Lower North Fork Prescribed Fire

Prescribed Fire Review

April 13, 2012

Requested by:
State of Colorado
Office of Executive Director
Department of Natural Resources
Denver, Colorado

Office of the President
Colorado State University
Fort Collins, Colorado

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EXECUTIVE SUMMARY

The Lower North Fork Prescribed Fire Project, located south of Conifer, Colo., is part of a large scale restoration effort on Denver Water property. Colorado State Forest Service (CSFS) planned the project to consist of six units in accordance with their 2011 Service Agreement with Denver Water. The 50 acre Unit 4A is one of the units identified for prescribed fire application following mastication treatments. On Thursday, March 22, 2012, Unit 4A was ignited according to plan. Ignition was completed by 2000 that evening. On Friday, March 23, crews worked to secure the burn and by the end of the day, the prescribed fire was put into patrol/monitor status. To this point in time operations were completed according to the plan with no problems. On Monday March 26, 2012, a three-person crew was monitoring the Unit during a "red flag warning". At approximately 1315 winds carried a stream of ground level embers across the established prescribed fire control line. This complex series of winds resulted in two spot fires outside control lines that were quickly contained by mop-up/ patrol personnel on scene. The crew responded to a third spot fire at 1340 located approximately 1500 feet southeast down the control line from the two earlier contained spot fires. The new spot fire quickly became established and it exceeded the capacity for control by ground forces resulting in an escape and subsequent conversion to a wildfire at 1430.

The Governor of Colorado and the President of Colorado State University (CSU) convened an independent team to review the Prescribed Fire and key factors that led to the escape. The Review Team interviewed personnel associated with the implementation of the prescribed fire; and reviewed and examined the written record of events and actions leading up to the escape.

The Review Team found four factors contributing to the escape and conversion to wildfire: of the four, the one that acted as the catalyst that finally set the outcome into motion was a rapidly escalating wind event. A fire weather watch for strong winds was issued at 1409 on Saturday, March 24, 2012 and at 0526 on March 25, 2012 was upgraded to a red flag warning for strong and gusty winds for Monday, March 26, 2012. Although the patrol crew was on scene Monday when the winds escalated to 15-20 miles per hour (MPH) steady, and were gusting to 55 MPH at ground level, they were not able to keep the Prescribed Fire contained. The prescribed burn unit had been mopped up 200 feet inside control lines but was an insufficient buffer area due to the combination of escalating winds and persisting hot spots at the interior of the burn area. Spot fires at multiple locations quickly exceeded the capacity of ground forces.

The other factors that potentially contributed to the prescribed fire escape include (See Page 55):

- Unburned fuel and residual heat present in the burn unit at the time of the wind event
- Operational actions drawn from experience and common practice
    - 200 foot buffer for mop-up

    - anticipation of need to respond to other wildfires
- Weather and fire behavior projections that did not/could not predict the complete set of circumstances that occurred.

Recommendations (See page 61):

- The WIMS-RAWS-NFDRS program needs improved operating procedures to ensure safe and more effective fire operations throughout the year.
- Replace use of the Keetch/Byram Drought Index (KDBI) with other indices such as NFDRS indices of Energy Release Component (ERC) or 1000-hour time lag fuel moisture as measures of fire danger and cumulative drought and input to fire planning
- Strengthen mop-up standards tied to fuel consumption and predicted weather as a required element in prescribed fire plans
- Refine the prescribed fire plan technical review process.
- Ensure that all prescribed fire plans include up-to-date information prior to implementation
- Separate masticated fuels from un-masticated fuels by sub dividing or redesigning treatment units to address fuel moisture and potential fire behavior variation.

BACKGROUND

Changing fuel complexes in combination with significant rapid expansion of those areas where structures and other human developments meet or intermingle with undeveloped wildland or vegetation fuels (wildland-urban interface [WUI]) have created a significant wildfire protection challenge. Wildfire risk to personal health and safety, communities, infrastructure, and natural resources is escalating across the western United States. Wildfire recognizes no boundaries or jurisdictional responsibilities; a single event can easily and quickly affect private, county, state, tribal and Federal lands; threaten communities, infrastructure, economies, and valuable natural and cultural resources.

The WUI areas along the Colorado Front Range are not immune to outcomes generated by interactions of wildfire, urban expansion and altered fuel complexes. In the past three decades, an increase in fire behavior, home and property losses, suppression costs, and threats to communities and social infrastructure, as well as attrition in ecological conditions are taking place. In Colorado, average annual statewide fire numbers by 10-year periods accounted for by the Colorado State Forest Service (CSFS) since 1960, show an alarming increased trajectory (Figure 1).

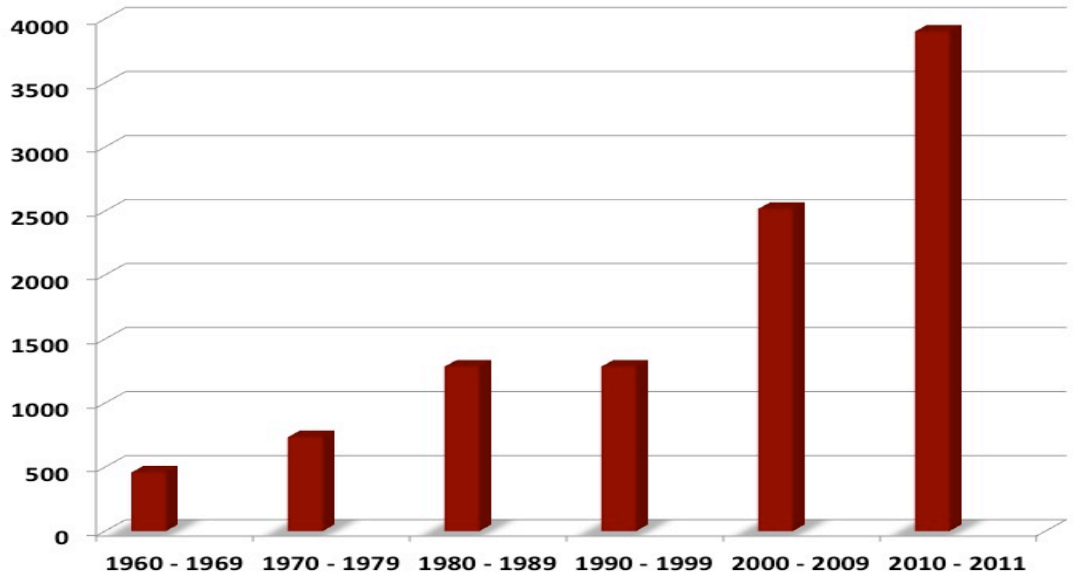

Figure 1. Average annual numbers of wildfires by 10-year periods in Colorado from 1960-2009, with 2010 and 2011, as one entry (source CSFS, Fort Collins, CO).

Increases in number and sizes of significant wildfires are occurring across all jurisdictions. In terms of large wildfire size in Colorado (fires reported as larger than 100 acres), the 30 largest fires on record have all occurred since 1996 (source Rocky Mountain Area Coordination Center). Seventy-seven (77) percent of these 30 fires have occurred since 2002 with slightly over half occurring during 2002, (57%) and the remainder occurring since 2002, (source RMACC). This data indicates that individual fire sizes have been increasing during recent years. Twenty (20)

percent of this set of large fires has occurred across the Front Range WUI area. Several notable individual wildfires occurred in the last 30 years that have had significant impacts on Front Range forest restoration and wildfire risk mitigation activities. These are shown in Table 1:

Table 1. Wildfires having significant influence on Front Range forest restoration and wildfire risk mitigation planning and implementation activities.

Fire Name	Year	Significance
Buffalo Creek	1996	Caused substantial erosion and sedimentation in Denver Water facilities in Denver metropolitan area. One of the 30 largest wildfires in Colorado history, 10 homes destroyed.
Hayman	2002	The largest in fire size and the most costly in terms of suppression costs in Colorado history, 133 homes destroyed.
Four Mile Canyon	2010	The most costly wildfire in terms of private property loss in Colorado history.

A more detailed description of significant Front Range wildfires is provided in Appendix B.

As large fires have become more damaging, vegetation manipulation and fuel reduction treatments represent an important component of wildfire risk mitigation being utilized along the Front Range. Strategic plans have been developed identifying fuel treatment projects to be completed in the Lower North Fork area of Jefferson County, Colo. Many specific projects have been completed over recent years.

The Lower North Fork Prescribed Fire was part of this overall program of work. The Prescribed Fire was conducted on March 22, 2012, in accordance with an approved Prescribed Fire Plan. On March 26, 2012, a severe wind event ignited a wildfire outside the burn Unit that became the Lower North Fork Wildfire.

In response to this event, the State of Colorado convened a Team to review the Prescribed Fire. This report represents the results of that review. Specific analysis and recommendations are provided in the following sections of the report.

PRESCRIBED FIRE PURPOSE AND PROGRAM GUIDANCE

Prescribed Fire Purpose

Protecting wildland-urban interface areas from the effects of wildfire is a focus of all land management and emergency response agencies/organizations. A central goal to improve protection capability involves reducing potential fire behavior and increasing the likelihood of successful fire suppression efforts. Under a given set of weather conditions, vegetation and fuel structure exert the dominant influence on fire behavior. To achieve reduced fire behavior potential, active management that concurrently modifies structure, composition and amounts of all components of fuel complexes is necessary.

A wide range of vegetation manipulation techniques and fuel treatment options are available. Specific methods allow focus on different components of the fuel bed. For example, thinning of trees mainly affects standing vegetation; mechanical methods such as chipping, mastication, and roller chopping can affect understory, mid-level vegetation and some lower level forest crown fuels. Mechanical thinning can be effective in reducing vertical fuel continuity (Graham and others 1999), but as a single treatment it does little to reduce surface fuel amounts. Mastication alone does not reduce fuel quantities; however, it is useful in changing fuel location and configuration. In some cases mastication affects the vertical fuel continuity but can actually add to surface fuels and potentially increase surface fire intensity. Generally mastication opens up forested stands, rearranges fuels from aerial positions to surface positions and can lower overall resistance to control and improve accessibility.

Prescribed fire is the application of fire through a planned ignition to meet specific objectives identified in a written and approved prescribed fire plan. It can be conducted as pile burning or broadcast burning. Pile burning follows other treatments to reduce woody debris remaining after those treatments. Broadcast prescribed burning removes natural and activity-generated fuels and modifies surface fuel complexes.

Prescribed fire represents a viable and widely accepted option for treating fuel and vegetation complexes. Experts agree that prescribed fire facilitates changes in potential fire behavior (Graham and others 2003, 2004). Overall, prescribed fire is useful for affecting fuel complex attributes (Graham and others 2004) by:

- Reducing quantities of fine fuels, duff, large woody fuels, rotten material, shrubs and other live surface fuels.
- Positively altering both vertical and horizontal fuel continuity (shrub, low vegetation, woody fuel layers).
- Reducing compactness of surface fuel components.

In some cases, multiple treatments of a single type may be needed. A combination of phased treatment of different types may also be necessary to accomplish objectives. This is especially true for areas that have experienced continual fire suppression, have altered fuel complexes or have substantial numbers of high values present, as is the case in WUI areas.

The combination of mechanical non-fire and prescribed fire applications as a fuel treatment process in WUI areas has been widely and successfully used. This sequence allows the

mechanical removal of ladder or vertical fuels followed by reductions in surface fuel amounts. Combinations of treatments are highly effective in decreasing the intensity and severity of potential wildfires (Graham and others 2004).

In 2006, the US Forest Service initiated a program to evaluate the effectiveness of prescribed fire, mechanical, and chemical treatments designed to reduce the risk of wildfire. When a wildfire starts within or burns into a fuel treatment area, an assessment is conducted to evaluate the resulting impacts on fire behavior and fire suppression actions. In 2011, the U.S. Forest Service made the effectiveness assessment mandatory whenever a wildfire impacted a previously treated area. The purpose of the effective assessments are to answer the questions of:

- Are fuel treatments affecting fire behavior by reducing the intensity and/or rate of spread?
- Does suppression effectiveness improve through enhanced firefighter safety, reduced suppression costs, and/or reduced potential fire damage?

Since 2006, over nine hundred assessments have been completed since the program began, and data has shown that fuel treatments are effective in reducing both the cost and damage from wildfires.

Table 2. Summary of US Forest Service Fuel Treatment Effectiveness on Wildfires

Year*	Number of Treatments Burned Over By Wildfire								Total Records
	Did Treatment Change Fire Behavior?				Did Treatment Help Control Fire?				
	No		Yes		No		Yes		
	Number	%	Number	%	Number	%	Number	%	
2006		0%	10	100%		0%	10	100%	10
2007	5	3%	185	97%	1	1%	189	99%	190
2008	3	2%	154	98%	1	1%	156	99%	157
2009	16	16%	87	84%	10	10%	93	90%	103
2010	19	13%	131	87%	7	5%	143	95%	150
2011	49	14%	293	86%	54	16%	288	84%	342
2012		0%	21	100%		0%	21	100%	21
Total	**92**	**9%**	**881**	**91%**	**73**	**8%**	**900**	**92%**	**973**

*Reporting was optional until Dec 2010. 2012 Data current through 4/5/12

Prescribed Fire Program Guidance

Prescribed fire planning and implementation is conducted by most state, federal, and tribal agencies and numerous local and private entities. An endorsed and comprehensive set of guiding statements exists to frame program planning and implementation. Useful guidance ranges from broad interagency information and recommendations to agency-specific rules and regulations. The set of prescribed fire program framework elements and sources that are pertinent to prescribed fire planning and implementation have been reviewed by this team. They are listed in Table 3. Materials listed in this table are general in nature and intended only to show the sources of prescribed fire framework information. A tabulation of information relevant to all levels of the Prescribed Fire Program is provided in Appendix C.

Table 3. Prescribed fire program framework source documents.

Document	Purpose	Source
Interagency Prescribed Fire – Planning and Implementation Guide	Establish interagency, recommended guidance at the programmatic scale	National Wildfire Coordinating Group (NWCG)
Quadrennial Fire Review	Provide interagency strategic recommendations at the programmatic scale	National Wildfire Coordinating Group (NWCG) (includes National Association of State Foresters [NASF] as a signatory)
A National Cohesive Wildland Fire Cohesive Strategy	Develop interagency, strategic recommendations and implementation guidance at the national scale	U.S. Department of the Interior, U.S. Department of Agriculture (includes National Association of State Foresters [NASF] as a member of Wildland Fire Executive Council [WFLC])
Living With Fire: Protecting Communities and Restoring Forests. Finding and Recommendations of the Front Range Fuels Treatment Partnership Roundtable	Develop a long-term vision and recommended course of action for protecting communities from the risks of wildfire and restoring forest health at a local scale for 10 Colorado Front Range counties	Front Range Fuels Treatment Partnership Roundtable (Colorado Department of Natural Resources, Colorado State University, and Colorado State Forest Service are member organizations)
Colorado Revised Statutes	Define statewide management objectives and requirements	State of Colorado
Services Agreement, Colorado State University (CSU)/Colorado State Forest Service (CSFS) and Denver Water Board	Establish working agreement for services furnished by CSU to Denver Water for wildland fire management planning and administration, wildland fire response, and prescribed fire planning and implementation interagency-level agreement stipulating site-specific planning and implementation work	Colorado State University and City and County of Denver Board of Water Commissioners, Denver Water
North Fork Fire Protection District Community Wildfire Protection Plan	Establishes strategic site-specific recommended practices for mitigating wildfire hazards	Jefferson County Department of Emergency Management, North Fork Fire Protection District, and Colorado State Forest Service
Prescribed Fire Program Guidelines and Procedures. Prescribed Fire Procedures.	Establishes agency-specific procedures to follow in planning and implementing prescribed burns. Agency-level institutionalization of policy and procedures.	Colorado State Forest Service

Colorado State Forest Service policy related to the preparation, review and approval of prescribed fire plans is contained within their Prescribed Fire Program Guidelines and Procedures (CSFS 2011). This policy addresses seven functions related to prescribed fire planning including:

- Contracting
- Permitting
- Writing
- Review and Approval
- Implementation
- Reporting
- Escaped Prescribed Fires

In addition, the Colorado State Forest Service utilizes a Prescribed Fire Desk Guide, which provides templates for prescribed plan writing, checklists for technical review and approval of plans and information sources useful for prescribed burn planners. The elements of the Colorado State Forest Service standard plan template are derived from the Interagency Prescribed Fire Planning and Implementation Procedures Guide (2008). The Interagency Prescribed Fire Guide provides unified direction and guidance for prescribed fire planning and implementation. It is approved for use by the U.S. Fire Administration, National Association of State Foresters, U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Indian Affairs, Bureau of Land Management and the National Park Service. Strict adherence to the guide is not mandated or expected and the guide states,

*"The guide describes what is **minimally** acceptable for prescribed fire planning and implementation. Agencies may choose to provide more restrictive standards and policy direction, but must adhere to these **minimums**." (NWCG 2008, Page 7)*

PRESCRIBED FIRE PROGRAM SUCCESS AND PAST ESCAPES

Prescribed fire is accepted as a highly feasible technique for vegetative manipulation and fuel treatment. The application of prescribed fire has been practiced for more than 80 years; however, it was done at a very small scale in its early history. It has been utilized extensively in forest management for site preparation, removal of competing vegetation, slash treatment, tree thinning, insect and disease control and for maintenance of visual scenes. It has also proved important for wildlife habitat manipulation and improvement, big game winter range improvement, livestock forage improvement, control of invasive species, watershed protection, maintenance of historic scenes, protection of cultural resources, sensitive species, ecosystem health maintenance and reduction of hazardous fuels. Without the option of prescribed fire, many land management objectives either could not be accomplished, or they could only be accomplished under much higher cost scenarios with potentially greater environmental damages.

The scale of prescribed fire utilization varies among land management agencies. The Colorado State Forest Service is one of the leading agency practitioners of prescribed fire in Colorado (Figures 3 and 4). These tables show that in terms of numbers of fires, the CSFS has ranked as the third highest for much of the 2001 to present time period (Figures 3 and 4). In terms of numbers of acres, the CSFS has ranked fourth (Table 4).

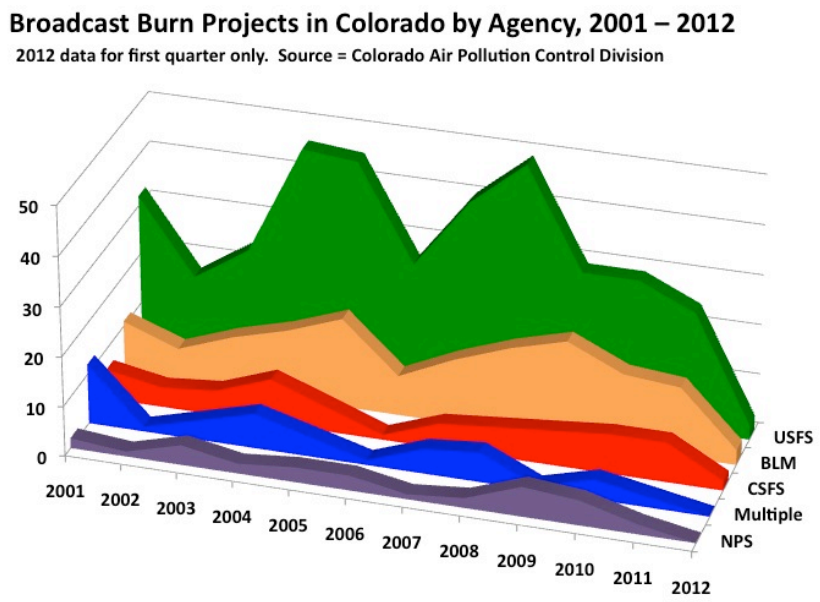

Figure 3. CSFS broadcast burn projects with air quality permits and activity from 2001 to present.

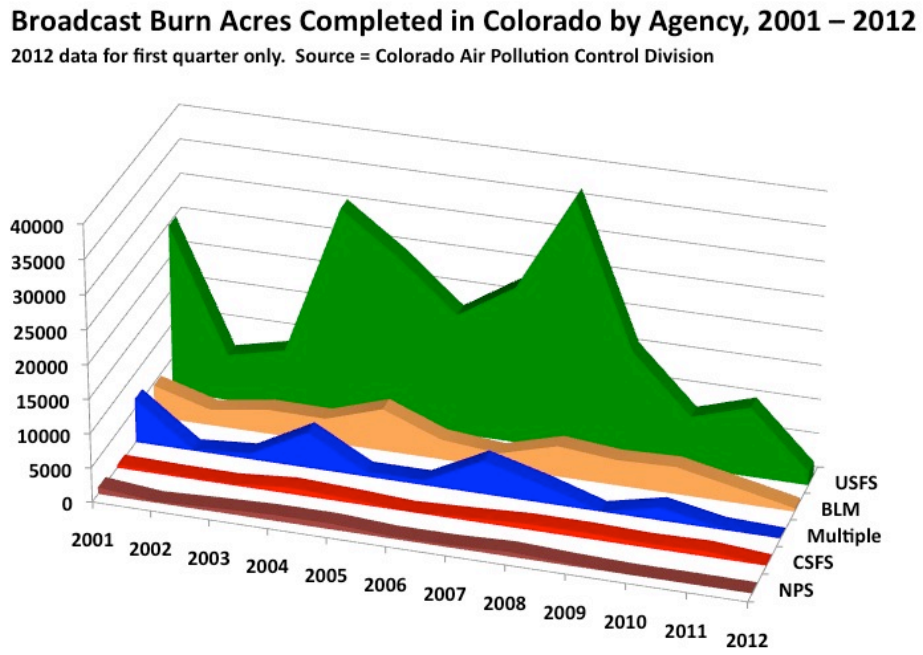

Figure 4. CSFS broadcast burn acres from 2001 to present.

Documentation of prescribed fire success and escape data is incomplete on a national interagency basis. Individual agencies have maintained data where possible and some information is available. This information indicates that escaped prescribed fires do not occur frequently, but they have occurred since the start of the Program. No agencies or organizations have been exempt from escaped prescribed fires.

Information regarding prescribed fire success during earlier time periods lacks clarity, but several known significant escaped fires, including the Bogus Fire in California in 1957 and the Mack Lake Fire in Michigan in 1980, have been documented (Forest Service 1957 and Simard 2003). Most land management agencies involved in prescribed burning seem to have experienced infrequent escaped prescribed fires. Some more notable examples include: Lowden Ranch Prescribed Fire, Bureau of Land Management, California – 23 residences destroyed; Upper Frijoles Units One and Five Prescribed Fire (Cerro Grande Wildfire), National Park Service, New Mexico – 235 buildings destroyed.

Colorado State Forest Service statistics show that between 2004-2011, the Agency implemented 175 prescribed fires for 14,189 acres, with only two of the fires escaping.

The frequency of escaped prescribed fires is relatively low, but escapes have happened. Dether and Black (2006) examined a number of prescribed fire escape reviews to help increase individual and organizational capacity to anticipate and respond to unexpected occurrences. They report that some important factors contributing to prescribed fire escapes are:

- Unforeseen and unexpected events - the most common form of unforeseen events are related to unexpected amplitude of events, such as greater than expected fire behavior due to winds, fuel moistures, fuel complexes and unexpected complexity.
- Weather was found to be the immediate causal factor in nearly 50% of the escapes reviewed; unexpected winds, in both strength and duration, were commonly cited as contributing weather factors.

REVIEW PROCESS

Review Guidance

Prescribed fires that have become escaped prescribed fires can result in serious consequences. These fires must be reviewed to determine specific factors that resulted in the escape. In all cases, escaped prescribed fires offer significant opportunities to learn from outcomes to improve future planning and implementation, and ultimately, reduce the incidence of future escapes.

Reviews concentrate on unintentional elements including mistakes, accidents, errors, system policy, protocol and procedural issues. Intentional rule violations warrant greater emphasis and are usually dealt with through other processes or investigations.

Recent interagency planning has created interagency endorsed broad-scale planning and implementation guidance for prescribed fire. This guidance includes recommendations for reviews of escaped prescribed fires (NWCG 2008). Colorado State Forest Service Prescribed Fire Procedures also outline a process and applicable questions for reviewing escaped prescribed fires (CSFS 2011).

In recent years, a great deal of work has been done to develop more successful and efficient review processes. Most past reviews have fixated on determining, in hindsight, what rules or protocol were broken, identify blame, and create additional rules and compliance incentives. The Facilitated Learning Analysis (FLA) (USFS 2012) recognizes a basic review principle, while accidents are very rare, risk is never absent.

This review has been designed based on both sets of guiding documents (NWCG 2008, CSFS 2011) and the FLA process. The report addresses the elements defined in the Colorado State Forest Service Prescribed Fire Procedures. It also seeks to fulfill the commitment to learning, and set the stage for meaningful improvement in the future. The full description of review processes, goals and objectives, inclusive elements, and documentation guidance can be found in the Interagency Prescribed Fire Planning and Implementation Procedures Guide (USDA-USDI 2008), Colorado State Forest Service Prescribed Fire Program Procedures (CSFS 2011), and the Facilitated Learning Analysis Implementation Guide (Forest Service 2012).

Review Objectives

The State of Colorado convened an independent Review Team to conduct a review of the Lower North Fork Prescribed Fire. The number of individuals assigned to the team, and their functional expertise, were commensurate with the scope and focus of the Review and the complexity of the situation. A formal Delegation of Authority (Appendix A) was provided to the team leader to conduct a thorough review of the Prescribed Fire. This Review was specifically charged to only address the Prescribed Fire up to the time of the wildfire declaration. Any review of the Wildfire will be separate from this review, as will an investigation of the fire origin and cause.

Goals of this review were to:

- Guide future program actions by minimizing future unintended outcomes
- Identify actions necessary to reduce the likelihood for escapes from prescribed fires generally

Given the above foundational goals, the specific purpose of the review was to:

- Document the review process
- Review the background situation
    - Document the problem statement associated with fuel alterations and WUI growth
    - Describe the environmental, social, economic and political setting
    - Describe the fuel treatment program for this portion of the Colorado Front Range
- Describe the Lower North Fork Prescribed Fire
- Document key observations and learning elements though analysis
- Summarize factors potentially contributing to the escape of the Prescribed Fire
- Define lessons learned from this event
- Provide recommendations to strengthen future program activities and build prescribed fire capacity

Factual information collected during the Review was centered on policy, protocols and performance.

Review Team

The Review Team consisted of:

Bill Bass	Team Leader
Tom Zimmerman	Team Member
Frankie Romero	Team Member
Dave Hamrick	Team Member
Tammy Williams	Team Member
Jace Ratzlaff	Team Member
Kelly Close	Team Member
Dean Clark	Team Member
Tim Mathewson	Team Member

Additional staff support and expertise was added to the team when necessary.

The Review Team interviewed personnel associated with the planning and implementation of the Prescribed Fire, reviewed written documentation of events and actions leading up to the declaration of the Prescribed Fire as a wildfire. The Team visited the Prescribed Fire site and developed a final report.

SETTING

Environmental, Social, and Political Setting

The Denver metropolitan area is located in the transition zone from the prairie to the Rocky Mountains. This area is a rapidly growing and expanding urban region. The majority of the geographic area is found adjacent to the mountains, and much of it exists in the foothills representing a significant WUI area. Denver serves as the economic and commerce hub of the central Rocky Mountains and western Great Plains. It is also home to one of the country's largest international airports, crossroads of two national interstate highways and commercial railways and home to over half of Colorado's population.

The foothills and mountains of the Colorado Front Range are adjacent, visible, and directly influential to the Denver metropolitan area. This area is critical for supplying water, providing recreational opportunities, providing highly valued scenery, supporting abundant species of wildlife, and contains many homes and businesses.

Jefferson County occupies part of the foothills area southwest of Denver. It is close to Denver, other parts of the metropolitan area, and is within commuting distance for local residents. These facts make this area highly desirable for mountain living. As a result, population growth and associated WUI expansion continues to occur. Jefferson County has the fourth largest population in the State with parts of the County experiencing a 20% population increase since 2000. It has been estimated that Front Range WUI areas in general may double over the next 20 years (FRFTP Roundtable 2006).

Vegetation in this area consists of forests, mixed conifer woodlands and grasslands. Ponderosa pine and Douglas-fir comprise the majority of forest, with aspen, lodgepole pine, and riparian hardwoods occurring in lesser amounts in isolated areas. A high proportion of this area is a fire-dependent ecosystem. This type of ecosystem has historically experienced frequent natural fire that maintained an open forest structure and diverse vegetation composition.

The Upper South Platte Watershed in the heart of this area is extremely important. This watershed supplies the Denver metropolitan area with 80 % of its water (Jefferson County 2011). It has experienced severe erosion and sedimentation following past fire events, and future wildfires may cause even more negative effects.

A majority of vegetated areas and fuel complexes in wildland areas have been subject to structural shifts and alterations as a result of a myriad of factors. These include changing land use, fire suppression, environmental changes, insect, disease, invasive species, spread and proliferation, landscape fragmentation and weather and climatological drivers. In this area, and across the entire western United States, changes in forest structure and composition over the past 60 to 100 years are increasing fuel loads. This makes coniferous forests more susceptible to intense and highly severe fires (Graham and others 2004). The Front Range has experienced a prolonged drought, continuous rapid expansion of the WUI and an accumulation of hazardous fuels in a fire-prone region. These circumstances have created incubation period for

catastrophic wildfires with significant risk to life and property. Fuel complexes that resist control, steep topography, and narrow, dead end roads complicate a difficult fire protection scenario.

Large impactful wildfires have been occurring on the Front Range, and they have caused great damage to infrastructure and natural resources. The Buffalo Creek Fire in 1996 caused severe post-fire erosion and sedimentation. This fire event served as the impetus to develop a comprehensive, long-term, strategic plan to increase watershed protection in the Upper South Platte area (Figure 2). In 1998, land and fire management organizations, including the Colorado State Forest Service (CSFS), Denver Water, U.S. Forest Service (USFS), Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), Natural Resource Conservation Service (NRCS) and the Coalition for the Upper South Platte (CUSP), formed a steering committee to address forest health issues within the watershed. As work proceeded, the U.S. Fish & Wildlife Service also became involved. The primary purpose of this effort was to demonstrate the effectiveness and plan for future implementation of landscape-scale forest protection and restoration practices.

