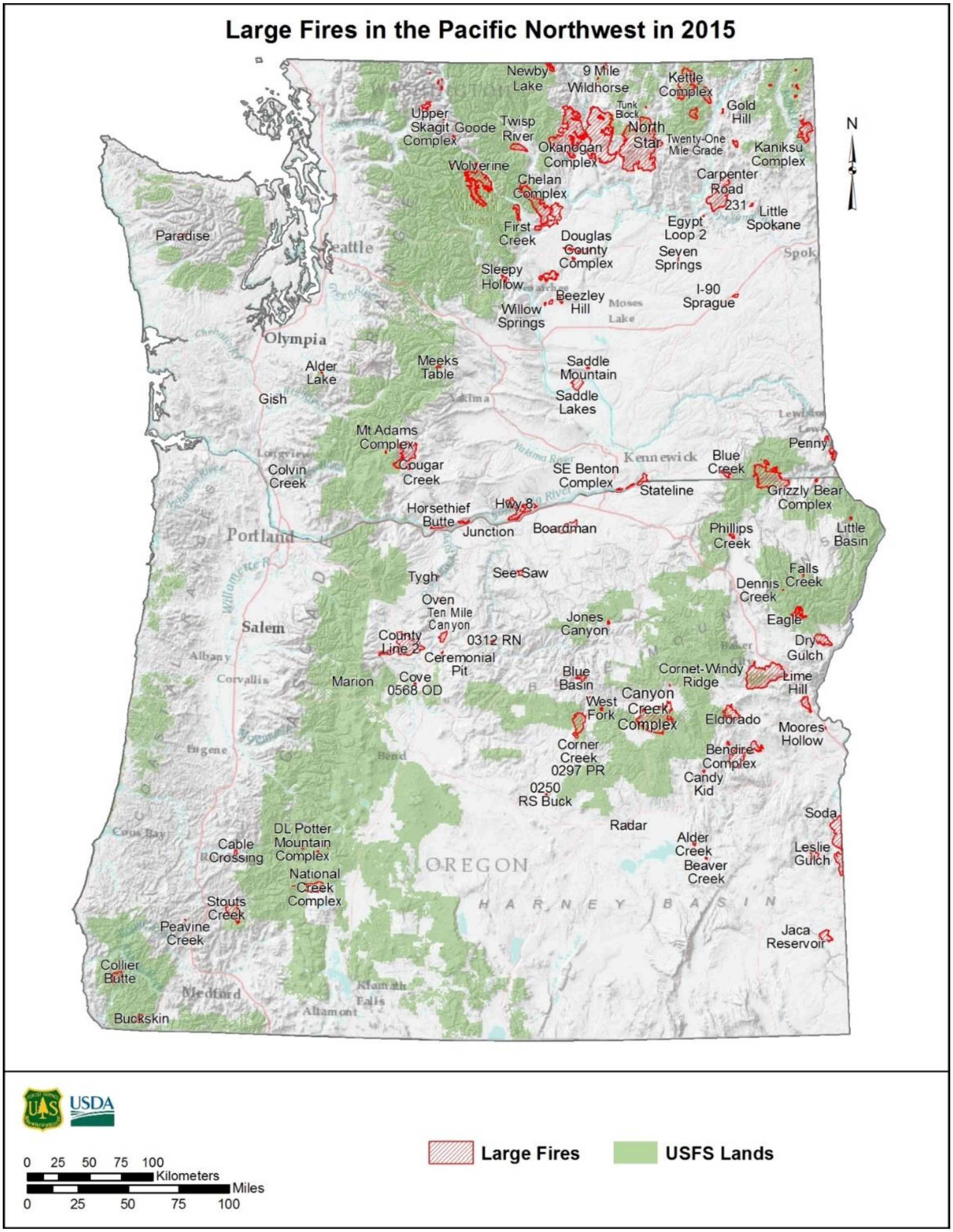

Figure 1. Location and extent of large fires that burned in the Pacific Northwest in 2015.

Fire starts in the Pacific Northwest are often caused by the combination of natural ignitions from lightning and ground fuels that are dry and flammable; although humans are the source of a significant number of starts too. Only a small percentage of all fire starts escape initial attack to become large wildfires. Figure 2 illustrates the number of large fires across the region during 2015 as the wildfire season progressed throughout the summer.

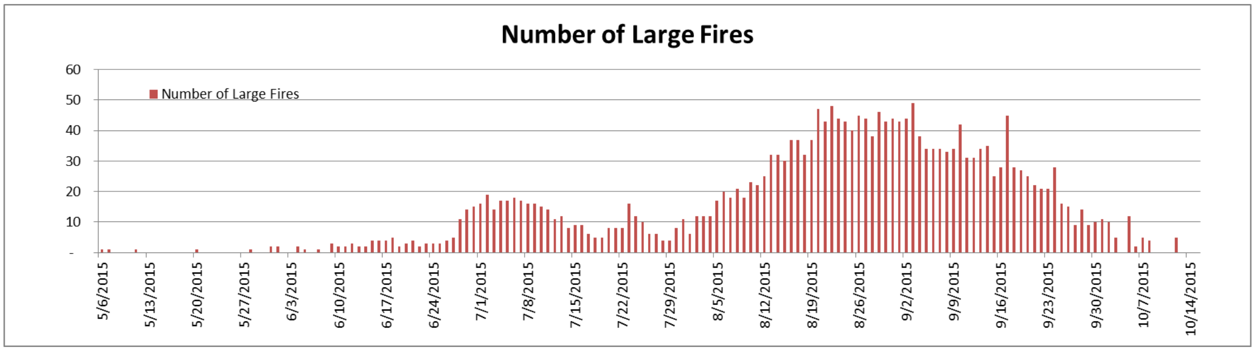

Figure 2. Number of Pacific Northwest large fires by day in 2015.

Once a wildfire grows larger than 100 acres on forested land or 300 acres on rangeland it's classified as a large fire. A large fire's growth and resultant emissions are not steady; much of the growth often occurs in only a few days. Once fires are ignited, two primary factors lead to days with large fire growth: enhanced meteorological instability and strong winds. Enhanced instability is often indicated by the presence of the thermal ridge at the surface. Strong winds are associated with strong pressure gradients. Figure 3 illustrates the growth on large fires throughout the season. Much of the large fire growth during 2015 occurred in August.

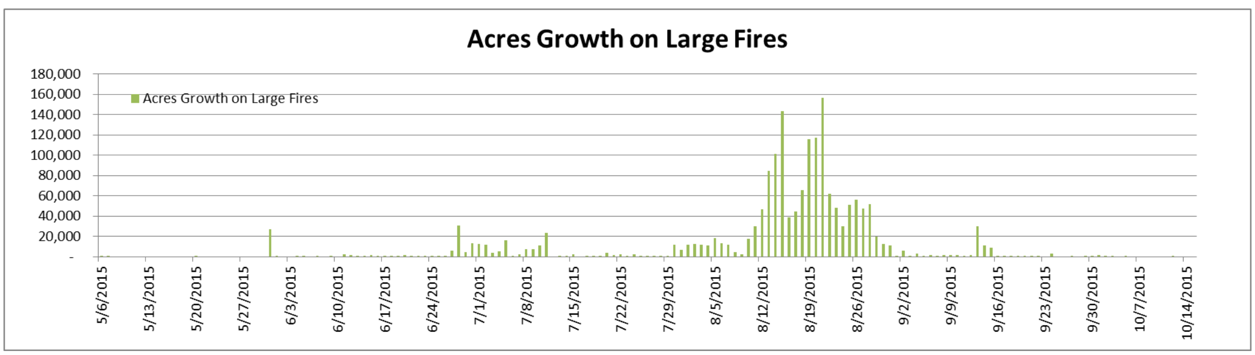

Figure 3. Growth of Pacific Northwest large fires by day in 2015.

The fires burned in many different types of vegetation across the region and fuels were determined as follows. In Washington, fire perimeters and vegetation cover type were obtained from the Washington Department of Natural Resources (WDNR) as provided to the USDA Forest Service Fire Sciences Lab (Ottmar R.D., personal communication). In Oregon, fire perimeters were obtained from the Northwest Interagency Coordination Center (NWCC) and overlaid on a map of existing vegetation. Geographic Information System (GIS) software was used to determine total acreage of each vegetation type.

Figure 4 illustrates the different types of vegetation and amount burned by wildfires in Washington for fires larger than 7500 acres. The fires burned relatively large amounts of Ponderosa pine (*P. ponderosa*) forests, Douglas fir (*Pseudotsuga menziesii*) forests, native perennial grasses, and exotic annual grasses.

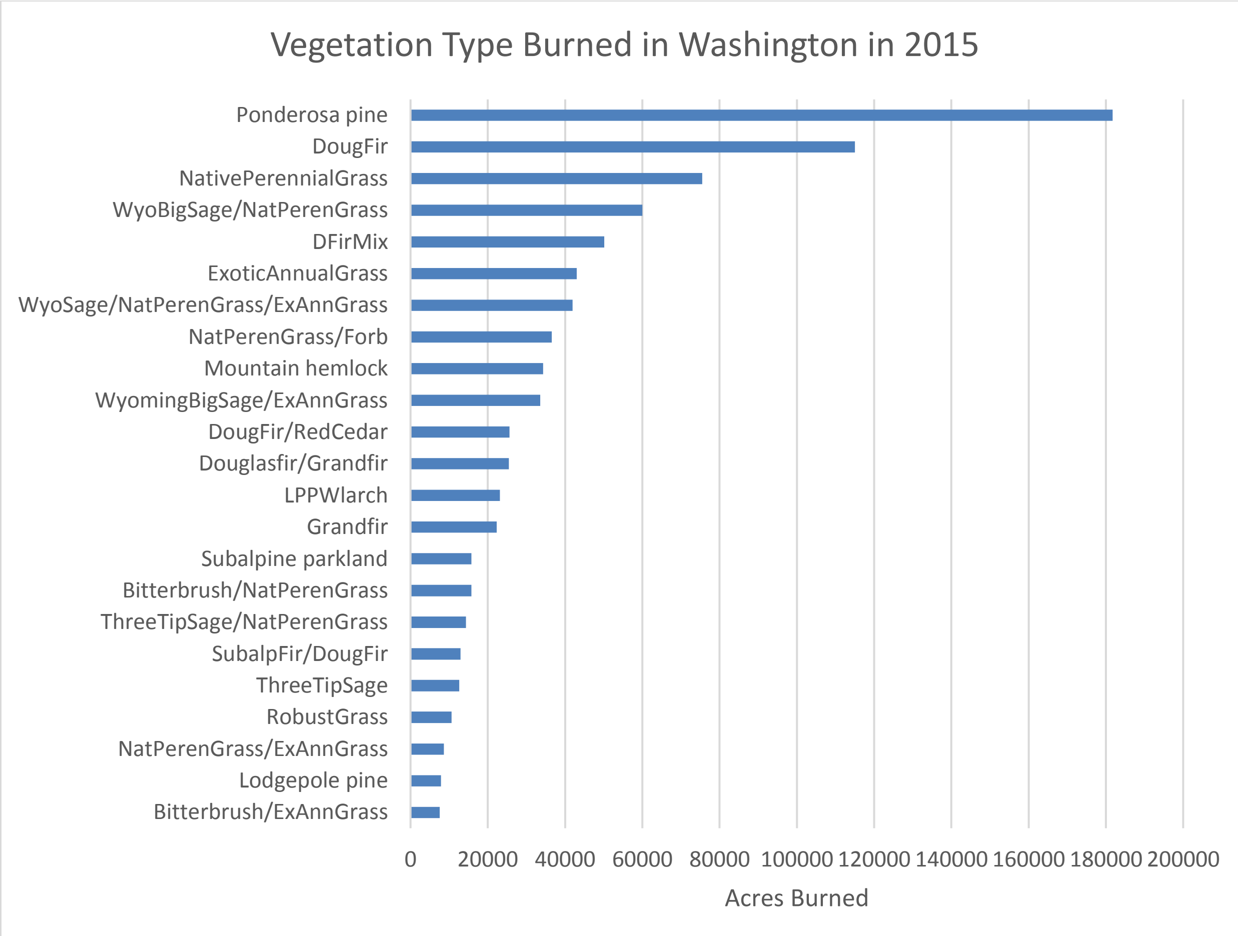

Figure 4 Vegetation type burned by wildfires in Washington

In Oregon, fires burned through nearly 130,000 acres of Douglas-fir/Pacific Ponderosa Pine/Oceanspray Forest and approximately 170,000 acres of sparse sagebrush shrubland, in Oregon.

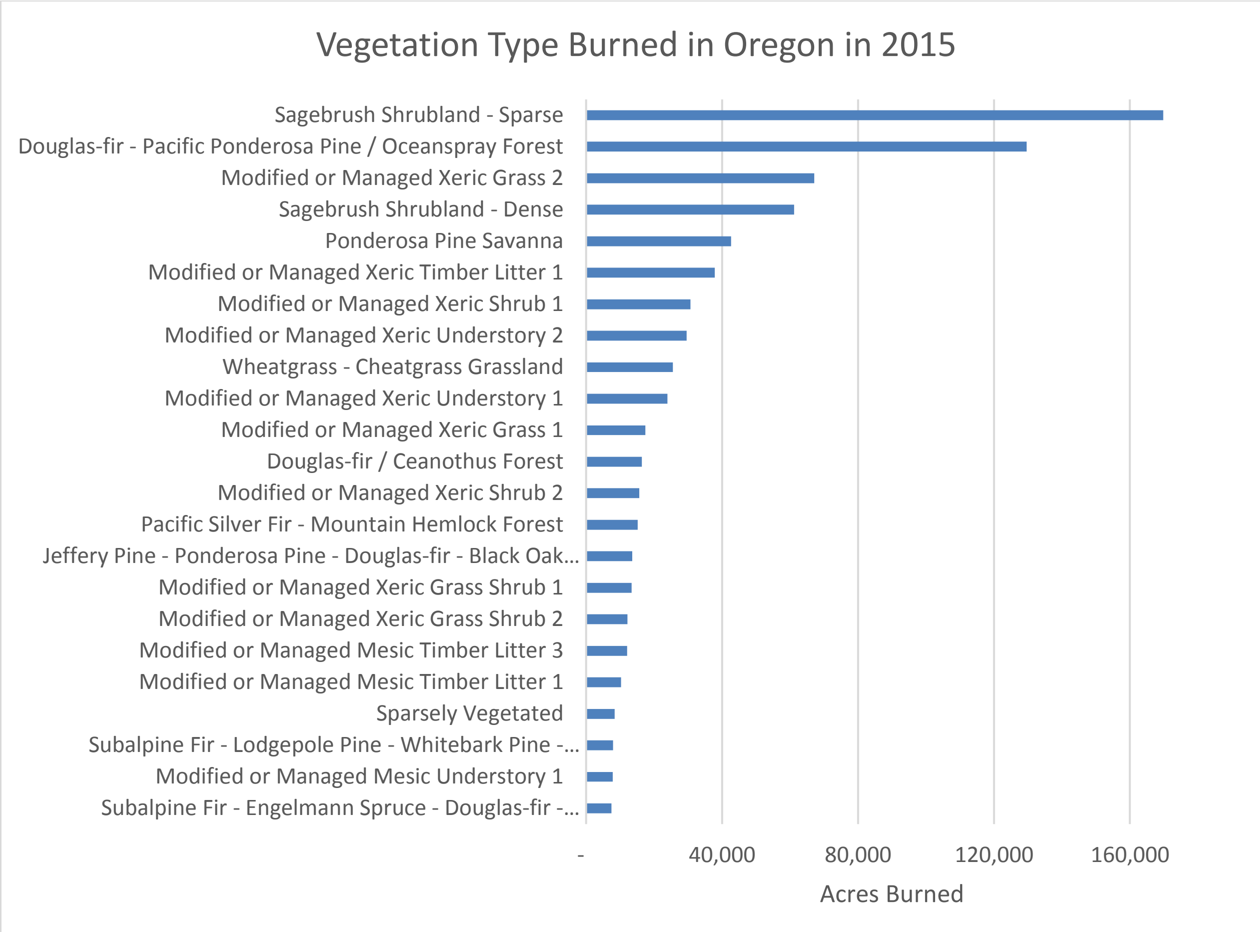

Figure 5. Vegetation types burned in Oregon due to wildfires in 2015.

