Arapaho Declared Wildfire Review

Arapaho National Wildlife Refuge

Walden, Colorado

October 16, 2015

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Executive Summary

On October 16, 2015, a prescribed burn implemented by the U.S. Fish and Wildland Service (FWS) on the Arapaho National Wildlife Refuge (NWR) escaped control lines and was declared a wildfire. An interagency review team convened on October 22 to analyze the incident, determine the elements that led to the escape, and provide recommendations for improvement of the fire management program.

The moderate-complexity prescribed fire was conducted on a 211-acre grassland unit, as referenced in the Incident Action Plan, on the refuge to reduce hazardous fuel loadings and to improve forage, cover, and habitat conditions for nesting waterfowl and other wildlife. During the ignition operations, fire spotted across the Illinois River and the fire became very active, burning towards structures. The escaped fire grew quickly and exceeded the capabilities of on-site resources. The fire burned a total of 578 acres, including 213 acres outside the original burn unit (approx. 70 off unit), before being controlled by on-site and contingency resources, as well as the local volunteer fire department and aviation resources which included a heavy helicopter, large air tanker (LAT), and a single engine air tanker (SEAT). Outside assistance, local expertise and professionalism were critical for success. No injuries occurred on the incident; however, local evacuations were made and 3 outbuildings were lost. Smoke did impact Highway 14 which was closed for 3-4 hours.

The Review Team found that the following contributed significantly to the escape and wildfire declaration:

- A fire whirl that occurred in the burn area started in the NW corner of the unit and carried across the burn unit then jumped across the river carrying fire upslope and burning three different out buildings on private property.

- Implementation decisions were based on incorrect weather information received from spot weather forecast.

- Access issues significantly hampered efforts to catch spots on the east side of the Illinois River, in addition the terrain and access restricted movement of equipment after the slop-over occurred.

Purpose of Review

Policy outlined in the Interagency Prescribed Fire Planning and Implementation Procedures Guide and the FWS Fire Management Handbook requires a review for all declared wildfire incidents. The overall goal of the declared wildfire review process is to help prevent future wildfire declarations by analyzing the prescribed fire plan and implementation actions and by gathering knowledge and insight from the

local participants for integration into future resource management and prescribed fire planning and implementation. Furthermore, this process promotes individual and unit learning, respectful interaction, beneficial dialogue, and problem solving. Most importantly, engaging in this process increases experience and insight, reduces serious accidents, and results in more efficient firefighting and prescribed burning.

As required, a copy of this declared wildfire review will be sent to the FWS National Fuels Program Lead.

Review Team

The FWS Regional Fire Management Coordinator (RFMC) for Region 6 appointed an interagency team (Table 1) to conduct a review into the key elements that led to the escaped prescribed fire and wildfire declaration. On October 22-24, 2015 the Review Team visited the site of the incident, interviewed key personnel associated with implementation of the burn, reviewed and analyzed events and actions leading up to and immediately following the escape, and analyzed the decision making process. In addition, the team was asked to determine: 1) the burn plan was adequate for the project and complied with policy, 2) if the prescription and procedures outlined in the burn plan were followed, 3) the level of awareness and understanding of the personnel involved, and 4) to recommend methods to improve prescribed fire planning and implementation based on their analysis.

Table 1. Review Team members.

Name	Team Position	Home Position	Home Unit
Jason Virtue	Team Leader	Deputy Fire Staff	U.S. Forest Service Rocky Mountain Region Black Hills National Forest
Colt Mortenson	Team Member	Fire Management Officer	Bureau of Land Management Northwest Colorado Fire Management Unit
Angie Simpson	Team Member	Fuels Program Manager	Bureau of Land Management Northwest Colorado Fire Management Unit

Refuge Description and Fire Management Organization

Arapaho NWR is located in an intermountain glacial basin in north-central Colorado, situated at an elevation of 8,200 feet. The basin opens north into Wyoming and is rimmed on three sides by mountain ranges. The basin is known locally as North Park. Slow, meandering streams, which crisscross the basin, flow toward the north to form the North Platte River. Most of the flood plain is irrigated meadow, while the adjacent uplands are characterized by sagebrush steppe. Prescribed fire is used in a variety of

habitats to remove hazardous fuel loads, enhance and maintain habitat values, and is often used in conjunction with other management tools such as grazing and noxious weed control.

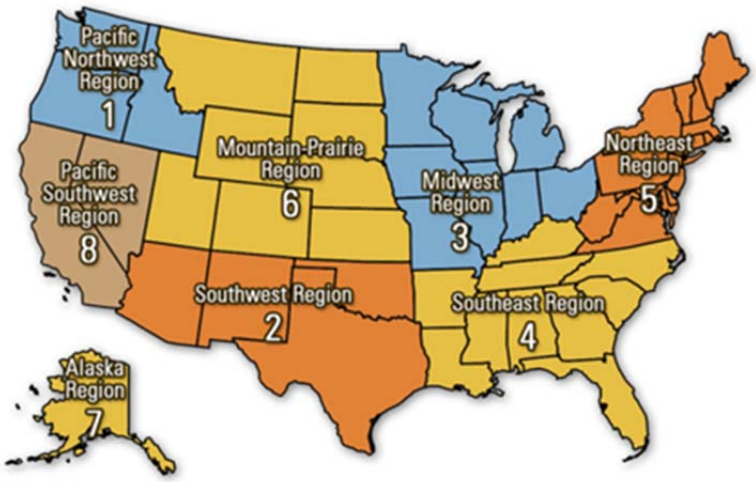
The Fire Management Program in Region 6 serves all refuges and hatcheries in the eight-state region. The programs operates in an interagency manner, where local, state, and federal agencies lend their support to neighboring agencies and departments to perform ongoing wildfire suppression and prescribed fire operations. To manage the program, the Region is divided into five different fire zones. The Arapaho NWR falls under the Rocky Basin Fire Management Zone. Each zone is managed by a fire management officer, specialists, and technicians. It is typical for all of zone fire personnel to move across refuge boundaries to support prioritized needs within the zone. The fire staff is also supported by fire qualified refuge biologists, technicians, and support staff to enhance suppression capacity and add their expertise to using prescribed fire to meet refuge management goals and objectives.

Permanent staffing for the Rocky Basin Zone includes a Fire Management Officer (FMO), one Assistant Fire Management Officer (AFMO), and two Engine Captains with one located at the Bear River MBR and one vacant engine captain located at Browns Park NWR. The Zone employs 2-3 seasonal positions per year and maintains a small force of collateral-duty (refuge militia) firefighters. When burning there is a heavy reliance on interagency partners including the National Park Service, US Forest Service, and Bureau of Land Management. Refer to Table 2 for responsible refuges.

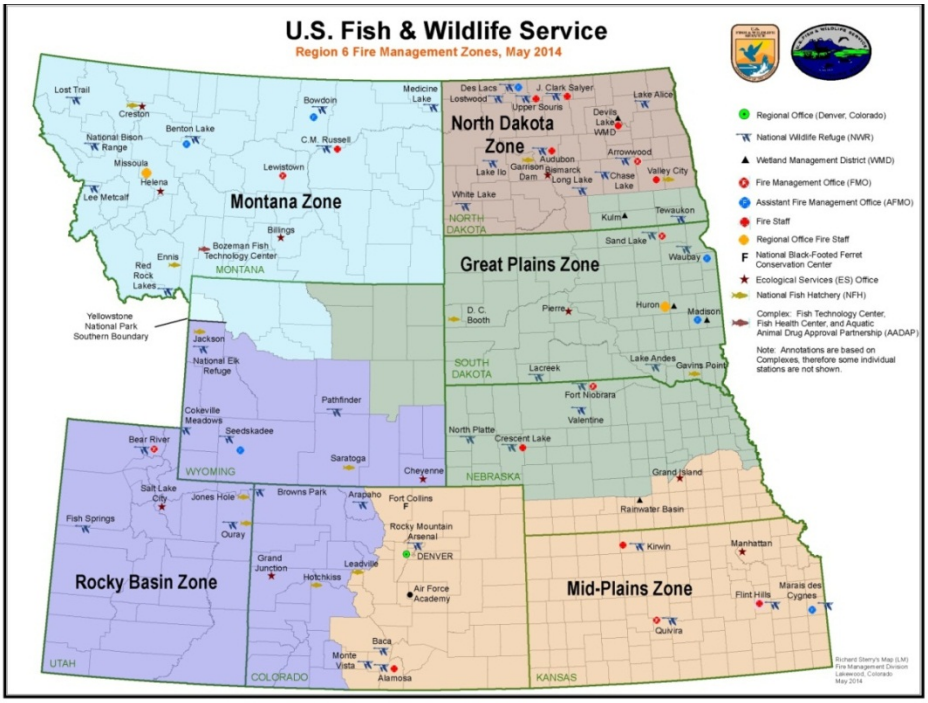
Table 2. Rocky Basin Fire Zone Responsible Refuges

Refuge	**State**
Arapaho NWR Complex	
Arapaho NWR	Colorado
Hutton Lake NWR	Wyoming
Mortenson Lake NWR	Wyoming
Bamforth NWR	Wyoming
Bear River Migratory Bird Refuge	Utah
Cokeville Meadows NWR	Wyoming
Fish Springs NWR	Utah
Jackson (National Elk Refuge)	Wyoming
Lower Green River NWR Complex	
Ouray NWR	Utah
Browns Park NWR	Colorado
Colorado River Wildlife Management Area	UT/CO
Pathfinder NWR	Wyoming
Seedskadee NWR	Wyoming

Map 1. FWS Map of all the Regions in the United States



Map 2. FWS Region 6 Fire Management Zone Map



Arapaho Description and Prescribed Fire Objectives

The Arapaho NWR is predominantly flat terrain which is intersected by numerous braided rivers, streams, and ditches. The project area transitions from the river bottoms to the uplands and can contain rapid changes in elevation, which can be described as a bluff. These bluffs tend to channel the local winds through the river bottoms and can lead to sudden changes in wind direction due to the eddying of the wind. All aspects are represented, and elevations range from 7,896 to 9,052 feet. Slopes range from flat to 70%, with an average slope of 3% being found on the refuge. The boundary of the Arapaho Burn Unit consists of mowed lines on the north and south ends of the unit. The east flank of the unit used the Illinois River as a holding line, while the west flank used a railroad grade/two track road. The on-site fuels are irrigated meadows, perennial grasses and sedges (Fuel Model 1). All surrounding fuels to the burn unit were the same Fuel Model 1.

There are other features that are found randomly across the refuge. One is a "Soaphole." This feature is identified by a bare earth surface in the meadows and riparian areas. These areas have very soft soil and will entrap vehicles and foot travelers alike (Engine 683 did get stuck in the burn unit and had to be pulled out by a tractor during the burn). Another is organic soils which will sustain fire under the surface of the ground. Other features to note would be the fences and irrigation ditches.

The refuge wide fire objectives were to remove a minimum of 80% of the thatch layer over a minimum of 75% of the ignition unit immediately following post-burn. Refer to Table 3 on the next page for the resource and prescribed fire objective differences between the three plans.

Table 3. Resource and Prescribed Fire Objective Differences:

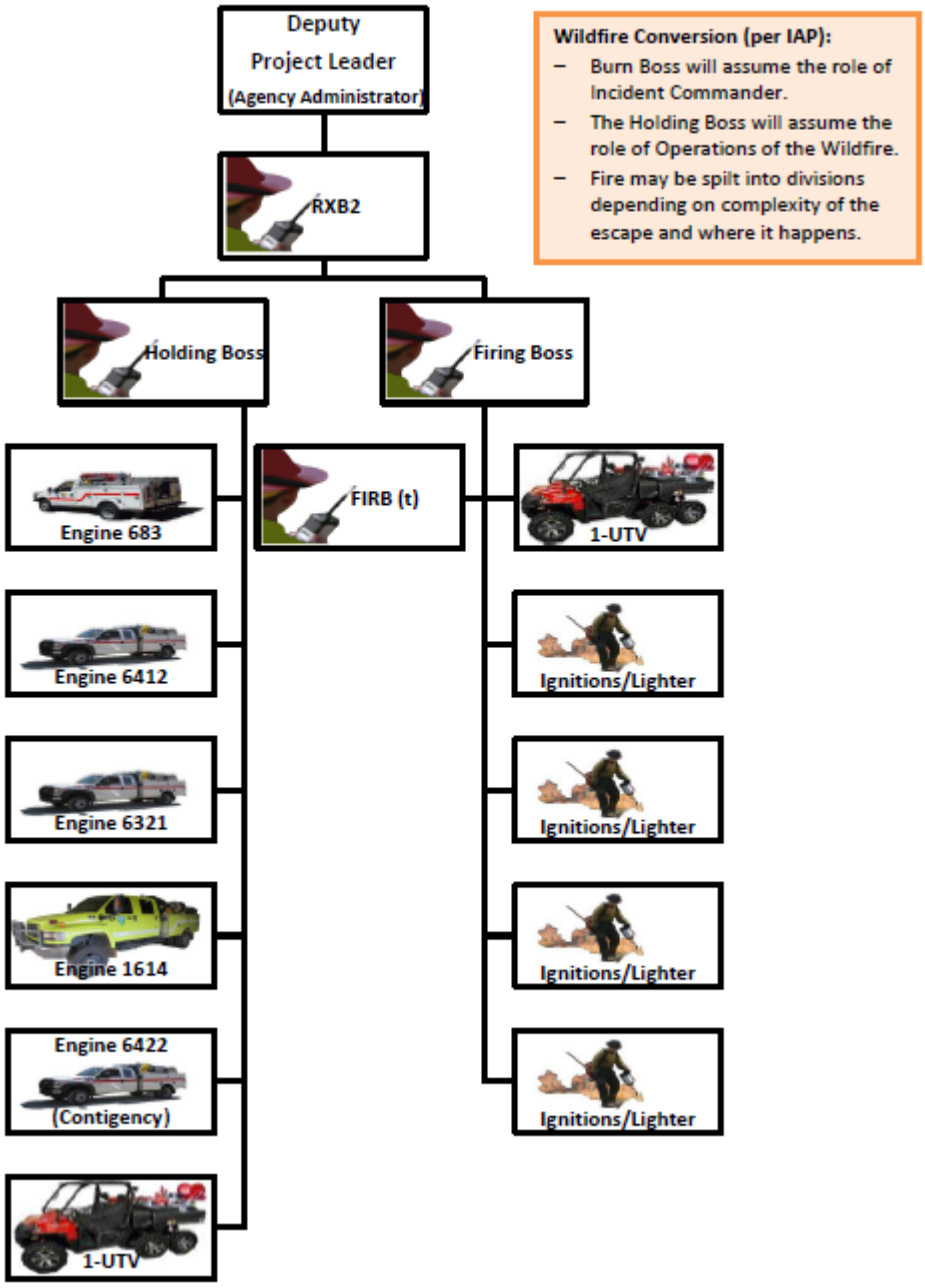
Objective	Rx Plan Used	IAP	Burn Plan at Refuge
Resource	Riparian Habitats a. Restore 50-100 acres of dense (40-100%) willow in patches greater than 0.5 acre and 20 meters wide in the central third of the Illinois River (from the north end of the island to the confluence with Spring Creek), to connect existing willow patches by 2014. Maintain 535 acres of dense willow in patches in the upper third of the Illinois River to benefit nesting Neotropical migratory songbirds and residence moose, rover otter, and beaver. b. Provide 3,630-3,845 acres, over a 5-year average, of a grass: forb (75:25) plant community composed primarily of native plants (rushes, sedges, grasses, and forbs) characterized by 10-30 centimeters visual obstruction reading, 0-10 centimeters duff layer, minimal (less than 5-percent) bare ground, and less than 40-percent (canopy closure) willow by 2019, to benefit nesting waterfowl and sage grouse broods. c. Provide 210-425 acres, over a 5-year average, of a grass: forb (75:25) plant community composed primarily of native species (grasses, sedges, forbs, and rushes) characterized by greater than 30 centimeters visual obstruction reading, 10-20 centimeters duff layer, minimal (less than 5-percent) bare ground and less than 40-percent (canopy closure) willow from mid-April through August, by 2009, to benefit nesting waterfowl and songbirds. Wetland Habitats a. Maintain 10 acres of, and attempt to establish in one other wetland basin, tall (greater than 60 centimeters visual	Rejuvenate grasses to improve forage and cover. Improve habitat conditions for nesting waterfowl, foraging sage grouse broods, and other wildlife by removing decadent grass cover around the Hampton ponds.	Riparian Habitat (Willow) 1. Restore and maintain dense (40-100 Percent) willow patches throughout riparian corridor to benefit nesting Neotropical migratory songbirds and resident moose, river otter, and beaver. 2. Minimize negative impacts to willows during prescribed fire by exclusion or strategic fire behavior and intensity. 3. Determine potential benefits of prescribed fire on willows through experimentation and research.