The Hayman Fire in 2002, the single largest fire in Colorado history, burned approximately 140,000 acres. The Fire consumed 133 homes, 466 outbuildings, and left portions of four counties highly vulnerable to post-fire flooding and erosion (FRFTP Roundtable 2006). Following the Hayman Fire, and the 2002, fire season, a coalition of organizations and government agencies came together to identify areas needing treatment to protect communities and restore forest health. This is referred to as fire risk mitigation and ecological restoration (Figure 2). The coalition, known as the Front Range Fuels Treatment Partnership Roundtable, identified approximately 1.5 million acres of forest that may be in need of treatment (approximately 60% of the area is privately owned). These activities are a sampling of the multitude of strategic planning and implementation activities that have taken place to date (Figure 2).

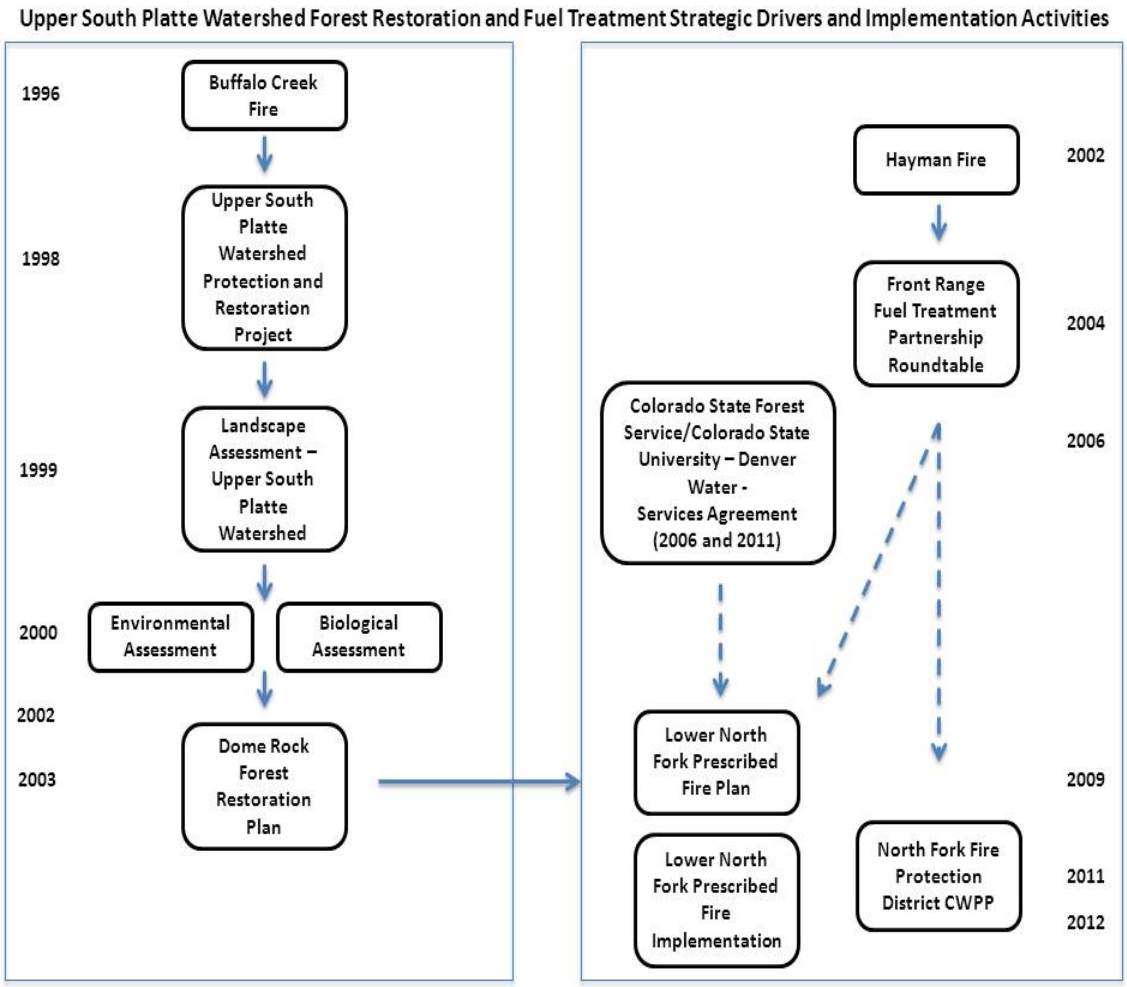

Figure 5. Upper South Platte Watershed forest restoration and wildfire risk mitigation activities. The solid arrows indicate sequential flow while dashed lines indicate indirect influence.

The magnitude of the areas needing fuel treatment, expanding WUI areas, increasing total fire numbers and growing sizes of large wildfires are symptomatic of a rapidly escalating community protection and forest health problem. A recent assessment of forest conditions and risk from wildfires shows that a majority of the Colorado Front Range WUI area is in the high to very high levels. Figure 6 shows Front Range forest conditions and wildfire risk assessment levels (FRFTP Roundtable 2006).

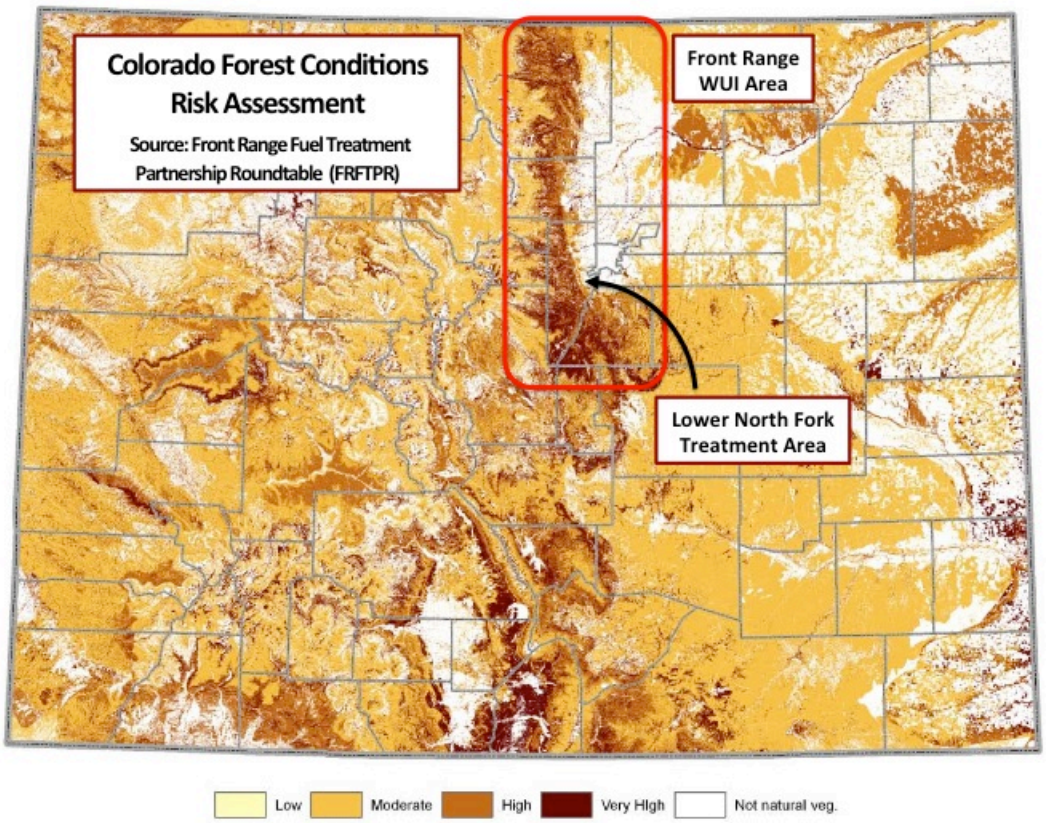

Figure 6. Colorado Front Range forest conditions and risk assessment identified for forest treatment, including fire risk mitigation and ecological restoration. (Source: FRFTP – 2006)

Community Wildfire Protection Plans (CWPP) are strategic plans that identify specific wildland fire risks facing communities and neighborhoods. They provide prioritized mitigation recommendations designed to reduce those risks. The Healthy Forests Restoration Act (HFRA) of 2003, provides the impetus for local communities to engage in comprehensive forest and wildfire management planning. It also serves as incentive for public land management agencies to consider CWPP treatment recommendations as they develop their own strategic management plans. The CWPP development process facilitates collaboration among community-based organizations, fire protection authorities, local governments, public land management agencies and private landowners in an effort to identify and prioritize measures to reduce wildfire risk.

CWPP's can include a fire behavior analysis and community wildfire hazard rating as a comprehensive and scientifically-based assessment. The actions recommended in a CWPP are designed to lower wildfire hazards to neighborhoods, the economy and ecological values at risk. Values at risk priorities for protection may include:

- Watersheds
- Tourism

- Private property and infrastructure. Many homes in the area have a "high" fire hazard rating due to expected fire behavior and surrounding wildland fuels.
- Aesthetics
- Recreation
- Historic/cultural resources

CWPP's also recommend treatment options that may include: shaded fuelbreaks, machine mowing, prescribed fire, brush mastication, timber mastication, manual thinning and felling and feller buncher removal of larger diameter trees.

Lower North Fork Prescribed Fire Project

Part of the focus to improve protection capability in the Upper South Platte Watershed area, and to support the Upper South Platte Watershed Restoration Plan, the Lower North Fork Prescribed Fire Plan was developed by the Colorado State Forest Service to reduce fuels and decrease potential fire behavior.

The Lower North Fork Prescribed Fire was developed consistent with the direction stated in the prescribed fire framework elements described in Table 1. The proposed burn areas are located in western Jefferson County, near the community of Foxton, on the Front Range area southwest of Denver (Figure 7).

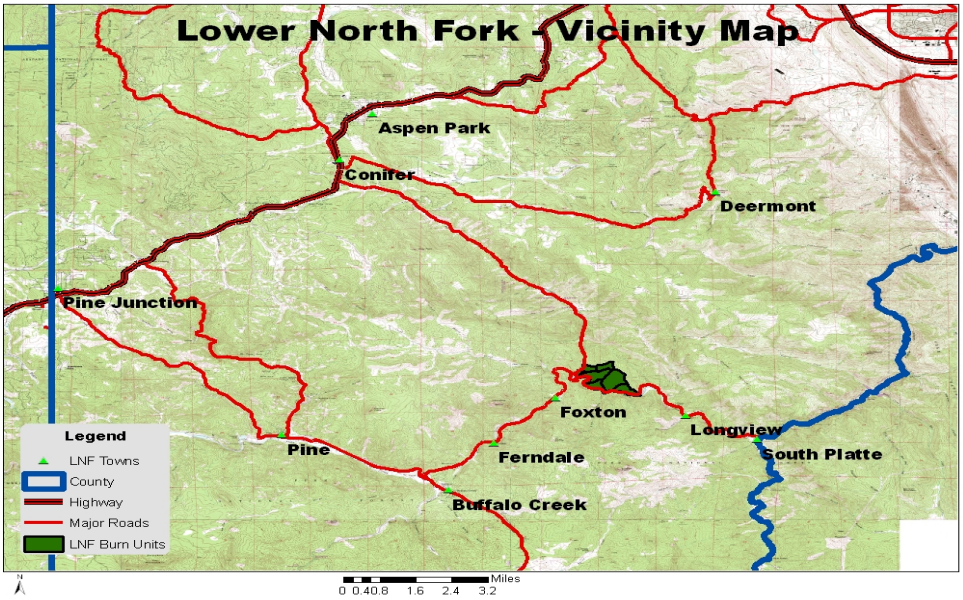

Figure 7. General vicinity of Lower North Fork Prescribed Fire.

The area is bounded by portions of the Pike National Forest (South Platte Ranger District) to the south and west, and private land to the north and east. Land ownership within the area is primarily individual homeowners and Denver Water. The Colorado State Forest Service and Jefferson County Open Space also own land tracts in the area.

A comprehensive plan valid for five (5) years was developed. It identified six (6) treatment units within the planned area (Figure 8). The maximum acres to be treated were 335. The management use/type of project was identified as natural fuel reduction (ecosystem management), activity fuel reduction and hazard fuel reduction. Prescribed fire was defined as the treatment method, with broadcast burning as the primary technique. The Lower North Fork Prescribed Fire was considered to be part of a project that included non-fire fuel treatments (mechanical mastication) with all treated material left on site.

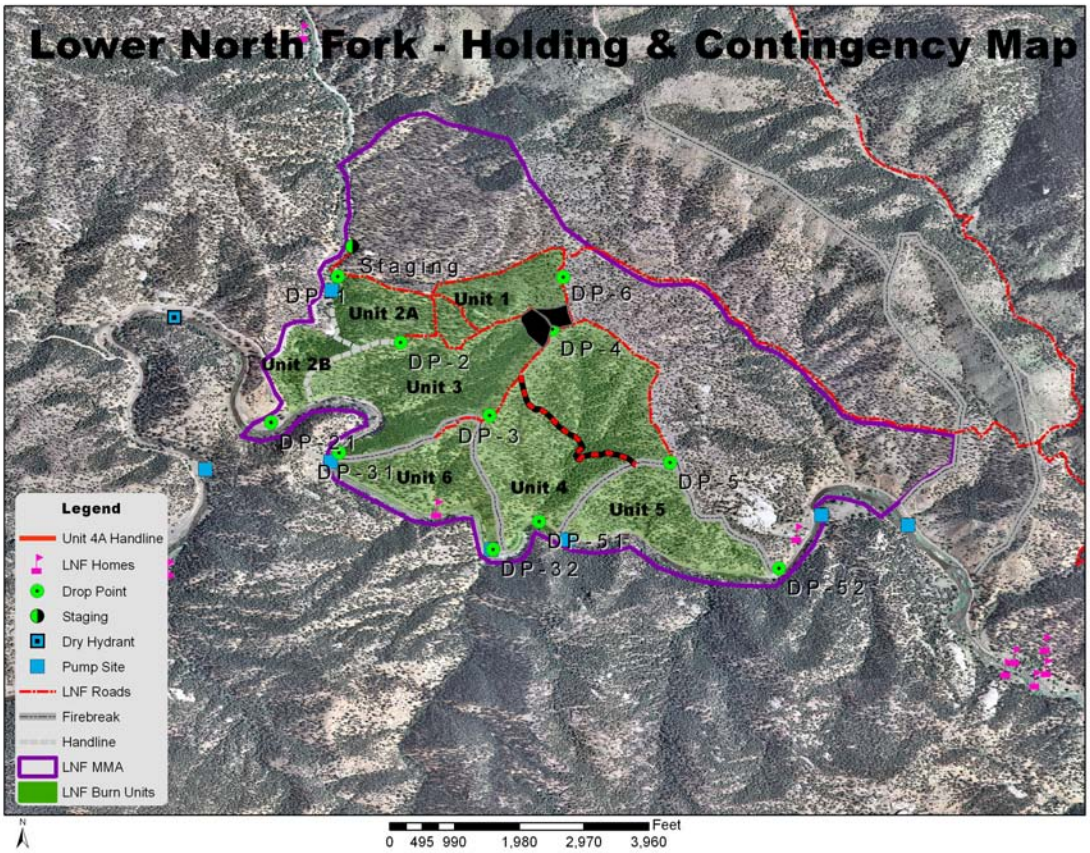

Figure 8. Lower North Fork Prescribed Fire treatment units.

Lower North Fork Prescribed Fire Objectives

The following objectives were identified for the Lower North Fork Prescribed Fire Project:

- Overall resource management goal (from general project plan):
  - Restore forest health and vigor
  - Reduce wildfire hazard
- General control objectives (from Incident Action Plan for Burn):
  - Provide for public and firefighter safety
  - Resource management:
  - Minimize smoke impacts to sensitive receptors through adherence of the smoke management plan

    - Provide on-the-ground training opportunities to local fire cooperators

- Prescribed fire objectives (from Prescribed Fire Plan):
    - Remove 70% or more of the woody fuel less than one inch in diameter
    - Remove 50% or more of the woody fuel greater than one inch in diameter
    - Retain 90% or more of the residual stand in the masticated areas
    - Create a mosaic of open patches (five acres or less) in the un-masticated areas, not to exceed 33% of the total untreated area

Additional information is described later in this report, and it is also available in the Lower North Fork Prescribed Fire Plan (on file at CSFS Golden District Office, Golden, CO).

DESCRIPTION OF THE EVENT

Chronology of Events Leading up to Wildfire Declaration

Table 3. Chronology of Events Leading up to Wildfire Declaration

DATE	EVENTS
2011 Mar. 1-2	First entry on Lower North Fork (LNF) Prescribed Fire project. Blacklining operations in Units 1 and 3
2011 Mar. 02	Smoke Form E (accomplishment) submitted for Unit 1 blacklining reports 3 acres
2011 Mar. 10	Fire effects report documents fire behavior and effects
2011 Sept. 28	LNF Unit 1 broadcast ignition operations
2011 Sept. 28	Smoke Form E (accomplishment) submitted for LNF Unit 1 reports 25 acres
2011 Sept. 29	Burn Boss report includes notes of short-range spotting on all burn days, long residence time for flaming and combustion in masticated fuels and variable wind conditions due to topography
2011 Oct. 04	LNF Unit 1 broadcast ignition operations continue. Go / No-Go Checklist signed by Burn Boss at 0905 hrs.
2011 Oct. 04	Test fire documentation reports “low end” fire behavior
2011 Oct. 04	LNF Unit 1, “Roaded Island” subunit burned, 7 acres ignited per Burn Boss report
2011 Oct. 04	Smoke Form E submitted for 11/04 operations reported 7 acres
2011 Oct. 12	Burn Plan Prescription Parameters revised based on observations from prior burn days, some prescription elements changed to allow increased flexibility to burn under typical site conditions while safely meeting objectives
2011 Oct. 13	Blacklining in Unit 4a on east side of unit along road, handlines improved on south and west side of unit
2011 Oct. 13 1430 hrs.	Burn Boss notes reported 50 x 50 spot on east flank near DP-5; contained w/in 10 min. GPS track of perimeter shows spot fire was .37 acres.
2011 Oct. 13	Smoke form E submitted for 11/13 blacklining reported 5 acres burned
2011 Oct. 17	Planned ignitions in Unit 4 cancelled due to poor weather forecast
2011 Oct. 19	Burn Boss report from 11/13 operations states blacklining created a +/- 50’ buffer along NE corner of Unit 4a
2011 Nov. 10	Test plots ignited along north perimeter Unit 4a, total acres .25, fuels reported not dry enough for broadcast burning

DATE	EVENTS
2012 Jan. 03	Smoke Form F (annual activity) submitted reporting 2011 LNF project accomplishments, reported 2011, burn days on March 1-2; Sept. 28; Oct. 4; Oct. 13 and Nov. 10 for total of 44 acres
2012 Mar. 13	CSFS Golden District Resources visited LNF Unit 4a to check fuel conditions and clear control lines
2012 Mar. 19	Blacklining operations in Unit 4a along NW side from DP-4 toward the weather station created blackline approximately 50-60 feet deep
2012 Mar. 20	Mop-up of area blacklined on 3/19, port-a-tank, pump and hose lay installed at DP-5 to plumb lower control line
2012 Mar. 21	Colorado State Forest Service personnel conducted 20 acre White Ranch Prescribed Fire on Jeffco Open Space lands; afterwards personnel continue preparations for LNF Unit 4a
2012 Mar. 21	Observations for Spot Weather Request taken at top of Unit 4 at 0945hrs. 39 dry, 34 wet, DP 28, RH 64, W 1-2 G 3 from NE
2012 Mar. 22	Burn day, Unit 4a ignition operations
2012 Mar. 22 0930 hrs.	Operational briefing is held at Reynolds Park, afterwards resources moved into position on the burn unit
2012 Mar. 22 1129 hrs.	Go / No-Go Checklist signed by RXB2, Ignition Specialist and Holding Specialist
2012 Mar. 22 1145 hrs.	Test fire ignited on northern edge of unit approximately 30 yds. E/SE of DP-4. Results acceptable, documentation by Burn Boss
2012 Mar. 22 1200-1700 hrs.	Ignition continues, resources on scene exceeded burn plan requirements for ignition operations: 2 Type 2 handcrews; 6 engines; qualified overhead
2012 Mar. 22 1700 -2030 hrs.	Initial mop-up begins. All resources released from LNF Unit 4a project area by 2030
2012 Mar. 22	Smoke Form E (accomplishment) submitted for Unit 4a reports 40 acres ignited
2012 Mar. 23	Burn unit perimeter is mopped-up approximately 200 feet deep; resources on scene were ICT4, 3 Type 6 engines, 2 Type 4 engines, and one Type 2 handcrew. The number of resources on scene exceeded burn plan requirements for extended mop-up operations
2012 Mar. 24	Patrol of LNF Unit 4a is conducted by ICT4 – only fire activity reported found in isolated stumps, logs, and duff pockets within the burn unit.
2012 Mar. 24	After update on unit conditions from the ICT4, the Burn Boss and CSFS Golden District Forester determined no need for patrol on Sunday
2012 Mar. 25	Lower North Fork Unit 4a is unstaffed
2012 Mar. 26	Burn Boss visited White Ranch Prescribed Fire site and declared burn “out”. He

DATE	EVENTS
	then returned to CSFS Golden District office.
2012 Mar. 26 1000 hrs.	ICT4 with two firefighters arrived onsite in morning for patrol. Fire activity observed is the same as found on March 24. Personnel patrolled control lines and found no concerns. Personnel began breaking down hose lay and have all water handling equipment packaged for backhaul by approximately 1230 hrs.
2012 Mar. 26 1240 hrs.	Winds increased blowing embers from interior of burn unit through the blackline reigniting fuels inside northeast flank of burn unit.
2012 Mar. 26 1300 hrs.	Firefighters have begun mop-up of smokes appearing within perimeter. FFT1 requested Type 6 engine from CSFS Golden District. ICT4 takes UTV w/ tank & pump to get water
2012 Mar. 26 1315 Hrs.	Two small spot fires discovered SE from DP-4. These are quickly contained and mopped-up. UTV w/ water back on-scene
2012 Mar. 26 1330 hrs.	New spot fire discovered outside control line near DP-5
2012 Mar. 26 1340 hrs.	ICT4 called CSFS Golden office to notify Burn Boss and District Forester
2012 Mar. 26 1347 hrs.	ICT4 requests additional resources through CSFS Golden office
2012 Mar. 26 1348 hrs.	Burn Boss (in Golden) requested additional resources through Jefferson County Sherriff's Office
2012 Mar. 26 1350 hrs.	ICT4 reported 1.5 acres outside burn perimeter and growing fast
2012 Mar. 26 1430 hrs.	Spot fire exceeded suppression capability of on-scene resources. The ICT4 (in communication with the Burn Boss) declared an escaped fire.

Narrative of events leading up to wildfire declaration

The first prescribed fire entries in the Lower North Fork Project Area occurred in 2011. These entries consisted of blacklining operations in Unit 1 and 3 followed by broadcast burning of Unit 1 in two phases and finally blacklining operations on Unit 4. CSFS personnel gained more experience with burning conditions in the masticated fuels during the burning of Unit 1. Observations of fire behavior resulted in revision of the burn prescription. Some prescription elements were changed to allow increased flexibility to burn under typical site conditions while safely meeting objectives.

The first entry into Unit 4A occurred on October 19, 2011, when a section of the upper perimeter was blacklined. This blacklining operation created an approximately 50' strip of "black" from DP-4 to DP-5. During this operation a spot fire occurred across the road in a small saddle north of DP-5. The spot fire was contained and extinguished. GPS mapping showed the spot fire to have been .37 acres in size. The Burn Boss reported five acres ignited during this blacklining operation.

On March 13 of 2012, CSFS personnel visited the Lower North Fork Project area to assess fuel conditions and clear control lines in preparation for continuing burning operations on Unit 4A. On March 19 an additional section of the Unit 4A perimeter was blacklined from DP-4 down the upper west side of the Unit toward the weather station. On March 20 personnel conducted mop-up of the

area blacklined the previous day. They also installed a port-a-tank, pump and hoselay to plumb the lower west side of the perimeter from DP-5 to the low point of the handline. CSFS personnel continued to monitor the weather, and based upon favorable forecasts, they decided to proceed with the main ignition of Unit 4A on March 22.

MARCH 22

Personnel met at Reynolds Park along Foxton Road a few miles north of the prescribed fire area for the operational briefing. After the briefing the resources proceeded to the Burn Unit. Time was spent performing reconnaissance of the Unit for resources who had not been there previously. The Firing Boss, in particular, took extra time to gain familiarity with the Unit. All personnel were in place and ready for the test fire by approximately 1100.

The Burn Boss reviewed the Go/No-Go checklist with the Firing Boss and Holding Specialist. After concurrence that all elements were a "Go" the checklist was signed at 1129. The test fire was initiated, results were favorable, and the test fire documentation was signed by the Burn Boss at 1145. Ignition operations targeted the masticated fuels with some ignition also in the "natural" fuels in the interior of the unit. The interior of the unit was not completely ignited. By approximately 1700 hours all resources on scene began mop-up of the perimeter. Mop-up efforts targeted the first 100 feet inside the burn perimeter. Additional actions included "grid" searches of the area outside the perimeter of the burn, and no spot fires were found. The Burn Boss Trainee indicated there were no holding or smoke management concerns when resources were released between 1900 and 2000 hours.

MARCH 23

Operations on March 23 were focused entirely on mop-up of the burn perimeter. The burn was well staffed with on-scene resources consisting of the following:

(1) RXB2/t / ICT4;
(1) Type-2 Handcrew (20 persons);
(2) Type-4 Engines with ENGB each and FFT2 each;
(3) Type-6 Engines with ENGB each and total (6) FFT2

On-scene resources totaled 34 persons and five engines, more than double the burn plan requirements for extended mop-up staffing. The Spot Weather Forecast issued March 23 for the LNF project contained a minimal discussion with no mention of upcoming wind events or red flag warnings; "clear through the afternoon with light winds and poor dispersal much of the day." One small spot fire (1/10 ac.) was discovered that morning below the lower handline on the west side of the Unit. The spot was quickly lined and extinguished. The engine crews mopped up along the roaded (upper) portion of the Unit and the handcrew worked along the lower handline.

Mop-up activities concentrated on areas within two to three chains of the road per burn plan direction. No significant holding concerns or excessive smoke production were noted. One of the Engine Captains felled two snags and reported that he heard at least four other snags come down within the Unit. Communication was passed advising personnel of the snag hazard and cautioning against working too far interior. Good progress was made and lots of water was utilized. Each engine refilled at least twice and the port-a-tank was refilled once. All personnel interviewed felt good about their progress with no smokes were reported within two chains of the road by the end of the day.

Resources were released late in the afternoon and all had departed the Unit by 1730. Prior to leaving the ICT4 met with personnel from Elk River Fire and gave them a key to the gate at the entrance to the project area. The ICT4 planned for a minimal patrol the next day.

MARCH 24

The NWS Zone Forecast issued 0523 hrs. MDT on March 24 indicated *"Max Temperature 58-68, Min Humidity 14 – 24%, Southwesterly flow aloft will increase and becomes south-southwesterly into Monday afternoon… Fairly strong low level winds are expected Monday… so fire danger will be worse."*

The ICT4 from the previous day performed the burn area patrol. During interview he stated that while driving into the area he saw no smoke until getting to the top of the burn unit near DP-4. He patrolled the area on foot and on ATV. He reported two visible smokes within the interior of the Unit. One was in the lower portion of the eastern half of the burn and the other well inside the western half. This smoke on the east side was described as deep duff burning in a shallow drainage. He finished his patrol and was leaving the Unit at approximately 1300.

The ICT4 removed burn signs that had been posted on Highway 285. He stated that this was done so that if a smoke was sighted from Highway 285 it would hopefully generate a 911 call. Prescribed burn signage was left in place along the Foxton Road.

The ICT4 contacted the Golden District Forester and the Burn Boss after return from the burn unit patrol. After discussing conditions on the burn the District Forester decided no patrol would be necessary on March 25 (Sunday). The plan was for the ICT4 to return to the unit on March 26 (Monday) for another patrol and possibly to remove the port-a-tank, pump and hoselay.

The NWS issued a Fire Weather Watch at 1409 *"…in effect from Monday afternoon through Monday evening for wind and low relative humidity for the Front Range Foothills below 7000 feet in Northern Colorado…"*

The NWS re-issued the Fire Weather Watch at 2131 PM *"…Fire Weather Watch remains in effect from Monday afternoon through Monday evening for wind and low relative humidity for the Front Range Foothills below 7000 feet in Northern Colorado… Timing… 12 noon MDT to 7 PM MDT on Monday… Winds… southwest 20 to 30 mph with gusts up to 50 mph."*

MARCH 25

No patrol operations occurred on Sunday, March 25. The burn was unstaffed.

The NWS Zone Forecast issued 0526 MDT on March 25 contained a *"Fire weather watch in effect from Monday morning through Monday evening for fire weather zones 215… 216… and 238 through 251 for strong winds and low relative humidity… Conditions may approach red flag criteria in areas south and southwest of Denver by late afternoon… The strong winds on Monday will make it to the surface… with red flag conditions a good bet for the plains. Fire Weather Watch in effect from noon Monday through 7 PM Monday for strong winds and low relative humidity… "*

The NWS upgraded the Fire Weather Watch to a Red Flag Warning at 1215 *"…for wind and low relative humidity… which is in effect from 10 AM to 7 PM MDT Monday. The Fire Weather Watch is no*

longer in effect… Winds…southwest 20 to 30 mph with gusts up to 50 mph. Winds will shift to the west late in the afternoon…"

The ICT4 and Burn Boss received pages on Sunday evening March 25 from the CSFS State FDO and also from Jefferson County Dispatch advising of the red flag warning for Monday.

