Smoke and Air Quality Monitoring Data Report
in Support of the
Washington State Department of Natural Resources
2016-17 Forest Resiliency Burning Pilot Project

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1. INTRODUCTION

Washington Department of Natural Resource (DNR) and the U.S. Forest Service, Pacific Wildland Fire Sciences Lab, collaborated to implement an air quality monitoring study designed to respond in part to the requirements of Engrossed Substitute House Bill (ESHB) 2928 passed by the Washington State Legislature during the 2016 regular session. ESHB 2928 instructed DNR to conduct a forest resiliency burning pilot project to monitor and evaluate the benefits of forest resiliency burning and the impacts on ambient air quality. Specifically they provided funding to (http://www.putfiretowork.org/):

- Safely complete controlled burns in priority areas
- Give 24 hour advance notice of burn approval to fire managers to encourage safe and successful completion of planned burns, and make it easier to complete multi-day burns
- Fully inform the public of planned burns, their purpose and projected effects
- Monitor how much smoke was forecasted and ultimately created by Pilot controlled burning and make recommendations for updating the DNR Smoke Management Plan
- Analyze and monitor fuel reductions and conditions of the forest stands before and after controlled burning
- Track outcomes and make recommendations for Pilot controlled burning to achieve more resilient forest conditions and reduce wildfire risks to communities in Washington

This report summarizes results of the ambient air quality monitoring portion of the pilot project and where available provides analysis of whether giving 24-hr advance notice of burn approvals to fire managers (instead of day-of-burn approval) had any noticeable impacts to air quality.

2. METHODS

2.1 Air Quality Monitoring Network

Fifteen potential pilot burn areas were identified on the Okanogan-Wenatchee National Forest (10 pilot units), the Colville National Forest (3 pilot units), and on lands managed by the Washington Department of Fish and Wildlife (2 pilot units) (Figure 1). Expert opinion from the fire managers about possible smoke movement from these pilot burns was used to identify locations for air quality monitoring. State air quality monitoring instruments were already in place at some of the at-risk locations but many locations were not represented. Nine temporary, portable monitors were deployed to locations throughout the state to detect air quality impacts from prescribed burning during the fall 2016 period of the pilot study and five were deployed during the spring of 2017.

Choosing an exact location for one of the temporary monitoring instruments depended on several factors 1) monitors needed to be in an area thought to be at risk from smoke impacts from a pilot burn, 2) monitors would ideally be placed near towns or other populated areas where people were likely to be affected by smoke, 3) access to electrical power, and 4) a clear view of the sky to allow data transfer via satellite modem. Figure 2 shows the locations of both the permanent (4) and temporary (9) monitors used in this study, in addition to the pilot burns from Figure 1. Table 1 lists details about the monitors including information on whether the monitor was permanent or temporary, what kind of monitor was used, and the nearest planned pilot burn. Figure 3 shows an example of one of the 9 temporary monitors deployed.

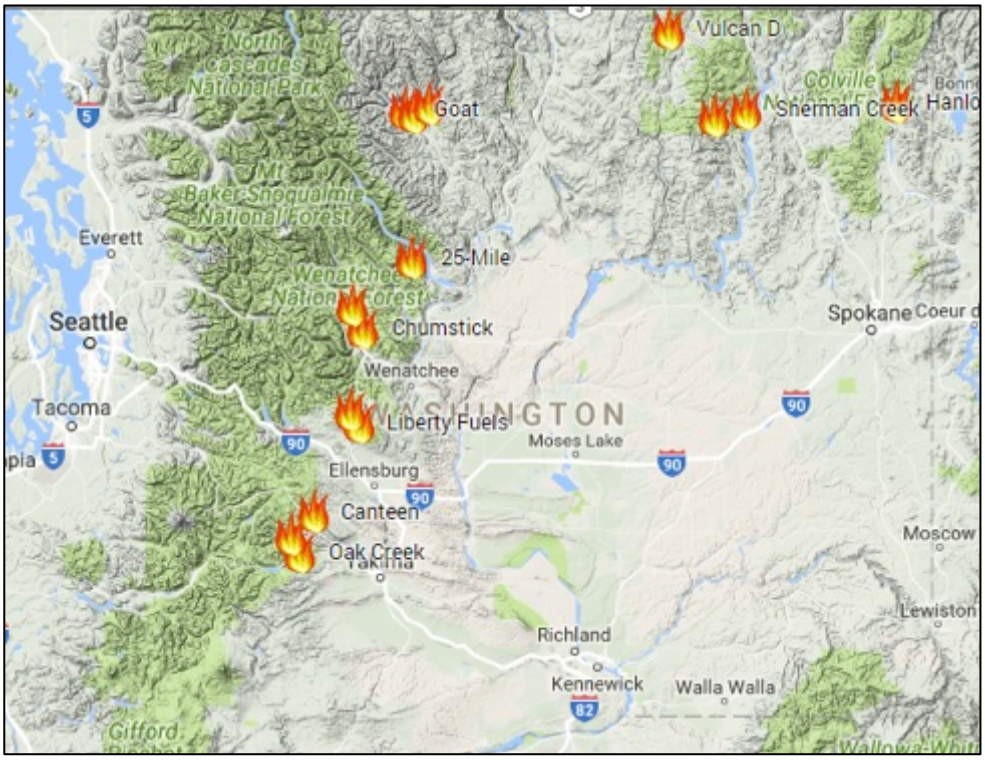

Figure 1: Location of the 15 proposed pilot burn units.

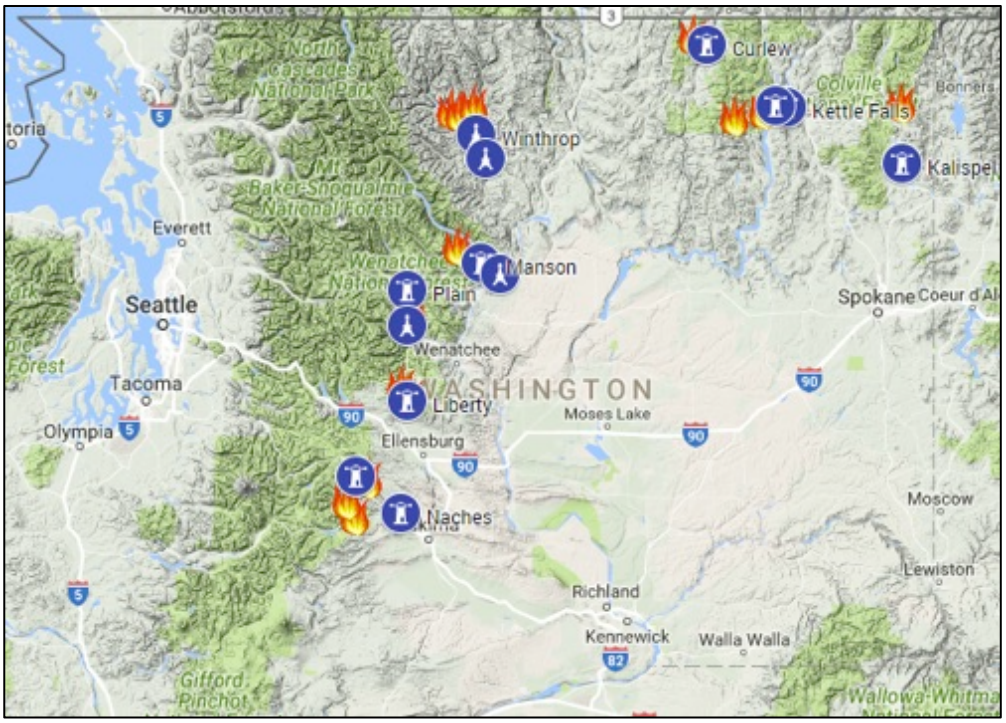

Figure 2. Locations of air quality monitors and 15 proposed pilot burns. The monitors at Leavenworth, Chelan, Twisp, and Winthrop are permanent (the narrow figure in the blue icons), others were installed for the study (the wide figure in the blue icons).

Table 1. Air quality monitors used for the 2928 Pilot burns, including location, name of nearest pilot burn units, and type of particulate monitor. "Neph" refers to Radiance Research M903 nephelometer, and EBAM and E-Sampler refer to the Met-One instruments. Nine temporary monitors were deployed in fall 2016 and five temporary monitors were deployed in spring 2017.

Air Quality Monitors	Location & Year	Nearby pilot burns	Latitude, Longitude	Monitor Type
Permanent	Winthrop	Goat, Eight Mile Bottom, Upper Rendezvous	48.48, -120.19	Neph
	Twisp	Goat, Eight Mile Bottom, Upper Rendezvous	48.36, -120.12	Neph
	Chelan	25 Mile	47.84, -120.02	Neph
	Leavenworth	Natapoc, Chumstick	47.60, -120.66	Neph
Temporary	Manson (2016,2017)	25 Mile	47.89, -120.15	EBAM
	Plain (2016)	Natapoc, Chumstick	47.77, -120.66	EBAM
	Liberty (2016)	Orion, Liberty Fuels	47.25, -120.67	EBAM
	Naches (2016, 2017)	Canteen, Angel, Oak Creek	46.73, -120.71	E-Sampler
	Pinecliff (2016, 2017)	Canteen, Angel, Oak Creek	46.90, -121.02	E-Sampler
	Curlew (2016)	Vulcan D	48.88, -118.61	EBAM
	Hatchery (2016, 2017)	Paradise 90, Sherman Creek	48.61, -118.13	EBAM
	Kettle Falls (2016, 2017)	Paradise 90, Sherman Creek	48.60, -118.06	E-Sampler
	Kalispel Tribal Center (2016)	Hanlon	48.34, -117.27	E-Sampler

Figure 3. Example of one of the E-Samplers deployed as part of the Pilot Burn Project. This unit was deployed at the Volunteer Fire Department in Plain, WA.

2.2 Prescribed Burn and Satellite Hotspot Information

The overall goal of the air quality monitoring portion of the pilot burn study was to test whether the 24-hour advance approval of prescribed burns increased the likelihood of air quality impacts. To do this other potential sources of air pollution that could impact a monitor need to be considered (not just the Pilot burns). Therefore, all prescribed burning events needed to be part of the analysis including those that received the standard day-of-burn approval. Other sources of air quality degradation could be present at the sites but were not identified as part of this study. They include sources such as wildfires, prescribed burning of <100 tons (does not need a permit so is not in the DNR database), tribal burning (which operates under Environmental Protection Agency authority), field burning, backyard burning, home wood heating, and any anthropogenic sources that may impact the more urbanized locations.

The DNR smoke management permitting webpage (https://fortress.wa.gov/dnr/protection/burnrequests/) was used to gather prescribed burn records for all pilot and non-pilot burning during the period of the study. Records of prescribed burns which received smoke management approval between Sept 1 and October 15, 2016 or April 1 thru June 23, 2017; reported accomplishments (i.e. were actually burned); and were located in the vicinity of the pilot burn study area were compiled. The DNR webpage was the source for date-of-burn, latitude/longitude of burn, and whether the burn received smoke management approval. DNR is known to rely on an older method of calculating fuel consumed that is especially suspect for modeling fuel consumption on the forests of the eastside of the Cascades. For this reason, reported fuel consumed from prescribed burning was retrieved from a federal burn-reporting database as information reported by Forest Service fire managers was believed to be more reliable and consistent. DNR reported consumption values were used for Washington Department of Fish and Wildlife burns. Appendix A provides a list of all the prescribed burning activity analyzed in this report.

In the future, it would be valuable to compare estimates of fuel consumed from both of the DNR estimates and FS estimates to the results of the companion study which measured fuel loading and consumption on many of the burns proposed for the pilot study (See the companion USDA Forest Service Pacific Wildland Fire Sciences Laboratory Report *Pre- and Post-Burn Fuel Characterization and Tree Mortality Assessment for the Forest Resiliency Burning Pilot*).

Satellites can detect "hotspots" on the ground which can be an alternative source of basic information about burning that does not show up in the prescribed fire database. Several different satellites detect "hotspots" which are reported in the National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System (HMS) product. Many factors affect how successful the satellites are at detecting fires, including the size of the fire and cloudiness. The geographic location of each hotspot was matched to GIS-mapped fuel types so a rough fire size and fuel consumed could be estimated. In some cases these hotspots are very likely the prescribed burns that are already in the database, in other cases it is likely they are the other unquantified categories of fires described previously.

2.3 Quantifying Air Quality Conditions

The Environmental Protection Agency (EPA) sets air quality standards for the purpose of protecting human health. PM2.5 is the primary regulated pollutant of concern when considering smoke from fires. The national ambient air quality standard (NAAQS) for fine particulate matter (PM2.5) is 35 µg/m^3 averaged over 24-hours. The EPA has also developed a simple index that can be used when communicating air quality conditions with the public (Table 2). The air quality index (AQI) color codes air quality conditions in one of 6 health-based categories depending on the level of PM2.5 concentration. It is important to note that these categories are based on 24-hour averages. People can often be concerned about smoke or feel health effects from smoke in a much shorter time period than 24-hours. For this reason tracking both 24-hour averages measured at the monitoring network but also short term 1-hour averages was important. One hour average PM2.5 does not have any official regulatory significance but it can indicate when the public may be affected or concerned by smoke concentrations. Wildland fire smoke can cause dramatic, short-term changes in $PM_{2.5}$ concentration however, the AQI for particle pollution is a 24-hour average to reflect EPA's national ambient air quality standards and the science on PM exposures and health. One other point to note is that none of the instruments used in this study (permanent or temporary monitors) are considered adequate for official EPA tracking of NAAQS.

Table 2. The national air quality index (AQI) links air quality conditions to health concern categories.

Levels of Health Concern	**AQI Values**	**PM2.5 24-hr ave. (µg/m^3)**
Good	0-50	0-12
Moderate	51-100	12.1-35.4
Unhealthy for Sensitive Groups (USG)	101-150	35.5-55.4
Unhealthy	151-200	55.5-150.4
Very Unhealthy	201-300	150.5-250.4
Hazardous	301-500	>250.5

3. RESULTS

Five of the pilot burns used the 24-hr prior approval process in this study for a total of 10 burn days in the fall of 2016 and 7 burn days in the spring of 2017. They were Orion Unit 2 (3 burn days, fall 2016), 25 Mile (2 burn days fall 2016, 1 burn day spring 2017), Paradise 90 (4 burn days, fall 2016), Sherman Creek (6 burn days, spring 2017) and Hanlon (1 burn day, fall 2016). Details about the burn locations, the date and ignition time they were burned, and tons of fuel consumed are given in tables 3 and 4 for fall 2016 and tables 5 and 6 for spring 2017.

Figure 4 shows an overview of all of the prescribed fires that were included in the fall 2016 analysis with the 24-hour advance approval pilot burns displayed with a darker fire icon. Figure 5 shows the prescribed fires included in the analysis for spring 2017. Satellite detected hotspots throughout the region are also shown (triangles) and the air quality PM2.5 monitoring sites (blue circles). This Results section presents the data and analysis for each of the monitoring sites, with sites in close proximity grouped together. Each section has maps centered on the monitor and showing all the prescribed burns and satellite hot spots in a 32-km radius. Time series of the 1-hr and 24-hr average PM2.5 concentrations with the prescribed burns and satellite hot spots are also given. Finally, a table summarizing all the fire activity (prescribed burns and satellite hot spots) with the day-of and day-after 24-hr PM2.5 concentrations and maximum 1-hr concentrations are provided for each monitoring location.

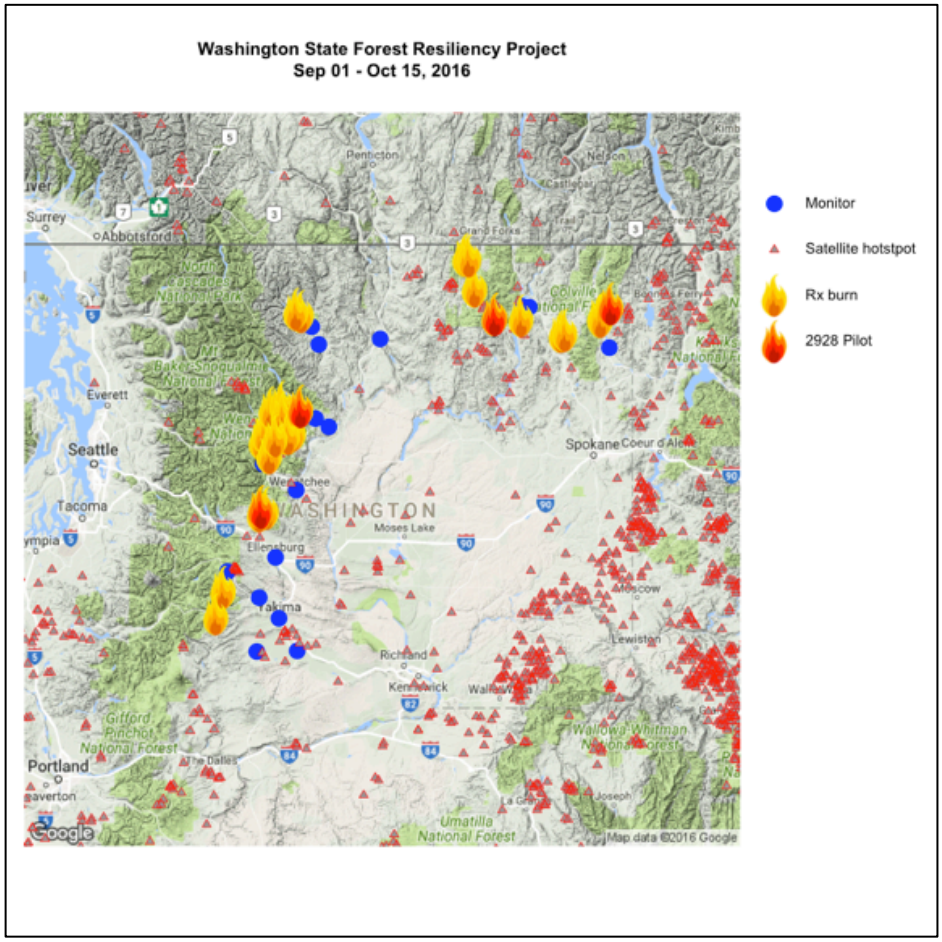

Figure 4: Map of reported prescribed fires, 2928 Pilot prescribed fires using 24-hour advanced approval, permanent and temporary air quality monitors (blue circles), and satellite detected hot spots for fall of 2016.

Table 3. Locations of the pilot burns accomplished using 24-hour advance approval during the fall of 2016.

Unit Name	Region	Land Owner	Nearest AQ monitor	Latitude	Longitude
Paradise 90	Colville NF	Three Rivers	Kettle Falls & Fish Hatchery	48.56	-118.40
Orion Unit 2	Wenatchee NF	Cle Elum	Liberty	47.32	-120.69
Hanlon HF Hand	Colville NF	Sullivan Lake	Kalispel Tribal Center	48.62	-117.26
25 Mile UB 2016	Wenatchee NF	Chelan	Manson	47.97	-120.2991

Table 4. Pilot burn accomplishments using 24-hour advance approval in fall of 2016.

Date	Ignition Time (PDT)	Unit	Proposed Tons	Accomplished Tons
9/14/16	11:00	Paradise 90	2400	1600
9/14/16	11:30	Orion Unit 2	1518	40
9/15/16	11:00	Paradise 90	960	480
9/21/16	9:30	Orion Unit 2	640	480
9/22/16	10:00	Orion Unit 2	680	624
9/26/16	15:00	Hanlon HF Hand	600	90
9/27/16	11:00	Paradise 90	7200	645
9/28/16	10:00	Paradise 90	7200	3627
9/28/16	10:30	25 Mile UB 2016	502	220
9/29/16	10:30	25 Mile UB 2016	502	290

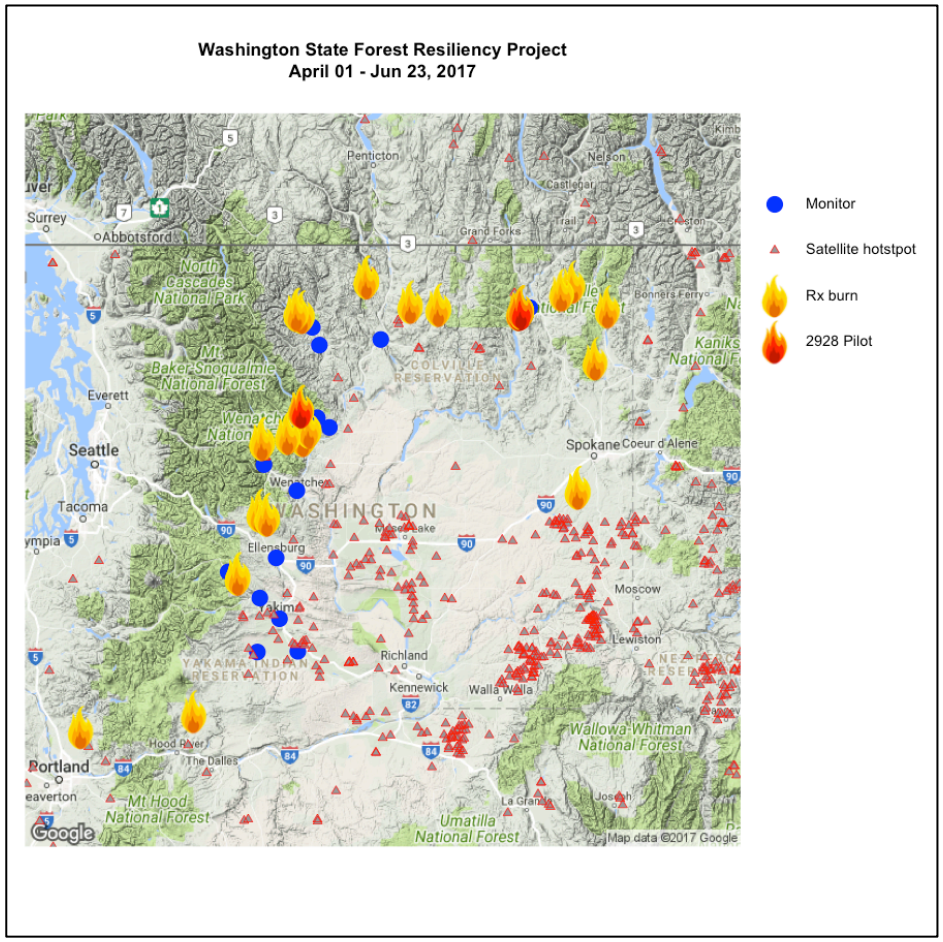

Figure 5: Map of reported prescribed fires, 2928 Pilot prescribed fires using 24-hour advanced approval, permanent and temporary air quality monitors (blue circles), and satellite detected hot spots for spring of 2017.

Table 5. Locations of the pilot burns accomplished using 24-hour advance approval during the spring of 2017.

Unit Name	Region	Land Owner	Nearest AQ monitor	Latitude	Longitude
25 Mile UB 2016	Wenatchee NF	Chelan	Manson	47.97	-120.2991
Rail	NE Region	WDFW	Kettle Falls & Fish Hatchery	48.59	-118.16
Bridge/Hatch/Trail	NE Region	WDFW	Kettle Falls & Fish Hatchery	48.597	-118.14
Bisbee	NE Region	WDFW	Kettle Falls & Fish Hatchery	48.604	-118.141

Table 6. Pilot burn accomplishments using 24-hour advance approval in spring of 2017.

Date	Ignition Time (PDT)	Unit	Proposed Tons	Accomplished Tons
5/8/2017		25 Mile 2017	797	245
5/9/2017		Rail	300	480
5/30/2017		Bridge/Hatch/Trail	300	129
6/1/2017		Bridge/Hatch/Trail	240	204
6/6/2017		Bisbee	360	180
6/12/2017		Bisbee	354	115
6/13/2017		Bisbee	364	91

Manson and Chelan

The small town of Manson, WA, approximately 12-km upriver from Chelan, WA was identified for placement of a temporary monitor because of the expected fire activity from the 25 Mile Pilot burn in the Wenatchee National Forest. A permanent monitor is also located in Chelan, WA.

All 24-hr average PM2.5 concentrations were within the good air quality category for these two sites during the pilot burning project. Manson and Chelan had a mix of Pilot and non-Pilot burns and there was no obvious difference in air quality impacts between Pilot and non-Pilot burns.