	obstruction reading) emergent vegetation in water depths greater than 4 centimeters over a 5-year period, to provide nesting habitat for over-water nesting birds. b. Provide 10 percent of the wetland acres, over a 5-year average, in short (less than 10 centimeters), sparse (less than 10 centimeters visual obstruction reading) emergent vegetation in water depths less than 4 centimeters, from April to August, to provide foraging habitat for shorebirds and waterfowl, as well as nesting and brood-rearing habitat for shorebirds. c. Provide 20 percent of the wetland acres, over a 5-year average, of emergent vegetation greater than 25 centimeters tall with visual obstruction reading greater than 80 percent of vegetation height in water depths 4-18 centimeters, to provide escape cover and foraging habitat for dabbling duck broods and molting ducks, and foraging habitat for water birds. Meadow Habitat a. Provide 20-50 acres, over a 5-year average, of a grass:forb (75:25) plant community composed primarily of native plants (rushes, sedges, grasses, and forbs) characterized by less than 20 centimeters height, less than 10 centimeters visual obstruction reading, with dry to moist soils (no standing water), adjacent to (within 50 meters) or intermingled with sagebrush (10- to 25- percent sage canopy cover), from early-June to late-July, to benefit sage grouse broods. b. Provide 1,650-1,850 acres, over a 5-year average, of a grass:forb (75:25) plant community composed primarily of native species (grasses, sedges, forbs, and rushes)		Meadow Habitats. 1. Provide and maintain suitable meadow habitat to benefit sage grouse broods and migratory birds. 2. Reduce residual growth accumulation (thatch/duff) layer as needed. Wetland Habitats 1. Maintain and provide emergent vegetation suitable for resting, feeding, and nesting migratory birds. Upland Habitats (sagebrush) 2. Exclude/suppress fire in upland habitat unless deemed necessary to maintain or restore native vegetative communities to benefit nesting waterfowl, songbirds, sage-grouse,

	characterized by 10-30 centimeters visual obstruction reading, 0-10 centimeters duff layer, and minimal (less than 5-percent) bare ground from mid-April to the end of July, to benefit nesting waterfowl and sage grouse broods. Upland Habitats a. Provide 630-790 acres, over a 5-year average, of a grass:forb (75:25) plant community composed primarily of native plants (grasses, sedges, forbs, and rushes) characterized by greater than 30 centimeters visual obstruction reading, 10-20 centimeters duff layer, and minimal (less than 5-percent)bare ground, to benefit nesting waterfowl and songbirds.		and other sage-obligate species.
Prescribed Fire	Refuge Wide a. Remove a minimum of 80% of the thatch layer over a minimum of 75% of the ignition unit immediately following post-burn. b. Provide training opportunities to refuge and partner staff to increase prescribed fire qualifications.	Removal of litter layer- reduction of hazardous fuels accumulation in meadow. Keep within designated boundaries. Acceptable range of results: Remove 80- 100% of litter on 75 to 100% of the area. Keep slop-over's and spot fires within thresholds described in contingency plan.	Refuge Wide 1. Remove a minimum of 80% of the thatch layer over a minimum of 75% of the ignition unit immediately following post-burn.

Organization and Equipment

Organizational Chart 1. Created on the day of the burn for all resources.



Chronology of Events

The following chronology details the events leading up to the wildfire declaration. The suppression response that followed was not within the scope of this review and is not fully included. Times are included when known; some have been approximated or averaged based on individual reports and the dispatch Wildcad Log.

10/14/2015

1528—Burn boss confirms primary command and secondary command channel plus two tactical channels. Air to ground 7 is assigned to the Arapaho RX.

10/15/2015

1344—NPS type 6 engine and BLM type 6 engine is assigned.

10/16/2015

0800—Engine 6412 set up pump at engine fill site. Engines filled their tanks.

0913—Burn Boss briefed all resources on site including the agency administrator. Copies of the IAP were handed out until they were gone. There were not enough IAPs for every resource. Ignition trainee was assigned.

1000—Firing boss and trainee viewed the eastern edge of the burn unit along the Illinois River with the UTV. Checked the four pumps in the river used to protect the willows.

1145—Started the test fire on the northeast section of the unit.

1155—Test fire successful.

1156—Four lighters with two UTVs started burning south, focusing on securing the ox bows along the Illinois River.

1203—Weather observations on site from burn boss' Kestrel Drop were 78 degrees, 15% relative humidity with wind variable at 2 mph.

1300—Operations normal, winds still variable, burned out along the ox bows. Engine 683 became stuck on the mow line on the east end of the fire. Weather observations were 69 degrees and 14% relative humidity

1330—Increased fire behavior with fire whirls, lighters were still igniting where feasible. Weather observations were 70 degrees and 13% relative humidity.

1400—Some extreme fire behavior within the unit, large fire whirls within the unit. Fire bumped the Illinois River real hard but did not cross. Weather observations were 70 degrees and 13% relative humidity.

1420-- Winds were predominantly from the NNW. The firing group was forced to move rapidly to the south where they tied in with Engine 683 that was stuck in a muddy ditch.

1430—large fire whirl carried fire over the Illinois River to the eastern side of the unit. One and a half acre slop over within one mile of structures experienced some extreme fire behavior. Reported by Engine 6321. Weather observations were 70 degrees and 12% relative humidity.

1440—Around this time the FWS tractor arrived and pulled out engine 683. Slop is 5-6 acres, actively burning in narrow strip. RXB2 asks if need to convert at this point. With fire behavior and fuels on hillside, Engine 6321 supervisor says not at this point and will update if changes. Fire behavior and direction look like head will pass structures and only flanks will hit hillside in the patchy fuels.

1445—6321 Engine boss calls to RXB2 that wind and fire behavior warrants conversion, can't contain with timeframe for resources on other side of river. Change in fuel continuousness below structures, not as patchy and there is a drainage leading right up to structure.

1453—The fire went outside the unit and IC declared it a wildfire. The Burn Boss became the IC and the holding boss became Operations. IC requested heavy air tankers, lead plane, and helicopter. The IC also requested law enforcement to close highway 14 and to start evacuating homes in the fire's path. The IC also orders the local fire department for structure protection.

1457—Jackson County Deputy and Fire Department responded. The fire was estimated at 500+ acres. Weather observations were 71 degrees and 12% relative humidity by Kestrel Drop on site.

1500--Start burnout operation at corner of county road and HWY 14 to try and save structures on other side from head fire. 6321 engine boss lighting and crewmember holding with 6321. Transmission to OPS/RXB2 we have begun burnout operations.

1510—Operations started moving resources around to the east side of the unit to help protect structures. The fire boss continued to the south and west to secure an anchor point on the southern edge alone the southern mow line. Highway 14 was closed.

1515—One structure was confirmed involved (outbuilding) more structures threatened. Highway 14 seemed to be holding.

1535—Sheriff Deputy shut down Highway 14

1541—Air attack off the ground at the Jefferson County Airport en route to the wildfire. Heavy Air Tanker 10, SEAT T888 and a heavy helicopter were all ordered. Weather observations were 68 degrees and 12% relative humidity by Kestrel Drop on site.

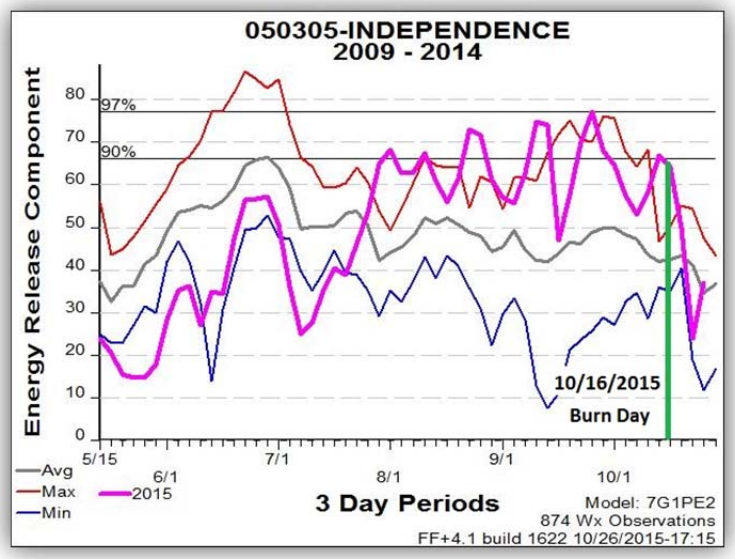
Findings

The emphasis of the Review Team's findings is based on the elements outlined in the Interagency Prescribed Fire Planning and Implementation Procedures Guide (April 2014) for declared wildfire reviews. The Review Team found that overall agency policy and guidance on prescribed fire implementation was adequate, that the FWS staff's awareness and understanding of prescribed fire procedures and guidance was satisfactory.

1: Seasonal severity, weather events, and on-site conditions leading up to the wildfire declaration

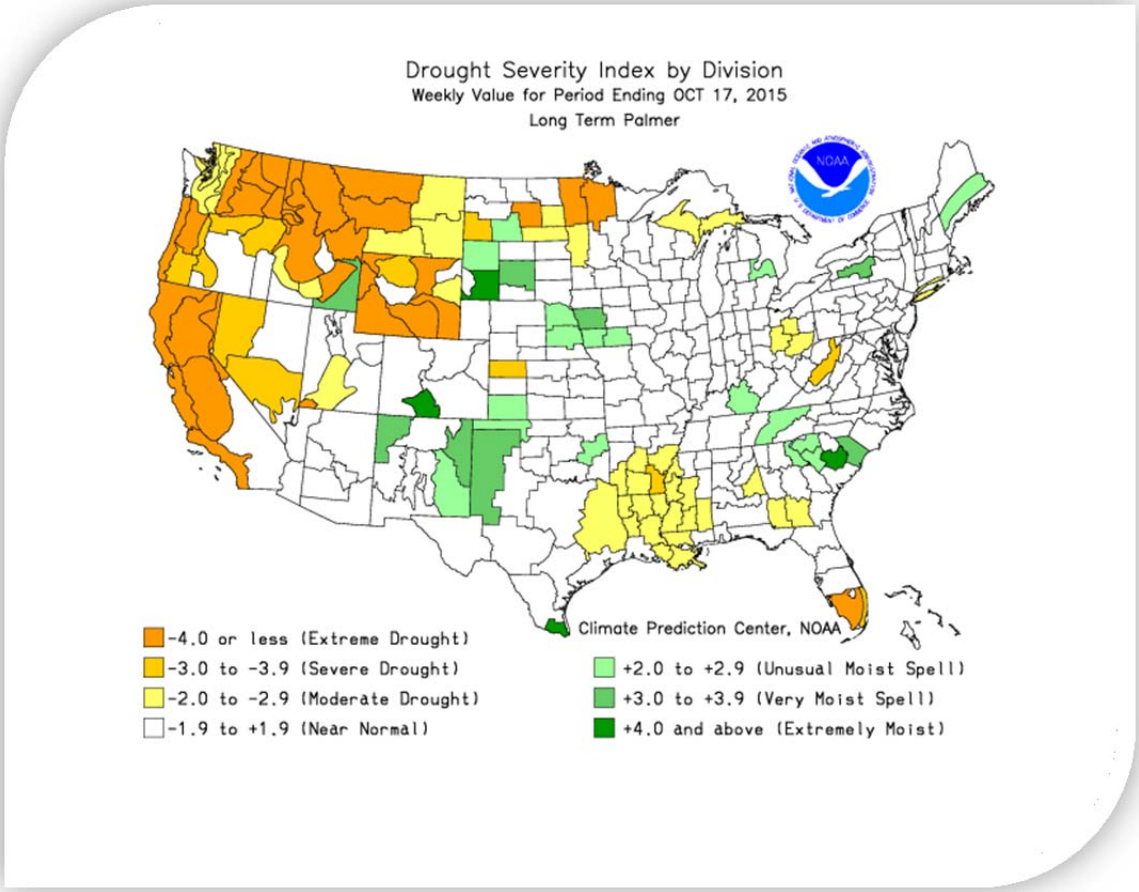
The mountain valleys of Northern Colorado experienced a normal fire season with a summer of near normal temperatures and precipitation; however the fall months of September and October have been above normal in temperatures and below normal in precipitation. The Energy Release Component (ERC) (see Graph 1) from the nearby Independence RAWS was near the 90 percentile. ERCs are a good indicator of short term (less than a month) seasonal dryness in this part of the United States. On October 16, 2015, the Independence Remote Automated Weather Station (RAWS) was at a historical six year high.

Graph 1. Independence RAWS ERC Chart near the 90th percentile on the day of the burn (10/16/2015).