MARCH 26

The NWS Zone Forecast issued 0551 MDT on March 26 contained a *"Red Flag Warning in effect from 10 AM until 7 PM for fire weather Zones 215… 216… and 238 through 251 for strong winds and very low humidity…20-foot winds / Valleys and Lower Slopes … southwest 8-13 mph with gusts to 25 mph increasing to 22-32 mph with gusts to 60 mph in the afternoon."*

The ICT4 arrived on the burn unit in a pickup truck with two firefighters around 1000. All control lines were patrolled and the lower handline was mapped with a GPS unit. No holding concerns were noted. The same two interior smokes that were noted on Saturday were still visible. One was located on the west side of the Unit and another one in a shallow drainage on the lower east side. No mop-up needs were observed, no additional mop-up was conducted.

The ICT4 and the two firefighters proceeded to break down the port-a-tank, pump and hoselay. The water handling equipment was loaded for backhaul by approximately 1230. The group proceeded from the area around DP-5 up the road toward DP-4 between 1240 and 1250. By this time winds had increased significantly to approximately 10-15 mph. The winds fanned the hot areas within the burn resulting in increased smoke and embers "like fleas" landing in the blackline area and reigniting available fuels. The patrol crew began to mop-up these new smokes within the perimeter.

At 1300 the ICT4 left the FFT1 and FFT2 at the burn and took a UTV w/ 70 Gallon tank and pump down to the creek to get a load of water. The FFT1 called on the radio to the CSFS Golden District office for a Type 6 engine to be brought up to the burn and specifically stated no additional firefighters were being requested, just the engine. Before the ICT4 returned, the two firefighters discovered a couple of small spot fires across the road approximately 1/8 mile SE of DP-4. Upon return to the unit at approximately 1315 the ICT4 found the two firefighters working the two "desk sized" spots. The spots had been lined and were being mopped up. Water in the UTV was used to extinguish the spots.

By this time wind speeds had increased and more smoke and embers were blowing across the control lines. The firefighters were surprised at material reigniting in the black and wondered "how is this stuff burning." They noticed an increase in smoke coming from the area around DP-5. The FFT1 was sent to investigate and viewed the area of concern from a higher point on the road. He reported back to the ICT4 that it was smoke from within the burn unit blowing across the line.

The ICT4 called on the radio to the CSFS engine en-route to the burn and heard they were approximately five minutes from the gate at the bottom of the project area. He was still concerned about the volume of smoke he was seeing around DP-5. At 1330 he took the UTV, which was out of water, down the road for a closer inspection. Upon arrival he discovered a new spot fire adjacent to the control line in the same saddle where a spot fire had occurred during blacklining the previous October. This new spot fire was approximately 10'x10' in size and was burning hot in the masticated

fuels. The ICT4 took the UTV back up the road and used the truck radio to call the CSFS Golden office at 1340 to report the spot fire and relay size-up information.

At 1347 he called the CSFS Golden office again to request more resources. Then he took the UTV back down to the creek to get more water. At 1348 the Burn Boss called Jefferson County Sherriff's Office Fire Management staff to request that North Fork Fire and Elk Creek Fire resources be sent to the burn. By this time the CSFS engine requested earlier had arrived on scene and was utilized by the ICT4 and two firefighters to work the new spot fire. At 1350 the spot was reported to be 1.5 acres in size, well established in the masticated fuels and resistant to control efforts given the increased winds.

Resources from North Fork Fire arrived between 1400 and 1415 and resources from Elk Creek Fire arrived approximately 10 minutes later. The ICT4 discussed the situation via radio with the District Forester and the Burn Boss. The fire was declared an escaped fire at 1430.

KEY ANALYSIS OBSERVATIONS AND LEARNING ELEMENTS

Seasonal Severity, Weather, and On-Site Conditions Leading Up to the Wildfire Declaration

Seasonal Severity

Strong low pressure systems brought near record snowfall and cooler than average temperatures to the Colorado Front Range in February. An abrupt pattern shift resulted in the driest and one of the warmest months of March on record. The record warmth and dryness leading up to March 26, 2012, quickly depleted February's snowfall gains below 9000 feet MSL. The weather pattern supported a high frequency of wind events, exacerbating the drying of fuels along the Front Range. See Appendix F.

Weather

March 19, 2012- Lower North Fork Blacklining Operations

Blacklining operations on March 19, 2012, on the Lower North Fork Unit was performed and completed under non-critical atmospheric conditions. On-Site observations indicate a prevailing south-southwest wind of 3 to 6 mph with gusts to 10 mph with good lift and dissipation of smoke. On-site temperature readings were consistent with Remote Automated Weather Station (RAWS) observations at similar elevations (6800-7100 feet msl), however relative humidity readings were 10% to 12% higher.

March 20-21, 2012

Site weather observations were taken on March 21, 2012, on the Lower North Fork Unit for the purpose of obtaining a spot weather forecast. The maximum temperature readings from local RAWS observations ranged from the mid-40s to low 50s. Minimum relative humidity range from 19% to 22%, with prevailing wind from the east to northeast at 7 to 10 mph with gusts 16 to 21 mph. Manual calculations of the Haines Index from Denver (DNR) Radiosonde data ranged from a 3-very low on the afternoon of March 20, 2012, and a 2-very low the afternoon of March 21, 2012. Much of the Colorado Front Range was under the influence of a "Cut Off" low pressure system centered over Kansas and Oklahoma. No precipitation was recorded in the Unit.

March 22, 2012- Lower North Fork Prescribed Fire

The eastern plains and Front Range of Colorado remained under the influence of a "Cut Off" low pressure system centered over southern Kansas and Oklahoma. On-site wind observations measured an east to northeast (at times variable) wind direction with maximum sustained wind speeds ranging 5 to 9 mph with maximum gusts of 10 to 12 mph. Maximum temperatures reached 59ºF with a minimum relative humidity of 21%. Calculated Haines Indices from the DNR radiosonde data ranged from 2-very low at 0600 MDT to a 3-low at 1800 MDT.

March 23-26, 2012- Changing Meteorological Conditions and the Lower North Fork Prescribed Fire and Wildfire
Meteorological Conditions March 23, 2012

March 23, 2012, marked the beginning of changing atmospheric conditions that became more conducive to support large fire activity. On March 23, 2012, a ridge of high pressure extended from New Mexico, northward into Colorado, eastern Wyoming and the Black Hills of South Dakota, as a new trough of low pressure began to take shape off the west coast. The shift in the pattern resulted in a significant air mass change across Colorado including the Front Range. Temperatures increased 15 to 20 degrees from the previous day of March 22, 2012, with maximum readings in the low 70s at the Bailey and Polhemus RAWS near the Lower North Fork burn site. Denver, Colorado set a new record high that afternoon of 76 degrees. Local RAWS also showed a steady decrease in relative humidity during the early morning hours, with values dropping into the single digits by 1400 MDT on March 23, 2012.

Meteorological Conditions March 24-25, 2012

The air mass along the Front Range and over the Lower North Fork Unit became more precarious on March 24 and 25, 2012, leading up to the critical fire weather pattern on March 26, 2012. The upper ridge that extended across Colorado on March 23, 2012, had shifted into the plains as an upper air trough and associated surface front migrated east into California and Nevada by the end of the day on March 25, 2012. The shift in the ridge resulted in a slightly cooler temperature, but still above average with readings in the mid-60s to around 70 at the Bailey and Polhemus RAWS sites. It is important to note, relative humidity dropped into the single digits on the afternoon of March 24 and 25, 2012. The air mass remained unstable and dry with calculated Haines Indices of 5 to 6.

A Fire Weather Watch was issued by the Boulder National Weather Service Office on Saturday, March 24, 2012, 0209 for Monday, March 26, 2012, from 1200 MDT to 1900 MDT, highlighting increasing winds (Southwest 20 to 30 mph with gusts up to around 45 mph), and low humidity (6%), including fire weather zone 216 that encompasses the Lower North Fork Unit.

The Fire Weather Watch for Monday, March 26, 2012, was upgraded to a Red Flag Warning by the Boulder National Weather Service office on Sunday, March 25, 2012, at 1215 MDT, highlighting a west to southwest wind of 25 to 35 mph and gusts up to 65 mph, including fire weather zone 216 that encompasses the Lower North Fork Unit.

Meteorological Conditions March 26, 2012-Lower North Fork Wildfire
Upper Air and Surface Pressure Features

Meteorological conditions that contributed to the escape of the Lower North Fork Prescribed Fire on March 26, 2012, were consistent with historic fire events that have occurred across Colorado (South Canyon 1994, Bobcat Gulch 2000, Hayman 2002, Overland Fire 2003). Analysis of upper air and surface pressure charts on March 26, 2012, showed an eastward shift of the upper ridge into the high plains as an upper air trough and associated cold front migrated into Utah early in the day (Similar to meteorological features outlined in the South Canyon Fire Investigation published in August 1994). The “Break Down of the Upper Ridge” (or shift eastward ahead of an upper trough and surface front) is highly recognized and well documented “critical fire weather pattern” that can produce strong

gusty winds, warm temperatures, low humidity (drying of fuels), enhance vertical lift (unstable atmosphere) and extreme fire behavior.

Meteorological Conditions During the Morning (Midnight to 1200 (Noon) MDT) of March 26

The Polhemus RAWS observations (ridge top) during the early morning hours (Midnight-0800) of March 26, 2012, showed steady temperatures (48ºF-50ºF), poor overnight relative humidity recovery (23%-28%), south-southwest winds 8 to 11 mph with gusts 20 to 24 mph. The Bailey RAWS data for the same time also showed steady temperatures overnight (44-46), moderately dry relative humidity recoveries of 36%-40% and light west to northwest winds of 2 to 4 mph. Early morning satellite sequence and local observations also revealed dense mid and high level cloudiness over the Lower North Fork Unit, ahead of the upper trough and surface front. Steady temperatures and poor relative humidity recovery are consistent with not only air mass characteristics in place at the time, but with known impacts from cloud cover and wind at night (both of which disrupt radiational cooling and corresponding rise in relative humidity).

Water Vapor (WV) satellite imagery revealed mid-level dry air extending northeast from the Desert Southwest into western Colorado at 0900 MDT. Utilizing Denver Radiosonde data from 12Z (0600 MDT), manual calculation of Haines Index was 6-High.

Meteorological Conditions During the Afternoon 1200 (Noon) MDT to 1800 MDT of March 26th

Between 1200 and 1230 visible satellite sequence show that mid and high level cloud cover had moved east of Jefferson County and the Lower North Fork Unit. Corresponding Water Vapor (WV) imagery also showed significant mid-level level dryness over the Lower North Fork at the same time. Polhemus solar radiation values from the 11:54 MDT and 12:54 MDT observations significantly increased indications cloud cover had dissipated and direct sun was reaching the surface. A similar increase was observed at the Bailey RAWS between the 10:22 MDT and 11:22 observation time. Temperatures during the same time frames increased 6ºF with corresponding relative humidity decreases from 17% to 9% at Polhemus and 12% to 9% at Bailey. Wind changes during this time were most noticeable at Polhemus with sustained 10-minute average winds increasing from 16 mph to 23 mph and gust increase from 36 to 49 mph from the west to southwest. Wind data from the portable weather station on the Lower North Fork Unit also showed the same increase in wind speed; however the wind direction sensor appeared to be malfunctioning (stuck at 169.9 degrees from March 19 through March 26, 2012).

The overall climatological and meteorological factors that contributed to rapid increase fire growth potential on the Lower North Fork Prescribed Fire include:

1. Record warmth and dryness during the month of March
2. Rapid depletion of snowpack gained in February, exposing fuels to prolonged warm temperatures, low humidity and wind.
3. Air mass change (warm, dry, and unstable) beginning March 23, 2012
4. Rapidly changing weather conditions (temperatures, relative humidity, wind, and instability).
5. A decrease in cloud cover resulted in increased vertical mixing between the air mass at the surface and aloft, allowing stronger winds to surface.

6. Critical fire weather pattern (above average temperature, low humidity, strong and gusty winds, Unstable Atmospheric Conditions, Haines Index of six, poor overnight relative humidity recovery)- Red Flag Conditions.

Fire Behavior

Topography

Terrain in the general vicinity of the Prescribed Fire Unit is mountainous, with a major river drainage (North Fork of the South Platte River) running to the south-southwest of the units (Figure 9). Elevation ranges from 6,300 feet along the river to 7,000 feet at the top of Unit 4A. The southernmost extent of Unit 4A is about 6,600 feet in elevation.

Slope in the area is moderate to steep. On Unit 4A itself, slope ranges from nearly flat along the upper road (1.8% slope) to 85% in the steepest portion near the bottom of the Unit. The average slope of Unit 4A is 36%.

Slope class, %	Percent area of Unit 4A
0-20	8.5
21-40	53
41-60	36
61-80	2.5
>80	<0.1

The aspect of Unit 4A is generally facing south to southwest. Several prominent draws run to the north, north-northeast, and east from near the bottom of the Unit.

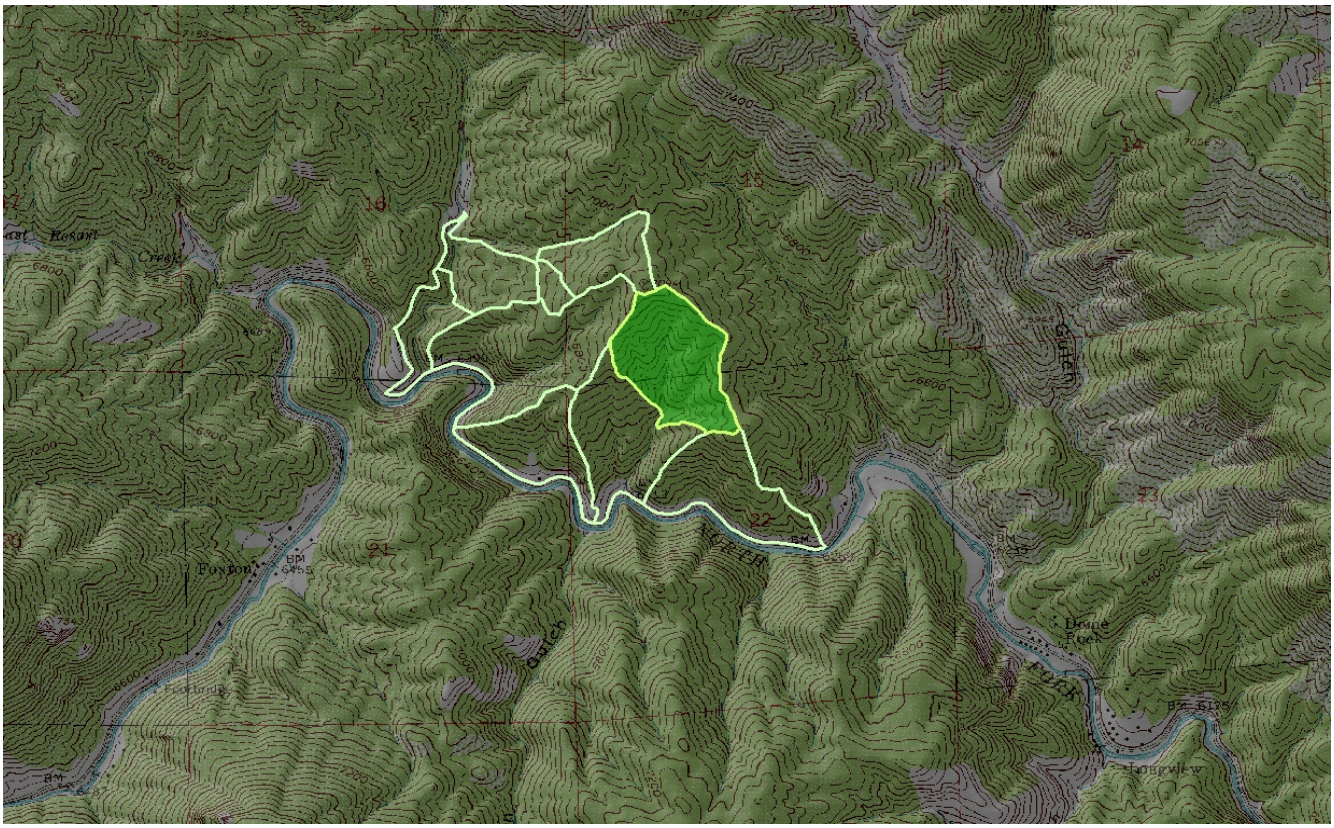

Figure 9. General terrain in the vicinity of Unit 4a (highlighted).

Fuels

Fuels within Unit 4A, include open ponderosa pine with light grass understory and denser mixed ponderosa pine/Douglas-fir stands with timber litter understory (Figure 10). Significant portions of the Unit were masticated fuels resulting from mechanical treatment of woody fuels (Figure 11). In the two draws in the southern portion of the Unit, fuels had not been mechanically treated due to access limitations by mechanical equipment (Figure 11).

Outside of Unit 4A, fuels varied. In Unit 1 and the upper portion of Unit 3, surface fuels were largely absent due to prescribed burning the previous year. To the north and northeast of Unit 4A, fuels were similar to those on the northern portion of Unit 4A – mechanically treated fuels with interspersed grass under open ponderosa pine. South of Unit 4A, fuels were similar to the lower portion of 4A – dense ponderosa pine/Douglas-fir stands on more northerly aspects, with open ponderosa pine and light grass on more southerly aspects. Surface fuels had been mechanically treated in a significant portion of the area north, east, and south of Unit 4A. See Fuels Treatment Map for a delineation of areas that had been mechanically treated.

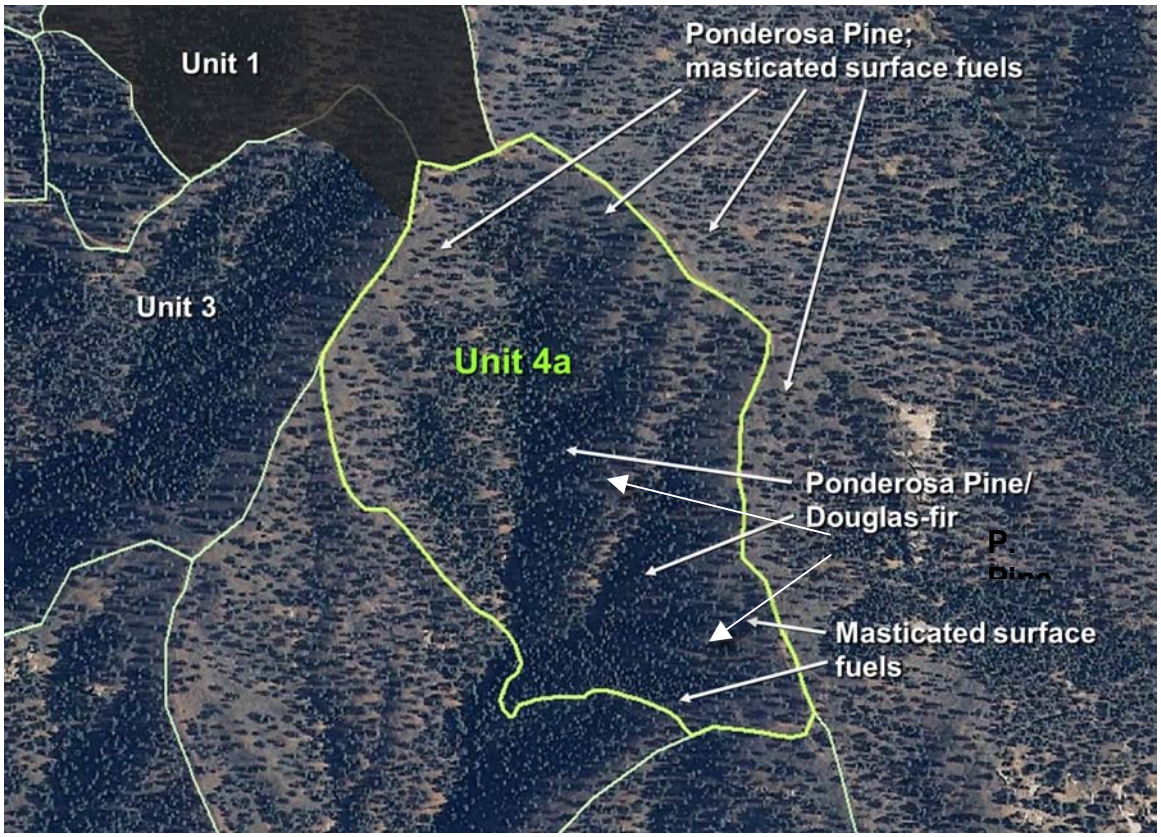

Figure 10. Fuels in Unit 4 and vicinity. Denser stands of mixed ponderosa pine/Douglas-fir are found on more north-facing slopes and in the lower reaches of the draws in the unit.

Figure 11. Mechanically treated fuels with interspersed grass (left), and non-treated fuels found within draws and on steeper northerly exposures (right) in Unit 4a. Photo Source: Fire Behavior and Effects Documentation, Lower North Fork Project (left), and site visit April 6, 2012 (right), (K. Close).

Fire Behavior

Fire Behavior on the Day of the Rx Burn – March 22, 2012

Winds were light and upslope and consistently out of the northeast to south during the firing operation. The RH was in the mid-20s, and temperature and RH held fairly constant from 1100 through 1600. Conditions throughout the operation remained well within prescription parameters with the exception of an occasional wind gust. Crews noted smoke moving to the southwest, with good dispersion all day through about 1900.

Fire behavior throughout the ignition operation was moderate, with intensity and spread rate largely controlled by the rate of ignition (Figure 12). Flame lengths were generally less than three feet, with higher intensities in pockets of heavier fuel accumulation. Crews reported occasional single-tree torching, but this was minimal and full consumption of the canopy of a torching tree was not occurring. No group-tree torching or other crown fire was observed. In fact, crews noted that the tree canopies were largely untouched, with good consumption of surface fuels.

Fuel consumption was nearly complete in mechanically treated fuels and lighter understory fuels, and fire activity was minimal by the end of the ignition operations (Figure 12). When active fire hit previously blacklined areas, the fire went out. There were some unburned pockets of fuel in the interior of the Unit, and crews burned out many of these.

The draw on the south portion of the Unit was the last to be ignited. Fire behavior there was more moderate than some expected – fire didn't get up into the crowns, and didn't make any significant runs up any drainages. There was good consensus among on-site personnel that "the fire behaved very nicely that day." In the heavier understory fuels found in untreated mixed conifer stands, fuel consumption was incomplete to spotty in mid-slope locations. In the lower reaches of deeper draws, and northerly aspects in the south and southeast portions of the Unit, significant areas appear to not have burned at all due to higher fuel moisture in these cooler locations (Figure 13).

Figure 12. Fire behavior in mechanically treated fuels during ignition (left) and post-flaming phase (right). Photo Source: Fire Behavior and Effects Documentation, Lower North Fork Project.

Figure 13. Nearly complete consumption of surface fuels near the control line at the southeast corner of Unit 4A (left). About 80-100 feet below this, in the bottom of a draw, fuels appear to have not burned at all (right). Duff in this scenario was about 3-5 inches deep. Photo Source: April 6, 2012 site visit. (K. Close).

Figure 14. Partial consumption of surface fuels in a draw on the southeastern portion of Unit 4a. There was no apparent consumption in the lower third of the draw. Past this point, consumption ranged from minimal with no duff reduction (left) to partial consumption over broader areas (right). Duff in this location was 2-3 inches deep, and had not been consumed to any significant degree. Above the halfway point, fuels consumed more completely. Photo Source: April 6, 2012 site visit. (K. Close).

In post-burn assessment of the two deeper draws in the southern portion of the Unit, there appeared to be a moisture gradient that influenced vegetation, and possibly fuel consumption. In the lower third of the draws, duff was 3-5 inches deep, and there was no visible evidence of any fire activity (Figure 13). Up to about the halfway point up the draws, fuel consumption was spotty, with only partial duff consumption. In the upper third of the draws, surface fuel consumption was more complete (Figure 14). In some areas, fuels had been reduced to white ash (Figure 15). Additionally, there was evidence of group-tree torching in the uppermost part of a draw, about 300 feet below the eastern perimeter.

Figure 15. Near-complete consumption of surface fuels in the upper portion of the draw, to white ash in many locations (left). About 300 feet below the road, there was evidence of a small group of trees torching (left and right). It was not clear if this torching occurred during the day of ignition or at some point later. Photo Source: April 6, 2012 site visit. (K. Close).

Fire Behavior March 23 and 24

Fire activity within Unit 4A was minimal on March 23 and 24, 2012. Patrol personnel reported that surface fuels had largely burned out within the Unit, and there was no apparent fire activity or heat within 200 feet of the perimeter. There were two locations in the interior of the Unit that were each producing a small amount of light, white smoke. This smoke did not increase in volume or density, and would dissipate when it reached the treetops.

Fire Behavior March 26

Mid to Late Morning – The area had been under a full cloud cover all morning. Weather recorded at the Bailey RAWS indicated temperatures were in the upper 50s, RH 14-17%, and winds 5-6 mph. On-site ridgetop winds measured at the HOBO weather station were about 4 mph through mid-morning, and began increasing in speed between 1000 and 1100 (Figure 16). Fire activity was minimal, and similar to that observed on March 24, 2012. Areas that had been burned and mopped up inside the control lines showed no visible fire activity. The only apparent activity within the Unit were the two small smokes noted previously, which were well within the interior of the Unit. Smoke from these two locations was light, and dissipated upon reaching the treetops.

Late Morning into early afternoon – After about 1100, conditions began changing on the site. The cloud cover began breaking up, and the morning surface inversion was also dissipating. Personnel on site noted that "everything still looked ok" at approximately 1200.

Between 1222 and 1254, the Bailey and Polhemus RAWS sites both indicated the cloud cover over the area had dissipated, with solar radiation increasing (Figure 16). The site was now subject to solar heating, which would have the effect of drying and warming fine fuels in the area. Winds were increasing, temperatures were increasing, and RH was steadily dropping. The RH dropped to single digits by about 1300.

Time	RAWS Station	Temp. (deg. F)	RH (%)	Wind Speed and Gust (), mph	Wind Dir.	Solar Rad. (W/m^2)
1022	Bailey	59	14	6 (13)	SW	394
1122	Bailey	59	12	5 (14)	SW	611
1222	Bailey	64	9	6 (16)	SW	809
1322	Bailey	66	6	6 (19)	SW	942
1422	Bailey	65	5	8 (17)	WSW	909
1522	Bailey	63	6	10 (19)	WSW	809
0954	Polhemus	51	23	11 (25)	SW	152
1054	Polhemus	54	22	16 (36)	SW	244
1154	Polhemus	54	17	23 (49)	SW	269
1254	Polhemus	59	9	21 (50)	WSW	875
1354	Polhemus	62	5	26 (47)	WSW	986
1454	Polhemus	63	4	27 (55)	WSW	805

Time	Location	Wind Speed (mph)
1000	HOBO (Unit 4a)	8.7
1100	HOBO (Unit 4a)	12.0
1200	HOBO (Unit 4a)	14.1
1300	HOBO (Unit 4a)	15.4

Figure 16. Weather readings from the Bailey and Polhemus, RAWS and HOBO weather station during March 26, 2012.

Shortly after 1230, as winds increased, personnel on site noticed “embers” being blown from inside the unit below DP4 and re-igniting spots in the existing black line below DP4.

At this time, personnel on the upper (north) road also reported seeing “duffers” – small smokes – appearing in the black line below the road, inside the unit, on the northern perimeter. These “duffers” began to work their way up the hill, and personnel on site began suppressing them. Personnel later remarked that this was a surprise, as this area had appeared black and cold since the day of the ignition.

Between 1240 and 1300, the “embers” coming into the upper part of the unit below DP4 intensified. Winds continued to increase, and the RH continued to drop. Winds across the road on the upper (north) part of the unit were estimated to be reaching 15 mph with stronger gusts.

Between 1320 and 1330, there was an increased volume of smoke in a draw in the eastern portion of the unit. Whereas smoke had previously been light and dissipated at the treetops, it was now moving up the slope and across the east line north of DP5, traveling to the northeast. Winds continued to increase, reaching 15-20 mph with strong gusts.

At about 1340, a 10’x10’spot fire was discovered across the road on the southern portion of the eastern perimeter (Figure 17). Personnel in the location of this third spot reported numerous small embers crossing the road in the saddle above one of the southernmost draws (Figure 18). They were not able to ascertain exactly where the embers were originating, only that these

embers were coming from the draw within the unit and crossing the control line above the draw.

The area in which the embers were landing, and the new spot fire started, consisted largely of masticated fuels. These fuels were now burning aggressively with the change in weather conditions. Within 15 minutes, the spot had grown to 1.5 acres and was "growing fast." By 1430, the spot had grown to 7 acres. Strong winds pushed the fire downslope from the control line, then up-canyon in a northerly direction.