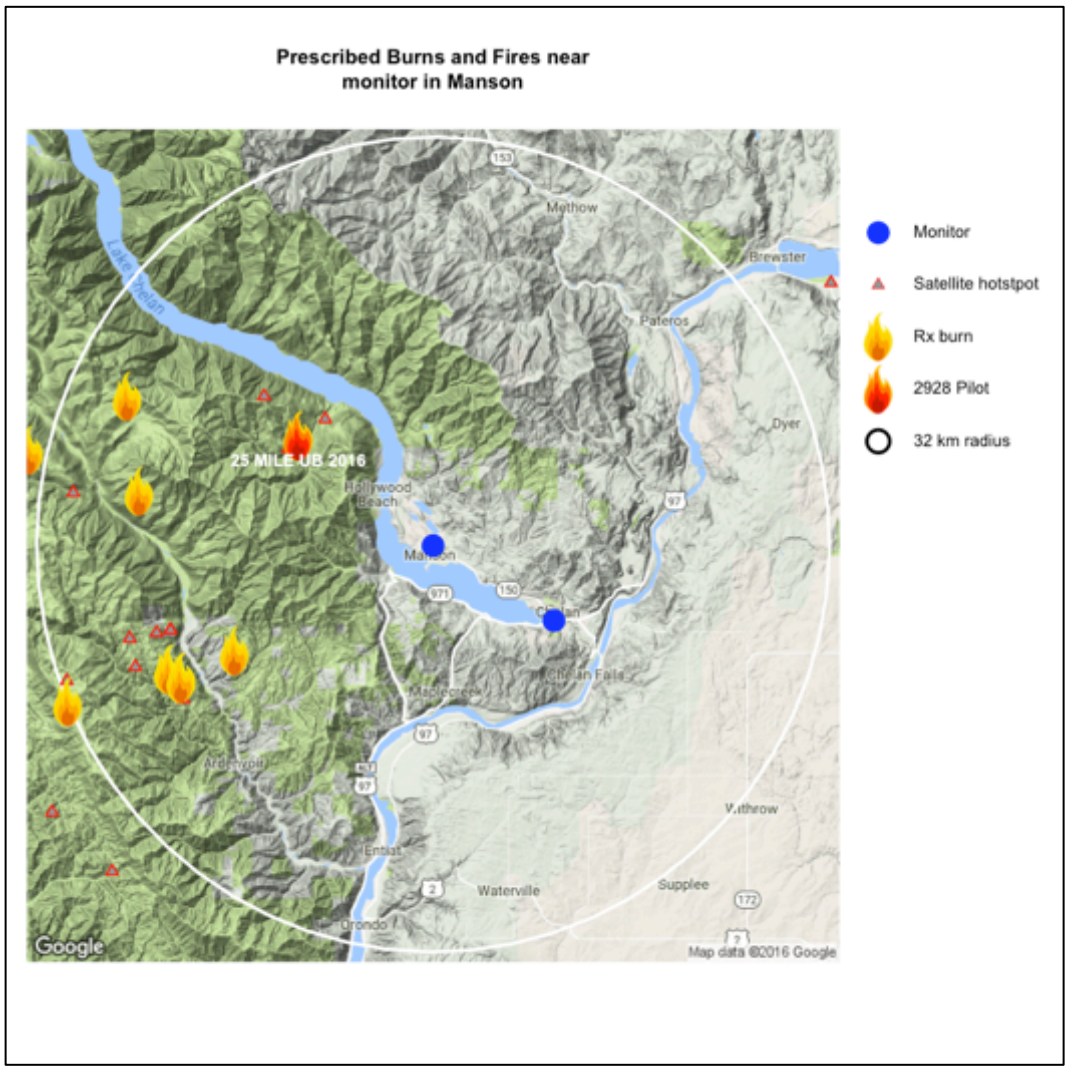

Figure 6: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Manson, WA in fall of 2016. One day of burning on the 25 Mile pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

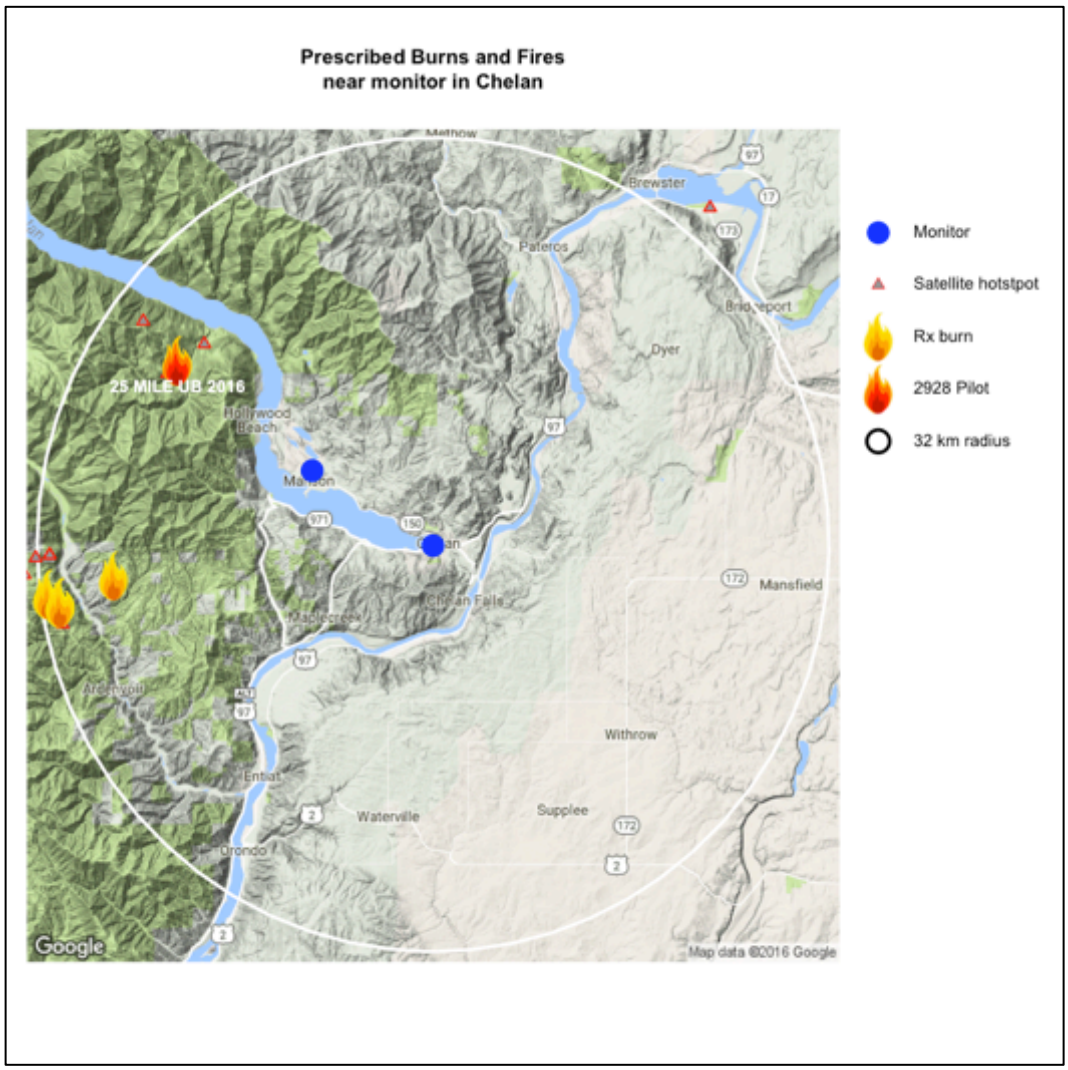

Figure 7: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Chelan, WA in fall of 2016. One day of burning on the 25 Mile pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

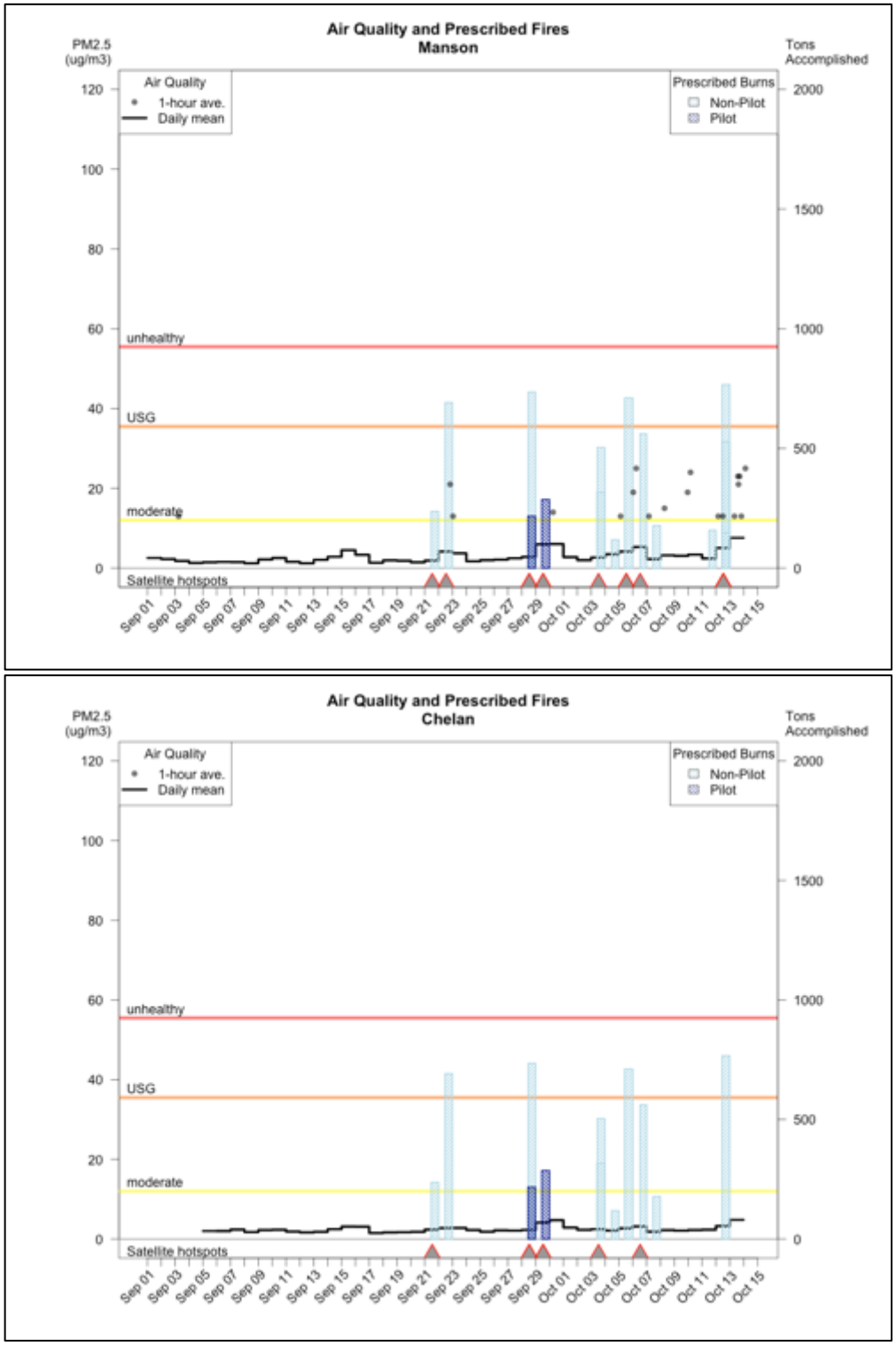

Figure 8: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Manson and Chelan, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 7: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Manson in fall of 2016.

Manson Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
21-Sep	LOWER TYEE FALL 2016	240	22.8	SW	2	8	1400	4	21	2000
21-Sep	satellite	28	22.8	SW						
22-Sep	LOWER TYEE FALL 2016	700	22.8	SW	4	21	2000	4	13	0100
22-Sep	satellite	112	25.4	SW						
28-Sep	25 MILE UB 2016*	220	13.8	W	3	8	2300	6	12	0200
28-Sep	LOWER TYEE FALL 2016	744	22.8	SW						
28-Sep	satellite	253	17.9	W						
28-Sep	satellite	28	22.2	SW						
29-Sep	25 MILE UB 2016*	290	13.8	W	6	12	0200	6	14	0600
29-Sep	satellite	253	13.9	W						
29-Sep	satellite	28	22.2	SW						
3-Oct	25 MILE UB 2016	510	13.8	W	3	7	0300	4	11	1200
3-Oct	LOWER TYEE FALL 2016	320	22.8	SW						
3-Oct	satellite	506	13.2	NW						
4-Oct	LOWER TYEE FALL 2016	120	22.8	SW	4	11	1200	4	13	0300
5-Oct	TYEE PILES 2016	720	23.4	SW	4	13	0300	5	25	0600
5-Oct	satellite	506	25.8	SW						
5-Oct	satellite	506	24.6	SW						
6-Oct	NORTH FORK POTATO FALL 2016	568	18	SW	5	25	0600	2	13	0400
6-Oct	satellite	28	23.5	SW						
7-Oct	TYEE PILES 2016	180	23.4	SW	2	13	0400	3	15	0700
11-Oct	SHADY PASS 2016	160	27.3	W	2	12	1100	5	13	0400
12-Oct	ENTIAT RIDGE REHAB 2015	534	31.9	SW	5	13	0400	8	23	1400
12-Oct	FROG ROCK MACHINE	150	24	W						
12-Oct	LOWER TYEE FALL 2016	776	22.8	SW						
12-Oct	satellite	28	23.3	SW						
12-Oct	satellite	1651	29.2	W						
12-Oct	satellite	251	31.4	SW						

*24-Hr Advance approval pilot burn.

Table 8: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Chelan in the fall of 2016.

Chelan Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
21-Sep	satellite	28	30.6	SW	2	3	1900	3	5	2000
21-Sep	LOWER TYEE FALL 2016	240	30.4	SW						
22-Sep	LOWER TYEE FALL 2016	700	30.4	SW	3	5	2000	3	5	100
28-Sep	satellite	253	29.2	W	2	3	2300	4	6	2200
28-Sep	satellite	28	30.9	SW						
28-Sep	25 MILE UB 2016*	220	25.2	W						
28-Sep	LOWER TYEE FALL 2016	744	30.4	SW						
29-Sep	satellite	253	25.3	W	4	6	2200	5	6	0000
29-Sep	satellite	28	30.9	SW						
29-Sep	25 MILE UB 2016*	290	25.2	W						
3-Oct	satellite	506	24.3	W	3	3	0600	2	3	2300
3-Oct	LOWER TYEE FALL 2016	320	30.4	SW						
3-Oct	25 MILE UB 2016	510	25.2	W						
4-Oct	LOWER TYEE FALL 2016	120	30.4	SW	2	3	2300	3	4	1200
5-Oct	TYEE PILES 2016	720	31.3	SW	3	4	1200	3	4	1200
6-Oct	satellite	28	30.5	SW	3	4	1200	2	2	0400
6-Oct	NORTH FORK POTATO FALL 2016	568	25.9	SW						
7-Oct	TYEE PILES 2016	180	31.3	SW	2	2	0400	2	3	1400
12-Oct	LOWER TYEE FALL 2016	776	30.4	SW	3	4	2200	5	9	1700

*24-Hr Advance approval pilot burn.

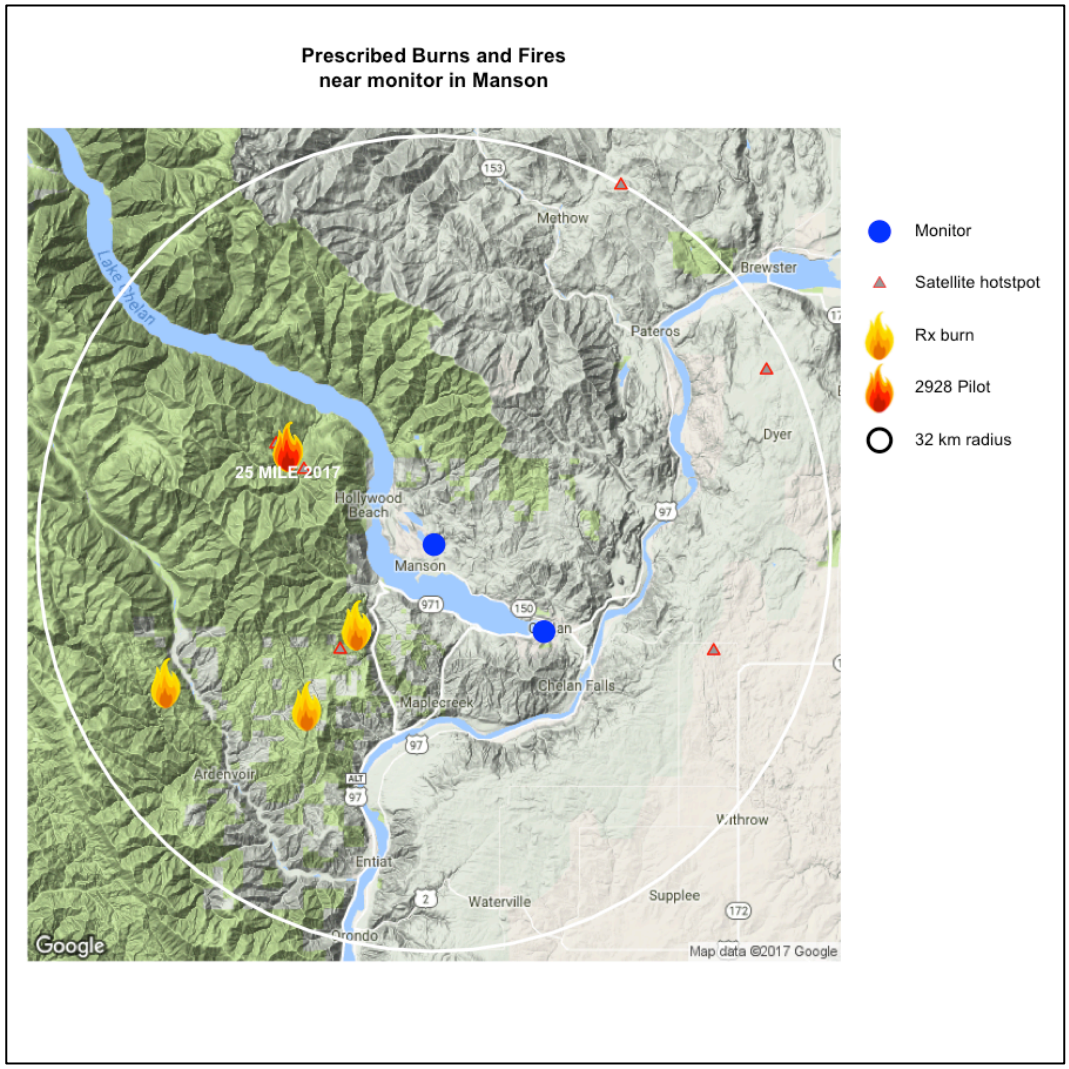

Figure 9: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Manson, WA in spring of 2017. One day of burning on the 25 Mile pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

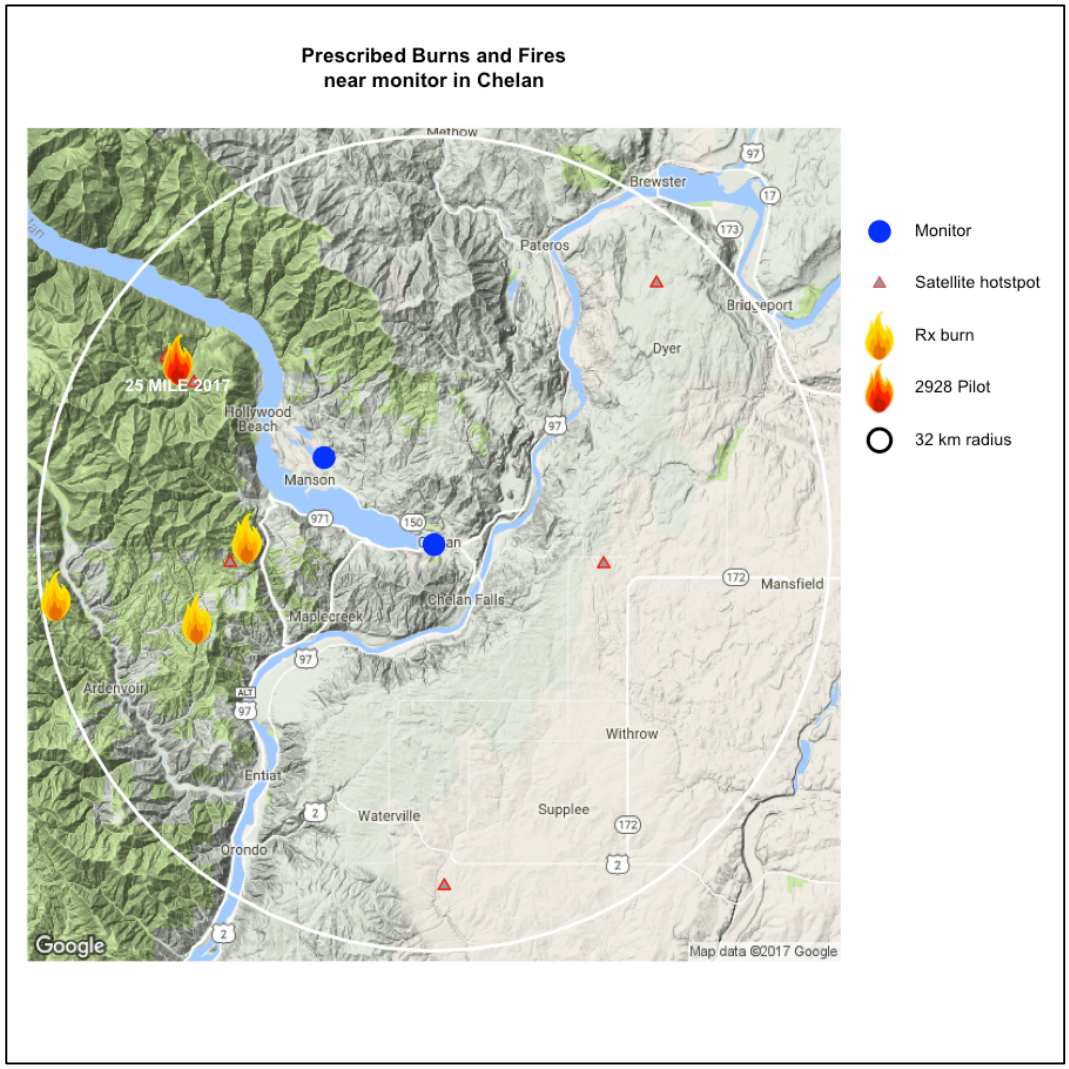

Figure 10: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Chelan, WA in spring of 2017. One day of burning on the 25 Mile pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

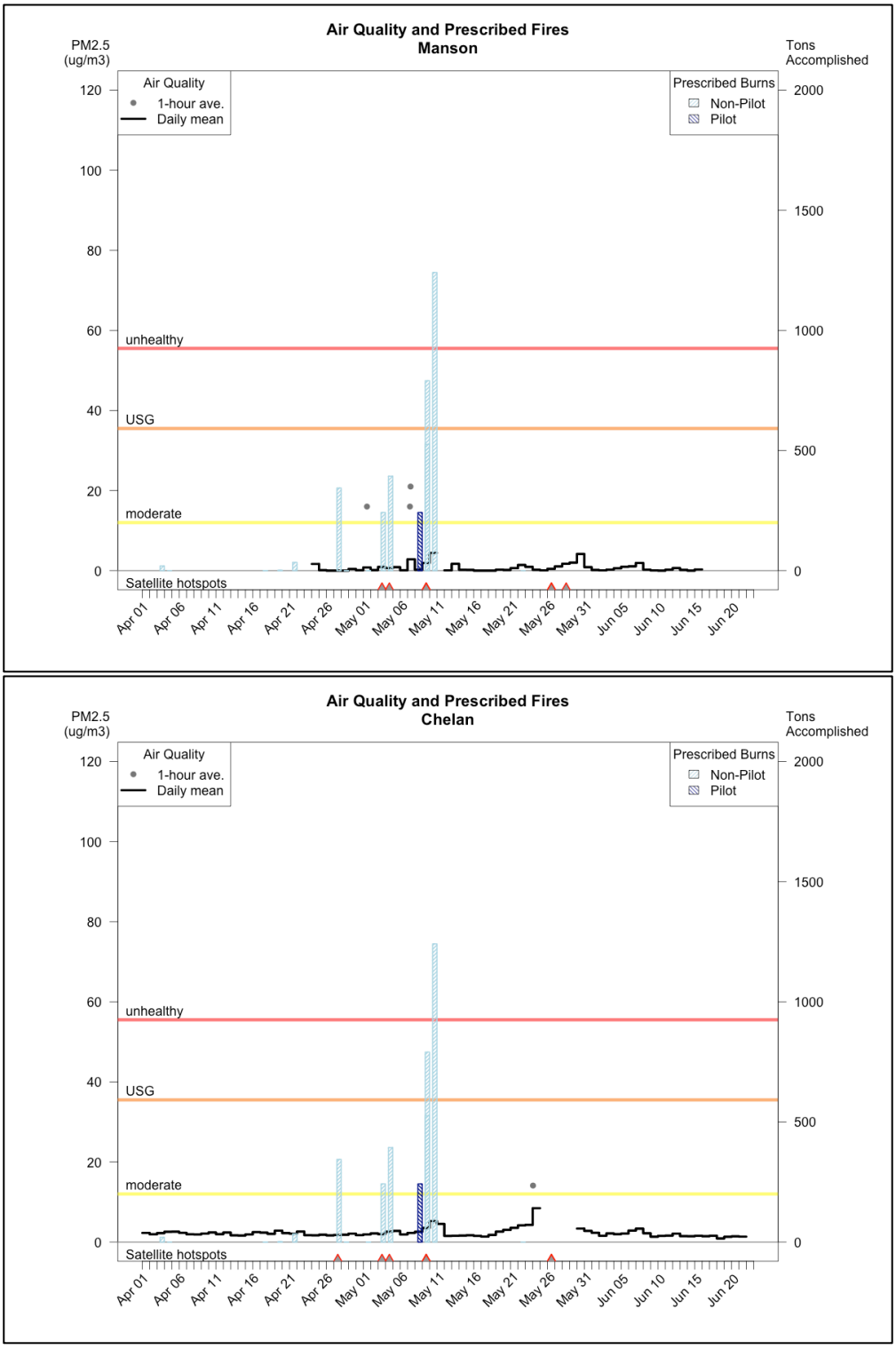

Figure 11: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Manson and Chelan, WA during the spring of 2017. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1μ/m^3 were not plotted to reduce clutter on the graph.)

