Okanogan-Wenatchee National Forest
Naches Ranger District

2007 Multi-Day Burn Pilot
Executive Summary
And Specialists Reports

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Executive Summary

Project Overview

In the spring of 2007, the Okanogan-Wenatchee National Forest (OWNF) - Naches Ranger District, in cooperation with the State of Washington Department of Natural Resources (DNR), the State of Washington Department of Ecology (DOE), and the Yakima Regional Clean Air Authority (YRCAA), tested a variety of new procedures intended to increase the possibility of accomplishing multiple-day, landscape-level prescribed burns during the spring burning program. This type of burning, needed to improve forest health and reduce the risk from wildfire, has been difficult to achieve in the past due in large part to air quality concerns in the local area.

The Naches district proposed burning up to 5,500 acres in 4 distinct units in the spring of 2007 by using a combination of extra scientific support and a modified smoke permitting process. In the end 3,512 acres were treated, short of the goal but still far more acres than had been treated in previous years. Typically the Naches district burns about 1,500-2,000 acres during the spring burning window. In addition, the burning was accomplished with minimal impacts to air quality.

This report provides a summary of the efforts of many contributors to the pilot project and identifies the factors that were most useful for making the spring 2007 burning a success.

Results and Recommendations

Numerous components were brought together to support the Naches spring burning. Following is a list of all procedures that were used for the trial, an assessment of their usefulness, and recommendations for the future:

1. **IMET:** A dedicated, onsite National Weather Service Incident Meteorologist (IMET) was assigned to the district to provide real time weather and smoke forecasts. Custom forecasts, balloon soundings, immediate availability of weather predictions, local knowledge gained for terrain effects are all examples of advantages gained through the dedicated assignment of the IMET to this pilot effort. The IMET was able to predict the approach of an ideal smoke dispersion window which enabled the district to gear up for and complete helicopter ignition of a landscape scale burn.

   This service was deemed **highly useful** for increasing the burning window and is **recommended** for future efforts.

   Issues needing resolution include paying the cost of dedicated IMETs, scheduling and availability of NWS staff, and training IMETs in this and potential additional related tasks (such as BlueSky smoke modeling and smoke monitoring instrument deployment).

2. **Conference Calls:** Daily Naches-specific collaborative conference calls with OWNF Fire staff, DNR smoke managers, and other Forest Service and National Weather Service science support staff were used for daily decision-making. The conference calls enabled customized daily burn plans, comparison of weather forecasts, and review of past burning accomplishments and effects. The calls were kept brief and efficient, typically about 20

minutes in length. The conference calls definitely helped to accomplish more burning especially on marginal days when the initial request was not appropriate for predicted dispersion but something less could be accomplished.

These focused conference calls were found to be **highly useful** to the goal of accomplishing more burning and are **recommended** for future efforts.

Implementing this option for multiple districts across the state in the format that was used during the Naches trial would be overly time-consuming so some method to prioritize and/or streamline the process would need to be developed.

3. **Modified Smoke Permitting Process:** The Okanogan-Wenatchee Forest Supervisor was given expanded decision authority to approve further burning once an initial approval was granted by DNR. This additional flexibility enabled extra burning to be accomplished outside the strict structure of the Washington smoke management program. For example, one day the plan was to burn 50 acres but the District had the information (visual observations and predicted meteorology) and authority needed to accomplish 200 acres.

   This extra authority was **highly useful** for accomplishing extra burning and is **recommended** for future implementation.

   Issues to resolve include investigating the willingness of DNR and Department of Ecology to continue and expand this authority for other Districts and Forests. Also, would we immediately trust all burn bosses to use this authority responsibly or would we want to implement some sort of pre-qualification requirement.

4. **Monitoring Instruments and Trigger Point Plan:** Four PM2.5 monitoring instruments for near-real-time measurement of air quality were deployed at strategic locations downwind of the burning. In addition, pre-defined air quality trigger levels and subsequent actions were defined to aid daily go/no-go decision making. The instruments (EBAMs) were found to be time consuming to operate and erratic in their performance. In addition, the lag time for data posting to the internet made the information of no value to operational decisions. There was value to seeing air quality impacts from burning the day prior.