Unusually large and severe wildfires have become more and more common in dry forests across the West due to fuel accumulation from decades of fire suppression (USDA Forest Service, 2013).

Figure 6 illustrates the upward trend in the number of acres burned by wildfires in Oregon and Washington since 1992 (USDA Forest Service, 2015). This includes all fuel types, not just forested acres. The trend is not consistent from year to year as some years such as 2008-2011 had far fewer acres burned than in 2012-2015.

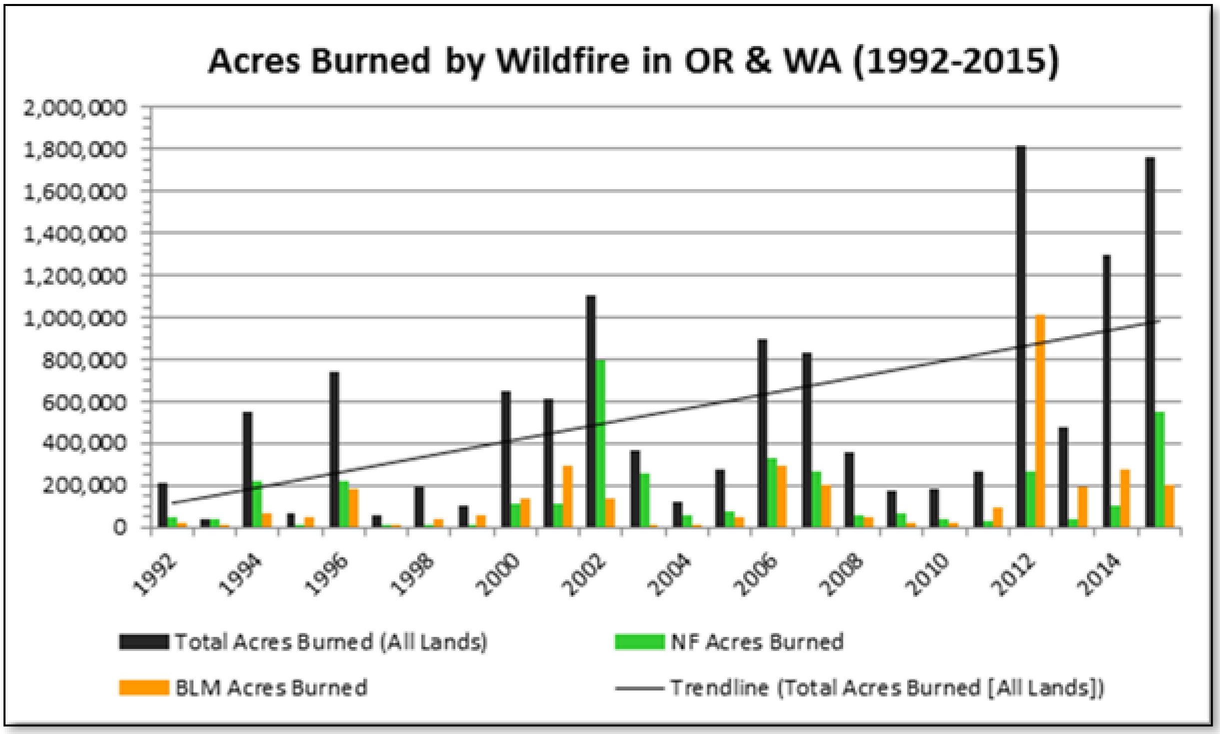

Figure 6. Acres burned by wildfires in Oregon and Washington (1992-2015)

Table 2 presents the historic rank in terms of acres burned on federal land management units (National Forests, BLM resource areas, and National Parks) in the Pacific NW by recent wildfires. Seventy-five percent of these federal land management units experienced their largest area burned since the middle of the last century by fires which occurred in the last three years. Additionally, since 2011, 75% of the federal units listed in Oregon and Washington have had more acres burned by a single fire than at any time since the middle of the last century (USDA Forest Service, 2016).

Table 2. Historic rank of acres of federal land burned by recent fires in the PNW National Forests, BLM resource areas, and National Parks.

Unit	Fire Name	Historical Rank (Top 3 Only)	Year	Size Estimate (Unit Specific Acres Only)
Colville NF	Stickpin	#2	2015	48,782
Columbia River Gorge SA	Rowena	#1	2014	1,411
Deschutes NF	Pole Creek	#2	2012	26,579
Fremont-Winema NF	Barry Point	#1	2012	43,133
Gifford Pinchot NF	Cascade Creek	#1	2012	20,296
Mt. Hood NF	Dollar Lake	#2	2011	6,286
	36 Pit	#3	2014	2,508
Ochoco NF	Corner Creek	#1	2015	29,660
Olympic NF	Big Hump	#1	2011	1,243
Umatilla NF	Butte Creek (Grizzly Complex)	#1	2015	71,285
Umpqua NF	Stouts Creek	#3	2015	14,824
Wallowa- Whitman NF	Cache Creek	#3	2012	56,845

Eugene BLM	Yellow Point	#3	2014	223
Prineville BLM	South Fork	#1	2014	23,826
	Razorback	#3	2011	12,887
Burns BLM	Miller Homestead	#1	2012	160,801
	Buzzard	#2	2014	87,141
	Holloway	#3	2012	74,912
Medford BLM	Big Windy	#1	2013	26,607
	Dads Creek (Douglas Complex)	#2	2013	12,671
Roseburg BLM	Rabbit Creek	#1	2013	6,267
	Stouts Creek	#3	2015	14,824
Vale BLM	Long Draw	#1	2012	548,379
	Holloway	#2	2012	164,870
	Saddle Draw (Buzzard Complex)	#3	2014	141,558
Olympic National Park	Paradise (Confine Strategy)	#1	2015	2,796
Crater Lake National Park	Crescent Fire (National Complex)	#1	2015	13,022
Colville Agency	North Star	#1	2015	170,561
	Tunk Block	#2	2015	81,936
Spokane Agency	Carpenter Road	#1	2015	20,583
Warm Springs Agency	County Line	#1	2015	67,367
	Sunnyside Turnoff	#2	2013	51,465
	Powerline	#3	2011	20,889
Yakima Agency	Cougar Creek	#1	2015	47,892

2.0 Particulate and Greenhouse Gas Emissions

Hundreds of compounds are emitted into the air by wildland fires but most are found in very low concentrations. The principal air pollutant of concern in smoke is particulate matter (National Wildfire Coordination Group, 2001). Greenhouse gases (GHGs) are also of interest due to their effect on climate. Fires also emit volatile organic compounds and nitrogen oxides which contribute to the formation of ozone. However, in the Pacific Northwest, ozone occurs in relatively low concentrations and as such is not included in this report.

Emissions of particulate matter less than or equal to 2.5 micrometers in diameter (PM2.5) and greenhouse gases (primarily CO_2 and methane) from the wildfires were calculated following the methods of Ottmar and Prichard (personal communication, 2015-2106), as follows.

Each vegetation type was assigned a fuelbed which characterizes the vegetation type and fuel loading by stratum (e.g., ground cover, shrub, down-dead wood, canopy), as identified in the Fuel Characteristics Classification System (FCCS) (Ottmar et al., 2007, Riccardi et al., 2007). The Fuel and Fire Tools software program, which contains FCCS, Consume, and the Fire Emissions Production Simulator (FEPS) was used to estimate the emissions of PM2.5 and GHGs under low, moderate, and high severity fires. The difference in severity was characterized by differing fuel moistures and consumption of canopy, piles, and shrubs.

Three burn scenarios were developed to represent different levels of fire severity (low, moderate, or high) which affected fuel consumption and ultimately emissions. The Fuel and Fire Tools (FFT) software program (USDA Forest Service, 2015) was used to quantify the emission rates under each of the scenarios. The fuel moisture (FM), slope, wind speed, and consumption rates for low, moderate, and high severity fire are shown in Table 3 (Ottmar, R.D. email communication, July 2016). The program calculates the consumption amounts of ground, wood, and lichen/litter/moss, whereas consumption rates of shrubs, piles, and the canopy were provided based upon professional judgement.

Table 3. Assumed environmental conditions associated with low, moderate, and high severity fires

Parameter	*Low Severity*	*Moderate Severity*	*High Severity*
FCCS			
Herbaceous FM	90	30	30
Shrub FM	120	60	60
Crown FM	150	90	30
1-hr FM	12	9	3
10-hr FM	13	10	4
100-hr FM	14	11	5
Slope	0	0	0
Wind Speed (m/hr)	4	4	4
Consume			
1000-hr FM	35	25	10
Duff FM	120	70	30
Shrub Consumption (%)	30	50	95
Canopy Consumption (%)	30	50	80
Pile Consumption (%)	100	100	100

Table 4 presents emission rates of PM2.5 and GHGs (expressed in CO_2 equivalents) on a per acre basis for several fuel beds burned during the 2015 wildfires season, under moderate severity conditions. PM2.5 and GHG emission rates varied across three orders of magnitude depending upon the vegetation type. PM2.5 emission rates ranged from a high of 1881 tons/acre for a subalpine fir/Engelmann Spruce/Douglas-fir/Lodge pole pile forest to 1 ton/acre for wheat grass/cheat grass. Similarly, GHGs emission rates ranged from 221,271 tons/acre to 353 tons/acre depending upon the vegetation type.

Table 4. Emissions per acre for selected fuel beds burned by wildfire in the Pacific NW in 2015 for moderately severe conditions.

Fuelbed	PM2.5 (tons/acre)	GHGs (tons/acre)
Subalpine Fir/Engelmann Spruce /Douglas-fir/Lodge pole Pine Forest	1,881	221271
Pacific Silver Fir/Mountain Hemlock Forest	1,218	145355
Modified or Managed Xeric Timber Litter 1	1,149	161171
Douglas-fir/Ceanothus Forest	996	132716
Subalpine Fir/Lodgepole Pine/Whitebark Pine/Engelmann Spruce Forest	927	140754
Modified or Managed Mesic Timber Litter 1	656	128017
Modified or Managed Mesic Timber Litter 3	390	86868
Jeffery Pine - Ponderosa Pine - Douglas-fir - Black Oak Forest	266	52509

Douglas-fir - Pacific Ponderosa Pine / Oceanspray Forest	253	51980
Modified or Managed Mesic Understory 1	236	51653
Modified or Managed Xeric Understory 2	212	38571
Ponderosa Pine Savanna	137	20541
Modified or Managed Xeric Shrub 2	62	14768
Modified or Managed Xeric Shrub 1	57	6625
Modified or Managed Xeric Grass Shrub 2	41	9989
Sagebrush Shrubland – Dense	33	10550
Modified or Managed Xeric Grass Shrub 1	25	6023
Modified or Managed Xeric Understory 1	20	6423
Modified or Managed Xeric Grass 2	13	4255
Sagebrush Shrubland – Sparse	7	2270
Modified or Managed Xeric Grass 1	2	672
Wheatgrass - Cheatgrass Grassland	1	353

Table 5 provides some insights as to why emission rates vary so widely across vegetation types. Predicted consumption per unit area, again under moderate severity conditions are presented by stratum for three common fuelbeds: Subalpine Fir/Engelmann Spruce /Douglas-fir/Lodgepole Pine Forest (FCCS reference fuelbed 59), Douglas-fir/Pacific Ponderosa Pine/Oceanspray (FCCS reference fuelbed 52), and Sparse Sagebrush Shrubland (FCCS reference fuelbed 60).

There are some significant differences between the total tons per acre consumed across fuelbeds, but also between strata. Downed wood and ground fuels, in particular, contribute to large differences between fuelbeds. The lack of a canopy, downed wood, and ground fuels result in relatively little fuel consumption and thus little smoke production in shrubland.

Smoke emissions occur during the flaming, smoldering, and residual phases of combustion. However, not all stratum burn during all three phases. The top three strata (canopy, shrub, and herb) mainly emit smoke during the flaming stage, whereas the remaining three strata (wood, lichen/litter/moss, and ground fuels) emit smoke during all three stages (Youngblood et al. 2008). Thus, not only does vegetation type affect emission rates, but also the duration of emissions.

Table 5. Difference in fuel consumption for three different fuelbeds under moderate severity conditions.

Stratum	Subalpine Fir/Engelmann Spruce /Douglas-fir/Lodgepole Pine Forest (tons/acre consumed)	Douglas-fir/Pacific Ponderosa Pine/Oceanspray (tons/acre consumed)	Sparse Sagebrush Shrubland (tons/acre consumed)
Canopy	6.35	7.86	0.0
Shrub	1.42	0.22	0.44
Herb	0.28	0.19	0.19
Wood	19.61	4.84	0.0
Lichen/Litter/Moss	0.91	1.92	0.03
Ground	37.13	0.1	0.0
Total	65.69	15.12	0.66

Figure 7 illustrates the difference in PM2.5 emissions between low, medium, and high fire severity conditions for a Subalpine Fir/Engelmann Spruce /Douglas-fir/Lodgepole Pine Forest (Fuelbed 52). Emissions are 42% less under moderate severity than low severity, and 140% greater under high severity conditions. The higher emission rates are a result of the higher amounts of fuels consumed during the high severity conditions.