Table 9: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Manson in spring of 2017.

Manson Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
3-Apr	2017 BISPING-PALMICH	20	16.3	S	NA	NA	NA	NA	NA	NA
19-Apr	FOREST JOHNSON 2017	2	8.9	S	NA	NA	NA	NA	NA	NA
21-Apr	25 MILE 2017	35	14	W	NA	NA	NA	NA	NA	NA
27-Apr	FOREST JOHNSON 2017	348	8.9	S	0	0	0000	0	0	0000
3-May	satellite	758	12	W	0.9	2	0300	0.6	2	2100
3-May	25 MILE 2017	245	14	W						
4-May	satellite	84	11.2	S	0.6	2	2100	0.9	3	0800
4-May	FOREST JOHNSON 2017	398	8.9	S						
8-May	25 MILE 2017*	245	14	W	0.2	1	0700	1.9	7	2300
9-May	satellite	506	14.9	W	1.9	7	2300	4.4	12	2100
9-May	satellite	279	24.4	SW						
9-May	25 MILE 2017	532	14	W						
9-May	LOWER TYEE 2017	800	24.2	SW						
10-May	LOWER TYEE 2017	1256	24.2	SW	4.4	12	2100	NA	NA	NA
26-May	satellite	553	30	NE	0.5	5	2100	1.1	4	1300
26-May	satellite	641	24	E						
28-May	satellite	1099	31.9	N	1.7	6	1200	2	8	2100

*24-Hr Advance approval pilot burn.

Table 10: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Chelan in the spring of 2017.

Chelan Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 μ/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 μ/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
3-Apr	2017 BISPING-PALMICH	20	20	SW	2.2	4	2100	2.6	3.9	1900
19-Apr	FOREST JOHNSON 2017	2	15.1	W	2.8	4.7	1400	2.2	3	1000
21-Apr	25 MILE 2017	35	25.2	W	2.1	3	2200	2.6	3.5	0200
27-Apr	satellite	553	26.9	SE	1.8	3.6	1400	1.8	1.9	0100
27-Apr	FOREST JOHNSON 2017	348	15.1	W						
3-May	satellite	758	23.1	W	2	2.3	2300	2.6	5.3	2300
3-May	25 MILE 2017	245	25.2	W						
4-May	satellite	84	16.5	SW	2.6	5.3	2300	2.8	4.8	0000
4-May	FOREST JOHNSON 2017	398	15.1	W						
8-May	25 MILE 2017*	245	25.2	W	2.6	2.8	1900	3.5	10.1	2300
9-May	satellite	506	26.1	W	3.5	10.1	2300	5.2	9.3	0000
9-May	satellite	279	30.8	SW						
9-May	25 MILE 2017	532	25.2	W						
9-May	LOWER TYEE 2017	800	30.7	SW						
10-May	LOWER TYEE 2017	1256	30.7	SW	5.2	9.3	0000	4.5	8.8	1000
26-May	satellite	553	27.2	N	Na	NA	NA	Na	NA	NA
26-May	satellite	641	13.7	E						

*24-Hr Advance approval pilot burn.

Plain and Leavenworth

The small town of Plain, WA was identified for placement of a temporary monitor during Fall of 2016 because of the expected fire activity in the Wenatchee National Forest and anecdotal accounts of smoke impacts in the area. A permanent monitor was already located in Leavenworth, WA, 22.5 km down-valley to the south of Plain. Plain experienced the greatest amount of prescribed fire activity with 10 prescribed fire projects within 32 km, many with multiple day burns. Many of the same prescribed fires were within 32 km of Leavenworth as well. None of the burns were 2928 pilot burns.

Air quality impacts were in the USG AQI category (> 38 $\mu g/m^3$) on two days at Plain. Seven days experienced 24-hr concentrations in the Moderate AQI category (> 12 $\mu g/m^3$). This location had the highest smoke impacts of all the monitoring sites. Conversely, Leavenworth only experienced two days of 24-hr average PM2.5 concentrations in the Moderate AQI category. Three prescribed fire units are most likely responsible for smoke into Plain; Fishloop, Natapoc, and possibly Entiat Ridge Rehab 2015.

Fishloop is located 4-km north of Plain and it was ignited on 4 separate days. It is most likely responsible for the USG occurrences. Furthermore, periods of elevated PM2.5 concentrations would continue during the night and early morning hours for several days after the prescribed fire was completed. Afternoons were generally clear. For example, during the Sep 28 – Oct 4 period smoke would clear during the day, then concentrations would be elevated overnight and into the early morning hours. Plain is in a small mountain valley and it is likely nighttime wind patterns would bring smoke from the higher elevation to the north down the valley. It is unknown at this point whether smoldering fuels were present in the unit to contribute to the nighttime smoke concentrations. The fourth and final Fishloop burn (on 9/28/2016) was probably responsible for the Moderate AQI category conditions in Leavenworth the following day.

Natapoc is located 1.4-km southwest of Plain and was ignited on three consecutive days (9/20-22/2016). It brought some smoke into Plain but not to the degree that Fishloop did even with similar tonnage and being closer to town. Daily average PM2.5 concentrations remained in the Good AQI category and peak 1-hr PM2.5 concentrations occurred late afternoon into the early evening (e.g. 83 $\mu g/m^3$ at 1800 PDT) and in one case into the evening (night of 9/22/2016). Natapoc did not impact Leavenworth.

Chumstick is located12-km southeast of Plain and 6 km north of Leavenworth. Interestingly enough it did not cause impacts of note to either town.

On October 13 both Plain and Leavenworth experienced a Moderate AQI category day. It is difficult to ascertain whether Entiat Ridge Rehab 2015 was responsible or if it was a combined effect from several burns further away (17-29 km) to the northeast.

The Orion Unit 2 pilot burn was approximately 32 km to the south of Leavenworth. This burn did not impact Leavenworth.

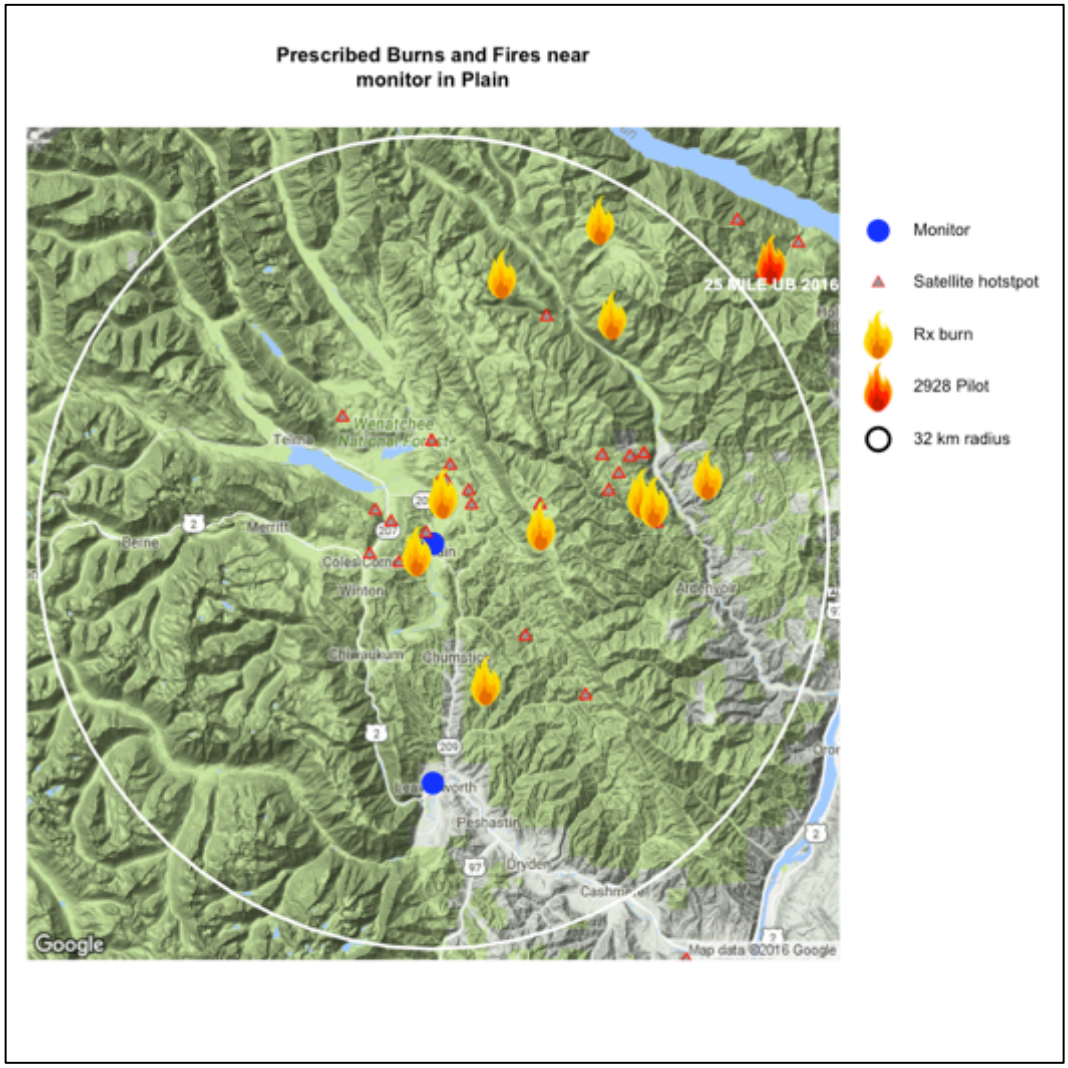

Figure 12: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Plain, WA in fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

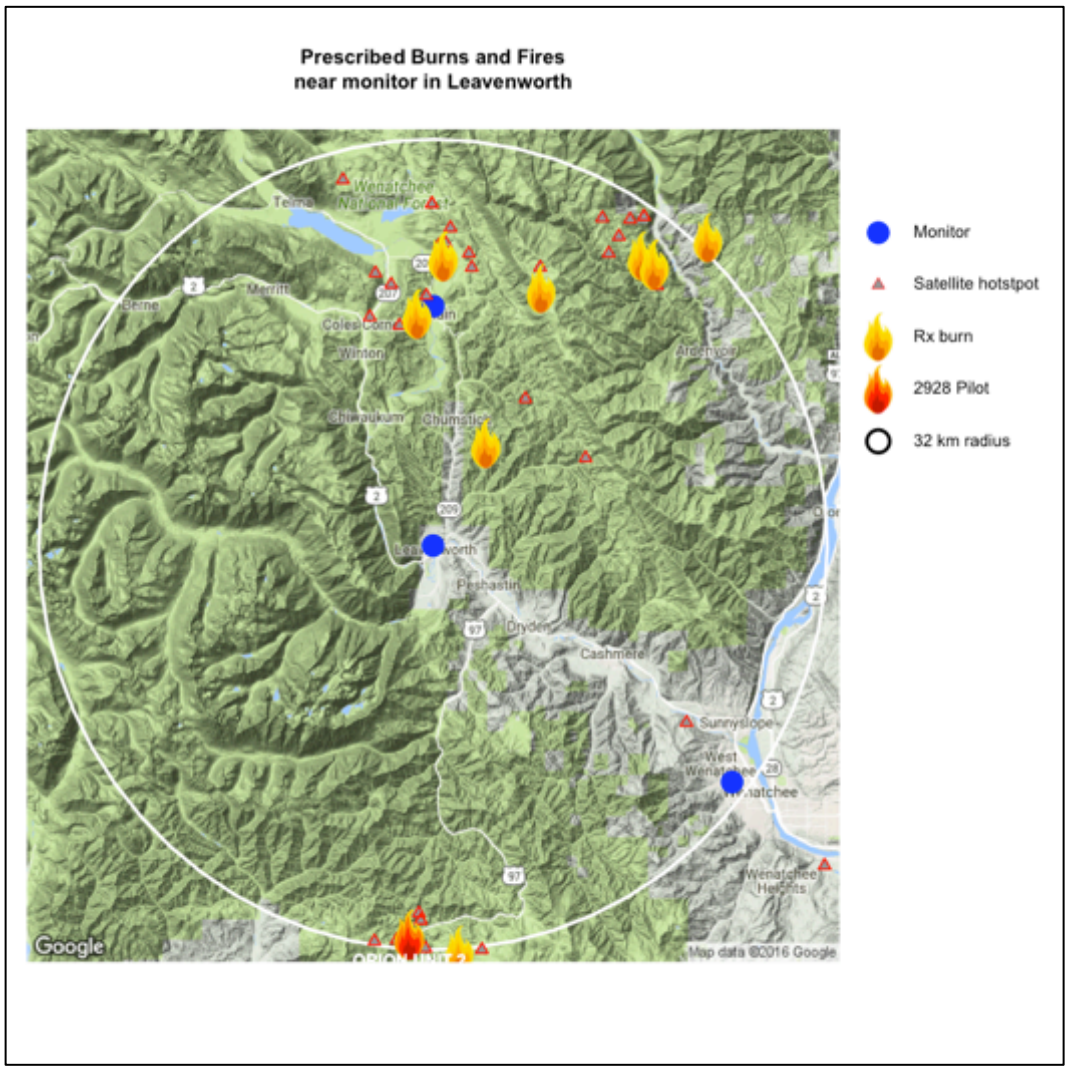

Figure 13: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Leavenworth, WA in fall of 2016. Two days of burning on the Orion Unit 2 pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

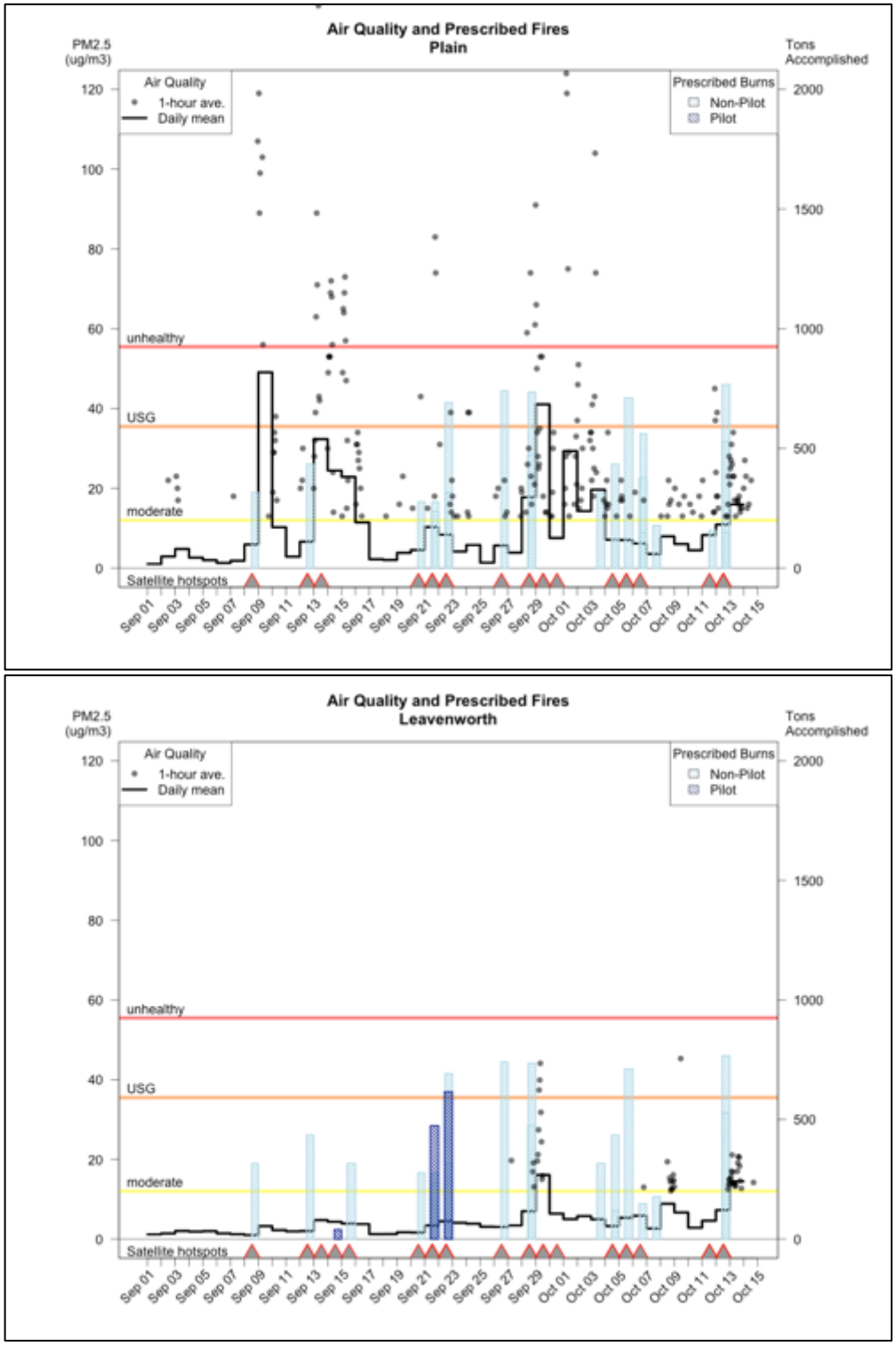

Figure 14: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Plain and Leavenworth, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 11: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Plain, fall 2016.

Plain Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
9/8	FISHLOOP UNDERBURNS	320	4.0	N	6	107	2300	49	185	0500
9/8	satellite	253	6.3	N						
9/12	FISHLOOP UNDERBURNS	440	4.0	N	7	30	0500	32	158	0700
9/12	satellite	506	5.0	N						
9/12	satellite	253	8.0	N						
9/13	satellite	253	8.0	N	32	158	0700	24	72	0600
9/20	NATAPOC	280	1.4	SW	5	43	1700	10	83	1800
9/20	satellite	4232	5.2	W						
9/21	LOWER TYEE FALL 2016	240	18.1	NE	10	83	1800	8	39	2100
9/21	NATAPOC	280	1.4	SW						
9/21	satellite	4232	1.0	NW						
9/21	satellite	846	3.1	SW						
9/21	satellite	28	18.0	E						
9/22	LOWER TYEE FALL 2016	700	18.1	NE	8	39	2100	4	18	0000
9/22	NATAPOC	320	1.4	SW						
9/22	satellite	112	15.3	NE						
9/22	satellite	846	5.3	NW						
9/26	FISHLOOP UNDERBURNS	750	4.0	N	6	22	1800	4	20	2300
9/26	satellite	846	12.3	NW						
9/28	FISHLOOP UNDERBURNS	480	4.0	N	18	74	1500	41	277	1000
9/28	LOWER TYEE FALL 2016	NA	18.1	NE						
9/28	satellite	28	18.4	NE						
9/28	satellite	253	4.8	N						
9/29	satellite	28	18.4	NE	41	277	1000	8	34	0700
9/29	satellite	253	4.3	NE						
9/30	satellite	846	5.0	NE	8	34	0700	29	146	0700
10/3	LOWER TYEE FALL 2016	NA	18.1	NE	20	104	0700	7	34	0500
10/4	CHUMSTICK UNDERBURNS	440	11.6	SE	7	34	0500	7	22	0400
10/4	LOWER TYEE FALL 2016	NA	18.1	NE						
10/4	satellite	846	10.4	SE						
10/5	TYEE PILES 2016	720	17.3	NE	7	22	0400	6	19	0400

10/5	satellite	253	14.8	E						
10/5	satellite	253	16.0	E						
10/6	CHUMSTICK UNDERBURNS	150	11.6	SE	6	19	0400	4	12	0600
10/6	NORTH FORK POTATO FALL 2016	568	22.8	NE						
10/6	TOMMY MAD	382	21.9	N						
10/6	satellite	28	18.1	E						
10/7	TYEE PILES 2016	180	17.3	NE	4	12	0600	8	22	1400
10/11	SHADY PASS 2016	160	28.7	N	8	45	2200	11	39	0200
10/11	satellite	1693	3.8	NW						
10/12	ENTIAT RIDGE REHAB 2015	534	8.8	NE	11	39	0200	16	34	0600
10/12	FROG ROCK MACHINE	150	23.0	N						
10/12	LOWER TYEE FALL 2016	776	18.1	NE						
10/12	satellite	28	17.3	NE						
10/12	satellite	1651	20.0	NE						
10/12	satellite	1011	17.2	SE						
10/12	satellite	251	9.2	E						

Table 12: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Leavenworth, fall 2016.

Leavenworth Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
8-Sep	satellite	253	25.1	N	1	2	2100	3	9	0800
8-Sep	FISHLOOP UNDERBURNS	320	22.8	N						
12-Sep	satellite	758	23.8	N	2	5	0700	5	11	0700
12-Sep	satellite	758	26.9	NW						
12-Sep	FISHLOOP UNDERBURNS	440	22.8	N						
13-Sep	satellite	253	26.9	NW	5	11	0700	4	8	1200
14-Sep	satellite	846	29.7	S	4	8	1200	4	6	1400
14-Sep	ORION UNIT 2*	40	30.9	S						
15-Sep	satellite	846	29.7	S	4	6	1400	4	7	1300
15-Sep	ORION UNIT 2	320	30.9	S						
20-Sep	satellite	4232	18.7	NW	2	2	0800	3	7	2300
20-Sep	NATAPOC	280	18.3	NW						
21-Sep	satellite	5079	19.7	NW	3	7	2300	5	8	0800
21-Sep	satellite	5079	17.6	NW						
21-Sep	satellite	5079	29.1	S						
21-Sep	satellite	5079	31.9	S						
21-Sep	satellite	28	28.7	N						
21-Sep	ORION UNIT 2*	480	30.9	S						
21-Sep	LOWER TYEE FALL 2016	240	28.5	N						
21-Sep	NATAPOC	280	18.3	NW						
22-Sep	satellite	112	29.2	N	5	8	0800	4	6	2300
22-Sep	satellite	2539	31.4	S						
22-Sep	satellite	846	22.0	NW						
22-Sep	ORION UNIT 2*	624	30.9	S						
22-Sep	LOWER TYEE FALL 2016	700	28.5	N						
22-Sep	NATAPOC	320	18.3	NW						
26-Sep	satellite	846	29.7	NW	3	9	1000	3	20	0600
26-Sep	FISHLOOP UNDERBURNS	750	22.8	N						
28-Sep	satellite	28	31.0	N	7	19	2000	16	44	0800
28-Sep	satellite	253	23.7	N						
28-Sep	FISHLOOP UNDERBURNS	480	22.8	N						
28-Sep	LOWER TYEE FALL 2016	744	28.5	N						
29-Sep	satellite	28	31.0	N	16	44	0800	6	8	1900

29-Sep	satellite	253	22.1	N						
30-Sep	satellite	846	23.2	N	6	8	1900	5	8	0800
3-Oct	LOWER TYEE FALL 2016	320	28.5	N	5	6	2000	3	6	0600
4-Oct	satellite	846	13.8	N	3	6	0600	5	12	0600
4-Oct	satellite	4232	31.7	S						
4-Oct	LOWER TYEE FALL 2016	120	28.5	N						
4-Oct	CHUMSTICK UNDERBURNS	440	9.1	N						
5-Oct	satellite	506	27.1	N	5	12	0600	6	13	1900
5-Oct	satellite	506	28.6	N						
5-Oct	TYEE PILES 2016	720	28.4	N						
6-Oct	satellite	28	27.3	N	6	13	1900	3	8	1100
6-Oct	CHUMSTICK UNDERBURNS	150	9.1	N						
7-Oct	TYEE PILES 2016	180	28.4	N	3	8	1100	9	19	1200
11-Oct	satellite	66	24.9	E	5	12	2200	7	15	2300
11-Oct	satellite	1693	20.9	NW						
12-Oct	satellite	28	30.2	N	7	15	2300	15	21	0400
12-Oct	satellite	1011	14.1	NE						
12-Oct	satellite	251	23.6	N						
12-Oct	LOWER TYEE FALL 2016	776	28.5	N						
12-Oct	ENTIAT RIDGE REHAB 2015	534	22.1	N						

*24-Hr Advance approval pilot burn.

