B.3 Appendices 1-4

Appendices

Appendix 1. Technical Analysis Protocols & Results – Day Before Approval

Is the UW-WRF forecast model sufficiently accurate to support next-day silvicultural burn decisions?

February 2021
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Atmospheric Scientist
Washington State Department of Ecology

Background

The Department of Natural Resources (DNR) regulates silvicultural burning in Washington State under the state Smoke Management Plan (SMP). The DNR meteorologist and smoke management staff consult several atmospheric forecast models along with surface and satellite observations, to determine whether to approve or deny large burns. Large burns are defined as those over 100 tons, or 300 tons when permitted in a designated low risk area. Many atmospheric models are available as guidance, and each of these models have varying strengths and weaknesses, temporal and spatial domains, and available output parameters. In practice, the University of Washington's (UW) Weather Research and Forecasting (WRF) models, run at multiple resolutions twice daily, are among the main forecast tools used to support daily burn decisions.

DNR and the Department of Ecology (ECY) proposed changes to the SMP, to allow for silvicultural burn decisions about 15 hours earlier than current practice. This document details analyses conducted to determine whether meteorological forecasts available in the evening can be used to support the next day's burn decisions, with no appreciable loss of accuracy. It is not so much an assessment of model performance, but rather the sensitivity of model performance to the choice of model initialization times. In other words, if the currently used models are subject to a certain percentage errors in a given range, are earlier forecasts also subject to similar errors?

Proposed Data and Methodology

This analysis protocol was developed in close consultation with Prof. Clifford Mass of the University of Washington, and Dr. Robert Kotchenruther and Mr. Randall Ruddick of EPA Region 10. It acknowledges that:

- Data needed for every preferred analysis may not exist, or cannot be generated in a reasonable time.
- This evaluation will be limited to the performance of operational meteorological models run by UW. Smoke dispersion models will not be considered.

- No new model runs will be performed, as UW already archives model data for forecast verification.
- Meteorological model performance evaluation will be confined to parameters measured at the surface. Vertical measurements are only made twice daily at 0Z and 12Z (5AM and 5PM PDT) in Spokane and Quillayute, and do not add much statistical power to the evaluation.
- Even though forecasters look at the UW 4km WRF ensemble models, these data are not archived and their performance will not be evaluated. Only the operational (non-ensemble) 4km and 1.33km resolution forecasts are considered here. Due to the voluminous amounts of data involved, these forecast are only archived every 6 hours (i.e. only forecast hours 6, 12, 18, 24… from each model run are saved).
- Even though older model data exist, this evaluation is limited to the last six years. Since models have undergone many version changes and improvements, evaluating the performance of a long-outdated model configuration is not very insightful.

The analysis was conducted as follows:

1. Obtain DNR's 6-year geospatial record of smoke management burn request data from 2014- 2019.
2. Restrict the evaluation to days on which DNR had to decide whether or not to allow permission for > 100 ton burns. In all, 1479 days were considered.
3. Assemble a list of meteorological observing sites in WA, where:

   - At least 300 days of observational data points per year from 2014- 2020 are available in the UW database.
   - Concurrent WRF forecast data had already been saved at UW.

   226 observational sites in WA were available for this work. The most commonly available parameters were wind speed, wind direction and temperature. Relative humidity and precipitation measurements were also measured at some sites.

4. Match each of the burn days in (2) above with the nearest site in (3), using ArcGIS near analysis based on planar distance. 1121 unique date-site combinations (387 days, 83 sites) were used.
5. Assemble historical forecast archives from operational UW-WRF 1.33-km and 4-km models initialized at 12Z and 0Z on the day of the burn, and from the previous day's 12Z model run.
6. Use the same parameters recorded at the verification sites to compute performance statistics at 6-hr time increments from 11AM PDT on the ignition day, through 5PM PDT the next day. The relevant forecast hours from each model run are shown in Table 1-1 below:

Table 1-1. Forecast hours from each model run used in the model evaluation

Evaluate model at	12Z model run on burn day	0Z model run on burn day	12Z model run on day before burn
11AM PDT, burn day	Use model's forecast hour (fhr) 6	fhr 18	fhr 30

Evaluate model at	12Z model run on burn day	0Z model run on burn day	12Z model run on day before burn
5PM PDT, burn day	fhr 12	fhr 24	fhr 36
11PM PDT, burn day	fhr 18	fhr 30	fhr 42
5AM PDT, burn day +1	fhr 24	fhr 36	fhr 48
11AM PDT, burn day +1	fhr 30	fhr 42	fhr 54

7. All model performance statistics were aggregated by season.

Model performance evaluation results

Appendix A contains the technical analysis report compiled by the University of Washington, with technical feedback from the author. The main findings in the summary table confirm that meteorological forecasts available the previous evening are not substantially better or worse than products currently used for same-day burn decisions. The *difference* in Mean Absolute Errors of each of the three different model initializations is very close to zero for the most important parameters considered. Precipitation forecasts are a little more sensitive to the choice of model initialization times, but this is not the most important parameter forecasters consider when making burn decisions.

In summary, if all other aspects of the silvicultural burn approvals process remain unchanged, on days when a burn decision is needed:

i. The use of the previous day's 12Z initialized meteorological models alone will not increase forecast uncertainty.
ii. It is very likely that the forecaster would have made the same operational burn decision on most occasions, if their forecast was based on the previous day's 12Z model. Wind speed is a parameter that features heavily in burn decisions. Figures 6 and 7 of Appendix A show how the previous day's 12Z models have slightly smaller wind speed forecast errors than the burn day's 12Z model, in the season when most burn decisions are made (fall). This lends more confidence that a status-quo or better burn decision will be made.
iii. USFS Bluesky smoke dispersion models which are sometimes consulted, also use 0Z and 12Z UW WRF meteorology. A meteorological forecast solution that is "locked in" the previous day would not lead to a very different smoke forecast.
iv. There is little evidence to suggest a systematically worse deterioration of air quality, purely on the basis of an earlier burn authorization.
v. After authorizing burns the previous evening, forecasters could:
    a. Use the burn day's 12Z operational model and 0Z 4km ensembles (when available) to re-check conditions
    b. Consider the latest $PM_{2.5}$ monitor readings where available, perhaps using EPA's Fire and Smoke monitor map. This map expands the state's monitoring network by including semi- quantitative data from low cost sensors, mostly operated by citizen scientists.

vi. By actively participating in the Northwest Regional Modeling Consortium, DNR forecasters could advocate for model products (mostly from UW) that facilitate better burn decisions with more public health safeguards in place.

Appendix A: Report on UW Verification of WRF Forecasts for DNR

23 February 2021

To: Karen Zirkle, Assistant Wildfire Division Manager, DNR

From: Jeff Baars and Cliff Mass, Department of Atmospheric Sciences, University of Washington

Subject: Report on UW Verification of WRF Forecasts for DNR

The University of Washington completed a verification project for the DNR to better understand how high-resolution UW WRF forecasts degrade as they age. For the purposes of prescribed burn decisions, are forecasts generated yesterday as good or nearly as good as ones generated today?

The focus was on weather parameters critical for prescribed burn decision making: temperature, relative humidity, wind speed and direction, 6-hr precipitation. The UW 1.3-km and 4-km resolution weather forecast models were verified, using the forecasts generated the day of, the evening prior, and the morning prior for 1479 previous prescribed burns from 2014 - 2019. Observations from the meteorological observing station nearest to each of these prescribed burns was used, with forecasts bilinearly interpolated to the meteorological observing stations.

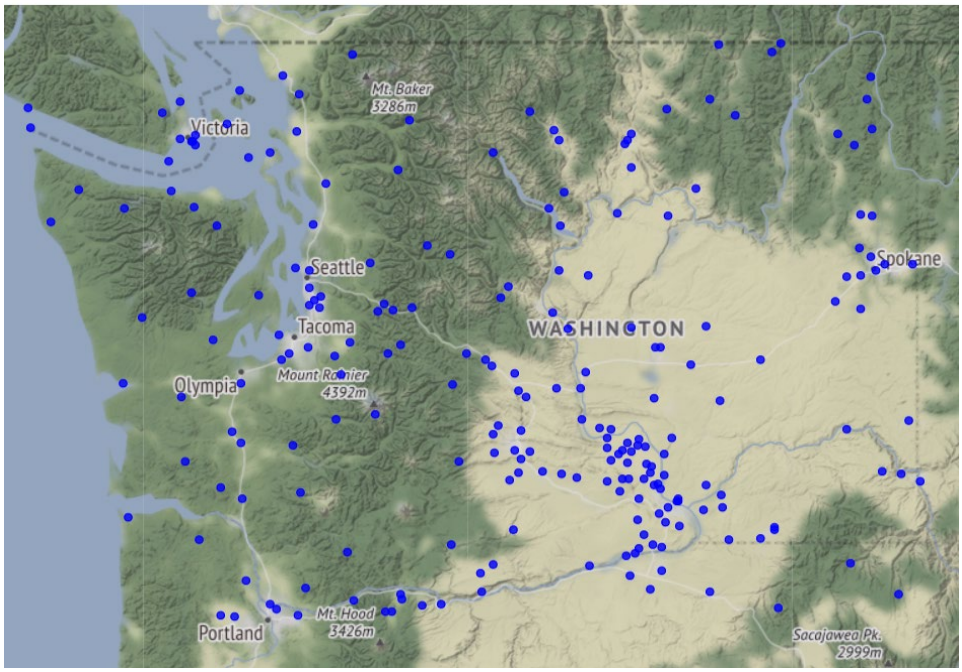


Figure 1. Map of meteorological observing sites used in this analysis.
Only sites with > 300 observations per year from 2014- 2020, recorded at 0Z each day are used.

Verification was divided into the seasons of January - March, April - June, July - September, and October - December. Since few burns are conducted in quarters 1 and 3, there are far fewer days for establishing model performance at those times. Statistics were calculated using the mean of forecast minus observation convention. So a negative (positive) mean error (ME) for a

parameter means the model is under (over) -forecasting it on average. For example, a negative mean error for temperature means the model is too cold on average.

Results show only a slight degradation in skill with age. 6-hr precipitation had the biggest decrease in skill with age. Forecasts from the 1.3-km model are slightly better than 4-km forecasts for all variables except 6-hr precipitation. Figure 10 through Figure 19 show MEs for all parameters.

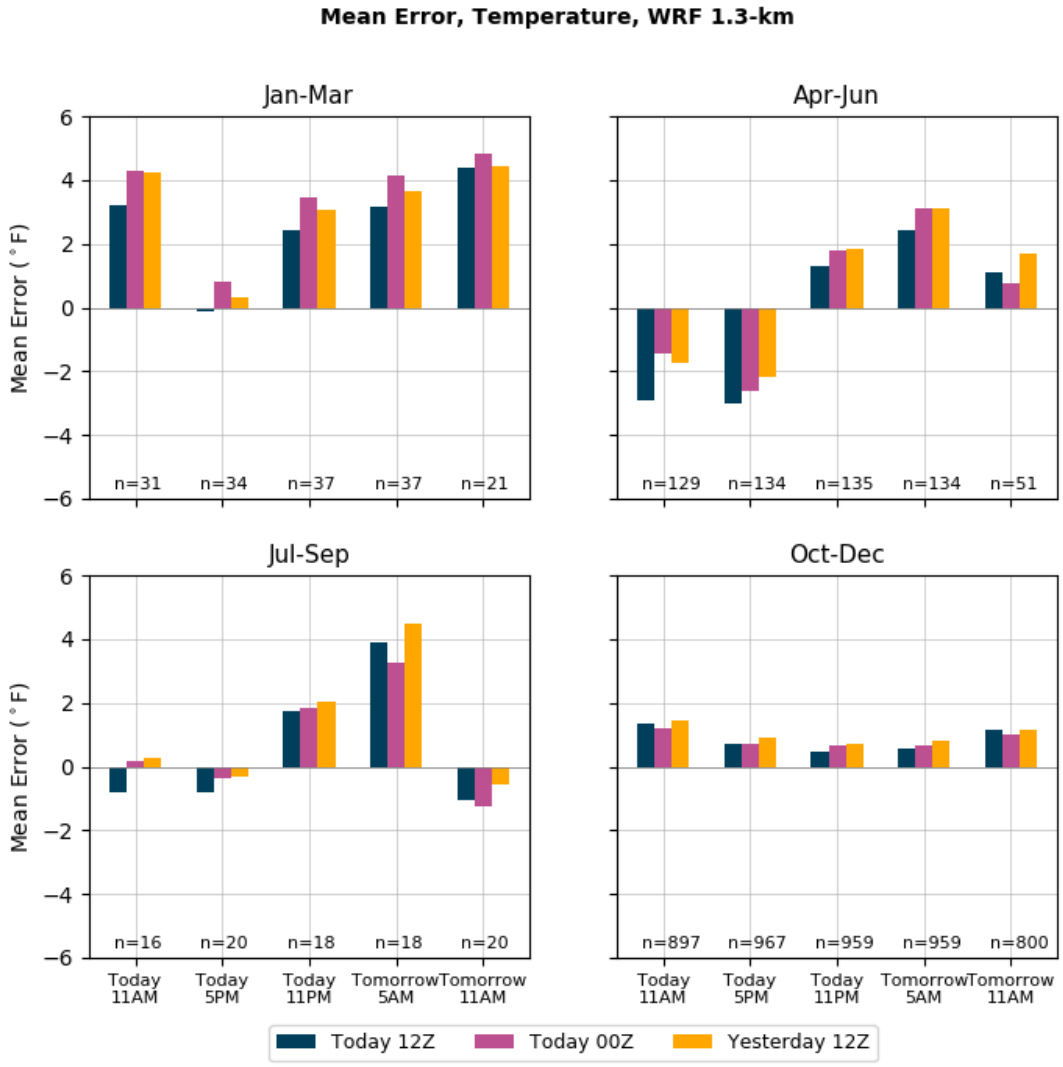


Figure 1. WRF 1.33km model temperature evaluation

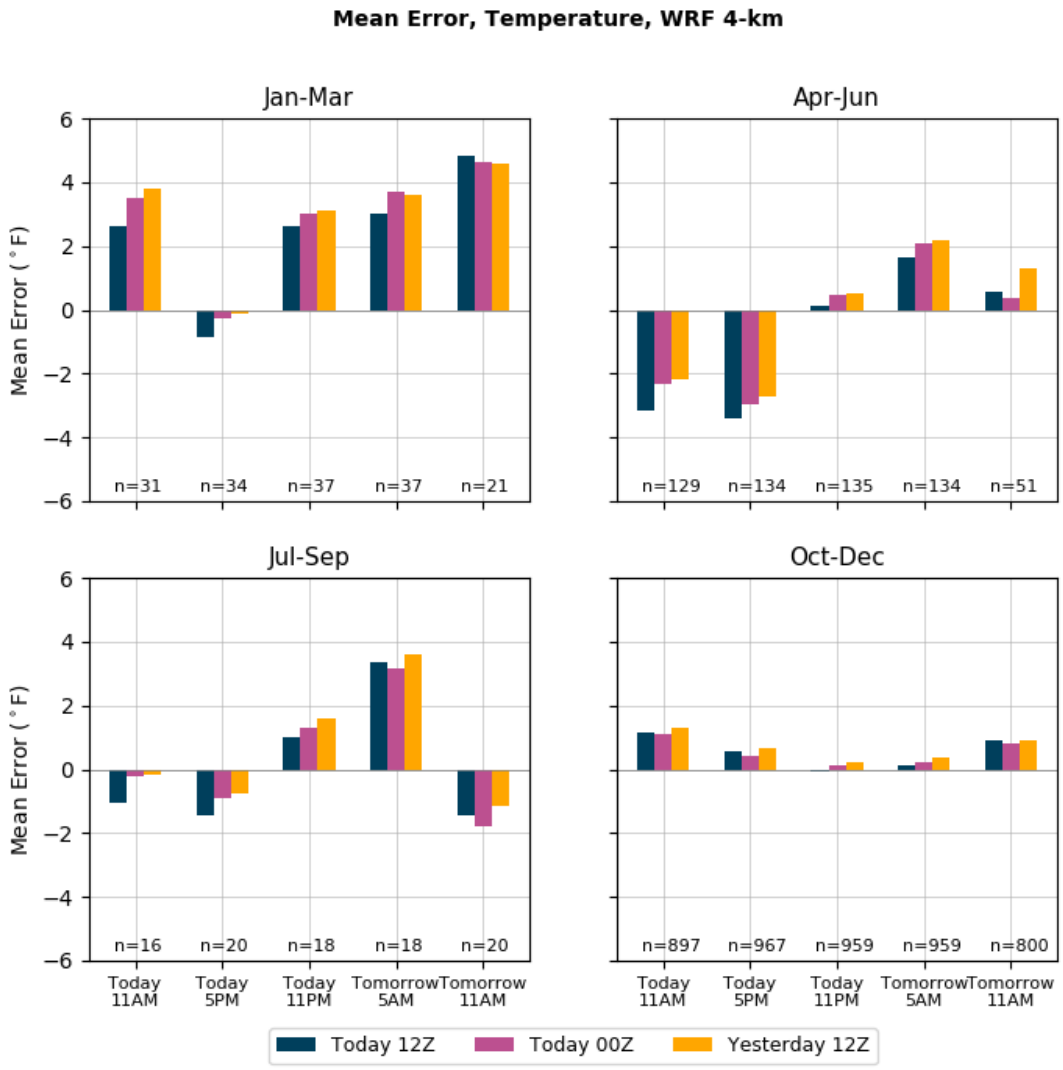


Figure 2. WRF 4km model temperature evaluation.

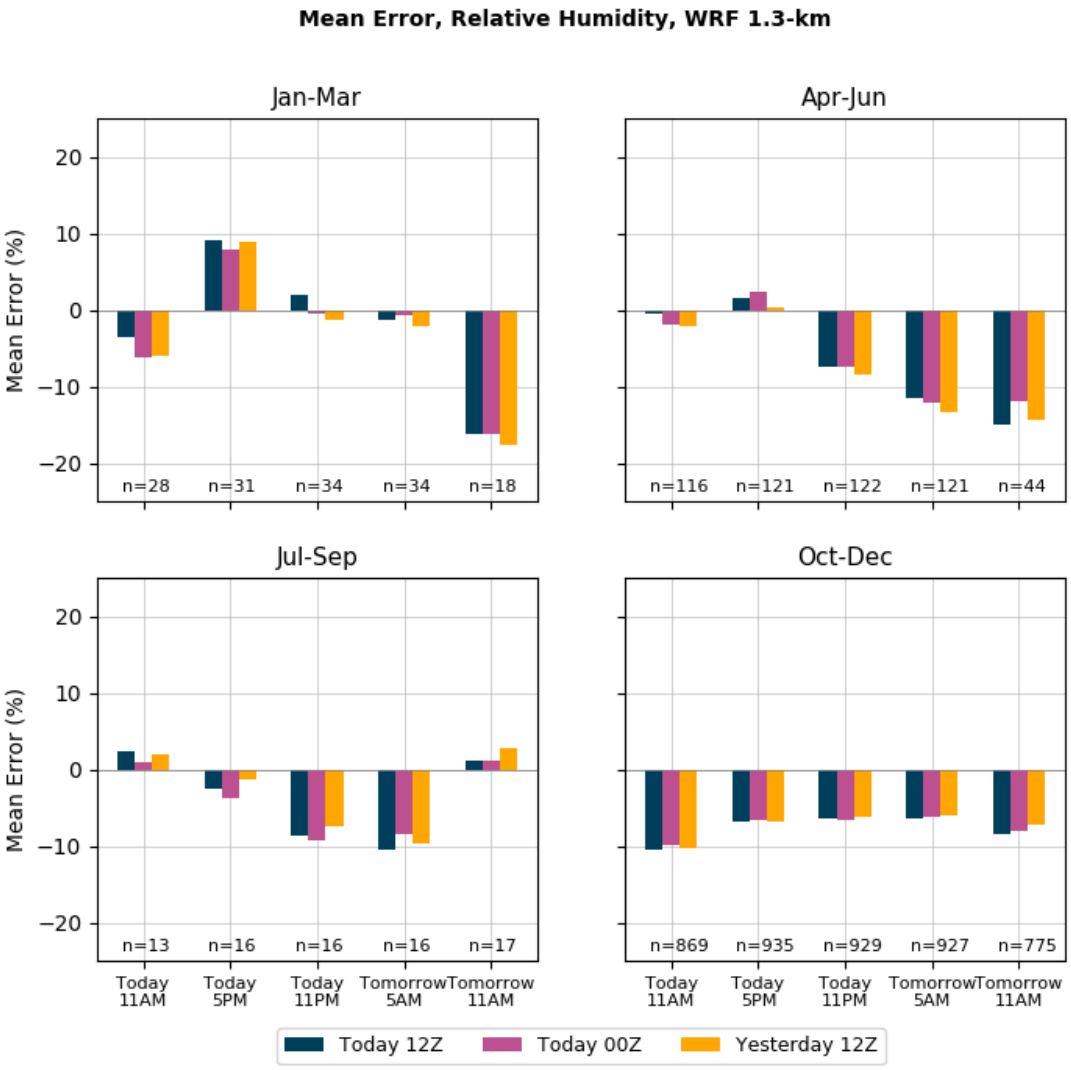


Figure 3. WRF 1.3-km model relative humidity evaluation.

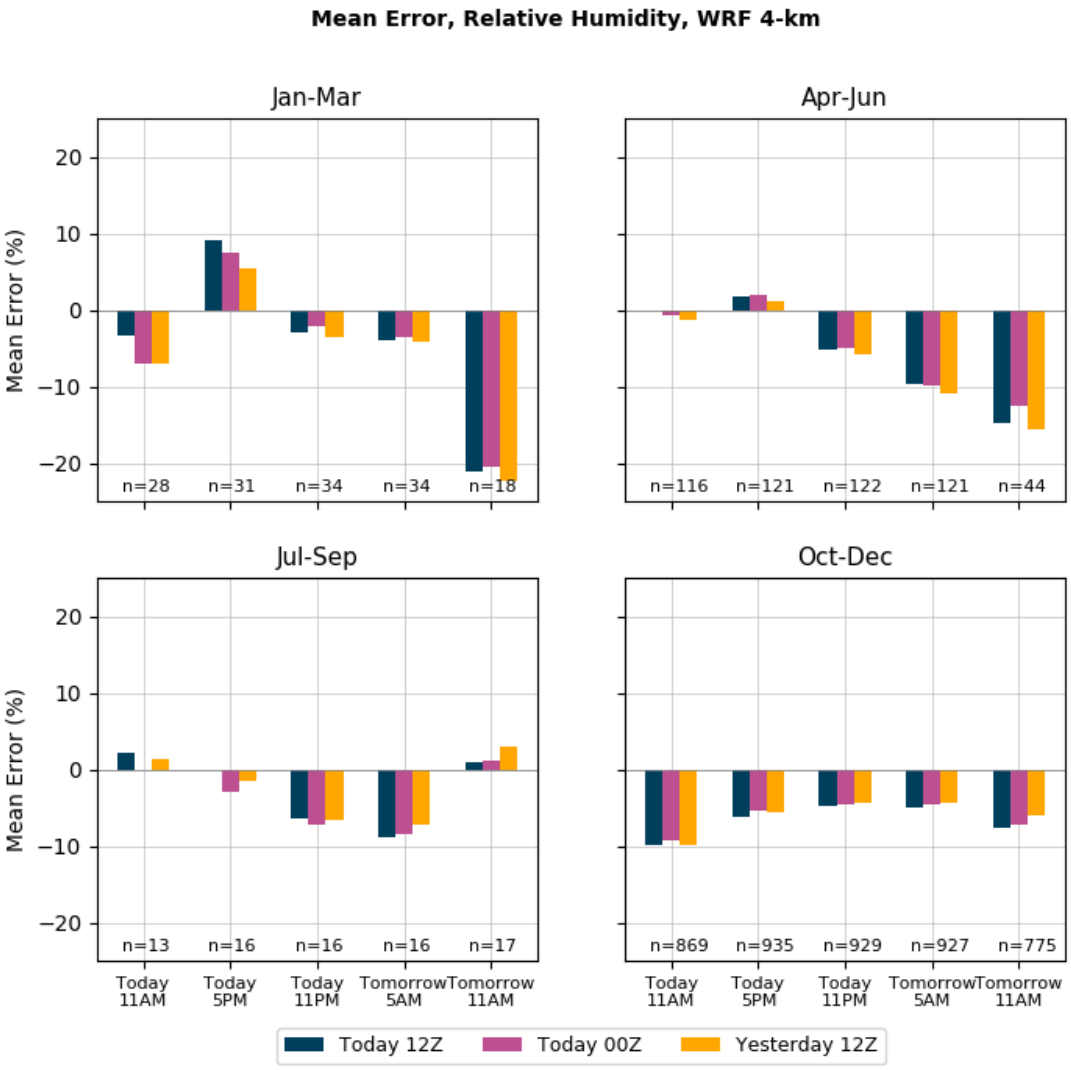


Figure 4. WRF 4-km model relative humidity evaluation.