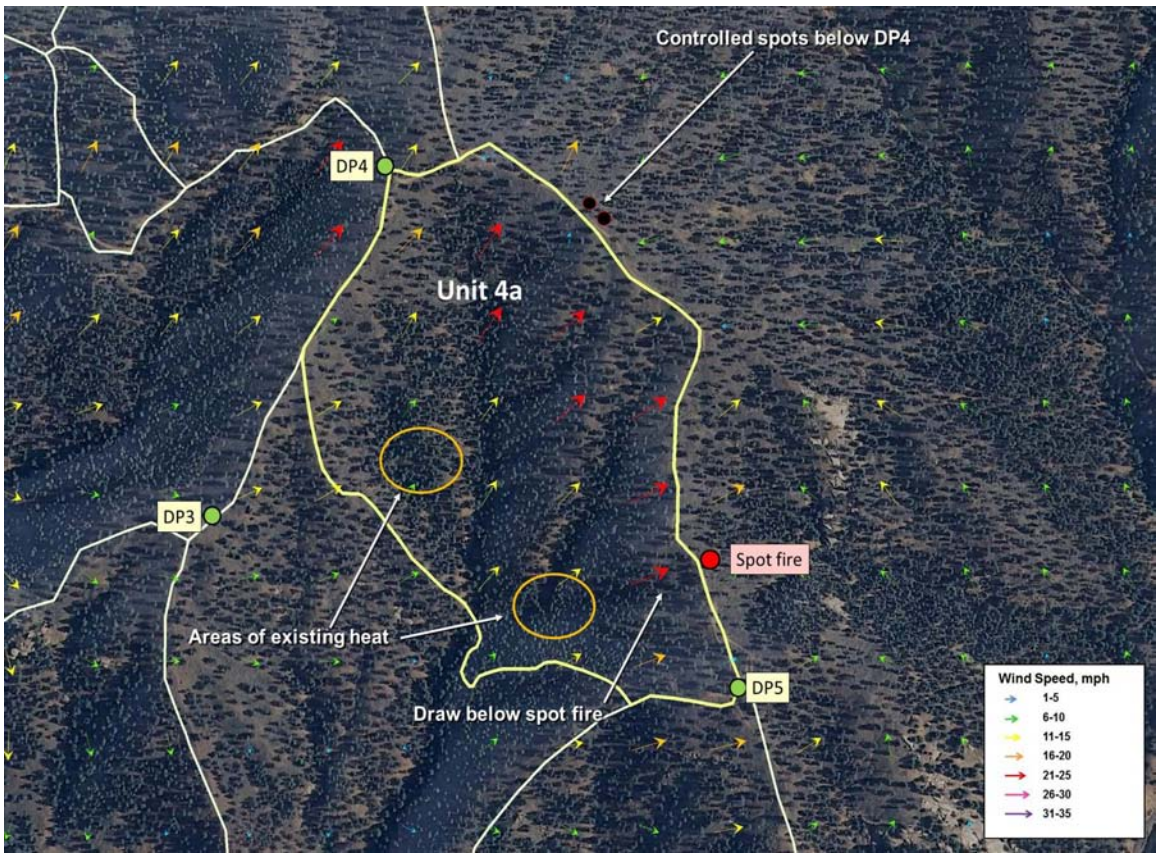

Figure 17. Location of spot fires, areas of residual heat in the unit, and simulated winds at 1400 on March 26, 2012.

Figure 18. View downslope into the draw from which personnel reported embers emanating while they were working on the new spot fire north of DP5 ("Spot fire"). View is from the road near the spot fire location looking downslope to the west-southwest. Photo Source: April 6, 2012 site visit. (K. Close).

Analysis of the Prescribed Fire Plan for Consistency with Policy

Table 4. describes each element of the Lower North Fork Prescribed Fire Plan and provides an evaluation consistency with Colorado State Forest Service policy and potential contribution to the escape.

Table 4. Lower North Fork prescribed fire plan elements, compliance, and potential contributions.

PRESCRIBED FIRE PLAN ELEMENTS:	COMPLIES WITH CSFS POLICY?	COMMENTS	DID THIS PLAY A ROLE IN ESCAPED FIRE?
1. Signature page	Yes	All preparers and technical reviewers signed as appropriate per CSFS policy, approved on 10/9/09 and valid through 10/9/14. This plan was reviewed by another burn boss as well as the district forester. Approving official is the Prescribed Fire Program Manager and while not an "agency administrator" by definition, CSFS policy specifies that this position has approval authority for prescribed fire plans.	No
2. Project Objectives	Yes	Clearly defined objectives stated in measurable terms. One objective is to create a mosaic pattern of burned and unburned patches in the areas that were not masticated earlier, thus reducing wildfire risk while still leaving a healthy overstory, adequate protection for soil on the steep slopes, and a more visually appealing landscape with a mix of green and burned vegetation in the Unit. Potential for protracted burning may be increased when some fuels are intentionally left unburned inside the treatment area, so there is a trade-off between meeting goals for forest health/aesthetics and mitigating the risk posed by longer duration of burning within the burn unit. The objective of reducing wildfire risk is achieved in part by controlling the fire edge while allowing the interior of the Unit to burn itself out rather than put it out directly. This maximizes the removal of fuels that would be available to a future wildfire.	Potential Factor
3. Complexity Analysis Summary	Yes	Used early version of Complexity Guide and noted this in the plan. Original analysis of Moderate was made in 2006 and was re-affirmed as part of the plan update in 2009. Original plan to burn Unit 4 as a 100+ acre unit was revised as planners agreed that the organization and technical difficulty of doing so would push it up to High complexity, thus the handline was put in to create a smaller burn unit (Unit 4A) that would be more easily managed as a Moderate complexity burn.	No
4. Scheduling and Notification	Yes	Part of a multi-phased project and scheduled during acceptable air quality time periods. All notification information requested is provided;	No

PRESCRIBED FIRE PLAN ELEMENTS:	COMPLIES WITH CSFS POLICY?	COMMENTS	DID THIS PLAY A ROLE IN ESCAPED FIRE?
		broad list of contacts on the list which was updated periodically throughout the project as new contact information was made available.	
5. Burn Area Description	Yes	Adequate descriptions of general location and burn units. A Maximum Manageable Area (MMA) is identified in the project planning and depicted on maps.	No
6. Fuels Description	Yes	Adequate description of fuel loading for both target area and adjacent area including photos. One piece of useful information not included was a map showing the distribution of fuels outside the Unit and beyond the MMA which would provide an initial indication of where the fuel type changes occurred across the landscape in the event of an escape.	No
7. Prescription Parameters	Yes	Prescription and Guidance parameters are provided and properly displayed; adjustments to parameters based on experience from previous burns were well documented and those changes were reviewed and approved as the plan was updated each year.	No
8. Smoke Management	Yes	Smoke Management is complete with very detailed information provided by both prescribed fire planners and the air quality regulatory agency as part of the annual permitting process. Managing smoke was an influential factor in planning and executing this project because acceptable wind directions and atmospheric conditions and burn unit size were limited to meet smoke production and down-wind impact objectives. Day of ignition all smoke related objectives were met.	No
9. Workforce & Equipment Requirements	Yes	Workforce and equipment needs are defined for all phases of the operation including blackline, burning and mop-up/patrol. Assignment of a Type 2 Burn Boss is consistent with complexity. Number and type of resources planned are appropriate for the scope of each phase of the project.	No
10. Safety Plan	Yes	All standard elements are addressed including special instructions for lookouts, communication, escape routes and safety zones. Safety of public driving roads that could be obscured by smoke is a high concern. Mitigation measures for both	No

PRESCRIBED FIRE PLAN ELEMENTS:	COMPLIES WITH CSFS POLICY?	COMMENTS	DID THIS PLAY A ROLE IN ESCAPED FIRE?
		firefighter and public safety are outlined.	
11. Medical Plan	Yes	Thorough and provided necessary information but hospital address was incorrect.	No
12. Communications Plan	Yes	Complete and updated with new information and adequate for the scope of the planned project including note that cell phones do not work well in the area.	No
13. Ignition Plan	Yes	Provides adequate description of intent leaving discretion to the burn boss, firing boss and holding boss to adjust patterns based on wind, fuels, and terrain on the day of the burn.	No
14. Holding Plan	Yes	Contains general directions and specific instructions for individual burn units detailing the number and type of resources required for each phase on each unit.	No
15. Mop-Up Plan	Yes	Optional guidelines based on Keetch/Byram Drought Index, but the responsiveness of this index to daily fire danger in this area is not well established and local managers are not sure of its utility. Regardless, the maximum level of interior mop-up specified in the plan (200 feet) was met or exceeded throughout Unit 4A by the end of shift Friday March 23, 2012. The 200 foot mop-up standard meets or exceeds standard practices for most prescribed fire operations, and in fact, a 200 foot buffer is widely used in wildfire operations as a reasonable measure of security under most conditions. Special Wind section places considerable discretion on the burn boss/incident commander and does not require a minimum number of resources to patrol once the 200 foot mop-up standard is met.	Potential Factor
16. Escape Fire Analysis and Action Plan	Yes	Meets policy and provides clear direction for a case of a prescribed fire being declared a wildfire. There are several actions detailed to guide transfer of command once a prescribed fire is declared a wildfire.	No
17. Monitoring Plan	Yes	Thorough and complete.	No
18. Briefing Checklist	Yes	All critical briefing points are included and go beyond most basic briefing checklists	No

PRESCRIBED FIRE PLAN ELEMENTS:	COMPLIES WITH CSFS POLICY?	COMMENTS	DID THIS PLAY A ROLE IN ESCAPED FIRE?
19. Go/No-Go Checklist	Yes	Elements in the check list match those required by CSFS policy and are consistent with accepted interagency standards.	No
20. Test Fire	Yes	Matches the agency template	No
21. Prescribed Fire Report	Yes	Matches master template form, and it was included in the plan for completion once the Prescribed Fire was declared out. The report was incomplete at the time of this analysis because the Prescribed Fire was converted to a wildfire	No
22. Attachments	Yes	A – Fire Behavior modeling was completed and model outputs were factored into the development of the prescription guidance.	No
	Yes	B – Smoke Analysis appears to be the same as the Smoke Management portion of the plan. Current Colorado Department of Public Health and Environment - Air Pollution Control Division (CDPHE-APCD) procedures do not require smoke modeling to be complete by the applicant and any smoke modeling and analysis for this project was to be conducted by CDPHE-APCD.	No
	Yes	C – Smoke Permit Application is filled out completely and a permit was issued by CDPHE-APCD.	No
	Yes	D – Project costs are well defined and a Service Agreement is in place between CSFS and Denver Water. The funding provided by the land owner to execute the project does not factor in potential contingency resources should additional resources be needed during execution of the plan, thus any unforeseen expenses fall to CSFS and the area cooperators to fund through their own limited operating funds. Interviews did not indicate there was any hesitancy to order additional resources due to funding concerns	No
	Yes	E – Actual Cost form matches master template form and was included in the plan for completion once the fire was declared out. The report was incomplete at the time of this analysis because the Prescribed Fire was converted to a wildfire	No
	Yes	F – Organizational Charts were completed for each operational period with specific names and assignments made each day	No

PRESCRIBED FIRE PLAN ELEMENTS:	COMPLIES WITH CSFS POLICY?	COMMENTS	DID THIS PLAY A ROLE IN ESCAPED FIRE?
	Yes	G – Project Maps were included in the plan and provided as part of operational briefing packets	No
	Yes	H – Project Photos section is reserved for photos of pre and post implementation and those photos were available	No
	Yes	I – Documented Changes to Approved Plan is a standard form that was used each time the plan was altered. These adjustments underwent technical review and approval before being included in the updated plan.	No
	Yes	J – Service Agreement is in place between CSFS and Denver Water, and was included in the plan documentation	No

Compliance and consistency with the prescription, actions, and procedures set forth in the Prescribed Fire Plan

MARCH 22 – IGNITION OF LOWER NORTH FORK PRESCRIBED FIRE UNIT 4A

Test Fire:
Go/No Go Checklist was reviewed and completed as appropriate. All conditions set forth in the plan were met and were considered ideal (see Table 5 below). Extended forecast was for cooler weather Sunday with some increase in wind Monday, but there was no indication of any extreme fire weather in the area. Test Fire was executed according to plan and met objectives.

Table 5. Comparison of Prescribed Fire Plan Prescription , parameters and observed conditions.

PRESCRIPTION MUST BE MET *Or Guidance- USeful but not required*	Parameters from Prescribed Fire Plan for Broadcast Burning	Observed Conditions on 3/22/12 Unit 4A
MID-LAMES WIND (MPH)	0 - 12	3-6 Gust to 9
RELATIVE HUMIDTY (%)	>9	22
AVERAGE FLAME LENGTH IN FEET	1 - 8	1 to 5
Temperature (F)	45 - 70	54
Conifer Live Fuel Moisture (%)	>95%	Unavailable
Rate of Spread (ch/hr)	0 – 20	<10

PRESCRIPTION MUST BE MET *Or Guidance- USeful but not required*	Parameters from Prescribed Fire Plan for Broadcast Burning	Observed Conditions on 3/22/12 Unit 4A
Spotting Distance (miles)	0.1 – 0.2	<10 ft
Scorch Height (ft.)	1 – 16	N/A
Transport Wind Direction	Any	N
Transport Wind Speed (mph)	10 – 40	12 - 20
Cloud Cover (%)	0 – 30	Partly Cloudy

Ignition & Holding Plan:

Objectives set forth in the plan were met including those for smoke dispersal, fuel consumption, and control. All indications are that the fire was executed as planned.

Initial Mop-Up Plan:

The burn plan states: *"Following completion of primary ignitions, the RXB2 & Holding Specialist will assign all holding resources to patrol and mop-up activities. Ignitions resources will be assigned to mop-up operations as available.*

Primary focus on day one will be on security of the burn unit. Secondary focus will be on reducing smoke generation. Initial mop-up will be focused on spotting, creeping, or other escape threats within 2 chains of the unit boundary and on any significant spotting threats in the interior of the unit. Continue patrolling the unit on a regular basis.

Additional mop-up on the first day will be conducted based on available time, resources, and smoke production, and will be focused on heavier, smoke-producing fuels in timber areas. Burning materials may be chunked and bone-piled to facilitate rapid combustion. The remainder of the unit will be allowed to burn out overnight, provided there are no significant down-drainage smoke impacts."

After ignitions were completed at approximately 1700 hours all resources on scene began mop-up of the burn perimeter. Mop-up efforts targeted the first 100' to 120' inside the burn perimeter. Additional actions included "grid" searches of the area outside the perimeter of the burn and no spot fires were found. The Burn Boss Trainee indicated there were no holding or smoke management concerns when resources were released between 1900 and 2000 hours. A substantial buffer of "cold black" had been established of between 40' and 130' around the entire unit. These actions were consistent with burn plan requirements.

MARCH 23 -25, EXTENDED MOP-UP AND PATROL STATUS

Burn Unit in Extended Mop-up status:

March 23 Staffing

- Unit 4 Extended Mop-Up: 12 persons and 2 engines required
- Resources On-Scene: 34 persons and 5 engines

Each engine refilled at least twice and the port-a-tank refilled once which amounted to well over 6,000 gallons of water used for mop-up that day which is a very significant effort on this size area. The number of resources on the burn unit March 23 well exceeded burn plan requirements for extended mop-up staffing.

March 23 Operations

The Spot Weather Forecast issued March 23 for the LNF project included a minimal discussion with no mention of upcoming wind event or red flag warnings. Conditions that day were forecasted to be "*clear through the afternoon with light winds and poor dispersal much of the day... 20' Winds SW 6-7 mph until 1200, then SE.*"

The burn plan contains mop-up and patrol guidelines tied to Keetch-Byram Drought Index (KBDI) values. The KBDI index ranges from 0 – 800 with lower values indicating wetter conditions and higher values indicating increasing levels of drought. Modeled values for the week of March 22 were less than 300, however the mop-up standard used equaled that for a much drier condition where KBDI would have exceeded 500. Final mop-up standard of 200 ft. "cold black" edge was achieved around the entire perimeter of the burn by end of shift. These actions actually exceeded burn plan requirements.

Mop-up activities concentrated on areas within 2 chains (132') of the road and by the end of the day mop-up had progressed to approximately 200 feet within the burn perimeter. One small spot fire (1/10 ac.) had been discovered below the handline that morning. It was quickly contained and extinguished. Other than that, no significant holding concerns or excessive smoke production were noted. Based upon his assessment of the burn unit at the end of the day the ICT4 recommended to the Burn Boss that the unit be placed in patrol status for the following days. These actions were consistent with burn plan requirements which state:

"Active mop-up will occur on the second day as necessary, and will again be focused on security of the unit. Following that, mop-up efforts will focus on any remaining heavy, smoke-producing fuels further interior in the unit.

Active mop-up will continue on additional days based on predicted weather and smoke production. Extended mop-up will be focused on areas with lingering smoke production. Once an RXB2 determines that fire behavior and smoke production have decreased to acceptable levels, the unit will be put into patrol status. The fire will be directly patrolled and monitored for a minimum of 3 days following the initial burn, and then until significant moisture is received or the fire is declared out.

…Possible Patrol Guidelines are based on the Keetch/Byram Drought Index and are established by fuel type. For Timber/litter: ***KBDI <200 =*** *Check control lines @ 0900 the day after the burn and mop-up any hazardous fuel concentrations* ***KBDI 200-500*** *= Check control lines @ 0900 & 1500 the day following ignition until no smokes are seen within 100 feet of the line. Mopup smokes within 50 feet of the line by 2nd day after ignition.* ***KBDI >500*** *Check control lines @ 0800 and 1800 each day and extinguish all smokes within 200 feet of the line. Continue to monitor each day until the 200 foot zone is smoke free, then patrol once daily for four days."*

MARCH 24

Burn Unit in Patrol status:

The ICT4 from the previous day performed the burn area patrol. A Spot Weather forecast was not requested that day and the burn plan contains no requirement that one be obtained for patrol operations. Burn managers and patrol personnel had the NWS zone fire weather forecast which provided the specific daily fire weather information necessary for the operations they were engaged in. While driving into the project area the ICT4 saw no smoke until arriving at the top of the burn unit near DP-4. He reported two visible smokes, both well within the interior of the unit. One was in the lower portion of the eastern half of the burn in a shallow drainage and the other in the western half.

The ICT4 then patrolled the area on foot and on ATV. He reported that he did not observe any heat within the 200 feet of the unit perimeter. The ICT4 finished his patrol and left the unit at approximately 1300. Later that afternoon he discussed his observations with the District Forester and Burn Boss. All believed that the burn was secure and that patrol would not be necessary on Sunday, March 25. They decided to send a patrol to the unit again on Monday, March 26. The actions were consistent with burn plan requirements.

"Once an RXB2 determines that fire behavior and smoke production have decreased to acceptable levels, the unit will be put into patrol status."

MARCH 25

Burn Unit in Patrol status:

No patrol operations occurred on Sunday, March 25. The burn was unstaffed. Leaving the burn unstaffed on the third day following ignition is **not consistent** with burn plan requirements.

The Extended Mop-up and Patrol plan states: *"The fire will be directly patrolled and monitored for a minimum of **3 days** following the initial burn, and then until significant moisture is received or the fire is declared out."*

The NWS issued a Red Flag Warning for wind and low relative humidity at 1215. This was received by Jefferson County Dispatch who forwarded an alert to CSFS personnel. CSFS personnel considered the warning and determined that their mop up standard of 200 ft. was already achieved and that additional mop up was not needed. Timing of the wind event was late enough in the day on Monday that additional patrol beyond that already planned for Monday morning seemed unwarranted. The burn plan does allow for this discretionary decision to be made after the 200 foot mop-up standard has been achieved; therefore this action is consistent with the plan.

"SPECIAL WIND NOTE: If high winds are predicted (CSFS personnel will be notified via radio or pager by NWS or Jeffco Dispatch) or are actually occurring in the area, the RXB2 or ICT4 will be immediately notified. The RXB2/ICT4 will direct resources to focUS mop-up efforts on the downwind edges of the unit(s). Additional resources will be ordered at the RXB2/ICT4's discretion. Resources will remain on scene until a minimum of 200 foot mop-up has occurred and/or the wind event has subsided."

MARCH 26 – PATROL & ESCAPED PRESCRIBED FIRE PROCEDURES

Patrol Actions:

The course of action agreed to on Saturday, March 24 was to send out a final patrol to Unit 4A on Monday morning. If the patrol found that the burn was still secure with no heat within 200 feet of the perimeter then they would backhaul the remaining water handling equipment.

The NWS Zone Forecast issued 0551 AM MDT on March 26 contained a *"Red Flag Warning in effect from 10 AM until 7 PM for fire weather Zones 215… 216… and 238 through 251 for strong winds and very low humidity…20-foot winds / Valleys and Lower Slopes … southwest 8-13 mph with gusts to 25 mph increasing to 22-32 mph with gusts to 60 mph in the afternoon."*

The ICT4 arrived on the burn unit with two firefighters around 1000. All control lines were patrolled and the lower handline was mapped. No holding concerns were noted. The same interior smokes that were noted on Saturday were still visible. No mop-up needs were observed around the perimeter of the burn. Additional resources were requested after winds and fire activity had increased. This action is consistent with the Prescribed Fire plan direction in the *Special Wind Note* states that *"Additional Resources will be ordered at the RXB2/ICT4's discretion."*

Events leading up to Wildfire Declaration:

The ICT4 discovered a spot fire across the control line in a small saddle near DP-5 and reported it to the Burn Boss in Golden at approximately 1340. Additional contingency resources were ordered at 1347. The spot fire was reported to be 1.5 acres at 1350 and growing fast. After conferring with the Burn Boss and District Forester the ICT4 declared that the prescribed fire had become a wildfire at 1430. At that time, the fire was not outside of the Maximum Manageable Area (MMA), but was approximately 7 acres in size and expected to breach the MMA under the current conditions. The declaration of escaped fire was consistent with the Prescribed Fire plan as the declaration was made well before the fire crossed the MMA. See Escape Fire Triggers: *"Any fire outside the MMA that is not fully contained within 1 hour of discovery will be declared an escaped fire….The RXB2 may declare an escaped fire at their discretion prior to the fire exceeding the MMA…"*

Table 6. Summarizes compliance and consistency with the prescription, actions and procedures set forth in the prescribed fire plan.

KEY ACTIONS:	COMPLIED WITH PLAN &/OR SOP:	INCREASED OR DECREASED RISK OF EVENTUAL OUTCOME	COMMENTS
Ignition of Lower North Fork Prescribed Fire Unit 4A - March 22			
Test Fire	YES	NEUTRAL	All conditions set forth in the plan were met and were considered ideal. Sufficient resources were present to extinguish the test fire if conditions were not favorable.
Ignition & Holding	YES	INCREASED	All indications are that the ignition and holding was executed as planned and the objectives of the prescribed fire plan were met. The decision to

KEY ACTIONS:	COMPLIED WITH PLAN &/OR SOP:	INCREASED OR DECREASED RISK OF EVENTUAL OUTCOME	COMMENTS
			ignite a prescribed fire always increases the short-term risk of an escape which is necessary to achieve the long-term benefits of a successful treatment.
Mop-up	YES	DECREASED	Initial mop-up efforts focused on security of the burn unit while secondary focus was placed on reducing smoke by mopping up larger materials. A depth of nearly 2 chains (132 ft.) was secured across the top of the Unit which was most susceptible to escape.
Extended Mop-Up and Patrol of Unit 4A - March 23			
Mop-up & Patrol	YES	DECREASED	Personnel assigned exceeded minimum required by the plan (34 personnel w/5 engines, plan required 13 personnel w/2 engines). Maximum prescribed mop-up standard of 200 feet was achieved around the entire perimeter of the fire by end of shift.
Patrol Actions Unit 4A - March 24			
Patrol	YES	NEUTRAL	Only 1 person (Type 4 Incident Commander) was assigned to patrol. Mop up standards had been met (200 ft.) and it is speculative whether additional personnel assigned would have engaged in further mop-up as it is standard procedure to allow the interior fuels to continue burning so long as the perimeter is judged to be secure
Actions Unit 4A - March 25			
Patrol	NO	NEUTRAL	Plan required patrol for 3 days following the initial burn. Impact is judged to be Neutral because mop-up standards were already met (200 ft.) and it is speculative whether continued patrol would have engaged in further mop-up.
Response to Red Flag weather warning	YES	NEUTRAL	Actions are in compliance with discretion allowed in the plan and did not result in any increase or decrease in response, thus the impact to risk is neutral. While this decision did represent a missed opportunity to take action, it would be speculative to say that increased response would have resulted in reduced risk because we cannot estimate how many additional resources would have been assigned or what their assignment would have been
Patrol & Escape Prescribed Fire Procedures - March 26			

KEY ACTIONS:	COMPLIED WITH PLAN &/OR SOP:	INCREASED OR DECREASED RISK OF EVENTUAL OUTCOME	COMMENTS
Patrol	YES	NEUTRAL	Patrol complete with no problems detected. No further mop-up performed so no change to potential risk.
Patrol left engine at station, only Pick-up and UTV on scene	YES	INCREASED	The additional capability provided by the water on the engine would have been a minimal advantage given the severity of the wind and the large area experiencing control problems with only three firefighters present
Taking apart pump and hose	YES	INCREASED	The additional capability provided by the water and hose would have been a minimal advantage given the severity of the wind and the large area experiencing control problems with only three firefighters present
Initial request for engine to assist	YES	DECREASED	The additional capability provided by the engine added minimal advantage to controlling the Fire given the severity of the wind and the large area experiencing control problems with only three firefighters present
Initiation of Escape Fire Action Plan and Declaration of a Wildfire	YES	NEUTRAL	The procedures and actions taken from initial recognition of fire across the control line up to the declaration of a wildfire were consistent with the plan and were taken well before established trigger points were reached. The actions are judged to have had neither a positive or negative effect on the outcome as that eventuality was set in motion well before the escape fire procedures were initiated.

Review of the Qualifications, Experience, and Involvement of Key Personnel Involved In the Prescribed Fire

Approving Agency Official's Qualifications, Experience and Involvement;

"The CSFS Prescribed Fire Program Manager (or other individuals designated by the Fire Division Supervisor) fulfills the role of Agency Administrator in the (*burn plan*) review process... An agency review ensures that the plan is complete, so all components of the plan, including Service Agreement or MOU are required unless prior arrangements have been made by the plan preparer." *(CSFS Prescribed Fire Program Guidelines and Procedures; October 18, 2011).*

In the Colorado State Forest Service Fire Division the position of Assistant Staff Forester, Fuels Mitigation and Prescribed Fire Program Manager is the agency official who is responsible for final review and approval of prescribed fire burn plans. This position is relatively new having been established in 2007. In addition to managing the prescribed fire program the incumbent oversees State Fire Assistance (SFA) grants and manages portions of the preparedness account including specifically the Engine program.

The incumbent has wildland fire experience beginning in 1982, with the National Park Service including working as a Yellowstone Helitack firefighter during the 1988 fires. The majority of this person's wildland fire experience is in aviation with current qualifications including Air Support Group Supervisor (ASGS), Helibase Manager Type 1 (HEB1) and Air Operations Branch Director trainee (AOBD/t). This individual has completed NWCG training for prescribed fire including Prescribed Fire Plan Preparation (RX-341), Prescribed Fire Implementation (RX-301) and Smoke Management (RX-410).

During Agency Administrator review of Colorado State Forest Service prescribed fire burn plans this individual works from a checklist of items which includes ensuring the plan has received a technical review from an appropriate level RX Burn Boss, that the project has been issued a smoke permit from CDPHE and that the public/media information plan is complete and appropriate. This process is consistent with established interagency practices for Agency Administrator review as described in the *Interagency Prescribed Fire Planning and Procedures Guide.*

Qualifications and Experience of Key Personnel Involved in the Prescribed Fire

The Colorado State Forest Service adheres to accepted interagency standards for wildland and prescribed fire qualifications. These standards are described in the *National Interagency Incident Management System Wildland Fire Qualification System Guide, PMS 310-1;* developed under the sponsorship of the National Wildfire Coordinating Group (NWCG).

The *PMS 310-1* Guide establishes minimum requirements for training, experience, physical fitness level and currency standards for wildland fire positions. All participating agencies have agreed to meet these requirements for national mobilization. The guide also establishes minimum qualifications for personnel involved in prescribed fires where resources of more than one agency are utilized—unless local agreements specify otherwise.

The qualifications and experience of the key personnel involved with the Lower North Fork Prescribed Fire were reviewed based on individual master records contained in the Incident Qualifications System (IQS) Database. Key positions on the prescribed fire and their qualifications are listed in Table 7.

Table 7. Qualifications of key personnel involved in the Lower North Fork Prescribed Fire.

Position	Qualification Date	Meets Requirements	OTHER QUALIFICATIONS
Burn Boss Type 2	2011, Sept. 20	Yes	ENGB, FIRB, ICT4, TFLD(t)
Burn Boss Type 2 , Trainee	RXB2(t) Task Book initiated 2009, Sept. 24	Yes	ENGB, FIRB, ICT4, TFLD(t)
Incident Commander,	2007, Aug. 20	Yes	ENGB, FIRB, TFLD(t), RXB2(t)

Position	Qualification Date	Meets Requirements	OTHER QUALIFICATIONS
Type 4			
Ignitions Specialist	FIRB – 2010, Dec. 14	Yes	CRWB, FALB, ICT5, RXB3
Holding Specialist	TFLD - 2011, Feb. 24 (not specified in burn plan)	Yes	CRWB, ICT4, STEN, DIVS(t)
Holding Specialist, Trainee	CRWB – 2006, Mar. 01	Yes	STEN,ENGB, FIRB, ICT4
Fire Effects Monitor*	FEMO(t) Task Book initiated 2010, May 20	Yes	ENGB, ICT5, RXB3
Field Observer	2002, Aug. 01	Yes	TFLD, ICT4, RXB2, DIVS(t)
Engine Boss	2008, Sept. 08	Yes	CRWB, FALB, RXB3
Engine Boss	2008, Dec. 30	Yes	ICT5, FALB, HECM
Engine Boss Trainee	ENGB (t) Taskbook, initiated 2011, June 15	Yes	FFT1, HMGB, ICT4
Engine Boss Trainee	ENGB (t) Taskbook 2011, April 27	Yes	FFT1, FALB, EMTB
Crew Boss	1995, Sept. 30	Yes	DIVS, FBAN, ICT4, RXB2
Crew Boss	2005, June 15	Yes	ENGB, FALC, ICT5
Smoke Monitor	1998, Sept. 30	Yes	RSUL, RXB2, ICT4, FIRB

*FEMO position optional in burn plan, note (t) indicates trainee.