Liberty

The tiny town of Liberty, WA was identified for placement of a temporary air quality monitor in fall of 2016 due to the proximity of a proposed 2928 pilot burn "Orion Unit 2" in the Wenatchee National Forest. Orion Unit 2 was burned on 4 occasions, with three of those occasions taking advantage of the 24-hr approval window. Two additional prescribed fires were accomplished on 2 different days in the area of the Liberty monitor using the standard DNR approval process.

The 24-hr average PM2.5 concentrations generally stayed in the Good AQI category (below 12 $\mu g/m^3$) with the exception of one day after the Orion Unit 2 burn on 9/22/2016, when the 24-hr average PM2.5 concentration went to a Moderate AQI 16 $\mu g/m^3$ on 9/23/2016. This burn used the 24-hr approval process. The maximum 1-hr PM2.5 concentration was 92 $\mu g/m^3$ at 9 AM PDT on 9/23/2016. This burn had the second highest tonnage consumed and like all the other prescribed burns was less than 8-km from town.

This site appears to be influenced by sources other than prescribed burning because 1-hr PM2.5 concentrations often ranged up to 30 $\mu g/m^3$ independent of any burning activities, and typical 24-hr PM2.5 concentrations ranged between 5-10 $\mu g/m^3$. In summary, some impact from prescribed burning activity was noticeable at this site, but only once resulting in anything other than good air quality.

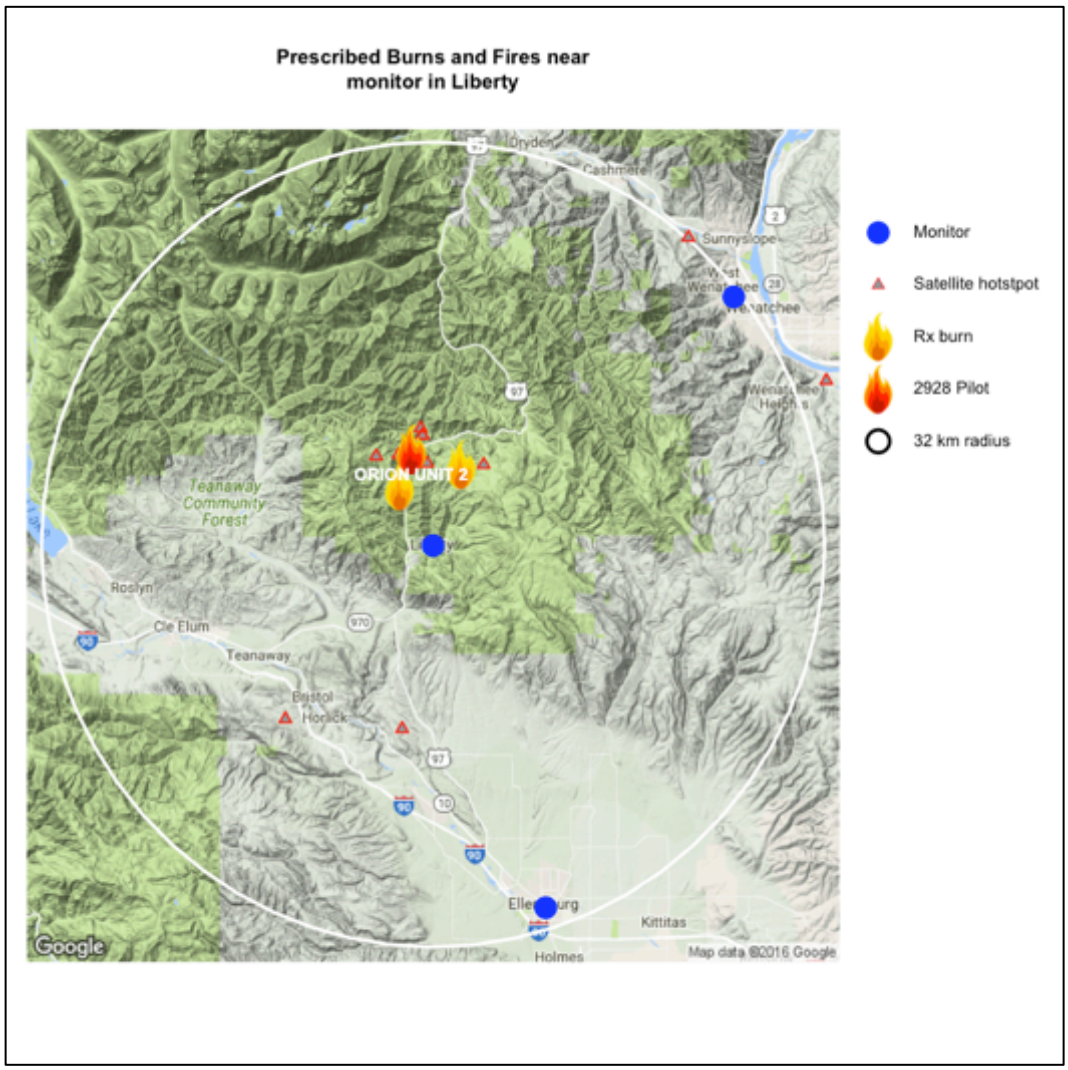

Figure 14: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Liberty, WA in fall of 2016. Two days of burning on the Orion Unit 2 pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

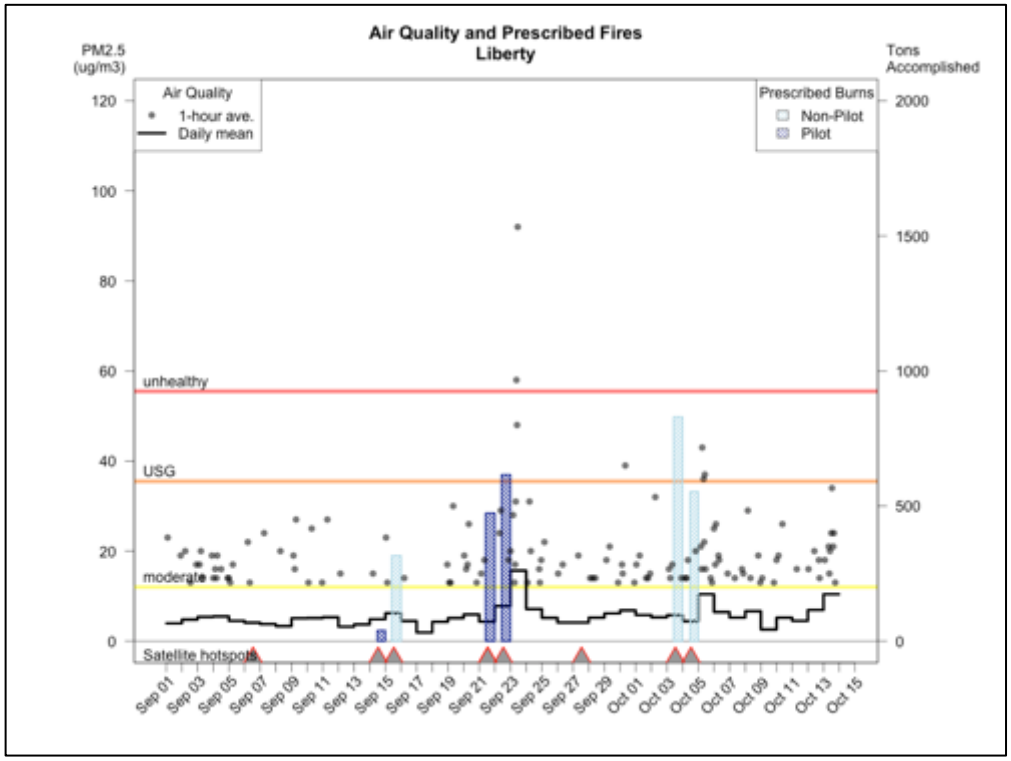

Figure 15: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Liberty, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 13: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Liberty in fall of 2016.

Liberty Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
6-Sep	satellite	364	14.8	S	4	22	0500	3.8	24.0	0600
14-Sep	satellite	846	8.8	NW	5	15	0500	6.2	23.0	0100
14-Sep	ORION UNIT 2*	40	7.8	NW						
15-Sep	Satellite	846	8.8	NW	6	23	0100	4.5	14.0	0500
15-Sep	ORION UNIT 2	320	7.8	NW						
21-Sep	satellite	5079	9.4	NW	4	18	0800	7.8	29.0	0900
21-Sep	satellite	5079	6.6	NW						
21-Sep	ORION UNIT 2*	480	7.8	NW						
22-Sep	satellite	2539	7.7	NW	8	29	0900	15.7	92.0	1100
22-Sep	ORION UNIT 2*	624	7.8	NW						
27-Sep	satellite	187	18.3	S	4	19	0800	5.2	14.0	0200
3-Oct	satellite	846	7.6	N	6	17	0800	4.4	20.0	2000
3-Oct	LIBERTY FUELS UNITS 52-56	840	6.8	N						
4-Oct	satellite	4232	8.5	NW	4	20	2000	10.4	43.0	0600
4-Oct	ORION SBA UNIT 8	560	5.5	NW						

*24-Hr Advance approval pilot burn.

Pinecliff and Naches

The narrow canyon northwest of Naches, WA was identified for a placement of a temporary air quality monitor because of the expected fire activity in the Wenatchee National Forest and anecdotal accounts of smoke impacts in the area. The monitor was located at Pinecliff, WA at a USDA Forest Service site. The Angel Underburn and Canteen were the only prescribed fires within a 32 km radius of Pinecliff and Naches in 2016 and 2017 respectively and they were not Pilot Burns. The Angel Underburn was burned on two days (9/15/2016 and 9/28/2016) and Canteen was burned on 5/25/2017 and neither caused air quality impacts to either Pinecliff or Naches.

In fall 2016, the 24-hr average PM2.5 concentrations were all in the Good AQI category (below 12 $\mu g/m^3$) for both sites with the exception of one day in the Moderate AQI category in Naches on 9/14/2016. Unknown fire activity occurred from 9/10-16/2016 on the ridge less than 10 km east of Pinecliff and 25-30 km northwest of Naches. This unknown fire activity is likely the cause of the peak 1-hr average PM2.5 concentrations that ranged up to 60 $\mu g/m^3$ during this time period. It is interesting to note that higher concentrations were measured at Naches rather than at Pinecliff.

In spring 2017, the 24-hr average PM2.5 concentrations were all in the Good AQI category (below 12 $\mu g/m^3$) for both sites with the exception of 3 days in the Moderate AQI category at Pinecliff 6/21-23/2017. These elevated concentrations are probably not due to fire activity because there were not any satellite hot spot detections or reported burn activity.

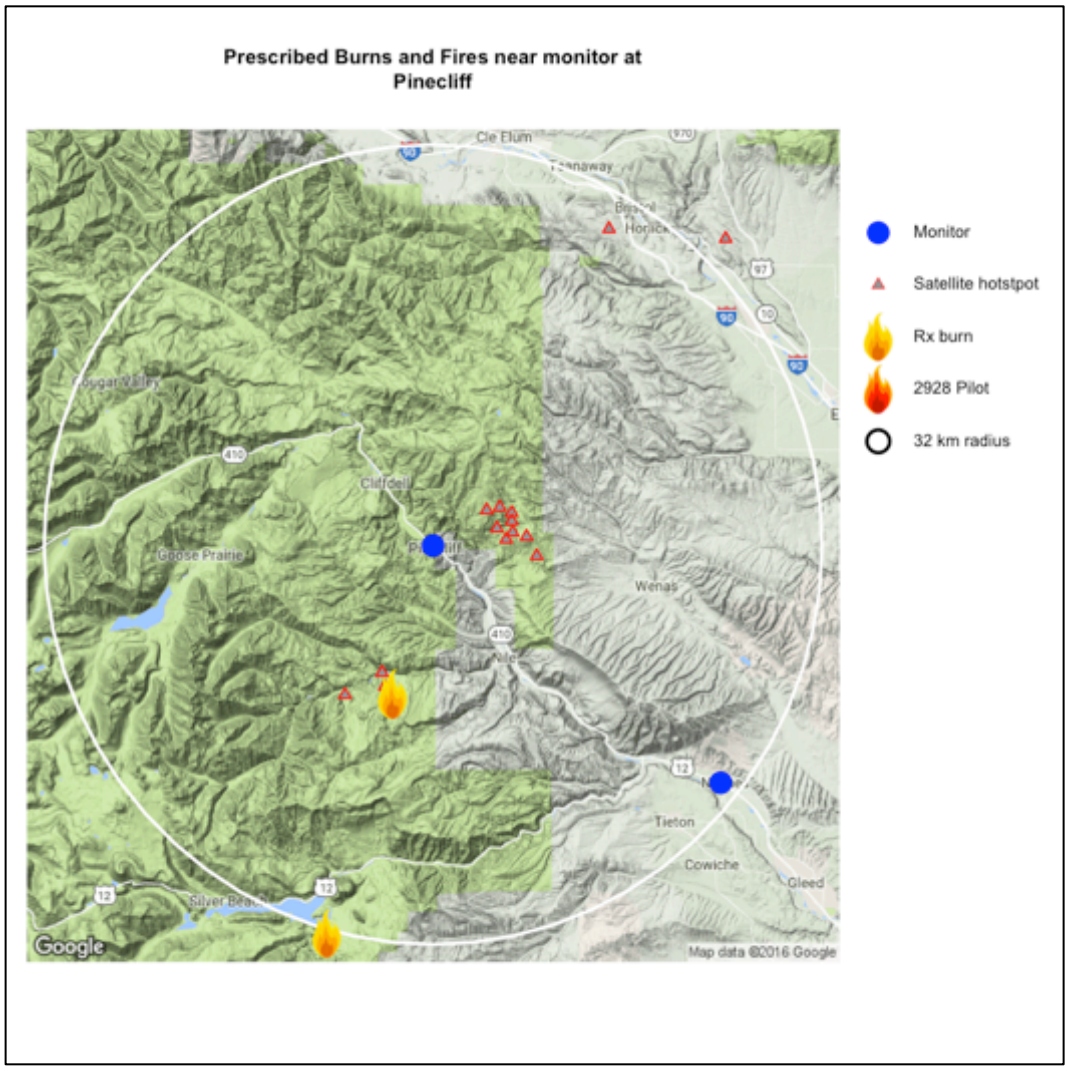

Figure 16: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Pinecliff, WA in fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

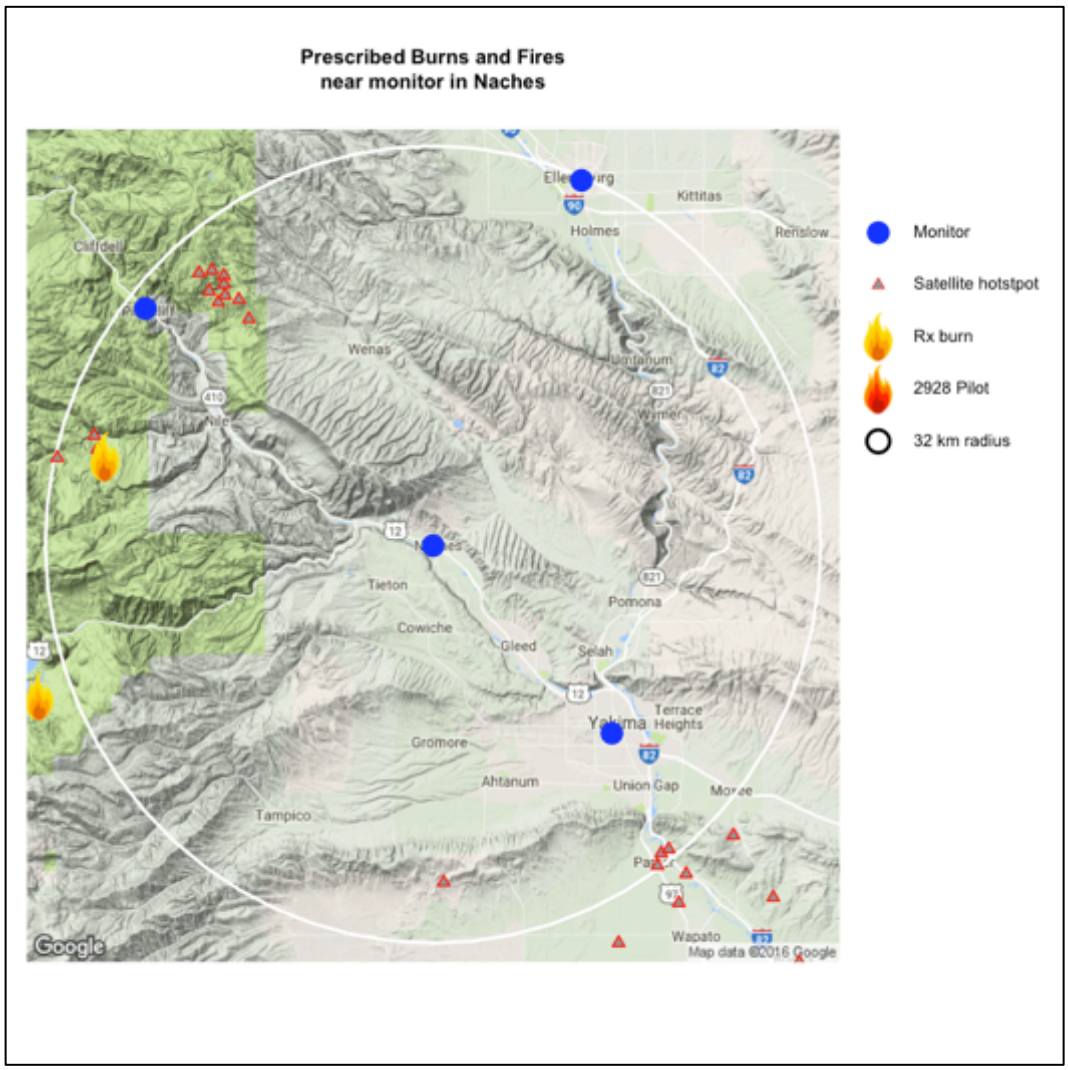

Figure 17: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Naches, WA in fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

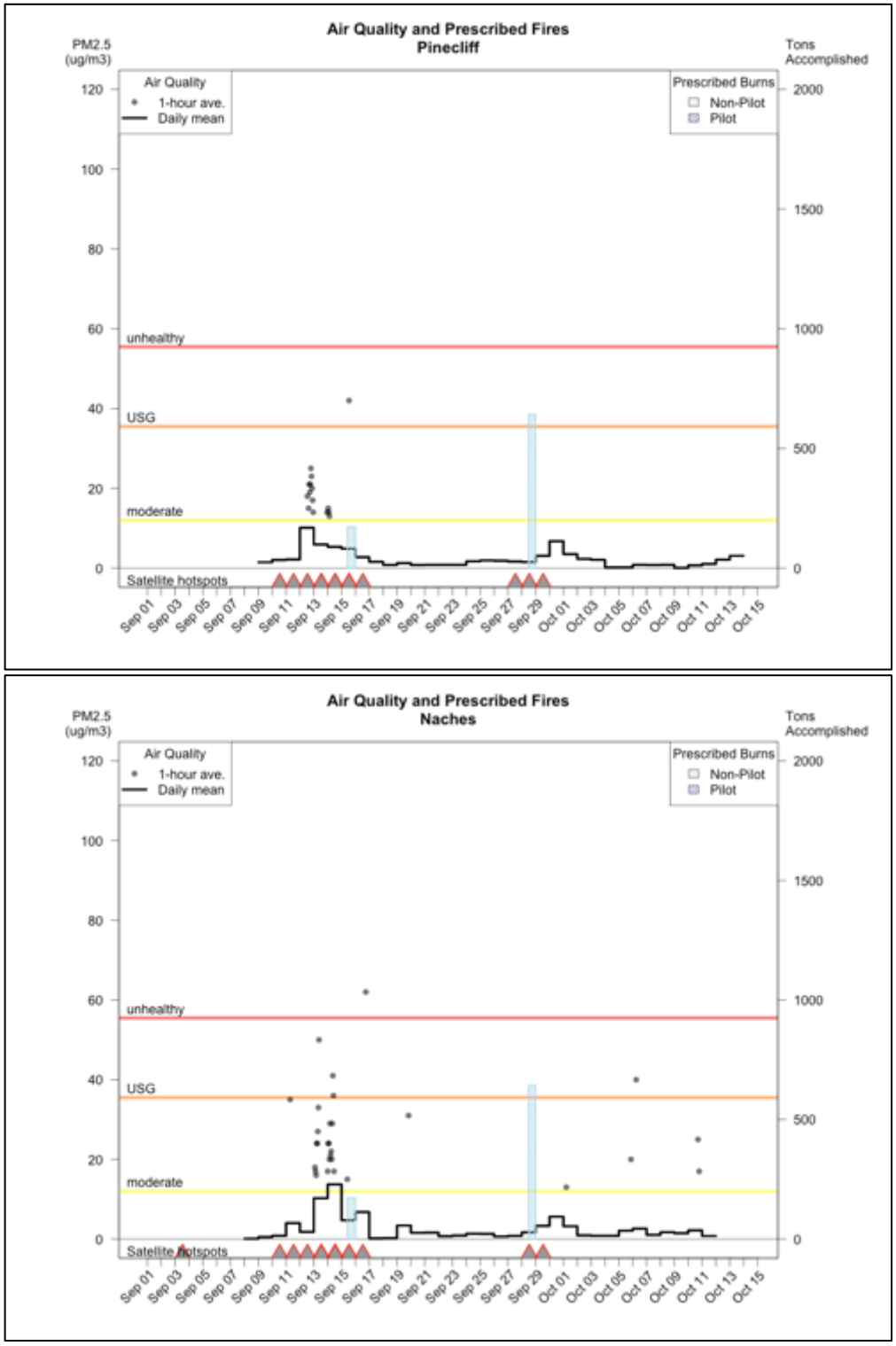

Figure 18: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Pinecliff and Naches, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 14: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Pinecliff in fall of 2016.

Pinecliff Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
10-Sep	satellite	11004	6.0	NE	2	5	0000	2.2	4	2000
11-Sep	satellite	4550	5.4	NE	2	4	2000	10.1	25	1900
12-Sep	satellite	6772	6.6	NE	10	25	1900	5.9	14	2300
13-Sep	satellite	3033	8.5	E	6	14	2300	5.3	15	0100
13-Sep	satellite	3033	6.7	NE						
14-Sep	satellite	758	7.7	NE	5	15	0100	4.9	42	1300
14-Sep	satellite	2539	5.2	NE						
15-Sep	ANGEL UNDERBURN 2016	174	12.4	S	5	42	1300	2.7	7	0700
15-Sep	satellite	1517	7.0	NE						
15-Sep	satellite	846	12.0	S						
16-Sep	satellite	253	6.3	NE	3	7	0700	1.6	4	0000
27-Sep	satellite	187	29.1	N	2	3	0000	1.5	3	2100
28-Sep	ANGEL UNDERBURN 2016	650	12.4	S	2	3	2100	3.1	6	2300
28-Sep	satellite	846	14.0	S						
29-Sep	satellite	846	11.0	S	3	6	2300	6.8	12	0300

Table 15: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Naches in fall of 2016.