   The air monitoring was time consuming and **did not increase the burning window** or directly allow more acres to be accomplished. Advisability of future monitoring efforts is **undetermined**.

   Air monitoring and trigger points may be a necessary part of future burning to build trust and buy-in from regulatory agencies and the public, especially if greater decision making authority is to be given to the Forest Service. Issues for future resolution include discussion with regulatory agencies and the public to gage whether monitoring would be necessary before they could be comfortable with new permitting procedures. Further work to refine monitoring techniques and trigger points may be needed.

5. **Outreach:** Extra effort was made for public outreach in support of the Naches spring burning. Ultimately, public support for increased use of fire, and the resulting increased risk of smoke impacts, is the best way to ensure this work can be accomplished. Just 3 smoke-related calls from the public were received during the spring burning. This was undoubtedly due in part because smoke concentrations never got very bad, and in part because the public was well briefed and knew what to expect.

   The extra outreach was **useful** to the success of the spring burning and is **recommended** for future efforts.

   The main issue to address in the future is how to continue to reach more people and ensure a thorough understanding of the goals of the fire program.

6. **BlueSky Dispersion Modeling:** Forest Service scientists (AirFire) provided customized BlueSky smoke dispersion modeling and interpretation. This information was valuable to the daily decisions although this sort of operational support is not a function AirFire can provide routinely.

   The BlueSky modeling framework should be updated to accommodate this planning function. We recommend training IMETs or other Forest personnel to provide the daily, operational support by utilizing BlueSky for prescribed burning.

7. **Fuel Measurement:** Forest Service scientists (FERA) measured preburn fuel loadings and post burn fuel consumption to increase the accuracy of BlueSky predictions and as a comparison to Naches District fuel monitoring techniques and results. The FERA work found the fuel measurements made by the Naches district to be very accurate.

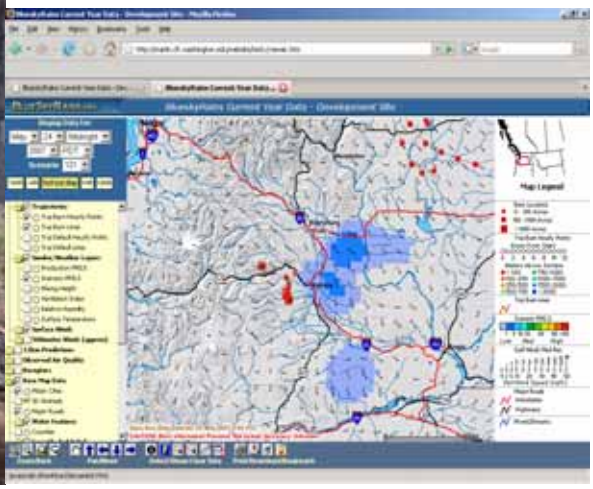
   The FERA measurements helped identify shortcomings in the ability of current consumption and emissions models to accurately predict smoldering duration and smoke transport in the underlying components of BlueSky. We recommend future research efforts to help solve these model shortcomings.

A few additional ideas for increasing the success of future prescribed burning efforts came up during the Naches trial including:

- Certify the Washington State Smoke Management Program with EPA so that prescribed burning NAAQS exceedences, if they occur, could be considered for exclusion under the Exceptional Events Rule.
- Develop a method to certify or approve burners for clearance to exceed permitted tons if meteorological conditions are ideal.
- The Washington Smoke Management Plan is overdue for revision and could use some carefully considered updates.
- The way nuisance smoke is defined in Washington is vague and needs to be clarified.