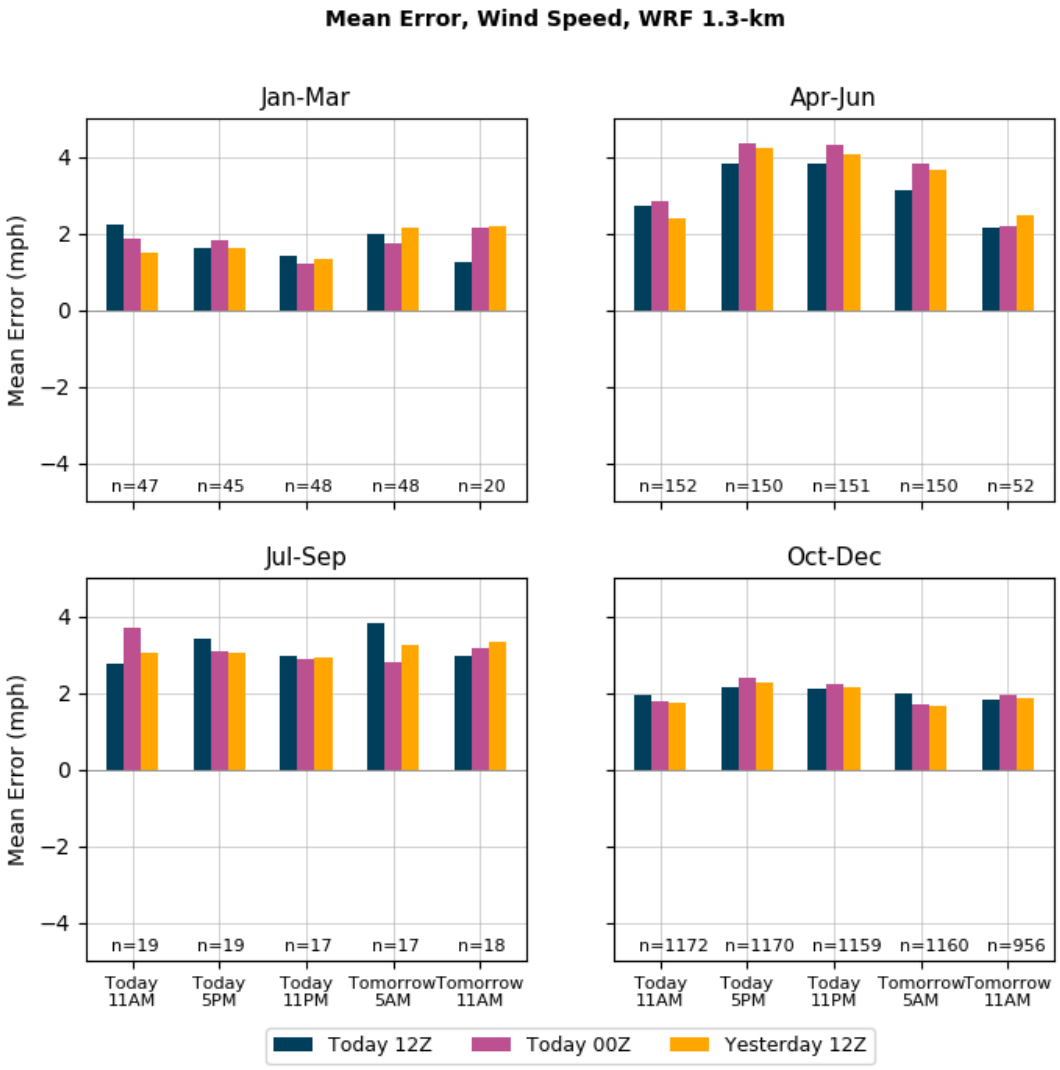


Figure 5. WRF 1.3-km model wind speed evaluation.

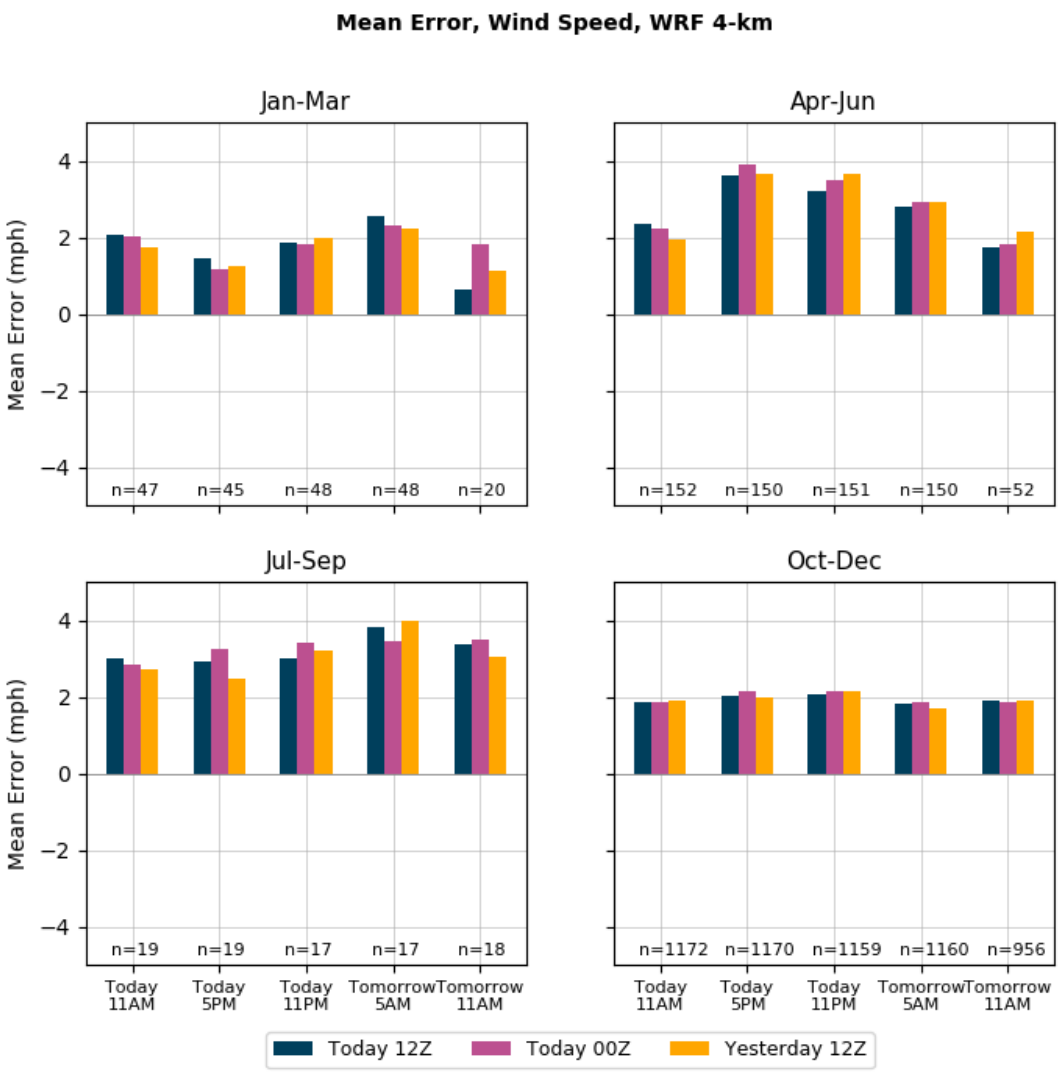


Figure 6. WRF 4-km model wind speed evaluation.

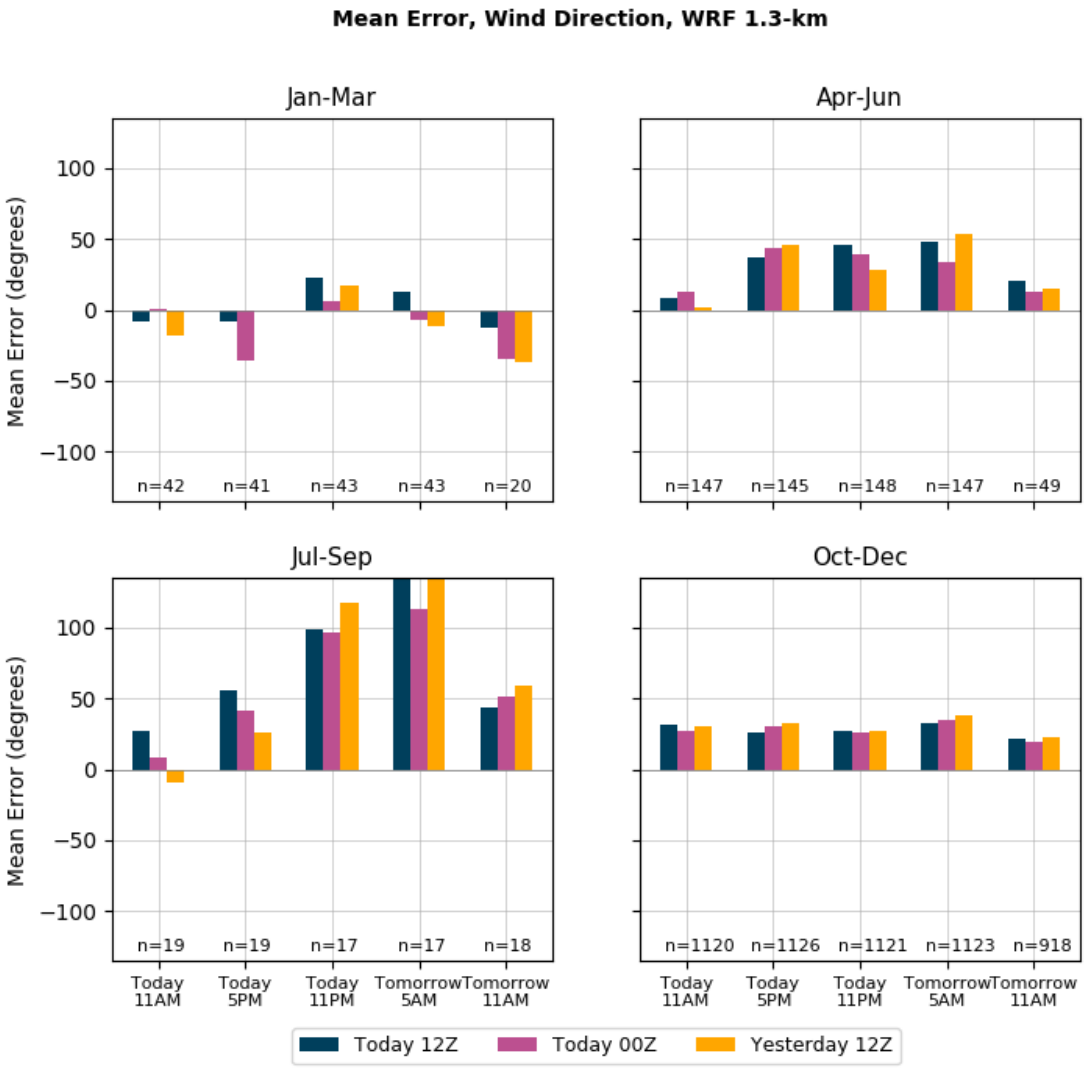


Figure 7. WRF 1.3-km model wind direction evaluation.

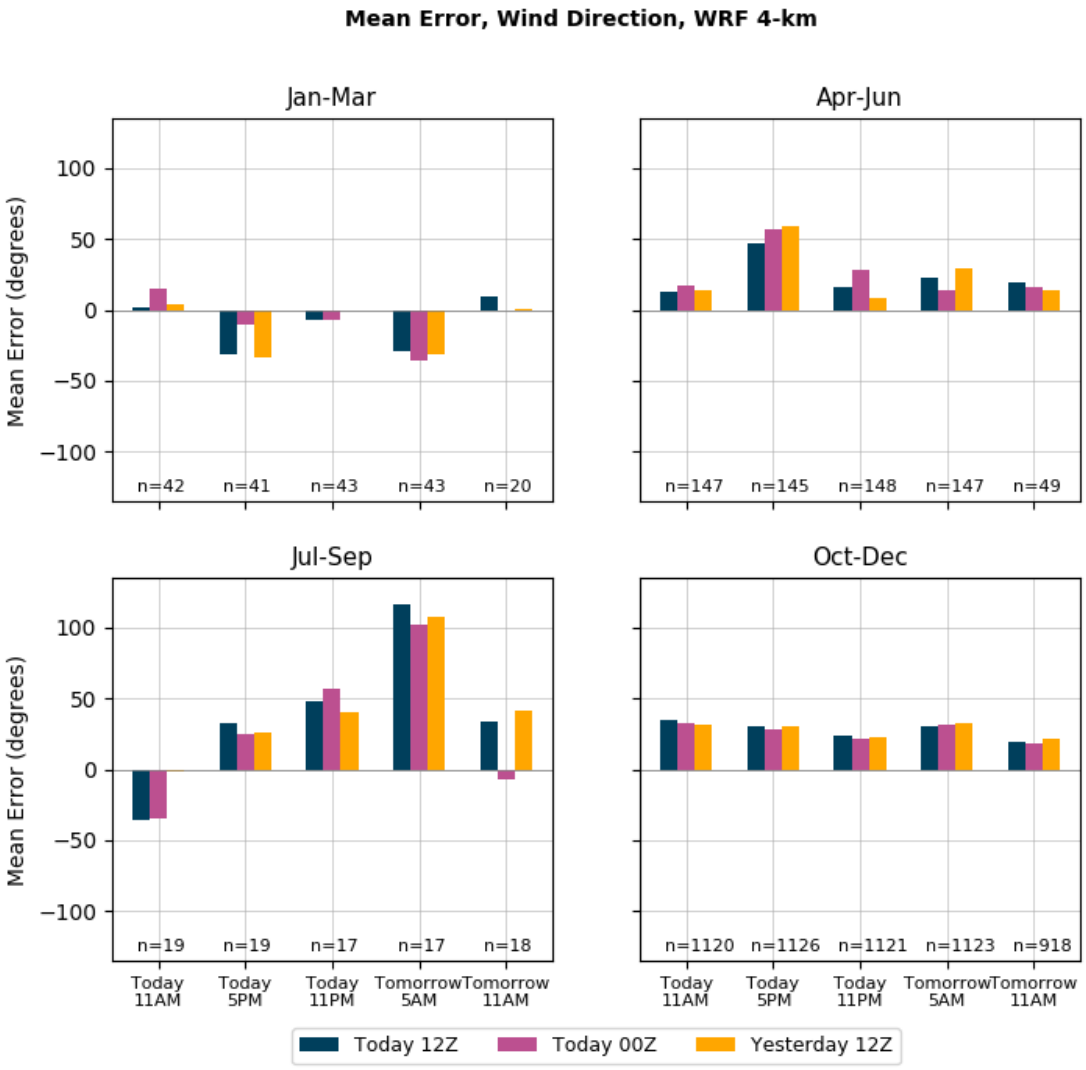


Figure 8. WRF 4-km model wind direction evaluation.

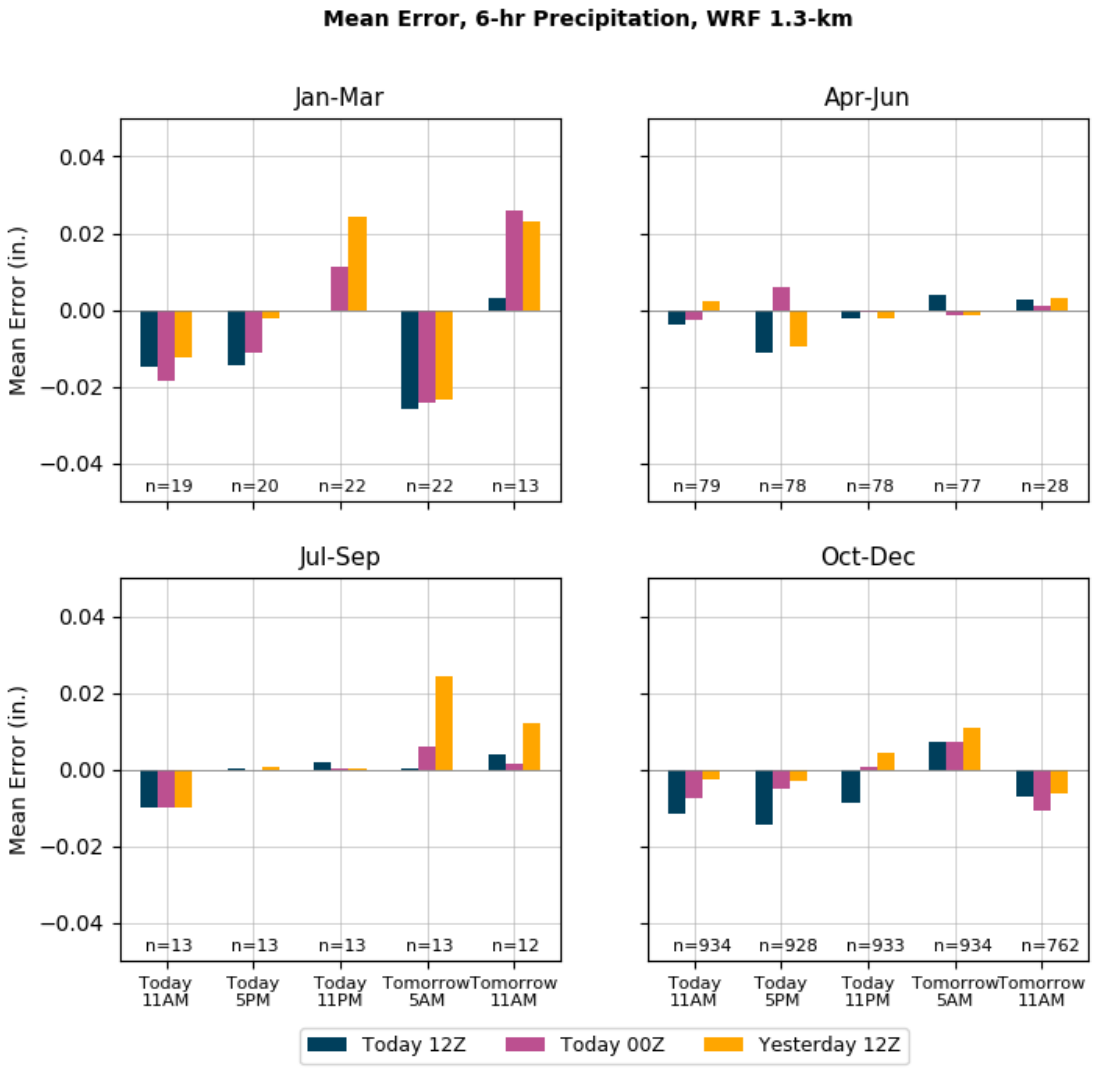


Figure 9. WRF 1.3-km model 6-h precipitation evaluation.

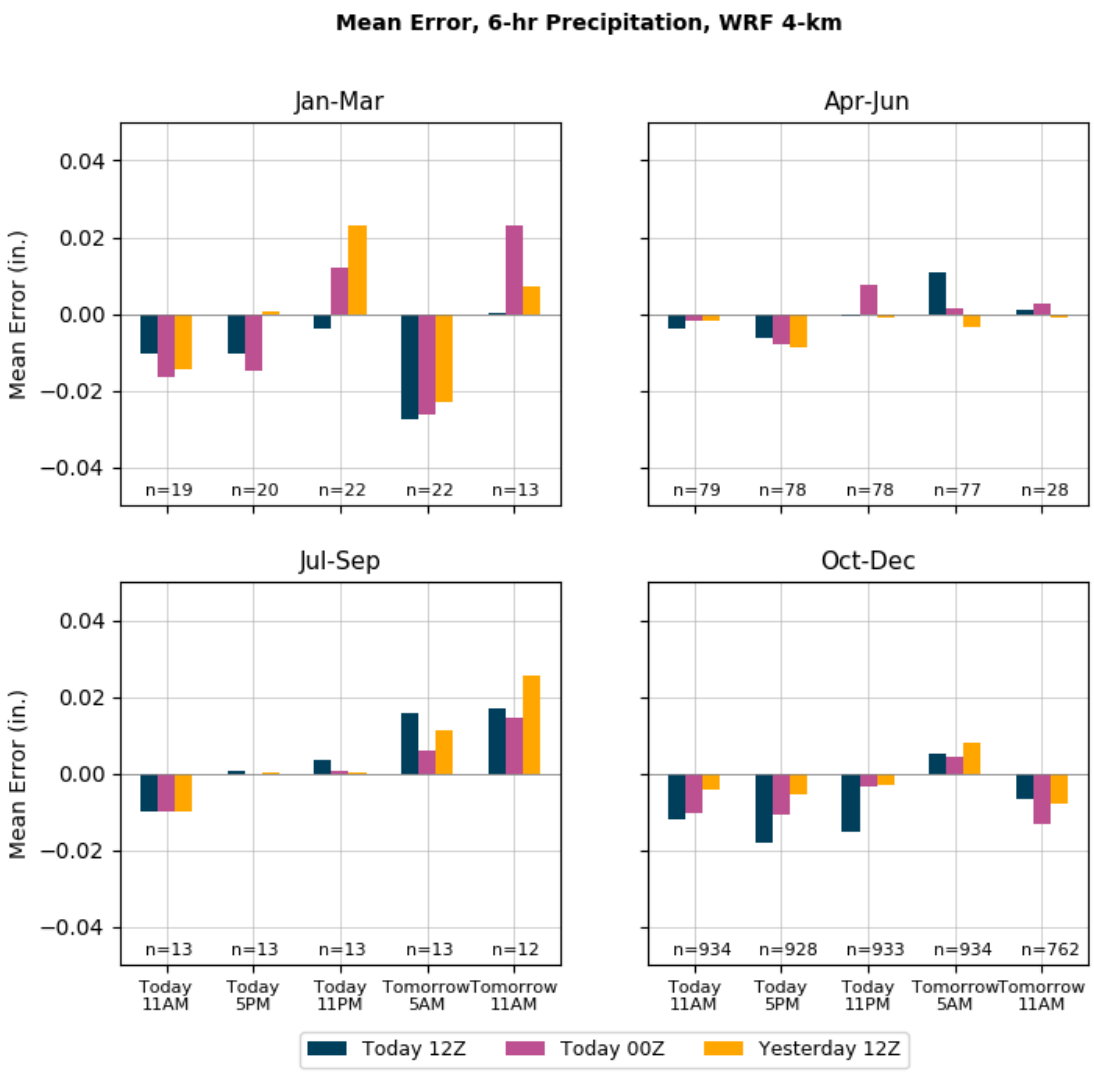


Figure 10. WRF 4-km model 6-h precipitation evaluation.