Chelan Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
3-Sep	satellite	321	27.1	SE	NA	NA	NA	NA	NA	NA
10-Sep	satellite	11004	26.3	NW	1	3	2300	4	35	0700
11-Sep	satellite	4550	27.5	NW	4	35	0700	2	8	2000
12-Sep	satellite	6772	26.4	NW	2	8	2000	10	50	0900
13-Sep	satellite	4973	31.1	SE	10	50	0900	14	41	0900
13-Sep	satellite	3033	23.6	NW						
13-Sep	satellite	3033	27.1	NW						
14-Sep	satellite	1658	31.2	SE	14	41	0900	5	15	1000
14-Sep	satellite	1658	31.7	SE						
14-Sep	satellite	758	25.4	NW						
14-Sep	satellite	2539	29.1	NW						
15-Sep	satellite	1517	27.6	NW	5	15	1000	7	62	1800
15-Sep	satellite	846	28.7	W						
15-Sep	ANGEL UNDERBURN 2016	174	27.9	W						
16-Sep	satellite	253	28.6	NW	7	62	1800	0	1	0600
28-Sep	satellite	846	31.7	W	2	5	2200	3	8	0800
28-Sep	ANGEL UNDERBURN 2016	650	27.9	W						
29-Sep	satellite	846	29.2	W	3	8	0800	6	9	0700

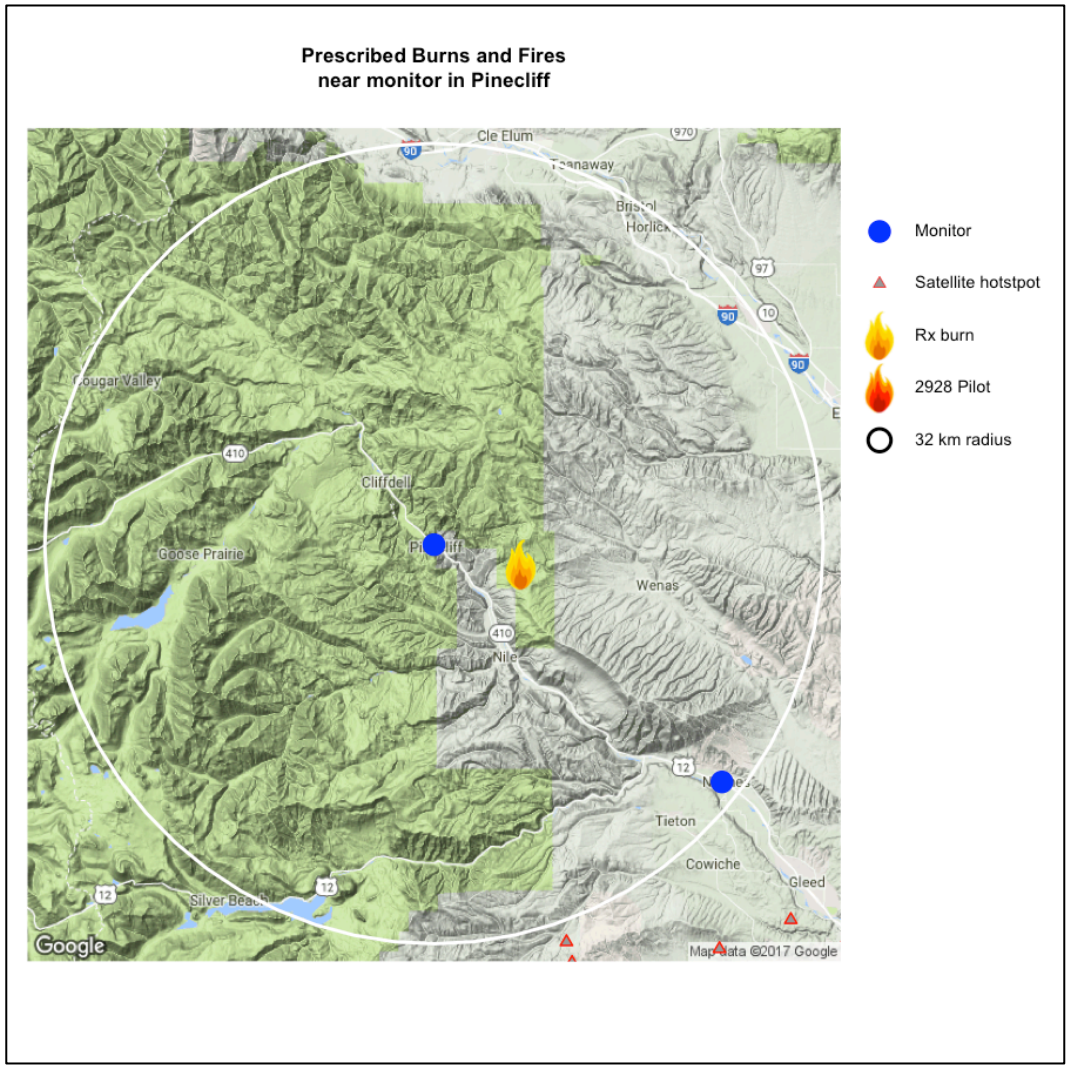

Figure 16: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Pinecliff, WA in spring of 2017. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

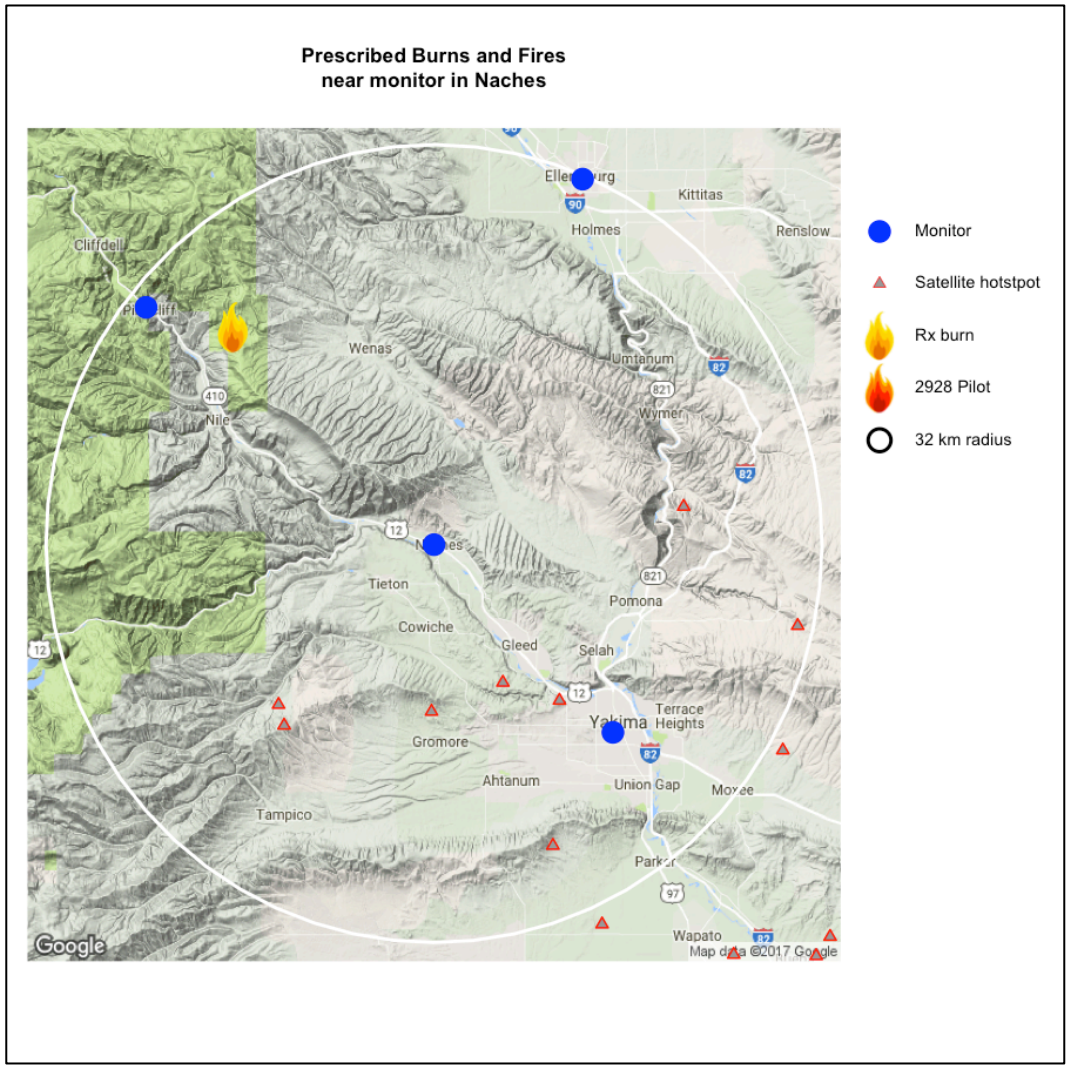

Figure 17: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Naches, WA in spring of 2017. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

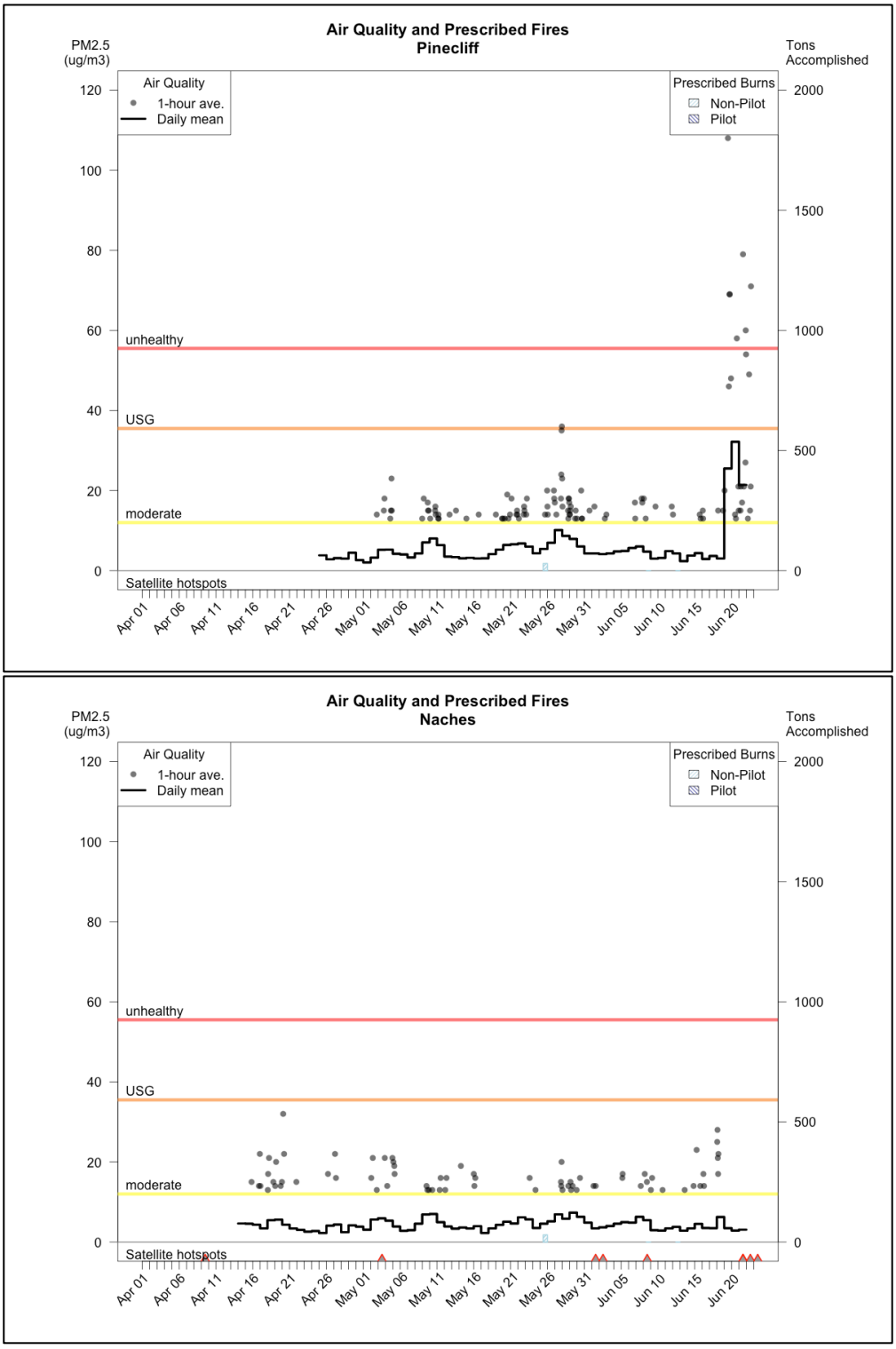

Figure 18: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Pinecliff and Naches, WA during the spring of 2017. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 14: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Pinecliff during spring of 2017.

Pinecliff Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
25-May	CANTEEN UB2017	30	7.3	E	5.4	20	2300	7	20	2100

Table 15: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Naches during spring of 2017.

Naches Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µ/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µ/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
9-Apr	satellite	20	26.1	SE	NaN	NA	NA	NaN	NA	NA
3-May	satellite	131	20.7	NE	5.9	21	2200	5.3	21	2300
25-May	CANTEEN UB2017	30	24	NW	4.6	12	2000	5.2	12	2100
1-Jun	satellite	561	12.4	SE	3.4	14	0600	3.7	9	0900
2-Jun	satellite	561	16.2	SE	3.7	9	0900	4	9	0200
8-Jun	satellite	561	13.4	S	5.5	17	0500	3	16	0500
21-Jun	satellite	413	18.1	SW	3.1	12	1200	NA	11	0600
21-Jun	satellite	413	19.1	S						
22-Jun	satellite	1926	30.6	E	NA	11	0600	NA	NA	NA
23-Jun	satellite	373	30.6	E	NA	NA	NA	NA	NA	NA

Twisp and Winthrop

Permanent air quality monitors are located in Twisp and Winthrop, WA. These two towns are approximately 12 km apart within the Methow valley. Two non-Pilot prescribed fires, 2016 Upper Rendezvous and 2016 Goat, were conducted about 30 km north of Twisp and 18 km north of Winthrop in both 2016 and 2017. They did not cause air quality impacts to either town.

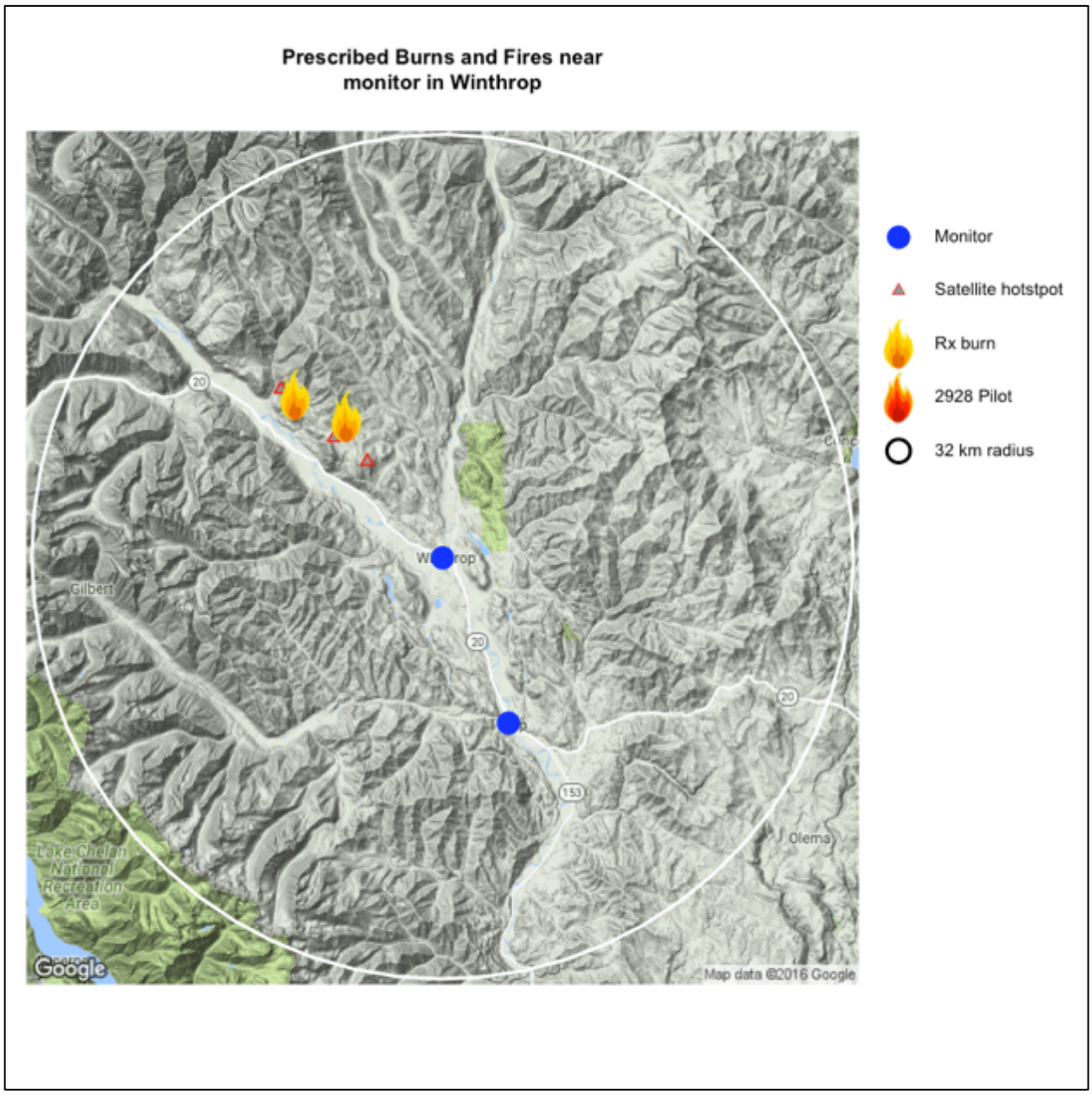

Figure 19: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Winthrop, WA in fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

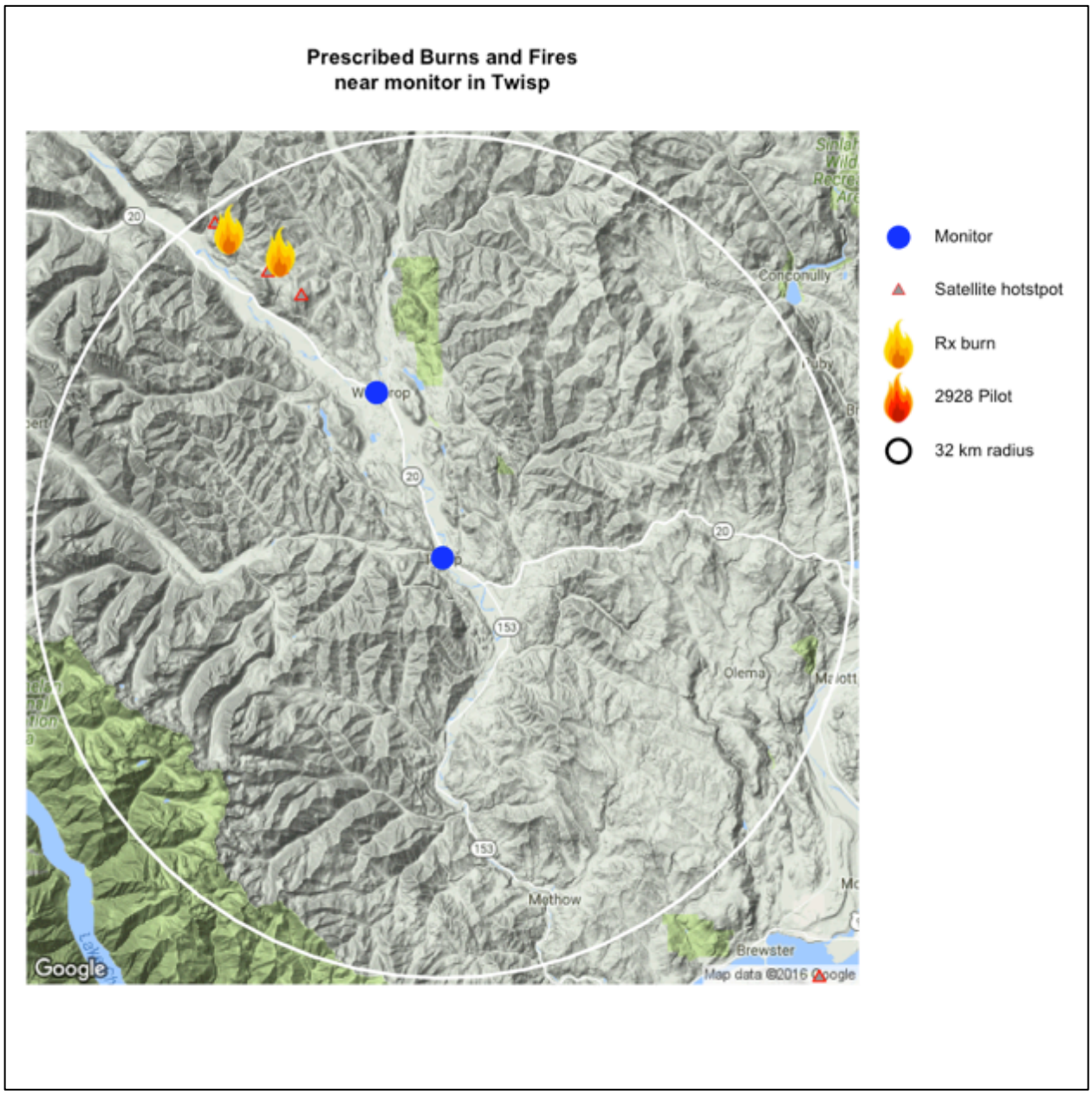

Figure 20: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Twisp, WA in the fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

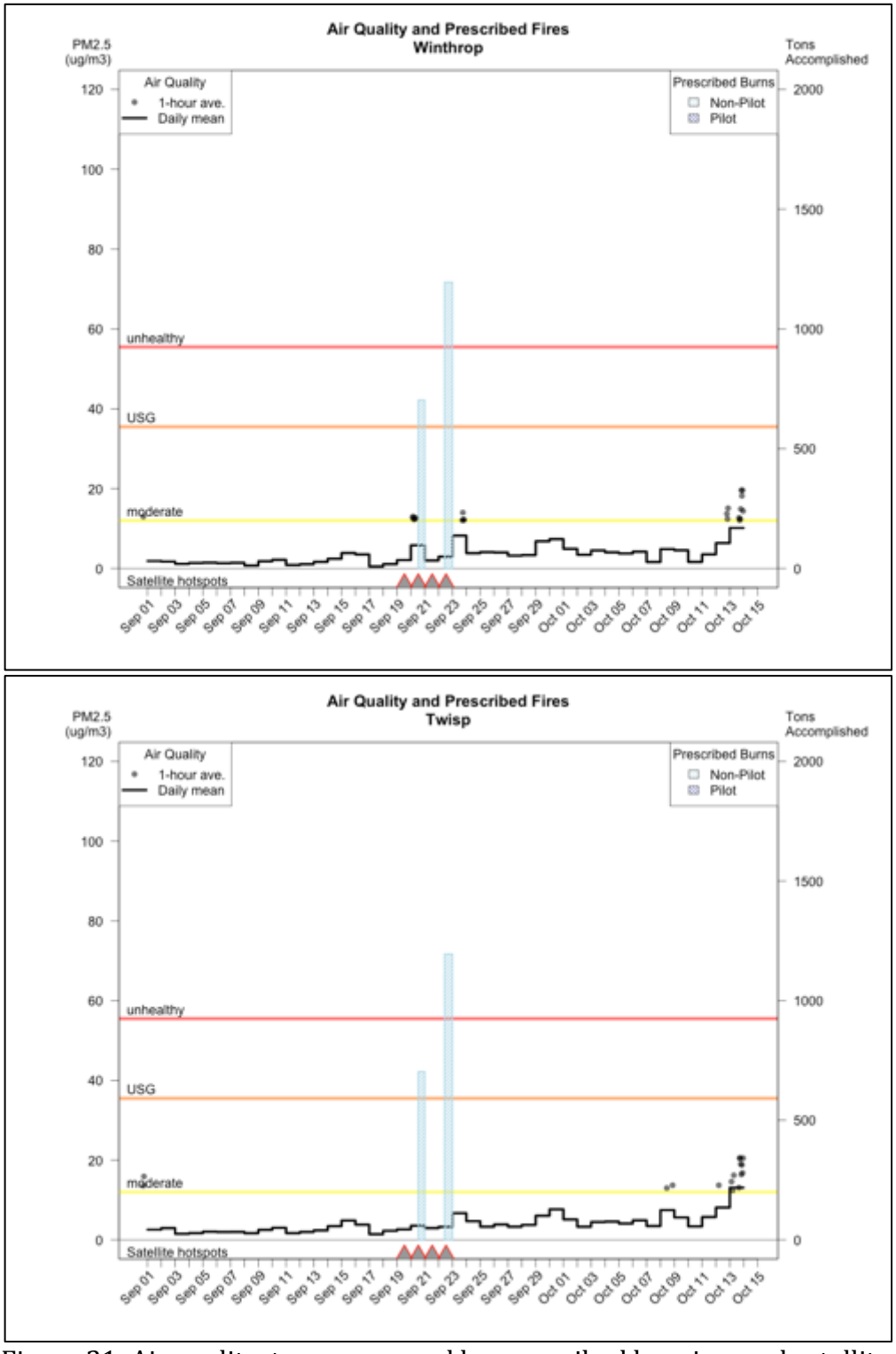

Figure 21: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Winthrop and Twisp, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µ/m^3 were not plotted to reduce clutter on the graph.)