Detailed
Specialist Reports

Appendix



Naches Pilot Program Practitioner's Report

Jim Bailey, Naches District Fuels Planner

- IMET
  - Forecasts have been extremely accurate and speak specifically to that day's particular burn unit.
  - Balloon soundings were a valuable tool in decision making. Balloon soundings give the Burn Boss a huge information advantage in making Go/No Go decisions in relation to smoke management.
  - Spot weather forecasts were normally received within 5 minutes of on-site observations being called in. This is not meant to reflect negatively on weather offices, but does display the time loss as a result of spot requests being radioed to dispatch, observations input and sent to the weather office, spot requests being in the queue and processed in the order they are received, the spot forecast being sent back to dispatch, and dispatch relaying the forecast to the Burn Boss. We never had to delay ignition in order to receive the spot weather forecast while we had an IMET.
  - The IMET would visit the project site or a lookout point daily. As a result of the familiarity gained, the forecaster had a greater knowledge of local terrain and how that would affect local meteorology, especially winds. This meant no big weather surprises for the Burn Boss.
  - Having the IMET at a lookout point allowed the Burn Boss to confidently make the decision to Go on the day that 50 acres was requested and 200 acres were actually burned.
    - If we had not been in the Pilot, we would never have considered exceeding our planned acreage by this amount, regardless of smoke dispersion conditions. On this day we were able to burn 4 times the requested acres.
  - The IMET provided assistance in E-BAM maintenance that otherwise would have come at the cost of a burn crew member.

- E-BAM
  - E-BAM's are a good tool for monitoring, but were of limited value for real-time decision making.
    - Long data posting lags did not allow the Burn Boss any capability to assess immediate smoke impacts and take immediate action. Posting someone at a monitor would allow real time air quality readings but this would require too much staff time.
    - Previous 24 hour average air quality values (midnight to midnight) were useful, but most current values (1-hour averages) should be weighted higher for decision making.
  - Several of the E-BAM's were sent out in a less-than-functional condition.
    - It was very time and labor intensive to get the monitors set up; some of the monitors did not even have the correct sensor-to-monitor plug-ins. This required rewiring on-site.

- Forest Service E-BAM's included meteorological instruments (temperature and relative humidity). EPA monitors did not have this instrumentation. This would have been good information to have from all monitors.
- Discussions need to take place regarding prescribed burning and outlying populations. While not a designated area, monitoring showed that smoke reached levels higher than what we realized in the Nile Valley. Comments from local residents were typically "It's not as bad as it has been during other springs" must weigh against the fact that the Nile monitor reached "Unhealthy for Sensitive Groups" on occasions. Qualitative assessments were not supported by monitoring data.
    - "I don't think the extra monitoring, although perhaps the responsible thing to do, is going to help us get any more burn days, just the opposite in fact." – Janice Peterson.

- Daily Conference Calls
    - Aside from the on-site IMET, I felt this was the most valuable tool in daily decision making.
    - All, or nearly all, information was summarized and good decisions were made. There was never a day that I left the conference call feeling that a No Go decision had been made for a day that I felt would be a good burn day.
    - The right people were on the conference call (District, S.O., AirFire, FERA, DNR Smoke Mgt., and National Weather Service).
    - Consider Netmeeting or Sametime, on a limited basis; a couple of satellite photos and models from the Weather Service, and a Google Earth map from the District could be of value to the decision makers.
    - Specialists should stick to their area of expertise. It is not our job to agree or disagree with the IMET; it is our job to apply the information given.
        - Segal's Law: A man with a watch knows what time it is. A man with two watches is never sure.
    - The daily conference calls gave us the opportunity to explore options for days that would normally be a No Go decision. Decisions to implement a 15:00 cutoff allowed us to burn some acres on days that normally would have been a no burn day.
        - Some burning got done meaning smoke output was lower later on.
        - People hired for prescribed burning were kept working at that task.
    - Conference calls were well managed; everyone had a chance to supply input, but the call was not a major time impact.
    - All parties involved worked to make daily burns and the project as a whole a success; there was no territorialism.