Below is a box plot of wind speed observations and corresponding 1.3-km and 4-km model "Today 00Z" forecasts. The boxes in these plots show the 25th and 75th percentiles, the line within the box is the median, and the whiskers are 5th and 95th percentiles. Sample sizes (not shown) for each forecast valid time are the same as those in the wind speed MAE and ME plots.

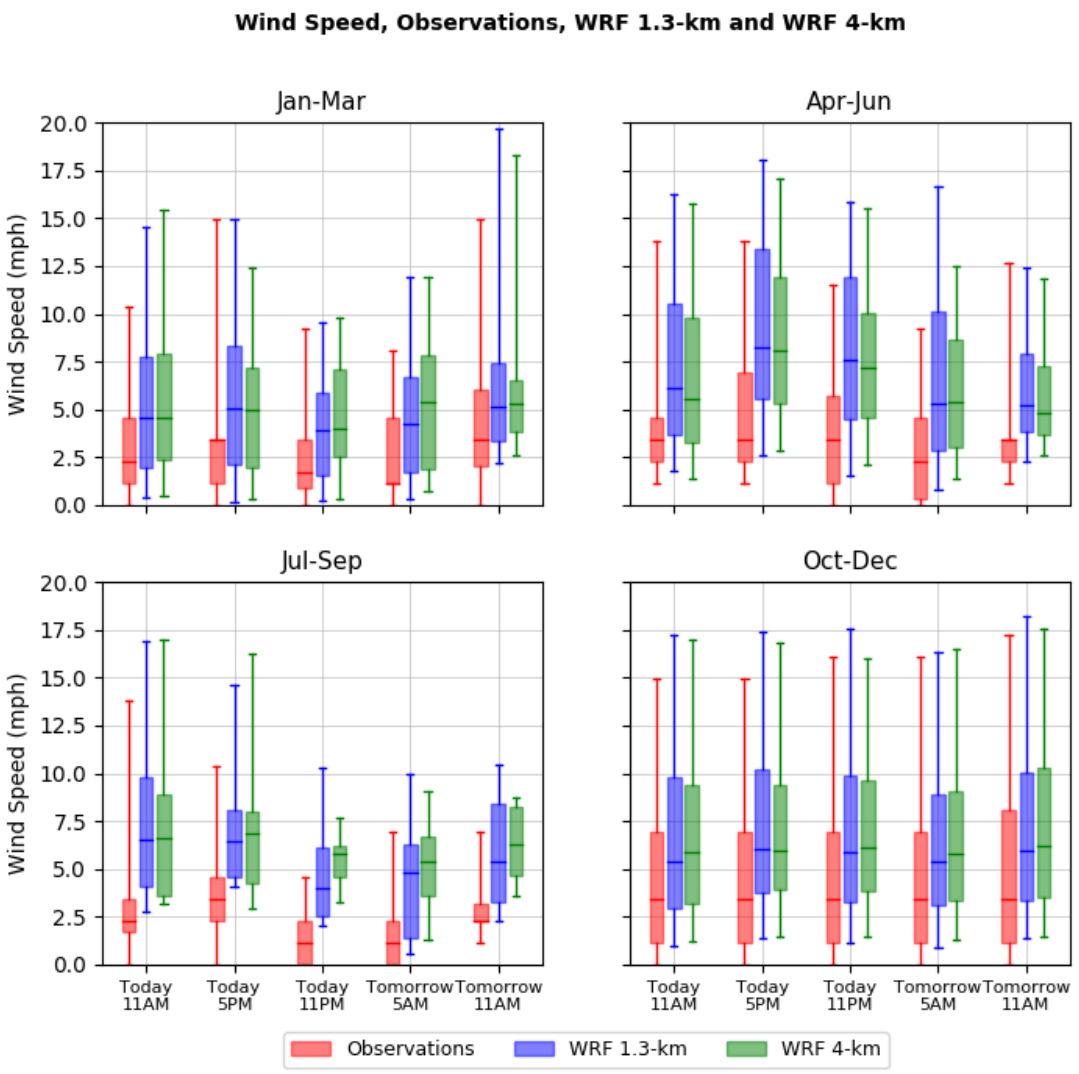


Figure 11 Wind speed observations, WRF 1.3 km and WFR 4 km

Below is a summary table of the percent difference in mean absolute error (MAE) relative to "today's 12Z run" for each model initialization, model, and variable for all of the forecast times considered in the ME bar plots. This is an overall indication of how much the older forecasts' accuracy deviated from the newest one available to forecasters at decision time.

Model Initialization	Model	Variable	MAE Percent Difference
Today 00Z	WRF 1.3-km	Temperature	2.5
Yesterday 12Z	WRF 1.3-km	Temperature	5.5
Today 00Z	WRF 4-km	Temperature	3.6
Yesterday 12Z	WRF 4-km	Temperature	5.5
Today 00Z	WRF 1.3-km	Dew Point Temperature	2.9
Yesterday 12Z	WRF 1.3-km	Dew Point Temperature	5.2
Today 00Z	WRF 4-km	Dew Point Temperature	4.0
Yesterday 12Z	WRF 4-km	Dew Point Temperature	6.5
Today 00Z	WRF 1.3-km	Wind Speed	3.0
Yesterday 12Z	WRF 1.3-km	Wind Speed	1.8
Today 00Z	WRF 4-km	Wind Speed	0.8
Yesterday 12Z	WRF 4-km	Wind Speed	1.8
Today 00Z	WRF 1.3-km	Wind Direction	0.4
Yesterday 12Z	WRF 1.3-km	Wind Direction	0.8
Today 00Z	WRF 4-km	Wind Direction	-0.8
Yesterday 12Z	WRF 4-km	Wind Direction	1.3
Today 00Z	WRF 1.3-km	6-hr Precipitation	7.6
Yesterday 12Z	WRF 1.3-km	6-hr Precipitation	17.3
Today 00Z	WRF 4-km	6-hr Precipitation	6.7
Yesterday 12Z	WRF 4-km	6-hr Precipitation	13.4
Today 00Z	WRF 1.3-km	Relative Humidity	0.5
Yesterday 12Z	WRF 1.3-km	Relative Humidity	2.5
Today 00Z	WRF 4-km	Relative Humidity	0.6
Yesterday 12Z	WRF 4-km	Relative Humidity	2.3

Appendices

Appendix 2. Technical Analysis Protocol– Summer Weekend Burning

Executive Summary:

This document encompasses the analysis of removing the weekend prohibition on summer burning for large burns (see Burn Decision Approval Section) that has been a part of the Washington Silvicultural Smoke Management Plan since its last revision in 1998. This prohibition only applied to large burns (100 tons or more or 300 tons in low risk areas). Burn and fire danger data from Washington Department of Natural Resources (DNR) databases, data from federal wildfire coordination centers related to resource availability and wildfire activity, and air quality monitoring data from the Interagency Monitoring of Protected Visual Environments (IMPROVE) Class 1 monitors was used (Federal Land Manager Database), in conjunction with reasonably foreseeable future changes to prescribed burning to demonstrate the potential impacts if the restriction is removed. This data is used to show historic burn trends that occur by month and by day of the week to demonstrate DNR's initial assumption, that increasing the number of days available to burn during the summer should have no appreciable impact to air quality due to the self-limiting factors of fire danger and resource availability, and the protections provided by the DNR large burn approval criteria. The addition of new prescribed burning under DNR's own burning program is also not expected to appreciably alter summer burning for the same limiting factors. Air quality will continue to be protected when new burning occurs because the prohibition was only for large burns and they will continue to need permission before igniting, through the burn approval decision process that DNR employs successfully, including during times of the year when exponentially more burning occurs.

The analysis below shows that burning during the summer months from June 15th-September 30th is severely limited, and any increases in burning provided by additional days available is within the ability of the burn decision criteria to protect air quality. Burn permits issued by DNR employ a number of permit conditions designed to limit the chances for fires to escape control and become a wildfire, which include restrictions on the dates, weather, and fire danger rating that a permit holder my ignite their burn. This set of permit conditions in effect, prevent pile burning during the specified summer months, leaving broadcast and under burning (see SMP glossary) as the only types of burning that can be assumed to occur during the summer. Due to planning, skill, and costs associated with conducting broadcast and under burns during elevated fire danger levels, organizations such as federal and state agencies and non-profit organizations are almost exclusively responsible for burning during these months. These agencies, though well trained and capable, have self-limiting policies to prevent prescribed fire (See SMP glossary) escapes as well, that limit when they can initiate prescribed fires if wildfire activity is sufficient to limit their access to resources or the fire danger is considered too risky. In addition to the fire danger factors that limit prescribed burning activity during the summer, analysis of year round burning activity by day of the week shows that regardless of the season, burning on weekends is far less frequent than burning Monday through Thursday.

Based on the limiting factors and DNRs burn program goals, estimations of the effect that removing the weekend burning prohibition were created as summarized in Table 1 for three different scenarios. The variation between scenarios accounts for differences in the accomplishments of the DNR burn program, as well as the number of newly available days that other burners would take advantage of and is described in detail in the following sections.

As can be seen in the table below, under each of the scenarios the median change in burning over the historic average does increase regardless of the scenario. In the low estimate, this is due entirely to the impacts of DNR's burning program, but for the moderate and high estimates, additional burning is a combination of DNR burn program additions as well as other burners taking advantage of additional days to accomplish more burning in the summer.

Table 1. Estimated burning under each emissions scenario in tons of biomass consumed for the summer months compared to the historic average. Median values for each estimate are determined from the predicted range shown in Table 3.

		Low Estimate		Moderate Estimate		High Estimate	
Month	Historic Average	Median	% Increase	Median	% Increase	Median	% Increase
June	9564	14885	56%	24165	153%	26065	173%
July	4611	8849	92%	14110	206%	16976	268%
August	4270	6004	41%	6455	51%	8710	104%
September	53203	75813	42%	93584	76%	116203	118%

While the overall increases appear significant, when the estimated range is compared to the historic range of variability, the contrast is far less stark, and in fact, these estimated ranges fall inside the historic range of variability for eight out of the twelve possible combinations of burning scenarios and summer months. The most likely scenario to occur is somewhere between the low and moderate estimate, and in this case, only the month of June has results that are greater than the historic range of variability.

Regardless of which scenario is the most accurate, increases in burning of the amounts determined for any of the estimated levels is not likely to negatively impact air quality. When looked at in the context of year round burning, activity during the month of June is orders of magnitude less than the months of April and May, while air quality monitors show a steady improvement in the air quality as measured in concentrations of organic carbon through the spring and into early summer. September burning additions are also inconsequential. Wildfire activity is declining, the first half of the month is generally unavailable to burn due to fire danger concerns, and the amount of burning that does occur is miniscule when compared to October and November. An increase in burning due to removal of the weekend burning prohibition under any scenario would have no discernable impact to air quality, and well within the abilities of the smoke management program to protect air quality through the burn decision approval process outlined in the Smoke Management Plan.

Introduction:

1998 Smoke Management Plan (SMP) adopted into the State Implementation Plan (SIP) for silvicultural burning in Washington State included restrictions for burning on the weekends

during the summer months. Weekends were identified as 12:01 AM Friday through midnight Sunday, and the summer was identified as June 15th to October 1st. The restriction specified that burns consuming more than 100 tons of material would not be allowed during the summer weekends and on the summer holidays of July 4th and Labor Day.

Exceptions to allow burning during the prohibited days may be granted on a case by case basis if certain criteria are met, including demonstrating that the burn could not be done outside the summer months and is so limited in opportunities to burn that the prohibited days must be used. In practice, very few burns have asked for an exception and for a variety of reasons, very few burns are conducted during these summer months.

The 2021 SMP removes the weekend summer burning restriction, allowing large burns (greater than 100 tons of consumed material in a single burn) to occur that would be subject to the same restrictions that apply to any other time of the year. Large burns would be required to meet the criteria for large burn approvals before smoke management approvals could be obtained, and would be subject to the terms and conditions applied to the burn permit that are always in effect. Large burns are subject to eight criteria before ignitions can be approved. This includes denying burns if DNR smoke experts think there is a likelihood an air quality violation could occur because of ignition (DNR smoke experts use many tools to make these decisions, see Section on Tools and Large Burn approval criteria), and there is not an impaired state of air quality in the location of the burn.

Determining the effects of removing the summer burning restriction requires a look at permit conditions applied to burn permits. Every burn permit application is given a set of permit conditions specific to the burn site and the surrounding area, that is dependent upon type and quantity of the burnable materials, adjacent values at risk, adjacent fuel, and local fire activity before the permit is issued. However, there are common permit conditions put in place for most burn permits. These are applied specifically for the protection of air quality in the micro and macro scales, as well as for protection against a burn escaping (see Appendix A for blank copy of permit with standard condition options). These permit conditions that are designed to protect against smoke and escaped fire hazards are set by DNR fire foresters. Fire foresters are trained firefighters responsible for a multitude of fire regulation activities that includes writing burn permits within their local area of operations. These foresters are intimately familiar with their area of operations, local fire trends, and micro scale weather that allows DNR to customize permit conditions to each burn. Specific to burning during the summer months, are permit conditions 8a, 8b, and 8f.

Permit condition 8a allows the permit issuing forester the opportunity to restrict times of the year when the burn may be conducted. This may span any time frame greater than one day. As part of the application process, burners may select the option of asking to burn during the "Closed Season" (April 15th through October 15th). This period relates to another fire regulation system, the Industrial Fire Precaution Levels which has no other burn permit related purpose more than loosely identifying the fire season, however if the applicant does not specifically request to burn during this period, they are prohibited from doing so to mitigate the potential for a fire to escape.

Permit condition 8b may be used in lieu of, or in conjunction with condition 8a. When checked, this prohibits burning unless the fire danger in the area of the burn is set to “Low”. There are occasions when applicants will request to burn during the closed season for any number of reasons and this restriction generally limits these burns to the fringes of the summer season while ensuring that if a burn does escape, that sufficient suppression resources are likely to be available.

Permit condition 8f sets a minimum relative humidity value at which the burn can occur, prohibiting the permit holder from initiating a burn if the air is dry enough to create fire escape problems, and is typically applied to burns regardless of if they are allowed to burn during the summer months. Due to the climatology of the state, this restriction is more prohibitive during the peak summer months. West of the Cascade crest the minimum RH value is typically set between 35% and 45% while permits east of the Cascades are set between 25% and 35% for minimum RH.

Permit issuing foresters have a wide authority to select the permit conditions they deem appropriate for the site and period that they allow burning to occur. This includes customized permit conditions in the “other special conditions or requirements” section or occasionally as addendums attached to the permit. Many permits are issued with special permit conditions waiving restrictions such as wind speeds, and minimum fire breaks if sufficiently wet or snowy circumstances are present. This allows safeguards to be more flexible with the seasons and to encourage pile burn permit holders to conduct burns when weather is least favorable for fire escape.

Permit conditions for federal land management agencies are different. The federal agencies are required to abide by the smoke management plan in effect and the air quality protections that are contained within. This makes them responsible for determining what time of year to burn, burn site weather needs, and any of the other permit conditions that DNR would set for other burners since they are responsible for fire protection on their own lands, undergo rigorous training, and create highly detailed burn plans. They are however, restricted by agency policy for prescribed fire that can be found in the Red Book (National Interagency Fire Center, 2021). These policies require approval by the agency administrator at respective agencies state or regional level for initiating a prescribed burn when the National Preparedness Level is a 4 or 5. There are also agency specific restrictions for the Bureau of Land Management, National Park Service, and US Fish and Wildlife Service that require at least a Region or State Director approval if the local geographic area is at a preparedness level 4 or 5 as well. The US Forest Service requires approval from the Regional Forester for National PL 4 or 5 or if the area of the burn is under Extreme fire danger.

The conditions placed on private, State, and Federal burners, provide important limiting factors that are explored in the following sections.

Methods:

Methods initially proposed for the analysis of this demonstration differed from the final analysis methods slightly. The proposal was designed around answering several questions related to the increases in burning that may occur as a result of more days of the year available to burn. In particular, the proposal intended to create a High, Medium or "Realistic", and Low estimate for the change in burning that could be expected to occur. The High estimate would be based on a reasonable maximum number of new days available to burn and thus an increase in emissions. The Medium estimate assumed that some days would be unavailable to burn due to wildfire activity, fire danger and other factors. The Low estimate would assume that no additional burning would take place and that summer burning would instead be spread out over a larger number of days.

In addition to these burning estimates, historical burning would be used to determine locations most likely to see additional summer burning along with the priorities for the DNR's 20 year Forest Health Strategic Plan: Central and Eastern Washington referred to from here on out as the Forest Health Plan. Weather information would be compared for the summer months to the rest of the year to determine if conditions in the summer are better suited for smoke dispersion, and impacts to Class 1 areas would be estimated for the various scenarios.

The actual analysis did deviate from the proposal as data was processed. A High, Medium, and Low estimate for emissions was conducted utilizing the historic average and range for each of the summer months. In the case of the High emissions estimate, it was assumed that most of the newly available summer days are available to burn each year, and that those will be exploited at a rate commensurate to the historic rates. It is also assumed that the DNR will be able to implement new prescribed fires, accomplishing the maximum proposed treatments each year.

The Medium emissions estimate assumes that fewer of the newly available summer days will be available to burn due to fire danger and resource availability. It also assumes that DNR will be able to implement prescribed burning at the median target goals instead of the maximum. Lastly, the Low estimate assumes that due to fire danger, historic trends in burn activity based on day of the week, and other factors, that none of the newly available burning days will be utilized, and that the DNR will meet only the minimum target goals for prescribed fire.

Common to each of these scenarios is the assumption that historic trends in burning activity will continue into the future, principally, that the proportion of burning conducted in each month will not significantly change. In addition, it is assumed that one standard deviation from the mean represents an acceptable range to determine the future range of burning in each month.

To reach these estimates, DNR burn data was gathered, encompassing an eleven year period from 2009-2019. This data includes information on the size of burn units, tonnages burned, date burned, type of burn (piled, broadcast, or natural), and land ownership. Additional data was obtained from the National Interagency Fire Center (NIFC) regarding national fire preparedness levels, and from the North West Coordination Center (NWCC) to obtain historic regional preparedness levels. DNR's fire danger history was also utilized, along with air quality

monitoring data from Washington's Class 1 area monitoring stations. These data sets show trends in burning by date with variations due to seasonal and annual weather patterns. This annual variability led to creating a range of results rather than single outputs for the final analysis. Finally, data from the DNR's Forest Health Plan and the staff responsible for its implementation was used to identify foreseeable future increases in burning.

From conversations with DNR burning staff, it was determined that there is still too much uncertainty in project locations to be able to ascertain where additional DNR forest health burning will occur. Planning documents have high priority treatment areas identified by HUC 5 watersheds spread throughout the eastern half of the state with only generalized treatment targets available, therefore answering the question of where summer burning is likely to occur is left to analysis of the historic dataset.

Results and Discussion:

Historical burn data was used to determine burn trends, as it is assumed that the best indicator of future burning activity is the recent history. Burn activity in Washington does vary significantly from year to year based on a myriad of factors including climate and weather patterns, log prices, land management policies and budgets (See Table 2). There is also variation between months, for example between July and October where regardless of which year is examined, October burning is significantly greater than July burning. This seasonal burning trend has remained constant over the study period. The vast majority of burning occurs in the fall and mid spring with October as the most active month in nine of the eleven years sampled. November took the top spot for the other two months.

Table 2. Total Tons of Burned Material by Month 2009-2019. Burned material by month for all burn types and sizes from 2009-2019 from DNR's database of post burn information. From 1998 through 2019, it was assumed that pile burns from parcels less than 10 acres in size would consume 30 tons of material. As of December 2019, all permits have required pile calculator results. Permits for pile burns where the total tonnage permitted was less than 100 tons have also been assumed as completed on the day the permit was issued, as they are not required to provide post burn data. Burning activity each year roughly follows the same pattern (See also Figure 1 below).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
January	6,810	1,986	1,829	13,879	13,742	25,898	7,886	4,274	15,731	5,501	6,828
February	3,895	1,786	2,149	3,590	2,686	4,004	4,928	5,415	4,448	2,567	1,720
March	3,280	18,339	3,453	3,972	5,460	5,327	3,028	8,099	4,594	5,145	1,763
April	77,438	62,186	39,256	36,584	118,425	42,147	109,129	92,910	10,848	33,808	44,354
May	145,917	80,627	29,719	88,371	85,388	131,149	17,931	36,796	76,927	76,401	117,320
June	3,917	946	14,385	13,958	8,937	20,489	562	19,030	8,918	7,391	16,216
July	200	106	93	26,546	7,065	4,743	555	11,727	897	1,143	90
August	22,415	230	553	18,785	348	665	783	36	96	183	6,883
September	140,227	37,206	27,679	6,915	85,794	80,660	10,711	106,539	48,970	33,853	49,999
October	205,616	288,844	283,698	150,679	140,279	312,655	127,066	189,035	181,021	199,876	186,740
November	57,611	158,762	170,099	199,889	124,058	103,843	142,361	72,692	149,434	142,575	84,493
December	15,552	3,299	14,774	11,581	48,934	53,366	32,278	25,934	29,680	53,210	5,324
Annual Total	682,878	654,317	587,687	574,749	641,116	784,946	457,218	572,487	531,564	561,653	521,730

Between mid-March and early June, there is an increase in burning as fuels are exposed that have been covered in snow, and dormant vegetation has not yet begun to uptake moisture. From June through the summer months, very little burning activity is conducted. Pile burners have the ability to burn their fuels under weather conditions that are unfavorable for fire to escape and pile permits are issued with conditions to encourage this.

As mentioned previously, every permit is conditioned to the site and the fuel conditions germane to it, and with very few exceptions, pile burns are prohibited during the summer months. While not specified in policy, unless a pile burner can provide a sufficient reason, all pile burning permits are restricted to Low fire danger. This approach is taught to DNR personnel in their annual regulation training. In addition, unless the applicant is explicit in asking to burn during the closed season (April 15-October 15), they are prohibited from burning during this period. Finally, most permits are issued with a restriction on the relative humidity (RH), barring ignition if the RH is expected to drop below an indicated value. This is supported by burn data, and pile burning is therefore excluded from analysis.

Relative humidity is a critical fire weather value affecting the receptiveness of fuel to ignite due to a fire brand (known as the probability of ignition), and the burning intensity of smaller diameter fuels, which in turn affects how fast a fire may spread (Rothermel, 1983). Relative Humidity restrictions are determined at the local level, are based on fire statistics, and so are variable to a degree but generally fall into the ranges listed above in the section regarding permit conditions.

Figures 1, 2, and 3 show the restrictions placed on pile burning are highly effective in limiting the amount of burning conducted by private entities during the summer months. Fire danger in July would allow for only 30% of permits to burn, while August and September are 6.1 and 17.5 percent respectively. When combined with the arbitrary date restriction of the closed season, and humidity restrictions targeted at preventing burning during weather events likely to lead to an escape, very few pile burns have been conducted during the summer months. This leaves primarily broadcast and under burning to account for the summer burning tonnages.

Due to the advantages of pile burning over broadcast burning, including less restrictive burning windows, reduced firefighting resource requirements, reduced potential for escape, and less complex planning requirements, DNR only issues a handful of broadcast burn permits every year. In addition, these same factors make obtaining an under burn permit a real possibility only for those with significant training and resources available. This is supported by the total tons consumed in the summer and in particular, the proportion of burning done by the federal agencies, which are responsible for the vast majority of tonnage consumed during these months. June, July, and August are 7th, 10th, and 11th respectively out of the year in tonnages consumed. For September, tonnages are accounted for almost entirely by Federal agencies as depicted in Figure 2.