SUMMARY OF FACTORS POTENTIALLY CONTRIBUTING TO THE PRESCRIBED FIRE ESCAPE

Several other factors contributed to the Prescribed Fire escape. Each of these factors individually would not have caused the escape, but together created a cascading effect that set the stage for the events of March 26, 2012. These factors are discussed below.

CRITICAL FIRE WEATHER EVENT

After ignition on March 22, 2012, the area continued to experience mild weather. As the atmosphere became drier over the course of several days, fuel moisture in unburned fuels decreased. This in combination with unburned fuel pockets and residual heat remaining on the Unit created circumstances conducive to increased combustion under the influence of high winds. Such a wind event occurred on March 26, 2012, and was the catalyst that set in motion the Prescribed Fire escape. As stated earlier in this document, the meteorological conditions that occurred on March 26, 2012, were similar (if not identical) to features that occurred on the South Canyon Fire in 1994.

UNBURNED FUELS AND RESIDUAL HEAT LEFT IN THE BURN UNIT

Due to a number of reasons including project design, burn plan objectives, moisture gradients, ignition pattern, and mop-up standards, Unit 4A continued to hold residual heat as well as unburned fuels within the perimeter of the control lines. The overall project design was to perform a combination of mastication treatments and prescribed fire. Due to slope constraints for the mastication equipment, only gentle slopes and ridge-tops were treated. This left Unit 4A with a mixture of masticated and natural fuels. The objectives set forth in the plan specifically call for a burn that would remove the majority of the material created by the mastication treatment but also create a burn pattern that left a mosaic of burned and unburned areas where mastication did not take place to improve forest health. This has the added benefit of producing less smoke and providing a more aesthetically pleasing visual effect by leaving smaller visible burn scars on the landscape. Previous burning experience in these masticated areas produced results that were felt to be too hot and the desire for this unit was to burn under cooler conditions to reduce the potential harm to the soil and overstory (Figure 19).

During the ignition operations on March 22, 2012, there was concern initially among firefighters that the interior of the Unit posed a hazard in terms of generating too much heat and throwing spots out of the Unit. Later in the day there was a feeling that because they had to move very slowly through the masticated fuels, they needed to concentrate ignitions along the fires edge to secure the Unit and did not introduce much fire into the center of the Unit, instead hoping that the fire would consume the interior on its own. Later on during mop-up of the Unit on March 23, 2012, firefighters recognized the safety hazard posed by fire weakened trees falling which were heard repeatedly crashing down throughout the day. For this reason, it was decided that the best strategy would be to avoid mop-up within the interior beyond the 200 foot buffer allowing the center to consume on its own inside of the cold black buffer. This technique is consistent with normal prescribed fire practice of controlling the perimeter while allowing the center to consume as much as possible to further reduce fuels.

One notable product resulting from the mastication treatment is that the stumps left over throughout the Unit provide a source for long-term ground fire. This area was masticated at least six years prior to the prescribed fire so the stumps had ample time to dry allowing fire to smolder in the root system for several days, possibly even weeks after ignition.

The topography on this Unit had a mixture of narrow draws and several hundred feet of elevation difference from top to bottom in addition to the masticated treatment allowing more sunlight onto the upper end of the Unit while the lower end that was not masticated remained shaded. This resulted in a moisture gradient where the masticated areas along the top were much drier and the shaded natural fuels at the bottom were wetter and initially did not burn very well. Much of the natural fuel area had significant duff from the fuels on site and debris from earlier mastication which had flowed downhill over the past several years.

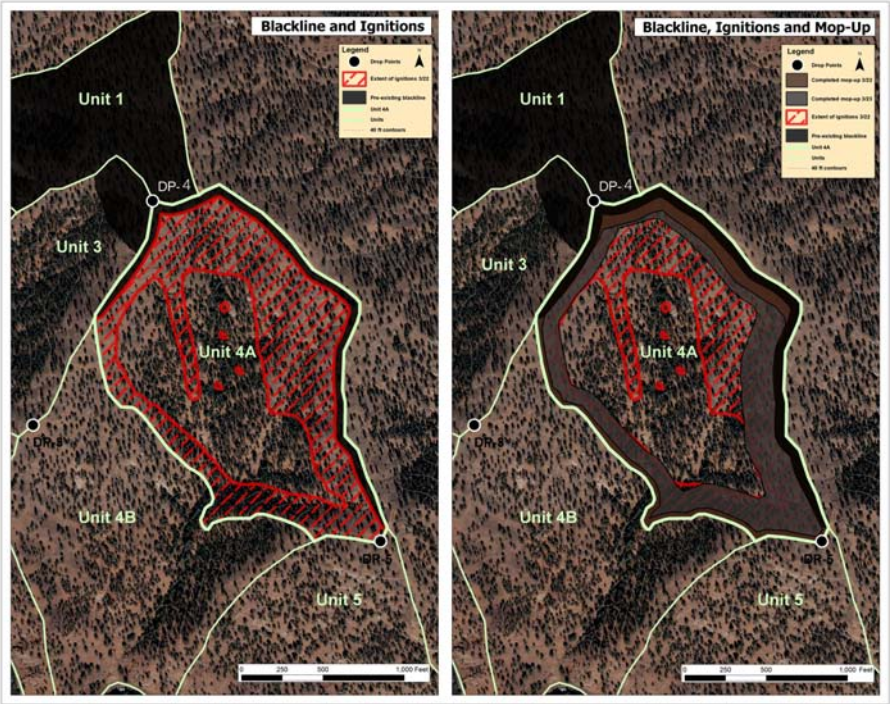

Figure 19. Lower North Fork Unit 4A Ignition Pattern and Subsequent Mop-Up Standard

OPERATIONAL ACTIONS DRAWN FROM COMMON PRACTICES AND EXPERIENCE

There are a number of standard operating procedures (SOP's) that are both common to the fire service as a whole, and some particular to this work group that may have been a factor in the outcome. The first and most prominent is the use of a 200 foot buffer as a standard for mop-up. This standard is widely used throughout the nation in many fuel types and is generally thought to be a reasonable standard of vigilance for securing a fire's edge. Case in point, the incident action plan for fighting the Lower North Fork Wildfire used the same 200 foot buffer as a mop-up standard on April 1, 2012. The problem with this standard lies in the fact that it is a reasonable measure of security under "most" fire behavior conditions, but not under all conditions. The key participants in this case were vigilant in attaining this standard and the group as a whole believed that the buffer would be sufficient enough to contain the Prescribed Fire under the Red Flag conditions predicted for March 26, 2012.

A local procedure which may have been a factor was the decision to take a pick-up truck to remove gear on March 26, 2012, and leave the engine at the station. Because of this, there was delay in taking action to control the Fire while the engine was shuttled from the station. Without hindsight, however, this action could make sense for various reasons. Earlier patrols and past experience prompted personnel to favor use of the pick-up over the engine to facilitate the removal of water handling equipment. It should also be said that the standard scenario for Colorado State Forest Service during a Red Flag day is they will be called to assist cooperating agencies with wildfire response. Because there was full confidence in the established 200 foot buffer, the first concern on March 26, 2012, was in retrieving the hose and other equipment off the Prescribed Fire in a timely fashion so they could return to the engine to be prepared for timely wildfire response. It is not unusual for this Unit to leave their engine behind as the Colorado State Forest Service does not have primary fire suppression responsibility on any lands, and are typically called in as support to wildland fires rather than first response. Additionally, during the mop-up operations on March 23, 2012, one of the crew vehicles broke an axle along the dirt road leading to the burn. Managing wear and tear on expensive equipment such as a fire engine was a consideration in planning daily activities.

LIMITATIONS OF WEATHER & FIRE BEHAVIOR FORECASTS

At various points in the chain of events, the forecasts made for weather and/or fire behavior either by computer models or human intuition did not accurately predict actual conditions. The first instance is in the long range forecasts issued prior to ignition on March 22, 2012. At that time, the forecast indicated a slight cooling trend for March 25, 2012 with only a minor disturbance and moderate winds on Monday, March 26, 2012. As the week went on, the forecast continued to improve until the critical weather event became evident on Saturday, March 24, 2012, when a Fire Weather Watch was issued.

There was wide-spread cloud cover at the time of the first assessment and a moderate but steady wind. The perception by the firefighters on patrol on the morning of March 26 was that even with the Red Flag conditions predicted, there was an extensive cold-black buffer around the entire unit and very little heat within the unit so no control problems were anticipated. This condition changed very rapidly as the front moved through the area and the cloud cover moved away, direct sun shine and drier air hit the burn area drying out the fuels, and stronger winds and a more unstable air mass impacted the area (Appendix F).

In creating the Prescribed Fire Plan, fire behavior model output did predict spotting distances in excess of 300 ft. with winds above 15 mph which was an indicator that fire control problems could be experienced whenever tree torching is a possibility under those winds. Tree torching from the interior of the burn unit is one possible source of embers that could have led to an escape. Firefighters however, did report that the fire was also propagating by embers blown across the ground into previously cold black reigniting any available fuels which were also blown across the ground igniting more spots ahead. This was described by one observer as looking like “little burning fleas moving across the ground”. This is a very rare mode of fire spread that is not normally experienced and indeed none of those who witnessed it report ever seeing such fire behavior previously. There are currently no models available that would provide an accurate estimation of how far a burning ember can travel across the ground in a high wind or how spotting can propagate via ground-blown debris

LESSONS LEARNED

Lessons Learned by Participants

These lessons learned were those identified by participants in the events during interviews and the site visit on Friday, April 6, 2012. Some participants felt that more lessons learned may come after more time has passed as they were still overwhelmed by the magnitude of the events surrounding the escape.

FUEL CONDITIONS and FIRE BEHAVIOR

- Chunks of charred material in the black can reignite on a hot windy day when exposed to ember wash. Fuel types having this type of material warrant greater awareness.
- In treatment units with a combination of masticated and natural fuels consider burning the masticated fuels separately from the natural fuels. Alternate treatment options could be considered for the natural fuel areas.
- Consider extending blacklines in masticated fuels to depths of 300' or more.
- Recognize that an area that gave you a problem during blacklining could be a problem area during subsequent ignitions or mop-up.

WEATHER

- Pay closer attention to the weather; request more frequent Spot Weather forecasts maybe through entire patrol / monitoring phase until burn is declared "out".

BURN PLAN IMPLEMENTATION

- Could use a better step-up procedure for patrol and mop-up
- Consider use of infra-red technology (heat-seeker) to identify hot spots during mop-up

Lessons Learned by Review Team

FUEL CONDITIONS and FIRE BEHAVIOR

- There was a lack of recognition of the amount of unburned fuels remaining in the interior of the Unit. Overall consumption within the unit was less than assumed.
- Extended burning and smoldering within the burn area leads to increased exposure to adverse weather events. Residual heat sources can be an escape threat during high winds.
- A 200 foot buffer is not sufficient in a high wind event with continued burning inside the line.
- Recognize that an area that presented holding problems during blacklining could be a problem area during subsequent ignitions or mop-up. In this case a spot fire occurred during blacklining operations on October 19, 2011, in the same location where the spot fire that resulted in the escape occurred on March 26, 2012.

BURN PLAN

- Patrol and monitoring needs to be more responsive and adaptive to changing conditions.

WEATHER

- The better the communications with the local National Weather Service office the better the understanding of weather conditions by the local manager; managers who use prescribed fire on a regular basis should ask more questions of and provide more feedback to their fire weather forecasters.
- Besides the 1 – 5 day forecast products from the National Weather Service, there are also products available from National and Geographic Area Predictive Services that may augment the ability of manager's to make better mid-range strategic decisions (3 – 10 day).
- Portable weather stations are a great source of site-specific weather information; need to make sure they are properly maintained, calibrated so the data can be relied on.

RECOMMENDATIONS

Recommendations have been synthesized from key observations and analyses conducted by the Review Team. These recommendations are not confined to site -specific scale planning and implementation but extend to include up through the programmatic scale. Some recommendations may warrant attention and/or actions by other agencies or even multiple agencies and organizations. Recommendations developed from review of the Lower North Fork Prescribed Fire include:

- The WIMS-RAWS-NFDRS program needs to be improved to insure safe and more effective fire operations across jurisdictions throughout the year. Inconsistent procedures must be resolved in the Rocky Mountain Area (RMA) between fire management agencies, co-operators and the supporting agencies involved with weather data collection, National Fire Danger Rating System (NFDRS), and information dissemination. The interagency Rocky Mountain Coordinating Group (RMCG) includes the Colorado State Forest Service, whose personnel rely on accurate and timely weather observations, NFDRS outputs, fire weather forecasts (NWS) and long term large fire risk assessments (Predictive Services). NFDRS output from some weather stations were erroneously moist during this period. Maintenance of weather stations is variable by agencies and this can degrade data outputs. Red flag watch and warning criteria are interpreted differently by the Predictive Services specialists and the National Weather Service which directly led to the issuance of a SAFENET for events that occurred during the time period under review.

- Colorado State Forest Service prescribed burn plans have a sound staffing plan based upon measures of fire danger and cumulative drought. However, consider replacing the Keetch-Byram Drought Index (KBDI) with indices such as NFDRS indices of Energy Release Component (ERC) and/or 1000 hour timelag fuel moisture. These two are in common use by in the interagency fire community. Ensure all prescribed fire plans include up-to-date information prior to implementation.

- CSFS prescribed fire operations need to be strengthened with specific attention to mop-up standards tied to fuel consumption and residual heat remaining in the burn unit. Consider adding an element of long-term patrol and monitoring to the existing table of organization. Patrol and monitoring activities should be maintained on prescribed fires in Wildland-Urban Interface (WUI) areas at a level commensurate with the risks until heat sources are minimal or non-existent or the fire is declared out.

- Refine the Prescribed Burn Plan Technical Review process. An outside reviewer from outside the area or another agency for more complex burns, particularly those within multiple jurisdictions, may be helpful to CSFS in this next phase of organizational recovery.

- Segregate mastication fuels from un-masticated and/or natural fuels by sub dividing or redesigning treatment units to address fuel moisture and potential fire behavior variation.

- Update the Medical Plan to list the new address of St. Anthony's Hospital and its helipad coordinates.

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APPENDICES

Appendix A. Delegation of Authority

STATE OF COLORADO

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Denver, Colorado 80203
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COLORADO
DEPARTMENT OF NATURAL RESOURCES

John W. Hickenlooper
Governor

Mike King
Executive Director

MEMORANDUM

To: Bill Bass, Prescribed Fire Review Team Leader

From: Mike King M.K.

Date: April 2, 2012

Subject: Delegation of Authority, Lower North Fork Prescribed Fire Review

This letter delegates authority to you to serve as team leader and to direct a team in the conduct of a thorough review of the Lower North Fork Prescribed Fire which preceded the Lower North Fork Wildfire (LNFW) in Jefferson County, Colorado (March 26, 2012). Please note the Origin and Cause Investigation Team for the LNFW has yet to complete its work. I ask that you conduct your review of the prescribed fire accordingly.

Your team will be made up of the following individuals: Tom Zimmerman, Frankie Romero, Grant D. Hamrick, an information officer, and a writer/editor. Resource Order CO-COS-000002 contains the related details of the named individuals (above) for this assignment. You may wish to consider additional staff support as needed.

The amount of information to be included and displayed in your analysis will correspond to the scale and complexity of the prescribed fire and be detailed enough to foster a factual understanding of the event, in a context appropriate for multiple audiences, and for trend analysis and syntheses. Your review report should be appropriate within and across agencies.

The goals of this review are to: (1) guide future program actions by minimizing future, unintended outcomes and (2) while cause and origin of the LNFW have not yet been determined, identify actions necessary to reduce the likelihood of escapes from prescribed fires generally. Factual information collection during the review is to be centered on policy, protocols, and performance.

Your report should include the following elements:

- Executive Summary
- Setting: Environmental, Social and Political
    - Prescribed Fire Objectives
    - Prescribed Fire Prescription

- Prescribed Fire Outcomes
- Discussion of seasonal severity, weather events, and on-site conditions leading up to the wildfire declaration.

- Chronology, Timeline
- Lessons Learned, Identified by Project Participants
- Lessons Learned, Identified by your Team
- Recommendations, including potential need for policy modifications
- Maps and Photos

In addition to the items listed above, I ask that your appendix to the final report include:

1. The approving agency official's qualifications, experience, and involvement;
2. The qualifications and experience of key personnel involved;
3. Compliance of the Prescribed Fire Plan with existing State policy and guidance related to prescribed fire planning and implementation;
4. Compliance with the prescription, actions, and procedures set forth in the Prescribed Fire Plan; and
5. Context to provide information on how frequently prescribed fires may escape.

I ask that your draft report be submitted to me no later than 30 days from the time you receive this delegation.

Should you have any questions or comments, please feel free to contact me at (303) 506-8696. You may also contact my Deputy Director, Bob Randall, at (303) 319-6832 when I am unavailable.

Appendix B: Significant Colorado Wildfires Since 1989

Fire Name	Year	Significance (fires in bold are particularly noteworthy)
Duckett	2011	FEMA FMAG
Indian Gulch	2011	FEMA FMAG
Crystal	2011	FEMA FMAG
Sand Gulch	2011	
Snyder	2011	
Maxwell	2011	
Left Hand OHV Area Fire	2011	
Four Mile Canyon	**2010**	**FEMA FMAG,** ***most costly wildfire in terms of private property loss in Colorado history***
Reservoir	2010	FEMA FMAG
Church's Park	2010	
Cow Creek	2010	
Olde Stage	2009	FEMA FMAG
Nash Ranch	2008	FEMA FMAG
Left Hand	2008	
Nash Ranch (Park County)	2008	
Newcastle	2007	FEMA FMAG
Mauricio Canyon	2006	FEMA FMAG
Malo Vega	2006	FEMA FMAG , *one of the 30 largest wildfires in Colorado history*
Red Apple	2006	FEMA FMAG
Mason	2005	FEMA FMAG ,*one of 30 largest wildfires in Colorado history.*
Picnic Rock	2004	FEMA FMAG, *one home destroyed*
McGruder	2004	FEMA FMAG
Cloudy Pass	2003	FEMA FMAG
Cherokee Ranch	2003	FEMA FMAG *two homes destroyed*
Buckhorn Creek	2003	FEMA FMAG
Overland Fire	2003	
Big Elk	2002	Three deaths (airtanker pilots, one helicopter pilot)
Schoonover	2002	13 structures destroyed.
Hayman	**2002**	**Largest fire size and most costly in terms of suppression costs in Colorado history.** 133 homes destroyed
Bobcat	2000	One of 30 largest wildfires in Colorado history. 18 homes destroyed.
High Meadow	2000	One of 30 largest wildfires in Colorado history. 51 homes destroyed.
Big Turkey	1998	
Buffalo Creek	**1996**	**Caused substantial erosion and sedimentation in Denver Water facilities in Denver metropolitan area.** One of 30 largest wildfires in Colorado history. 10 homes destroyed.
Hourglass	1994	Burned CSU's Mountain Campus, Pingree Park
Black Tiger	1989	44 homes destroyed.
Olde Stage Road	1989	10 homes destroyed.

Appendix C. Prescribed fire program framework documents, sources, and applicability to prescribed fire planning and implementation.

Source Document	Type of Document	Applicable Information to Prescribed Fire Planning and Implementation
Interagency Prescribed Fire – Planning and Implementation Procedures Guide (NWCG 2008)	Interagency (includes National Association of State Foresters (NASF) as a signatory)	General goals for the prescribed fire program include: • Provide for firefighter and public safety as the first priority. • Ensure that risk management is incorporated into all prescribed fire planning and implementation. • Use prescribed fire in a safe, carefully planned, and cost-efficient manner. • Reduce wildfire risk to communities, municipal watersheds and other values and to benefit, protect, maintain, sustain, and enhance natural and cultural resources. • Utilize prescribed fire to restore natural ecological processes and functions, and to achieve land management objectives.
Quadrennial Fire Review (NWCG 2009)	Interagency (includes National Association of State Foresters as a signatory)	• Land-use plans and tiered fire management planning should contain strong and effective linkages to Community Wildfire Protection Plans (CWPP) and reflect relative costs, values, and landscape resiliency associated with proposed actions, alter- natives and decisions. • Create community defensible space/fuels reduction zones for the WUI
A National Cohesive Wildland Fire Strategy (DOI-USDA 2011)	Interagency (includes National Association of State Foresters as a member of Wildland Fire Executive Council (WFLC))	Provides an overall cohesive strategy for the wildfire problem. Three primary factors are identified that present the greatest challenges and the greatest opportunities for making a positive difference in addressing the wildland fire problems: • Restoring and maintaining resilient landscapes – ensuring that management activities address the current decline in ecosystem health. • Creating fire-adapted communities – utilizing all options and opportunities to engage communities and work with them to become more resistant to wildfire threats. • Responding to Wildfires - this area considers the full spectrum of fire management activities and recognizes the differences in agency missions and capabilities. Guiding principles, crafted through discussions with Federal, state, tribal, and local governmental and non-governmental organizational representatives, create a set of overarching principles applicable to all stakeholders in

Source Document	Type of Document	Applicable Information to Prescribed Fire Planning and Implementation
		the wildland fire management community and also reach across different elements, from resilient landscapes and fire-adapted communities to wildfire response. • Reducing risk to firefighters and the public is the first priority in every fire management activity. • Sound risk management is the foundation for all management activities. • Actively manage the land to make it more resilient to disturbance, in accordance with management objectives. • Improve and sustain both community and individual responsibilities to prepare for, respond to and recover from wildfire through capacity-building activities. • Rigorous wildfire prevention programs are supported across all jurisdictions. • Wildland fire, as an essential ecological process and natural change agent, may be incorporated into the planning process and wildfire response. • Fire management decisions are based on the best available science, knowledge and experience, and used to evaluate risk versus gain. • Federal agencies, local, state, tribal governments support one another with wildfire response, including engagement in collaborative planning and the decision-making processes that take into account all lands and recognize the interdependence and statutory responsibilities among jurisdictions. • Where land and resource management objectives differ, prudent and safe actions must be taken through collaborative fire planning and suppression response to keep unwanted wildfires from spreading to adjacent jurisdictions. • Safe aggressive initial attack is often the best suppression strategy to keep unwanted wildfires small and costs down. • Fire management programs and activities are economically viable and commensurate with values to be protected, land and resource management objectives, and social and environmental quality considerations
Colorado Revised Statutes (State of Colorado 2007, 2008, 2009)	Specific to State of Colorado (only those elements pertinent to prescribed fire are listed)	**23-31-202 Powers and duties of board of governors of the Colorado state university system.** 1). The authority granted to the board by section **23-31-201** shall include the following powers and duties: a) To provide for the protection of the forest resources of the state, both public and private, from fire, insects, and

Source Document	Type of Document	Applicable Information to Prescribed Fire Planning and Implementation
		diseases; (c) To carry on an educational program with landowners, in the application of the practice of forestry on forest lands, by the growing, harvesting, and marketing of forest products from such lands. **23-31-311. Watershed protection and forest health protection projects.** 1). "The Colorado state forest service, representing the state of Colorado, shall, in consultation with the governmental agencies participating in such projects, identify watershed protection projects and forest health projects that will use moneys received pursuant to section 37-95-112.5, C.R.S., including, but not limited to, the harvesting of trees infested with beetles." **23-31-312. Community wildfire protection plans – county governments – guidelines and criteria – legislative declaration – definitions.** **23-31-313. Healthy forest – vibrant communities – funds created.** **1). Short title.** This section shall be known and may be cited as the "Colorado Healthy Forests and Vibrant Communities Act of 2009". **2). Legislative declaration.** The general assembly hereby declares that addressing the wildfire risk in Colorado and the development of community wildfire protection plans to bring together federal, state, and local interests, including nongovernmental entities such as electric, gas, and water utilities, to address wildfire risk to life, property, and infrastructure in Colorado is a matter of statewide concern. **3). Definitions.** (g) "Wildfire risk mitigation" or "fuel mitigation treatments" means preventive forest management projects or actions, which meet or exceed forest service standards or any other applicable state rules, that are designed to reduce the potential for unwanted impacts caused by wildfires, including: (I). The creation of defensible space around structures; (II). The establishment of fuel breaks; (III) The thinning of woody vegetation for the primary purpose of reducing risk to structures from wildland fire; (IV). The secondary treatment of woody fuels by lopping and scattering, piling, chipping, removing from

Source Document	Type of Document	Applicable Information to Prescribed Fire Planning and Implementation
		the site, or prescribed burning; and (V). Other nonemergency preventive activities designed to reduce the unwanted impacts caused by wildfires that the forest service may deem to be risk reduction or fuel mitigation treatments. **6). Community watershed restoration.** (a) In order to support communities and land managers in moving from risk reduction to long-term ecological restoration so that the underlying condition of Colorado's forests supports a variety of values, particularly public water supply and high-quality wildlife habitat, the forest service shall: (II). Facilitate and work collaboratively with landowners, local governments, including conservation districts created pursuant to article 70 of title 35, C.R.S., and county noxious weed program administrators and other appropriate parties, including any electric, gas, and water utilities in the affected area, to design and safely implement prescribed fire projects and to encourage increased responsible use of prescribed fire as a tool for restoring healthy forest conditions consistent with programs established pursuant to section 25-7-106 (7) and (8), C.R.S. The forest service shall emphasize providing training and technical assistance for landowners, local communities, and state agencies.
Services Agreement – Colorado State Forest Service and Denver Water Board (2011)	Agreement between Colorado State University /CSFS and City and County of Denver, Board of Water Commissioners, Denver Water	**Excerpted from:** **Exhibit A to Services Agreement. Scope of Work.** "Denver Water grants the University/CSFS the right of access to Denver Water properties within Jefferson County for the following purposes provided by University/CSFS: C. Prescribed Fire Planning and Implementation. i. Develop prescribed fire plans as needed for fuel hazard reduction, wildlife habitat, forest management, and other purposes on properties of Denver Water. ii. Individual prescribed fire projects implementation plan will be included in an Annual Work plan under a separate agreement which will be submitted to Denver Water for review and approval.
North Fork Fire Protection District Community Wildfire Protection Plan (Jefferson County 2011)	Local, area-specific	This is a strategic plan that identifies values, hazards, and recommended mitigation practices for the North Fork Fire Protection District (NFFPD) area of Jefferson County. Decades of absence of fire and other natural disturbances coupled with years of persistent drought have resulted in altered vegetation and fuel complexes with a net result of significant hazardous fuels within the district and risk of higher than normal fire intensity. The CWPP provides wildfire hazard and risk assessments

Source Document	Type of Document	Applicable Information to Prescribed Fire Planning and Implementation
		for neighborhoods and subdivisions identified as Wildland-Urban Interface (WUI) and Intermix zones within the NFFPD. Due to highly dispersed housing density and location combined with limited infrastructure adjacent to large and remote wildland areas, there is high potential for loss of life and property from wildfire. This CWPP builds upon previous plans completed for the Lower North Fork and South Platte areas, which provide specific hazard assessments and recommendations for individual homes within those smaller assessment areas. This plan identifies actions to reduce risks and includes a fire behavior analysis and community wildfire hazard rating as a comprehensive, scientifically-based assessment. The actions recommended in this CWPP are designed to lower wildfire hazards to neighborhoods, economic, and ecological values at risk. The plan identifies treatment options that include: shaded fuelbreaks, machine mowing, prescribed fire, brush mastication, timber mastication, manual thinning and felling, and feller buncher removal of larger diameter trees.

Colorado State Forest Service Prescribed Fire Procedures (2009)	Agency-specific procedures	This information contains agency procedures for the following areas:
		• Prescribed Fire Participation Guidelines and Procedures
		  o Prescribed Fire Participation
		• Prescribed Fire Program Guidelines and Procedures
		  o Prescribed Fire Procedures
		• Prescribed Fire Desk Guide
		  o Prescribed Fire Plan

Appendix D. Team Biographies

William (Bill) Bass *(Review Team Lead)*: Bill Bass has been the Forest Supervisor on the Bighorn National Forest located in Sheridan, Wyoming since 2000. He is responsible for all aspects of National Forest Management on over 1million acres. During his 35 year tenure with the U.S. Forest Service he has worked on National Forests in Utah, Idaho, Colorado and Wyoming. He has spent the last 22 years of his career in a leadership role as a Line Officer and Agency Administrator.

Bass has been actively involved in fire management since 1975, and is a former Division Group Supervisor, and Supply Unit leader. Bass holds a Bachelor of Science in Range Science from Utah State University (1979).

Thomas (Tom) Zimmerman *(Review Team Planning Section Chief):* Tom Zimmerman retired in 2011 after 32½ years of federal service. Since his retirement he has stayed active in wildland fire management through training, conference presentation, consulting, and is currently serving on the Board of Directors of the International Association of Wildland Fire (IAWF).

During his career he worked for the Bureau of Land Management, the U.S. Forest Service, and the National Park Service. His assignments spanned all organizational levels (field, state, regional, and national offices) as well as both functional areas of land management (operations, research and development).

Zimmerman is a leader in all aspects of fire management, both nationally and internationally. His accomplishments include program management, training, policy development and technology transfer. His work focused on wildland fire use, prescribed fire, incident management, fire ecology, fire behavior, long-term risk assessment, decision support, and other field operational activities. His efforts resulted in the development of Fire Use Management Teams and Fire Use Modules; fire behavior training course consolidation; creation of the Wildland Fire Implementation Plan (WFIP) for documentation and implementation of wildland fire use decisions; development of the Wildland Fire Decision Support System (WFDSS) and the Wildland Fire Management Research, Development, and Application program (WFM RD&A).

Zimmerman has worked in incident management for over 30 years, serving as both an Incident Commander and Area Commander on wildland fire, prescribed natural fire, and wildland fire use events; and all hazard emergency responses, including six hurricanes. He has published over 50 articles, technical reports, and professional papers on fire ecology, fire management, fire economics, wildland fire use, fire management policy, science application and integration, risk assessment, decision making, and change management. He also worked on the 1995, 2001, and

2009 reviews, clarification, or modifications to the Federal Wildland Fire Management Policy, and co-authored the Wildland Fire Use Implementation Procedures Reference Guide.