- BlueSky
    - My feeling is that BlueSky was a more valuable tool than the E-BAM's in terms of decision making.
    - Miriam Rorig did an excellent job of applying BlueSky to the IMET's forecast. BlueSky trajectories were typically supported by the IMET's forecast, and

Miriam used this to project ground-level concentrations by considering often reduced tonnages or acres.
    - When/if BlueSky can address smoldering and fold that into a new or continued ignition, its value for decision making will be at a premium.

- Public Information/Media Relations/Interagency Coordination
    - Lots of good help from Doug Jenkins, Kim Larned, Randy Shepard, and Paul Hart.
    - No question as to the necessity of good public and media relations, but they can often "get in the way" of the Burn Boss and take up time and focus that is needed elsewhere. A dedicated Public Information person(s) took a lot of stress and time impacts off of the Burn Boss.
    - There seemed to be some confusion early in the process about what other agencies (DOE, YRCAA) roles would be in this Pilot. Was this due to assumptions on their parts, or in how we communicated the process to them?

- Pre-Implementation
    - Purpose and Need, goals, and objectives were very clear before the first driptorch was lit, as well as the expectation that this project be "100% successful".
    - The *Plan for Community Smoke Exposure and Trigger Point Monitoring During Prescribed Burning Trial, Naches Ranger District, Okanogan-Wenatchee National Forest, 2007* (the implementation plan) was well thought out, and provided clear direction. I don't recall a time that we were unsure of how to proceed due to ambiguity in the plan.
    - **A LOT** of preseason time and work went into this project. My thanks to: Jason Emhoff, Janice Peterson, Randy Whitehall, Jim Russell, Candace Krull, Tom Robison, Miriam Rorig, Roger Ottmar, Bob Vihnanek and crew, Julia Ruthford, Dave Grant, Darrel Johnston, Doug Jenkins, Kim Larned, and Randy Shepard.
    - Thank you to everyone for having the confidence in the Naches Ranger District to take this project on.

Naches Pilot Program Incident Meteorologist Report

Julia Ruthford, Meteorologist

WHAT WORKED WELL:

Coordination with WA-DNR was excellent…especially with Dave Grant. Dave had many very useful smoke and weather related insights that made my job as a forecaster significantly easier and smoother. **Recommendation:** Get other NW IMETs familiar with WA-DNR's Smoke Management Program including the criteria and tools they use to make their burn/no burn decisions. The fall fire weather meeting would be a good venue for this.

The daily conference calls were great for coordination for making sure everyone was on the page. Miriam Rorig's Bluesky input and Dave's smoke knowledge as well as discussion of smoke and weather observations was very valuable to me as a forecaster (not to mention the large weather knowledge of the group was a good check to make sure I hadn't missed anything). **Recommendations:** My only recommendation for improving this process would have been to better clarify exactly what weather information you were looking for from me…I got the impression I was information overloading everyone while I was trying to cover everything that was important.

Coordination with the Spokane NWS was also excellent. The Spokane forecasters were very helpful when I called and always willing to discuss any weather events of concern or puzzlement.

Bluesky was a very useful tool that I hadn't used previously. It was especially valuable with Miriam's input and interpretations. The graphic/user interface seemed very bandwidth intensive which made it run quite slowly through the cell modem card on the laptop (much more so than other products with images that appeared to be of similar resolutions). This limited my ability to view more than a few images from Bluesky within a reasonable amount of time. **Recommendation:** Provide Bluesky training for northwest IMETs and fire weather forecasters (another good topic for the fall fire weather meeting). Also adding some sort of lower tech/lower resolution way to view Bluesky images would be very useful for IMETs and other people in the field that would like to use the products.

Getting out in the field as much as possible was very beneficial to understand operations, fuels involved and burning conditions. Also just seeing the topography and where the smoke was going proved one of the most valuable forecasting and analyzing tools.