Federal and state agencies conducting prescribed fire are well trained but have policies for prescribed fire implementation in place due to decades of lessons learned and from a few costly and destructive escaped fires. In addition to fuels and fire behavior analysis that is used to determine appropriate weather conditions needed to reach the resource objectives for a prescribed burn, special approvals from the USFS, USFWS, and NPS Regional leadership, or the

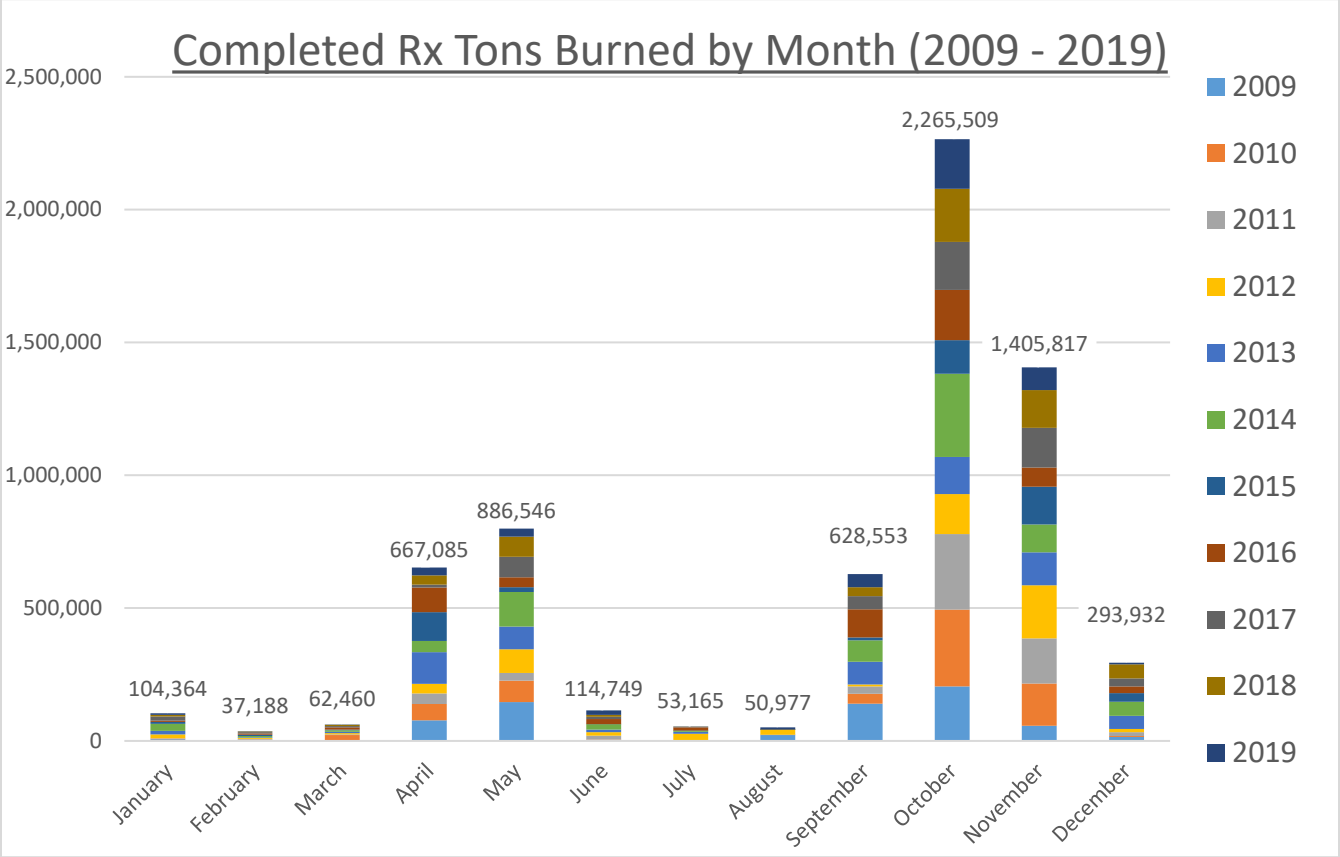
BLM State Director approval must be obtained to ignite a prescribed fire if the geographic area or National preparedness levels (PL) are at a 4 or 5.

Preparedness levels (PL) are an aggregate of ongoing fire activity, fuel and weather conditions, and the availability of suppression resources on a 1 to 5 scale. PL1 indicates conditions unlikely to support significant wildfire activity, with adequate resource availability while a PL5 indicates full resource commitment to ongoing fires, with potential for significant new fires to emerge. These rating occur at both the regional geographic area and National levels.

Over the study period (2009-2019), the preparedness levels for the Pacific Northwest geographic area and the National preparedness levels have routinely provided restrictions to burning within the peak summer months in July, August, and September. In the Pacific Northwest, 10.9% of the days in July were at a PL4 or PL5, 43.4% of the days in August met this threshold, and 19.1% of September days can be included as well (Figure 4). Nationally, 15.3% of July, 48.8% of August, and 15.8% of September have coincided with PL that would restrict federal burning activity (Figure 5). These levels are by no means consistent every year, varying with climate patterns that influence wildfire activity (Figure 6). Year to year however, a general pattern persists with PL typically peaking in the latter half of August.

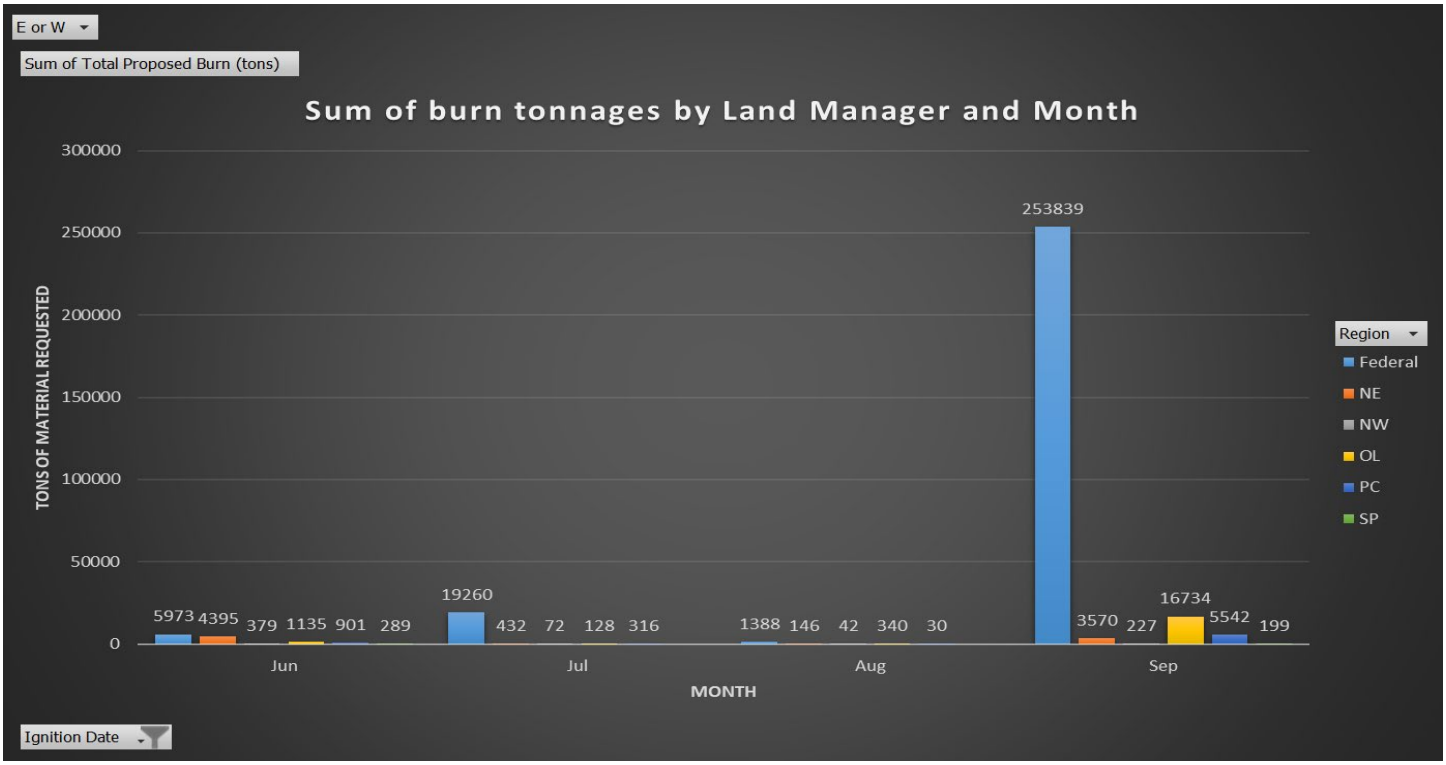
Regional and National PL do not necessarily mimic each other, however for this demonstration it will be assumed that the PL4 and PL5 days are concurrent and not complimentary. The full month of June is used, as the data provided was not parsed out to analyze by day. It can therefore be said that approximately 20.4% of days during the summer would be unavailable to burn as 20.4% of the days fall under either a geographic area, or National PL4 or PL5. Continuing further to weekend days, which make up approximately 35% of the days of the summer, and it can be said that the mean number of weekend days unavailable to burn due to PL restrictions is 9 days.

Figure 1. Stacked graph of all DNR permitted burning from 2009 through 2019 by month. Individual years are color coded. Source: DNR post-burn report data.



There are climatic events that do allow for burning to take place during the summer months, as can be seen in the data of figure 7. Summer burning activity in the months of July and August is made up mostly from tonnage consumed in 2012, while other years show very little to no activity in those months. Conducting a frequency analysis of burn quantities shows that four out of the eleven July's in the sample had total burn tonnages of less than 500 tons, while August fell into this threshold five times, and in both months, consumed tonnages have exceeded 50,000. This is in contrast to other low consumption months such February, in which ten of the eleven years have fallen into the 5,000 to 50,000 tons of consumed material bin. This demonstrates that mid-winter burn variations are subject to fewer variables than summer burning.

Figure 2. Consumed tonnages for all burning types during the summer months by fire protection jurisdictions. Federal type includes all lands owned or managed by the Federal government and subject to the Washington State Implementation plan of the Clean Air Act. Burns by all other entities other than Federal are listed by the DNR region with permit and suppression jurisdiction NE=Northeast Region, NW=Northwest Region, OL=Olympic Region, PC=Pacific Cascade Region, and SP=South Puget Sound Region. No recordable activity occurred in the DNR Southeast Region, so it is absent.



When small burns are removed, and a frequency analysis is re-run on consumed tonnages, fifteen out of forty-four (34%) summer months have no large burning whatsoever, and July and August experience no large burns 59% of the time. It is important to reassert, that only large burns are subject to the restrictions on weekend burning during the summer months. Years in which burning did occur in those months shows a correlation to overall fire danger. For example in 2012, over 26,000 tons were burned in July and over 18,000 tons were burned in August. July and August of 2012 also had the lowest or second lowest aggregate fire danger of the last decade until the middle of August. Fire danger then quickly rose, and stayed high through the month of September, with burn activity inversely related to the fire danger.

In addition to an analysis of burn activity based on fire danger metrics, burning was also evaluated based on day of the week to determine the proportion of burning activity that occurs on weekends when no specific restriction is in place. During the months in which no weekend restriction on burning is in place, 9% of the total consumed tonnage between 2009 and 2019 was burned on a Saturday or Sunday, and Friday represents 15% of the burning totals by itself (Figure 8). When no weekend restrictions are in place, the proportion of burning on weekdays to weekends is approximately 2.38 to 1. The proportion can be carried into the summer months to help estimate the activity that may occur with the weekend restrictions lifted.

Figure 3. Aggregate fire danger frequency for Washington State 2009-2019. Column data labels are the percentage of days at a given level for the period. Until 2020, Very High and Extreme fire danger were lumped as a single fire danger level in DNR databases.

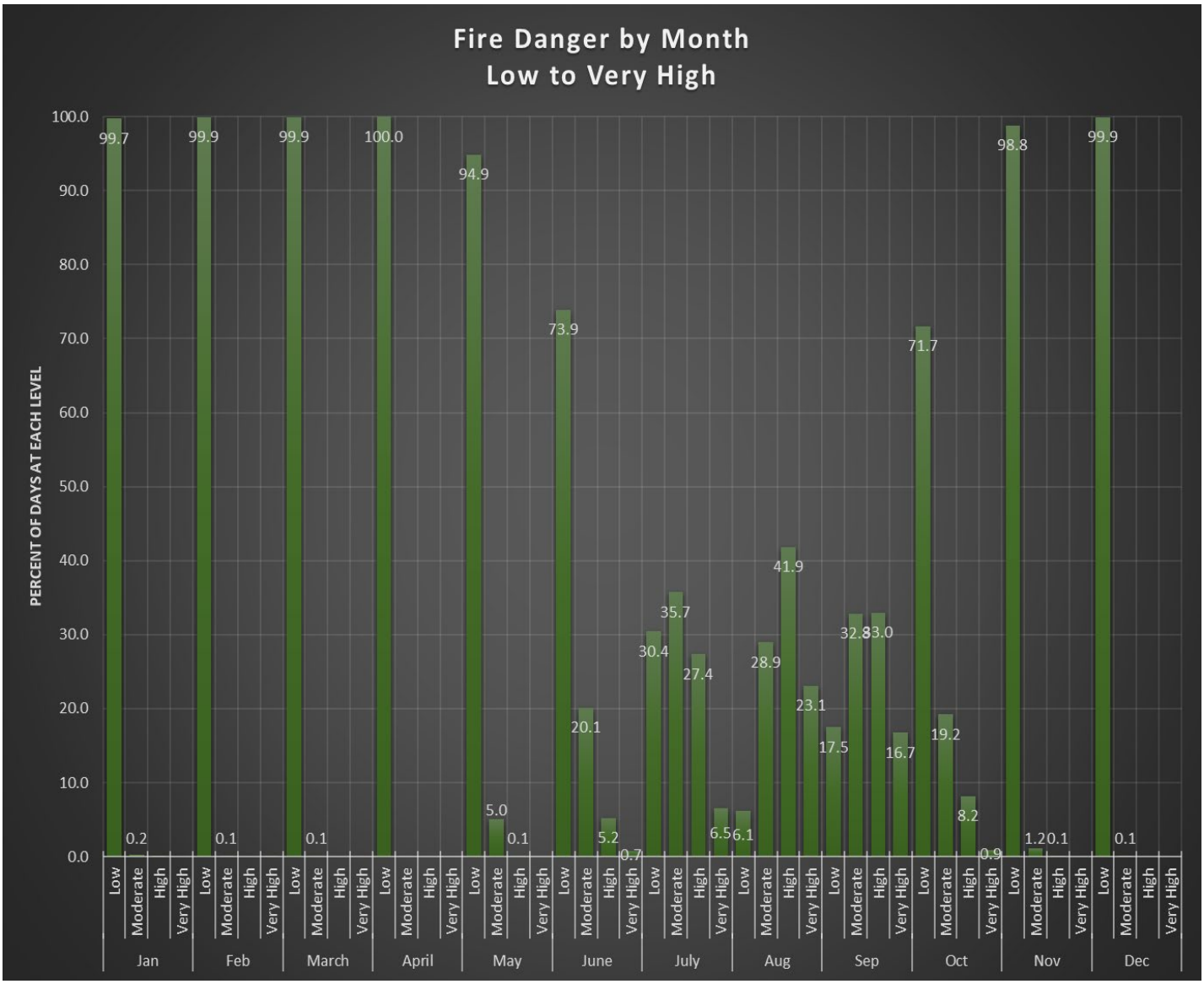
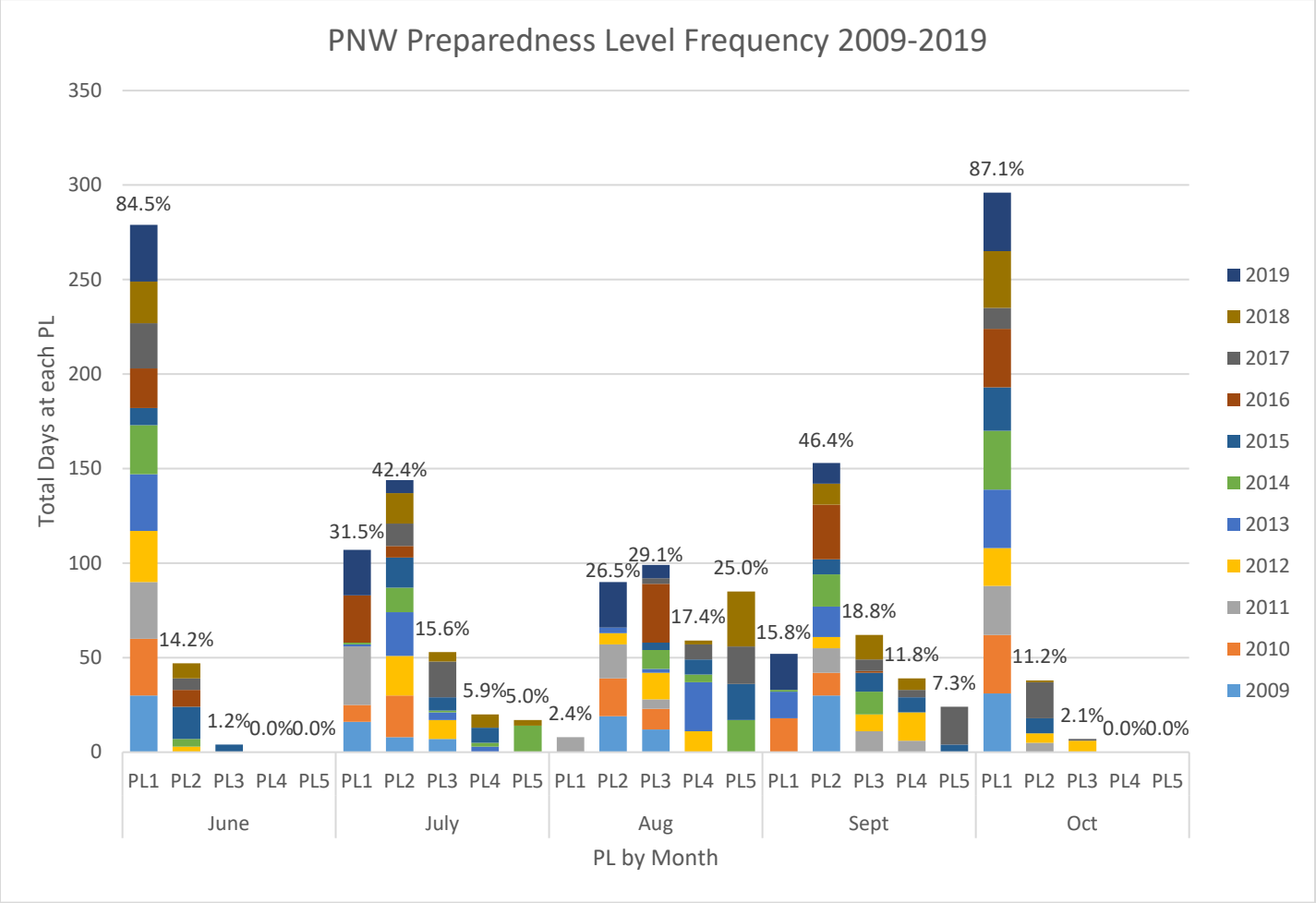


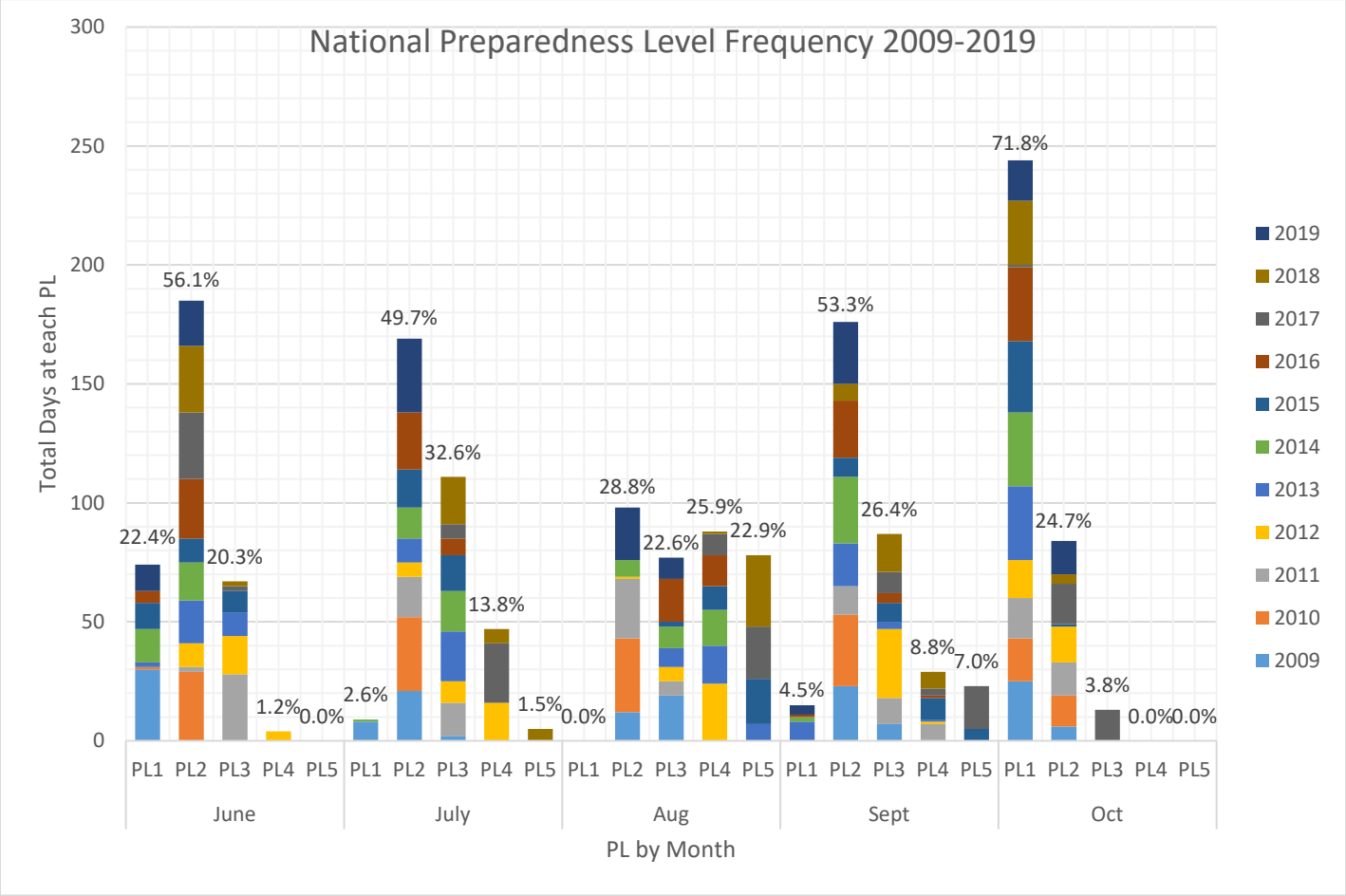
Figure 4. Stacked Preparedness levels for the Pacific Northwest Geographic Area provided by the Pacific Northwest Coordination Center. Column Data labels show the percent of each month spent at an individual PL.



Burning from year to year depends upon many variables however the trends in who is burning, where and when they burn, is assumed for the purposes of this evaluation to remain constant within a range. The lone exception is DNRs own prescribed fire program. As part of the Forest Health Plan, DNR is building a prescribed fire program (Forest Health Plan, 2018). This new burning has not been accounted for in the historical data, and prescribed fire treatment targets range between 7,000-12,000 acres per year (Unofficial Agency Planning Documents).

Several assumptions have to be made to account for this additional burning. Burning will incorporate thinned and piled materials that will be burned under Low fire danger conditions, and treatment goals may be met with naturally ignited wildfire, both reducing the acreage intentionally ignited during the summer months (Forest Health Assessment and Treatment Framework, 2020). It is also assumed, that burns requiring a summer prescription, will follow the same trends as burns with similar ecological objectives, mimicking the burning trends of Federal agencies as demonstrated in Figures 2 and 9. Given the highly variable nature of fuel loading and uncertainty in final treatment locations, fuel consumption is set at 19 tons per acre. This is based on the median tons per acre of forest health burns between 2014 and 2021 conducted by all agencies.