The Palmer Drought Severity Index (PDSI) is based on a supply-and-demand model of soil moisture. The index uses a 0 as normal, and drought is shown in terms of negative numbers; for example, -2 is moderate drought, -3 is severe drought, and - 4 is extreme drought. Palmer's algorithm also is used to describe wet spells, using corresponding positive numbers. Palmer also developed a formula for standardizing drought calculations for each individual location based on the variability of precipitation and temperature at that location. The Palmer index can therefore be applied to any site for which sufficient precipitation and temperature data is available. The burn plan calls for a PDSI greater than -4. Map 3, shows the PDSI for the United States through October 17, 2015. The state of Colorado, according to this index does not indicate drought.

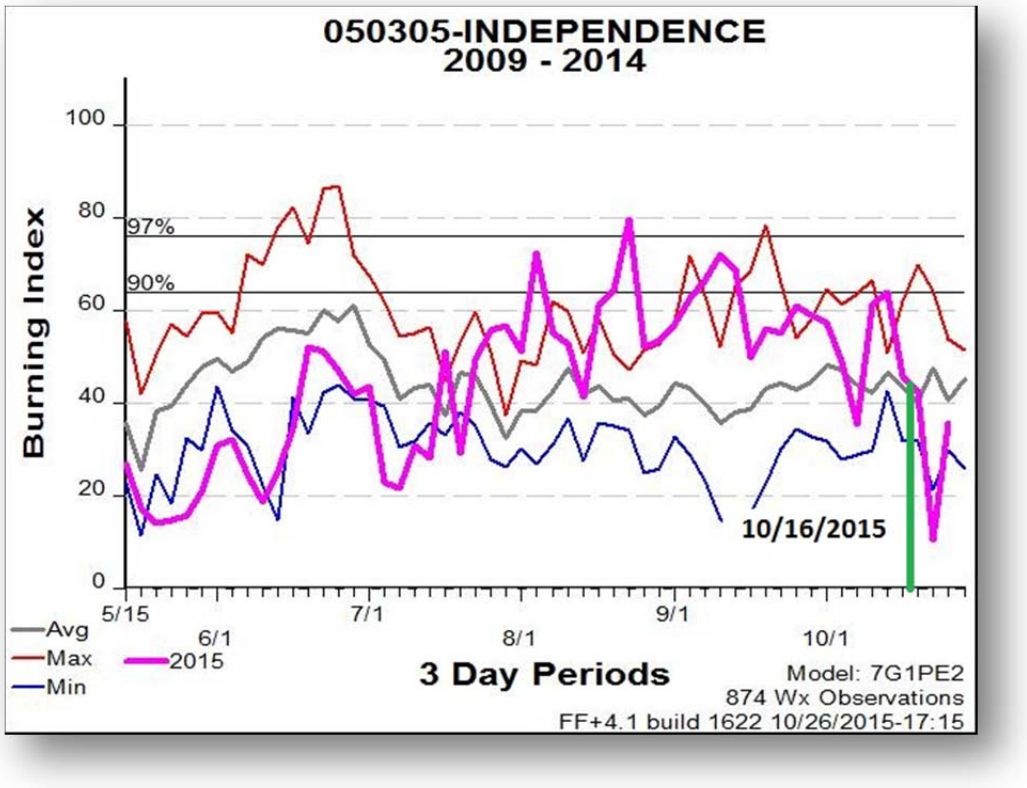
Map 3. Palmer Drought Severity Index for the fall seasons when the escaped prescribed fire occurred.



The National Fire Danger Rating System (NFDRS) Model for Burning Index (BI) is used to help with staffing decisions on a land management unit that has a significant amount of flashy fuels (grass/brush),

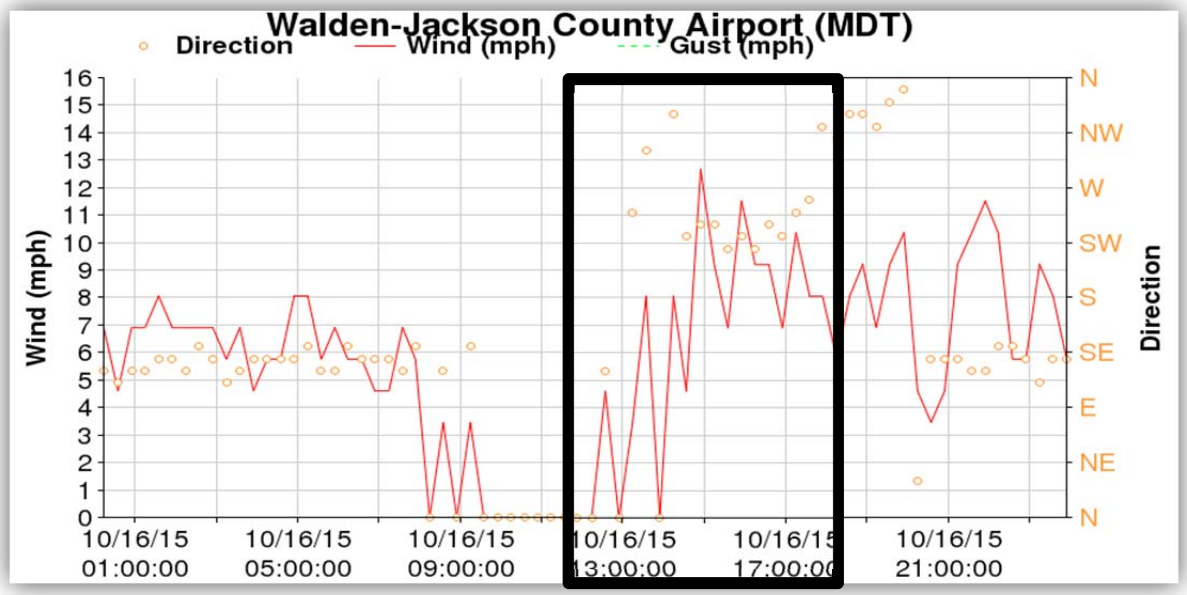
and is very sensitive to wind speed. On the day of the burn, the BI was just above average for this time of year (see Graph 2) which indicates that high wind speeds probably were not a significant factor.

Graph 2 Burning Index from the Independence RAWS 15 miles northeast of the Arapaho Prescribed



The spot weather forecast from the National Weather Service (NWS) on the day of the burn called for 20 foot wind speeds to be upslope/upvalley, 4-10 mph until noon, then west 8-10 mph with gusts to 20 mph. The Walden Airport NWS Weather Station less than three miles from the burn showed winds around 1400 to be out of the west northwest at eight mph and by 1445 the wind had increased to near 13 mph out of the northwest (see Graph 3).

Graph 3. Wind speed and direction for the Walden Airport Weather Station.



Winds with a northerly component turned the planned backing and flanking fire into a head fire which was not desired in the prescription. With the intensity of a head fire and the contrast between unburned light colored fuel and the black burned area, multiple fire whirls appeared and moved in and out of the flaming front. Fire whirls or dust devils form when the air near the ground heats up creating a thin hot layer. This layer then breaks, heat surges upward, and light winds start it spinning. Stronger surface winds can help prevent this phenomenon from happening by keeping the air mixed reducing the chance of a thin hot layer of air near the ground.

The burn boss and holding boss saw a large dust devil form on the western portion of the burn unit. The dust devil moved northwest to southeast along the flaming front. When the dust devil hit the flame front, flames engulfed the dust devil, turning it into a fire whirl. Smoke limited their visibility but multiple firefighters on the burn mentioned that the fire whirl either crossed the Illinois River or threw spots across the river creating spot fires on the other side of the river. These spots quickly established themselves and burned southeast toward the structures along Highway 14.

Weather observations were taken on site by the burn boss using a Kestrel Drop (Picture 1). Kestrel DROPs are small, rugged, environmental data loggers used to measure relative humidity, temperature, dew point and the heat stress index. The Kestrel DROP was set to record these readings every 10 minutes and these recordings were sent to the burn boss' smartphone via Bluetooth transmissions. Kestrel DROPs do not record wind speed or direction.

Picture 1. Kestrel DROP 2 Smart Humidity Date Logger.

2: Analysis of prescribed fire plan for consistency with agency policy and guidance related to prescribed fire planning and implementation

The implemented prescribed fire plan for the Arapaho NWR broadcast burning is a programmatic plan for three ignition units. (Appendix C). The Review Team also found a programmatic prescribed burn plan for the Arapaho NWR which included twenty ignition units and was signed in 2014. (Appendix D). Programmatic burn plans are typically used when multiple units on a refuge have similar objectives, vegetation/fuel types, and complexity. Each unit should have site-specific information developed for applicable plan elements such as ignition, holding, and contingency prior to technical review and approval. Programmatic burn plans are often supplemented with a more site-specific incident action plan. Arapaho RX did have an IAP (Appendix E) on the day of the burn. The programmatic plan was originally approved in 2008. It was then updated to add three new units in 2013. This fall, the AFMO for the Rocky Basin Zone located at Bear River NWR in Utah called the project lead at the Arapaho NWR in Walden, Colorado to see if he had any units to burn. The Acting Project Leader at Arapaho, who is also new to the Refuge, is also the acting Refuge Manager. He recalled the Biologist talking about burning the next unit to the south of the Home Unit. The Acting Project Leader made the Arapaho Unit - 2015 map on 10/12/2015 (Figure 3). The Review Team found a Refuge-wide Broadcast Burn Plan signed

6/23/2014 which included twenty ignition units, one being the Fox unit, which actually included the 2015 Arapaho unit.

Success of a prescribed fire is dependent on the continuity of open and comprehensive conversations between the agency administrator, planners, cooperators, dispatch centers, and those actually implementing the burn plan. Gaps or weaknesses in coordination and communication greatly increase the probability of failure of the burn. Upon examining the information collected during this escaped prescribed fire review, frequent problems stemmed from a lack of adequate communication and coordination between members of the Arapaho NWR and Rocky Basin Fire Management Zone, in the planning phases. The people who wrote and approved the burn plan are both gone. The person who peer-reviewed and tech reviewed the burn plan is in a separate location. The Burn Boss is new to the agency and from a separate location, arrived the day before the burn and had no local resources to implement the burn.

Table 4. Prescribed Fire Plan Elements and Review Team Comments.

<table>
<tr><th>PRESCRIBED FIRE PLAN ELEMENT</th><th>COMMENTS/FINDINGS</th><th>Did this play a role in the escaped fire?</th></tr>
<tr><td>1. Signature Page</td><td>No dated signatures on the burn plan provided to dispatch and the review team. The RXB2 had a signed signature page dated 9/22/2008. The one the team found at the refuge was signed 9/10/2014 but the re-certification process says, “During the period it is valid a Plan may be executed more than once, but it must be re-approved by the Project leader/Refuge Manager prior to each ignition”. (See Appendix C and D).</td><td>Possibly, could have saved some pre planning time if they had the latest plan.</td></tr>
<tr><td>2A. Agency Administrator Ignition Authorization</td><td>No issues, signed 10/16/2015, the day of the prescribed burn.</td><td>No</td></tr>
<tr><td>2B. Prescribed Fire Go/No-Go Checklist</td><td>No issues, signed 10/16/2015, the day of the prescribed burn.</td><td>No</td></tr>
<tr><td>3. Complexity Analysis Summary</td><td>The Implemented Plan did not have a dated signature for the Complexity Analysis. The 2014 RX Plan Dated and signed 9/10/2014 had the Complexity Analysis approved by the Agency Administrator on 9/10/2014. (Appendix D, Page 46).</td><td>No</td></tr>
<tr><td>4. Description of Prescribed Fire Area</td><td>4 Project Area: The Project area for this plan was the lands within the refuge boundary which the refuge staff has identified as treatment (ignition) units.
5 Ignition Units: (Appendix C, Page 10).
<table>
<tr><th>Ignition Unit</th><th>Acreage</th></tr>
<tr><td>Hampton</td><td>149</td></tr>
<tr><td>Home - Northwest</td><td>61</td></tr>
</table></td><td>Possibly</td></tr>
</table>

	<table><tr><td>Hone - Southwest</td><td>61</td></tr></table> On 10/12/2015 the Deputy Project Lead made the map that showed the Arapaho Unit at approximately 344 acres. **D. Maps – Attach in Appendix A** 1. Vicinity – *Vicinity map that include the refuge boundary and the 2014 proposed Rx Burns.* 2. Project/Ignition unit(s) – *2014 Planned Rx Burn Map (Hampton, Home Northwest and Southwest). Did not include Arapaho Unit.* 3. Ignition Sequence Map (Required – Ground Ignition Pattern can be shown on Ignition Unit Map). – *Not included. This is the map that was created 10/12/2015 and not included in any Prescribed Burn Plans.* The 2014 Prescribed Burn Plan that was at the refuge found by the review team actually had 20 different ignition units to include the "Arapaho Unit" which was called the Fox Ignition Unit for 778.7 acres. It covered the Arapaho Unit that was created on 10/12/2015.	
5. Objectives	Resource objectives were different in the following three places: the Implemented RX Plan, the 2014 Signed RX Plan and the IAP. Objectives should describe how a treatment accomplishes project goals as described through the NEPA process and documented in the decision document.	No
6. Funding	No issues.	No
7. Prescription	The prescription was written for a backing or flanking fire. The prescription was different in the IAP than what was found in both Burn Plans. *See Adequacy of the Prescribed Fire Prescription.*	Possibly
8. Scheduling	No issues.	
9. Pre-burn Considerations and Weather	Control lines were not evaluated by the Burn Boss within three days prior to ignition for perceived viability. The RXB2 visited the site one day prior to ignitions. Weather observations were taken by the RXB2 but not broadcasted to the burn organization. They were down loaded from the Kestrel D2 by the review team. Appendix H: Contact / Notification List were not current.	Possibly
10. Briefing	No issues.	No
11. Organization and Equipment	The organization was set the morning of the prescribed burn and not included in the IAP. The plan called for two Type 6 engines and two UTV's. The burn had 4 type 6 engines and	No

	two UTV's.	
12. Communication	No issues.	No
13. Public and Personnel Safety, Medical	D. Emergency Evacuation Methods. *The IAP had coordinates from Western Utah for the Helispot Closest to Project. Also the phone numbers were the same for Greeley Air Life and North Park Medical Clinic.*	No
14. Test Fire	Test fire was completed at the appropriate location due to predicted weather.	No
15. Ignition Plan	In the 2014 RX Plan under Appendix I: Ignition Unit Specific Documentation, there was not mention of Oxbows because the Ignition Sequence map and description were found in the 2014 RX Plan that the RXB2 did not use. FIRB was assigned and scouted that morning 10/16/2015.	Possibly – different plan.
16. Holding Plan	No issues. TFLD was assigned and scouted the unit the morning of 10/16/2015.	Possibly
17. Contingency Plan	Contingency resources were on scene.	No
18. Wildfire Declaration	No issues.	No
19. Smoke Management and Air Quality	Smoke permits were obtained as per burn plan but the ignition units approved for the permit (Home RX and Hampton RX) were different than the actual Arapaho ignition unit. Smoke permits were requested on 10/14/2015 and approved 10/15/2015.	Possibly, they delayed ignition due to the smoke requirement interpretation.
20. Monitoring	No issues.	No
21. Post-burn Activities	No issues.	No
Burn Plan Appendices	B (Technical Review): Was not provided by the Burn Boss. The one found at the refuge was Technical Reviewed 4/29/2014. Should be updated to the newest approved template. C (Complexity Analysis) – The CA signed on 9/10/2014 was in the 2014 RX Plan was only for Burn Subunits Hampton, Home-NW and Home-SE. Need to include all the burn units for the Complexity Analysis. D (JHA) – Burn Boss did not have the newest plan, the team found one signed 6/23/2014 at the Refuge. E (Fire Behavior Modeling) - Some fuel models used represented the burn unit and some did not. *See Adequacy of the Prescribed Fire Prescription.*	Possibly – Not operating on the most current information leads to miss information and different outcomes.