Visiting Naches and WA-DNR before the project began was very helpful for getting up to speed on the project objectives and goals. It allowed me to learn about WA-DNR's smoke management program and the air quality regulations they are constrained by as well as understanding what the Pilot Program was and who all was involved. These trips also allowed me to get a look at the terrain and fuels ahead of time and to get an idea of level of detail and weather elements would be most important to forecast.

The cell modems…with these it was possible to take the IMET laptop in the field and still check weather data easily! A great plus where coverage is good. However the connection gets really slow and noisy at the edge of cell coverage. **Recommendation:** The NWS should get antennas or other signal boosting devices for the IMET laptops.

TECHNOLOGY ISSUES:

EBAMS: These were great tools for smoke monitoring but frustrating and time consuming to assemble because of missing and incompatible parts. These problems really should be resolved before they are shipped to the field. Also meteorological instruments on all EBAMS would be very useful, particularly relative humidity and wind sensors.

FireRAWS: These also could have been extremely useful tools unfortunately both stations had very questionable temperature and relative humidity output. The temperature/RH sensor on the FireRAWS near the Kaboom underburn was obviously bad but it was harder to tell about the data quality for the Devil's Table FireRAWS.

I couldn't connect the IMET laptop to the internet at the Ranger Station. I got a huge run around trying to resolve this with the USFS tech support people before I finally got the answer it wasn't possible. The cell modem worked fine because Naches has excellent coverage but this is not likely to be the case everywhere else so it would be good to find a solution for hooking NWS computers into a USFS network (or some other way to get internet). The backup IMET satellite communication system will work anywhere (once the Pacific satellite is up) but is expensive. It cost $6 per mb to download data.

OTHER COMMENTS AND THOUGHTS:

This project provided a wonderful opportunity to gain more local knowledge in a very geologically complex area of the Pacific Northwest as well as to interact with fire managers and fire fighters at the field level. I learned quite a bit about smoke forecasting, prescribed burning and the local meteorology on the Naches RD. All of this was extremely valuable knowledge to gain. The assignment also provided great interaction with a key fire weather customer. I would highly recommend this type of assignment to any IMET with the opportunity to participate in such a program.

Naches Pilot Program BlueSky Smoke Dispersion Model Support

Miriam Rorig, AirFire Research Meteorologist

Model Runs

Output solutions from BlueSky were available both for the "default" daily production model runs, and additional customized "scenario" runs which varied the inputs for acreages, fuel loadings, number of plumes, and timing of the burns. In addition to surface PM2.5 concentrations, BlueSky provides above-ground smoke trajectories, and predictions of mixing height. All three outputs provided valuable information for this project.

Default runs: Each day the burn information for that day's burn came into the system through the normal burn-reporting process that downloads files each night from the WA DNR. A fuel type (and associated fuel loadings) is assigned to the burn based on the reported location (lat/lon).

Scenario runs: For each of the units (Devils Table, Kaboom, Elderberry, and Rattle) there were 5 predefined scenarios, for a total of 20 scenarios.

(1) a 68-acre burn, starting at 1100 local time, and lasting 6 hours
(2) a 100-acre burn, starting at 1100 local time, and lasting 6 hours
(3) a 200-acre burn, starting at 1100 local time, and lasting 6 hours
(4) a 100-acre burn, split into 5 individual burns of 50, 25, 12.5, 6.25, and 6.25 acres, all starting at 1100 local time, and lasting 6 hours
(5) a 68-acre burn, starting at 1100 local time, and using BlueSky's default duration

Five additional scenarios were subsequently included:

(21) Devils Table – a 125 acre burn split into 5 individual burns of 25 acres each, starting at 1100 local, with each burn starting the next hour (so the last burn starts at 1500 local), using FERA's fuel loadings
(22) Kaboom – a 125 acre burn split into 5 individual burns of 25 acres each, starting at 1100 local, with each burn starting the next hour (so the last burn starts at 1500 local). A sixth burn of 125 acres was included, starting at 2000 local with a duration of 3 hours, and fuel loadings for 1000+ hour and rotten fuels only. The intention was to simulate smoldering.
(23) Kaboom – a 1000 acre burn split into 5 individual burns of 200 acres each, starting at 1100, with the last burn igniting at 1500 local, using FERA's fuel loadings (except for duff and litter).
(24) Kaboom – a 2300 acre burn split into 5 individual burns of 460 acres each, using the same fuel loading and timing as the previous scenario.
(25) Kaboom – a 125 acre burn starting at 1200 local, and lasting 120 hours, as an alternate method to simulate smoldering.