Zimmerman's work includes serving as a review team leader or member on 17 reviews, including the South Canyon Fire, Cerro Grande Prescribed Fire and the Twin Prescribed Fire. He has also served on a multitude of after incident, after action reviews and programmatic reviews.

Zimmerman earned a Bachelor of Science in Forestry from the University of Montana, a Master of Science in Forestry and Fire Ecology from the University of Idaho, and a Ph.D. in Forest Fire Science from Colorado State University.

Francisco (Frankie) Romero (*Review Team Fire Behavior Analyst*)*:* Frankie Romero is the USDA Forest Service, National Applied Fire Ecologist. One of his primary duties is to oversee the Prescribed Fire Program for the U.S. Forest Service which averages 4,000 prescribed projects treating nearly 1.2 million acres annually. He is responsible for policy updates, agency-wide workforce planning and training; monitoring program accomplishments and performance including escaped prescribed fires agency-wide. Romero's review experience includes the Salt Fire Shelter Deployment Review, and the Breaks One Escape Prescribed Fire.

Romero has 27 years of fire management experience, across all western states, as well as Alaska, Florida, Oklahoma, Mexico, Indonesia, and throughout Central America. His experience includes handcrews, helitack, heli-rappel (Gila National Forest), smokejumper (Payette National Forest), Assistant Fire Management Officer (Payette National Forest), and Zone Fire Management Officer (White River National Forest), Smoke Jumper Base Manager (Payette National Forest). Romero is qualified as a Type 3 Incident Commander, Type 1 Prescribed Fire Burn Boss, Fire Behavior Analyst, Long-Term Fire Analyst, and Strategic Operations Planner.

Romero holds a Bachelor of Business Administration with majors in Computer Information Systems and Business Management from New Mexico State University (1989) and a Master of Science in Forestry - Fire Science from Colorado State University (1997).

Grant (Dave) Hamrick (*Review Team Operations Chief):* Dave Hamrick has served as the North Zone Fire Management Officer for the Arapaho and Roosevelt National Forests' Canyon Lakes Ranger District and Pawnee National Grassland since 2007.

Hamrick began his fire career in 1989 with the Alpine Interagency Hotshot Crew, a National Park Service crew based (then) in Zion National Park in Utah. In 1991 Dave accepted a promotion to

an Engine Captain position in Sequoia – Kings Canyon National Park where he later served as Foreman of the Park Initial Attack Handcrew before returning to the Alpine Hotshots as Logistics Foreman in 1996. Hamrick became the Alpine IHC Assistant Superintendent in 2000 before moving to the U.S. Forest Service in 2003 to become Superintendent of the Roosevelt IHC.

Hamrick was the Chair of the U.S. Forest Service Region 2 and Region 4 Interagency Hotshot Crew Working Group from 2005 to 2007 and is currently serving as the U.S. Forest Service Region 2 Chainsaw Program Coordinator. He was a Division Supervisor on the Rocky Mountain Area Type 1 Incident Management Team (IMT) from 2008-2011 and is currently an Operations Section Chief Type 2 trainee on the RMA Type 2 IMT "A". Hamrick has also served on two prior review teams. Lonetree 3 Escaped Prescribed Fire Review and the Crandall Ranger Station Felling Accident.

Hamrick is qualified as an Incident Commander Type 3 (ICT3), Operations Section Chief Type 2 trainee (OPS2/t) and Prescribed Fire Burn Boss Type 2 (RXB2).

Hamrick holds a Bachelor of Arts in English, from Washington & Lee University (1984) and Technical Fire Management, from Washington Institute (2001).

Tammy Williams (*Review Team Public Information Officer*)*:* Tammy Williams has been a Public Affairs Specialist on the Arapaho and Roosevelt National Forests and Pawnee National Grassland (ARP) since September 1998 and the facilitator of the ARP Leadership Team since 2001.

Williams has worked for the U.S. Forest Service for 22 years. Prior to becoming a Public Affairs Specialist, Williams was a Lands Forester for the ARP for five years. Williams has also worked in the Washington Office as a Fire Prevention Specialist and on the Coconino National Forest in Flagstaff, Arizona as a Zone Fire Prevention Officer. Williams started her career in natural resources in 1981 with the Colorado State Forest Service where she held positions as a Student Forester in Fort Collins and Forester on both the Fort Morgan and La Veta Districts.

Williams is qualified as a public information officer Type 2 and has been actively involved in fire management since 1982. She formerly served as a Strike Team Leader Trainee and Crew Representative.

Williams holds a Bachelor of Science degree from Colorado State University (CSU) in Outdoor Recreation (1984) and a Master of Science in Technical Communication and Journalism (2005) which focused on crisis communication.

Jace Ratzlaff (*Review Team Public Information Officer*)*:* Jace Ratzlaff has been a Public Affairs Specialist on the Pike and San Isabel National Forests, Cimarron and Comanche National Grasslands (PSICC) since 2009. Ratzlaff also serves as the partnership coordinator and the web master for the PSICC.

Ratzlaff has worked for the U.S. Forest Service for almost three years and has worked in Region 2 and Region 3. Prior to becoming a Public Affairs Specialist, Ratzlaff served for nine years for two Members of Congress as Area Director specializing in small business, education, and agriculture. Ratzlaff has worked as the initial attack Public Information Officer for many fires on the PSICC. Ratzlaff has placed focus on internal communication across the PSICC, and he has led the effort to integrate social media into the PSICC and Cibola fire information methods.

Ratzlaff holds a Bachelor of Science degree in Business Management from American University (2008) with a minor in English.

Lester (Dean) Clark (*Technical Specialist):* Clark has worked in fire management in the western United States for 43 years. Clark retired in 2008 after 34 years of federal service encompassing positions in both the U.S. Forest Service and the National Park Service. He began his career in 1969 as firefighter at Mariposa for the State of California and most recently served as the National Park Service Deputy Fire Management Officer for the Intermountain Region which includes Montana, Wyoming, Utah, Colorado, New Mexico, Arizona, Oklahoma, and Texas. In this position he reviewed Fire Management Plans for policy compliance, site specific prescribed burn plans for adequacy, planned and conducted interagency operations, led and participated in a variety of fire reviews.

Clark has been involved in prescribed burning since 1972 starting as a Foreman (crew boss) for experimental burn projects in the Giant Sequoia Kings Canyon National Park. He has been the Fire Boss and project leader on more than 100 controlled burns in California Chaparral vegetation type from 1976-1982 at Pinnacles National Monument. He was the Prescribed Fire Manager for Yosemite National Park from 1995-1999, and was assigned to Bandelier National Monument as Fire Management Officer in the aftermath of the Cerro Grande fire from 2001-2003. Clark was one of the first certified federal Burn Bosses in 1984 and served on the national federal training cadre until 1990.

Clark is qualified as a Type 1 Burn Boss.

Kelly Close (*Fire Behavior Analyst):* Kelly has been a Captain with the Poudre Fire Authority (PFA) since 2004. Close has 24 years of experience in wildland fire management and for 14 years has been involved in PFA's Wildland/Urban Interface program in ongoing efforts involving training, response guidelines, operational directives, annual training, and managing the department's red card program. He has also assisted the U.S. Forest Service, National Park Service, and City of Fort Collins' Natural Areas in prescribed fire implementation.

Close has held a variety of fire positions, including PFA Firefighter and Emergency Medical Technician from1995 - 2003, Rural Fire Coordinator for Montana Department Of Natural Resources from1990-1995, and Fuels Technician for the U.S. Forest Service on the Powell Ranger District of the Clearwater National Forest from 1988-1990.

Close holds a Bachelor of Science in Botany from the University of California, Davis (1980) and a Master of Science in Forestry and Fire Management from the University of Montana. His thesis research focused on the use of geographic information systems (GIS) for fire management planning in the wildland/urban interface

Close is qualified as Fire Behavior Analyst, a Long-term Analyst, Division Group Supervisor, and an Incident Commander Type 4. He has worked on a variety of wildfires and participated in three review teams: Monument Fire entrapment investigation, Hayman Fire Case Study Interagency review, and the Cramer Fire Fatality Investigation. Additionally Close has participated in the analysis and review of fire behavior for the "Backfire 2000" case in western Montana, the analysis and review of fire behavior and spread of the Canberra (Australia) fires of 2003 and was a keynote speaker for the Fire Behavior Specialist course for the Canadian Forest Service. Close served for seven years on of the National Wildfire Coordinating Group Fire Behavior Committee, and is an instructor and steering committee member for the Advance Fire Behavior Interpretation Course (S-590).

Timothy O. Mathewson (*Review Team Fire Weather and Predictive Services*): Mathewson has been with the Bureau of Land Management as the interagency Fire Weather Program Manager/Fire Meteorologist for the Rocky Mountain Area since 2001. One of his primary duties includes oversight of the Rocky Mountain Area Predictive Services program, a decision support group for the Rocky Mountain Area Coordination Center that helps determine current and future resource needs and strategic allocation. He is responsible for issuing a variety of Fire Potential/Risk products for a daily and seasonal time scale that covers Wyoming, South Dakota, Nebraska, Kansas and Colorado.

Mathewson's fire weather experience expands beyond the United States. In 2007, he was selected for a thee-week assignment to provide international fire weather support to the Bureau of Meteorology in Melbourne, Australia during an historic fire period (December 2006–

March 2007).

In 2003, Tim was selected to provide subject matter expertise (Fire Weather) and co-author the national rewrite of introduction to Wildland Fire Behavior (S190) and Intermediate Wildland Fire Behavior (S290).

Prior to his employment with BLM, Mathewson worked as a Forecaster and Incident Meteorologist for eight years for the National Oceanic and Atmospheric Administration (NOAA) – National Weather Service in Cheyenne, Wyoming; Waterloo, Iowa; Goodland, Kansas and Missoula, Montana. Mathewson holds a Bachelor of Science in Earth Science (Emphasis in Meteorology) from the University of Northern Colorado (1995).

Mathewson is a veteran of the Armed Forces, having served as a Medic in the United States Air Force from 1988-1992.

Appendix E. Glossary of Acronyms and Terms

The main reference glossary for this guide is the NWCG glossary, which is updated periodically: http://www.nwcg.gov/.

Blackline/Blacklining – Preburning of fuels adjacent to and within a control line before igniting a prescribed burn. Blacklining is done prior to main ignitions to reduce heat on holding crews and lessen chances for spotting across control line.

Broadcast Prescribed Burning – Prescribed burning activity where fire is applied generally to most or all of an area within defined boundaries for reduction of fuel hazard, as a resource management treatment, or both.

Chain – Unit of measure equaling 66 feet.

CRWB (Crew Boss) – A person in supervisory charge of usually 16 to 21 firefighters and responsible for their performance, safety, and welfare.

Cutoff-Low – A closed upper-level low which has become completely displaced (cut off) from basic westerly current, and moves independently of that current. Cutoff lows may remain nearly stationary for days, or on occasion may move westward opposite to the prevailing flow aloft (i.e., retrogression).

"Cutoff low" and "closed low" often are used interchangeably to describe low pressure centers aloft. However, not all closed lows are completely removed from the influence of the basic westerlies. Therefore, the recommended usage of the terms is to reserve the use of "cutoff low" only to those closed lows which clearly are detached completely from the westerlies.

Escaped Prescribed Fire – A prescribed fire that has exceeded or is expected to exceed prescription parameters or otherwise meets the criteria for conversion to wildfire. Criteria are specified in "Interagency Prescribed Fire – Planning and Implementation Procedures Reference Guide".

ENGB (Engine Boss) – The Fire Effects Monitor is responsible for collecting the onsite weather, fire behavior, and fire effects information needed to assess whether the fire is achieving established resource management objectives.

Fire Duty Officer (FDO) - Individual working for a jurisdiction or agency responsible for coordinating that agency (Wildland Fire Response) on a give day.

FIRB (Firing Boss) – The Firing Boss reports to the Prescribed Fire Burn Boss and is responsible for supervising and directing ground and/or aerial ignition operations according to established standards in the Prescribed Fire Plan.

ERC (Energy Release Component) – Index of the National Fire Danger Rating System (NFDRS) relating to the available energy (BTU) per unit area (square foot) within the flaming front at the head of a fire. It is a cumulative or "build-up" type of index and is an indicator of potential fire intensity.

FEMO (Fire Effects Monitor) – The Fire Effects Monitor is responsible for collecting the onsite weather, fire behavior, and fire effects information needed to assess whether the fire is achieving established resource management objectives.

FFT1 (Fire Fighter) – A working leader of a small group (usually not more than seven members), who is responsible for their performance, safety, and welfare.

FOBS (Field Observer) – This position is responsible for collecting and reporting situation information for an incident.

Haines Index – Is an index developed by meteorologist Donald Haines in 1988 that measures the potential for large fire growth (Plume-Driven). The index is derived from the stability (temperature difference between different levels of the atmosphere) and moisture content (dew point depression) of the lower atmosphere. The data may be acquired from radiosonde information. The index is calculated over three ranges: low elevation (950-850mb), mid elevation (850-700mb), and high elevation (700-500mb).

A Haines index of 6 means a high potential for large fire growth. 5 means medium potential, 4 low potential, and anything less than 4 (2 and 3) means very low potential.

Helibase – The main location within the general incident area for parking, fueling, maintenance, and loading of helicopters.

HECM (Helicopter Crew Member) – An individual assigned to an agency or call-when-needed helicopter to support helicopter operations.

HEB2 (Helibase Manager Type 2) – This position is responsible for controlling helicopter take-offs and landings at a helibase, managing helibase assigned helicopters, supplies, fire retardant mixing and loading.

HEB1 (Helibase Manager Type 1) – This position is responsible for controlling helicopter take-offs and landings at a helibase, managing helibase assigned helicopters, supplies, fire retardant mixing and loading.

Incident – An occurrence either human-caused or natural phenomenon, that requires action or support by emergency service personnel to prevent or minimize loss of life or damage to property and/or natural resources.

ICT1/ICT2/ICT4/ICT5 (Incident Commander) – The Incident Commander position is responsible for overall management of the incident. The Incident Commander reports to the Agency Administrator for the agency having incident jurisdiction.

Maximum Management Area (MMA) – The maximum geographic limits of spread within which a wildland fire use fire is allowed to spread.

MOP-UP – Extinguishing or removing burning material near control lines, felling snags, and trenching logs to prevent rolling after an area has burned, to make a fire safe, or to reduce residual smoke.

National Wildfire Coordinating Group (NWCG) – An operational group designed to coordinate programs of the participating wildfire management agencies.

Pile Burning – Cut material piled either by hand or mechanical – resulting from logging or fuel management activities – are burned during the wetter months to reduce damage to residual stand and to confine fire to the size of the pile. Piling allows for the material to cure, producing less smoke and rapid consumption when burned.

Prescribed Fire Burn Boss – Type 1 (RXB1) – Person responsible for supervising a prescribed fire from ignition through mop-up. See definition for "Type" below.

Prescribed Fire Burn Boss – Type 2 (RXB2) – Person responsible for supervising a prescribed fire from ignition through mop-up. See definition for "Type" below.

Prescribed Fire Plan – A plan required for each fire application ignited by management. It must be prepared by qualified personnel and approved by the appropriate agency administrator prior to implementation. Each plan will follow specific direction and must include critical elements and how to mitigate each element.

Prescription Guidelines – Guidelines used to show upper and lower reaches of a prescription.

Safety Officer Type 2 – Person responsible for monitoring and assessing hazardous and unsafe situations and developing measures for assuring personnel safety.

Standard Operating Procedure (SOP) – Rules for the operation of a fire department, such as how to respond to varioUS types of emergencies, training requirements, use of protective equipment, radio procedures; often include local interpretations of regulations and standards. In general, "procedures" are specific, whereas "guidelines" are less detailed.

Strike Team – Specified combinations of the same kind and type of resources, with common communications, and a leader.

STCR (Strike Team Leader Crews) – This position is responsible for supervising a strike team of crews and report to the Holding Boss.

STEN (Strike Team Leader Engines) – This position is responsible for supervising a strike team of engines and report to the Holding Boss.

SOPL (Strategic Operational Planner) – Primary task of this position is to coordinate the development of the course of action for a wildfire (unplanned ignition).

Task Force – Any combination of single resources assembled for a particular tactical need, with common communications and a leader. A Task Force may be pre-established and sent to an incident, or formed at an incident.

1,000-hr (thousand-hour) timelag fuel moisture – an index of the NFDRS relating to moisture content of large, dead fuels. It provides an indication of longer-term seasonal drying trends.

TFLD (Task Force Leader) – The Incident Command position responsible for supervising a Task Force. This position reports to the Holding Boss.

Type (1/2/3) – Refers to resource capability. Resource typing provides managers with additional information in selecting the best resource for the task.

Wildfire – An unwanted wildland fire.

Wildland Fire – Any nonstructural fire, other than prescribed fire, that occurs in the wildland. This term encompasses fires previously called both wildfires and prescribed natural fires.

Wildland Urban Interface (WUI) – The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels.

Appendix F. Climate, Weather and Fire Behavior

Introduction

The Colorado Front Range is historically prone to large fires. Fires can occur anytime of the year but are *most* frequent during three distinct periods; late winter and early spring (March-early April) prior to green up, the early summer warm season (June through mid- July) prior to the onset of the Southwest Monsoon; and the Indian Summer period of late September through October.

The majority of *large fires* (100 acres in timber and 300 acres in grass fuels) along the Colorado Front Range burn under critical meteorological patterns (Break Down of Upper Ridge) that produce strong westerly component winds, above average temperatures, low humidity, and unstable atmospheric conditions in combination with receptive fuels (Bobcat Gulch 2000, Hayman 2002, Overland Trail 2003, Fourmile Canyon 2010, and Crystal 2011).

Fire behavior is ultimately determined by the interaction between three main environmental elements: Fuels, Weather and Topography. All three are equally important when determining fire behavior. However, weather and fuels are the most variable in time and space, and weather is typically the most difficult to predict.

Fire Weather and Climatology

This section provides an analysis and chronology of climatological and meteorological conditions that contributed to rapid fire growth on the Lower North Fork Incident in Jefferson County Colorado on Monday, March 26, 2012.

Data Collection and Considerations

Data collection and considered for this analysis includes:

- NOAA- National Weather Service Boulder Fire Weather Planning Forecast (FWF)
- NOAA- National Weather Service Boulder Spot Forecasts (Site Specific Forecasts)
- NOAA- National Weather Service Radiosonde Data for DNR (Denver)
- NOAA- National Weather Service Cooperative Observer Data
- NOAA- National Climate Data Center Archived Upper Charts
- NOAA- Hydrologic Prediction Center (HPC) Data
- Rocky Mountain Area Predictive Service 7-Day Outlook
- Rocky Mountain Area Predictive Service Daily Fire Potential Outlooks
- Department of Agriculture Natural Resource Conservation Service (NRCS)
- Archived U.S. Forest Service Remote Automated Weather Station (RAWS) Data
- USDA-United States Drought Monitor

- Colorado State Cooperative Institute for Research in the Atmosphere
- University of Wyoming- Archived Upper Air Data

Seasonal Severity Assessment-

Strong low pressure systems brought near record snowfall and cooler than average temperatures to the Colorado Front Range in February, however and abrupt pattern shift in resulted in the driest and one of the warmest March on record was the driest and one of the warmest on record. The record warmth and dryness leading up to March 26th quickly depleted February's snowfall gains below 9000 feet MSL, leaving fine and heavy fuel types dry and receptive to burn. Additionally, the weather pattern supported a high frequency of wind events, exacerbating the drying of fuels along the Front Range.

The Percent of Average Precipitation provides a good assessment of long-term dryness (Drought) or wetness. Percentages are calculated by comparing long-term averages to amounts that have fallen over periods ranging from 30 days up to 5 years. The regional maps below (Figure 1) depict the Percent of Average Precipitation (liquid) for a 90-Day period (January through March 2012) and 30-Day period (March 2012). The precipitation information displayed reveals wet (125% to 250% of average) conditions along the central and northern Colorado Front Range for the January through March period, a result of near record snowfall (Figure 2) during the Month February. In contrast, unprecedented dryness occurred in March across much of the state, but especially along the Front Range. Denver (DIA) only received 0.03 of an inch precipitation finishing as the driest March on record and the second warmest on record.

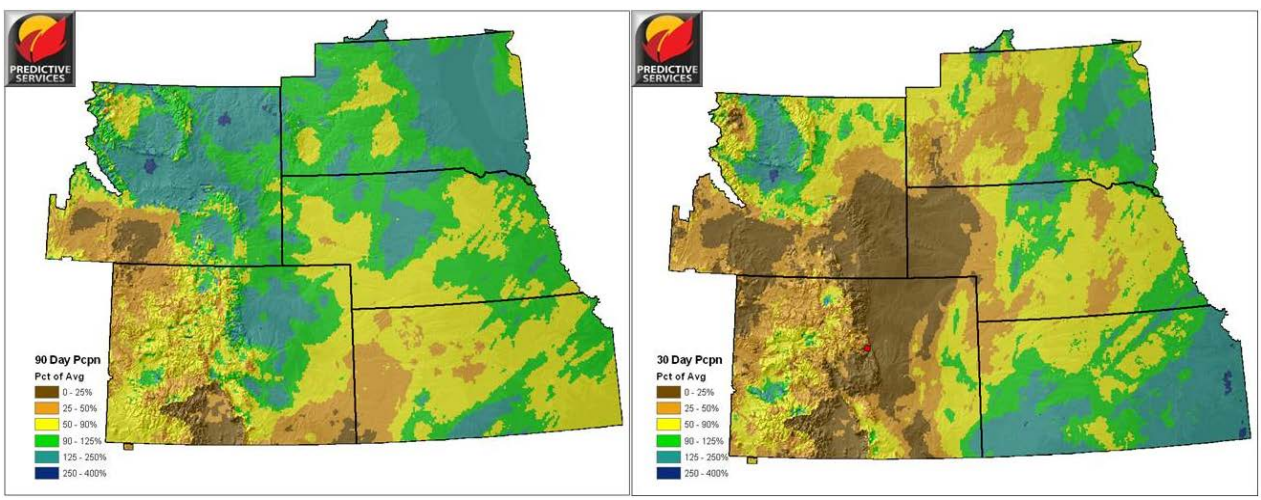


Figure 1. *January through March 2012 (left) and March 2012 (right) Percent of Average Precipitation. Dark brown colors indicate percent of average precipitation ranging from 0% to 25%, orange 25% to 50%, yellow 50% to 90%, green 90% to 125%, light blue 125% to 250%, and 250% to 400%. Data was extracted from NOAA's Hydrologic Prediction Center and displayed using ArcGIS.*

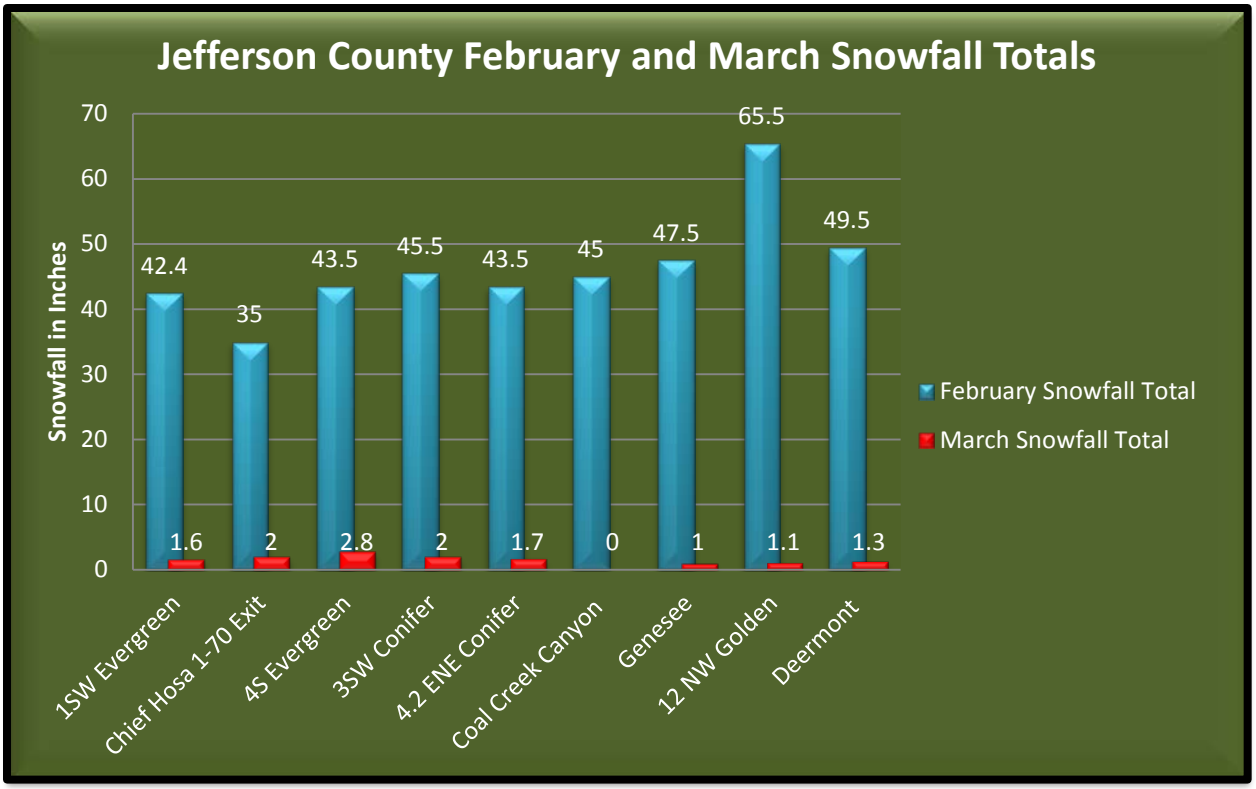


Figure 2. *Jefferson County snowfall totals for February and March. Notice the significant drop in snowfall totals from February to March (typically the snowiest month along the Colorado Front Range). Data displayed from the NWS Cooperative Observer Network.*

Precipitation amounts on the Lower North Fork Unit were consistent with conditions represented in the 30-Day Percent of Average Precipitation map in Figure 1. Precipitation amounts measured at Remote Automated Weather Stations (RAWS) in Jefferson, Douglas and Park counties were consistent with amounts recorded for the month of March at Denver (DIA) (Figure 3).

RAWS	County	March Precipitation Amounts
Bailey	Jefferson	0.00
Polhemus	Douglas	0.02
Lookout Mountain	Jefferson	0.00
Cheeseman	Jefferson	0.00
Lake George	Park	0.02

Figure 3. *Data collected from the RAWS Archive- Western Region Climate Center (WRCC)*

In addition to above average snowfall across much of the Colorado Front Range in February, temperatures were cooler than normal (-2°F to -4°F temperature anomalies). The cooler than average temperature pattern continued into the first few days of March before an abrupt weather pattern shift resulted in anomalous warm periods for the remainder of the month.

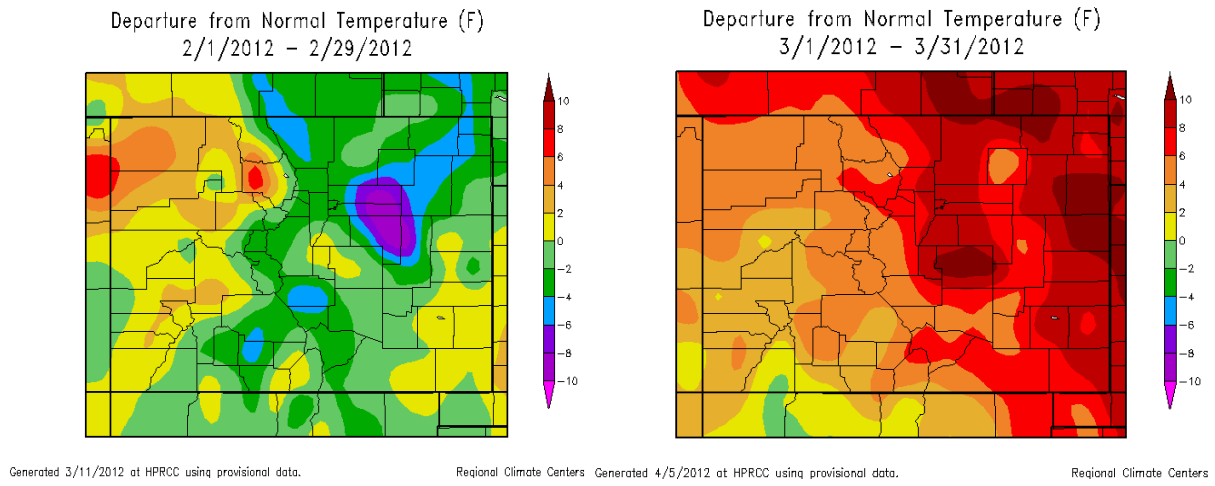


Figure 4. *Colorado temperature departure from normal for February 2012 (left) and March 2012 (right), developed by the Western Region Climate Center (WRCC). Temperatures were 2°F to 4°F below average (depicted by the blue and green colors) along the Front Range in February, but were 6°F to 10°F above average (depicted by the red and maroon colors) in March, including Jefferson County.*

Polhemus RAWS temperature observations near the Lower North Fork Unit were consistent with conditions observed along the entire Front Range. Figure 5 depicts daily observed maximum temperatures during the month of March vs. an approximate 7-year average (station data period 6/2005 to present). Cooler than average temperatures were observed during the first few days of March, on the 7th and 8th, and again on the 19th, 20th and 21st. Importantly, observation data shows a substantial temperature increase beginning on March 23rd.