	F (Cost) – No issues. G (Medical Plan) No dated signatures. Not using the most current prescribed fire plan. Different information in the IAP due to cut and pasting from another IAP. H (Contact List) – Not up-to-date with current positions and contact information. I (Ignition Units Specific Documentation) – Not included in the implemented plan.	
Incident Action Plan	Did not include the same information as the prescribed burn plan that was used.	No
Project File	The team was notified that they should do everything electronic and there was some confusion on what documents were stored between the Refuge in Colorado and the Fire Office in Utah.	Possibly if they had all the current information.

3: Adequacy of Prescribed Fire Prescription

The review team found three documents that contained the burn prescription:

1. The burn plan used by the burn boss to implement the burn.
2. The burn Incident Action Plan (IAP) handed out to the briefing the day of the burn which contained the ignition units that were burned.
3. The burn plan at the Arapaho Refuge which contains the signatures of the agency administrator.

Prescription discrepancies that were found are listed in the following table (Table 5). To determine if the burn was ignited within prescription the review team used the parameters found in the Burn Plan at the Refuge and did not use the prescription in the Incident Action Plan (IAP).

Table 5. Prescription comparisons between the two burn plans and the IAP.

	Burn Plan Used (1)	IAP (2)	Burn Plan at Refuge (3)
Temperature (F)	30-89	30-89 desired 60	30-89
Relative Humidity	10-59%	15-59 desired 20	10-59%
Eye Level Winds	0-15 mph	1-15 desired 7	0-15 mph
Wind Direction	SW-N-SE (SSW-S-SSE is excluded)	315-any	SW-N-SE, (SSW-S-SSE is excluded)
Calculated 1 Hr Fuel Moisture	2-12%	3-11 desired 5	2-12%
Flame length – observed along perimeter	0-5 feet	Backing 1.7 Flanking 1.0-2.4 Head 1.9-10.0	0-5 feet
Fuel Models Used	GR8, GR2, GS2, 8	FM1	GR8, GR2, GS2,8
Number of ignition units	Three Units (They did not include the units that were burned)	Two Units (both slightly different from the Rx Plans)	20 Units (Fox Unit was burned)

The burn plans (1) and (3) mention that the desired fire behavior using the prescription is for a backing or flanking fire. Flame lengths along the perimeter of the fire were not to exceed five feet. One can assume that head fire could and probably would occur within the unit away from any control lines along the perimeters. The ox bows along the eastern edge of the burn unit from maps provided in the IAP would make it almost impossible to burn without expecting some head fire. The burn plan at the Arapaho Refuge (3) does not mention using the Illinois River with all of its ox bows as a unit perimeter. Instead, the toe of the hill just west of Highway 14 is the eastern burn perimeter which is found in the Refuge Burn Plan (3) in Appendix I under Fox Unit. It was not found in Burn Plan (1).

Fuels along the eastern edge of the Fox Unit are a moderate load, dry climate grass-shrub (GS2). Flame lengths from a backing or flanking fire in this fuel model (GS2) would not exceed five feet under the burn plan (1) and (3) prescription.

Mow lines were created along the northern and southern end of the IAP burn unit. This changed the fuel characteristics and essentially changed the fuel model from a high load, dry climate grass (GR7) to a low load, dry climate grass (GR2). Flame lengths from a backing or flanking fire in this fuel model (GR2) would not exceed feet limit stated in the burn plans (1) and (3).

The fuel model for the un-mowed perimeter lines along the Illinois River is represented by a GR7 fuel model. This fuel model is not in any burn plan prescription and does not keep flame lengths under the 5 foot prescription. Table 6 details the fuel models in the burn plans. Photos of the respective fuel models are located in Appendix L. Fuel Model 8 and GR8 are both mentioned in the plan but do not represent the fuels that were burned.

Table 6. Fuel models listed in the two burn plans and the IAP. Fuels Model GR7 was never listed in any of the plans but this model represents most of the burn unit.

Fuel Models within the Two Burn Plans and the IAP		
Fuel Model Letter or #	**Description**	**Plan Location**
GS2**	Moderate Load, Dry Climate Grass-Shrub	Both RX Plans
FM 1*	Short Grass	IAP
GR2**	Low Load, Dry Climate Grass	Both RX Plans
GR8**	High Load, Very Coarse, Humid Climate Grass	Both RX Plans
FM 8*	Closed, Short Needle Timber Litter	Both RX Plans
GR7**	High Load, Dry Climate Grass	Is representative of the Burn Unit
*Anderson, 1982	** Scott and Burgan 2005	

All of the environmental prescription parameters on the burn were within both burn plan prescriptions. All the environmental parameters within the IAP were met with the exception of relative humidity. In the high fire intensity column of the prescription in the IAP, relative humidity was 15% but actual reading during the burn was 10 %. Both burn plans allow for the relative humidity to go as low as 10%.

The burn plans did not list desired prescription parameters, instead the prescription stated a range for acceptable environmental parameters. The IAP for the burn and most burn plans include a table like the one below. The Arapaho Burn Plans did not have a similar table.

Table 7. Environmental prescription table used in the IAP.

A. Environmental Prescription:	Acceptable Prescription Range			Outside area at critical holding point minimum acceptable moisture
	Low Fire Intensity	Desired Fire Intensity	High Fire Intensity	
Temperature (°F)	30	60	89	
Relative humidity (%)	59	20	15	
Mid-flame wind speed	1	7	15	
Wind direction (azimuth°)	315 -any	315-any	315-any	
1-hr fuel moisture (%)	11	5	3	3
10-hr fuel moisture (%)	12	7	4	n/a
100-hr fuel moisture (%)	n/a	n/a	n/a	n/a
1000-hr fuel moisture %	n/a	n/a	n/a	n/a
Live fuel moisture (%)	300	120	50	n/a
Duff moisture (%)	n/a	n/a	n/a	n/a
Soil moisture (%)	n/a	n/a	n/a	n/a
Additional Information				
1 hour fuels will be measured the traditional way via the Fire Line Handbook or Fire behavior Field Reference guide based on Temperature, Relative Humidity, Time of day, Month, Percent Slope, & aspect. Aspect will be considered **South** for all Arapaho units				

Both burn plans mention blackline operations as a possible implementation tool but the prescription only includes the primary ignition. There is no prescription indicated for blacklining. Assuming the prescriptions are the same, both should be included in the burn plan.

4: Approving agency administrator's qualifications, experience, and involvement

The Project Leader (PL) is responsible for the safe and efficient implementation of fire management activities within their unit, including cooperative activities with other agencies or landowners, in accordance with delegations of authorities. The Project Leader on the Arapaho NWR is vacant and the Acting Project Leader (APL) was the agency administrator for the Arapaho prescribed burn. The APL signed the Agency Administrator Ignition Authorization on the morning of the burn, October 16, 2015.

In March of 2015, the APL completed the Local Fire Management Leadership course in Grand Junction, CO.

5: Qualifications and experience of key personnel involved

All personnel associated with the Arapaho prescribed fire were qualified for their positions. Position codes listed in the Incident Qualification and Certification System (IQCS) master record and that are labeled "On Red card" are listed below. Trainee positions are indicated by "t" following the position code.

Technical Reviewer: RXB2 Qualified

Burn Boss (RXB2): ATGS, ATVO, CRWB, ENGB, ICT3, RXB2, STEN, TFLD

Firing Boss (FIRB): BHAV, DIVS, FBAN, FIRB, ICT3, TFLD

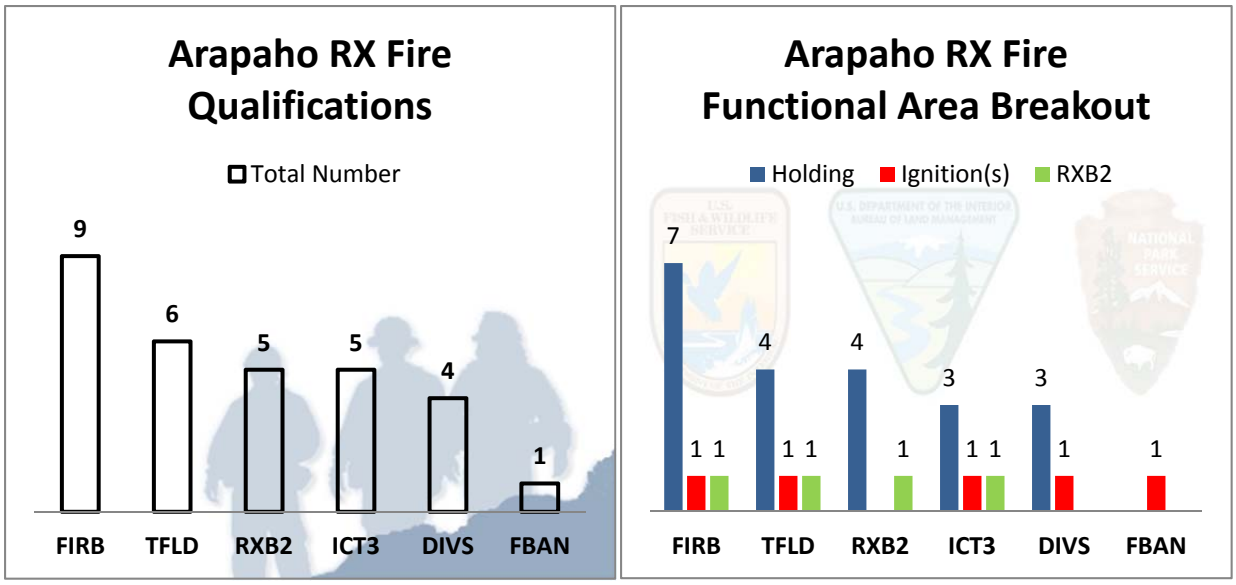
Firing Boss (FIRB)"t": ATVO, CRWB, ENGB, FAL3, HECM, ICT4, UTVO, WTOP

Holding Boss (TFLD): AREP, DIVS, FIRB, ICT3, RXB2, SOPL

Weather monitoring duties were done by the RXB2 as no Fire Effects Monitor (FEMO) was available or assigned to monitor weather.

In addition, the 19 fire personnel assigned to the Arapaho Prescribed Fire carried a higher level of prescribed fire and wildfire qualifications. Below in Graph 4 is a breakdown of fire qualifications.

Graph 4. Fire personnel qualifications.



6: Communication

The success of a prescribed fire is dependent on the continuity of open and comprehensive conversations between the agency administrator, planners, cooperators, dispatch centers, and those actually implementing the burn plan. Gaps or weaknesses in coordination and communication greatly increase the probability of failure of the burn.

Assuming that everyone did their jobs competently, the cause for an escape does not reside with any one person. Therefore, closer – open and comprehensive – communication and *true* team involvement in the burn's planning and preparation stages could significantly lessen the probability of escape.

While this level of communication and coordination might not always be possible, burn bosses *always* need to recognize that they could be walking into a situation where the expectation to successfully burn is high and problems – not apparent in the burn plan – could exist that might easily jeopardize the success of their burn.

Recommendations

- Burn overhead personnel (Burn Boss, Firing Boss, and Holding Boss) should walk the burn unit as a group, noting any potential trouble spots in advance of ignition while discussing how to resolve them.

- The Fire Management staff should thoroughly review the burn plan prior to implementation to understand what the burn plan requires and to understand the decision space provided within the burn plan. Consider conducting a sand table or Google Earth scenario if an on-site visit is not feasible.

- When an Incident Action Plan is prepared for a prescribed burn, ensure consistency with the burn plan.

- Given the level of communication within the burn team, it was acknowledged that this may make them vulnerable to confirmation bias or "Group Think". To combat this tendency, the group may want to consider making more use of outside observers or internal players who are able to play "devil's advocate" to question the groups reasoning and force decisions to be analyzed with a critical eye.

- Spend more time "gaming out" all possible scenarios where fire movement can give you problems. For instance, identifying and addressing contingencies for fire in inaccessible areas.

- Engage internal and external players early on (partners, cooperators, managers, etc.)

- Ensure layout of prescribed burns takes advantage of the best holding lines available.

- Identification of weak holding points may best determine the required resource mix.
- Ensure documentation is thorough and complete pre, during, and post-prescribed fires.
- Communicate site specific weather reading over the local tactical radio throughout the burn operation.

Lessons Learned

Effective Communication

• All individuals involved in implementing a prescribed burn have a shared responsibility to voice concerns, hazards or issues when recognized at any point throughout the planning process or operational period.	• Critical questions need to be asked such as: What could go wrong? What am I not seeing that you might be seeing? Who holds the "big picture" of what is going on? This "disconfirming process" could have helped detect or anticipate problems. • Be willing to share your experiences and observations with others. Some participants regret that they had seen signals on other burns that could have provided some indication of what potential fire behavior could be on October 16. In retrospect, they now wish they would have been more eager to share their experience and insights with the rest of the burn team.