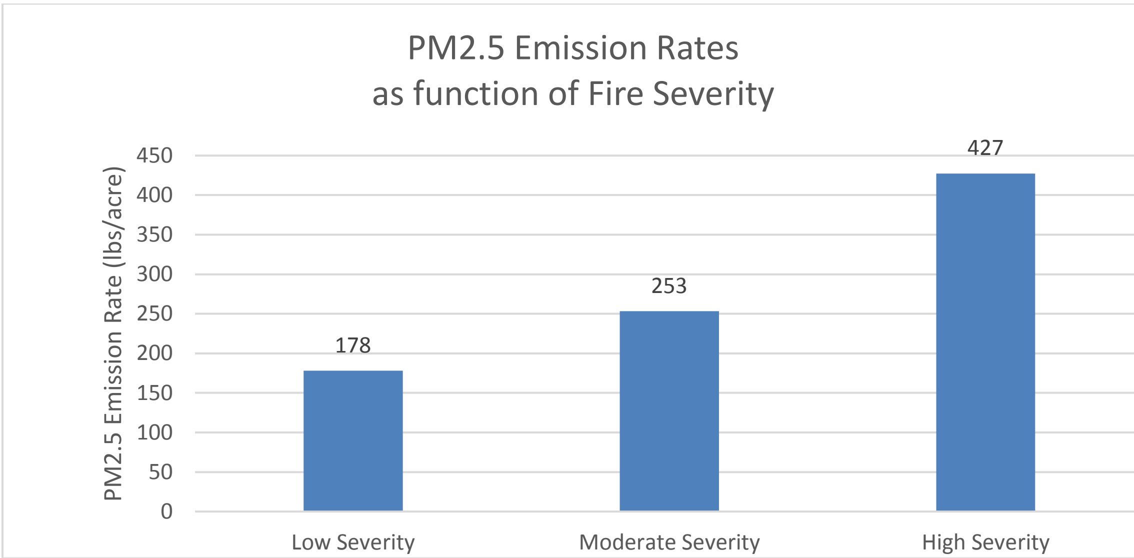

Figure 7. PM2.5 emission rate as a function of fire severity in the Subalpine Fir/Engelmann Spruce/Douglas-fir/Lodgepole Pine Forest fuel type.

Figure 8 illustrates the GHG emission rates as a function of fire severity for the Subalpine Fir/Engelmann Spruce/Douglas-Fir/Lodgepole Pine fuel type. High severity fires in this fuel bed emit 133% more GHG emissions than low severity fires, and moderately severe fire emit 51% more GHGs than low severity fires. Thus, not only do emissions change as a function of vegetation type and fuel loading, but also as a function of severity (all of which ultimately determine fuel consumption).

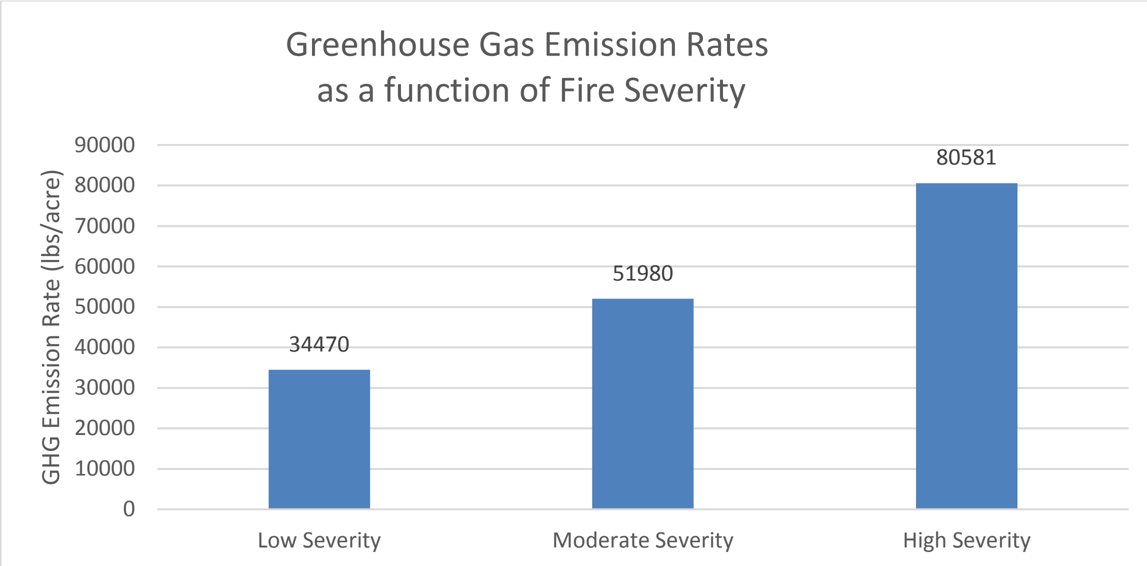

Figure 8. Greenhouse gas emissions as a function of fire severity in the Subalpine Fir/Engelmann Spruce/Douglas-fir/Lodgepole Pine Forest fuel type.

Table 6 is a summary of emission estimates from the 2015 Pacific Northwest wildfires. It was assumed that one third of all acres were burned under low, moderate, and high severity, respectively (personal communication with Ottmar, R.). For Oregon, a total of 685,809 acres burned, resulting in approximately 90,341 tons of particulate matter less than 2.5 micrometers in diameter (PM2.5) and 14,262,479 tons of greenhouse gases (GHG) expressed in units of carbon dioxide equivalent (CO_2 eq.). This is approximately 55% greater than the average from the previous 10 years. The 2015 emissions from wildfires are equivalent to approximately 3 million passenger vehicles driven or 1.3 million homes' energy use over the course of a full year. In Washington, a total of 1,089,966 acres burned, which resulted in approximately 161,369 tons of PM2.5 and 26,525,892 tons of CO2 eq. This is 6-7 times greater than the average emissions from wildfires in the previous 10 years. The 2015 emissions from the wildfires in Washington are equivalent to the emissions from approximately 5.6 million passenger vehicles or energy use for 2.4 million homes.

Table 6. Air pollutant emissions from Pacific Northwest wildfires in 2015.

	Oregon	Washington
Acres Burned by Wildfire (all land owners)	685,809	1,089,966
PM2.5 (tons)	90,341	161,369
Greenhouse Gases (tons)		
Carbon Dioxide (CO_2)	13,345,004	24,998,017
Methane (CH_4)	36,699	61,115
CO_2 equivalent [1]	14,262,479	26,525,892
Equivalent passenger vehicles driven for one year [1]	3,002,627	5,584,398
Homes' energy use for one year[1]	1,301,321	2,420,246

[1] www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

3.0 Meteorology

Meteorology is discussed here because it is a primary factor related to fire and thus affects fuel consumption and emissions of air pollutants, but also because it affects transport and dispersion of smoke. However, due to the complexity of day-to-day meteorology across the Pacific Northwest, only monthly summaries are presented here.

June 2015 in the Pacific Northwest started off cloudy and wet for the first few days but quickly transitioned into a month of record shattering temperatures and abundant sunshine. Portland International Airport set a June monthly record with 27 consecutive days without any measureable precipitation. University of Washington Atmospheric Science Professor Cliff Mass noted that June 2015 was "probably the sunniest month in Northwest history."[1] The unusually hot and dry early-summer conditions were caused by an anomalous upper-level ridge of high pressure over the eastern Pacific centered over the Washington coast coupled with significantly higher than average sea-surface temperatures (SSTs) throughout much of the Pacific Basin (Figure 9). For the month, coastal locations averaged 2-4°F above average, while interior sections of the region were 7-10°F above average. Temperatures in the Puget Sound and Willamette Valley were 5-7°F above normal with many cities, including Bellingham, Eugene, Portland, and Seattle recording their hottest June on record.

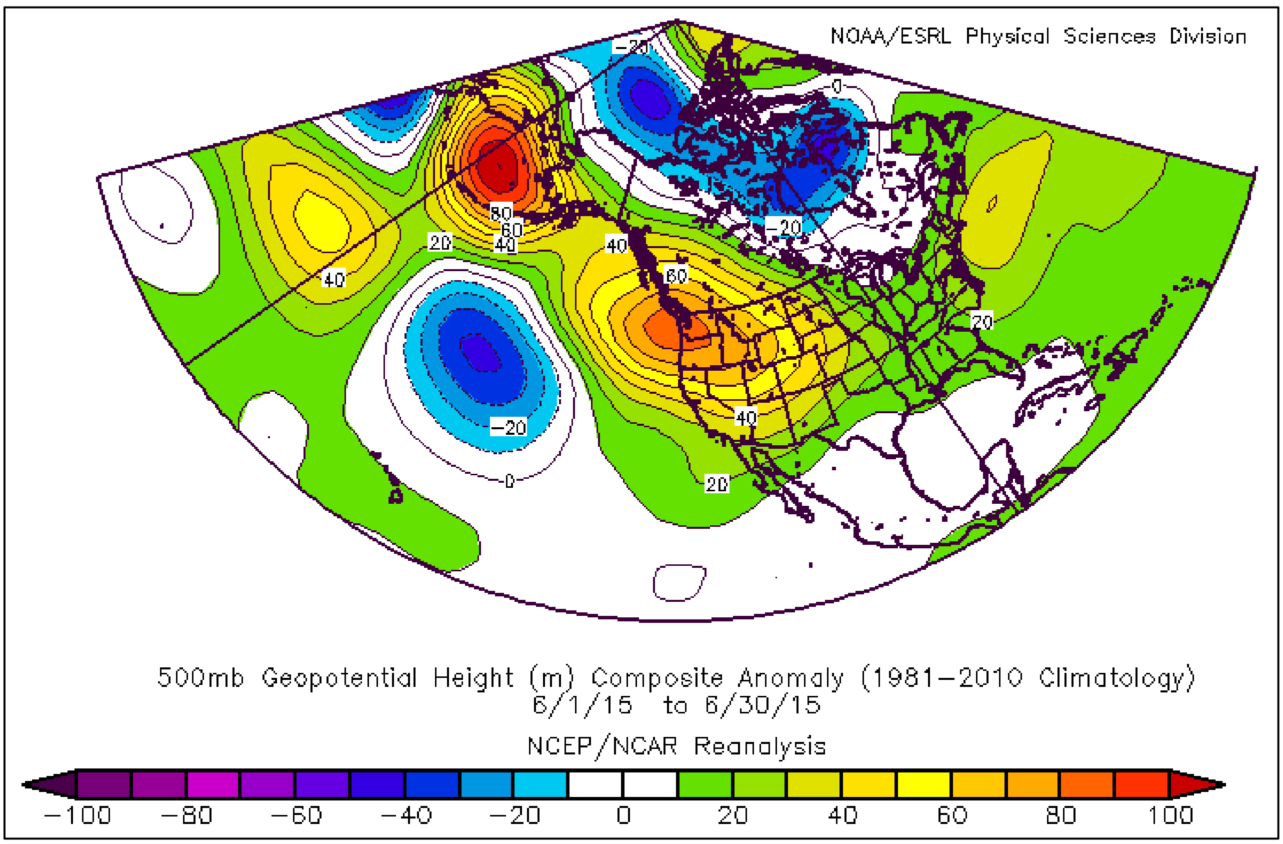

Figure 9. High pressure pattern located over the Pacific Northwest in June, 2015

[1] Cliff Mass Weather Blog, June 25, 2015. www.cliffmass.blogspot.com

The anomalously hot and dry conditions continued unabated into July 2015 with an upper-level ridge over the PNW similar to that observed in June (Figure 10). Generally, mean monthly temperatures averaged 3-5°F above normal throughout the region except in the Blue Mountains and northern Great Basin region of southeastern Oregon where temperatures were close to normal and rainfall was 150%-400% of normal. During a six-day period beginning on July 10th, there were nearly 20,000 lightning strikes scattered mainly about Oregon's Blue Mountains and Great Basin which were accompanied by widespread moderate precipitation. The mid-month precipitation resulted in a less fire conducive burning environment as characterized increases in 1000 hour fuel moistures and reductions in the energy release component (ERC) in SE Oregon. However, by July 25th, hot and sunny conditions were prevalent throughout Washington and western Oregon and remained so for the rest of the month.

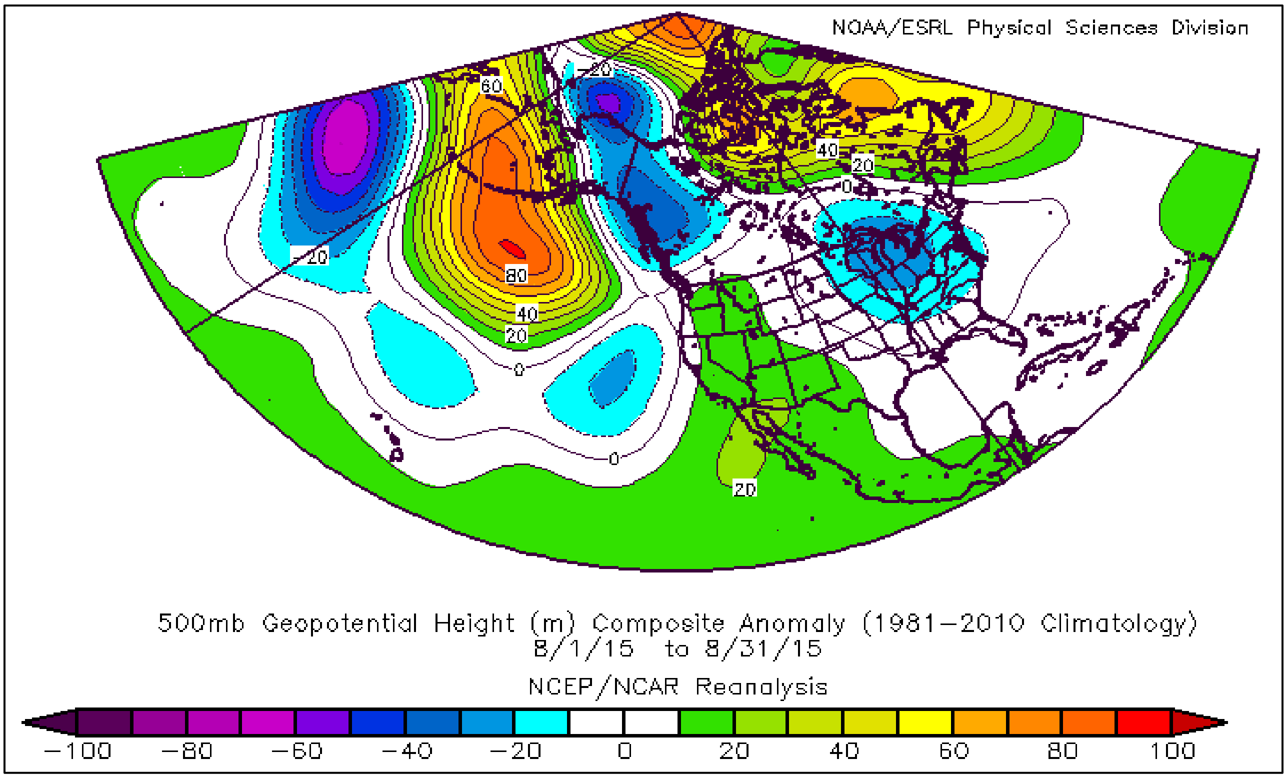

Figure 10. High pressure remains influential over the Pacific NW in July.