BlueSky Predicted Surface PM2.5

Predicted surface PM2.5 concentrations in some cases represented what was observed, and in others did not characterize the observations well. Most of the burning was accomplished when ventilation was good, therefore there was not much smoke at the surface downwind from the units during the day. BlueSky also showed little or no PM2.5 at the surface during the day for most of the scenarios. At night, however, when the mixing heights decreased and the

atmosphere became more stable, the smoke generated from smoldering did accumulate in the nearby valleys. BlueSky did not predict the presence of this smoke from residual smoldering because:

1. Prescribed burns in BlueSky have a default duration based on the size of the fire. Once the fire is "out" (all the acreage is burned), there is currently no method to generate additional emissions from residual smoldering.
2. The current minimum model resolution of 4km is too large to resolve individual valleys where smoke impacts were seen, therefore even if BlueSky more accurately represented smoldering several hours after ignition was complete, the valleys where smoke accumulates are too small to be resolved by the model terrain.

Trajectories/Mixing Heights

Even though PM2.5 from residual smoldering was not present in the model output, the potential for smoke accumulations from smoldering could be inferred from predicted trajectories and mixing heights in BlueSky. On most burn days, the mixing heights were several thousand meters above ground during the afternoon hours, but would start decreasing by about 1800 to 1900 local time, and by sunset the mixing heights were only a few hundred meters or less above ground level. Likewise, the trajectories would show good lofting during the day, with the transport winds taking the smoke well downwind of the burn unit, but by early evening, consistent with the mixing heights, the trajectories would show the smoke remaining close to the ground and pooling close to the burn site. The monitoring data did indeed show inversions forming over night, although the timing was somewhat later.

Conclusions

1. It is desirable to run the BlueSky framework at finer resolutions for prescribed burn applications. At the very least, a 1-km resolution should be used, and even finer resolutions would be preferable. (The modeling framework is not currently set up to downscale the MM5 grids which define the model resolution, but this is something AirFire will be pursuing in the future.) The primary reason for this is that the model terrain does not adequately resolve the areas that will be impacted by the smoke (narrow valleys and drainages, roads, etc.).
2. Based on the differing outputs from the various scenarios, we will likely need to reconsider the way prescribed burns are handled in BlueSky. One known issue is that the predicted heat generated by larger fires can cause the model to loft smoke well above ground, resulting in a prediction of no smoke impacts close to the burn. While this is valid in some cases, sometimes there is smoke on the ground close to the burn, especially when ignition occurs over a protracted period of time. Dividing the burns into several smaller fires appears to produce more realistic output.
3. Additionally, there should be further investigation into methods to better incorporate smoldering after the active burning is complete. A couple of scenarios were added in which additional burning was continued after the main burn was complete, but this was merely a "fix" that did not represent the actual situation on the ground. We will need to determine better ways to burn the reported acreage (in terms of how quickly the unit burned, how many plumes to include, and when to extinguish the fire), especially in light of the fact that active burning was occurring on the units up to a week or more after the prescribed burn activities were complete.

Monitoring Pre-fire Fuel Characteristics and Fuel Monitoring Pre-fire Fuel Characteristics and Fuel Consumption for Devils Table and Kaboom

Roger Ottmar, Research Forester

Research Overview

The Pacific Northwest Research Station's Fire and Environmental Research Applications Team (FERA) located at the Pacific Wildland Fire Sciences Laboratory, Seattle, Washington completed the monitoring of the Devils Table and Kaboom units. These units were part of the multiple day burn demonstration project on the Naches Ranger District of the Wenatchee National Forest. The project included the monitoring and a report of 1) pre-burn fuel loading; 2) FCCS fuelbed comparisons; 3) Naches District fuel loading comparison; 4) fuel consumption; and 5) fuel consumption predicted from Consume 3.0 comparison.