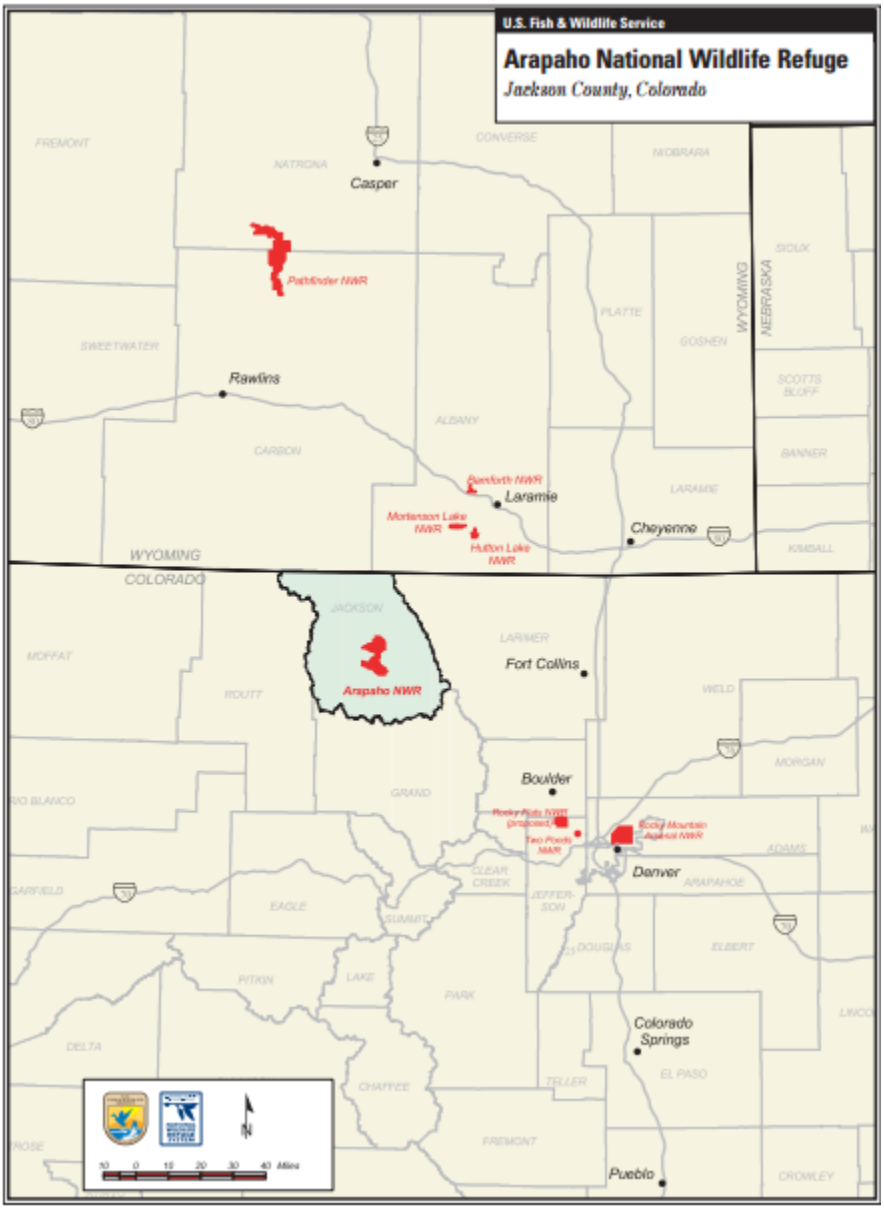
Commendations:

Team Selection: All personnel were qualified and experienced for their assigned prescribed fire positions. The organization for this prescribed burn was a highly qualified and competent group.

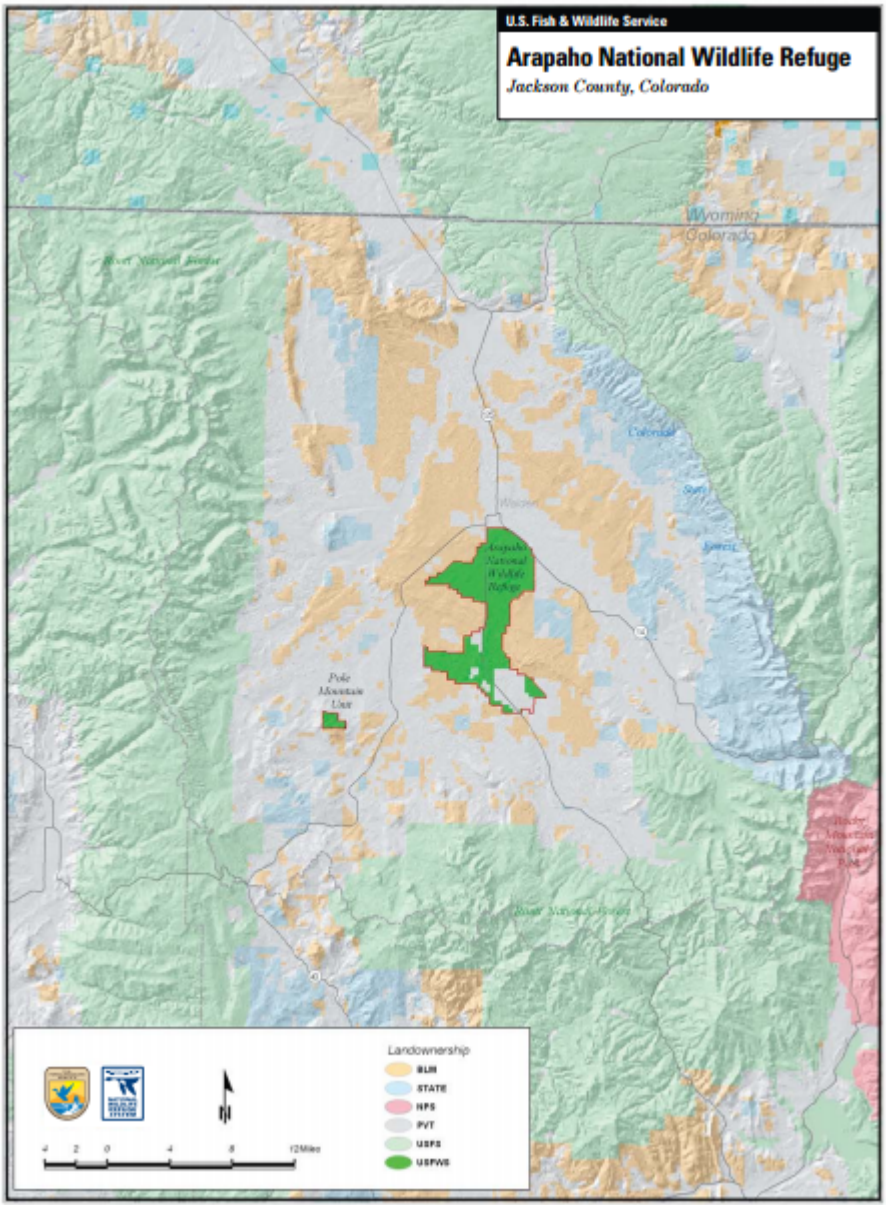
Wildfire Declaration: The Burn Boss did an excellent job in safely reconfiguring from prescribed fire organization to a wildfire organization when the prescribed fire was converted to a wildfire.

Appendix A: Maps

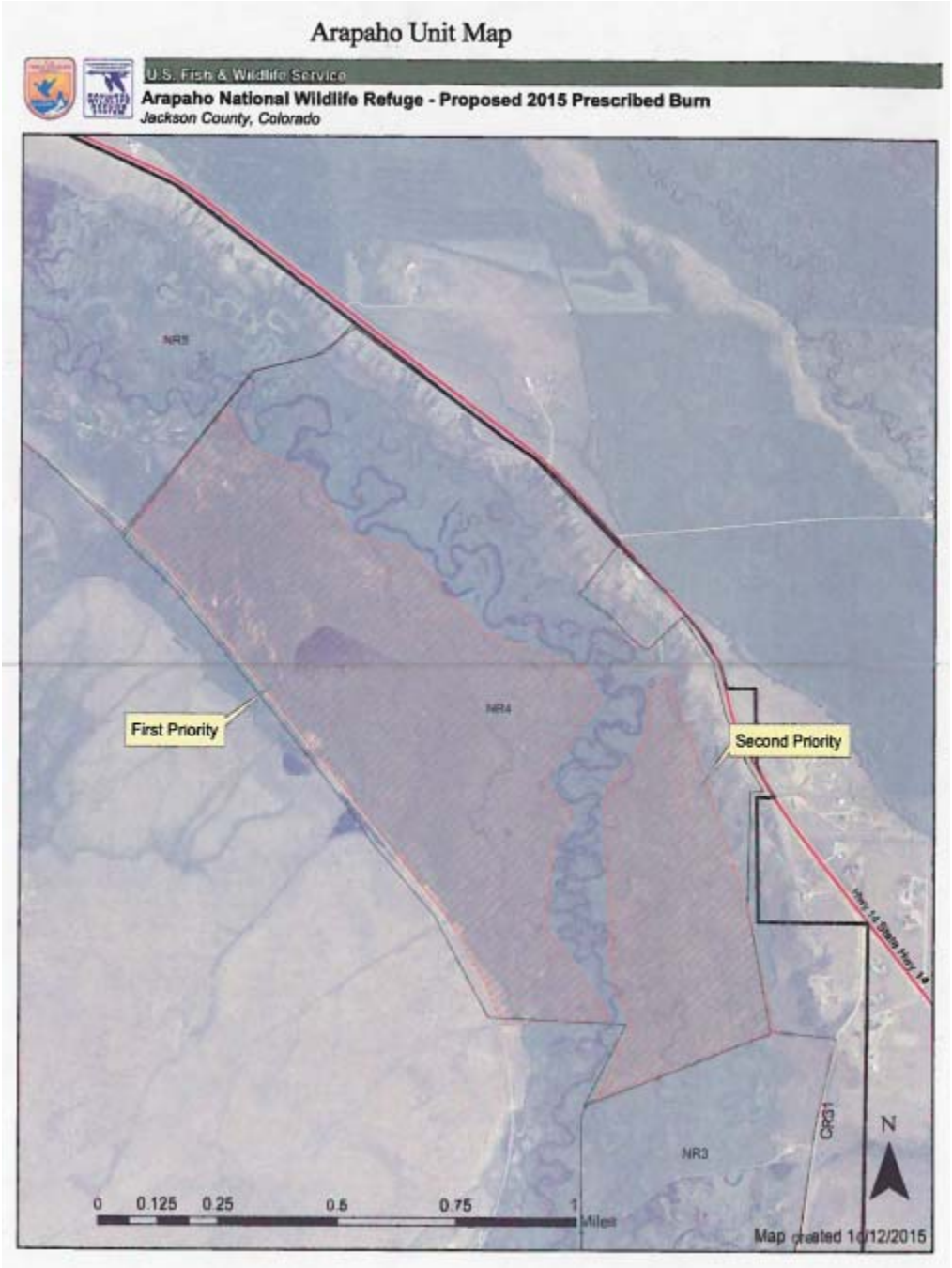
Map 4. Vicinity map for Arapaho National Wildlife Refuge, Colorado



Map 5. North Park area of Colorado



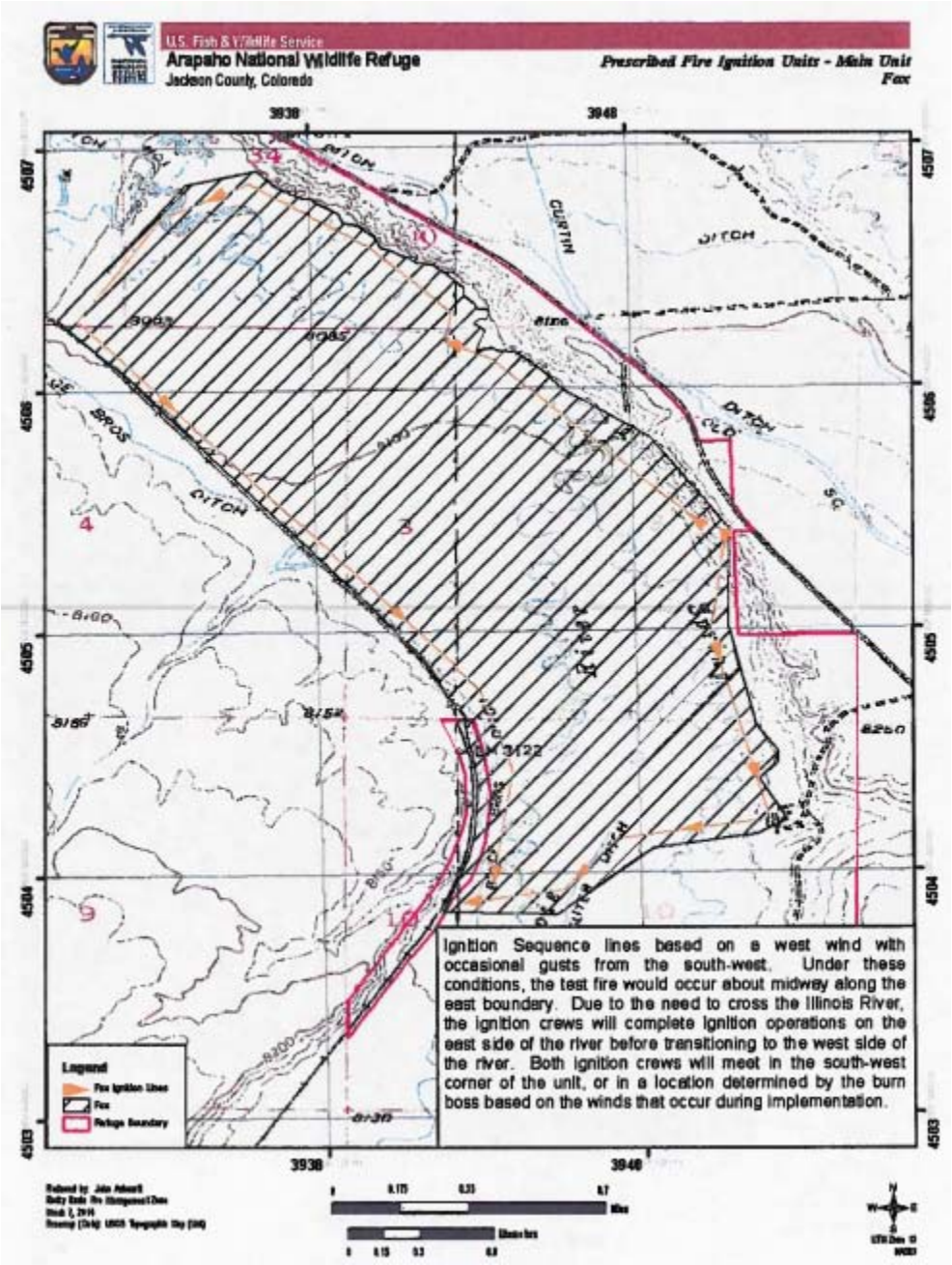
Map 6. Arapaho Unit Map



Map 7. Prescribed Fire Ignition Map – Main Unit Fox (2014 Prescribed Burn Plan).

Maps:

Map 8. Prescribed Fire Ignition Sequence Map – Main Unit Fox (2014 Prescribed Burn Plan).



Appendix B: Photos

Photo 1. Overview of Arapaho Unit showing the test fire site.