Figure 5. Stacked National Preparedness level data provided by the National Interagency Fire Center (NIFC). Column data labels show the percent of each month spent at each PL.



Final determination of the amount of new burning added to historic trends to create High, Middle, and Low estimates of burning activity during the summer takes the above assumptions along with the proportion of forest health burns (Appendix 9 SMP) that occur during the summer months as shown in Figure 9. Therefore, the proportion of the new burning conducted by DNR that may occur in the summer months is assumed to be 23% of the targeted acres per year. For the High estimate, assuming the full 12,000 acres is treated at 19 tons per acre; the result is 52,440 tons of material burned during the summer months per year. The Moderate estimate assumes 9,500 treatment acres, resulting in 41,515 tons of material burned during the summer, and the Low estimate assumes 7,000 treatment acres, results in 30,590 tons of additional material burned during the summer. Some of these burns will, in all likelihood, be small burns that would not be subject to the summer weekend restriction; however, it is assumed for the analysis that all burning activity will be greater than 100 tons per burn.

Figure 6. Plot of Regional preparedness levels from June 1 through October 31 for each year from 2009 through 2019 with an average level as a trend line.

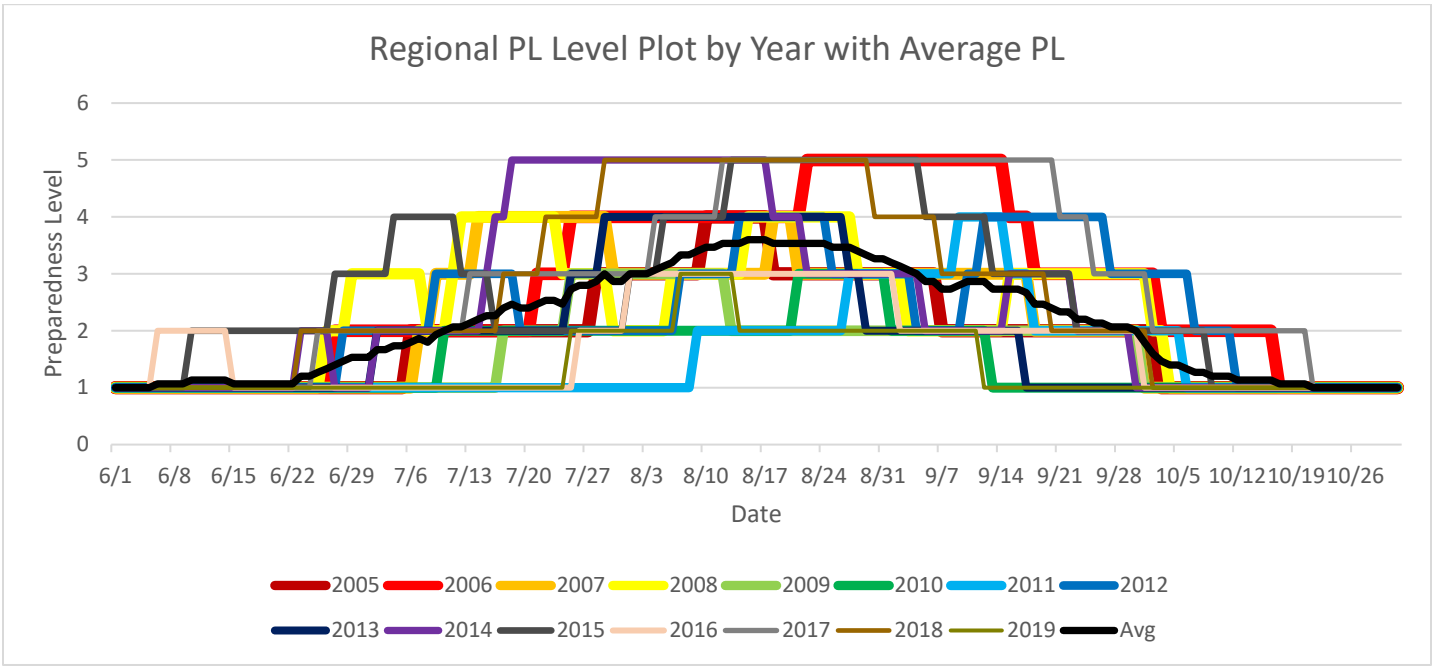


Figure 7. Day of year burning statistics for the summer months split by year. Note 2012 provides the majority of tonnages in July and August for the entire 11 year period.

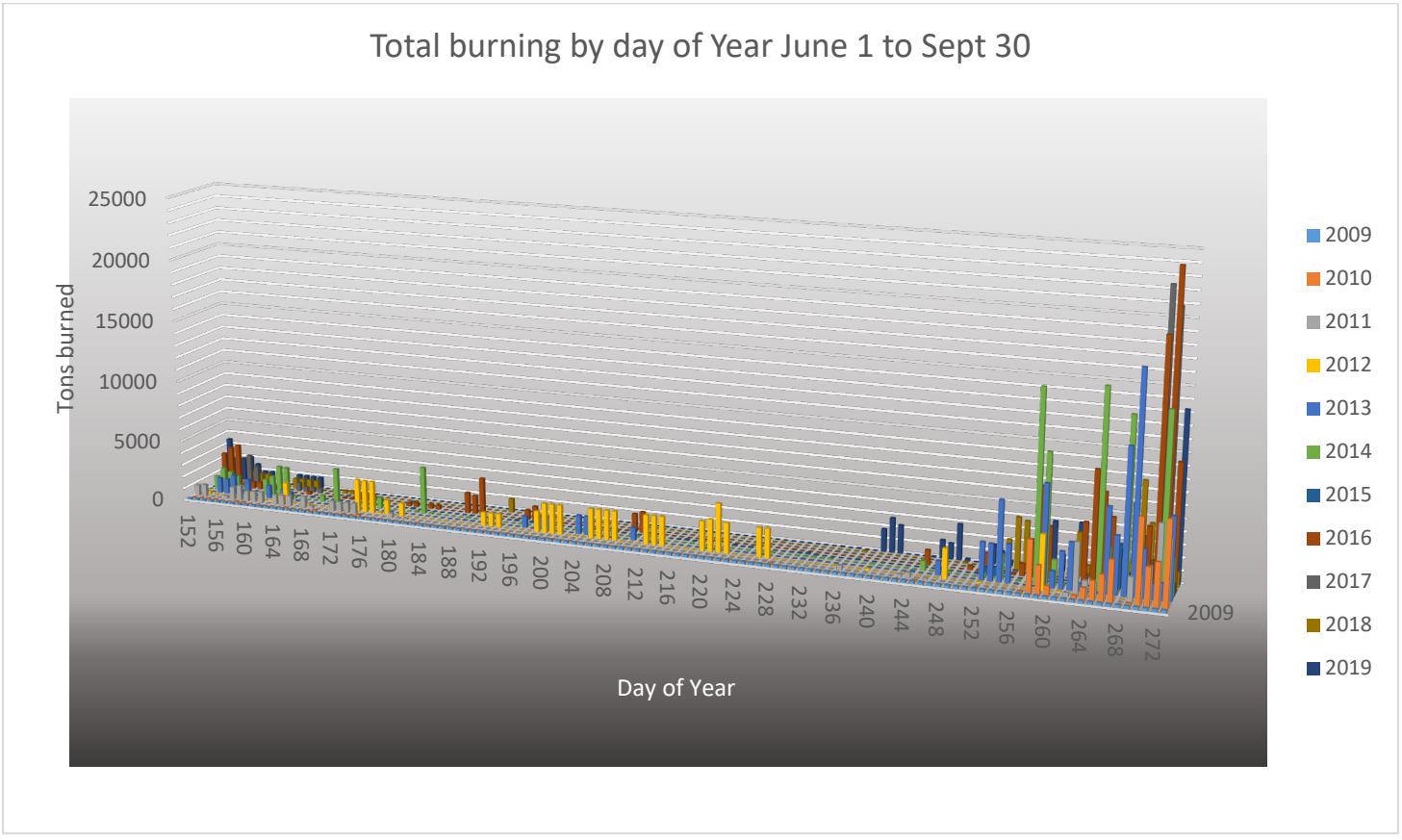
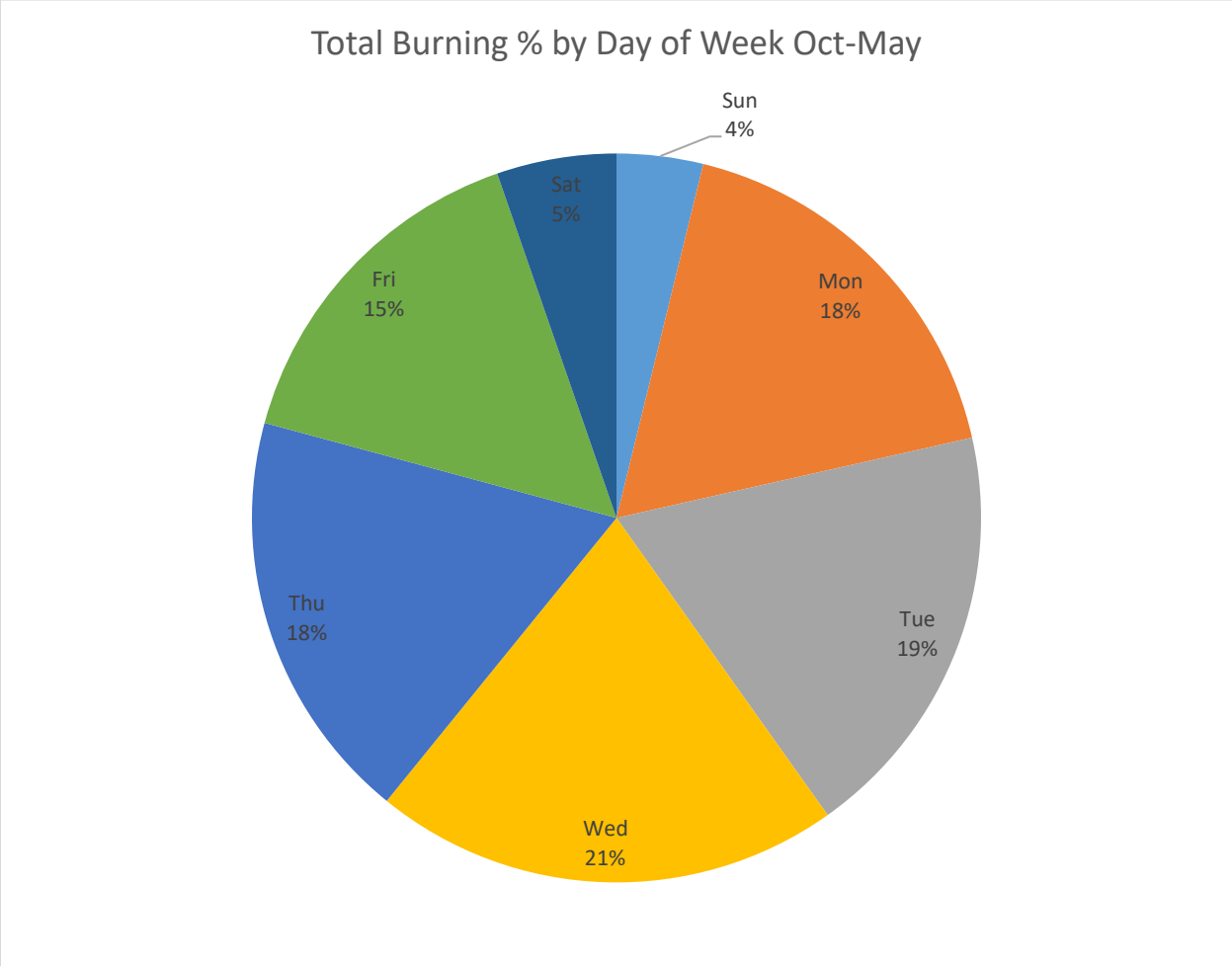


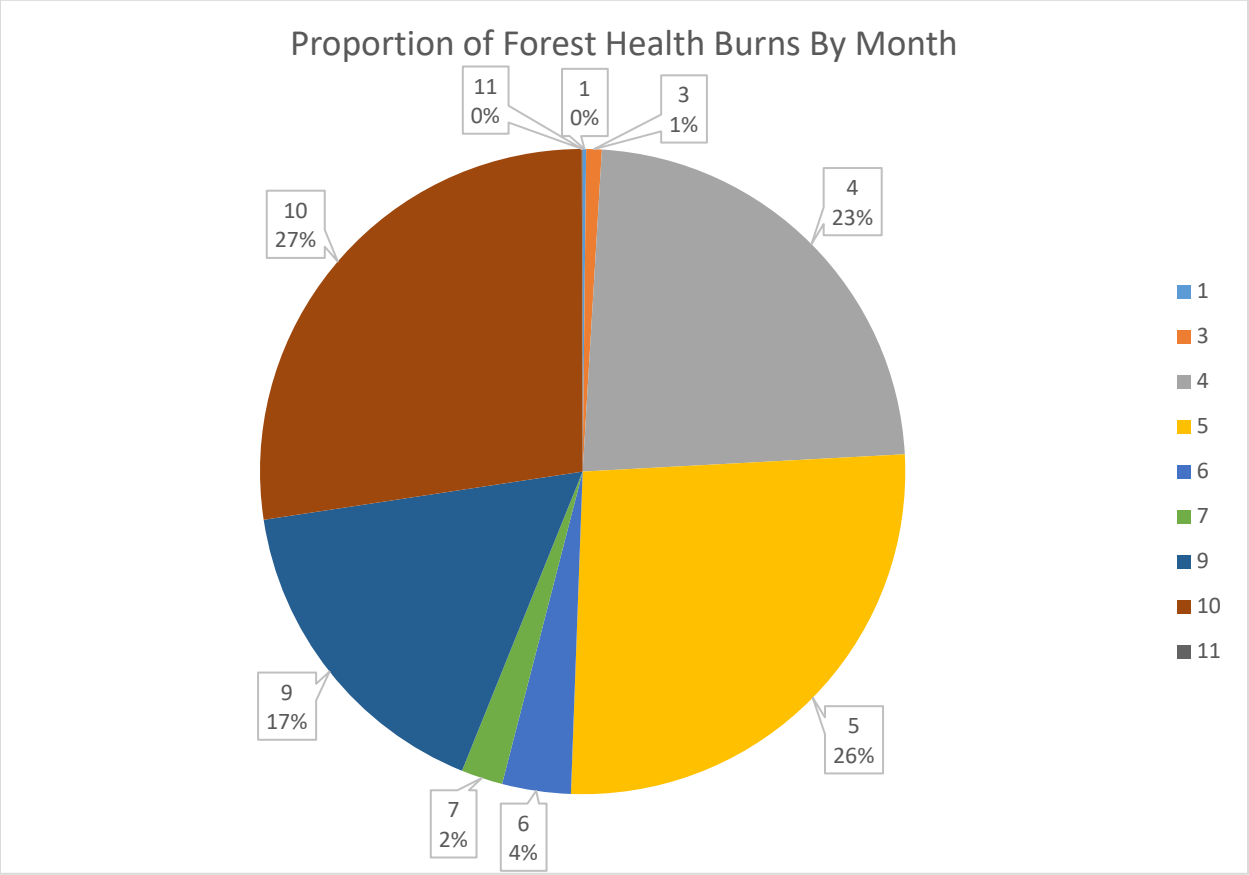
Figure 8. Proportion of burn consumption by day of the week when no weekend restrictions are in place.



When these results are split further by individual month, they show the additional tonnage burned in June may range between 5,320 and 9,120 tons. For July, the range is 2,660 to 4,560 tons of burned material. August has no additional tonnage since there are no records of large forest health burns occurring during August, and September ranges from 22,610 to 38,760 tons of additional material burned from adding DNR sources.

Determining potential additional quantities of burned material that the historic burners may add when additional days are exposed will rely on the frequency analysis of large burns by month (Figure 10). The results are applied to the Moderate and High scenarios below. Taking the assumption of 44 additional days available to burn each year, this can be split into the new days available for each month. In June, it is assumed that there will be six additional burn days each year, thirteen additional days each for July and August, and twelve for September. Tonnage frequencies (Figure 10.) provide an additional 1,230 tons of material per additional burn day in June, 479 tons of additional material per newly available burn day in July, 451 tons of material per additional day in August, and 2,424 tons per additional day in September.

Figure 9: The proportion of Forest Health burn request tonnages across all agencies. Percentages are rounded to the nearest whole number. November and January are each less than 0.5% to round down to zero. Months are identified by month number. February and August are omitted for having no recorded forest health burns.



Low Estimate of Burning: This scenario is based on the assumption that DNR will make the minimum contributions to additional burning based on the target goals of the Forest Health Plan. In other words, 7,000 acres per year will receive treatment at 19 tons per acre, with 4% of this burning occurring in June 2% in July, and 17% in September. It also assumes that no significant changes to burning activity are expected from the historical trends, therefore no additional burning is added from other sources. The range of possible burning is then expressed as:

$$Monthy\ Avg\ tons \pm Std\ Dev + DNR\ Low\ Estimate$$

Results are in Table 1 in the executive summary and reproduced below as well.

Moderate Estimate of Burning: This scenario is based on the assumption that DNR will burn 4% of targets in June, 2% in July, and 17% in September, just as in the low estimate, but with overall acreages of 9,500 at 19 tons per acre. In addition, 20 additional days of burning from traditional sources are expected. Based on fire danger and preparedness levels (Figure 3,4, and 5.), it is assumed that 6 additional days in June would be used, 9 days in July would be used, 1 additional day in August would be available, and 4 days in September. The calculation for the

range of consumption each month is below where Dx=days newly available to burn, Tm=daily tonnage multiplier determined from the frequency analysis, Tavg = the monthly average tonnage burned, TstdDev = the monthly standard Deviation, and DNRe = estimate of tons consumed by the DNR burn program for each respective month.

$$Tavg \ \pm TstdDev + (Dx * Tm) + DNRe$$

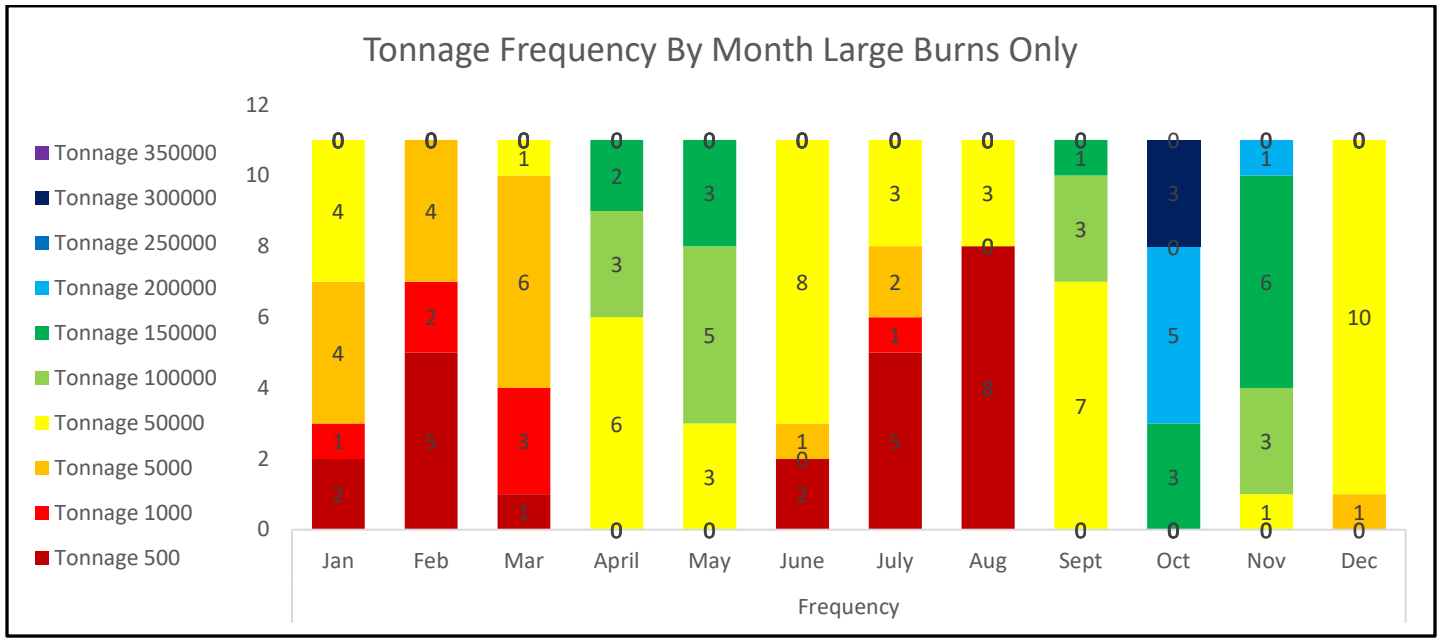
High Estimate of Burning: This scenario utilizes the same equation as the Moderate scenario. The differences are that the expected additions due to DNR agency burning are set to the maximum of 12,000 acres per year treated at 19 tons per acre, and that 35 weekend days are assumed utilized. 35 days were used instead of the maximum possible 44 days due to the historic trends. On average 9 d of the weekend days per summer are unavailable to burning due to a combination of fire danger and preparedness levels. Those are split into 6 additional days in June, 13 days in July, 6 days in August, and 10 days in September.

Discussion of Burning Impacts:

Air impacts in the Low estimate scenario are negligible as the estimated consumption with the addition of DNR burning lies within the historic range of variability. The addition of burns conducted by DNR is entirely absorbed by the ability to space out emissions over a greater number of available burn days. Further analysis of this Low estimate is not necessary.

The Moderate range falls into a mixed pattern with July, August and September within the historic range of variability, while June exceeds it at the upper end of the estimates by roughly 11,000 tons. This equates to a 59% increase in June when considering the maximum of the historic range against the maximum of the estimated range. Looking at overall burn numbers and the typical pattern of June burning, most of this additional tonnage is likely to be burned prior to June 15th when the summer prohibition takes effect. Even when assuming that all 11,000 tons of material is burned when the summer weekend prohibition is normally in effect, this amount of consumed material is largely inconsequential. Monitoring data from the IMPROVE network of Class 1 area monitors shows that air quality as measured by the presence of organic carbon has no significant change between the months of April, May, and June (Figure 11). April and May account for six and eight times more burned material respectively as the month of June, suggesting that an increase in emissions by the amount specified in this scenario would have an inconsequential impact on air quality.

Figure 10. Frequency chart and table of consumed tonnages by month for only burns that consumed greater than 100 tons per event, classified as large burns by DNR and subject to both smoke management approval processes, and the summer weekend prohibition on large burns 2009-2019.



Tonnage Frequency of Large Burn (>100 tons) Activity by Month													
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Tonnage	500	2	5	1	0	0	2	5	8	0	0	0	0
	1000	1	2	3	0	0	0	1	0	0	0	0	0
	5000	4	4	6	0	0	1	2	0	0	0	0	1
	50000	4	0	1	6	3	8	3	3	7	0	1	10
	100000	0	0	0	3	5	0	0	0	3	0	3	0
	150000	0	0	0	2	3	0	0	0	1	3	6	0
	200000	0	0	0	0	0	0	0	0	0	5	1	0
	250000	0	0	0	0	0	0	0	0	0	0	0	0
	300000	0	0	0	0	0	0	0	0	0	3	0	0
	350000	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. Estimated burning under each emissions scenario for the summer months compared to the historic average. Median values for each estimate are determined from the predicted range shown in Table 3.

		Low Estimate		Moderate Estimate		High Estimate	
Month	Historic Average	Median	% Increase	Median	% Increase	Median	% Increase
June	9564	14885	56%	24165	153%	26065	173%
July	4611	8849	92%	14110	206%	16976	268%
August	4270	6004	41%	6455	51%	8710	104%
September	53203	75813	42%	93584	76%	116203	118%

Table 3. Estimates of the range of burning expected after the removal of the weekend summer prohibition. All results are in Tons.