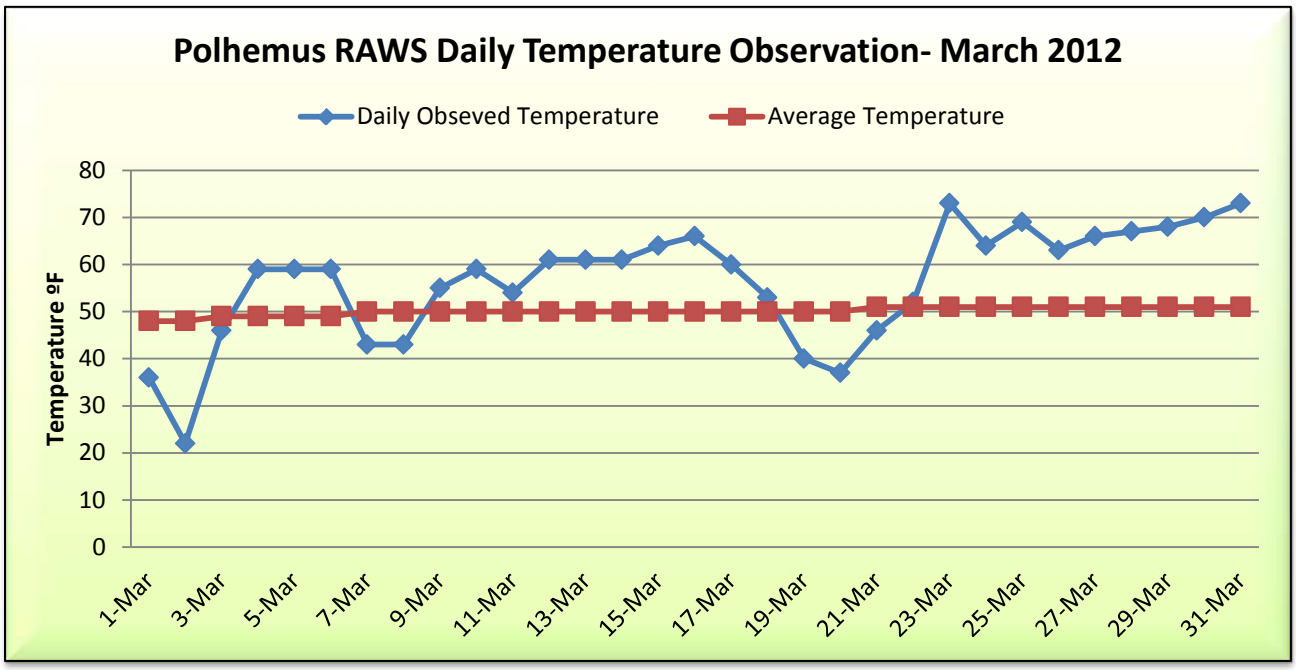


Figure 5*. Polhemus RAWS observed daily temperatures for March 2012 vs. Average Temperature.*

Finally, The U.S Drought Monitor reflects both short-term (1 to 3 month) and long-term (6 to 60 months) precipitation trends. Other indices that contribute to the monitor during the growing season include, the USDA/NASS Topsoil Moisture, Keetch-Byram Drought Index (KBDI), and NOAA/NESDIS satellite Vegetation Health Indices. Indices used primarily during the snow season and in the West include snow water content, river basin precipitation, and the Surface Water Supply Index (SWSI). Other indicators include groundwater levels, reservoir storage, and pasture/range conditions. Though the maps are based on the key indices and other measures of moisture, the final maps are tweaked to reflect real-world conditions as reported by numerous experts throughout the country. *(Source: National Drought Mitigation Center)*

Drought indices at the end of February (Figure 6) ranged from Abnormally Dry to Moderate across western Colorado, and Abnormally Dry to Extreme in southeast Colorado. Drought conditions over southeast Colorado are part of long-term dryness that developed in the fall of 2010. Drought conditions over western Colorado develop during the last 3-months (January through March).

Drought Severity

D0 - Abnormally Dry D1 Drought - Moderate D2 Drought – Severe D3 Drought - Extreme

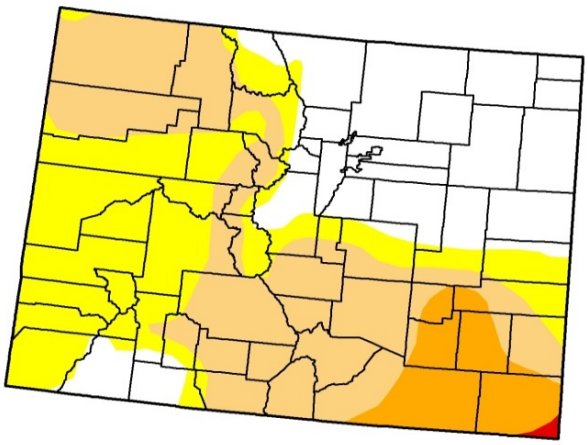


Figure 6. *Colorado Drought Monitor- February 28, 2012*

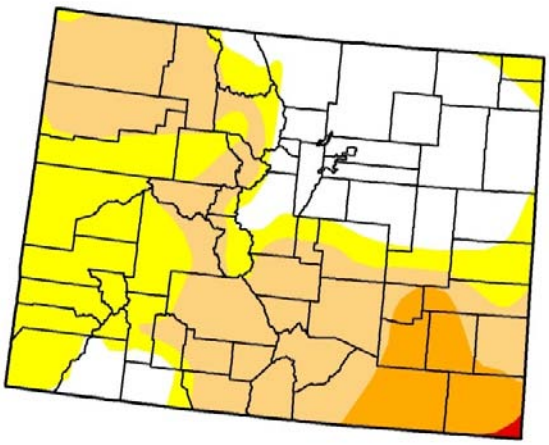


Figure 7. *Colorado Drought Monitor- March 20, 2012*

Contributing Meteorological Factors and Findings-

Nationally recognized fire behavior courses refer to critical fire weather patterns as atmospheric conditions that encourage *extreme fire behavior* resulting in large wildland fires. “Extreme Fire Behavior” (as defined in the NWCG glossary of wildland fire terminology) -

implies a level of fire behavior characteristics that ordinarily precludes methods of direct control action. One or more of the following is usually involved: high rate of spread, prolific crowning and/or spotting, presence of fire whirls, and strong convective column. Predictability is difficult because such fires often exercise some degree of influence on their environment and behave erratically, sometimes dangerously.

Atmospheric conditions that contributed to rapid fire growth (extreme fire behavior) of the Lower North Fork Fire on March 26th were consistent with historic critical fire weather patterns and related fire events that have occurred across Colorado (South Canyon 1994, Bobcat Gulch 2000, Hayman 2002, Overland Fire 2003) and the western United States.

Meteorological Conditions on Monday, March 19, 2012- Lower North Fork Blacklining

Blacklining operations on March 19th on the Lower North Fork Unit was performed and completed under non-critical fire weather conditions. On-Site observations (Figure 7 and Figure 8) from fire personnel during blacklining operations indicate a prevailing south-southwest wind of 3 to 6 mph with gusts of 8 to 10 mph, and good lift and dissipation of smoke. On-site temperature readings were consistent with Remote Automated Weather Station (RAWS) observations at similar elevations (6800-7100 ft. msl); however relative humidity readings were 10% to 12% higher.

Date	Time (MDT)	Dry Bulb	Wet Bulb	RH %	Wind Speed (MPH)	Wind Direction
3/19	1100	42	30	24	2-4	SW
3/19	1200	48	34	23	4-6 G8	SSW
3/19	1245	50	35	21	4-6 G8	NNW
3/19	1345	51	35	21	4-6 G10	SSW
3/19	1445	45	33	29	4-6 G8	SSW
3/19	1545	41	31	34	6-8 G10	N

Figure 7. *On-site weather observations for on ridgeline, blacklining operations. March 19, 2012.*

Date	Time	Elevation	Wind Speed	Wind	Elev. Smoke Column Above Ground	Column Direction
3/19	1110	6900	3-5	SSW	200-300	ENE
3/19	1130	6900	3-5 G7	NNE	300-400	WSW
3/19	1135	6900	4-8 G8	SSW	300-400	ENE
3/19	1200	6900	4-6	SSW	400-500	ENE
3/19	1245	7100	N/A	SSW, NNW	900	ENE
3/19	1300	N/A	N/A	N/A	SSW	N/A
3/19	1315	7100	N/A	SSW	300-400	NNE
3/19	1415	7100	N/A	SSW	200	NNE

Figure 8. *Wind and smoke observations from the Lower North Fork Unit. March19, 2012.*

Meteorological Conditions on Tuesday and Wednesday, March 20-21, 2012

No on-site weather observations were taken on the Lower North Fork Unit; however maximum temperature readings from local RAWS observations ranged from the mid-40s to low 50s. Minimum relative humidity range from 19% to 22%, with prevailing wind from the East to Northeast at 7 to 10 mph with gusts 16 to 21 mph. Manual calculations of the Haines Index from Denver (DNR) radiosonde data yields a value of 3 on the afternoon of March 20th and a 2 the afternoon of March 21st. Much of the Colorado Front Range was under the influence of a "Cut Off" low pressure system (Figure 9) centered over Texas, Oklahoma, and Kansas. No precipitation was recorded at the unit.

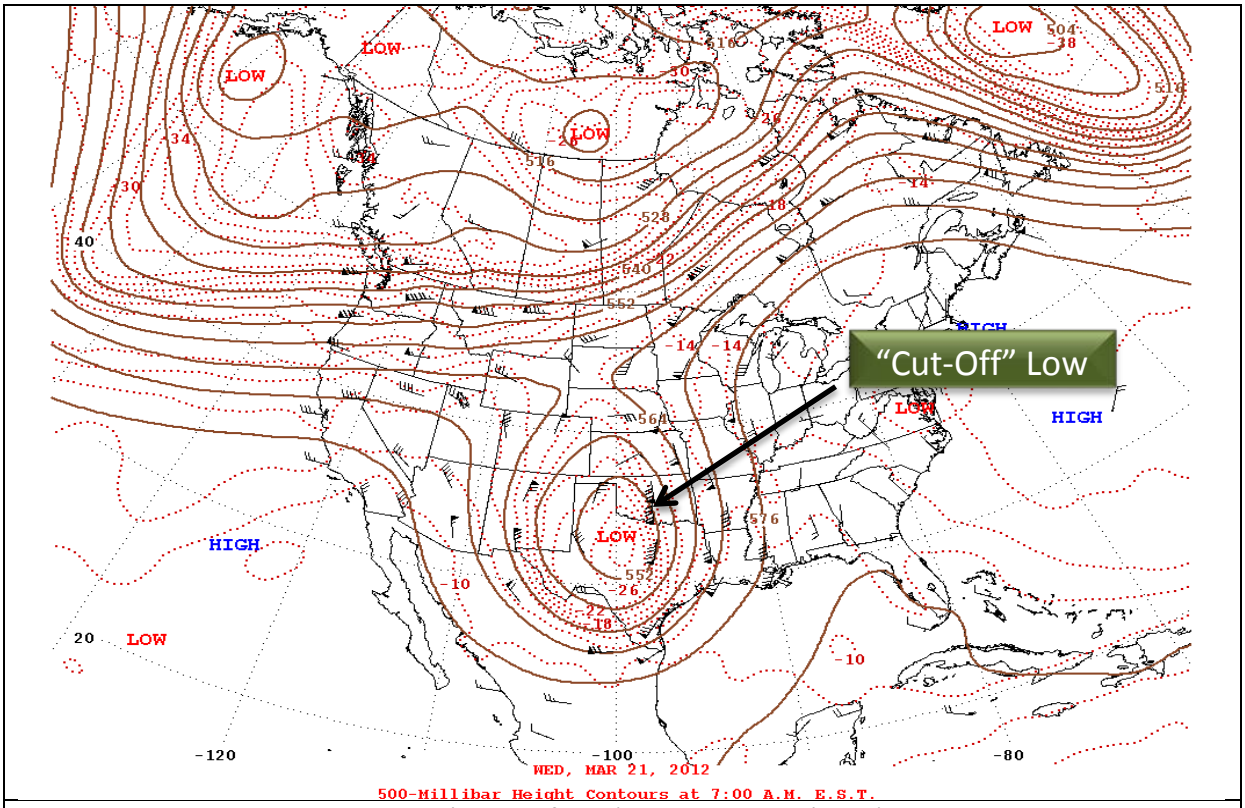


Figure 9. *500 hPa Geopotential Height (~18,000 ft. msl) and Wind Barbs (Knots) -Valid Wednesday, March 21, 2012 6:00 A.M. MDT. "Cut Off "upper low over Texas and Oklahoma with a new trough taking shape over the Gulf of Alaska.*

Meteorological Conditions on Thursday, March 22, 2012- Lower North Fork Burn

The eastern plains and Front Range of Colorado remained under the influence of a "Cut Off" low pressure system center over southern Kansas and Oklahoma. Heavy precipitation extended across much of Kansas (>1.00"), with light to moderate rainfall totals (.025" to 0.45") across extreme eastern Colorado. A deep and broad northeast flow extended west and into the Lower North Fork burn area.

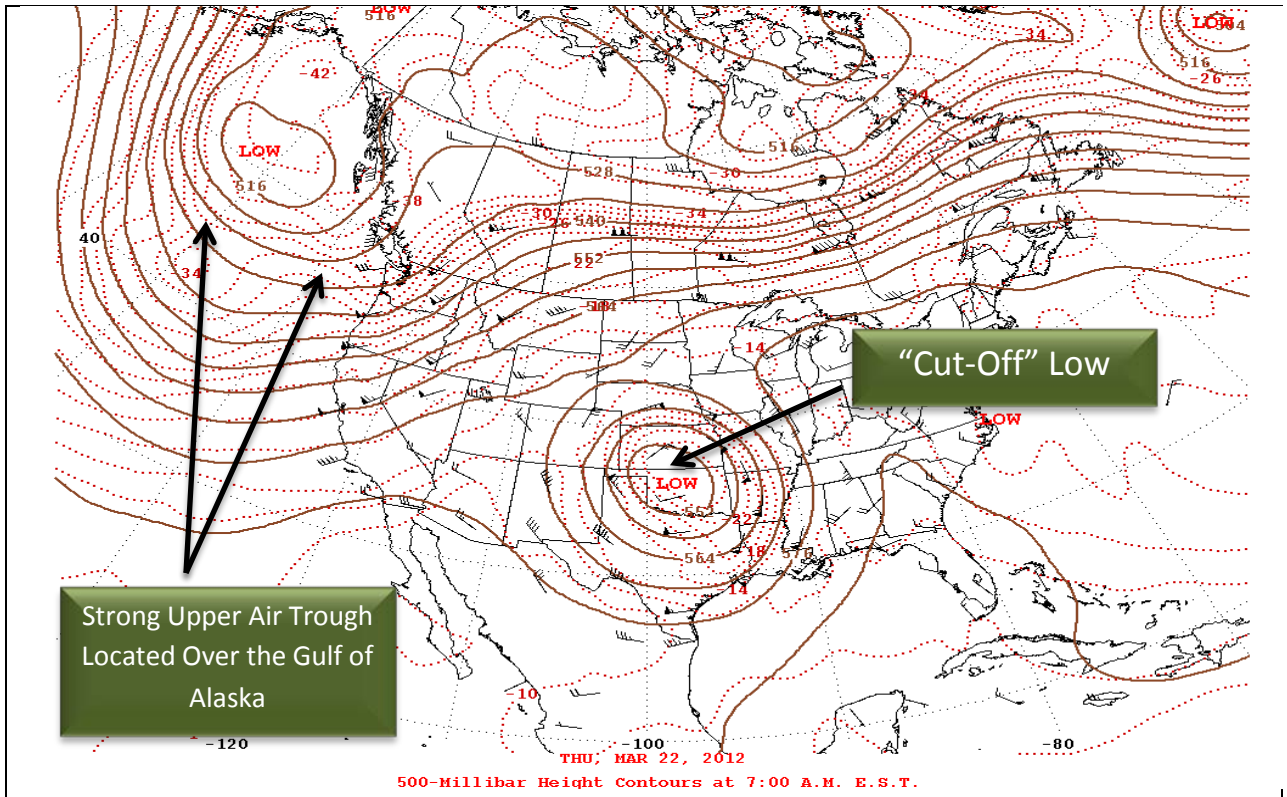


Figure 10. *500- hPa Geopotential Height (~18,000 ft. msl) and Wind Barbs (Knots)- Valid Thursday, March 22, 2012 6:00 A.M. MDT.*

On-site wind observations from fire personnel (Figure 11) measured an east to northeast (at times variable) wind direction with maximum sustained wind speeds ranging 5 to 9 mph and maximum gusts of 10 to 12 mph. Maximum temperatures reached 59°F with a minimum relative humidity of 21%. On-site observations were consistent with meteorological conditions at local RAWS (Bailey, Polhemus, and Cheeseman) observations.

Date	Time (MDT)	Temperature (F)	RH (%)	Wind Speed (MPH)	Wind Direction
3/22	1045	54	22	3-6 G9	NE
3/22	1115	54	26	3-6 G9	Variable
3/22	1215	56	25	4-7 G10	ESE-ENE
3/22	1245	56	25	5-8 G12	ESE-ENE
3/22	1315	56	25	5-8 G12	ESE-ENE
3/22	1430	58	23	6-9 G12	Variable
3/22	1545	58	23	6-9 G12	Variable
3/22	1600	59	21	N/A	ENE

Figure 11. *On-site weather observations on the Lower North Fork Prescribed Burn- March 22, 2012*

The Haines Index relates the *potential* for large fire growth (plume-driven) to atmospheric stability and dryness, and does not consider wind as an input. The Haines Indices for March 22, 2012 (2-very low at 0600 MDT and 3- very low at 1800 MDT) were manually calculated using

High Elevation layers to determine stability (T700 mb – T500 mb) and atmospheric moisture (T700 mb – T700 Dpd) from Denver (DNR) radiosonde data.

Friday through Monday, March 23-26, 2012- Changing Meteorological Conditions and the Lower North Fork Prescribed Fire and Wildfire

Meteorological Conditions on Friday, March 23, 2012

March 23rd marked the beginning of changing atmospheric conditions that became more conducive to fire activity. On the 23rd, a ridge of high pressure extended (Figure 12) from New Mexico, northward into Colorado, eastern Wyoming and the Black Hills of South Dakota, as a new trough of low pressure began to take shape off the Pacific Northwest coast.

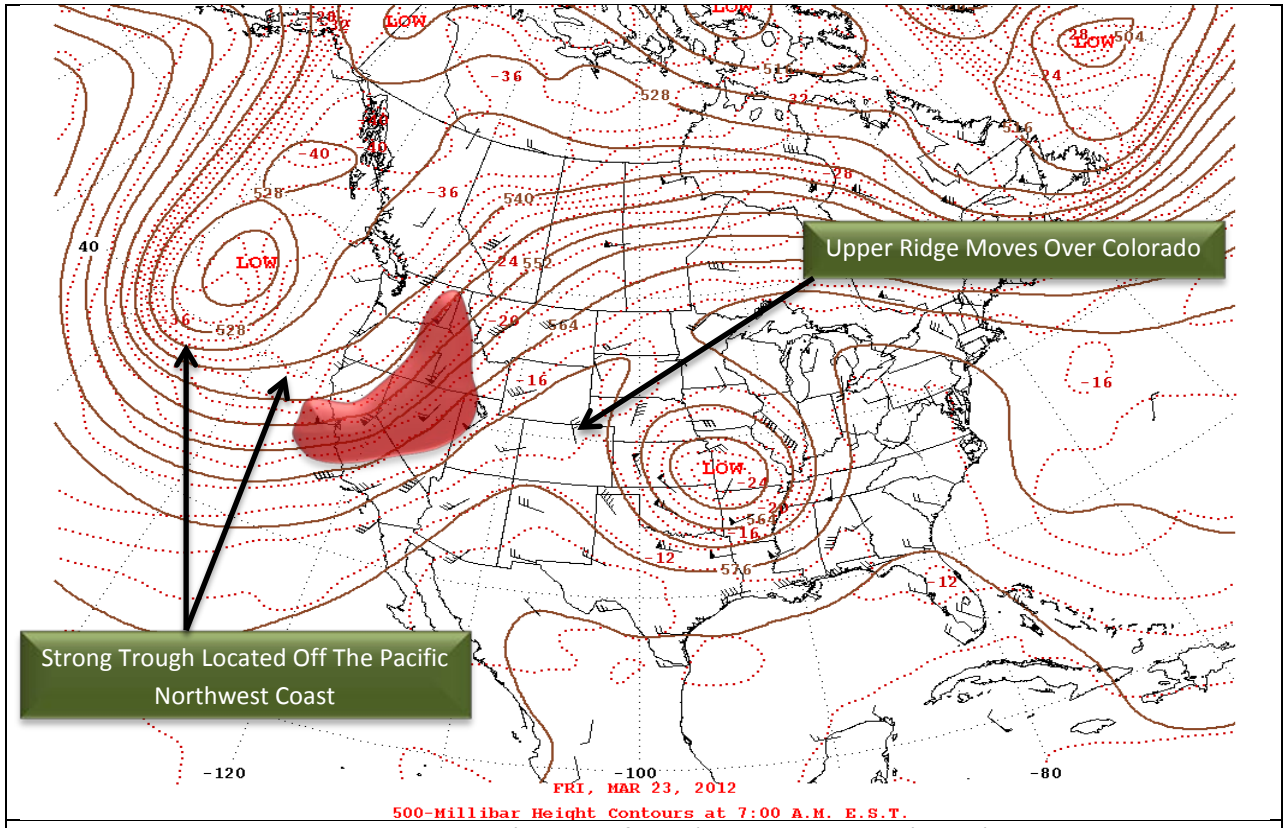


Figure 12. *500- hPa Geopotential Height (~18,000 ft. msl) and Wind Barbs (Knots)- Valid Friday, March 23, 2012 6:00 A.M. MDT. Highlighted (Red) area depicts wind 50 knots or greater.*

The shift in the pattern resulted in a significant air mass change across Colorado including the Front Range. Temperatures increased 15 to 20 degrees from the previous day (March 22, 2012- The Day of the Burn), with maximum readings in the low 70s at the Bailey and Polhemus RAWS near the Lower North Fork. Denver, Colorado set a new record high that afternoon of 76 degrees. Local RAWS also showed a steady decrease in relative humidity during the early

morning hours, with values dropping into the single digits by 1400 MDT on the 23rd. Diurnal wind flow (upslope-upvalley) was apparent at most observation sites with wind speeds ranging from 4 to 7 mph and gust reaching 18 mph (Polhemus RAWS). Manual calculation of the Haines Index yields a value of 5-Moderate at 0600 MDT and 6-High at 1800 MDT.

Meteorological Conditions on Saturday and Sunday, March 24-25, 2012

The air mass along the Front Range and over the Lower North Fork Unit became more precarious March 24th and 25th leading up to the critical fire weather pattern on March 26th. The upper ridge that extended across Colorado on the 23rd (Figure 13) had shifted into the plains as an upper air trough and associated surface front migrated east into California and Nevada by the end of the day on the 25th.

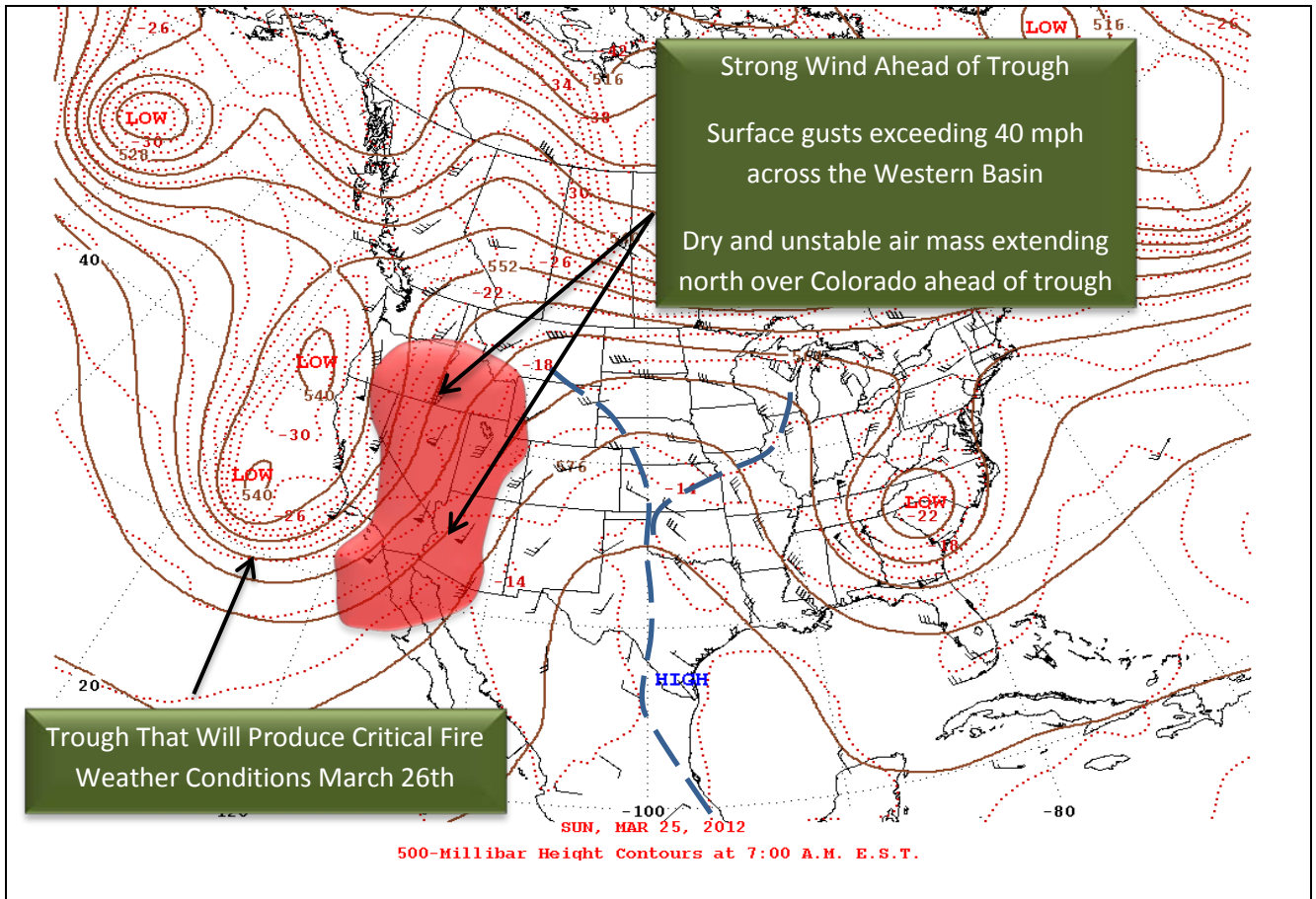


Figure 13. *500- hPa Geopotential Height (~18,000 ft. msl) and Wind Barbs (Knots)- Valid Sunday, March 25, 2012 6:00 A.M. MDT. Highlighted (Red) area depicts winds 50 knots or greater.*

The shift in the ridge resulted in a slightly cooler temperature, but still above average with readings in the mid-60s to around 70 at the Bailey and Polhemus RAWS sites. Importantly, relative humidity dropped into the single digits on the afternoon of the 24th and 25th. The air

mass remained unstable and dry with calculated Haines Indices of 5 to 6, supportive of large fire activity.

Meteorological Conditions on Monday, March 26, 2012- Lower North Fork Wildfire

Analysis of upper air (500 hPa Geopotential Heights and Wind) and surface pressure charts (Figure 14 and 15) on March 26th showed an eastward shift of the upper ridge into the high plains as an upper air trough and associated cold front migrated into Utah early in the day (Similar to meteorological features outlined in the South Canyon Fire Investigation published in August 1994). The "Break Down of the Upper Ridge" (or shift eastward ahead of an upper trough and surface front) is recognized as a "critical fire weather pattern" that produce strong gusty winds, warm temperatures, low humidity (drying of fuels), enhance vertical lift (unstable atmosphere (Haines of 6), and an ultimate increase in fire behavior. Complex terrain can further exacerbate fire weather conditions and fire behavior as descending air on the lee-ward side warms and dries through compression at a rate of 5.5 F/1000 (9.9 C/km). Additionally, terrain can alter direction of wind flow by channeling and increasing speeds through constrictions associated with canyons and narrow drainages.