Photo 2. Starting to burn out the first oxbow.

Photo 3. Completing the first oxbow.

Photo 4 Center firing the oxbow to pull the fire together.

Photo 5. The RX burn starts to be a northerly wind.

Photo 6. RX burn is starting to push to the south.

Photo 7. Head fire pushing south.

Photo 8. View of the burn unit the following week.

Appendix C: Implemented Prescribed Fire Plan (2008-2014 Combination)

http://gacc.nifc.gov/rmcc/dispatch_centers/r2crc/dispatch/Plans%20and%20Guides/RX%20Burn%20Plans/CO-ARR%20Programmatic%20Broadcast%20RX%20Plan%202014.pdf

Appendix D: 2014 Signed Prescribed Fire Plan

http://gacc.nifc.gov/rmcc/dispatch_centers/r2crc/dispatch/Plans%20and%20Guides/RX%20Burn%20Plans/2014%20RX%20Plan.pdf

Appendix E: Arapaho Incident Action Plan (IAP)

http://gacc.nifc.gov/rmcc/dispatch_centers/r2crc/dispatch/Plans%20and%20Guides/RX%20Burn%20Plans/IAP%20-%20Arapaho%20Rx%202015.pdf

Appendix F: Arapaho Smoke Permit

Burn Name **Arapaho**

2015 COLORADO BROADCAST PRESCRIBED FIRE SMOKE PERMIT

PROJECT-SPECIFIC PERMIT CONDITIONS:

Conditions category **1c rural** Maximum annual perimeter acres **600**

Ventilation[1]	Acres[2]	End Ignition by X Hour(s) before Sunset	Wind Directions[3]
Excellent or Very Good	600	end by sunset	Any if 300 acres or less; SW – SE (No South) 301 acres or greater
Good	600	end by sunset	Any if 300 acres or less; SW – SE (No South) 301 acres or greater
Fair	600	1	SW – SE (No South)
Poor	0	No burning	n/a

GENERAL PERMIT CONDITIONS:

1. Notify the public at least 24 hours but no more than 120 hours before planned ignition. Include the name of a person whom the public may contact regarding the burn.
2. Send APCD a Notification of Ignition 2-48 hours before each day of expected ignition.
3. Unless otherwise specified above, this permit is not valid during periods of publicly announced air pollution emergencies or alerts in the area of the proposed burn.
4. Use a National Weather Service forecast to establish compliance with the permit's weather conditions. Keep a copy of the forecast for 18 months.
5. The burn supervisor must have a copy of this permit on site.
6. Burn only the forest fuel described in the application. Do not burn milled or treated lumber.
7. Monitor the burn's smoke.
8. This project has not been reviewed for fire safety or road or other transportation safety.
9. Send APCD a Daily Actual Activity form by 10:00 on the business day after each notified ignition day, regardless of whether the burn occurred.
10. Send APCD an Annual Fire Activity form by March 1 of the following year, even if no burning occurs.
11. This permit is for compliance with state air pollution control requirements only. It is not a permit to violate any existing local laws, rules, regulations, or ordinances regarding fire,

[1] National Weather Service's forecast of day's best ventilation adjective
[2] Maximum daily black perimeter acres, including blackllning
[3] Range of acceptable transport wind directions, listed clockwise and precise to 2 letters.

Colorado Air Pollution Control Division, Smoke Management Program
Permit expires December 31.
page 1 of 7

Permit Number: **ARR-15-319**

Appendix G: Spot Weather Forecast

Spot Forecast for Arapaho Rx Burn

National Weather Service NWFO Denver/Boulder
659 AM MDT Fri Oct 16 2015

```
IF CONDITIONS BECOME UNREPRESENTATIVE,
CONTACT THE NATIONAL WEATHER SERVICE.

SPOT FORECAST FOR ARAPAHO RX...USFWS
NATIONAL WEATHER SERVICE DENVER/BOULDER CO
659 AM MDT FRI OCT 16 2015

FORECAST IS BASED ON IGNITION TIME OF 1030 MDT ON OCTOBER 16.
IF CONDITIONS BECOME UNREPRESENTATIVE...CONTACT THE NATIONAL
WEATHER SERVICE.

.DISCUSSION...AN UPPER LEVEL RIDGE AXIS WILL REMAIN OVER THE AREA
THROUGH TONIGHT AND THEN SHIFT SLOWLY EASTWARD THROUGH THE
WEEKEND. DRY CONDITIONS WILL PERSIST THROUGH SATURDAY...WITH A
SLIGHT CHANCE OF SHOWERS REACHING THE FORECAST AREA BY SUNDAY.
TEMPERATURES WILL REMAIN ABOVE NORMAL WITH LOW HUMIDITY READINGS
FOR THIS TIME OF YEAR. THE WARM TEMPERATURES WILL RESULT IN GOOD
MIXING AND SMOKE DISPERSION DURING THE LATE MORNING AND AFTERNOON
HOURS.

.TODAY...

SKY/WEATHER.........SUNNY.
MAX TEMPERATURE.....AROUND 64.
MIN HUMIDITY........20%.
WIND (20 FT)........UPSLOPE/UPVALLEY 4-10 MPH UNTIL 1200...THEN
                    WEST 8-10 MPH WITH GUSTS TO 20 MPH.
CWR.................0 PERCENT.
LAL.................1.
HAINES INDEX........5 MODERATE.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 1000. 7300-8300 FT AGL
                    AFTER 1500.
TRANSPORT WINDS.....SOUTH AROUND 10 MPH UNTIL 1200...THEN WEST.
SMOKE DISPERSAL.....POOR UNTIL 1200...FAIR UNTIL 1400...THEN GOOD
                    AFTER 1400.

.TONIGHT...
SKY/WEATHER.........PARTLY CLOUDY(30-35%).
MIN TEMPERATURE.....AROUND 30.
MAX HUMIDITY........90%.
WIND (20 FT)........DOWNSLOPE/DOWNVALLEY 2-8 MPH.
CWR.................0 PERCENT.
LAL.................1.
HAINES INDEX........3 VERY LOW.
MIXING HEIGHT.......6400 FT AGL UNTIL 1900. BELOW 1000 FT AGL AFTER
                    2100.
```

TRANSPORT WINDS.....SOUTHWEST UP TO 10 MPH UNTIL 2400...THEN LIGHT.
SMOKE DISPERSAL.....FAIR UNTIL 1900...THEN POOR.

.SATURDAY...
SKY/WEATHER.........PARTLY CLOUDY(40-50%) UNTIL 1200...THEN MOSTLY
                    CLOUDY.
MAX TEMPERATURE.....AROUND 65.
MIN HUMIDITY........30%.
WIND (20 FT)........UPSLOPE/UPVALLEY 4-10 MPH.
CWR.................0 PERCENT.
LAL.................1.
HAINES INDEX........3 VERY LOW.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 1000. 7900-8900 FT AGL
                    AFTER 1200.
TRANSPORT WINDS.....SOUTHWEST AROUND 10 MPH.
SMOKE DISPERSAL.....POOR UNTIL 1200...THEN GOOD UNTIL 1600...THEN
                    FAIR UNTIL 1700...THEN POOR.

.FORECAST DAYS 3 THROUGH 5...
.SUNDAY...MOSTLY CLOUDY. SLIGHT CHANCE OF RAIN SHOWERS AND
ISOLATED THUNDERSTORMS. LOWS IN THE MID 30S. HIGHS IN THE LOWER
60S. TYPICAL SLOPE/VALLEY WINDS LESS THAN 10 MPH.
.MONDAY...MOSTLY CLOUDY. SLIGHT CHANCE OF RAIN SHOWERS...SNOW
SHOWERS AND ISOLATED THUNDERSTORMS. LOWS IN THE MID 30S. HIGHS IN
THE LOWER 60S. TYPICAL SLOPE/VALLEY WINDS LESS THAN 10 MPH.
.TUESDAY...PARTLY CLOUDY. CHANCE OF RAIN AND SNOW SHOWERS. LOWS
IN THE LOWER 30S. HIGHS IN THE UPPER 50S. TYPICAL SLOPE/VALLEY
WINDS LESS THAN 10 MPH.

FIRE WEATHER TABLE FOR ARAPAHO RX.

+++ DATA IN THE FOLLOWING TABLE HAS BEEN SAMPLED DIRECTLY FROM THE
     FORECAST DATABASE. VALUES IN THE TABLE MAY VARY SLIGHTLY FROM
     INFORMATION IN THE NARRATIVE FORECAST. FEEDBACK WELCOME. +++

FORECAST VALID AT	SC %	PP %	WR %	AT F	RH %	20-FT WIND MPH	G S T	H I L	A L	15KFT WIND MPH	MIXG HGT AGL	TRANS WIND MPH	VENTL RATE KT-FT	AJTV RATNG
10/16-06	0	0	0	28	88	S	3	3	4	1	W 12	554	S 5	2222	P
10/16-07	0	0	0	26	100	S	2	2	4	1	W 13	564	S 5	2185	P
10/16-08	0	0	0	28	95	S	2	2	5	1	W 14	574	S 5	2146	P
10/16-09	0	0	0	36	70	S	2	2	5	1	W 14	584	SSW 5	2104	P
10/16-10	5	0	0	45	48	S	5	5	5	1	W 15	1924	SSW 7	10864	P
10/16-11	10	0	0	51	38	SW	7	7	4	1	W 16	3265	WSW 9	25096	P
10/16-12	15	0	0	56	30	WSW	9	15	4	1	W 16	4605	WSW 12	44801	F
10/16-13	14	0	0	60	25	WSW	10	17	4	1	WNW 16	5872	WSW 12	59593	F
10/16-14	13	0	0	62	22	W	12	18	3	1	WNW 15	7139	W 13	75451	G
10/16-15	13	0	0	64	20	W	12	18	3	1	WNW 15	8406	W 13	92373	G
10/16-16	16	0	0	62	21	W	10	16	3	1	WNW 14	7743	W 12	75559	G
10/16-17	20	0	0	61	22	W	9	14	3	1	WNW 13	7080	W 10	60377	G
10/16-18	24	0	0	57	27	W	7	7	3	1	W 12	6417	WNW 8	46826	F

```
10/16-19 23  0  0 51 34 WSW  6  6 3 1   W 12  4495   W  7 25444 P
10/16-20 23  0  0 48 39 SSW  5  5 3 1   W 12  2573  SW  5 10353 P
10/16-21 22  0  0 44 47   S  5  5 3 1   W 12   651 SSW  2  1554 P
10/16-22 22  0  0 39 58   S  5  5 3 1   W 13   615 SSW  3  2001 P
10/16-23 21  0  0 38 61   S  5  5 3 1   W 14   579   S  5  2386 P
10/17-00 21  0  0 36 67   S  5  5 3 1   W 15   544   S  6  2710 P
10/17-01 25  0  0 34 73   S  5  5 3 1   W 15   524   S  6  2716 P
10/17-02 29  0  0 32 79   S  6  6 3 1   W 15   505   S  6  2715 P
10/17-03 33  0  0 32 78   S  6  6 3 1   W 15   486 SSW  7  2707 P
10/17-04 37  0  0 33 74   S  6  6 3 1 WSW 14   494 SSW  7  2981 P
10/17-05 41  0  0 32 76   S  5  5 3 1 WSW 14   503 SSW  7  3046 P
10/17-06 45  5  1 31 78   S  5  5 3 1 WSW 13   511 SSW  7  3112 P
10/17-07 45  5  1 30 90   S  5  5 3 1 WSW 12   538 SSW  7  3200 P
10/17-08 46  5  1 34 83   S  5  5 2 1  SW 12   565 SSW  7  3281 P
10/17-09 47  5  1 40 70   S  5  5 2 1  SW 12   592 SSW  7  3354 P
10/17-10 47  5  1 47 56 SSW  5  5 2 1  SW 12  2757 SSW  7 17662 P
10/17-11 47  5  1 54 44 SSW  6  6 3 1  SW 13  4922 SSW  8 35170 P
10/17-12 70  7  1 61 35  SW  6  6 3 1  SW 13  7087 SSW  9 55878  F
10/17-13 70  7  1 64 32  SW  6  6 3 1 SSW 14  7893 SSW  9 60798   G
10/17-14 70  7  1 65 30  SW  7  7 3 1 SSW 15  8699 SSW  9 65424   G
10/17-15 70  7  1 65 30  SW  7  7 3 1 SSW 16  9506 SSW  8 69757   G
10/17-16 70  7  1 64 31  SW  7  7 3 1 SSW 16  8584 SSW  7 51248  F
10/17-17 70  7  1 62 33 SSW  6  6 3 1   S 15  7663   S  6 35261 P
10/17-18 85  6  1 59 37 SSW  6  6 3 1   S 15  6741 SSE  3 21797 P
10/17-19 85  6  1 54 47 SSW  6  6 3 1   S 15  4707   S  5 17957 P
10/17-20 85  6  1 49 59   S  6  6 3 1   S 15  2673   S  5 11751 P
10/17-21 85  6  1 44 73   S  6  6 3 1   S 15   639   S  6  3180 P
10/17-22 85  6  1 41 82   S  6  6 3 1   S 15   595 SSW  7  3578 P
10/17-23 85  6  1 39 87   S  5  5 2 1 SSW 15   552 SSW  8  3886 P
10/18-00 74  9  2 38 89   S  5  5 2 1 SSW 15   509 SSW  9  4105 P
10/18-01 74  9  2 38 90   S  5  5 2 1 SSW 16   484 SSW  9  3692 P
10/18-02 74  9  2 38 92   S  6  6 2 1 SSW 17   459  SW  8  3301 P
10/18-03 74  9  2 37 96   S  6  6 2 1 SSW 20   434  SW  8  2932 P
10/18-04 74  9  2 36 97   S  6  6 2 1 SSW 20   415  SW  8  2824 P
10/18-05 74  9  2 35 98   S  6  6 2 1  SW 21   395 SSW  8  2714 P
10/18-06 70  9  2 34100   S  6  6 2 1  SW 22   376 SSW  8  2601 P
10/18-07 70  9  2 35 99 SSW  6  6 2 1  SW 23   507 SSW  9  3886 P
10/18-08 70  9  2 37 96 SSW  7  7 2 1  SW 23   638 SSW  9  5366 P
10/18-09 70  9  2 41 86 SSW  7  7 2 1  SW 24   769 SSW 10  7042 P
10/18-10 70  9  2 48 66 SSW  8 13 2 1  SW 26  2478 SSW 16 33918 P
10/18-11 70  9  2 54 53  SW  8 14 2 1  SW 28  4187  SW 21 76272   G
10/18-12 70 18  4 59 44  SW  9 15 2 2  SW 29  5895 WSW 26134104    V
10/18-13 70 18  4 62 39  SW  9 15 2 2 WSW 29  6532 WSW 25141470    V
10/18-14 70 18  4 63 38  SW  9 15 2 2 WSW 29  7169 WSW 24147448    V
10/18-15 70 18  4 62 39  SW  9 15 2 2 WSW 29  7806 WSW 22152038     E
10/18-16 70 18  4 61 40  SW  9 14 2 2 WSW 30  7134 WSW 22136740    V
10/18-17 70 18  4 59 43  SW  8 14 2 2 WSW 32  6461 WSW 22121858    V
10/18-18 58 14  3 56 47  SW  8 13 2 2 WSW 35  5789 WSW 22107392    V
10/18-19 58 14  3 51 56  SW  7  7 2 2 WSW 33  4089 WSW 17 62667   G
10/18-20 58 14  3 46 68  SW  7  7 2 2 WSW 32  2389  SW 14 28909 P
10/18-21 58 14  3 42 79  SW  6  6 2 2 WSW 31   689  SW 10  6116 P
10/18-22 58 14  3 40 85 SSW  6  6 2 2 WSW 32   702  SW  9  5372 P
10/18-23 58 14  3 38 90 SSW  5  5 2 2 WSW 32   714 SSW  7  4597 P
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10/19-00 53 11  2 37 92 SSW  5  5 2 1   W 33   727 SSW  6  3791 P
10/19-01 53 11  2 37 91 SSW  5  5 2 1 WSW 35   688 SSW  6  3579 P
10/19-02 53 11  2 36 93 SSW  5  5 2 1 WSW 36   648 SSW  6  3367 P
10/19-03 53 11  2 36 91 SSW  5  5 2 1 WSW 38   609 SSW  6  3156 P
10/19-04 53 11  2 35 94 SSW  5  5 2 1 WSW 37   611 SSW  6  3226 P
10/19-05 53 11  2 34 97   S  5  5 2 1 WSW 36   614 SSW  6  3298 P
10/19-06 65 13  3 34 96   S  5  5 2 1  SW 35   616   S  6  3369 P

KEY:

FORECAST    - MONTH/DAY-HOUR OF FORECAST
VALID AT    - /24-HOUR CLOCK LOCAL TIME/
SC          - SKY COVER /PERCENT/
PP          - PROBABILITY OF PRECIPITATION 0.01 INCH /PERCENT/
WR          - PROBABILITY OF WETTING RAIN 0.10 INCH /PERCENT/
AT          - TEMPERATURE /DEGREES F/
RH          - RELATIVE HUMIDITY /PERCENT/
20-FT WIND  - 20-FOOT WIND /MPH/
GST         - 20-FOOT WIND GUST /MPH/
HI          - HAINES INDEX
LAL         - LIGHTNING ACTIVITY LEVEL
15KFT WIND  - 15000 FEET ABOVE MEAN SEA LEVEL FREE-AIR WINDS /MPH/
MIXG HGT    - MIXING HEIGHT /FEET ABOVE GROUND LEVEL/
TRANS WIND  - TRANSPORT WINDS /MPH/
VENTL RATE  - VENTILATION RATE /KNOT-FEET/
AJTV RATNG  - SMOKE DISPERSION ADJECTIVE RATING
                P - POOR  F - FAIR  G - GOOD
                V - VERY GOOD  E - EXCELLENT
```