Month	Historic Range	Average	Std Dev	Low Range		Moderate Range		High Range	
June	0-19317	9564	6561	8323	21446	17603	30726	19503	32626
July	0-26433	4611	7766	2660	15037	7921	20298	10787	23164
August	0-21850	4270	7738	0	12008	451	12459	2706	14714
September	6679-137610	53203	38938	36875	114751	54646	132522	77265	155141

The High emissions scenario increases the amount of emissions in June to 32,626 tons of material burned, a total of 13,309 tons, or a 68%, increase over the historic maximum. This is similarly inconsequential to air quality for June. A 68% increase in biomass burned appears to be significant, but as in the Moderate scenario, April and May still account for several times the amount of material burned, with statistically insignificant changes in the organic carbon levels. Therefore, the same conclusion can be drawn that this level of increased burning is well within the ability of the air quality and the smoke management program to absorb. Similarly, to the moderate scenario, July and August are again within the historic range of variability and thus not expected to have an appreciable impact to air quality any greater than in the past. September does however show the potential to creep above the historic maximum just as in June. In this example, the estimated burning of 155,141 tons of material is 17,531 tons or 13% greater than the historic maximum. Average burning in September increases throughout the month, staying greater than 1,000 tons per day and peaking at over 7,000 tons per day towards the end of the month (Figure 12). At the same time, Organic carbon trends lower throughout the month. This too suggests that prescribed fires overall, are not the primary driver of atmospheric organic carbon, and that this increase will not negatively impact air quality.

Figure 11. Organic Carbon Concentrations at all of the Washington IMPROVE monitors with the exception of the Makah and Puget Sound monitors in µg/m^3. Data is from 1988-Jan 31, 2020. (Federal Land Manager Database)

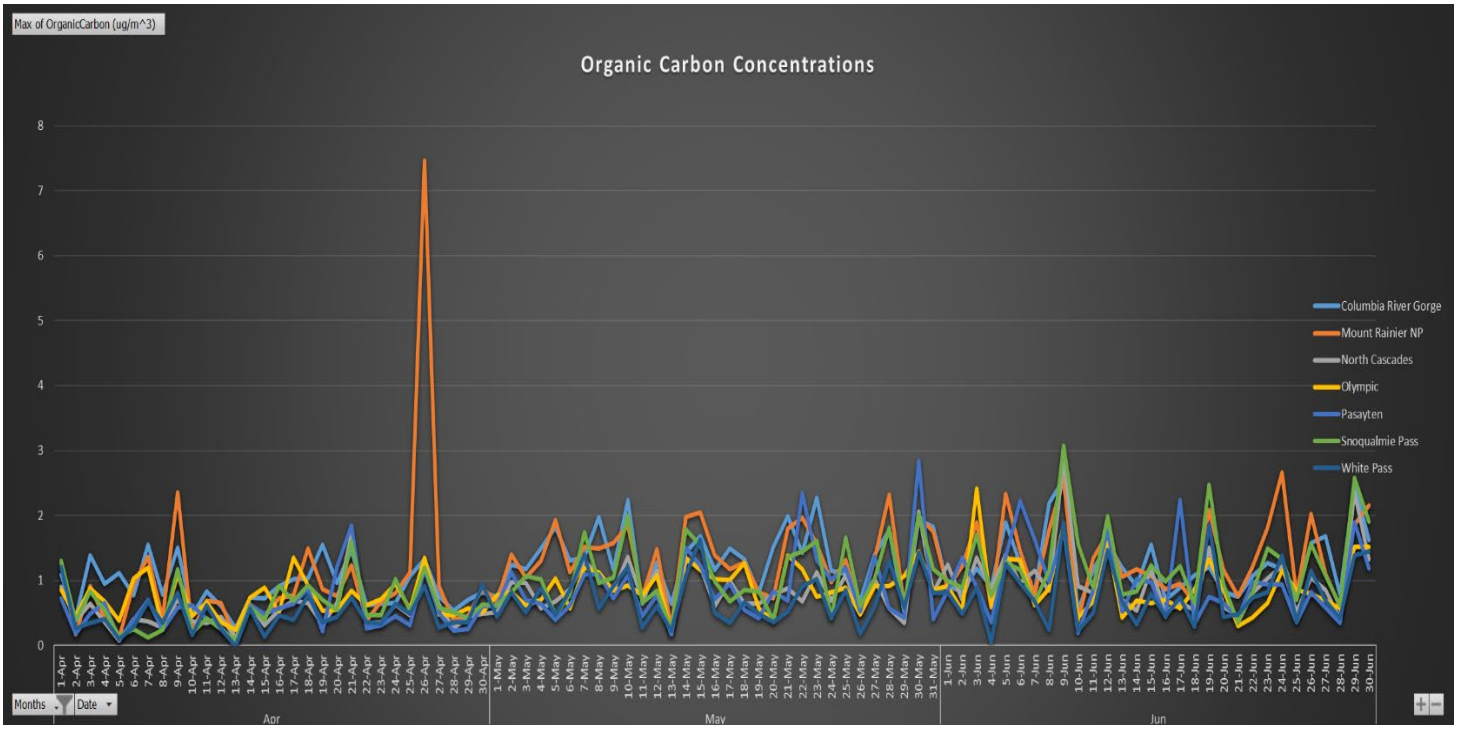
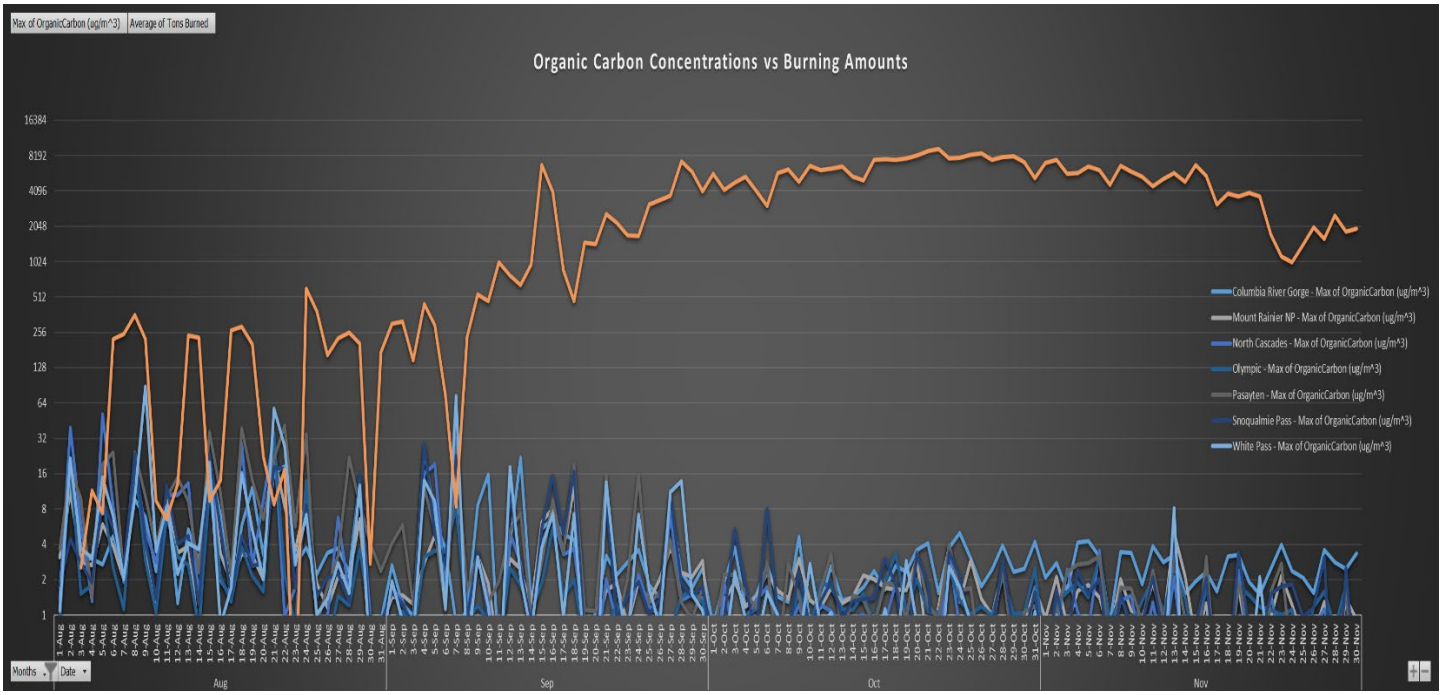


Figure 12. Organic Carbon (µg/m^3) data vs average tons burned on a logarithmic scale. The Y axis represents both µg/m^3 and tons of biomass consumed. Biomass is represented by the orange line.



Conclusion:

Due to many varied reasons, prescribed burning during the summer months makes up only a small fraction of the total biomass burned with silvilcultural burn permits in the state of Washington. Restrictions due to fire danger placed on permits issued to the public, as well as the practice of piling slash fuels, leads to the vast majority of burning occurring during the early spring and fall seasons. The primary source of summer ignitions is from prescribed burning with the intent of improving landscape conditions for fire resistance and resilience, pathogen mitigation, habitat improvement etc. These burns are undertaken during the summer months, only due to necessity for reaching their ecological objectives, and almost exclusively by highly trained Federal, State, and Non-profit organizations with rigorous fire training and expertise in order to obtain permissions to burn under fire danger conditions any greater than “Low”. The prevalence of pile burning provides private landowners a means of disposing of their forest debris during the lower fire danger months of the late fall through early spring, where the risk of damage due to a fire escape and the costs associated with obtaining adequate equipment to safely burn in the summer, are minimized. Of the burns that must be ignited in the summer, there are additional self-restrictions placed by policy such as requiring approval from the highest levels of management to ignite a prescribed fire when fire activity and resource draw down would not allow adequate resources to maintain control of a fire. These conditions lead to a relatively few burns conducted during the summer.

The argument can be made that the weekend summer restriction is responsible for the relatively small amounts of summer burning, however when compared to the rest of the year, it is apparent that burning on the weekends is not common regardless of the season. Multiple scenarios of estimated emissions were created to account for this variability and to account for the future increase in burning as the DNR itself engages in prescribed fire. Of the three scenarios, increases in burning due to the addition of DNR burns and to units taking advantage of more days available to burn present no significant impacts to air quality.

Based on empirical observations, conversations with burning practitioners and knowledge of the workings of burn programs, the most realistic scenario seems to lie somewhere between the low and moderate estimate of burning. Supporting this assertion is the fact that DNR only has records of seven exception requests to burn during the summer weekend prohibition going back to 2017. In these scenarios, the estimates land within the historic range of variability for each of the summer months and therefore no significant impacts are expected. In the event that the high estimate of emissions is the case minor impacts could be encountered in June or September, however air quality monitors indicate that the additional emissions would be largely inconsequential. Due to the DNR large burn approval process, the program has been able to burn upwards of 280,000 tons of material in large burns during the month of October without causing negative impacts to air quality. This is more than double the amount burned in the most active September in the study period and nearly fifteen times amount burned in the most active June. It should be noted that climate change is beyond the scope of this analysis and could dramatically affect prescribed application in timing, scope and location.

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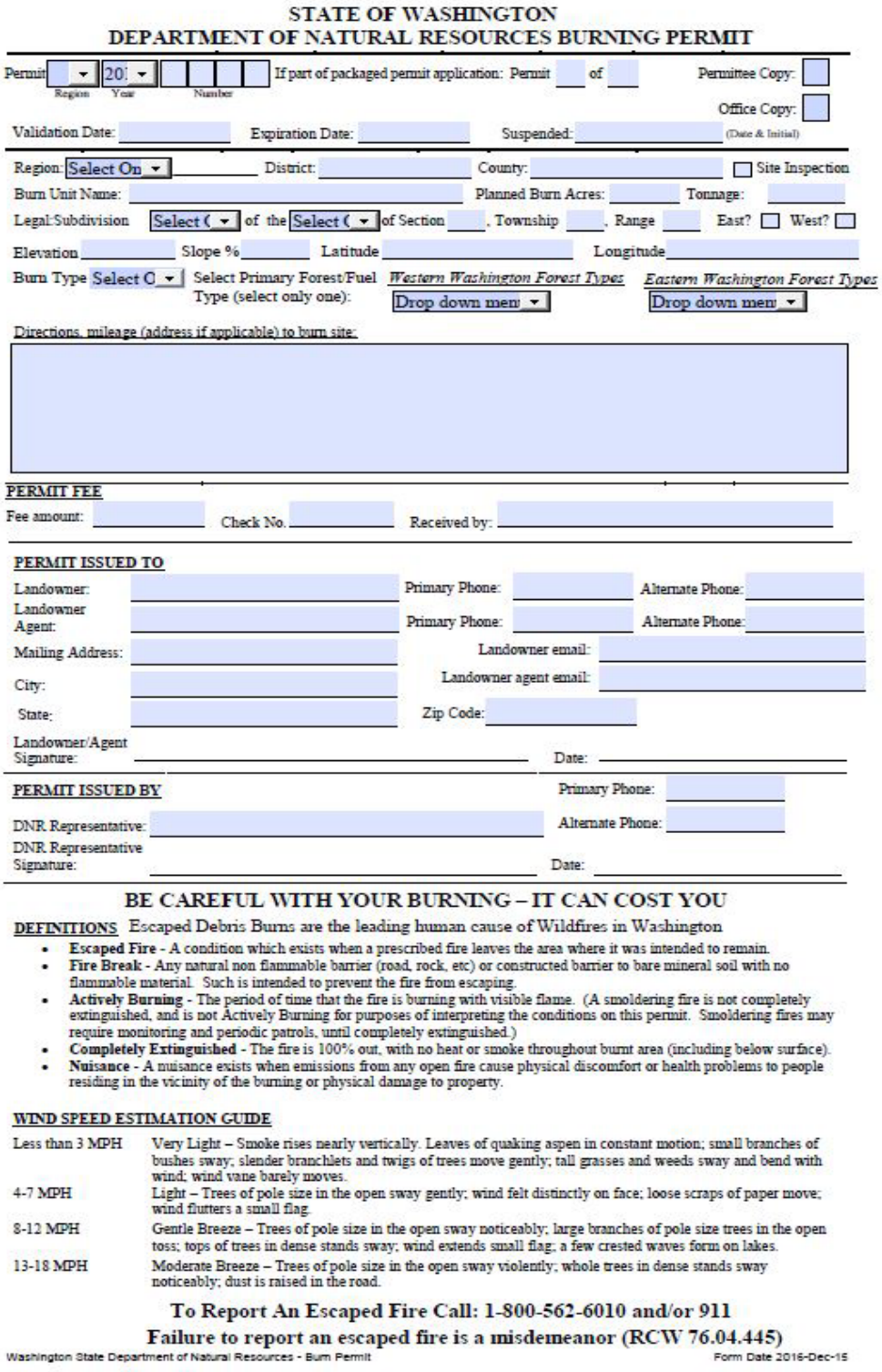
Washington Department of Natural Resources. (2020). Forest Health Assessment and Treatment Framework 2020. RCW 76.06,200, State of Washington, Department of Natural Resources, Olympia.

Appendices:

Appendix A: Blank copy of DNR burn permit with permit conditions



STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES BURNING PERMIT

Permit [ ] [20] [ ][ ][ ][ ] If part of packaged permit application: Permit ___ of ___ Permittee Copy: [ ]
Region Year Number
Office Copy: [ ]

Validation Date: _____ Expiration Date: _____ Suspended: _____ (Date & Initial)

Region: Select On _____ District: _____ County: _____ ☐ Site Inspection

Burn Unit Name: _____ Planned Burn Acres: _____ Tonnage: _____

Legal: Subdivision Select (of the Select (of Section ____, Township ____, Range ____ East? ☐ West? ☐

Elevation _____ Slope % _____ Latitude _____ Longitude _____

Burn Type Select O Select Primary Forest/Fuel Type (select only one): *Western Washington Forest Types* Drop down menu *Eastern Washington Forest Types* Drop down menu

Directions, mileage (address if applicable) to burn site:

PERMIT FEE

Fee amount: _____ Check No. _____ Received by: _____

PERMIT ISSUED TO

Landowner: _____ Primary Phone: _____ Alternate Phone: _____
Landowner Agent: _____ Primary Phone: _____ Alternate Phone: _____
Mailing Address: _____ Landowner email: _____
City: _____ Landowner agent email: _____
State: _____ Zip Code: _____
Landowner/Agent Signature: _____ Date: _____

PERMIT ISSUED BY

Primary Phone: _____
DNR Representative: _____ Alternate Phone: _____
DNR Representative Signature: _____ Date: _____

BE CAREFUL WITH YOUR BURNING – IT CAN COST YOU

DEFINITIONS Escaped Debris Burns are the leading human cause of Wildfires in Washington

- **Escaped Fire** - A condition which exists when a prescribed fire leaves the area where it was intended to remain.
- **Fire Break** - Any natural non flammable barrier (road, rock, etc) or constructed barrier to bare mineral soil with no flammable material. Such is intended to prevent the fire from escaping.
- **Actively Burning** - The period of time that the fire is burning with visible flame. (A smoldering fire is not completely extinguished, and is not Actively Burning for purposes of interpreting the conditions on this permit. Smoldering fires may require monitoring and periodic patrols, until completely extinguished.)
- **Completely Extinguished** - The fire is 100% out, with no heat or smoke throughout burnt area (including below surface).
- **Nuisance** - A nuisance exists when emissions from any open fire cause physical discomfort or health problems to people residing in the vicinity of the burning or physical damage to property.

WIND SPEED ESTIMATION GUIDE

Less than 3 MPH	Very Light – Smoke rises nearly vertically. Leaves of quaking aspen in constant motion; small branches of bushes sway; slender branchlets and twigs of trees move gently; tall grasses and weeds sway and bend with wind; wind vane barely moves.
4-7 MPH	Light – Trees of pole size in the open sway gently; wind felt distinctly on face; loose scraps of paper move; wind flutters a small flag.
8-12 MPH	Gentle Breeze – Trees of pole size in the open sway noticeably; large branches of pole size trees in the open toss; tops of trees in dense stands sway; wind extends small flag; a few crested waves form on lakes.
13-18 MPH	Moderate Breeze – Trees of pole size in the open sway violently; whole trees in dense stands sway noticeably; dust is raised in the road.

To Report An Escaped Fire Call: 1-800-562-6010 and/or 911
Failure to report an escaped fire is a misdemeanor (RCW 76.04.445)

Washington State Department of Natural Resources - Burn Permit Form Date 2016-Dec-15

BURNING IS AUTHORIZED SUBJECT TO THE FOLLOWING CONDITIONS

Failure to follow any of the conditions of this permit is a violation of this permit

☐ To Notify Before Ignition: _____ Phone: _____

☐ To Notify Before Ignition: _____ Phone: _____

☐ To Notify Before Ignition: _____ Phone: _____

1. This permit is not valid until fees are paid and permittee receives their validated permit. Permit may be suspended or modified any time when deemed necessary for the protection of life, property, air quality, or violation of permit conditions.
2. Validated permit and any addendums/attachments must be on site while burning.
3. Permittee shall comply with all requirements of Chapter 332-24 WAC, the Smoke Management Plan in effect at the time of burning, and any additional terms and conditions specified in writing by the Department.
4. Permittee, by igniting a fire pursuant to this permit, accepts all responsibility for fire suppression costs that result from a violation of any of the conditions of this permit. If the fire escapes, regardless of cause, the permittee shall be responsible for paying for people and equipment for fire suppression as required by Chapter 76.04 RCW.
5. Permittee shall call **1-800-323-BURN (2876)** or visit **https://fortress.wa.gov/dnr/protection/firedanger/** each day of ignition prior to lighting any fire. The instructions provided for the county you are burning in, including fire danger and air quality burn bans, become a condition to this permit.
6. No prohibited material shall be burned. Prohibited materials include: Garbage, dead animals, asphalt, petroleum products, paints, rubber products, plastics, treated wood, metal or any substance other than natural vegetation, which when burned releases toxic emissions, dense smoke, or odors.
7. Fire ignited pursuant to this permit shall not create a nuisance from smoke, obscure visibility on public roads and highways, or endanger life and property through negligent spread of fire or pollutants.
8. Permittee shall comply with the following checked conditions:

☐ a. Burning prohibited from _____ through _____

☐ b. Burning prohibited unless daily Fire Danger rating is "Low" (See number 5 above to check daily Fire Danger rating)

☐ c. Burning prohibited within 50 feet of any structure

☐ d. Burning prohibited if wind is blowing from the: ☐N ☐NE ☐E ☐SE ☐S ☐SW ☐W ☐NW

☐ e. Burning prohibited if wind exceeds _____MPH (see reverse side of permit for wind speed estimation guide)

☐ f. Burning prohibited if relative humidity (RH) is below _____ percent

☐ g. Burning prohibited on ☐ Sun ☐ Mon ☐ Tue ☐ Wed ☐ Thu ☐ Fri ☐ Sat

☐ h. No ignition or adding fuel to burning piles before _____ a.m. or after _____ p.m.

☐ i. Fire must be completely extinguished within _____ days of ignition

☐ j. Maximum number of piles allowed to be actively burning at one time _____

☐ k. Piles contain no dirt, stumps, green slash, yard/garden debris; or slash greater than _____ inches in diameter

☐ l. Construct a _____ foot minimum width fire break around each pile

☐ m. Number of people required to be in attendance at fire while actively burning is _____

☐ n. Water requirements (shall be on site during burning with an operator capable of operating the equipment):

☐ Charged hose line of sufficient length to reach all piles **or** ☐ _____ pump cans on site

☐ Pump truck/trailer with a _____ gallon capacity and filled to capacity with water (see Appendix A for recommended)

☐ o. Equipment Requirements (shall be at the burn site during burning with an operator capable of operating the equipment):

☐ Shovel & rake ☐ Excavator/Grapple ☐ Dozer ☐ Tractor/Backhoe ☐ Skidder ☐ Fans

☐ p. Smoke management approval is required if ignition on any single day will equal or ☐ exceed 100 tons ☐ exceed 300 tons

☐ q. Permittee has been issued multiple permits. No more than _____ permit(s) shall be burned at one time.

Other special conditions or requirements (1000 characters)

Washington State Department of Natural Resources - Burn Permit Form Date 2016-Dec-15

Appendix B: Additional Charts and Figures

The figures listed below were used in the analysis and help to provide context to the assumptions made and the conclusions that were drawn. They were removed from the main body, as there is no direct reference in the text, but are included here for additional reference.