As shown in Figure 11, the upper-level ridge pattern that prevailed during June and July weakened and modified during August allowing a few storms to pass through the region bringing average to slightly above average precipitation to the entire coastal PNW from northern California to British Columbia. This helped moderate the extreme fire risk in western Washington by mid-month to normal levels but higher than average ERC values still prevailed across the majority of the region. Temperatures throughout the PNW during August were generally 1-3°F above average capping a record-breaking hot summer for many locations. While August showers brought much needed rainfall to western Washington and the northern Willamette Valley, west-side locations south of Salem, Oregon and areas east of the Cascades received little precipitation during the month. The precipitation throughout the PNW coastal ranges helped reduce the fire danger throughout the coastal zones, but only northeastern Washington recorded a season-ending event by the end of the month.

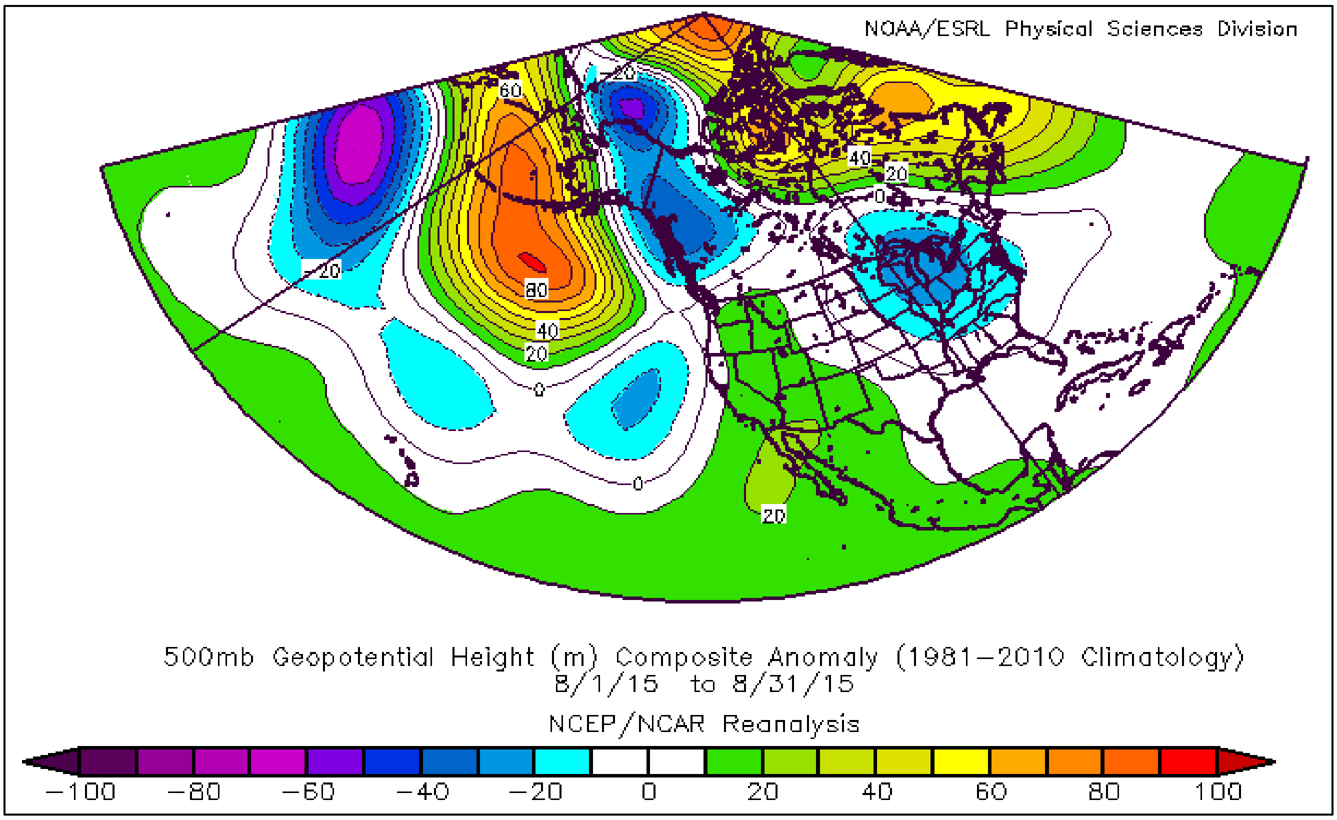

Figure 11. High pressure is no longer influential over the Pacific NW in August.

September saw an increase in storm activity throughout the PNW that led to above average precipitation and season-ending events for western Washington and the Columbia Plateau early in the month. Further south into Oregon, dry conditions continued with precipitation generally only about half of average. The increased trough activity seen in Figure 12 moderated temperatures significantly during September with the majority of the region averaging approximately 1-3°F below normal. Additionally, the increased storm activity, cloud cover, and cooler temperatures during September helped firefighters gain control of the region's many fires and minimized smoke and wildfire impacts across the region. However, it was not until October that the majority of the PNW experienced season-ending rains.

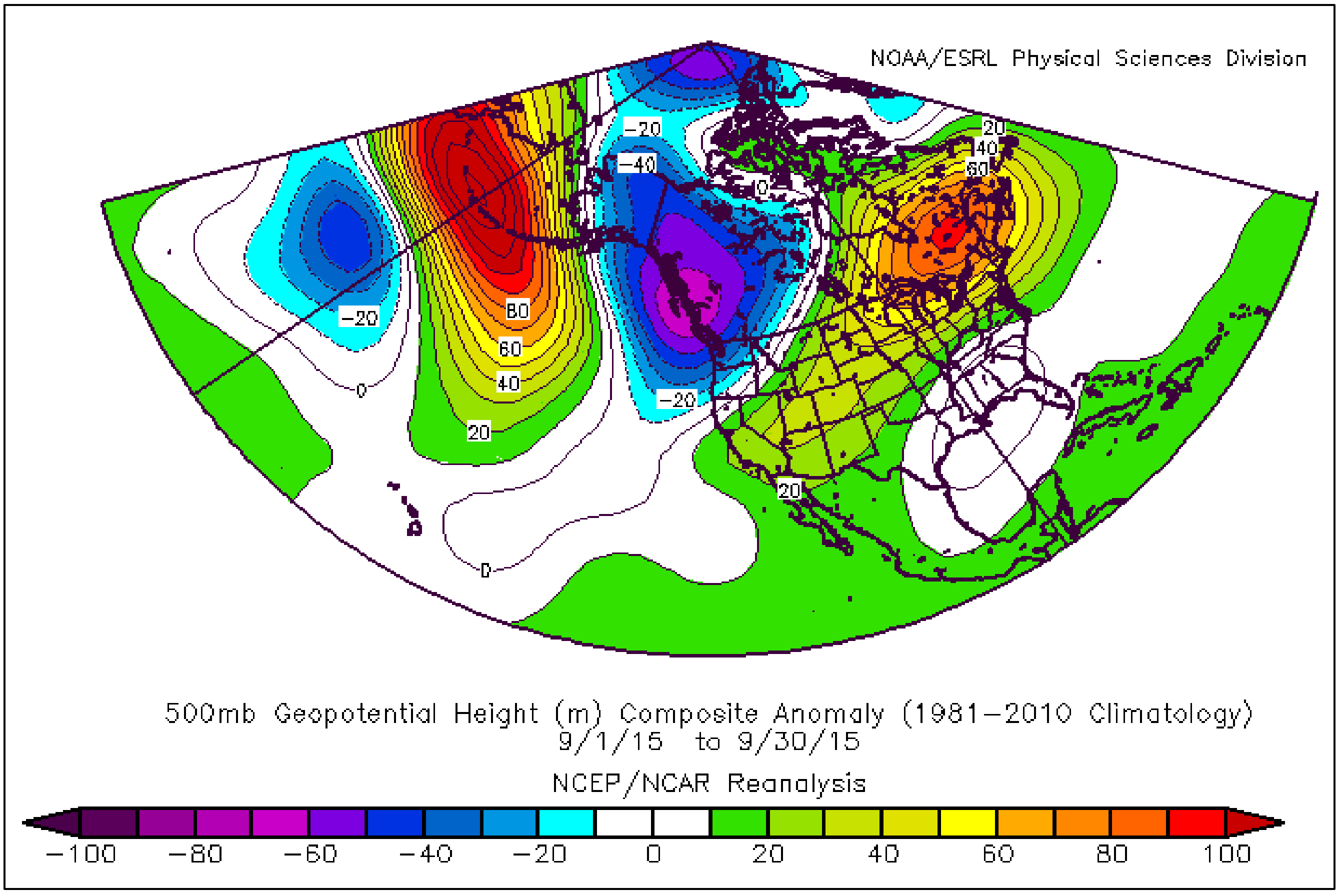

Figure 12. Low pressure to the north, beginning to influence the Pacific NW in September.

4.0 Air Quality

Air quality is monitored year round in Washington by the state Department of Ecology and in Oregon by the Department of Environmental Quality. Air monitoring serves two purposes including (1) to determine whether or not an area is in compliance with the National Ambient Air Quality Standards (NAAQS) and (2) to help alert the public of potentially harmful conditions which warrant altering one's behavior or outdoor events. The NAAQS apply to six pollutants (particulate matter, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead), and are reviewed and possibly modified once every five years by the U.S. Environmental Protection Agency (EPA). Smoke from wildfires can cause or contribute to exceedances of some of these standards (e.g., PM2.5 and ozone). However, because wildfires are not reasonably controllable using techniques that tribal, state, or local air agencies may implement in order to attain and maintain the NAAQS, they are treated differently by air quality agencies than controllable sources (72 FR 13560).

As such, air quality monitoring for smoke from wildfires is more focused on providing information needed to alert the public of potentially harmful conditions in near-real time. This is accomplished through state-sponsored networks of permanent air quality monitors which prioritize population centers. When wildfire smoke affects small communities or rural areas, portable monitors can be brought in to supplement the permanent air monitoring network. The portable monitors are not considered as accurate as the state monitors but are very useful when there is no alternative. The air quality monitors most useful during smoke episodes measure particulate matter less than 2.5 micrometers in diameter (PM2.5) in near real-time, and share this information publically on federal and state air quality web sites.

The relative severity of air pollution concentrations is characterized by the air quality index (AQI), a nationally uniform index promulgated by the EPA for reporting and forecasting daily air quality across the country in a form that is easily understood by the public. The AQI ranks measured air quality conditions in one of six categories (good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous) (table 7). The AQI ranking can be based on any of the major pollutants regulated by EPA but during smoke episodes, the pollutant of most concern is PM2.5. The AQI value for a given day is determined by the 24-hour average of PM2.5 when addressing smoke from wildfires. The unhealthy for sensitive groups (USG) category was selected as the metric to focus on for this report because (1) it is equivalent to the 24-hour PM2.5 concentration in excess of the national ambient air quality standard of 35 µg/m3, and (2) is the threshold at which sensitive people may begin experiencing health effects.

Table 7. The Environmental Protection Agency's air quality index (AQI) for reporting air quality conditions.

AQI Index	AQI Value	Meaning
Good	0-50	Air quality is considered good, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 - 300	Health warnings of emergency conditions. The entire population is more likely to be affected.
Hazardous	301 - 500	Health alert: everyone may experience more serious health effects.

Figure 13 shows where air monitoring was conducted in the Northwest during the time period between June 1 and September 30, 2015, and the number of days at each site where air quality impairment from PM2.5 reached the category of USG or worse. Nearly all locations throughout the region experienced air quality which degraded to USG or worse, except for some sites in northwestern Washington and a few temporary monitoring locations scattered across the region. In Washington, the area in and around the Colville Reservation experienced the worst air quality, most likely due to the close, downwind proximity to the largest fires (Okanogan Complex, North Star and Tunk Block). Nespelum experienced 10 days with air quality in the hazardous AQI category (refer to Table 3 and 4). Republic (20 days), Omak (16 days), and Nespelum (16 days) had the most days with degraded air quality.