Discussion

Pre-fire fuel loading measured by the Naches Ranger District personnel on the Devils Table and Kaboom units were within 18 and 35 percent of the FERA measured values. The differences were due primarily to the way FERA chose to position our plots. We positioned the plots in areas with more fuel loading to capture the extreme values of fuel consumption. The Naches District values were averages for the entire unit.

Fuel loading is a critical variable in estimating total smoke production and the Naches District did a superb job in estimating the fuel loading. Although we surveyed the Fuel Characteristic Classification System for an appropriate fuelbed, none were found that provided a fuel loading within $\pm$ 20% of the measured. The fuelbeds developed for the Wenatchee/Okanogan that represented thinning from below assumed the fuels had been treated. We did not have a fuelbed that was thinned and not treated. Consequently, we will be building 15 more fuelbeds to represent this situation for the Okanogan/Wenatchee National Forest. Not finding an exact fit in the fuelbeds available from the FCCS is not a real problem since customizing a closest-fit fuelbed is an easy remedy.

Total fuel consumption was estimated within 3-6% of measured consumption by Consume 3.0 (Table 3). There were significant differences in the predicted fuel consumption by fuelbed component, however total consumption is the critical variable and Consume 3.0 is providing respectable outputs.

The emissions for PM 2.5 generated for each burn is related to the fuel consumed. Since the Devils Table and Kaboom units consumed approximately the same amount of fuel, the PM 2.5 produced for each unit was the same; 0.12 tons/acre. There was slightly more fuel consumed during the Kaboom prescribed fire and consequently the heat output was slightly higher than the Devils Table prescribed burn.

Assuming eighty percent of the 200 acres burned at Devils Table were blackened, a total of 1,440 tons of fuel were consumed resulting in 22 tons of PM 2.5 being emitted (Table 3). Assuming eighty percent of the 2300 acres burned at Kaboom were blackened a total of 16,560 tons were consumed resulting in 258 tons of PM 2.5 being produced.

Key Findings

- Fuel loading ranged from 19.1 tons per acre on Kaboom to 23.1 tons per acre on Devils Table.
- The Fuel Characteristic Classification System did not contain a fuelbed that closely matched Devils Table or Kaboom because of the lack of fuelbeds representing thinning units without treatment. Fifteen additional fuelbeds will be built for the Okanogan and Wenatchee Forest to account for this inadequacy.
- The Naches Ranger District has an excellent fuels inventory program in place that captured the fuel loadings of Devils Table and Kaboom units within $\pm$ 30%.
- Consume 3.0 predicted total consumption of the woody and forest floor fuels within 8% of measured values. Consume 3.0 is adequately capturing the fuels consumed.
- Approximately 0.12 tons/acre of $PM_{2.5}$ was predicted to have been produced during this fire with a heat output of approximately 3,400 BTUs per $foot^2$.

Recommendations

- Build 15 FCCS fuelbeds representing thinning units without treatment for the Okanogan/Wenatchee National Forest.
- Adapt a Naches District or similar pre-burn fuel inventory program.
- Collect 3+ large woody fuel moisture content samples prior to burning.
- Run Consume 3.0 to estimate total fuel consumption and emissions.

Future Needs

The multi-day prescribed burn trial was very successful and brought together scientists, managers and regulatory agency representatives to implement new technology and direction. The project was limited to the spring burning window and future project may want to direct their efforts to fall prescribed burning. In addition, methods to monitor fuel consumption rate and duration of the stumps, large logs, and snags have been developed and should be implemented to better account for low buoyancy, smoldering smoke. Implementation of Consume 3.0 and FEPS should be considered to improve the output of BlueSky.