Figure 13. Climate anomalies for precipitation in 2012 for the months of June, July, August, and September. (NACSE, 2021)

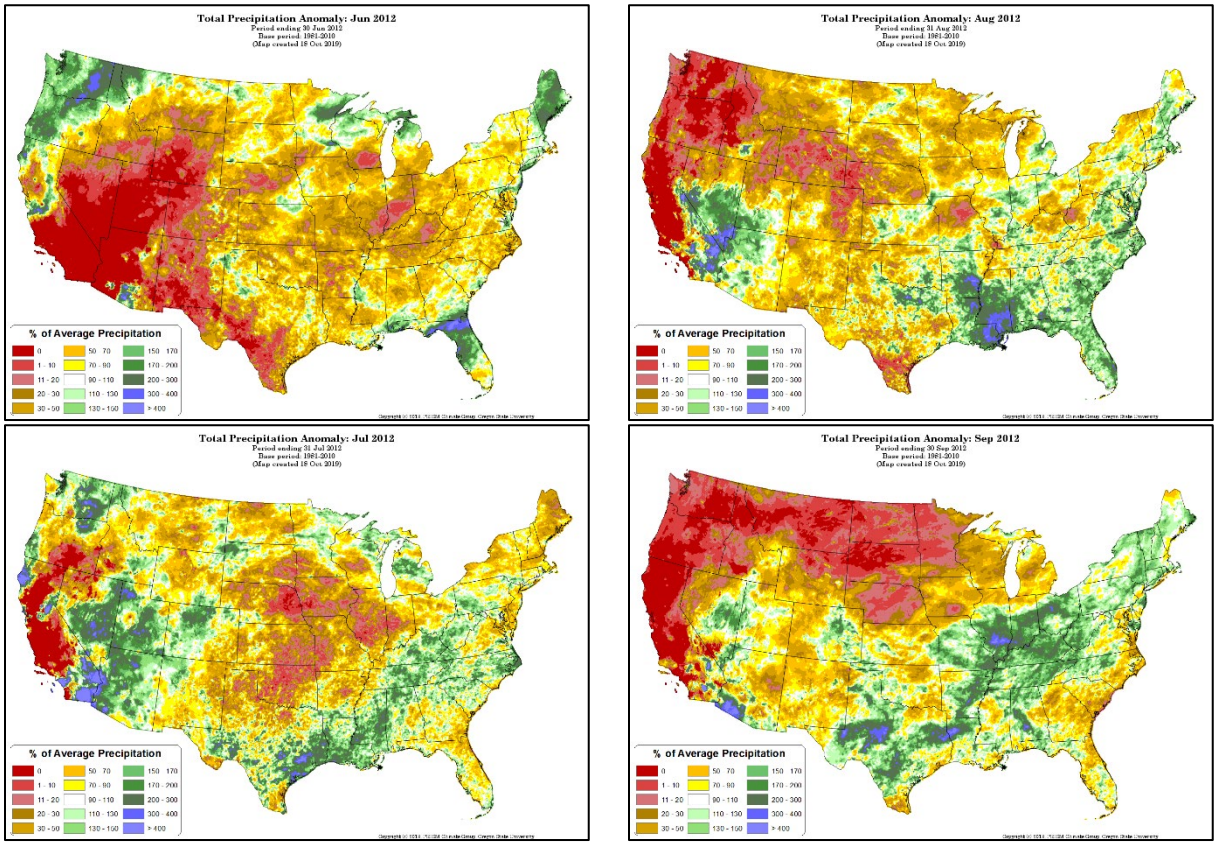


Figure 14. Chart of monthly large burn consumption, defined as greater than 100 tons of consumed material per event. (DNR post burn reports)

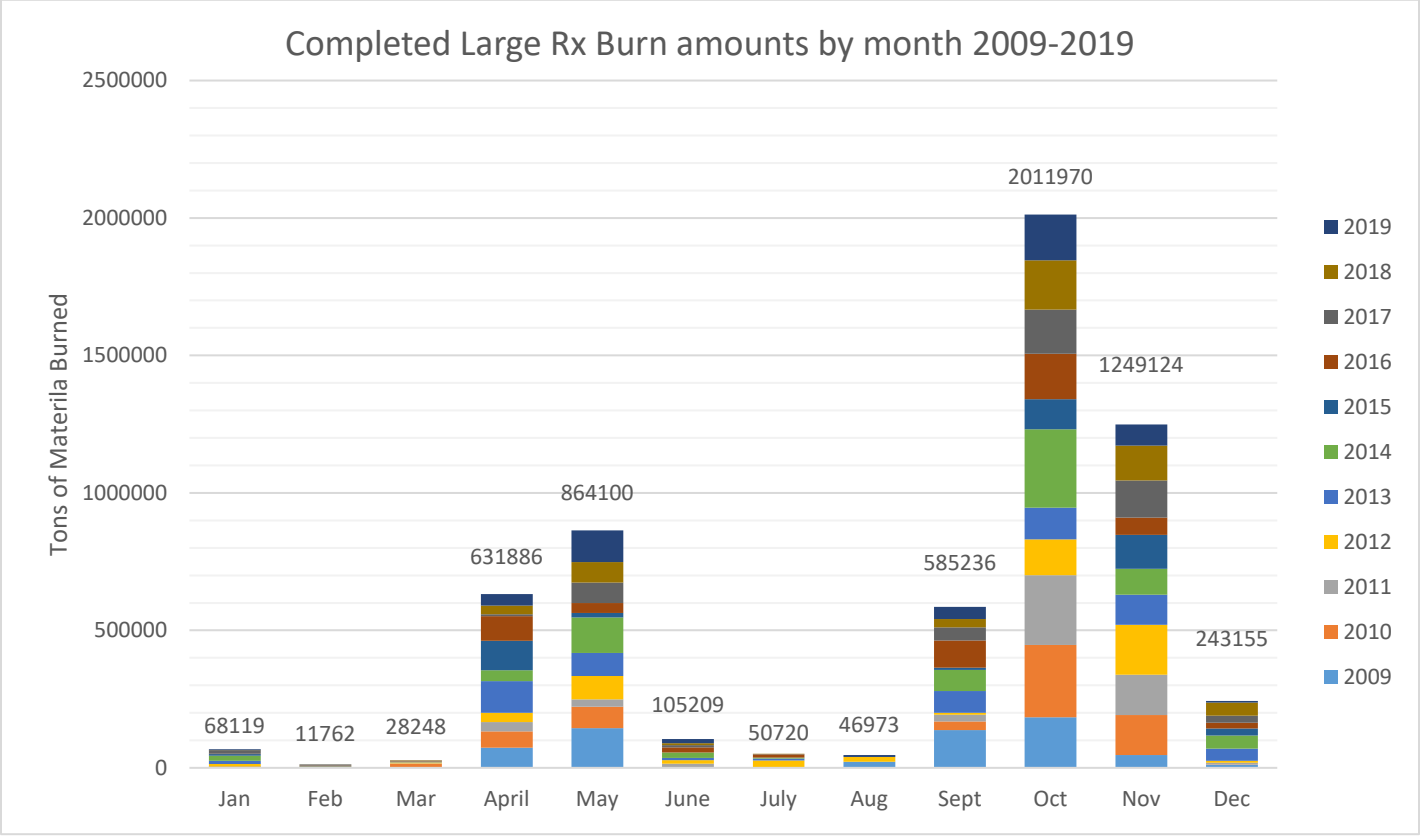


Figure 15. Stacked chart of all burning types and sizes of burns from 2009 through 2019.

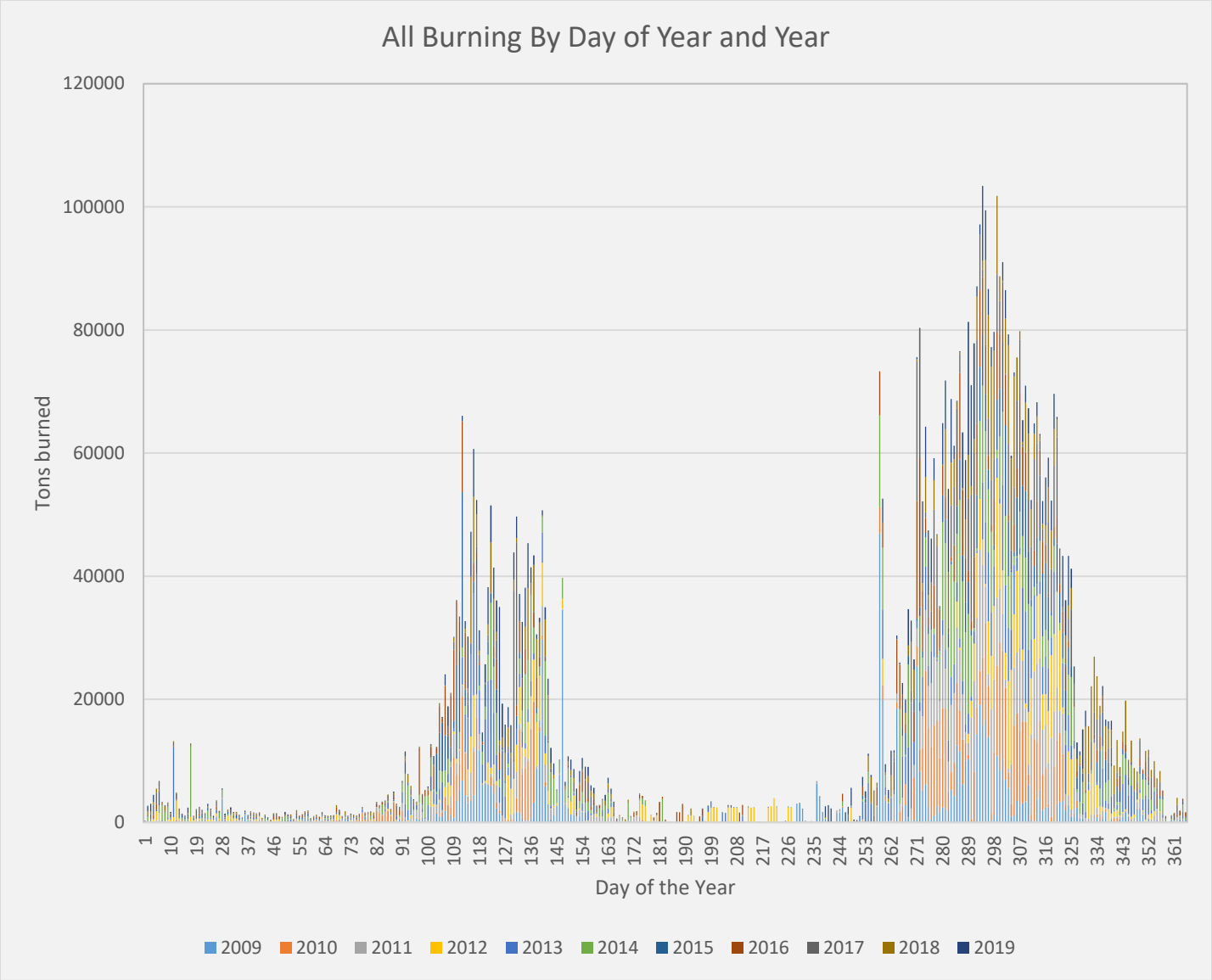


Figure 16. Frequency chart of tonnages consumed by month for all burns of any size.

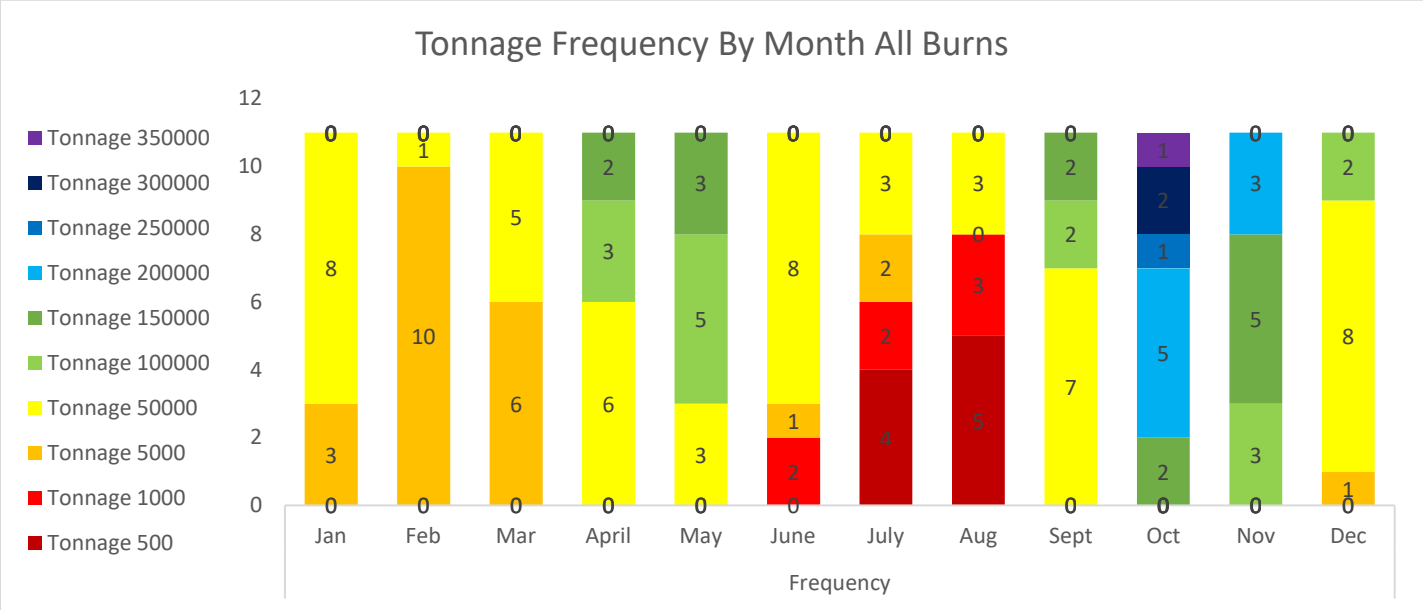


Figure 17. Percentage of burn summer burn requests by month for all burn sizes and types.

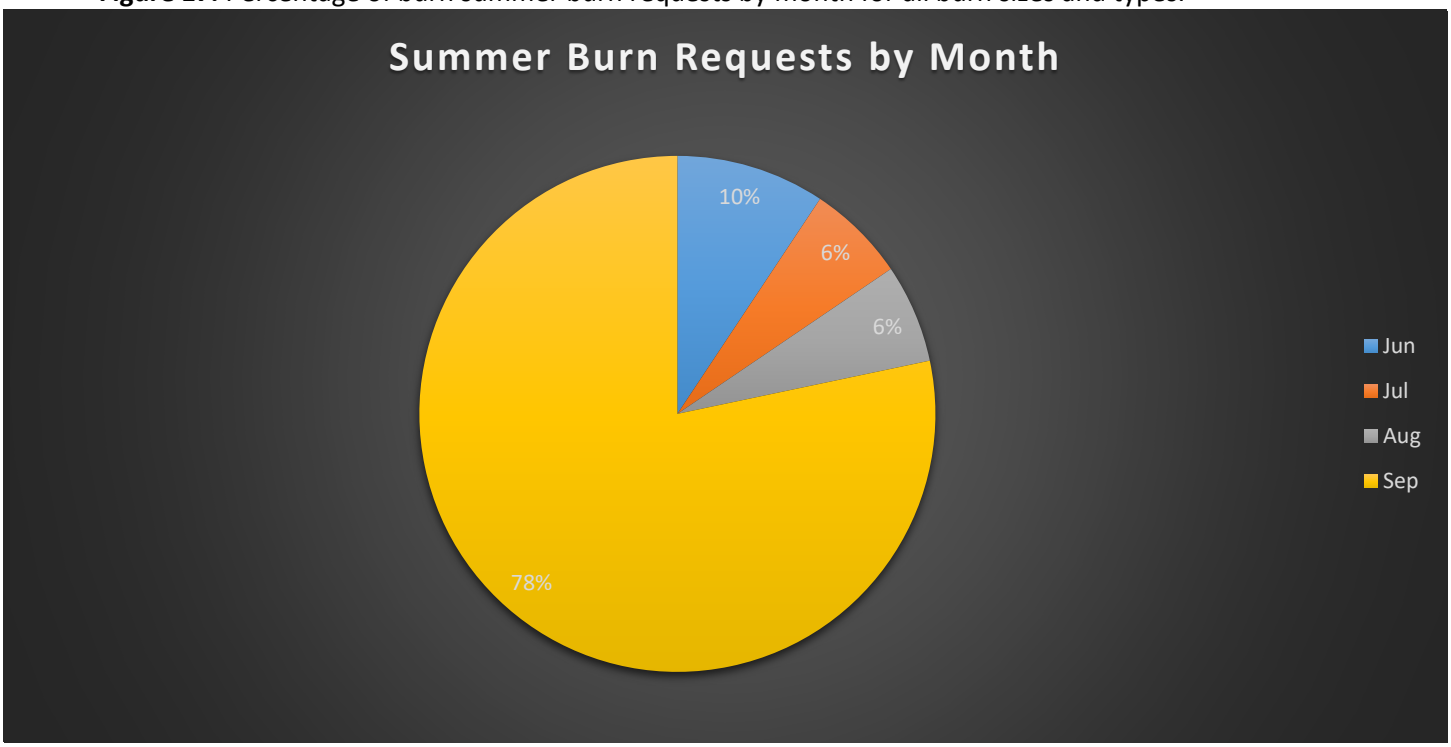
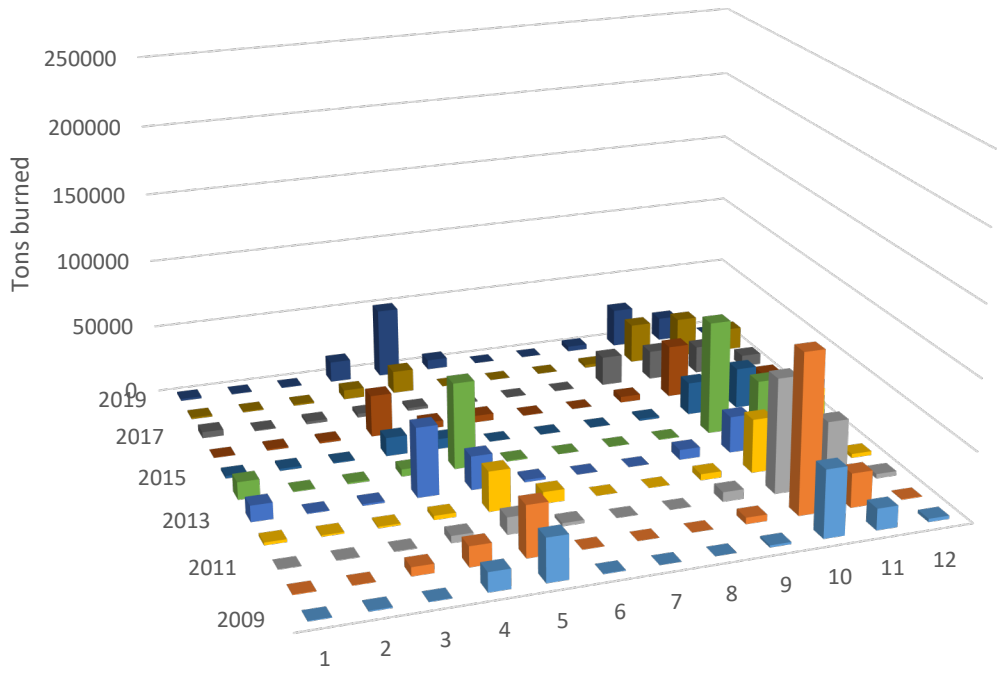
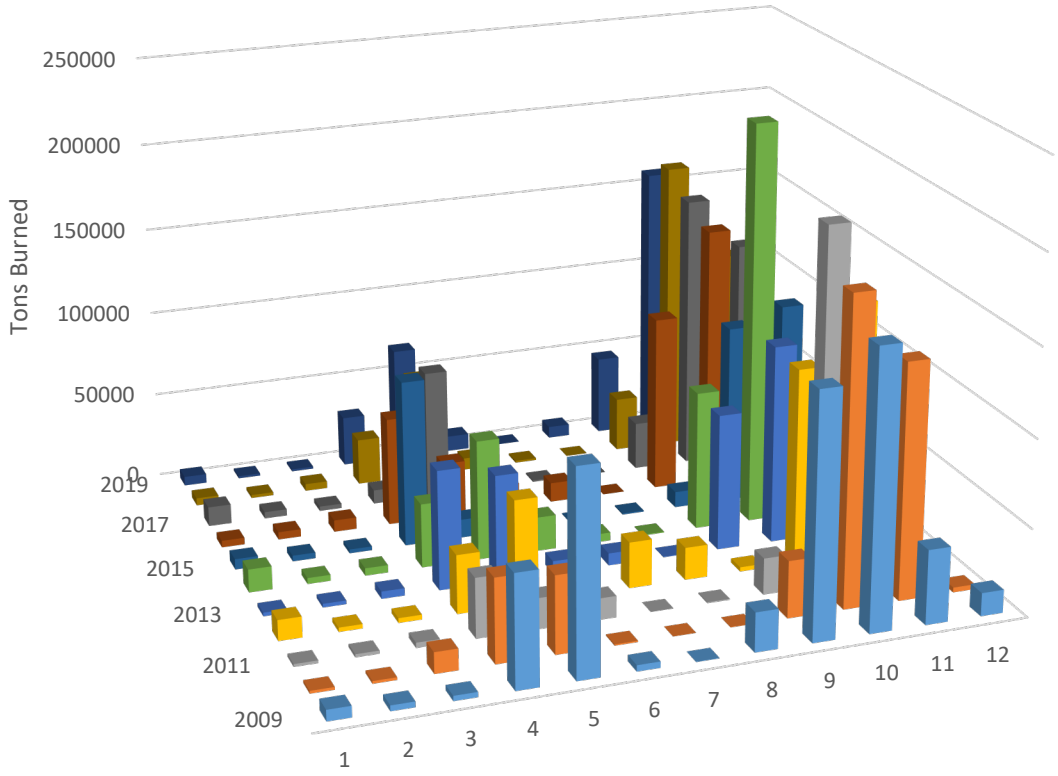


Figure 18. Distribution of weekend (Friday-Sunday) burning by month and year in tons consumed



	1	2	3	4	5	6	7	8	9	10	11	12
2009	493	720	376	13723	30676	369	11	3	1518	47946	15220	2346
2010	438	283	6293	14410	36461	198	38	0	4597	113543	24333	512
2011	291	385	461	5086	12102	2193	47	3	6847	81780	46026	3161
2012	2041	1106	1230	3001	28535	8367	60	148	4445	38552	54291	2862
2013	11640	556	1221	49875	24116	1691	30	0	7191	26112	34982	8700
2014	12620	527	1029	5172	62086	716	60	191	470	81655	33439	11383
2015	1846	1578	778	13356	7254	150	97	92	1476	23509	29371	5060
2016	396	1073	1299	30217	4783	4901	384	0	4266	37869	15302	7478
2017	4471	685	1977	2793	2009	955	30	30	21275	21135	19784	8306
2018	1191	759	1056	6831	16255	390	0	140	2218	28924	28859	16119
2019	1512	367	501	15110	50506	7092	0	43	3669	28172	17163	0

Figure 19. Distribution of weekday (Monday-Thursday) burning by month and year.



	1	2	3	4	5	6	7	8	9	10	11	12
2009	6317	3175	2904	63715	115241	3548	189	22412	138709	157670	42391	13206
2010	1548	1503	12046	47776	44166	748	68	230	32609	175301	134429	2787
2011	1538	1764	2992	34170	17617	12192	46	550	20832	201918	124073	11613
2012	11838	2484	2742	33583	59836	5591	26486	18637	2470	112127	145598	8719
2013	2102	2130	4239	68550	61272	7246	7035	348	78603	114167	89076	40234
2014	13278	3477	4298	36975	69063	19773	4683	474	80190	231000	70404	41983
2015	6040	3350	2250	95773	10677	412	458	691	9235	103557	112990	27218
2016	3878	4342	6800	62693	32013	14129	11343	36	102273	151166	57390	18456
2017	11260	3763	2617	8055	74918	7963	867	66	27695	159886	129650	21374
2018	4310	1808	4089	26977	60146	7001	1143	43	31635	170952	113716	37091
2019	5316	1353	1262	29244	66814	9124	90	6840	46330	158568	67330	5324

Figure 20. Fire Danger trends aggregated by the entire state of Washington. Note that western Washington is typically at lower fire danger ratings through the summer months skewing the statewide average lower than where the majority of summer burns occur.