Table 16: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Winthrop in fall of 2016.

Winthrop Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
19-Sep	satellite	506	11.9	NW	2	4	0700	6	13	0400
20-Sep	satellite	1011	12.4	NW	6	13	0400	2	3	2200
20-Sep	2016 UPPER RENDEZVOUS 1	712	13.0	NW						
21-Sep	satellite	254	9.4	NW	2	3	2200	3	6	1600
22-Sep	satellite	1264	17.9	NW	3	6	1600	8	14	1800
22-Sep	2016 GOAT	1210	16.8	NW						

Table 17: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Twisp in fall of 2016.

Twisp Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
19-Sep	satellite	506	25.2	NW	3	4	0700	4	7	2100
20-Sep	satellite	1011	25.5	NW	4	7	2100	3	4	0000
20-Sep	2016 UPPER RENDEZVOUS 1	712	26.4	NW						
21-Sep	satellite	254	22.7	NW	3	4	0000	3	5	2100
22-Sep	satellite	1264	30.9	NW	3	5	2100	7	11	1000
22-Sep	2016 GOAT	1210	29.9	NW						

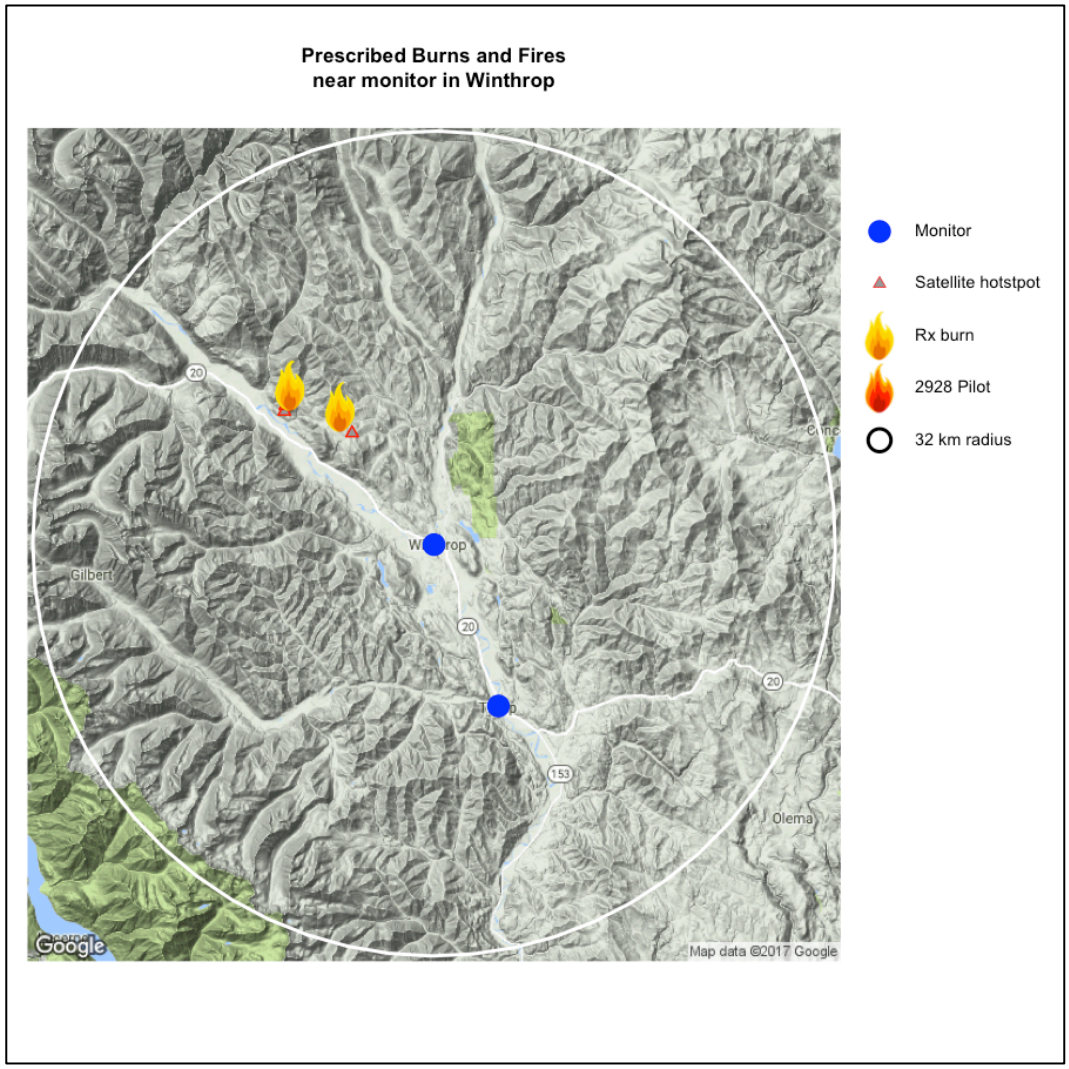

Figure 22: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Winthrop, WA in spring of 2017. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

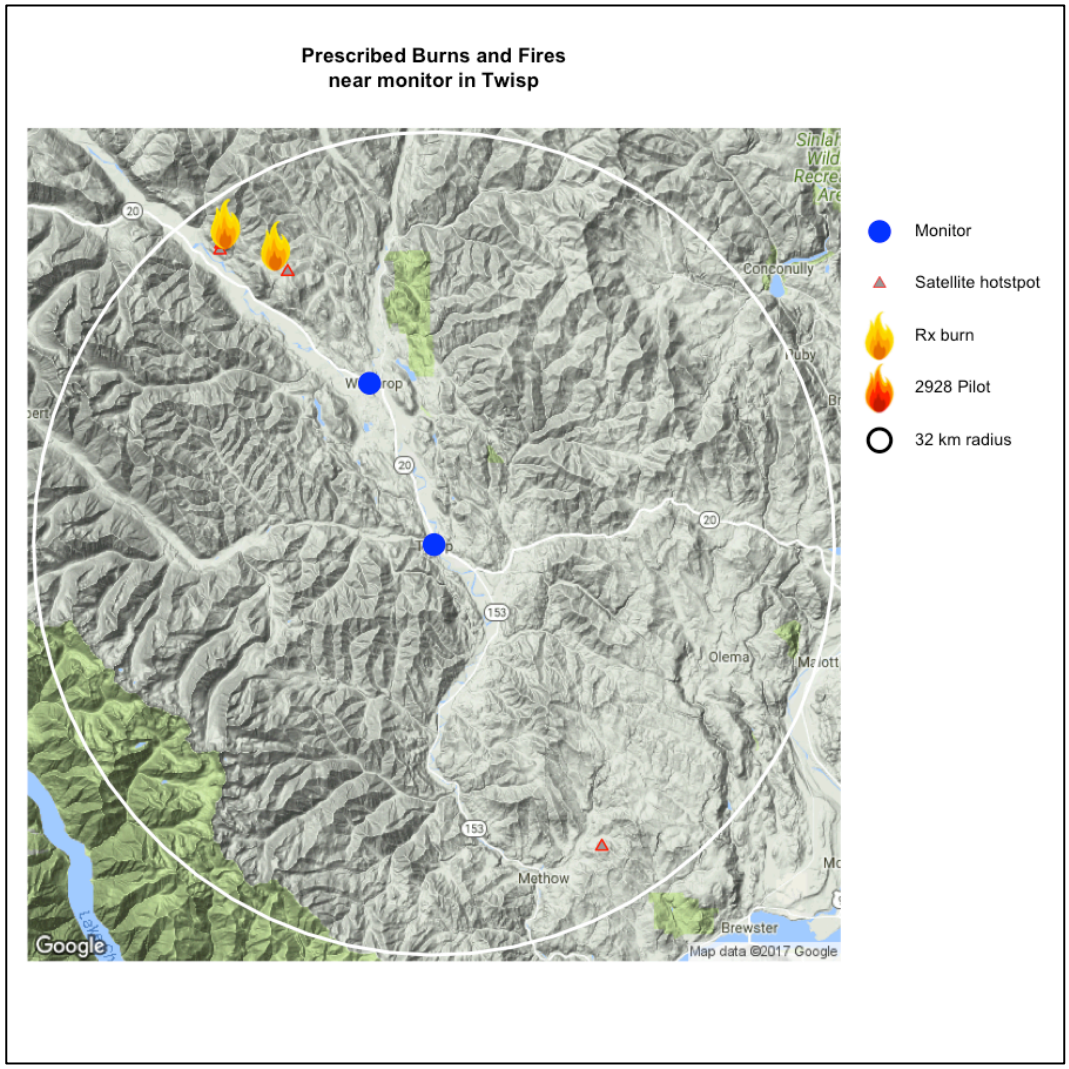

Figure 23: Location of prescribed fires and hotspots detected by satellite in the vicinity of the permanent monitor in Twisp, WA in spring of 2017. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

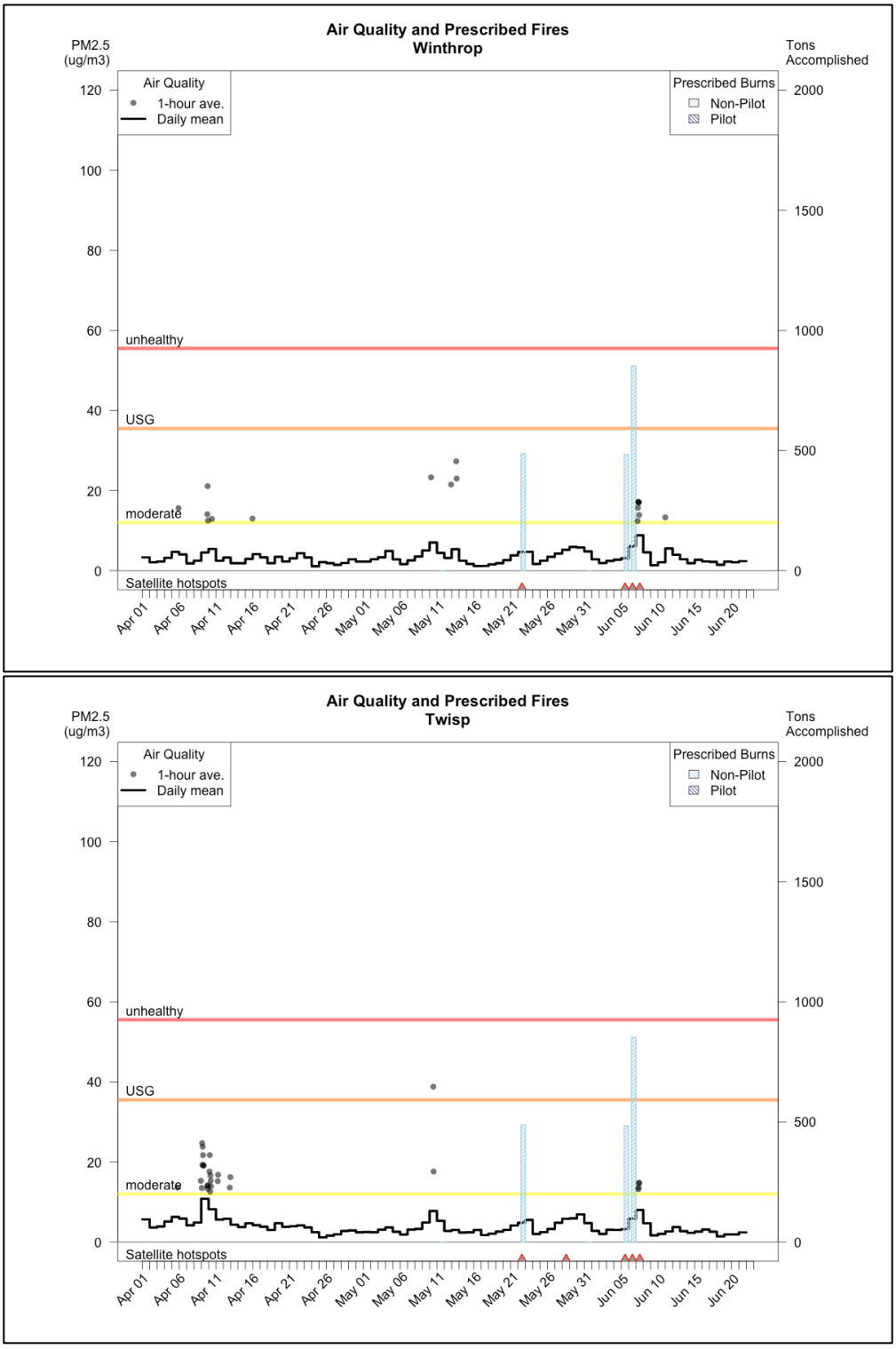

Figure 24: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Winthrop and Twisp, WA during the spring of 2017. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 18: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Winthrop in spring of 2017.

Winthrop Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
22-May	satellite	506	15.7	W	4.6	7.1	2200	4.7	7.1	0500
22-May	2017 GOAT	493	16.8	NW						
5-Jun	satellite	3630	10.8	NW	3.1	6.8	2300	6.1	11.5	0500
5-Jun	2017 UPPER RENDEZVOUS 1	489	13	NW						
6-Jun	satellite	10889	16.2	NW	6.1	11.5	0500	8.8	17.2	0800
6-Jun	2017 GOAT	863	16.8	NW						
7-Jun	satellite	907	16	W	8.8	17.2	0800	4.6	8.9	0700

Table 19: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at Twisp in spring of 2017.

Twisp Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
22-May	satellite	506	28.5	NW	4.8	5.8	1400	5.5	8.9	0900
22-May	2017 GOAT	493	29.9	NW						
28-May	satellite	1099	27.1	SE	5.8	8.1	0600	5.9	8.8	0600
5-Jun	satellite	3630	24.2	NW	3.2	4.7	2200	5.8	9.9	0800
5-Jun	2017 UPPER RENDEZVOUS 1	489	26.4	NW						
6-Jun	satellite	10889	29.3	NW	5.8	9.9	0800	8	14.8	1100
6-Jun	2017 GOAT	863	29.9	NW						
7-Jun	satellite	907	28.8	NW	8	14.8	1100	4.7	10.9	0600

Curlew

The tiny town of Curlew, WA was identified for placement of a temporary air quality monitor in fall of 2016 due to the proximity of a proposed 2928 pilot burn "Vulcan D" on Forest Service managed lands. Vulcan D was not burned in the fall of 2016 due to grazing conflicts although the Colville National Forest hopes to burn Vulcan D in the spring of 2017. Six prescribed fire ignitions in 3 different treatment units were accomplished on 5 different days in the area of the Curlew monitor using the standard DNR approval process.

Prescribed burns in the vicinity of Curlew during the fall 2016 time period of the study were mostly small although burning in the Vulcan 49 unit on 9/28/2016 consumed 956 tons and was just 7.3 km W-NW of the Curlew monitor. Twenty-four hour average PM2.5 concentrations stayed well below the Moderate AQI threshold (12.1 $\mu g/m^3$) and maximum 1-hour values never exceeded 35 $\mu g/m^3$. One hour values do appear elevated at times but no direct link to prescribed burning in the area is obvious. Maximum 1-hour values seem to increase later in the time period of the monitoring which may point to a home heating cause. In summary, air quality in Curlew was not significantly impacted by prescribed burning during the time period of the pilot study.

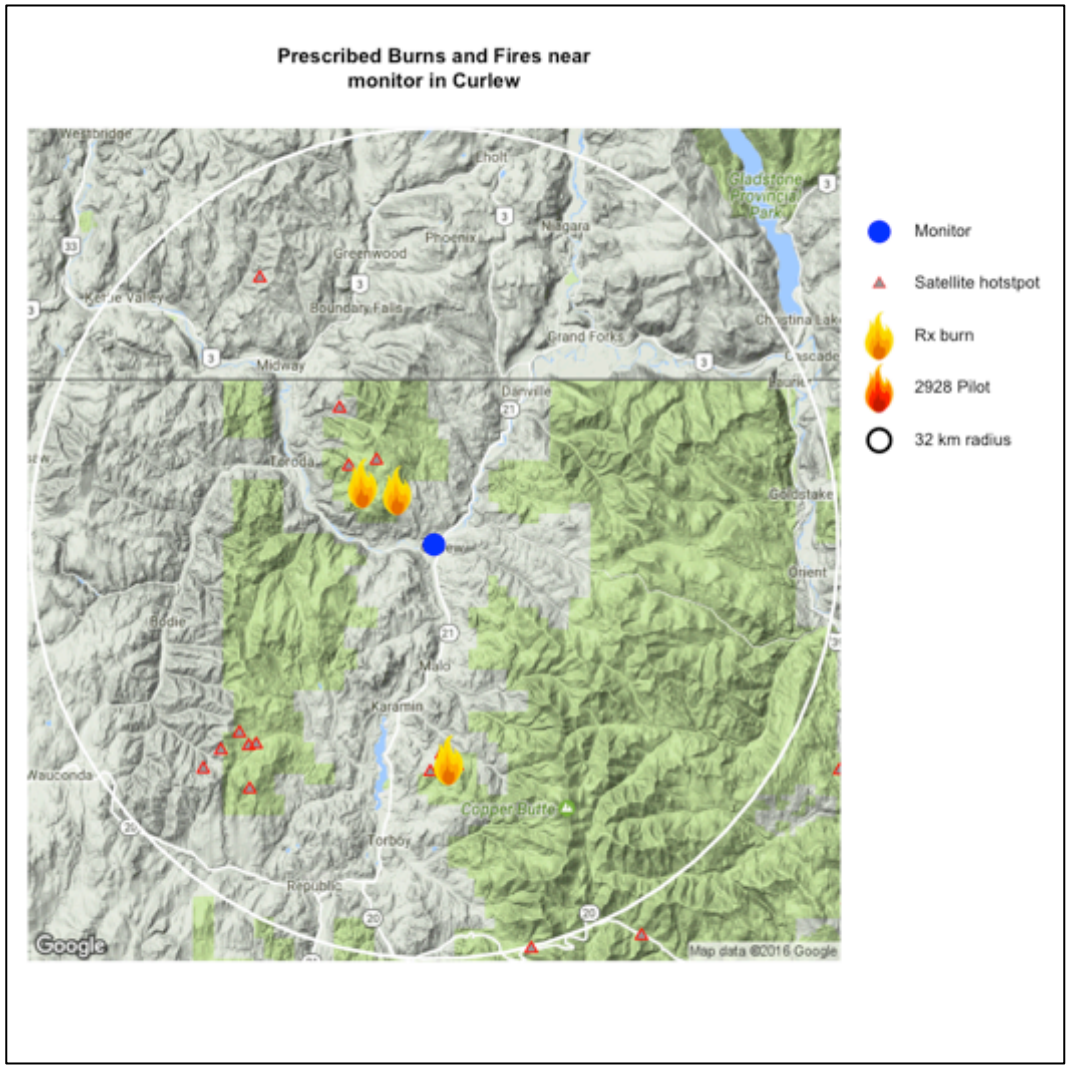

Figure 25: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed in Curlew, WA in fall of 2016. No prescribed burning in the vicinity was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

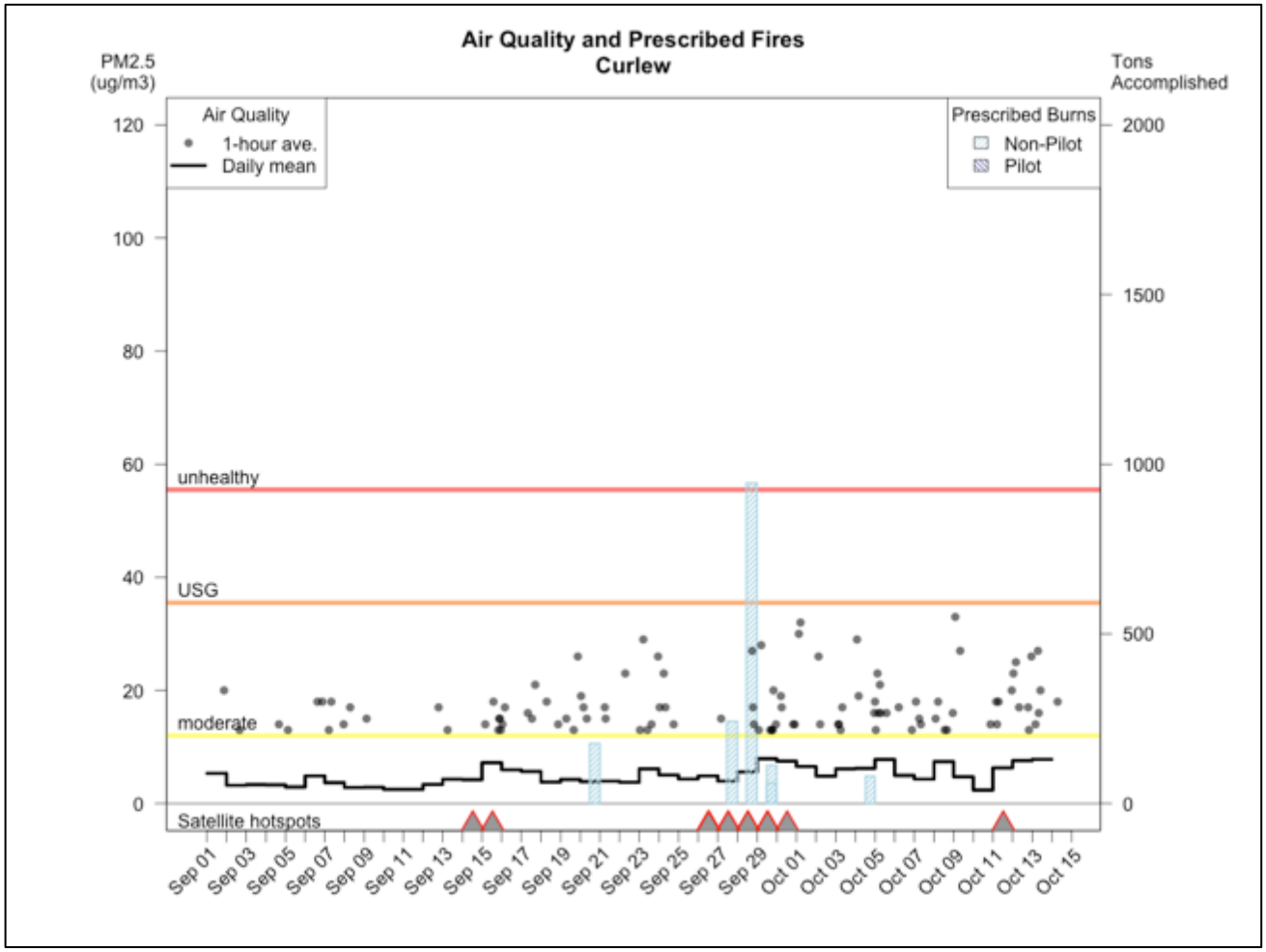

Figure 26: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Curlew, WA during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 20: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of Curlew, WA in fall of 2016. (None of the prescribed fires near this location were burned using 24-hour advance approval.)