Appendix H: RAWS and on Site Weather Data

Table 8. On site weather taken from a Kestrel Drop 2

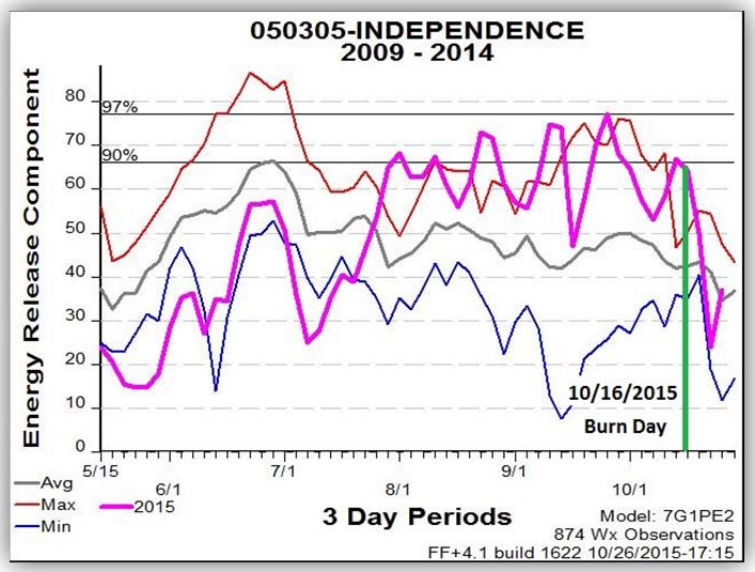
On Site Weather Taken for Kestrel Drop 2 Obtained from the Burn Boss				
Device Name			Bear River #1	
Device Model			Kestrel DROP 2	
FORMATTED DATE-TIME	Temperature	Relative Humidity	Heat Stress Index	Dew Point
YYYY-MM-DD HH:MM:SS	Â°F	%	Â°F	Â°F
10/16/15 10:00	67.4	22.6	62.6	28
10/16/15 11:10	66.6	21.4	61.3	26
10/16/15 11:20	61.9	21.2	56.5	21.9
10/16/15 11:30	74.7	17.8	70.3	28.1
10/16/15 11:40	67.9	16.6	62.8	21
10/16/15 11:50	71.1	15.9	67.1	22.5
10/16/15 12:00	78.2	14.8	73	26.6
10/16/15 12:10	74.4	14.7	69.6	23.4
10/16/15 12:20	79.9	12.9	74.7	24.6
10/16/15 12:30	79.6	11.7	74.1	21.9
10/16/15 12:40	71.6	13	67.3	18.2
10/16/15 12:50	72.7	13.9	68.4	20.6
10/16/15 13:00	68.5	13.6	63.3	16.7
10/16/15 13:10	69	13.1	63.9	16.4
10/16/15 13:20	72.9	14.3	68.5	21.5
10/16/15 13:30	70.4	13.5	66.2	18.2
10/16/15 13:40	68.4	13.8	63.3	17.2
10/16/15 13:50	67.6	13.7	62.1	16.2
10/16/15 14:00	70.2	12.9	65.7	17
10/16/15 14:10	68.7	12.6	63.7	15.2
10/16/15 14:20	70.7	12.7	66.6	17
10/16/15 14:30	69.9	12	65.1	15
10/16/15 14:40	76.5	10.4	71.2	16.8
10/16/15 14:50	70.5	10.8	66	13.1
10/16/15 15:00	70.5	11.6	65.8	14.7
10/16/15 15:10	68.2	11.5	62.8	12.6
10/16/15 15:20	67.4	11.9	61.5	12.9
10/16/15 15:30	67.9	11.3	62.2	12.1
10/16/15 15:40	67.6	12.2	61.9	13.6
10/16/15 15:50	68.8	11.9	63.7	14
10/16/15 16:00	69.9	11	64.9	13

Table 9. NFDRS data pulled from two nearby RAWS stations and the East Zone Preparedness and Dispatch Levels for the day of the burn.

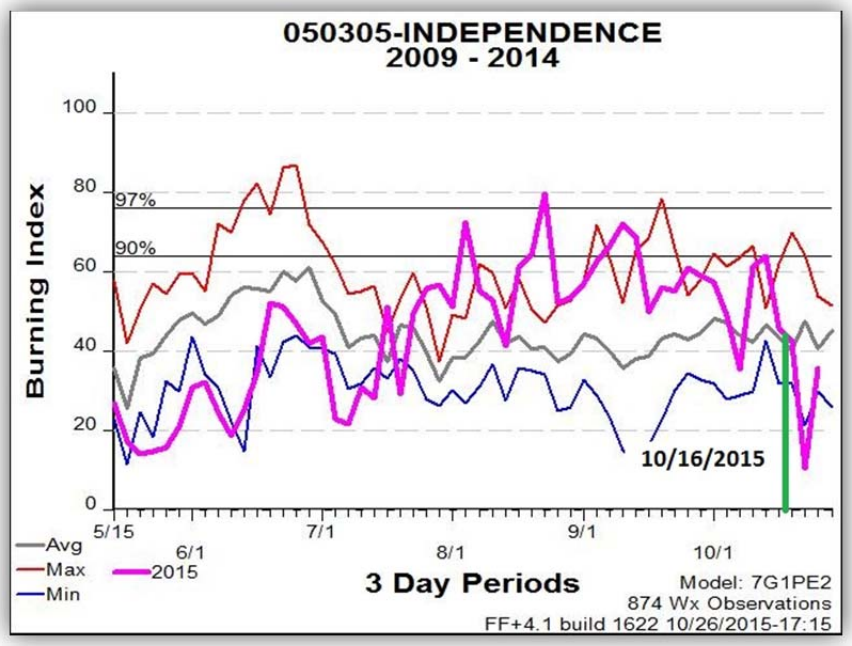
NFDRS* and RAWS Data				
Date	**Indices**	**Zone or RAWS Station**	**Rating**	**Percentile**
10/16/2015	Preparedness Level	East Zone	III*	N/A
10/16/2015	Dispatch Level	East Zone	High	N/A
10/16/2015	Adjective Rating	East Zone	Moderate	N/A
10/16/2015	Energy Release Component	Independence	65	88%
10/16/2015	Burn Index	Independence	50	70%
10/16/2015	1 Hour 1300 Reading	Independence	3	90%
10/16/2015	10 Hour 1300 Reading	Independence	4	90%
10/16/2015	Energy Release Component	Willow Creek	59	84%
10/16/2015	Burn Index	Willow Creek	64	78%
10/16/2015	1 Hour 1300 Reading	Willow Creek	4	80%
10/16/2015	10 Hour 1300 Reading	Willow Creek	5	80%
*NFDRS indices use fuel model G				
**Duty Officer Adjusted from a IV to a III				

Appendix I: NFDRS ERC and BI Charts

Graph 5. Independence RAWS ERC Chart near the 90th percentile on the day of the burn (10/16/2015).

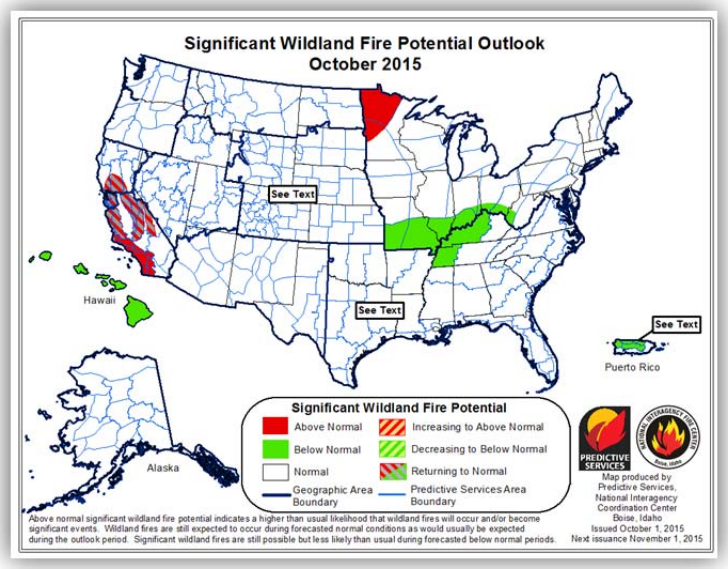


Graph 6. Burning Index from the Independence RAWS 15 miles northeast of the Arapaho Prescribed Fire. The Burning Index was average the day of the burn.

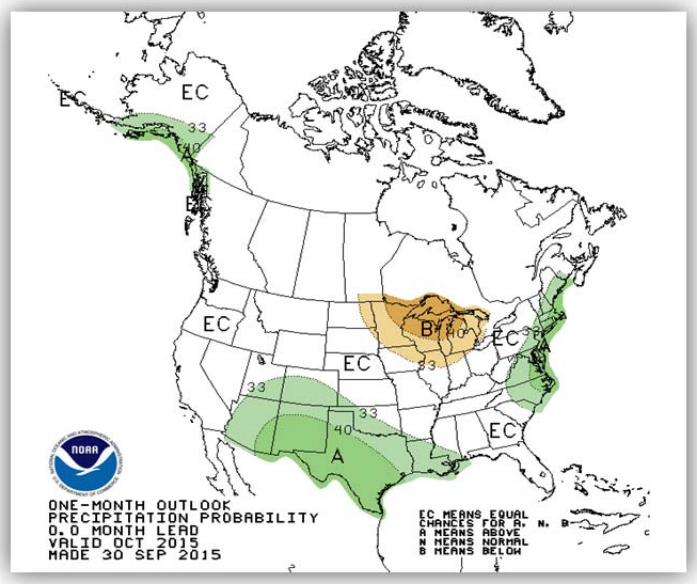


Appendix J: Seasonal Weather Outlooks and Palmer Drought

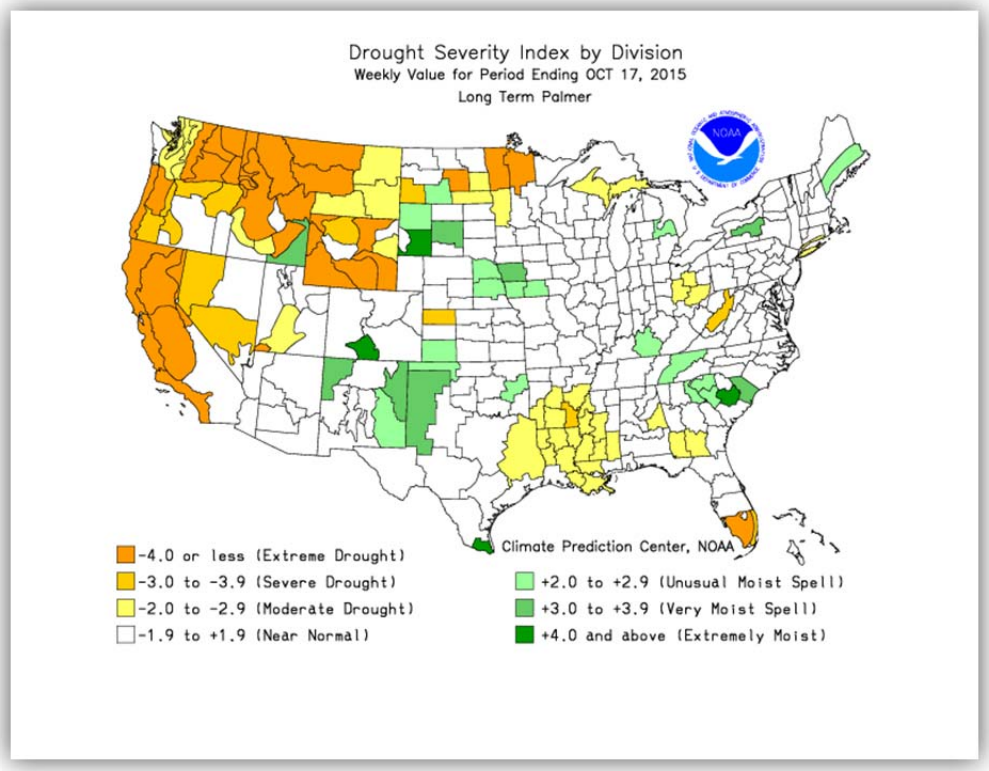
Map 9. United States significant wildland fire potential for October Map.