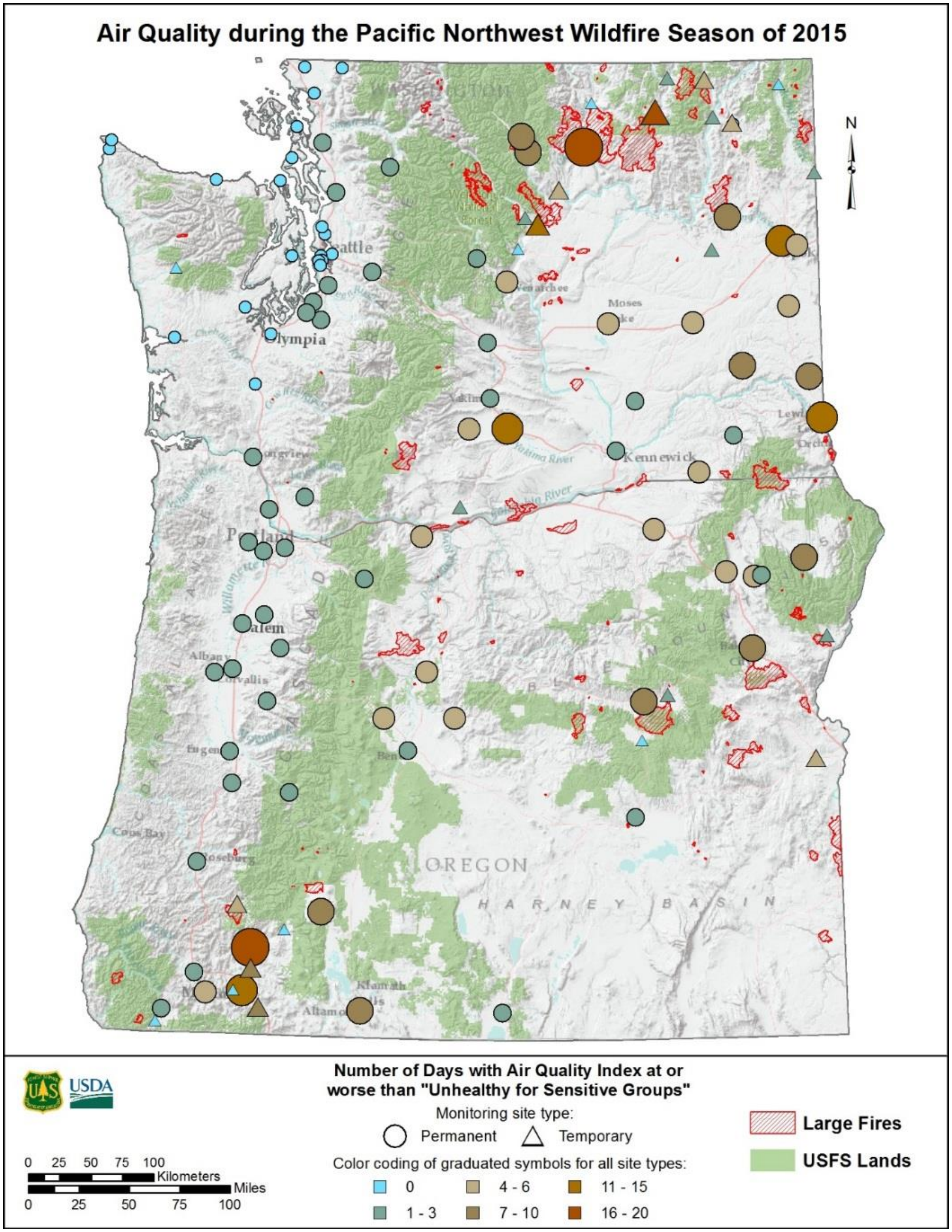

Figure 13. The number of days the air quality index was in the unhealthy for sensitive groups (USG) category or worse for areas of Oregon and Washington.

In Oregon, Shady Cove (17 days), Medford (15 days) and Baker City (10 days) had the most days with degraded air quality (table 5 and 6). Shady Cove was the only location in Oregon which experienced air quality in the hazardous AQI category.

Appendix A contains four tables which list the number of days observed in each AQI category for each permanent and temporary smoke monitoring in Washington and Oregon.

Figure 14 illustrates the estimated population exposed to degraded air quality by day for the period June 1 – September 30, 2015. Population exposure was estimated for each day by using the number of people living within the city limits of the area in which the smoke monitor was located summed for each monitor where the AQI was greater or equal to USG.

In June, approximately 100,000 people were exposed to air quality conditions which reached the USG ranking. This impact was caused by residual smoke from a prescribed fire which entered Bend, OR on June 7th, during nighttime drainage air flows. The prescribed burn associated with this event was one in which burners and smoke forecasters are attempting to test different approaches towards accomplished prescribed burns in the West Bend Vegetation Management project area, located within 5 miles west of Bend. Keeping smoke out of Bend from this area is particularly difficult to the almost daily occurrence of night time temperature inversions which trap smoke from smoldering fuels and drain along the Deschutes River into downtown Bend. This was the only known event in which air quality reached the USG ranking for the period from June 1 – September 30th due to smoke from prescribed fire. The remaining smoke events were all believed to be caused by wildfires. There were a few other days in June when smoke reached the USG level, but these occurred in less populated areas.

In July, there were approximately four days which reached or exceeded the USG ranking, exposing approximately 100,000 people each day to degraded air quality. In early August, this increased to 300,000 – 400,000 on a given day, until August 22-23, when more than 2.5 million people were impacted when east winds brought smoke into major metropolitan areas on the west side of the Cascades (see the following Case Study for details of this event). After the end of the east-wind event, smoke exposure was limited to areas located in the less densely populated parts of central and eastern Washington and Oregon. After the beginning of September, wildfire activity decreased and smoke exposure rapidly reduced for the remainder of fire season.

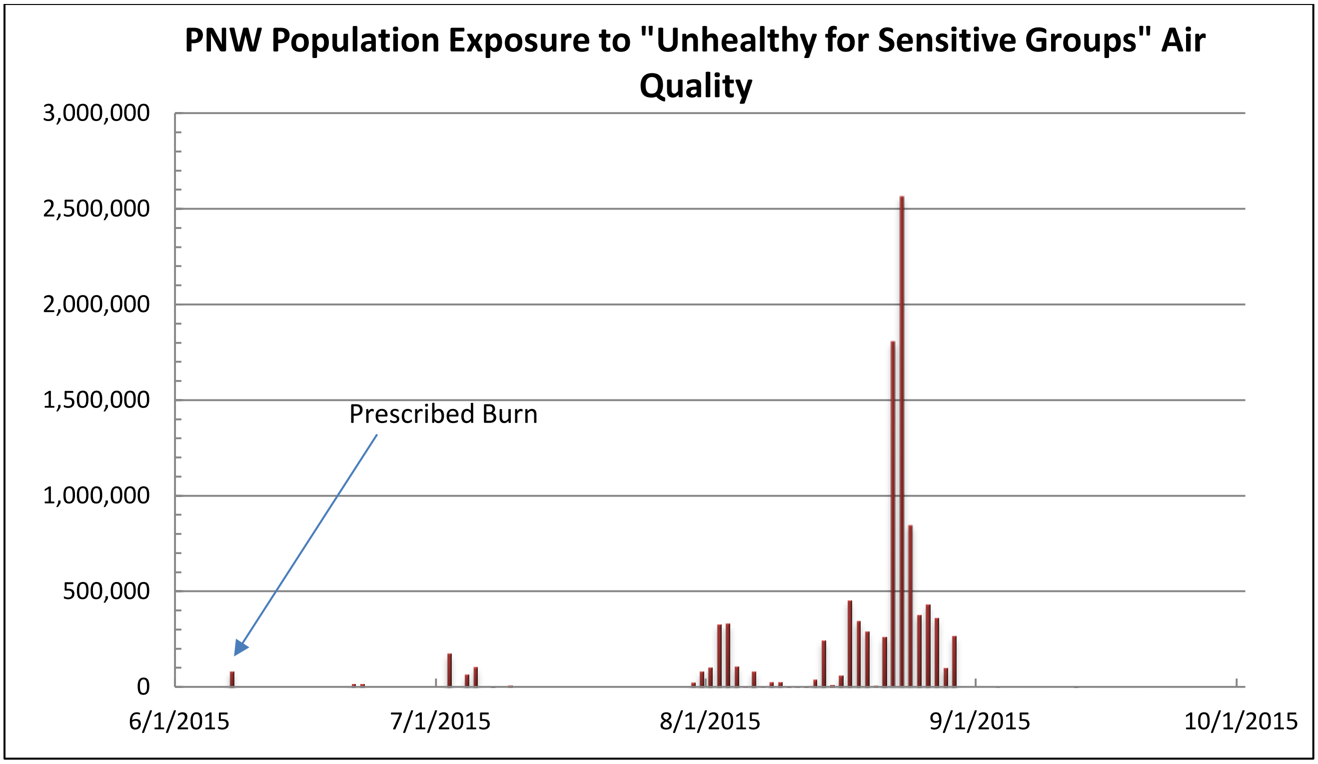

Figure 14. The approximate number of people in the Pacific Northwest exposed to USG or worse air quality (AQI > 100) by day between June 1 and September 30, 2015.

August 22-23, 2015 Smoke Event Case Study

After two hot and dry months, an extended period of lightning strikes occurred from August 7-14 and ignited fifteen major fires in Oregon's Blue Mountains and throughout the Washington Cascade Range. On August 21, a surface cold front pushed through British Columbia and Washington leading to the establishment of a surface high pressure system over the Fraser and Upper Columbia River valleys. This feature produced low-level easterly winds for August 22 and 23 that transported smoke westward from fires burning throughout interior Washington and Oregon's Blue Mountains to the major population centers of Eugene, Portland, and Seattle.

This event led to the worst two-week period for PNW regional air quality during the summer 2015 wildfire season. From August 16-29, nearly a quarter of the smoke monitoring stations in Oregon and Washington reported USG or worse air. Moreover, during that same period, the population exposed to USG or worse air exceeded 8 million. The presence of an upper-level ridge over the PNW produced strong subsidence during the final half of August which exacerbated smoke impacts by lower mixing heights 2,000-2,500 feet below that observed earlier in the month. Meteorology and wildfire smoke conspired over the weekend of August 22 and 23, 2015 to result in widespread, serious air quality degradation throughout much of Oregon and Washington (cover photo and figure 15). Smoke degraded air quality to the AQI category of hazardous in the southeastern corner of Washington, and into Idaho. Only the Olympic Peninsula in Washington, and portions of southeastern Oregon remained relatively unimpaired.

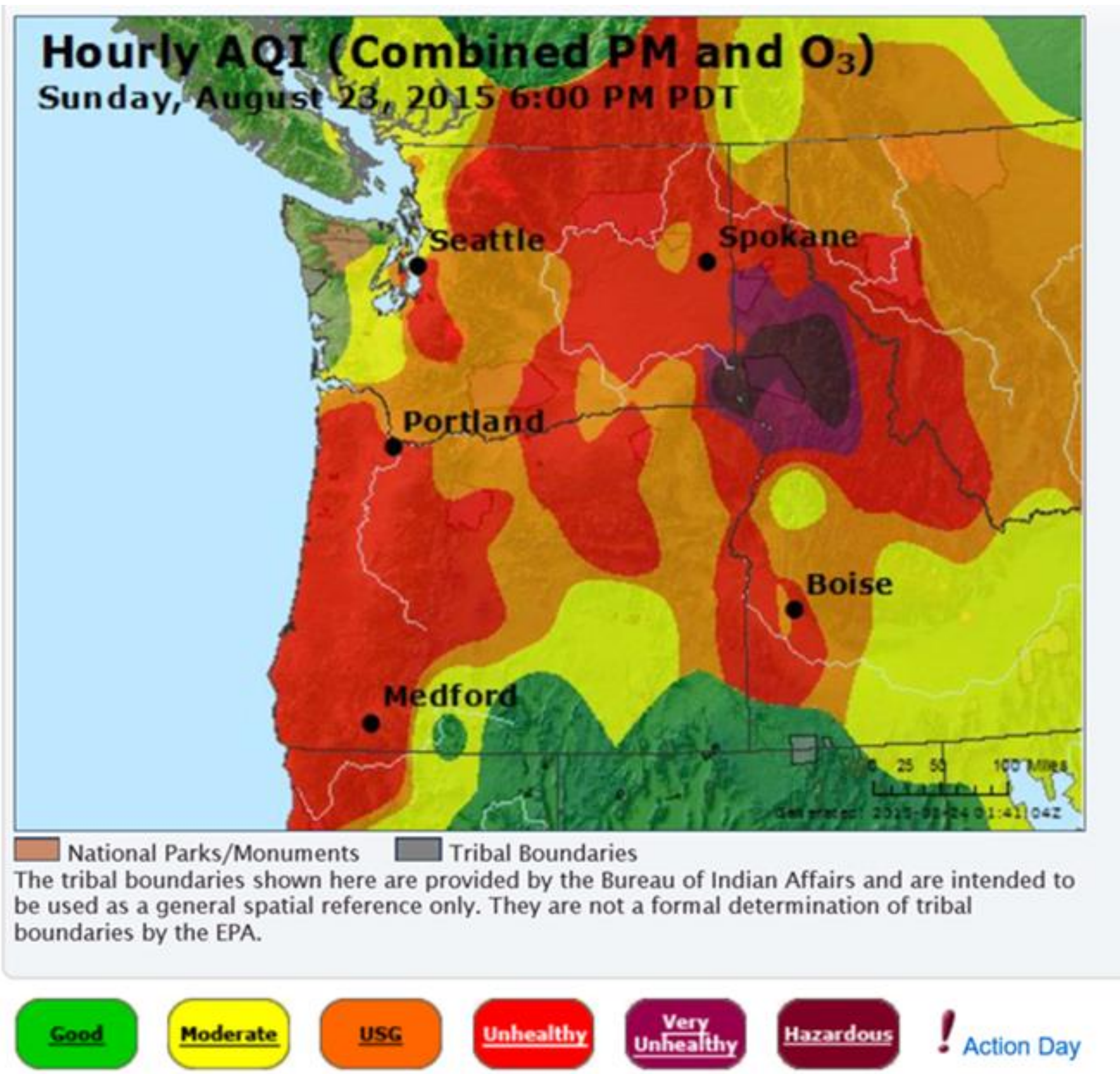

Figure 15. EPA's Air Quality Index map from August 23, 2015 shows widespread degraded air quality conditions across most to the Pacific NW

5. Response

Air Resource Advisors

Air Resource Advisors (ARAs) are individuals trained in air quality and smoke dispersion science who can be assigned to wildfires when smoke impacts are of concern. ARA's work with incident command teams, agency administrators, and state and local agencies to help predict and inform the public of air quality conditions and the risks from smoke. Their expertise includes: air quality monitoring, smoke dispersion modeling, data analysis, regulatory compliance, and computer simulation modeling. During wildfire events when smoke is a concern, an ARA's objective is to provide timely smoke impact and forecast information and messaging based on best available science. An ARA works with multiple agencies to address public health concerns, smoke risk to transportation safety, and firefighter exposure.

During the 2015 Pacific Northwest wildfire season, 16 ARAs and trainees were deployed to the Pacific Northwest to support the wildfire response for a total of 206 person-days. ARA's were deployed as early as mid-June in Oregon and early July in Washington (figure 16). Most of the assignments occurred during August and September to support the fires and communities in southwestern and northeastern Oregon and north central and northeastern Washington. During the peak of wildfire activity, as many as nine ARAs were simultaneously at work somewhere in the region.