Curlew Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
14-Sep	satellite	506	21	S	4	10	1800	7	18	1400
15-Sep	satellite	253	21	S	7	18	1400	6	17	0400
20-Sep	MEL 130145149	179	17	SE	4	19	0100	4	17	0600
26-Sep	satellite	2275	24	S	5	12	0300	4	15	0400
26-Sep	satellite	2275	21	SW						
26-Sep	satellite	2275	23	SW						
26-Sep	satellite	2275	25	SW						
27-Sep	satellite	1011	17	SE	4	15	0400	6	27	1800
27-Sep	satellite	1011	18	S						
27-Sep	MEL 130145149	245	17	SE						
28-Sep	satellite	253	17	SE	6	27	1800	8	28	0500
28-Sep	satellite	253	9	W						
28-Sep	VULCAN 49	956	7	W						
29-Sep	satellite	253	16	SE	8	28	0500	8	19	0500
29-Sep	satellite	253	8	NW						
29-Sep	MEL 130145149	61	17	SE						
29-Sep	VULCAN 49	114	7	W						
30-Sep	satellite	86	13	NW	8	19	0500	7	32	0500
4-Oct	VULCAN 212269	81	5	NW	6	29	0200	8	23	0300
11-Oct	satellite	NA	25	NW	6	20	2300	8	26	2300

Kettle Falls and Sherman Creek Fish Hatchery

The small town of Kettle Falls and the nearby Sherman Creek Fish Hatchery were identified for placement of temporary air quality monitors in fall 2016 and spring 2017 to detect possible smoke impacts from proposed 2928 pilot burns.

Fall 2016

In fall 2016 there were two proposed 2928 pilot burns: Paradise 90, and Sherman Creek. Burning with 24-hour approval notification under the conditions of the pilot was accomplished on 4 different days in the Paradise 90 unit. A total of 6,352 tons of material was consumed in the Paradise 90 unit with an impressive single day accomplishment of 3,627 tons on 9/28/2016. No burning was accomplished in the Sherman Creek unit in 2016.

Very little in the way of air quality impacts were measured at Kettle Falls with the exception of a fairly short term spike in measured PM2.5 on 10/4/2016. This may have been from the prescribed fire Rickey Point which was ignited on that day. Twenty four hour average concentrations bumped up to Moderate AQI category due to the short term elevation of PM2.5. None of the 4 days of burning on the Paradise 90 pilot burn, appear to have significantly impacted Kettle Falls with smoke. There is evidence of a bit of smoke entering Kettle Falls on September 14-16, 2016 but the 1-hour stayed below 20 $\mu g/m^3$.

Paradise 90 burning looks to have sent some smoke into the area of the Sherman Creek Fish Hatchery monitor around September 29 – 30, 2016. The last ignition of Paradise 90 took place on September 28, 2016 but it's not uncommon for fuels to smolder for a day or two after ignition. Smoldering combustion can be problematic for air quality since the smoke says close to the ground and doesn't disperse as easily. The 24-hour average PM2.5 concentration indicates that air quality was in the Moderate AQI category for 1 day.

Overall, fall 2016 burning on the Paradise 90 pilot burn seems to have been quite successful with four days of burning on the unit resulting in minimal impact to air quality.

Spring 2017

In spring 2017 burning with 24-hour approval notification under the conditions of the pilot was accomplished on 6 different days in the Sherman Creek pilot burn in three sub-units: Bridge Hatch Trail, Rail and Bisbee. An additional 5 days of burning not using the 24-hr advance notice was also conducted for a total of 11 burns in spring 2017 in the Sherman Creek unit.

Air quality remained in the good category during spring 2017 at Kettle Falls.

Two days in the Moderate AQI category occurred at the Fish Hatchery. They are both attributable to the Bisbee sub-unit burns just 0.6 km from the monitor. Bisbee was burned on three consecutive days (June 5, 6, and 7, 2017). The second day (June 6) used the 24-hr

advance notice. The two moderate days are most likely attributable to the June 6 and 7, 2017 Bisbee burns, when smoke impacts occurred the mornings after those burns (June 7 and June 8 respectively). After the June 6 Bisbee pilot burn, a maximum 1-hr average PM2.5 concentration of 204 µg/m^3 occurred at 0100 PDT on June 7 giving a June 7 24-hr PM2.5 average of 31 µg/m^3. After the non-pilot Bisbee burn on June 7, a maximum 1-hr average PM2.5 concentration of 75 µg/m^3 occurred at 0500 PDT on June 8 giving a June 8 24-hr average concentration of 14.5 µg/m^3. Thus a mixture of pilot and non-pilot burning both yielded Moderate AQI category impacts at the Sherman Creek Fish Hatchery.

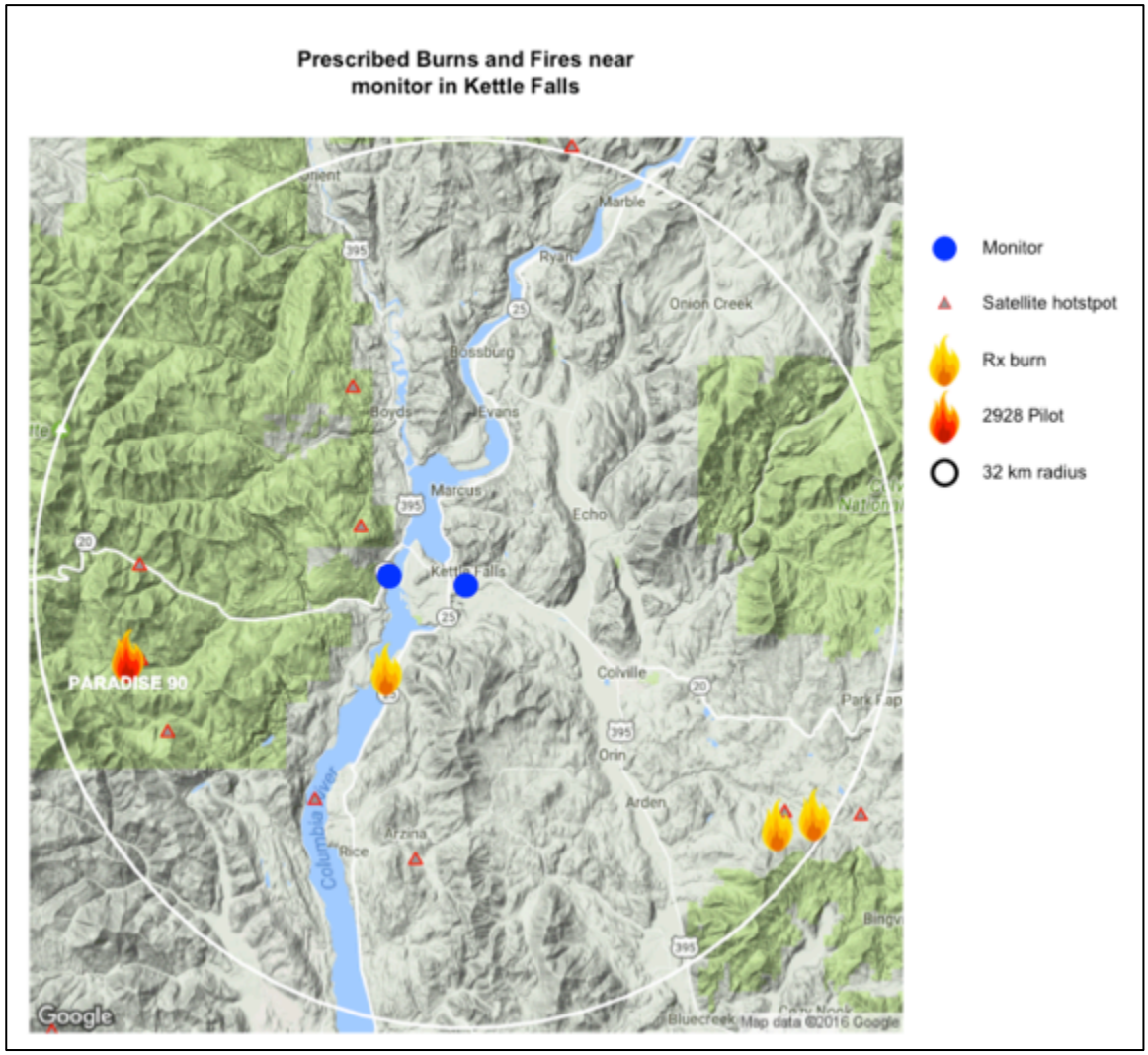

Figure 27: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitors placed in Kettle Falls in fall of 2016. Four days of burning on the Paradise 90 pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

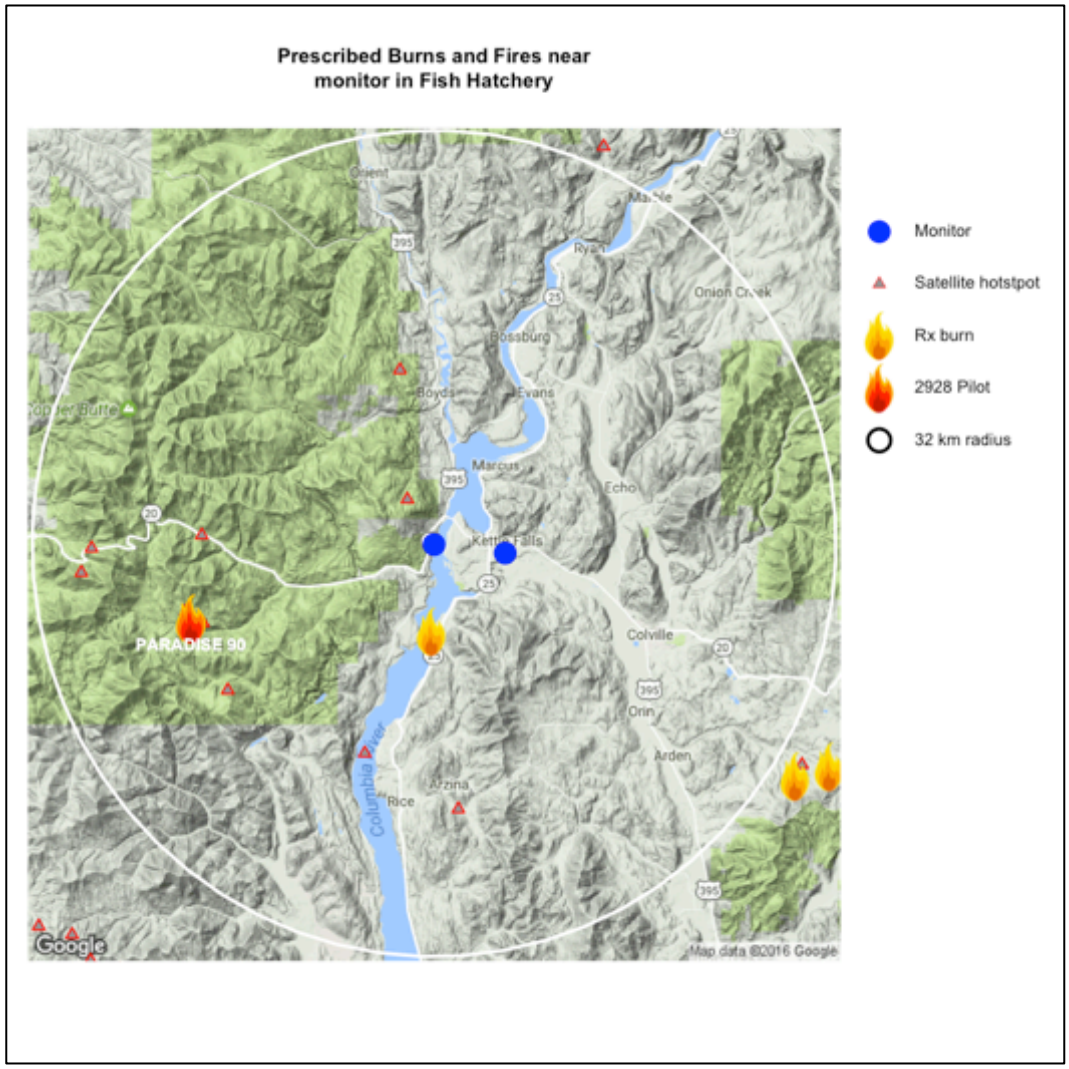

Figure 28: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed at the Sherman Creek Fish Hatchery in fall of 2016. Four days of burning on the Paradise 90 pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

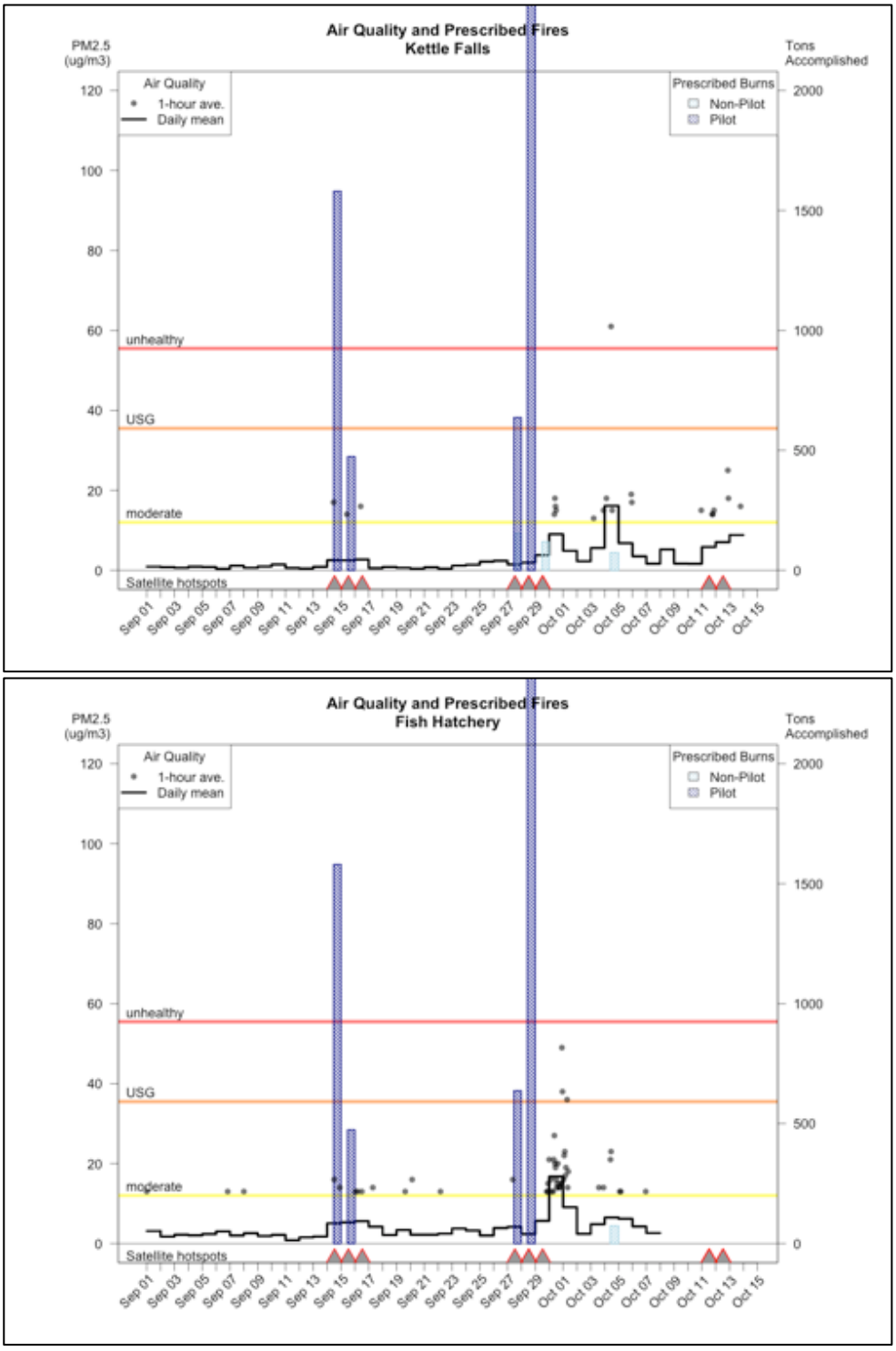

Figure 29: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Kettle Falls and Fish Hatchery monitors during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 21: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of Kettle Falls, WA in fall of 2016.

Kettle Falls Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
14-Sep	satellite	506	25.7	SW	3	17	1100	3	14	1000
14-Sep	PARADISE 90*	1600	25.5	SW						
15-Sep	satellite	253	25.7	SW	3	14	1000	3	16	1000
15-Sep	PARADISE 90*	480	25.5	SW						
16-Sep	satellite	253	24.1	W	3	16	1000	1	6	1500
27-Sep	satellite	506	24.6	SW	2	4	0500	2	9	1800
27-Sep	PARADISE 90*	645	25.5	SW						
27-Sep	LOG BARN MEADOW	156	28.8	E						
28-Sep	satellite	574	19.1	S	2	9	1800	4	8	1800
28-Sep	satellite	253	24.5	SW						
28-Sep	PARADISE 90*	3627	25.5	SW						
29-Sep	satellite	253	28.7	E	4	8	1800	9	18	1000
29-Sep	satellite	253	24.6	SW						
29-Sep	CHRISTIANSEN	120	30.6	E						
4-Oct	RICKEY POINT	75	8.5	S	16	152	1200	7	19	2200
11-Oct	satellite	253	20.2	S	6	15	2100	7	25	2100
11-Oct	satellite	253	8.8	W						
12-Oct	satellite	253	16.4	NW	7	25	2100	9	16	1900

*24-Hr Advance approval pilot burn.

Table 22: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at the Sherman Creek fish hatchery in fall of 2016.

Hatchery Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
14-Sep	satellite	506	20.4	SW	5	16	1200	5	11	0200
14-Sep	PARADISE 90*	1600	20.2	SW						
15-Sep	satellite	253	20.4	SW	5	11	0200	6	13	0100
15-Sep	PARADISE 90*	480	20.2	SW						
16-Sep	satellite	253	18.5	W	6	13	0100	4	14	0700
27-Sep	satellite	506	19.3	SW	4	16	0900	2	8	1500
27-Sep	PARADISE 90*	645	20.2	SW						
28-Sep	satellite	574	17.1	S	2	8	1500	6	15	2200
28-Sep	satellite	253	19.9	SW						
28-Sep	PARADISE 90*	3627	20.2	SW						
29-Sep	satellite	253	19.3	SW	6	15	2200	17	49	2200
4-Oct	RICKEY POINT	75	6.8	S	7	23	1100	6	13	0200
11-Oct	satellite	253	20.6	SE						
11-Oct	satellite	253	4.1	NW						
11-Oct	satellite	758	27.2	SW						
12-Oct	satellite	253	13.8	NW						
12-Oct	satellite	253	28.1	SW						

*24-Hr Advance approval pilot burn.

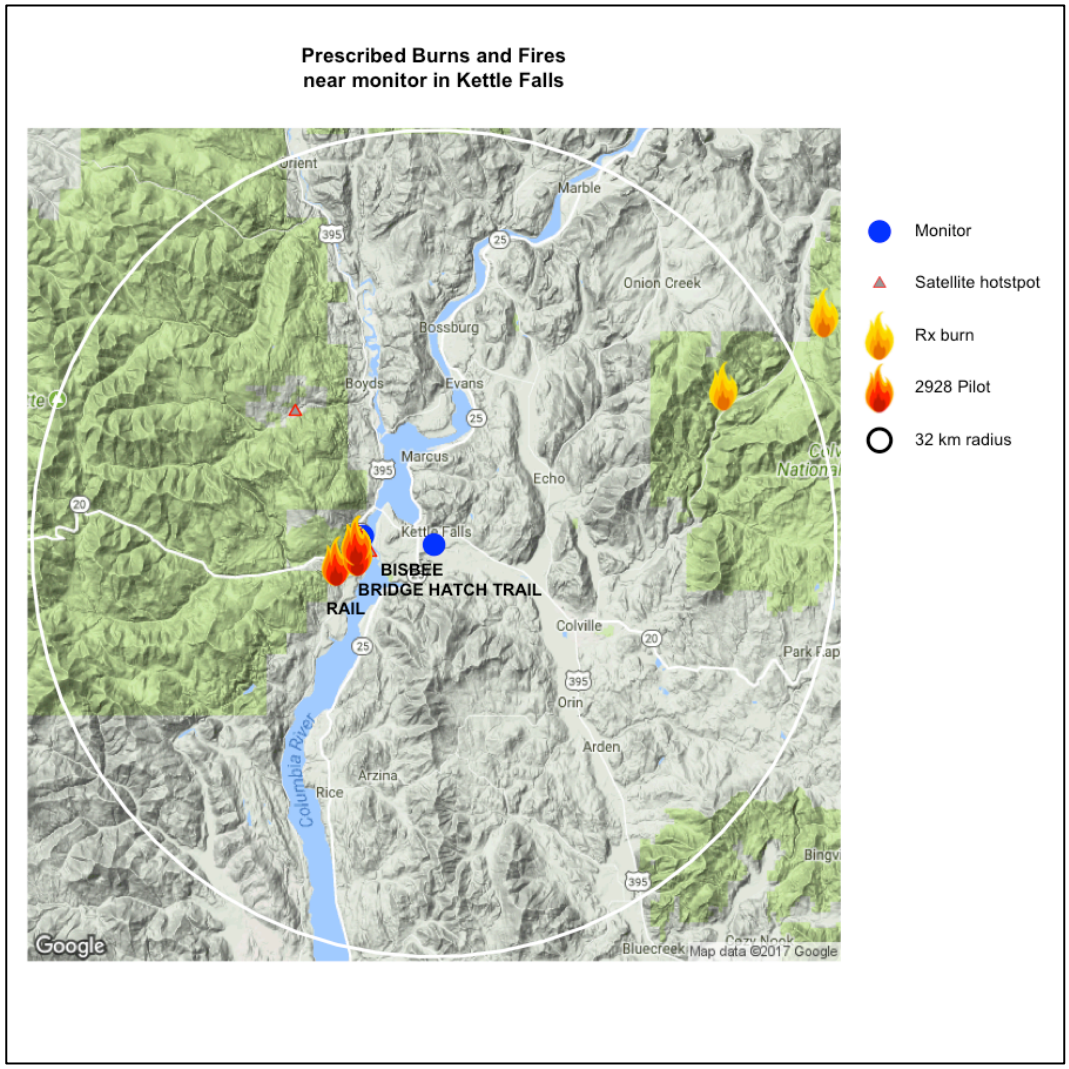

Figure 27: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitors placed in Kettle Falls in spring of 2017. Six days of burning on units collectively called Sherman Creek (Bisbee, Bridge/Hatch/Trail, and Rail) was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

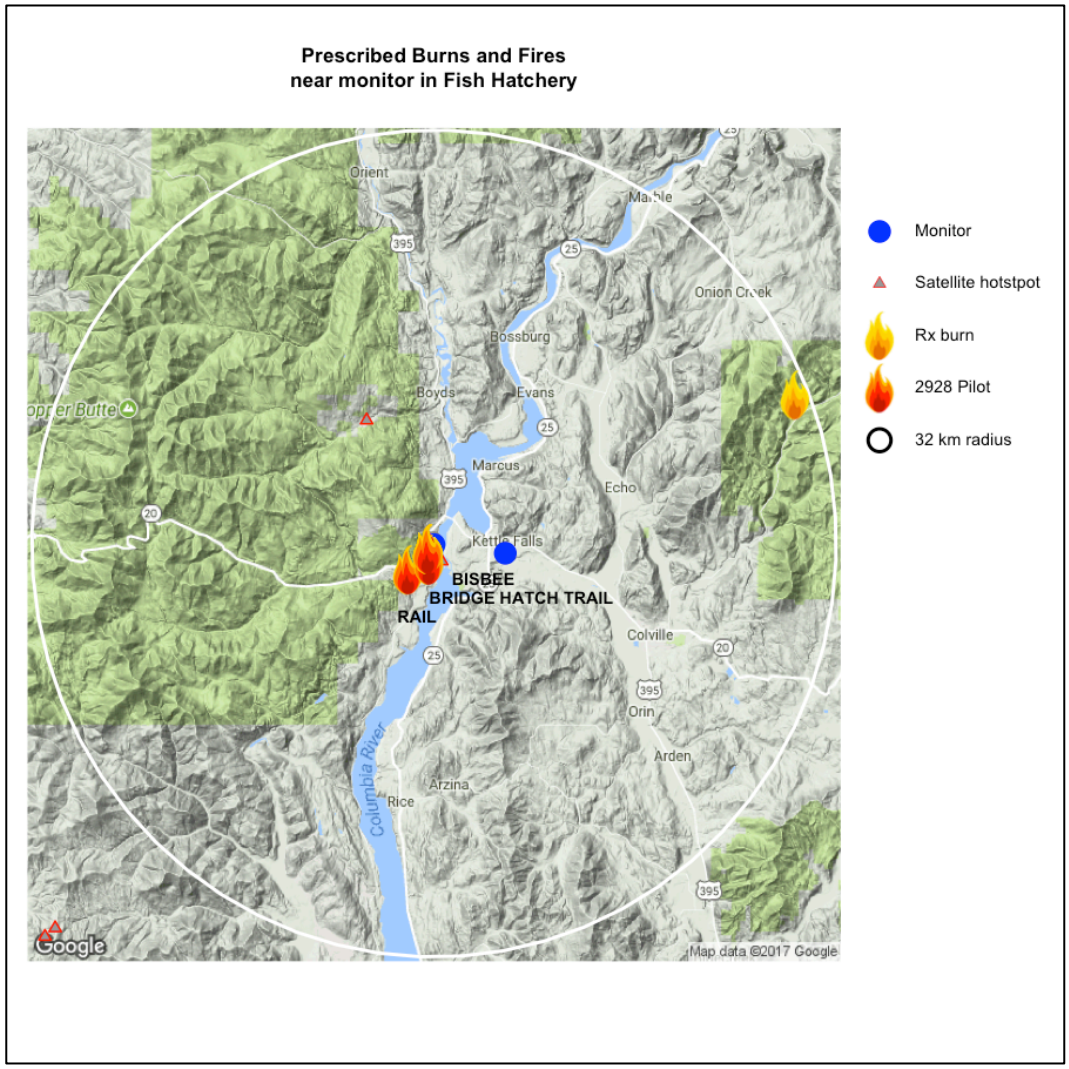

Figure 28: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed at the Sherman Creek Fish Hatchery in spring of 2017. Six days of burning on units collectively called Sherman Creek (Bisbee, Bridge/Hatch/Trail, and Rail) was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