Map 10. United States October precipitation map, Northern Colorado has an equal chance of above, below or normal precipitation.

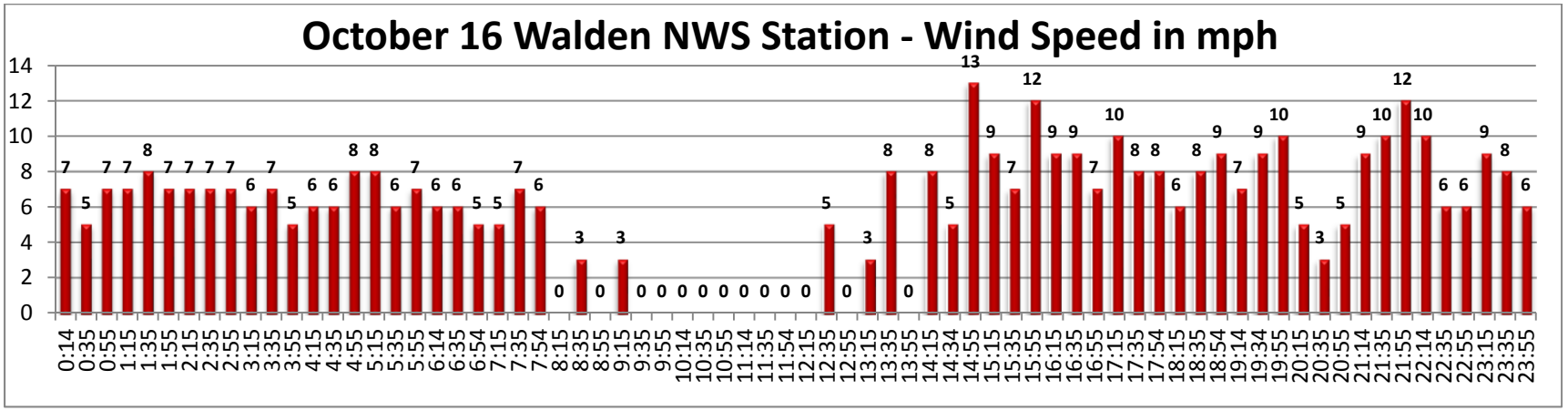


Map 11. Palmer Drought Severity Index for the fall seasons when the escaped prescribed fire occurred.

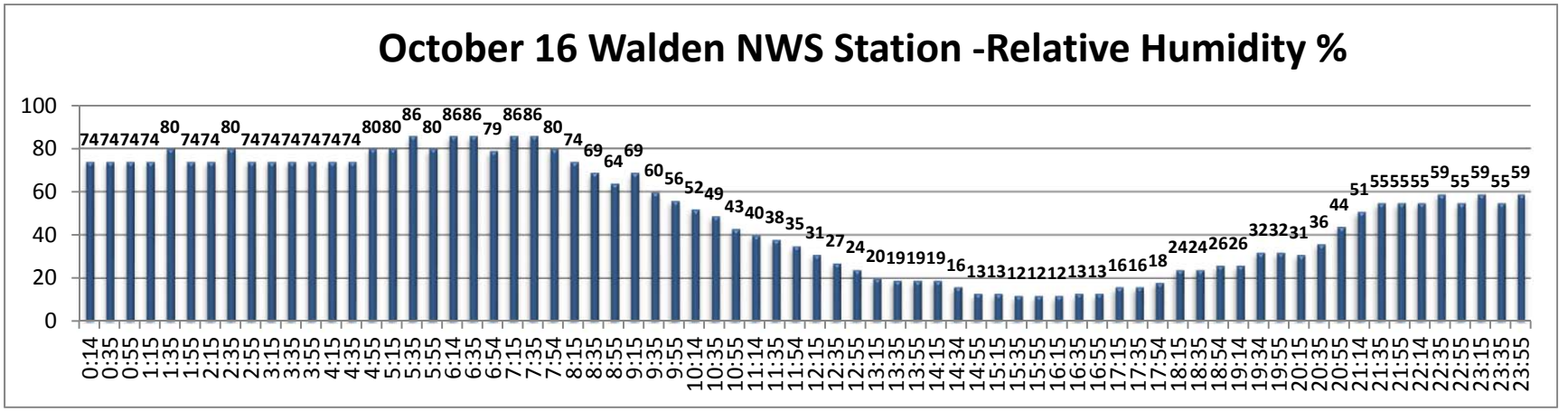


Appendix K: Walden Airport Winds and Weather

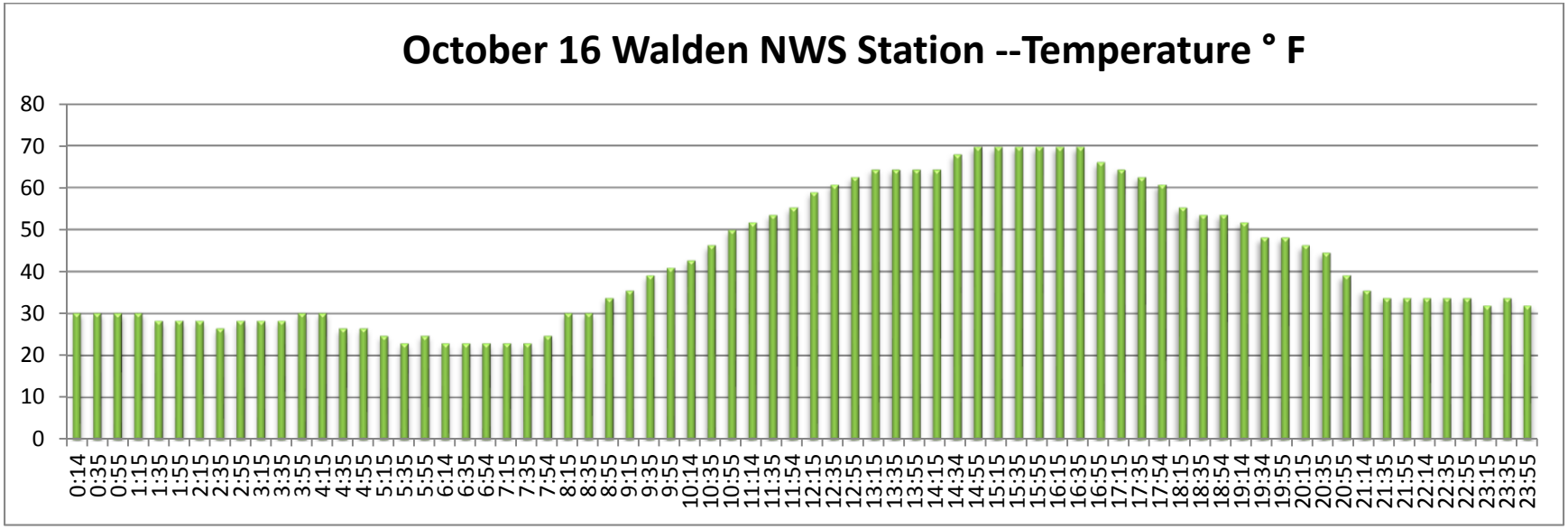
Graph 7. Walden NWS Station wind speeds for the day of the burn, the prescription allows for winds up to 15 mph.



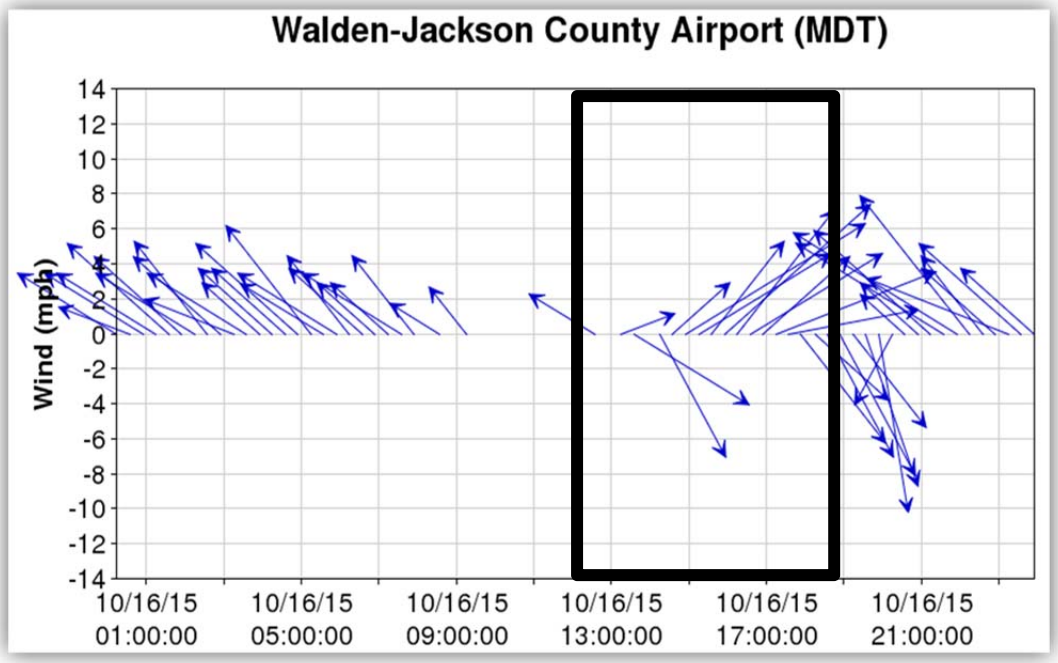
Graph 8. Walden NWS Station relative humidity for the day of the burn, the prescription allows for relative humidity down to 10%.



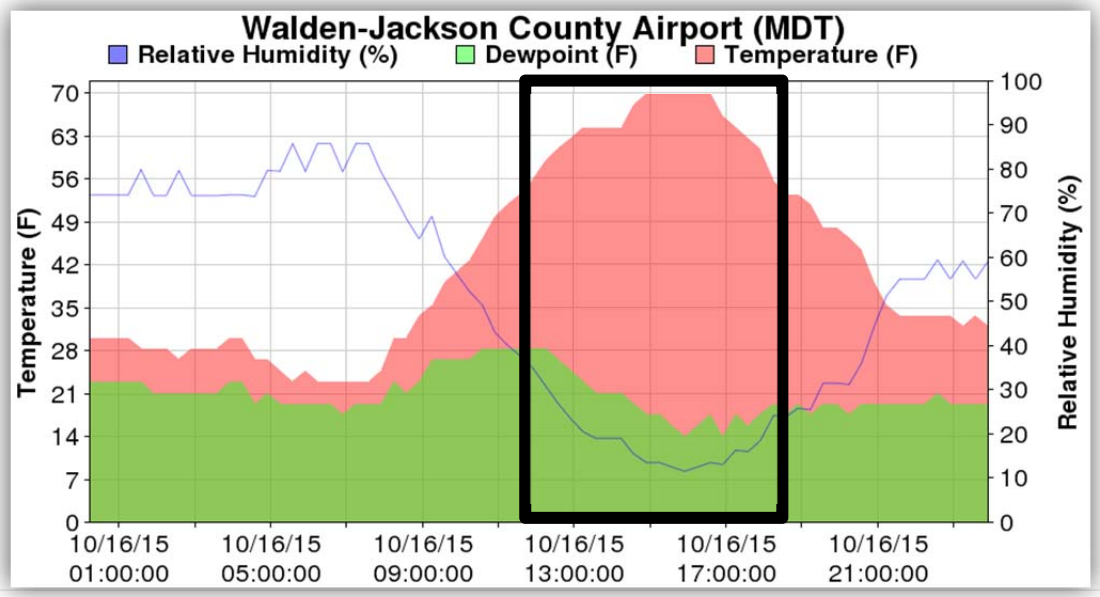
Graph 9. Walden NWS Station temperatures for the day of the burn, the prescription allows for temperatures up to 89 degrees.



Graph 10. Wind direction and speed for the day of the burn, notice the winds change directions from 1300 to 1500 on the northwest.



Graph 11. Relative Humidity, dewpoint and Temperature at the time of the burn



Appendix L: Fuels Model Photos

Photo 9. Fuel Model 1 is the fuel model listed in the IAP.

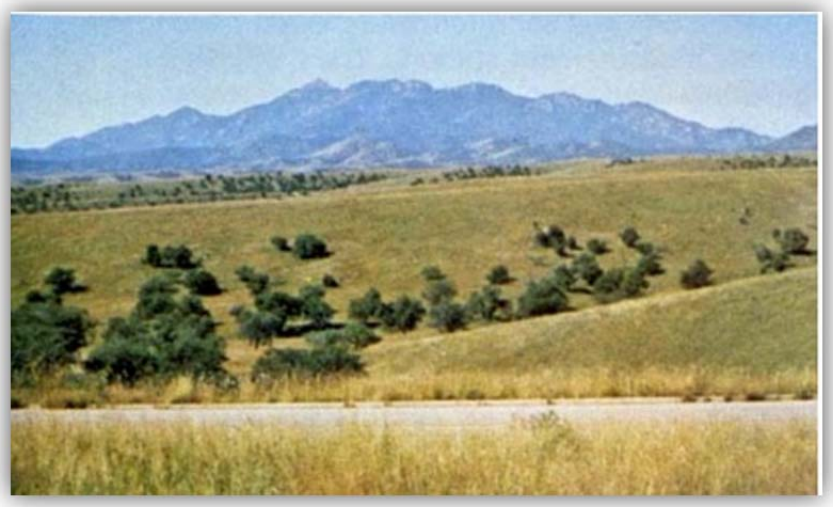


Photo 10. Fuel Model 8 Closed, Short Needle Timber Litter, this model doesn't seem to represent the burn unit.

Photo 11. GR2 Low Load, Dry Climate Grass could represent the western perimeter of the burn unit and the mow lines.

Photo 12. GS2 Moderate Load, Dry Climate Grass-Shrub could represent the eastern perimeter near the toe of the hill by Highway 14.

Photo 13. GR8 High Load, Very Coarse, Humid Climate Grass does not seem to represent the burn unit.

Photo 14. GR7 High Load, Dry Climate Grass seems to represent most of the burn unit.