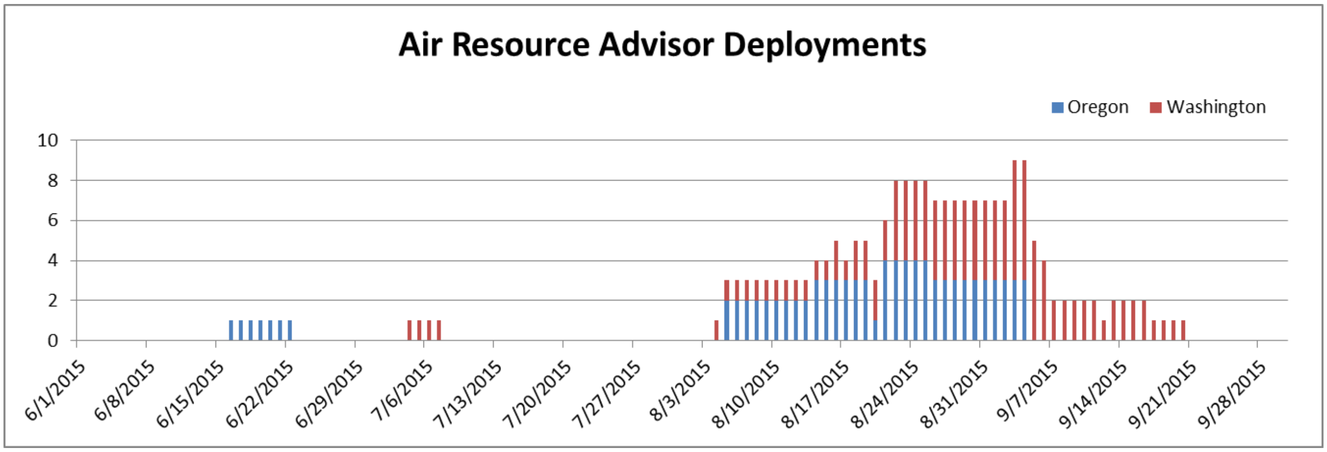

Figure 16. Air Resource Advisor deployments in the Pacific Northwest in 2015.

Dissemination of Information

Information about the location, timing, and magnitude of air quality impacts; and recommendations to protect the public was disseminated through numerous channels including Federal, State, and local air quality and health agency websites, national weather websites, news releases, the Washington and Oregon Smoke Blogs, State Department of Transportation, and public meetings.

State Department of Environmental Quality and state and local health departments and County health agencies provided warnings to the public on the health risks of smoke during severe smoke events. In Oregon, six health warnings were issued during the 2015 wildfire season (as posted on the Oregon Smoke Blog). In Washington, seven health warnings were issued during the 2015 wildfire season (as posted on the Washington Smoke Blog).

Smoke Blogs

The state smoke blogs (wasmoke.blogspot.com and oregonsmoke.blogspot.com) were used increasingly in 2015 to disseminate information to the public about air quality conditions, forecasts, and recommended actions to protect oneself (table 8). They also provided useful links to information about individual fires, real-time air quality maps, health information, and guidance documents for public schools and handling of outdoor events (figure 17).

Table 8. Monthly activity on the Oregon and Washington smoke blogs in 2015.

	Oregon Smoke Blog		Washington Smoke Blog	
	Posts	Views	Posts	Views
June	16	8,188	6	4,890
July	9	8,937	25	28,757
August	96	277,141	81	459,683
September	12	19,937	35	52,880

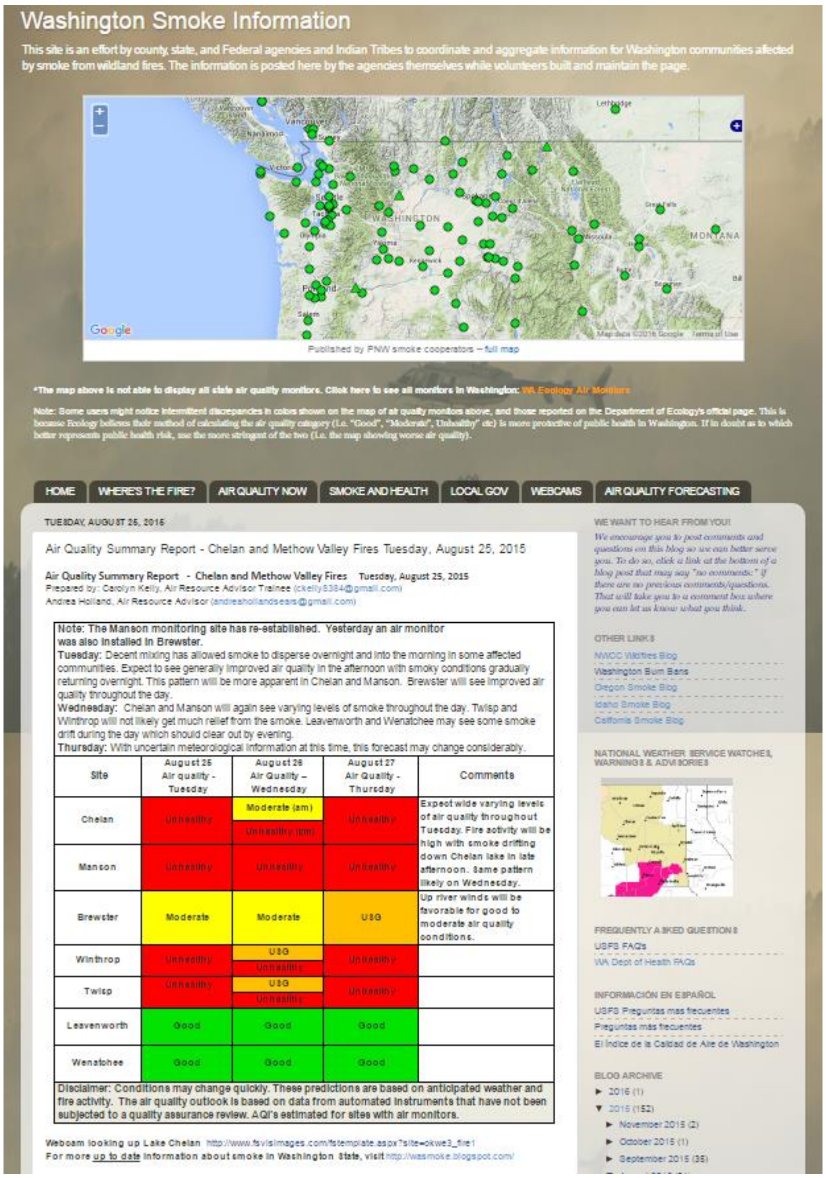

Figure 17. The Oregon and Washington smoke blogs were used extensively during the 2015 wildfire season to communicate air quality conditions and warnings to the public.

In addition to news releases, air quality warnings were also disseminated by the National Weather Service and posted on forecast area websites. Almost three-quarters of the air quality alerts issued by regional

National Weather Service Forecast Offices (NWSFO) between June and September occurred in August (table 8). Some offices were very active with posting air quality alerts, other offices posted none.

Table 9. Dates when air quality alerts were issued by regional National Weather Service offices during the 2015 wildfire season.

NWSFO	June	July	August	September	Total Days
Seattle	-	-	-	-	0
Spokane	-	-	3, 12, 13, 14, 15, 17, 19, 20, 21, 23, 24, 26, 27, 28, 30, 31	30	17
Portland	-	-	-	-	0
Pendleton	-	-	17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	1	16
Medford	-	-	-	-	0
Boise	-	-	15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27	-	12

6.0 Prescribed Fire

Prescribed fire, when combined with mechanical thinning, is an effective fuel treatment and necessary for restoring and maintaining ecosystem resilience. However, prescribed fire emits smoke, which has the potential to cause air quality concentrations to exceed acceptable thresholds. Prescribed fire is the intentional use of fire in wildlands in a controlled manner to accomplish any of a number of diverse land management objectives including restoring the natural role of fire in ecosystems, reducing the risk of uncontrolled wildfire, disposing of brush and debris from logging operations, enhancing wildlife habitat, etc. Air quality is an important criteria in every decision about the intentional use of fire in Oregon and Washington. Both states have smoke management programs that rely on smoke forecasters to keep smoke from prescribed fire from causing adverse impact to the public health and safety.

In 2015, prescribed fire was used 3,693 times in Oregon to treat a total of approximately 179,598 acres of public and private forest land (table 10). This burning emitted approximately 25,971 tons of PM2.5, and 7,697,804 tons of GHGs. Approximately 56% of the tons burned were from activity and natural fuels[2], with the remaining 44% from pile burning[3].

In 2015, prescribed fire was used 1,820 times in Washington to treat a total of approximately 62,814 acres. This burning emitted approximately 3,095 tons of PM2.5 and 917,359 tons of GHGs. In Washington, approximately 7% of the tons burned were from activity and natural fuels, with the remaining 93% due to pile burning.

Nine smoke intrusions[4] occurred in Oregon in 2015 (table 11) including: one in Klamath Falls, one in Cottage Grove, and seven in Bend, OR. One intrusion of smoke was attributed to prescribed fire in Washington in 2015 when smoke impacted the Lake Wenatchee area for about 5 hours on October 14, 2015. No air quality monitor was located nearby to measure the severity of the impact.

Figure 18 illustrates the 24-hour average of the PM2.5 concentrations at the three locations in Oregon where smoke intrusions occurred. The intrusions resulted in 24-hour average PM2.5 concentrations generally below the 35 μg/m3 threshold of the national ambient air quality standard (NAAQS), except for

[2] *Activity fuels* result from, or are altered by, forestry practices such as timber harvest or thinning. *Natural fuels* result from natural processes and are not directly generated or altered by land management practices.

[3] Pile burning is the intentional ignition and consumption by fire of mounds of woody debris left after logging, pruning, mechanical thinning or cutting of trees including logs, chips, bark, branches, stumps, and broken understory trees or brush.

[4] In Oregon, a smoke intrusion is defined as a verified entrance of smoke from prescribed burning into a Smoke Sensitive Receptor Area at ground level. (Reference: OAR 629-048-0005(26))

the June 7th smoke intrusion into Bend. Smoke from this event was observed in Bend between midnight and 9 am. A few near exceedances of the NAAQS also occurred in Klamath Falls in December, but these were not attributed to prescribed fire and as such were not characterized as smoke intrusions.

Table 10. PM2.5 Emissions from Prescribed Fires in Oregon and Washington.

	Oregon			Washington		
Burn Type	**Acres Burned**	**Tons Consumed**	**PM2.5 Emissions (tons)**	**Acres Burned**	**Tons Consumed**	**PM2.5 Emissions (tons)**
Activity	15,521	467,779	3,950	2,132	24,888	177
Natural	15,937	969,740	13,785	2,206	16,838	94
Piles	148,140	1,085,452	8,236	58,476	529,651	2,824
Total	179,598	2,522,971	25,971	62,814	571,377	3,095

Table 11. Smoke intrusions from prescribed fire in Oregon during 2015.

Date	Impacted Community	Intrusion Severity
May 4, 2015	Bend	Light: 2 hours
May 6, 2015	Bend	Light: 1 hour
May 29, 2015	Bend	Heavy: 2 hours Moderate: 2 hours Light: 3 hours
June 6, 2015	Bend	Heavy: 2 hours Moderate: 4 hours Light: 3 hours
June 7, 2015	Bend	Heavy: 4 hours Moderate: 1 hour Light: 4 hours **Air quality standard was likely exceeded although Bend monitor is not an official federal reference method type of monitor.*
October 6, 2015	Bend	Light: 8 hours
October 22, 2015	Klamath Falls	Light: 3 hours **Wildfire and wood heating smoke also implicated*
October 23, 2015	Bend	Moderate: 5 hours Light: 2 hours
November 3, 2015	Cottage Grove	Moderate: 2 hours Light: 2 hours

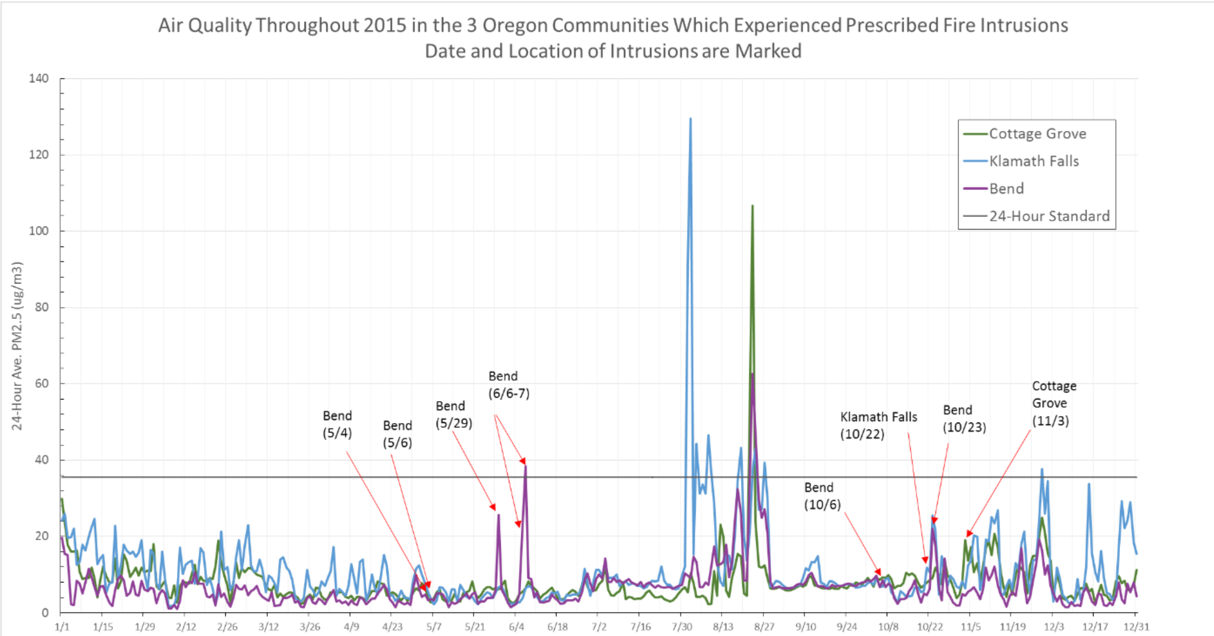

Figure 18 Three communities in Oregon experienced intrusions of smoke from prescribed burning in Oregon during 2015 for a total of 9 events. High PM2.5 values seen from late July through August are from wildfires. Elevated values during winter months are likely from home heating.

State smoke management programs (SMPs) facilitate prescribed burning while maintaining good air quality. SMPs inherently ensure compliance with the national ambient air quality standards (NAAQS) determined by the US Environmental Protection Agency (EPA). The NAAQS have two forms: the primary standards which are designed to be protective of human health and secondary standards which are designed to be protective of welfare and the environment. The standards are designed to be protective of sensitive populations as well as the general public.