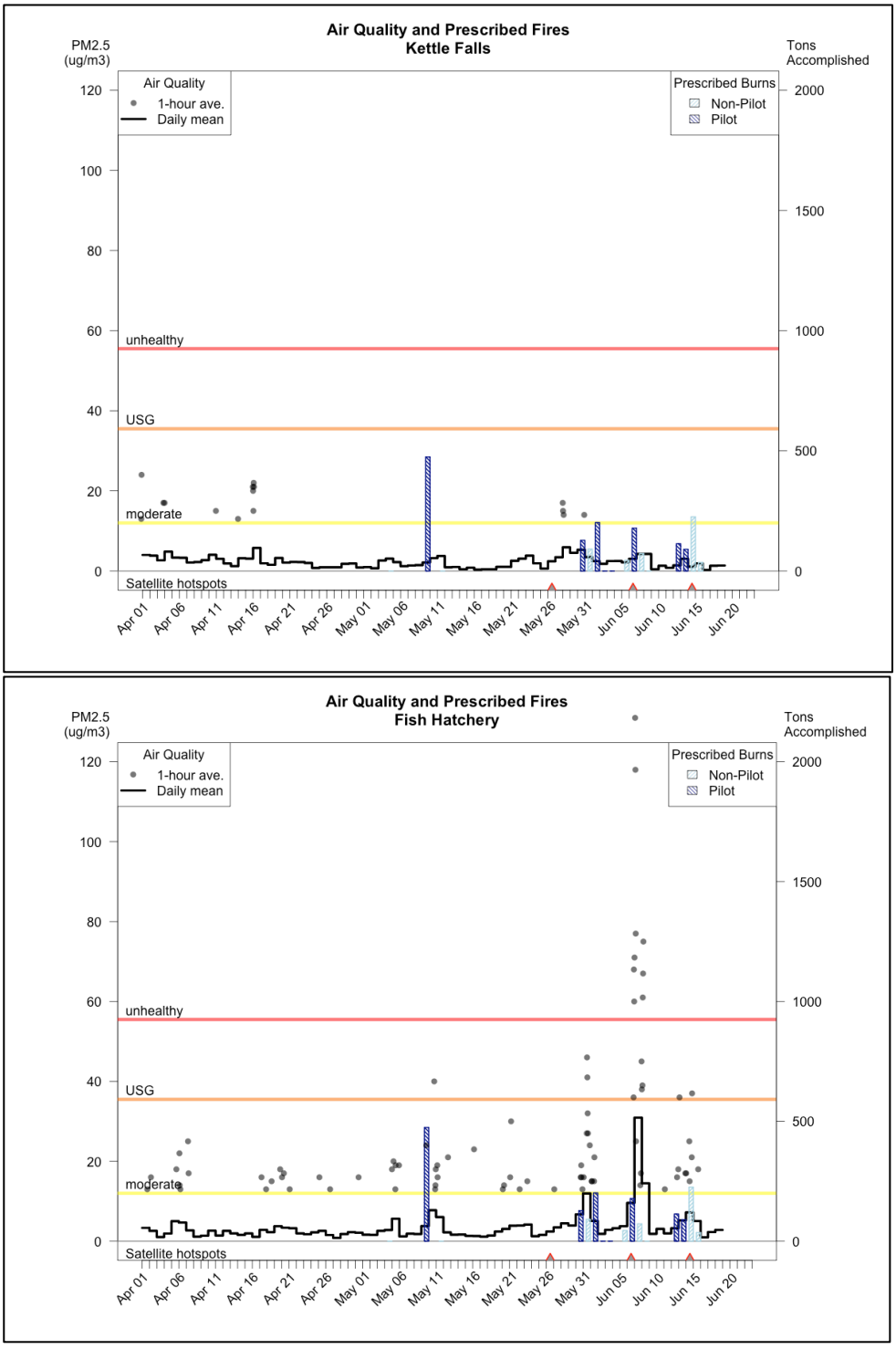

Figure 29: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of Kettle Falls and Fish Hatchery monitors during the spring of 2017. Daily mean PM2.5 values can be compared to colored horizontal lines to see how air quality measurements compare to national Air Quality Index health thresholds. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 23: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of Kettle Falls, WA in spring of 2017.

Kettle Falls Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
9-May	RAIL*	480	7.8	SW	2.1	5	2000	3.2	6	2100
26-May	satellite	253	15	W	2.4	10	2000	3.4	8	2300
30-May	BRIDGE HATCH TRAIL*	129	6.1	SW	5.3	14	2200	3.5	6	0700
31-May	BRIDGE HATCH TRAIL	92	6.1	SW	3.5	6	0700	2.5	9	1400
1-Jun	BRIDGE HATCH TRAIL*	204	6.1	SW	2.5	9	1400	1.8	8	1600
5-Jun	BISBEE	45	6.2	W	2.2	5	2200	3	6	2300
6-Jun	satellite	2722	6.3	W	3	6	2300	4.2	7	0800
6-Jun	BISBEE*	180	6.2	W						
7-Jun	BISBEE	73	6.2	W	4.2	7	0800	4.2	11	0900
12-Jun	BISBEE*	115	6.2	W	1.4	3	2100	3	5	1400
13-Jun	BISBEE**	91	6.2	W	3	5	1400	1.1	2	0100
14-Jun	satellite	64	5.1	SW	1.1	2	0100	1.9	4	0900
14-Jun	BISBEE	228	6.2	W						
15-Jun	BISBEE	36	6.2	W	1.9	4	0900	0.3	2	2300

*24-Hr Advance approval pilot burn.

**Request for 24-hr approval was denied although burning of <100 tons could proceed.

Table 24: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the monitor at the Sherman Creek fish hatchery in spring of 2017.

Fish Hatchery Date (2017)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 µg/m^3 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
9-May	RAIL*	480	2.8	SW	3.8	24	1600	7.8	40	1800
26-May	satellite	253	11	NW	2.4	8	1900	3.5	13	0200
30-May	BRIDGE HATCH TRAIL*	129	1.2	S	6.7	19	1800	12	46	1300
31-May	BRIDGE HATCH TRAIL	92	1.2	S	12	46	1300	5.1	21	1300
1-Jun	BRIDGE HATCH TRAIL*	204	1.2	S	5.1	21	1300	1.8	9	0300
5-Jun	BISBEE	45	0.6	SW	3.8	11	0300	9.6	68	2200
6-Jun	satellite	2722	0.7	NW	9.6	68	2200	30.9	204	0100
6-Jun	BISBEE*	180	0.6	SW						
7-Jun	BISBEE	73	0.6	SW	30.9	204	0100	14.5	75	0500
12-Jun	BISBEE*	115	0.6	SW	3.2	18	2300	5.2	36	0300
13-Jun	BISBEE**	91	0.6	SW	5.2	36	0300	7.2	37	2000
14-Jun	satellite	64	1.4	SE	7.2	37	2000	5	18	1600
14-Jun	BISBEE	228	0.6	SW						
15-Jun	BISBEE	36	0.6	SW	5	18	1600	1	5	1600

*24-Hr Advance approval pilot burn.

**Request for 24-hr approval was denied although burning of <100 tons could proceed.

Kalispel Tribal Center

A temporary monitor was placed at the Kalispel Tribal Center near Cusick and Usk, WA in the fall of 2016 to monitor for air quality impacts from the Forest Service Hanlon pilot burn. One day of burning on the Hanlon unit was accomplished under terms of the pilot and a second day of burning on Hanlon used the standard DNR approval process. The first burn day (pilot) accomplished just 90 tons. The second burn day (non-pilot) was more significant and accomplished 1250 tons.

September 26, 2016, the day Hanlon was burned under terms of the pilot, shows no evidence of smoke at the monitor. On September 28, 39, and 30, 2016 a fairly significant amount of tons were consumed on 2 prescribed fires permitted using the standard DNR procedure: Hanlon, Blue Ruby West, and Misery. It appears some smoke from this burning found its way to the Kalispel Tribal Center monitor resulting in modestly elevated 1-hour concentrations and 1 day where the 24-hour AQI was Moderate.

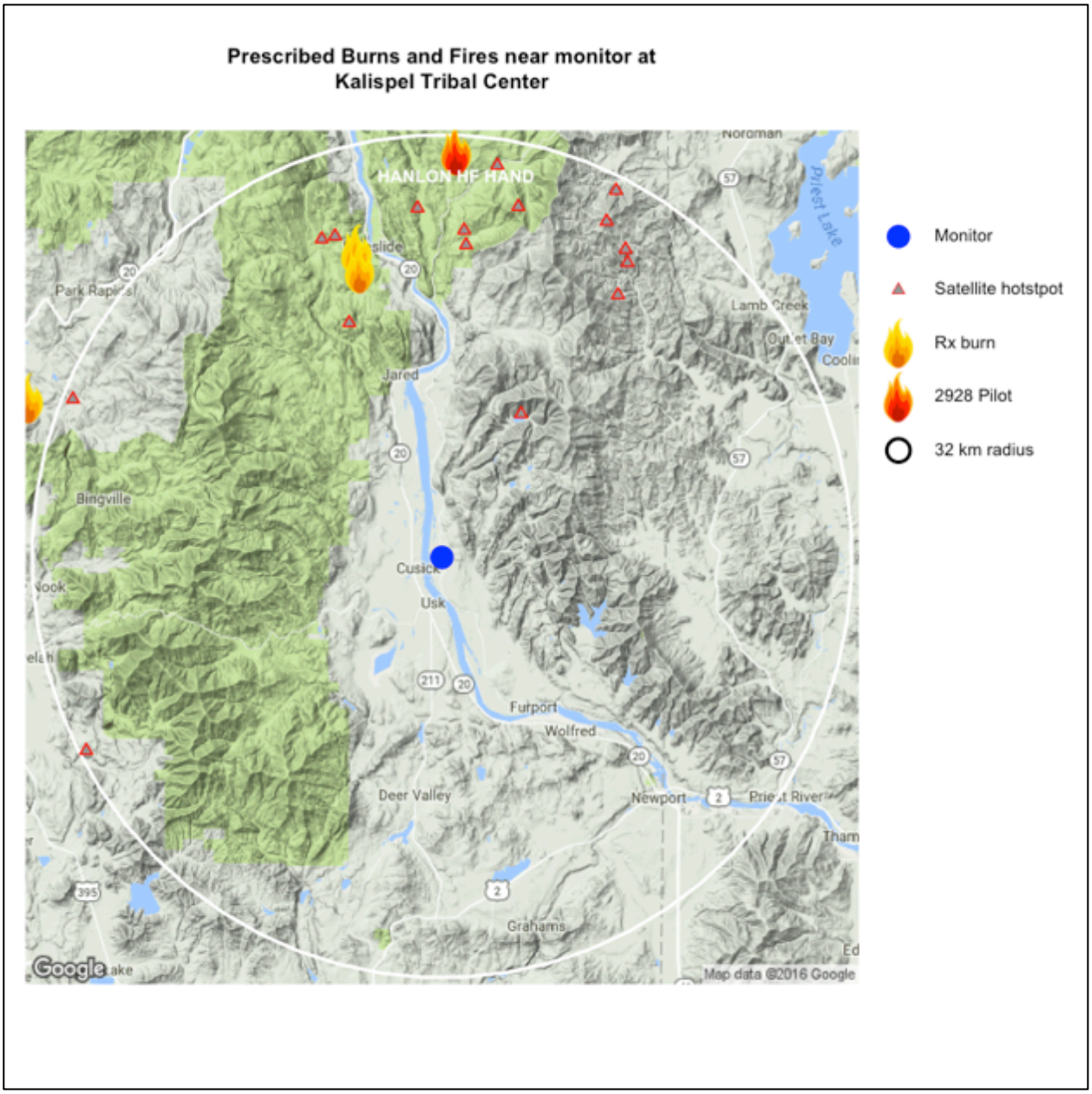

Figure 30: Location of prescribed fires and hotspots detected by satellite in the vicinity of the temporary monitor placed at the Kalispel Tribal Center in fall of 2016. One day of burning on the Hanlon pilot burn was accomplished using the 24-hour pre-approval process allowed by the 2928 pilot study.

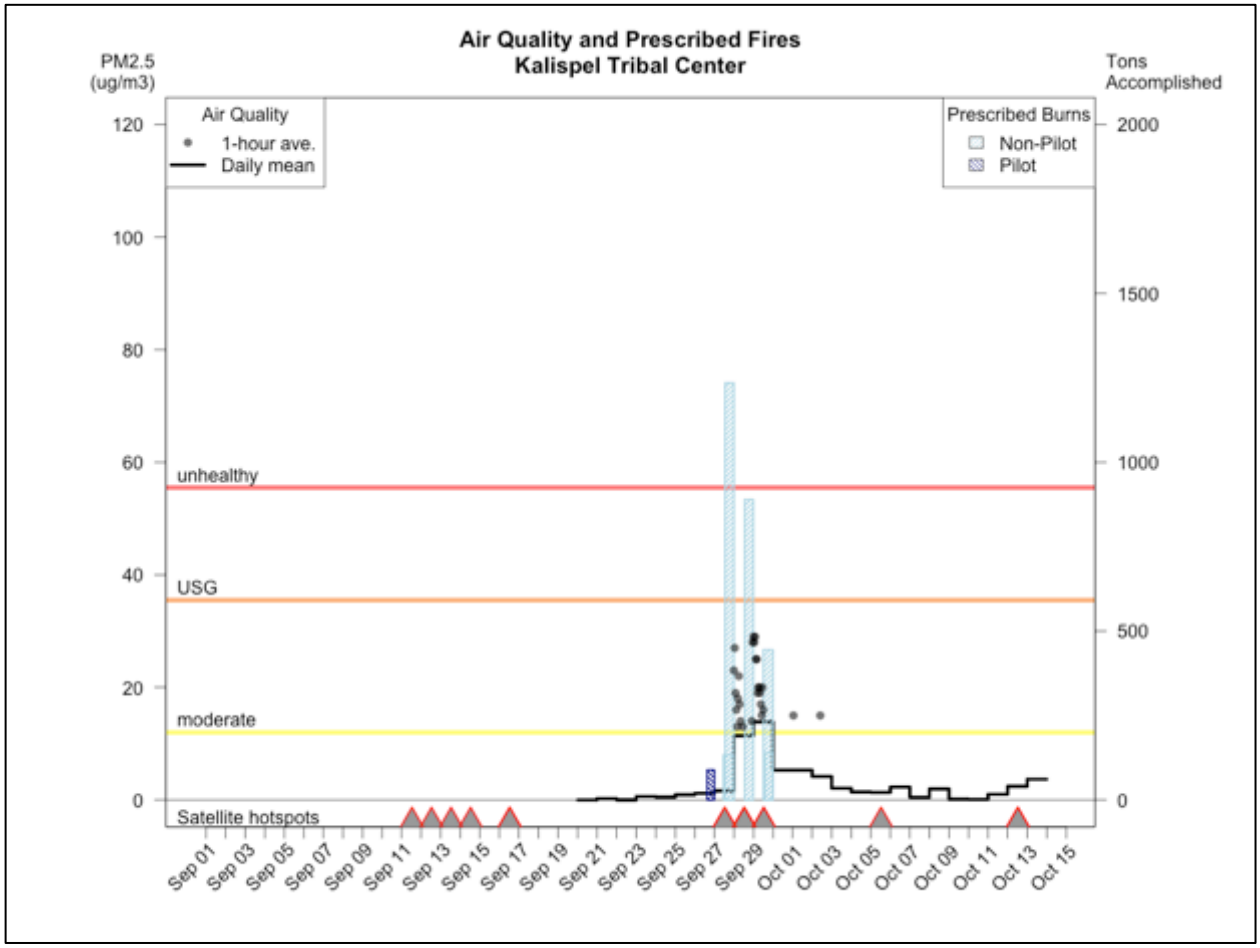

Figure 31: Air quality, tons consumed by prescribed burning, and satellite-detected hotspots by date in the vicinity of the Kalispel Tribal Center during the fall of 2016. Daily mean PM2.5 values can be compared to colored horizontal lines to determine the amount of impact to air quality in comparison to national Air Quality Index health thresholds. Equipment difficulties at this location resulted in missing data early in the study window. (One-hour average measurements (dots) below 12.1µg/m^3 were not plotted to reduce clutter on the graph.)

Table 25: Prescribed fires, satellite detected hotspots, and air quality by date in the vicinity of the Kalispel Tribal Center near Cusick, WA, fall 2016. PM2.5 concentrations in units of µg/m³.

Kalispel Date (2016)	Prescribed Burn or Satellite Hotspot	Tons Burned	Distance from Monitor (km)	Direction from Monitor	Day of Burn			Day after Burn		
					PM2.5 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT	PM2.5 (24hr)	Max PM2.5 (1-hr)	Time of Max 1-hr PDT
11-Sep	satellite	253	28.5	N						
12-Sep	satellite	846	30.9	N						
13-Sep	satellite	846	27.4	N						
14-Sep	satellite	95	31.4	SW						
16-Sep	satellite	846	26.6	N						
16-Sep	satellite	846	24.8	N						
26-Sep	HANLON HF HAND*	90	30.9	N	1	3	1100	2	7	2300
27-Sep	satellite	846	27.2	N	2	7	2300	11	28	2300
27-Sep	satellite	1693	23.7	N						
27-Sep	BLUE RUBY WEST AERIAL RX HF	135	24.2	NW						
27-Sep	HANLON HF AERIAL	1250	30.9	N						
28-Sep	satellite	253	12.5	N	11	28	2300	14	29	0000
28-Sep	satellite	253	26.5	NW						
28-Sep	satellite	846	25.7	NW						
28-Sep	BLUE RUBY WEST AERIAL RX HF	900	24.2	NW						
29-Sep	satellite	253	19.2	NW	14	29	0000	5	8	1300
29-Sep	satellite	253	25.9	NW						
29-Sep	BLUE RUBY WEST HAND RX HF	450	24.2	NW						
29-Sep	MISERY 54 62	141	22.8	NW						
5-Oct	satellite	846	24.1	N	1	4	1000	2	5	0900
12-Oct	satellite	846	30	N	2	6	2100	4	6	1100
12-Oct	satellite	253	31.1	W						

*24-Hr Advance approval pilot burn.

SUMMARY AND CONCLUSIONS

Four Pilot burns were conducted over 10 burning days during the fall of 2016 and two pilot burns were conducted over 7 burning days during the spring of 2017. A total of 55 individual fires were accomplished in the fall of 2016 and 25 individual fires were accomplished in the spring of 2017 (see Appendix A). Overall, for the cases analyzed here, there was not an appreciable difference between the standard day-of approval burns and the 24-hr approval burns. Burning conducted by the pilot burn project seems to have been successful with burning either resulting in minimal impact to air quality or impacts on-par with non-pilot burns.

- 16 days with air quality in the Moderate AQI category.
    - Thirteen days were from non-pilot burns
    - Three days were from pilot burns, two of which may have been due to longer term smoldering of fuels (Paradise 90 and Sherman Creek at the Sherman Creek Fish Hatchery monitor).
- 2 days with air quality in the unhealthy for sensitive groups AQI category. This was due to non-pilot burns at Plain, WA
- In the spring of 2017 there were three days in the Moderate AQI category at Pinecliff but no burning was reported or detected by satellites in the area. Therefore, the air quality impacts were probably due to another source.

Specifically:

- The Orion Unit 2 pilot burn 8-km northwest of Liberty, WA burned on 3 different days. One day resulted in a Moderate AQI category day with a 24-hr PM2.5 concentration of 16 $\mu g/m^3$. This site appears to be impacted by other sources because 1-hr PM2.5 concentrations > 12 $\mu g/m^3$ often occurred independent of burning.
- The 25 Mile pilot burn NW of Manson and Chelan burned on 2 different days and did not cause air quality impacts. If anything, greater air quality impacts occurred with the non-Pilot burns at this site.
- The Paradise 90 pilot burn west of Sherman Creek Fish Hatchery (20-km) and Kettle Falls (25-km) burned on 4 days with an impressive total of 6,352 tons of fuel consumed. Smoldering fuels are possibly responsible for the Moderate AQI category day at the Fish Hatchery two days after ignition on 9/29/2016. Fish Hatchery had the most nearby 24-hr approval burns and the impacts were minor or on-par with other non-pilot burns.
- None of the 4 days of burning on the Paradise 90 pilot burn appear to have significantly impacted Kettle Falls with smoke.
- The Sherman Creek pilot burn burned on 11 individual days in 2017, six of which used the 24-hr advance notice. Two days of Moderate AQI category impacts occurred at the Sherman Creek Fish Hatchery monitor; one due to an advance notice pilot burn and one due to a non-advance notice burn. In both cases, impacts occurred the next morning probably due to overnight smoldering of fuels. This burn was only 0.6 km from the Sherman Creek Fish Hatchery monitor. Smoke impacts did not occur in Kettle Falls, about 6-km away from these burns.

- The Hanlon pilot burn 31-km north of the Kalispel Tribal Center burned on one day with minimal consumption (90 tons) and did not cause any air quality impacts. Non-pilot prescribed burns in the following days impacted the site resulting in modestly elevated 1-hr concentrations and one day in the Moderate AQI category.

Plain, WA experienced the greatest amount of prescribed fire activity and had the highest smoke impacts with 7 days of moderate air quality and two days of USG. None of the prescribed burns at this location were pilot burns. Often at this site PM2.5 concentrations would be elevated during the nighttime and early morning hours, then clear during the day. This pattern would persist sometimes for several days after the prescribed burn was originally ignited. The combination of smoldering fuels and nighttime valley drainage flows could be responsible for this pattern.

As a final note, these data are far too limited to draw definite conclusions and many other factors come into play such as location (proximity of the burn to populations), multiple burns on the same day (which burn caused the impacts?), wind patterns (valley inversions, drainage flows, day/night patterns, etc.), presence of other sources, and quantity of fuels consumed both during the day of ignition and whether any smoldering fuels continue to put smoke into the atmosphere for days afterward.

FUTURE WORK

Future work could include smoke modeling to evaluate the utility of smoke forecasting systems in helping with the go/no-go decisions and assessing impacts from multiple burns in an area on a given day. This work should include the fuel consumption information measured by the FERA team in their companion study *Pre- and Post-Burn Fuel Characterization and Tree Mortality Assessment for the Forest Resiliency Burning Pilot*.

A meteorological analysis could identify typical wind patterns (valley inversions, drainage flows, day/night patterns, etc.) in these areas of complex terrain, which can also aid in go/no-go decision-making. This could be especially helpful to an area such as Plain, WA where there was lots of burning and lots of impacts – is there ever a good time to burn near Plain?

Finally, two of the sites in particular, Liberty and Curlew, appear to have other sources of PM2.5 impacting air quality. Analyzing the measured temperature data to look for correlations with low temperatures and elevated nighttime PM2.5 concentrations could give insights into whether wood stove smoke could be a source of PM2.5 at a location.