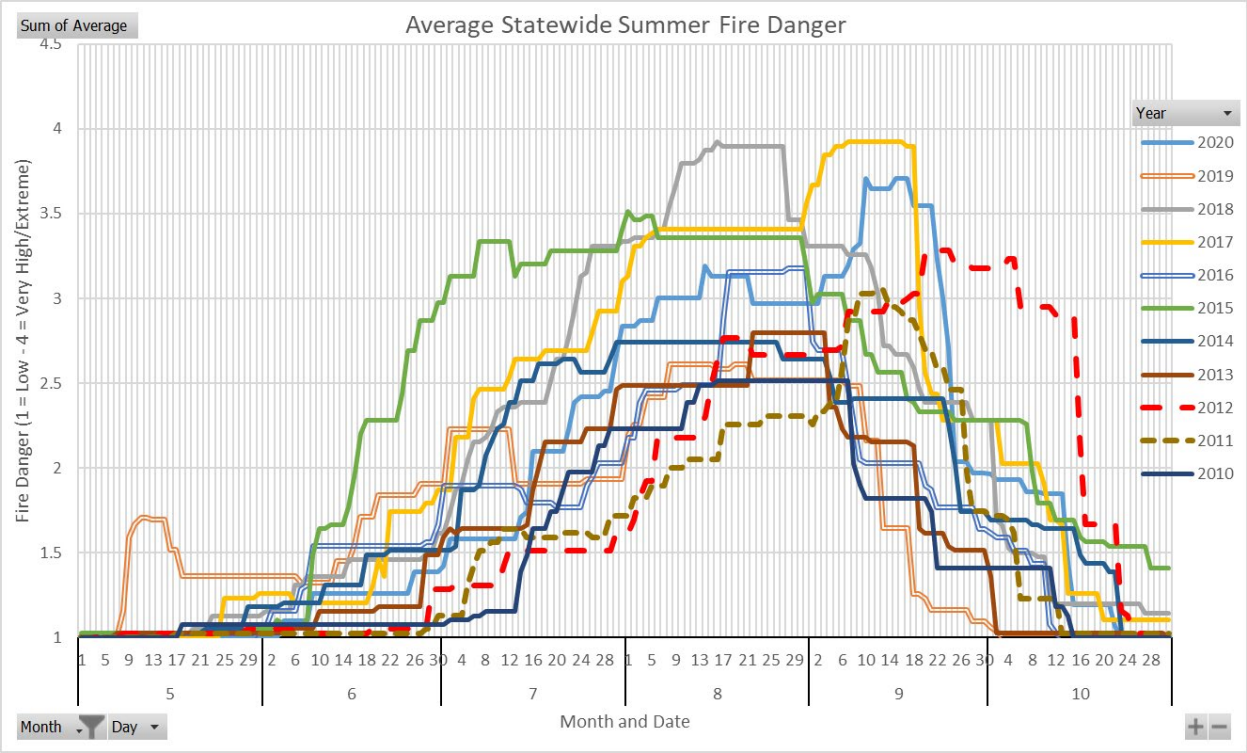


Table 4. Frequency distribution of preparedness levels in the Pacific Northwest Geographic Area (Oregon and Washington) from 2009 through 2019.

Regional Preparedness Level Frequency													
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Percent
June	PL1	30	30	30	27	30	26	9	21	24	22	30	84.5%
	PL2	0	0	0	3	0	4	17	9	6	8	0	14.2%
	PL3	0	0	0	0	0	0	4	0	0	0	0	1.2%
	PL4	0	0	0	0	0	0	0	0	0	0	0	0.0%
	PL5	0	0	0	0	0	0	0	0	0	0	0	0.0%
July	PL1	16	9	31	0	1	1	0	25	0	0	24	31.5%
	PL2	8	22	0	21	23	13	16	6	12	16	7	42.4%
	PL3	7	0	0	10	4	1	7	0	19	5	0	15.6%
	PL4	0	0	0	0	3	2	8	0	0	7	0	5.9%
	PL5	0	0	0	0	0	14	0	0	0	3	0	5.0%
Aug	PL1	0	0	8	0	0	0	0	0	0	0	0	2.4%
	PL2	19	20	18	6	3	0	0	0	0	0	24	26.5%
	PL3	12	11	5	14	2	10	4	31	3	0	7	29.1%
	PL4	0	0	0	11	26	4	8	0	8	2	0	17.4%
	PL5	0	0	0	0	0	17	19	0	20	29	0	25.0%
Sept	PL1	0	18	0	0	14	1	0	0	0	0	19	15.8%
	PL2	30	12	13	6	16	17	8	29	0	11	11	46.4%
	PL3	0	0	11	9	0	12	10	1	6	13	0	18.8%
	PL4	0	0	6	15	0	0	8	0	4	6	0	11.8%
	PL5	0	0	0	0	0	0	4	0	20	0	0	7.3%
Oct	PL1	31	31	26	20	31	31	23	31	11	30	31	87.1%
	PL2	0	0	5	5	0	0	8	0	19	1	0	11.2%
	PL3	0	0	0	6	0	0	0	0	1	0	0	2.1%
	PL4	0	0	0	0	0	0	0	0	0	0	0	0.0%
	PL5	0	0	0	0	0	0	0	0	0	0	0	0.0%

Table 5. Monthly large burn consumption in tons (DNR post burn reports)

	Monthly Burned tonnage by Large Burns only (>100 tons per burn)										
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Jan	4716	177	107	8698	11400	19655	4835	1224	12906	863	3538
Feb	2300	0	450	780	0	1354	919	2649	2470	400	440
Mar	887	14772	1208	2401	1461	1704	550	2746	522	1997	0
April	73919	59049	33421	33515	115856	38882	107263	90040	7188	30916	41837
May	143862	79023	25731	85740	83497	129136	16431	35757	74995	74396	115532
June	2854	0	12770	12785	8270	19317	0	18315	8177	6715	16006
July	0	0	0	26433	6950	3800	0	11572	822	1143	0
Aug	21850	0	0	18313	0	0	0	0	0	0	6810
Sept	137610	31164	24323	6679	79112	77508	8106	99354	47014	30404	43962
Oct	183985	262785	253730	130458	114888	285965	109518	164623	160381	179362	166275
Nov	46696	145566	146977	181576	109005	94487	123529	62658	135036	127112	76482
Dec	11561	1203	6459	7001	43510	47704	25260	21712	24971	48450	5324

Table 6. Frequency table of tonnages consumed by month for all burns of any size

Tonnage Frequency by Month All Burn Activity													
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Tonnage	500	0	0	0	0	0	0	4	5	0	0	0	0
	1000	0	0	0	0	0	2	2	3	0	0	0	0
	5000	3	10	6	0	0	1	2	0	0	0	0	1
	50000	8	1	5	6	3	8	3	3	7	0	0	8
	100000	0	0	0	3	5	0	0	0	2	0	3	2
	150000	0	0	0	2	3	0	0	0	2	2	5	0
	200000	0	0	0	0	0	0	0	0	0	5	3	0
	250000	0	0	0	0	0	0	0	0	0	1	0	0
	300000	0	0	0	0	0	0	0	0	0	2	0	0
	350000	0	0	0	0	0	0	0	0	0	1	0	0

Table 7. Frequency analysis of nationwide preparedness levels from 2009-2019.

		National Preparedness Level Frequency											
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Percent
June	PL1	30	1	0	0	2	14	11	5	0	0	11	22.4%
	PL2	0	29	2	10	18	16	10	25	28	28	19	56.1%
	PL3	0	0	28	16	10	0	9	0	2	2	0	20.3%
	PL4	0	0	0	4	0	0	0	0	0	0	0	1.2%
	PL5	0	0	0	0	0	0	0	0	0	0	0	0.0%
July	PL1	8	0	0	0	0	1	0	0	0	0	0	2.6%
	PL2	21	31	17	6	10	13	16	24	0	0	31	49.7%
	PL3	2	0	14	9	21	17	15	7	6	20	0	32.6%
	PL4	0	0	0	16	0	0	0	0	25	6	0	13.8%
	PL5	0	0	0	0	0	0	0	0	0	5	0	1.5%
Aug	PL1	0	0	0	0	0	0	0	0	0	0	0	0.0%
	PL2	12	31	25	1	0	7	0	0	0	0	22	28.8%
	PL3	19	0	6	6	8	9	2	18	0	0	9	22.6%
	PL4	0	0	0	24	16	15	10	13	9	1	0	25.9%
	PL5	0	0	0	0	7	0	19	0	22	30	0	22.9%
Sept	PL1	0	0	0	0	8	2	0	1	0	0	4	4.5%
	PL2	23	30	12	0	18	28	8	24	0	7	26	53.3%
	PL3	7	0	11	29	3	0	8	4	9	16	0	26.4%
	PL4	0	0	7	1	1	0	9	1	3	7	0	8.8%
	PL5	0	0	0	0	0	0	5	0	18	0	0	7.0%
Oct	PL1	25	18	17	16	31	31	30	31	1	27	17	71.8%
	PL2	6	13	14	15	0	0	1	0	17	4	14	24.7%
	PL3	0	0	0	0	0	0	0	0	13	0	0	3.8%
	PL4	0	0	0	0	0	0	0	0	0	0	0	0.0%
	PL5	0	0	0	0	0	0	0	0	0	0	0	0.0%

Appendices

Appendix 3. 1998 and 2022 SMP Approval Criteria for Large Burns and Burns of any size in UGAs Comparison

1998 SMP	2022 SMP Approval Criteria	Approach/Exception	Notes
1.There is the likelihood of an "intrusion" of smoke into "designated areas," which includes air space 2,000 feet above the ground, or "sensitive areas," such as population centers.	1. There is a likelihood of an exceedance of state air quality standards in the ambient air up to 2,000 feet above ground level over areas designated by Ecology (designated areas) (RCW 70A.15.5140).	Approach: Smoke will not significantly disperse within approximately eight hours of ignition, and be fully dispersed by 12:00 PM the next afternoon unless the burn meets the criteria and requirements of a multiple day burn. This does not include residual smoke in the immediate burn area itself.	Revised to comport with RCW, which specifies exceedance of air quality standards (NAAQS) as decision standard. See also Criteria #6; DNR will use best available science and individual expertise to protect public health. Additionally, we will pay special attention to critical areas designated by the department of ecology.
2. There is any likelihood of an over-flight of smoke above a designated area or special public events specified by DNR Region Managers; but over-flights of smoke may be approved over designated areas on days when visibility would be reduced naturally by cloud, fog, rain, snow, etc.	2. Burning will not protect the public welfare, preserve visibility, protect scenic, aesthetic, historic, and cultural values, and prevent air pollution problems that interfere with the enjoyment of life, property, or cultural attractions. (70A.15.1005).		The 2022 SMP Criteria restates the 1998 Criteria using language in RCW to delineate all values at risk.

1998 SMP	2022 SMP Approval Criteria	Approach/Exception	Notes
3. Burning will not comply with the SIP of the federal Clean Air Act regarding visibility protection of Class I federal areas.	3. Burning will not comply with the federal Clean Air Act regarding visibility protection of federal Class I Areas. (42 USC 7470).		
4. Any state or federal air quality regulations, laws, or rules would be violated.	4. Ignition will violate any other state or federal air quality regulations, laws, or rules (RCW 70A.15.5140, 76.04.205 and 70A.15.5020).		
5. Burning on state and private lands does not meet the requirements of Washington State's Forest Practices Rule and Regulations relating to threatened or endangered species protection.	5. Burning will occur in areas of the state where federal or state ambient air quality standards are exceeded for any criteria pollutant (RCW 70A.15.5020).	Exception: This does not apply to silvicultural burning used to improve or maintain fire dependent ecosystems for rare plants or animals within state, federal, and private natural area preserves, natural resource conservation areas, parks, and other wildlife areas (RCW 70A.15.5020).	The 2022 SMP Criteria #5 is a new addition, intended to ensure that DNR does not allow burning in any area that is in nonattainment of standards. 1998 Criteria #5 has been removed, since the analysis required to meet it is already complete in state and federal environmental analysis, and private Habitat Conservation Plans.
6. Burning will cause mandatory emission reduction levels to be exceeded as described in this plan.	6. Burning will cause mandatory emission reduction levels to be exceeded (RCW 70A.15.5020).	Exception: Emissions from silvicultural burning in eastern Washington that is conducted for the purpose of restoring forest health or preventing the additional deterioration of forest heath are	

1998 SMP	2022 SMP Approval Criteria	Approach/Exception	Notes
		exempt from the reduction when certain conditions are met.	
7. Burning will knowingly violate another state's published air quality standards.	7. Burning will knowingly violate another state's published air quality standards (42 USC 7470).		DNR staff employ best professional judgement and consult colleagues in adjacent states when appropriate.
8. Smoke will not significantly disperse within approximately eight hours of ignition, and be fully dispersed by 12:00 PM the next afternoon unless the burn meets the criteria and requirements of a multiple day burn. This does not include residual smoke in the immediate burn area itself.	8. There is a declared stage of impaired air quality (RCW 70A.15.5040), or air quality conditions are deteriorating and are expected to continue to deteriorate such that an air quality episode is likely to be called in the next 24-hours.		The 2022 SMP Criteria #8 is a new addition, intended to reflect coordination between DNR, Washington State Department of Ecology, and Local Clean Air Agencies.

Appendices

Appendix 4. Comparison between 1998 and 2022 SMP Visibility Protection sections

1998 SMP Visibility Protection	2022 SMP Visibility Protection and Related Provisions
VISIBILITY PROTECTION The federal Clean Air Act (CAA) established a national visibility goal to ". . . prevent any future, and remedy any existing, impairment of visibility in mandatory Class I areas." Washington has eight (8) federal Class I areas that are national parks and wilderness areas (see map, Appendix 7). All states must develop programs to make "reasonable progress" toward meeting the visibility goals in the Class I areas as part of its State Implementation Plan (SIP) for the federal Clean Air Act. The Washington State DOE has the primary responsibility for SIP development, with the DNR being responsible for enforcing the portions related to its jurisdiction. One or more burns that consume 100 tons or more of material have the potential to affect visibility significantly over large areas. The cumulative effect of many smaller burns may also have an impact on visibility. The visibility portion of this plan concentrates on burns that consume 100 tons and greater at this writing. Added control of small burns may be included in future plan amendments if that source is a significant contributor to visibility degradation, and if workable implementation thresholds can be established. The visibility protection section of the current SIP was created in 1985 after consultation with DNR, USFS, private landowners, DOE, and other stakeholders. Presently, visibility protection practices meet or exceed the requirements of the 1985 SIP, mainly	Visibility Protection The federal Clean Air Act (CAA) established a national visibility goal to ". . . prevent any future, and remedy any existing, impairment of visibility in mandatory Class I areas." Washington has eight (8) federal Class I areas that are national parks and wilderness areas. States must develop strategies to make "reasonable progress" toward meeting the visibility goals in the federal Class I Areas as part of its Regional Haze SIP. Ecology has the primary responsibility for Regional Haze SIP development and submittal to EPA. One or more burns that consume 100 tons or more of material have the potential to affect visibility significantly over large areas. The cumulative effect of many smaller burns may also have an impact on visibility. The visibility portion of this plan concentrates on burns that consume 100 tons and greater at this writing.

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because of voluntary agreements between large private landowners and the DNR. In 1991, the Washington Clean Air Act amendments (RCW 70.94.011; Declaration of Public Policies and Purpose) added language describing the legislature's intent to ". . . preserve visibility, to protect scenic, aesthetic, historic, and cultural values, and to prevent air pollution problems that interfere with the enjoyment of life, property, or natural attractions of the state." This, combined with the federal visibility requirements, has motivated many stakeholders and the managers of Class I federal areas to ask for increased visibility protection beyond the 1985 SIP requirements and the current operating level developed through the voluntary agreements. The following provisions of this plan will be another significant step toward making "reasonable progress" to meet national visibility goals for Class I federal areas, and will balance the needs of various stakeholders in meeting the intent of the legislature as stated in the Washington Clean Air Act amendments of 1991: • Reduced particulate emissions due to the mandatory emission reductions described in this plan and RCW 70.94. 11 8/98 • Restricted burning during poor air quality days, which are also the days that have generally poor visibility conditions, due to implementation of the mandatory "call-in" requirement before igniting burns of less than 100 tons. • Increased use of alternative methods of debris disposal to reduce the need to burn forest debris. • Increased use of "pile-burning" techniques to reduce visible smoke by increasing combustion efficiency through the use of fans, etc. The use of pile-burning techniques will also allow burning to	In 1991, the Washington Clean Air Act amendments (RCW 70A.15.1005; formerly RCW 70.94.011; Declaration of Public Policies and Purpose) added language describing the legislature's intent to "... preserve visibility, to protect scenic, aesthetic, historic, and cultural values, and to prevent air pollution problems that interfere with the enjoyment of life, property, or natural attractions of the state." In addition, "…Further, it is the intent of this chapter to prevent any areas of the state with acceptable air quality from reaching air contaminant levels that are not protective of human health and the environment…" The following provisions of this SMP assist with "reasonable progress" to meet national visibility goals for federal Class I Areas: Maintain particulate emissions below mandatory emission reductions levels described in this plan and RCW 70.94 (RCW 70A.15.1005). Restrict burning during poor air quality days, which are also the days that have generally poor visibility conditions, due to implementation of the mandatory "call-in" requirement before igniting burns of less than 100 tons. Promote use of alternative methods of debris disposal to reduce the need to burn forest debris. Promote use of "pile-burning" best management practices to reduce visible smoke by increasing combustion efficiency through the use of fans, etc. The use of pile-burning techniques will also allow burning to occur outside heavy tourism periods when broadcast burning is not possible, allow burning of large units to be done in smaller sub-units (thereby keeping smoke impacts more

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occur outside heavy tourism periods when broadcast burning is not possible, allow burning of large units to be done in smaller sub-units (thereby keeping smoke impacts more localized), and will allow burning during cloudy or low visibility rainy days. Directive: Burns that will consume 100 tons or more of material will NOT be allowed under the following circumstances: On weekends (midnight Thursday through midnight Sunday) between June 15 and October 1 statewide On Independence Day or Labor Day holidays. All burning on weekends between June 15 and October 1 in western Washington west of Interstate 5 may be approved by the Land Manager on a case-by-case basis if: • The burn will meet all of the eight criteria for burn approval described on page 8, AND • The burn is a high-priority unit for abatement of extreme hazard if required by law, OR • The Land Manager determines that annual burning opportunities on a particular site are so limited as to justify an exception. • Multiple day burns conducted between June 15 and October 1 in eastern Washington may be approved by the land manager on a case-by-case basis if the land manager certifies in writing to the Department of Ecology that: • The burn is conducted to restore or maintain forest health, as defined in appendix 16, AND	localized), and will allow burning during cloudy or low visibility rainy days. ** To mean days when visibility would be reduced naturally by cloud, fog, rain, snow etc., may be approved over designated areas on days when visibility would be reduced naturally by cloud, fog, rain, snow, etc. **Exceptions to Provisions of the Smoke Management Plan** Any entity wishing to burn can request an exception to provisions if they can demonstrate that said provision make necessary burning impossible to conduct. Exceptions to provisions of the plan can be granted if the requestor can demonstrate that carrying out the project will result in the same or greater protection of public safety, health, and welfare to that provided by the plan. At a minimum, exceptions requests must include: The specific provision of the Smoke Management Plan for which an exception is requested. A rationale for why an exception is warranted, and supporting documentation. Elements in the applicant's burn plan that are relevant to the exception request. Location, including a map of the project's perimeter. A description of any additional steps taken to ensure that smoke does not intrude on a designated area, a sensitive area, or *a Federal Class I area. (italics added)* A description, with supporting documentation, of how the exception, if granted, will result in the same or greater protection of public safety, health, and welfare.

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• The burn will meet all of the eight criteria for burn approval described on page 8, AND • The burn could not be conducted prior to June 15 due to unfavorable weather conditions, AND • Smoke impacts to Class I areas can be avoided and such consideration is included in the prescription for the burn. The burn plan will address visibility protection as an objective and will address management actions (i.e. stop lighting, rapid mop up, public notification) to be taken if these impacts are not avoided due to changing atmospheric conditions. All of these provisions will be reviewed within one year of adoption of this plan to: Determine their effectiveness toward improving visibility Document the actual impact on burners' ability to meet their debris-management objectives Allow time to review newly published studies related to silvicultural burning and their impact on Class I areas (National Park Service, "Prevent Study") Allow additional time for industrial burners to develop management strategies for alternative methods of debris disposal.	Burners should submit exception requests as soon as possible but no fewer than three weeks in advance of the date of proposed ignition. DNR encourages burners to submit requests for exceptions as far in advance as possible. DNR will not revoke an exception unless conditions change such that the underlying reason for the exception request are no longer valid. Any requests submitted less than three weeks in advance of proposed ignition will have minimal chance of approval. DNR and Ecology will review the proposal in a timely manner. The time line for the review will consider needs of the proponent. DNR will notify the landowner of the decision. DNR's response may include a request for more information or clarification. If both agencies concur and the exception is approved, the project is still subject to the Approval Criteria on pages 8 and 9 of this plan, and will be approved or denied final permission to burn based on any of the go/no-go criteria. ……. **Approval Process for Multiple Day Burns** The Wildland Fire Management Division and Regions will apply the same criteria that is used to approve large burns, regardless of burn size. The following notification requirements apply to multiple day burns to ensure that DNR has the opportunity to properly analyze the project prior to approval, and that communities who might be smoke-impacted have ample time to prepare. <Map omitted> Above: Map of the Washington State Department of Natural Resources regions.

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	The following information and actions are required from the burner before DNR will approve a multiple day burn: Rationale for the need to ignite over more than one operational period. Smoke monitoring plan which can include any combination of temporary or permanent monitors, cameras, and staff. Communication Plan, to include outreach to targeted audiences. Coordination call plan, including proposed participants and timing. An extinguishment plan for implementation as a last resort. Three months before the burn the burner must give DNR the above information to determine the size and scope of the proposal for DNR's review. Two months before the burn DNR will determine if the burner has demonstrated that the project's goals meet the criteria for a multiple day burn, and will notify the burner of additional steps needed. If DNR determines that the burn has the potential to affect communities, the burner must notify the public of the burn at least one week before they plan to burn. The notification may be published in local newspapers, on traditional broadcast media, or on social media, and may be a paid advertisement, press release, or public service announcement. The notice will list the location, size and duration of the burn, and must include a landowner's phone number to call for updates or more information about the burn. If the burner cannot mitigate potential adverse impacts such that DNR is confident that air quality will not fall below a level that is unhealthy for sensitive populations (defined as 20.5 $\mu g/m^3$ of $PM_{2.5}$). DNR will withhold approval.

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	The following resources must be provided and maintained during the course of multiple-day burn conduct: Forecasting: The burner must request a spot forecast for each day of ignition. Monitoring: Burners must identify existing monitoring resources. These can include permanently sited air quality monitors, publicly accessible private air quality monitors, cameras, and on-site or regional staff. In some cases, burners may be required to site temporary monitors in agreed-upon locations. Daily Coordination: For the duration of the project, all participants identified in the request will have a conference call to discuss objectives and risks, and additional calls prior to the commencement of burn operations daily. Expanded Burn Authority: For federal burns, the responsible land manager—e.g., Forest Supervisor or National Park Superintendent—will have expanded authority to deviate from a day's burn plan, not to exceed the total approved tonnage, in the event that conditions allow. Operationally, the decision process is as follows: The initial request to initiate burning is made. DNR Wildland Fire Management Division will issue a Yes or No decision using established protocol for approval of large burns When a Yes decision is received from DNR Wildland Fire Management Division, decisions to expand ignition beyond the requested tonnage will be made by the land manager based on weather and site conditions. Factors used to make that decision will include: current and expected weather, ability to meet prescription objectives of the burn, and if available, monitoring data from various air quality monitors in the area and coordination with the participants identified in the request.

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	If the land manager suspends burning to avoid breaching one of the burn approval criteria, burning operations may resume once conditions warrant without going through the permission process again, so long as burning resumes during the window authorized by the initial smoke management decision. For example, if the smoke management approval authorized burning for four days, and the burner suspended ignition beginning the second day, they can resume on either of the next two days. If the burn meets the criteria to be considered an intrusion (see the following section), DNR will consult with the burner to discuss mitigation measures, and modify the burn plan as necessary. If burning is suspended for a period extending outside the window of the initial smoke management decision for any reason, the burn approval process will return to Step 1 for approval. DNR Wildland Fire Management Division will have the Meteorologist or designee available throughout the multiday burn for consultation.