EPA is required to review the NAAQS once every five years. Since the promulgation of the Clean Air Act, the NAAQS for PM has changed considerably. Figure 19 illustrates the trend in the 24-hour NAAQS for PM, (US EPA, 2016). The figure illustrates that with time, the size of the PM which has been regulated has become smaller, with our increased understanding of how PM effects human health. The smaller particles are able to penetrate deeper into the respiratory system. As such, EPA has applied the standard to smaller and smaller diameter PM (from TSP (approximately PM30) to PM2.5). Concurrently, the 24-hour standard has decreased from 260 µg/m3 to 35 µg/m3 between 1971 and 2006.

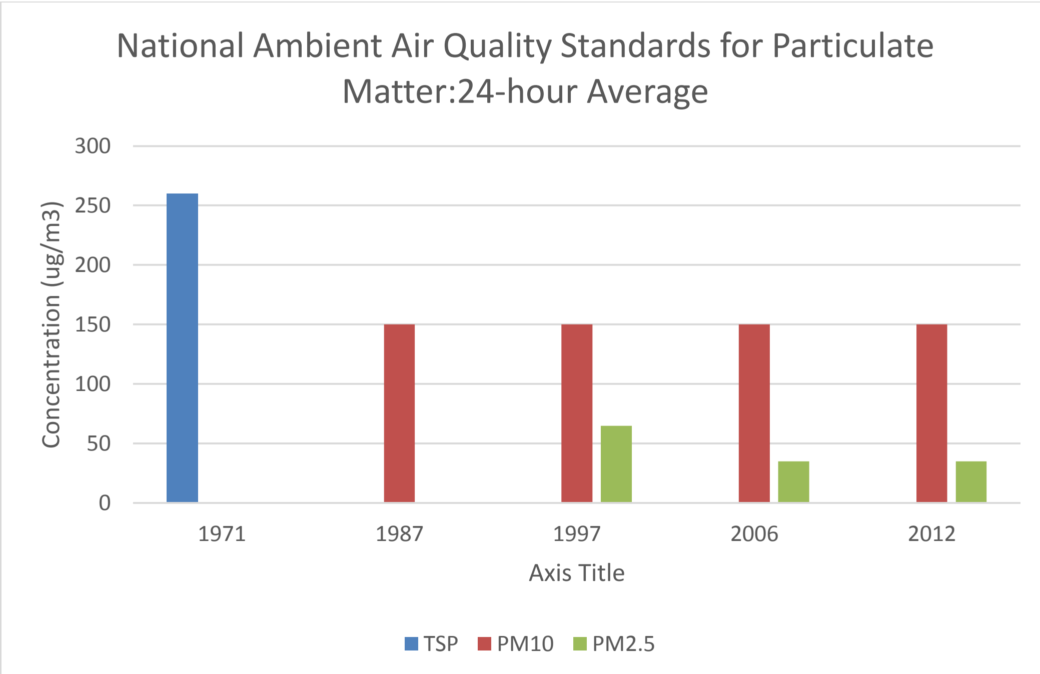

Figure 19. Changes in the 24-hour PM NAAQS since 1971.

There are other regulations besides the NAAQS which restrict prescribed burning based upon factors besides the protection of human health. State smoke management plans further restrict prescribed burning to keep smoke from out of population centers. Regional Haze regulations, which are also incorporated into SMPs attempt to keep smoke from prescribed fires out of Class I areas.

7.0 Fuel Treatment Effectiveness

Fuel treatments, including controlled burning are discussed here because they are recognized as a means of modifying wildfire behavior, which indirectly modifies the amount of smoke produced and resulting air quality. Fuel treatments reduce fire severity, crown and bole scorch, and tree mortality compared to untreated forests, post-wildfire: most consistently for thin plus burn treatments (Kailies, 2016).

The Forest Service, along with its many partners and stakeholders, is working collaboratively to implement the National Cohesive Wildland Fire Management Strategy (https://www.forestsandrangelands.gov/strategy/thestrategy.shtml) across all landscapes, using the best science, to make meaningful progress towards three goals: (1) increasing resilient landscapes, (2) increasing and improving fire-adapted communities, and (3) increasing the safety and effectiveness of wildfire response. Fuel treatments (also referred to as vegetation treatments) are a critical part of the cohesive strategy and are defined as the manipulation or removal of fuels to reduce the likelihood of ignition and/or to lessen potential damage and resistance to control. Examples of fuel treatments include thinning, mowing, lopping, chipping, crushing, mastication, piling and burning.

During the 2015 fire season in the Pacific Northwest, fuel treatments were found to (1) have contributed to safer, more effective control of wildfires, (2) preserve or improve the overall integrity of forest cover, watershed protection, wildlife habitat, and forest products, and (3) reduce the risk of wildland fires in the Wildland-Urban Interface (WUI) from entering communities (USDA Forest Service, 2016). While difficult to quantify, these treatments may reduce the severity and duration of degraded air quality if the amount of fuel consumed during a wildfire is reduced due to being modified by interaction with a fuel treatment.

Figure 20 illustrates the locations of fuel treatments conducted on lands managed by the USDA Forest Service and USDI Bureau of Land Management (BLM) during the past 10 years, along with the locations of the 2015 wildfires in the Pacific Northwest. In Washington, the majority of fuel treatments occurred on the east slope of the Cascades and in Northeastern Washington. In Oregon, fuel treatments are more wide-spread across the state. In many cases, wildfires intersected lands which had received some form of fuel treatment.

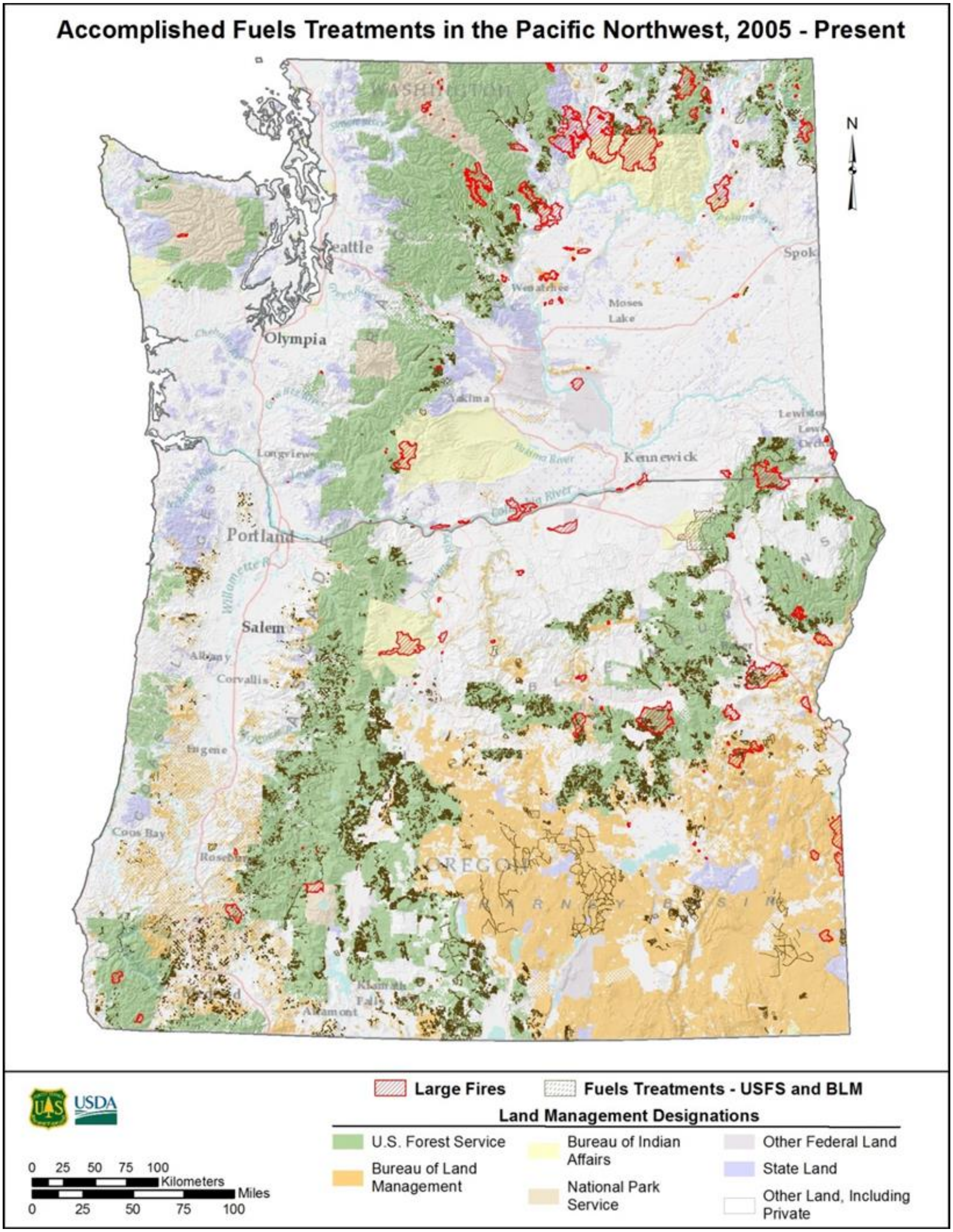

Figure 20 Location of large wildfires in 2015 and fuel treatments within the prior 10 years.

Fuel treatments vary in type and include: commercial harvesting, thinning, piling, mowing, biological, biomass removal, burning, chemical treatments, chipping, crushing, mastication, lop and scatter, grazing, or some combination thereof. The effectiveness of each treatment is dependent upon a number of factors including the objective and the specifics of when and where a wildfire intersects a fuel treatment including meteorology, topography, fuels, and elapsed time since treatment.

During the summer of 2015, fuel treatments affected the behavior of the many wildfires including in Washington and Oregon, which are catalogued in the Fuel Treatment Effectiveness Monitoring (FTEM) database. A few of success stories are highlighted below.

- **North Star Fire**: Vegetation treatments enhanced and increased firefighter safety and created greater protection for several communities.
- **Tunk Block Fire**: Vegetation treatments were designed to reduce fuel loadings and stand densities with the intent to reduce large fire growth in order to protect communities, infrastructure, and natural resources. These treatments reduced overall fire behavior allowing for more direct suppression tactics. "In the northeastern portion of the fire, near Peony Creek at the west end of Aeneas Valley, stark contrasts were apparent between the little remaining crowded forest of charred trunks, vaporized needles, and ash coated ground on Road 3015, compared with the green and healthy trees along Road 3010 where thinning had occurred" (observations by Bob Schumacher, as appeared in the Spokesman Review, Nov 15, 2015).
- **Carpenter Road Fire**: The Spokane Tribe of Indians has implemented a total of 4,038 acres of prescribed burning and 2,004 acres of mechanical fuel reduction treatments within the Carpenter Road Fire perimeter. These treatments included thinning, chipping, pruning, mastication, and lop and scatter were strategically placed to break-up the continuity of fuels and reduce wildfire risk, especially in the Wildland-Urban Interface (WUI). Lands outside of the fuel treatment areas experience more severe fire effects (e.g., greater tree mortality) than land within the fuel treatment areas. More than eight million board feet of timber- valued at over $2.1 million was saved from loss in the fuel treatment areas.
- **Chelan Complex:** Previous thinning and burning treatments allowed for direct attack, holding actions and initiation of burn out operations which successfully contained the fire along the western flank throughout Purttemann Gulch and Echo Ridge ski area. Although the majority of treatments in the project area were not able to be used to control fire spread, they were effective in creating a fire resilient landscape demonstrated by the abundance of live trees remaining post-fire. Fire effects in some areas were stand replacing events that resulted from large fire runs that developed below or outside of treated areas. There was evidence of crown fires transitioning to surface fire in the treated areas. Figure 21 illustrates the effect of various fuel treatments on fire behavior and smoke production. Notice the difference in flame lengths and smoke color.
- **Corner Creek Fire:** Vegetation treatments proved to be a considerable advantage in controlling the southern spread of the fire towards private property and sage grouse habitat.

- **Bendire Complex:** Vegetation treatments contributed to minimizing damage and improving ecological outcomes.
- **County Line 2**: Several vegetation treatments were used to help suppress the fire by allowing firefighters to safely engage the fire. These treatments also protected primary residences, businesses, and infrastructure.

A

B

C

Figure 21 . Fire behavior during the Chelan Complex in A: untreated stands; B: thinned, piled, and piles burned but no underburning; and C: burnout in previously thinned, pruned, piled, pile burned, underburned (photos by Kari Greer).

8.0 Discussion

This report documents the extensive air quality impacts resulting from one of the largest fire seasons experienced in the Pacific Northwest in recent history. Smoke degraded air quality conditions for two to three weeks in communities located in close proximity to the fires across much of the region. While most of the fires were located east of the Cascade Divide, the heavily populated areas in the Willamette Valley and Puget Sound also experienced smoke from these fires. During an east-wind event in August, the smoke pushed into the major metropolitan areas exposing millions of people to unhealthy concentrations of $PM_{2.5}$.

The multiagency short-term response to the severe smoke caused by these fires was focused on monitoring and forecasting smoke, and providing recommendations to the public on how to reduce exposure. Based upon the large number of site visits to the state smoke blogs, these efforts are of great interest to the public. The long-term strategy is focused on restoring and maintaining an ecosystem which is departed from natural conditions and helping homeowners prepare their lands to be more resilient to fire. Prescribed burning is a critical part of the solution in restoring and maintaining forested ecosystems, especially when combined with forest thinning in locations which have a high probability of fire occurring and being transferred to communities.

Emissions and air quality impacts from prescribed burning are kept to a minimum due to state smoke management programs. Of the 5,513 ignitions which occurred, only 10 of these resulted in smoke intrusions and no escapes. One intrusion which occurred in Bend, Oregon exceeded unhealthy levels. This event resulted from smoldering fuels (tree stumps, rotten logs, and basal accumulations of duff), the emissions of which were trapped underneath the nocturnal temperature inversion and followed the Deschutes River drainage into town. The event was limited to the overnight hours and was over as soon as the inversion broke with morning heating by the sun.

Land managers recognize the altered nature of the landscape and are activity engaged in restoration and maintenance activities needed for healthy forests. The USDA Forest Service has expressed the need to increase the pace and scale of restoration on National Forest System Lands (USDA 2012). Similarly, other land management agencies and private land owners have expressed this need.

However, barriers remain to increasing the pace and scale of restoration treatments using prescribed fire. These barriers include (1) limited number of days in which burn units are within prescription due to weather (e.g., too wet, too dry, too windy, etc.), (2) limited capacity to accomplish the work, and (3) air quality/smoke management (Melvin, M., 2015).

Efforts are being made to improve our understanding of the barriers at the local scale and remedy the situation. Researchers from the US Forest Service Pacific Northwest Fire Science Lab have been making strides towards improving our understanding of the specifics of the emissions and meteorology associated with overnight smoke impacts. The outcome of this effort is likely to result in improved ability to accurately forecast smoke impacts on communities.

The air quality regulatory community is beginning to recognize the complicated and oversetting nature of restricting prescribed burning. For many years, air quality regulators have not only ensured compliance with the NAAQS, but also have attempted to keep all smoke from prescribed fires out of communities. However, limitations on prescribed burning identified previously (including air quality regulations) limit the ability of land managers to restore forested ecosystems to desired conditions at pace and scale which exceeds that which may be accomplished by potentially more severe wildfires (so called “being outpaced by wildfire”).

Air quality agencies responsible for controlling air pollution recognize the need for prescribed burning, but must also protect air quality. Some individual have postulated the need to examine the tradeoff between air quality impacts from prescribed burns and wildfires to help evaluate the risk associated with each and make informed decisions. However, no such guidance is offered on how to evaluate the tradeoff.

Table 12 presents a comparison between some characteristics of the prescribed and wildfire impacts in the Pacific Northwest during 2015. While the comparison is not intended to imply a one to one tradeoff, the comparison does provide the first step towards quantifying the existing conditions which would serve as the basis for a tradeoff analysis.

The amount of land treated by prescribed fire was only 14% of that burned by wildfires, or only 2% if not including pile burning. Emissions of PM2.5 from prescribed burning (including pile burning) were 12% of that emitted from wildfires, whereas GHG emissions from prescribed burning were only 6% of that emitted from wildfires. No structures or homes were lost due to prescribed fire whereas primary residences and structures were lost to wildfire. Additionally, because the smoke was so widespread and extensive in duration, 407 days were recorded by air monitors across the region which met or exceeded the unhealthy for sensitive people in which more than 10 million people were exposed to these conditions. In comparison, prescribed fire exposed approximately 81,000 people to unhealthy levels of smoke for sensitive groups.

Table 12. Comparison of prescribed fire and wildfire characteristics in Oregon and Washington in 2015.

Characteristic	Prescribed Fire	Wildfire
Acres Burned (including piles)	242,415	1,775,775
Acres Burned (not including piles)	35,796	1,775,775
Fatalities	0	3
Homes and Structures Lost	0	634
GHG Emissions (tons of CO2eq)	2,615,163	40,788,371
GHG Emissions (tons/acres)	10.79	22.97
PM2.5 Emissions (tons)	29,066	251,710
	0.12	0.14
Smoke Intrusions	10	n/a
Number of Days AQI > USG	1	407
Population Exposure to > USG	81,310	10,056,547

In response to the devastating impacts from wildfires over the past few years, the public and land managers have been asking "what can be done to change this trend" (larger fires, more smoke, more demands on resources)? Federal, State, and local agencies have increased their air quality response to wildfires by dedicating more resources to inform the public about smoke impacts. The response includes daily smoke management coordination calls, deployment of air resource advisors, and increased use of tools to disseminate information to the public, including the use of smoke blogs.

However, the increased response to wildfire (not just air quality response, but overall fire suppression costs) has resulted in a growing proportion of the Forest Service's annual budget dedicated to wildfire. As more and more of the agency's resources are spent each year to provide the firefighters, aircraft and other assets necessary to protect lives, property, and natural resources from catastrophic wildfires, fewer funds and resources are available to support other agency work – including the very program and restoration projects that can mitigate wildfire behavior and effects. This situation has a negative impact on the availability of funds for recreation, restoration, planning, and other activities of the Forest Service (USDA Forest Service, 2015)

Fuel treatments such as thinning and burning have proven effective for altering fire behavior and agencies are attempting to increase the pace and scale of these fuel treatments. However, it's not sufficient to keep up with the need in fire-dependent ecosystems. Approximately 10.4 million acres of land in Oregon and

Washington are in need of restoration which includes fire as part of the prescription (thinning and/or low severity fire) in forests that were historically maintained by frequent low or mixed severity fire (Haugo, 2015). Restoration needs vary across watersheds and range from as little as 5% to as much as 80% departed from natural range of variation. In Washington 3.2 million acres are in need of restoration which includes fire. In Oregon 7.2 million acres are in need of restoration with fire. These totals do not include maintenance burning, which can be in the millions of acres, as well.

In addition to prescribed burning, the use of naturally ignited fires on wildlands must also increase to accomplish restoration and maintenance goals. This allows fire to occur at times of the year when it normally occurs which best mimics the fuel conditions under which it naturally occurs and naturally functions in the ecosystem. However, the risks associated with this scenario have potentially high consequences should the fire get out of control and thus is used prudently. As fire modeling tools improve, the use of naturally ignited fires on wildlands may increase accordingly.

9.0 Conclusions

This report documents the air quality emissions and impacts from the 2015 fire season in the Pacific Northwest. This was one of the worst fire seasons on record for the region, and not surprisingly, air quality impacts were quite extensive as well, affecting nearly all communities in the PNW, not just those near the fires. As many as 2.5 million people were exposed to unhealthy air quality levels due to wildfire smoke on August 22 when east winds brought smoke from the fires in Central Washington and Oregon into the Portland metropolitan area. Air quality degraded to hazardous levels in Nespelem, Washington on one day, while several communities in Washington and Oregon experienced between two and three weeks of unhealthy air quality due to wildfire smoke.

Federal and State land management agencies have been attempting to increase the pace and scale of restoration projects to make forests more resilient to wildfires. Presumably, if all lands were within their historical range of natural variability, then the number, size, and severity of fires, as well as air quality, would be less than experienced in 2015. One of the key tools to restoring and maintaining resilient landscapes is to utilize thinning and prescribed burning.

A comparison between the emissions and air quality impacts from prescribed fire and wildfires is provided as a basis for future trade-off analyses in which the air quality impacts from wildfires may be offset by increased thinning and prescribed burning. The comparison illustrates that prescribed burning results in lower emissions per acre treated, less air quality impacts, and less loss of property and life than wildfire. Information such as this may be helpful in making informed changes to state smoke management plans to allow for increasing the pace and scale of prescribed burning on the landscape.

10.0 References:

Haugo, R., Zanger, C., DeMeo, T., Ringo, C., Shlisky, A., Blankenship, K., Simpson, M., Mellen-McLean, K., Kertis, J., Stern, M. 2015. A new approach to evaluate forest structure restoration needs across Oregon and Washington, USA. Forest Ecology and Management. 335 (2015) 37-50.

Kalies, E., Yocom Kent, LL, 2016. Tamm Review: Are fuel treatments effective at achieving ecological and social objectives? A systematic review. Forest Ecology and Management. 375 (2016) 84-85.

Melvin, M. 2015. National Prescribed Fire Use Survey Report, Technical Report 02-15, Coalition of Prescribed Fire Councils, Inc. and National Association of State Foresters. www.prescribedfire.net

National Wildfire Coordination Group, 2001. Smoke Management Guide for Prescribed and Wildland Fire, 2001 Edition. Sponsored by the US Department of Agriculture, US Department of Interior, and the National Association of State Foresters, PMS 420-2, NFES 1279.

Ottmar, R.D., Burns, M.F., Hall, J.N., and Hanson, A.D. 1993. CONSUME User's Guide. USDA Forest Service. Gen. Tech. Rep. PNW-GTR-304.

Ottmar, R.D., Sandberg, D.V.; Riccardi, C.L.; Prichard, S. J. 2007. An overview of the Fuel Characteristic Classification System (FCCS) - quantifying, classifying, and creating fuelbeds for resource planning. Can. J. For. Res. 37:1-11.

Riccardi, C.L.; Prichard, S.J., Sandberg, D.V., and Ottmar, R.D. 2007. Quantifying physical characteristics of wildland fuels using the Fuel Characteristic Classification System. Can. J. For. Res. 37: 2413-2420.

USDA Forest Service, 2015. Email correspondence from Joshua Chapman, which references Karen Short's point-based data set for acres (https://www.fs.usda.gov/rds/archive/Products/RDS-2013-0009.3/), and MTBS fire history perimeters (http://www.mtbs.gov/dataacess.html). USDA Forest Service, Region 6. November 29, 2015.

USDA Forest Service, Fire and Environmental Research Application Team. Fuels and Fire Tool, September 2015 Release, version 2.0.967. http://www.fs.fed.us/pnw/fera/fft/index.shtml.

USDA Forest Service. 2015. Narrative timeline of the Pacific Northwest 2015 fire season http://www.wfmrda.nwcg.gov/docs/_Reference_Materials/2015_Timeline_PNW_Season_FINAL.pdf.

USDA Forest Service, 2013. Restoration of fire-dependent forest: a sense of urgency. In: USDA Forest Service Pacific Northwest Region, Portland, OR. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5423599.pdf.

USDA Forest Service, 2015. The Rising Cost of Wildfire Operations: Effects on the Forest Service's Non-Fire Work. http://www.fs.fed.us/sites/default/files/2015-Fire-Budget-Report.pdf [Date Accessed: August 3, 2016]

USDA Forest Service, USDOI Bureau of Indian Affairs, and USDOI Bureau of Land Management, 2016. How Fuel Treatments Helped Suppression Efforts on the 2015 Pacific Northwest Fires.

US Environmental Protection Agency. 2015. Treatment of Data Influenced by Exceptional Events – Rule Revisions and Notice of Availability of Draft Guidance. Federal Register Volume 80, Number 224. Friday, November 20, 2015.

US Environmental Protection Agency. 2016. Particulate Matter (PM) Standards – Table of Historical PM NAAQS. https://www3.epa.gov/ttn/naaqs/standards/pm/s_pm_history.html. [Date Accessed: August 1, 2016]

Youngblood, A. Wright, C.S., Ottmar, R.D., and McIver, J.D. 2008. Changes in fuelbed characteristics and resulting fire potential after fuel reduction treatments in dry forests of the Blue Mountains, northeastern Oregon. Forest Ecology and Management 255 (2008) 3151- 3169.

Appendix A.

This appendix contains listings of the number of days observed in each AQI category for all permanent and temporary smoke monitors operating in Washington and Oregon in 2015. The only known exception is data from the temporary smoke monitor located in Ashland in November and December.

Table A-1 Number of days that select cities in Washington experienced impaired air quality by AQI category between June 1 and September 30, 2015.

Monitor Location	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Chelan	27	8	2	10	1	0
Clarkston	79	22	7	6	1	0
Darrington	90	3	1	1	0	0
Dayton	115	6	1	0	0	0
Ellensburg	102	17	1	2	0	0
Kennewick	101	14	3	0	0	0
Inchelium	43	6	3	5	0	0
Kent	114	7	1	0	0	0
Lacrosse	98	16	6	1	0	0
Leavenworth	107	12	3	0	0	0
Longview	119	2	1	0	0	0
Marysville	109	5	1	1	0	0
Mesa	100	19	3	0	0	0
Moses Lake	95	21	3	1	0	0
Nespelem	50	22	2	4	0	10
North Bend	115	6	1	0	0	0
Omak	78	21	5	4	2	5
Pullman	95	20	2	5	0	0
Puyallup	90	8	2	0	0	0
Ritzville	96	21	2	3	0	0
Rosalia	97	20	4	1	0	0
Spokane	85	20	3	3	0	0
Tacoma	99	4	1	0	0	0
Toppenish	92	15	8	4	0	0
Twisp	87	18	1	8	0	0
Walla Walla	108	10	3	1	0	0
Wellpinit	100	12	8	2	0	0
Wenatchee	90	9	4	1	0	0
White Swan	100	15	2	2	0	0
Winthrop	63	15	1	7	0	0
Yakima	71	23	2	1	0	0

Table A-2 Number of days in air quality index categories at temporary monitoring sites which were installed in select areas impacted by wildfire smoke and not well represented by permanent state monitors.

Monitor location and dates of operation in 2015	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Brewster (8/25-9/27)	25	4	0	3	1	0
Entiat (8/27-9/29)	33	1	0	0	0	0
Kettle Falls (8/29-9/10)	9	2	1	1	0	0
Manson (8/6-9/30)	19	6	0	1	0	0
Orient (8/31-9/10)	1	5	4	0	0	0
Republic (8/25-9/30)	8	9	6	10	1	3
Tonasket (9/1-9/30)	28	1	0	0	0	0

Table A-3 Number of days that select cities in Oregon experienced impaired air quality by AQI category between June 1 and September 30, 2015.

Monitor Location	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Albany	108	2	0	2	0	0
Baker City	94	13	8	2	0	0
Beaverton	114	4	0	2	0	0
Bend	97	20	2	1	0	0
Burns	106	14	2	0	0	0
Canby	118	2	0	2	0	0
Cave Junction	92	27	2	1	0	0
Corvallis	115	0	0	2	0	0
Cottage Grove	84	14	2	1	0	0
Cove	65	15	2	4	0	0
Crater Lake	54	17	9	0	0	0
Enterprise	97	13	3	5	0	0
Eugene-Springfield	88	10	2	1	0	0
Grants Pass	101	18	2	1	0	0
Hillsboro	120	0	1	1	0	0
John Day	90	21	4	5	0	0
Klamath Falls	90	23	7	2	0	0
La Grande	96	14	4	2	0	0
Lakeview	105	16	1	0	0	0
Lyons	77	6	0	2	0	0
Madras	87	13	3	1	0	0
Medford	86	21	8	7	0	0
Mt. Fanny	92	9	1	2	0	0
Multorpor (Mt. Hood)	64	9	0	2	0	0
Oakridge	91	7	1	1	0	0
Pendleton	102	16	2	2	0	0
Portland	102	4	1	1	0	0
Prineville	99	16	3	2	0	0

Provolt (Applegate Valley)	97	19	4	2	0	0
Roseburg	109	11	2	0	0	0
Salem	116	2	0	2	0	0
Sauvie Island	118	1	1	1	0	0
Shady Cove	95	10	8	6	2	1
Silverton	90	4	0	2	0	0
Sisters	103	15	3	1	0	0
Sweet Home	116	4	0	2	0	0
The Dalles	104	14	1	3	0	0

Table A- 4. Number of days in air quality index categories at temporary monitoring sites which were installed in select areas impacted by wildfire smoke and not well represented by state monitors.

Monitor location and dates of operation in 2015	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Ashland (8/11-8/31)	4	9	5	3	0	0
Eagle Point (8/9-8/22)	0	6	6	2	0	0
Halfway (8/25-8/31)	2	2	0	3	0	0
Jacksonville (8/9-8/16)	4	3	0	0	0	0
Prairie City (8/25-9/8)	7	2	1	2	0	0
Seneca (8/26-8/31)	3	3	0	0	0	0
Tiller (8/8-8/17)	1	4	2	3	0	0
Vale (8/21-8/28)	0	3	3	2	0	0