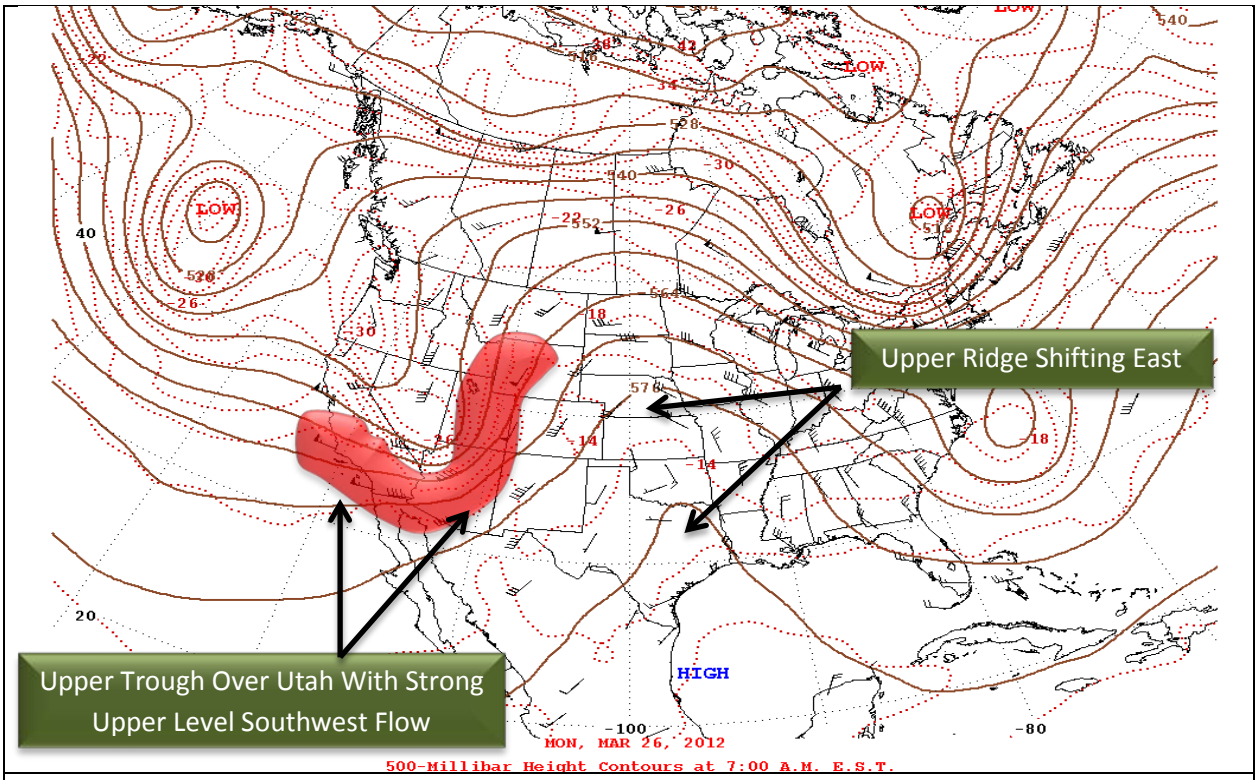


Figure 14. *500-Millibar Height Contours (~18,000 ft. msl) and Wind Barbs (Knots) - Valid Monday March 26 2012 6:00 A.M. MDT. Highlighted (Red) area depicts strong winds 50 knots or greater.*

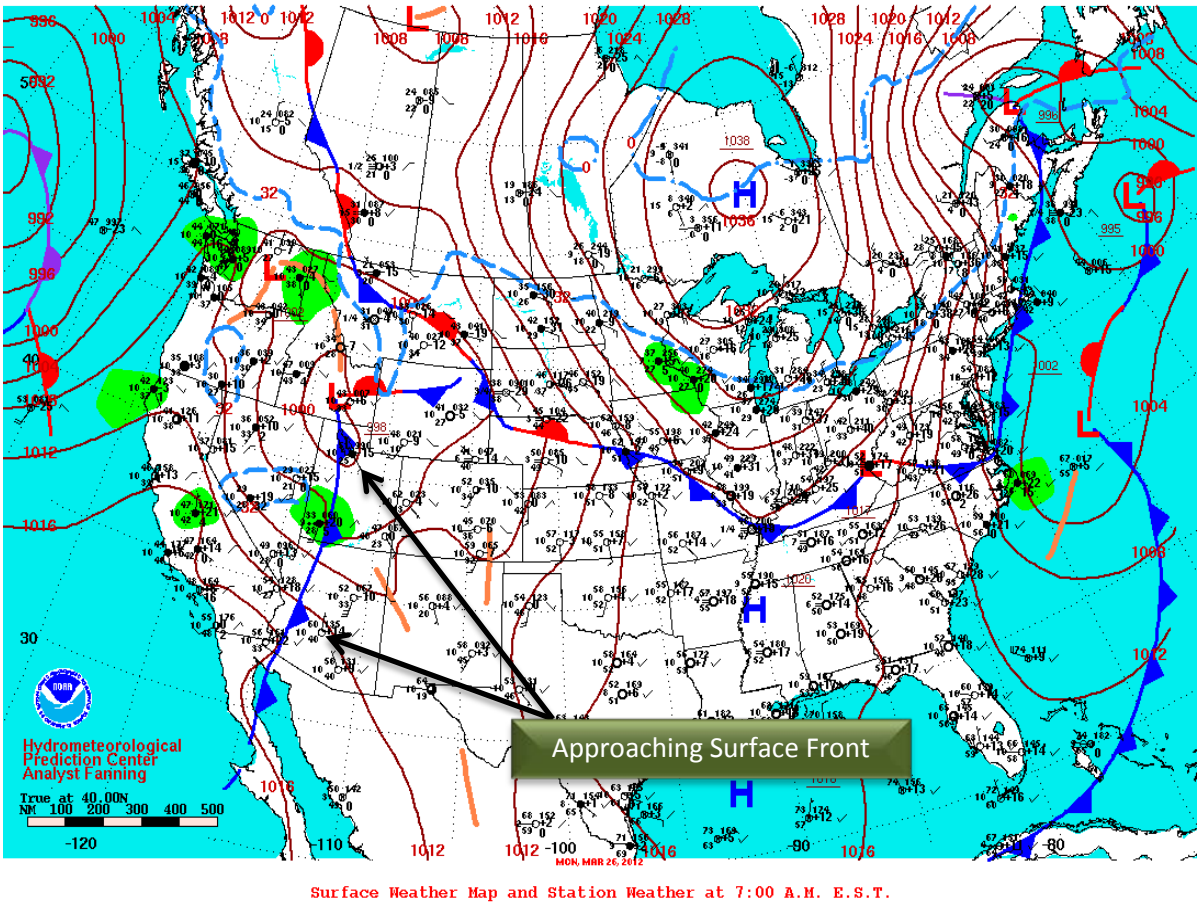


Figure 15. *Surface Pressure Chart and Station Plots Valid Monday, March 26 2012 6:00 A.M. MDT. Surface front extending from southeast Idaho, south into Utah and Arizona.*

Meteorological Conditions during the Morning (Midnight to 1200 (Noon) MDT) of Monday, March 26, 2012.

The Polhemus RAWS observations (ridge top) during the early morning hours (Midnight-0800) of the 26th showed steady temperatures (48°F-50°F), poor overnight relative humidity recovery (23%-28%), south-southwest winds 8 to 11 mph with gusts 20 to 24 mph. The Bailey RAWS data for the same time also showed steady temperatures overnight (44-46), moderately dry relative humidity recoveries of 36%-40%, and light west to northwest winds of 2 to 4 mph.

Early morning 1-KM visible satellite sequence (Figure 16) and local observations also revealed dense mid and high level cloudiness over the Lower North Fork unit, ahead of the upper trough and surface front. Steady temperatures and poor relative humidity recovery are consistent with not only the air mass characteristics in place at the time but known impacts from cloud cover and wind at night (both of which disrupt radiational cooling and corresponding rise in relative humidity).

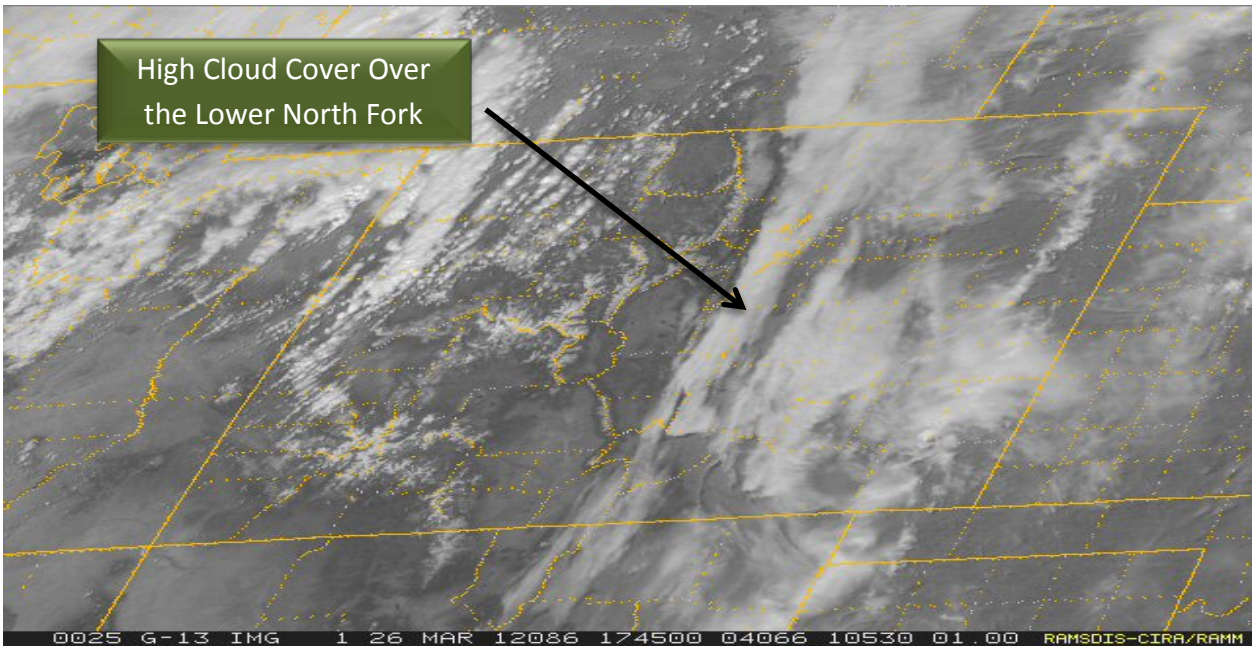


Figure 16. *1-KM Visible Satellite Image from valid March 26, 2012 1745 Z (1145 MDT). High and mid-level cloud shield over the Lower North Fork Fire. Image obtained from* ***Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA).***

Water Vapor (WV) satellite imagery (Figure 17) also revealed mid-level dry air extending northeast from the Desert Southwest into western Colorado at 0900 MDT, just west of the Lower North Fork Unit.

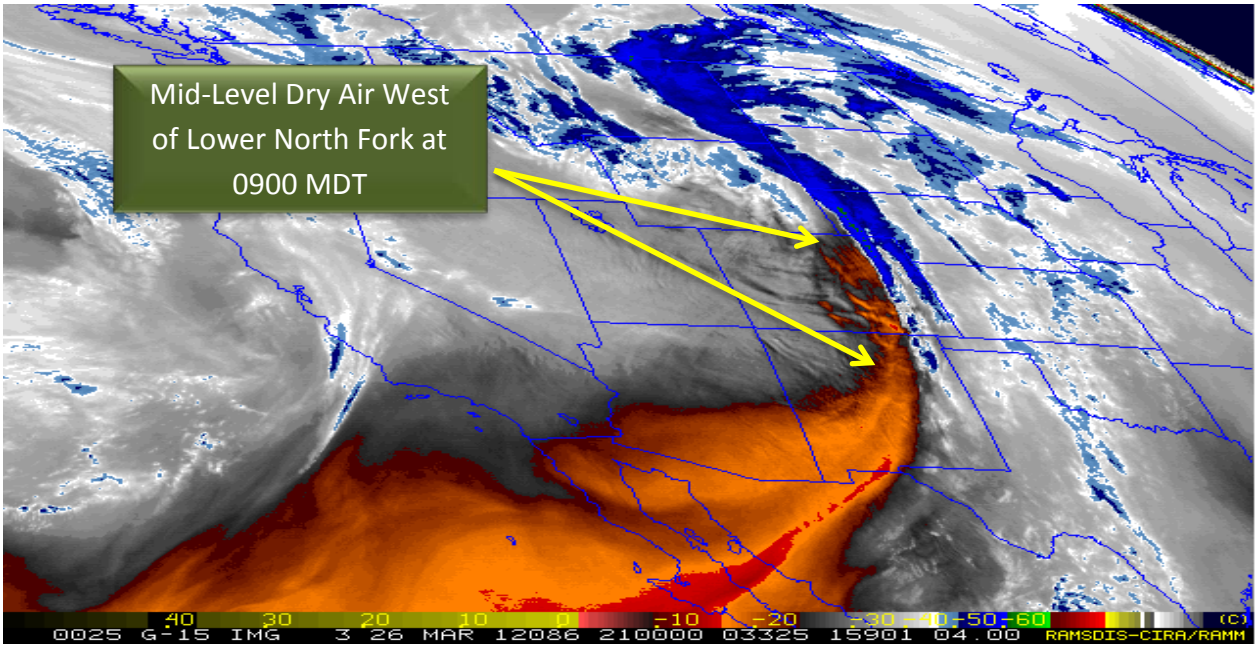


Figure 17. *16-KM Water Vapor Image at 2100Z (0900 MDT) on Monday, March 26, 2012. Dry air at mid-levels extending from the Southwest (Indicated by the Dark and Orange enhancement). Image obtained from* ***Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA).***

Analyzed Denver (DNR) radiosonde data for 12Z (0600 MDT) March 26th and 00Z March 27th (1800 MDT March 26th) generated (manual calculations) Haines Indices of 6 (High Potential for Large Fire Growth (Plume-Driven)). Refer to Figures 18 and 19.

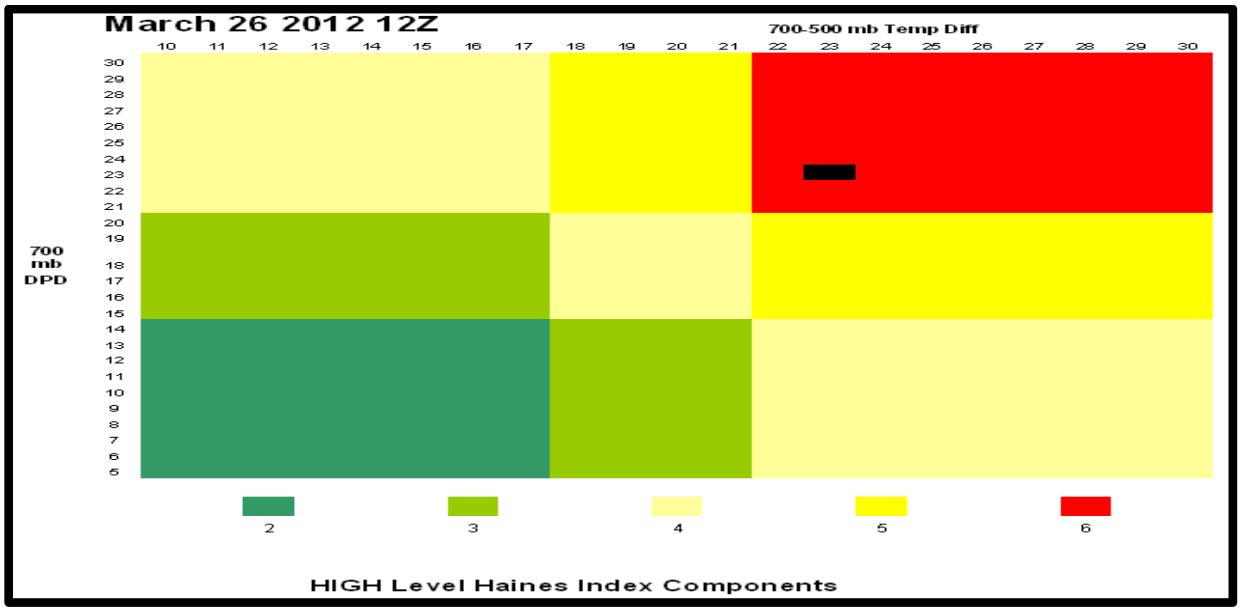


Figure 18. *Haines Index of 6-High (indicated by black pixel) based on radiosonde data from Denver (DNR) valid at 0600 MDT Monday, March 26, 2012. Graphic developed using John Saltenberger (Fire Meteorologist Northwest Coordination Center) Haines calculation excel program.*

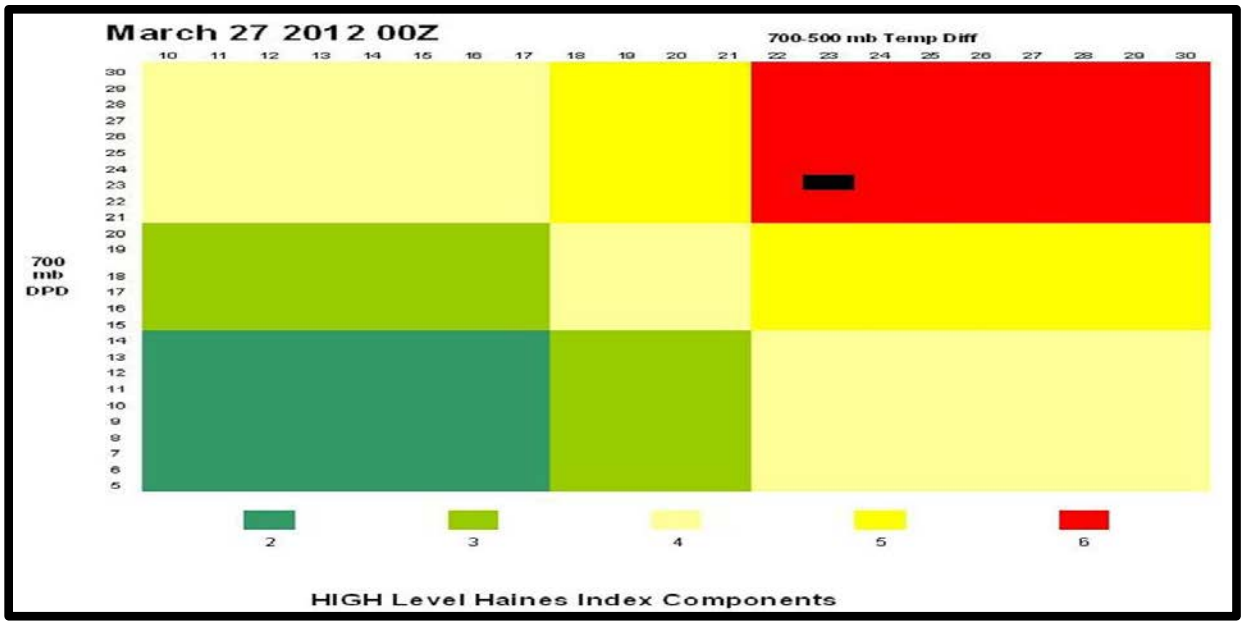


Figure 19*. Haines Index of 6-High (indicated by black pixel) based on radiosonde data from Denver (DNR) valid at 1800 MDT Monday, March 26, 2012 (00Z March 27th). Graphic developed using John Saltenberger (Fire Meteorologist Northwest Coordination Center) Haines calculation excel program.*

Meteorological Conditions during the Afternoon 1200 (Noon) MDT to 1800 MDT of Monday, March 26th

Between 1200 and 1230 1-KM visible satellite imagery (Figure 20) showed that mid and high level cloud cover had moved east of Jefferson County and the Lower North Fork unit. Corresponding Water Vapor (WV) imagery also showed significant mid-level level dryness pushing into the Front Range and Lower North Fork along the back edge of the cloud shield.

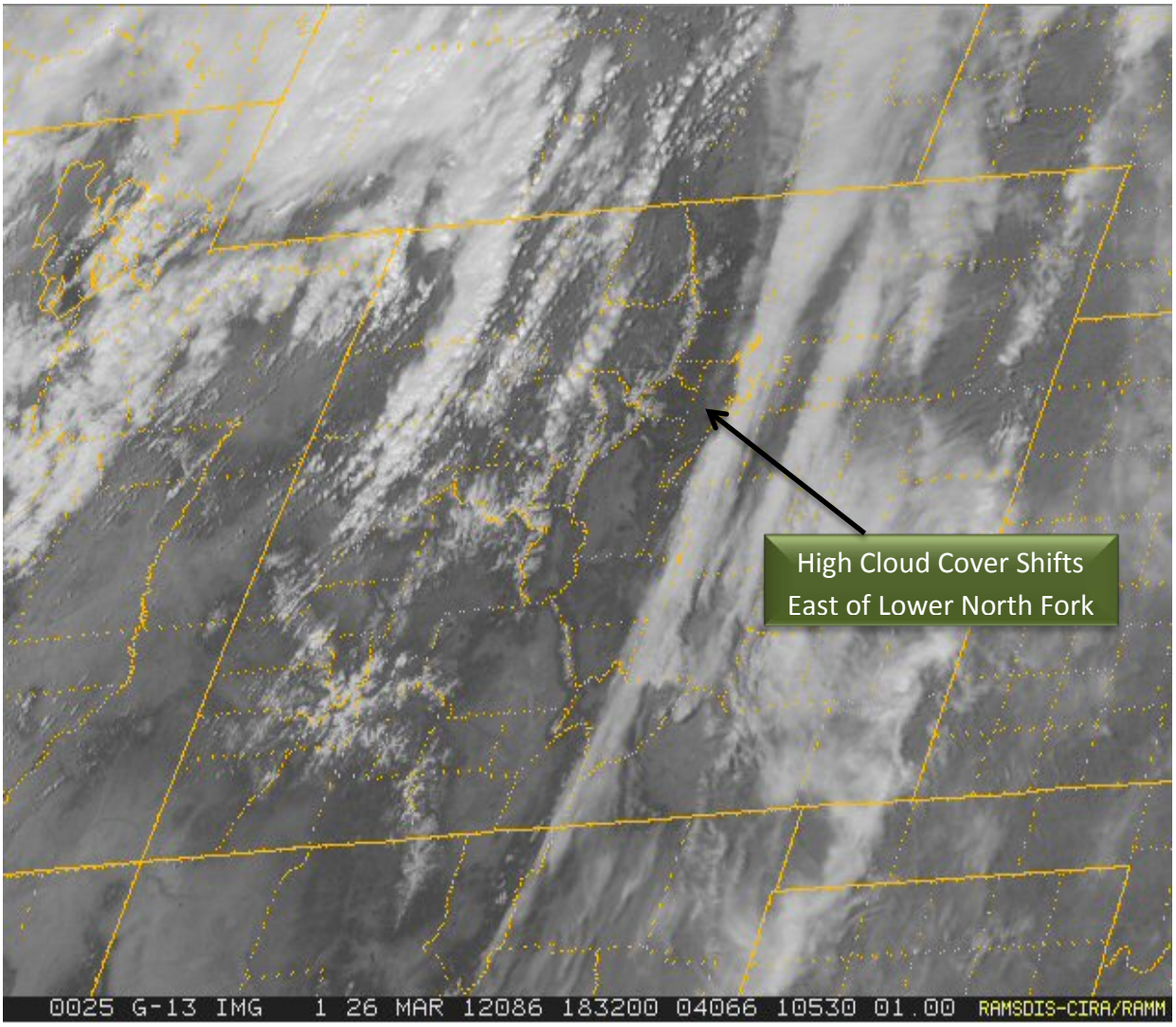


Figure 20. *1-KM Visible Satellite Image at 1832Z (1232 MDT) on Monday, March 26, 2012. Image shows mid and high level cloudiness exiting Jefferson County and the Lower North Fork Unit. Image obtained from* ***Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA).***

At the same time solar sensor data (Figure 21) from Jefferson County RAWS revealed significant increases in radiation values, corresponding to loss of cloud cover. Polhemus solar radiation values from the 11:54 MDT and 12:54 MDT increase from 269 W/m^2 to 875 W/m^2, respectively.

A similar increase was observed at the Bailey RAWS between the 10:22 MDT and 11:22 observation time.

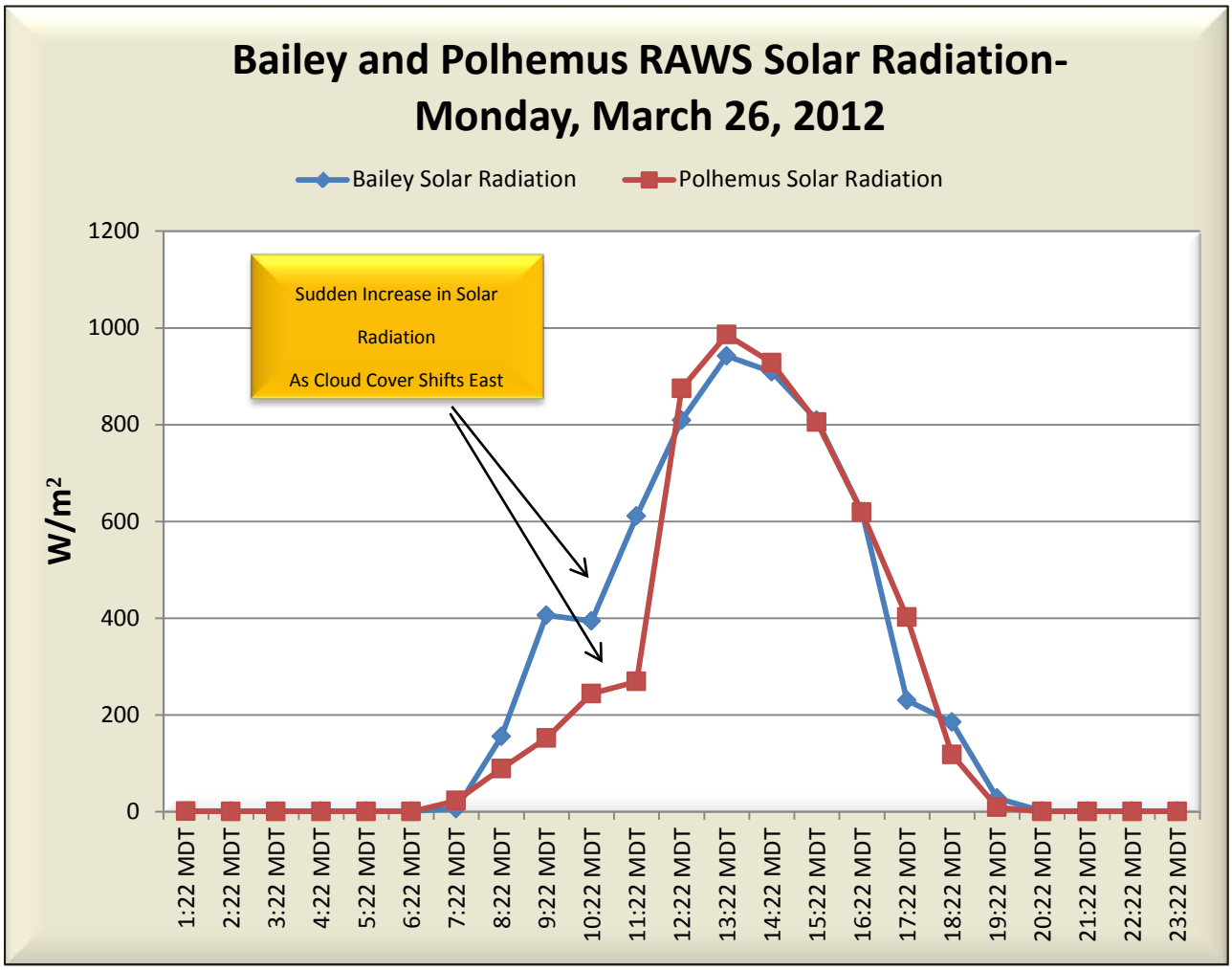


Figure 21. *Bailey and Polhemus solar radiation data for Monday, March 26, 2012. Notice the sudden increase in solar radiation, which is congruent with cloud shield moving east of the Lower North Fork Unit.*

Temperatures during the same time frames increased 6°F with corresponding relative humidity decrease from 17% to 9% at Polhemus and 12% to 9% at Bailey (indicative of increased mixing). Wind during this time were most noticeable at Polhemus with sustained 10 minute average winds increased from 16 mph to 23 mph and gust increase from 36 to 49 mph from the west to southwest (Figure 22 and 23). Wind data from the portable weather station on the Lower North Fork also showed the same increase in wind speed; however the wind direction sensor appeared to be malfunctioning (stuck at 169.9 degrees from March 19th through the 26th).

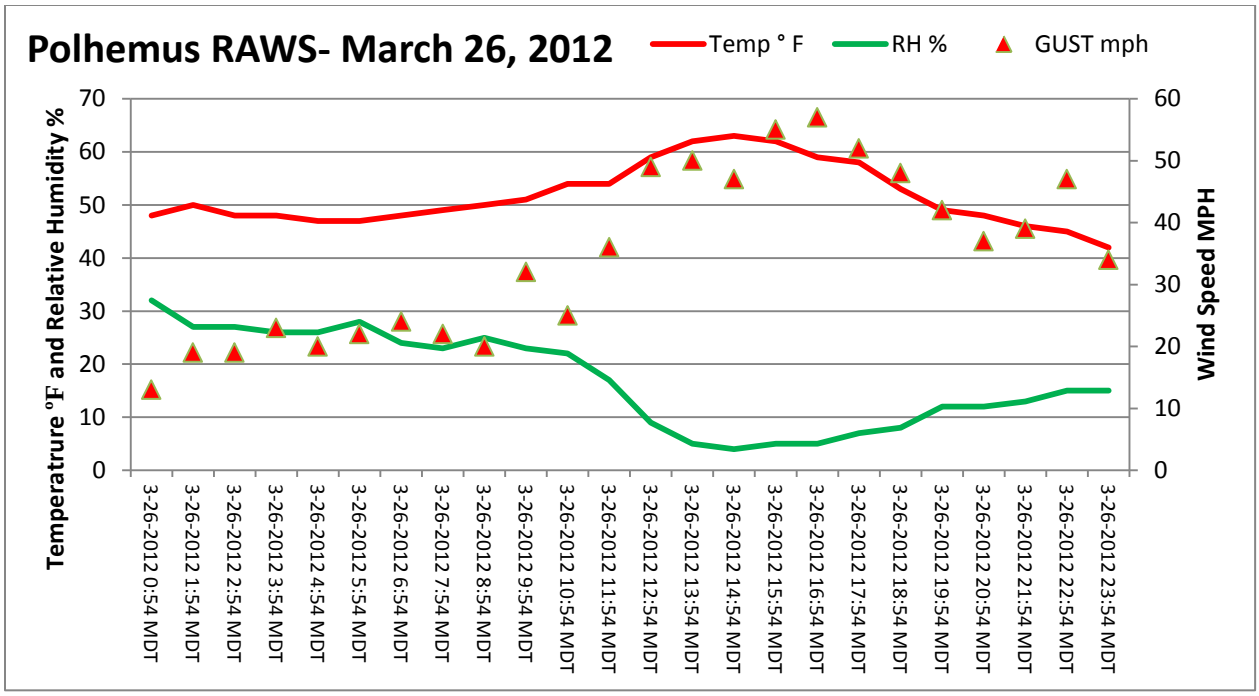


Figure 22. *Polhemus RAWS Temperature °F, Relative Humidity %, and Wind Gusts (MPH) for Monday March 26, 2012. Notice the increase in temperature, drop in relative humidity and wind gusts that increase in speeds between 1154 MDT and 1254 MDT.*

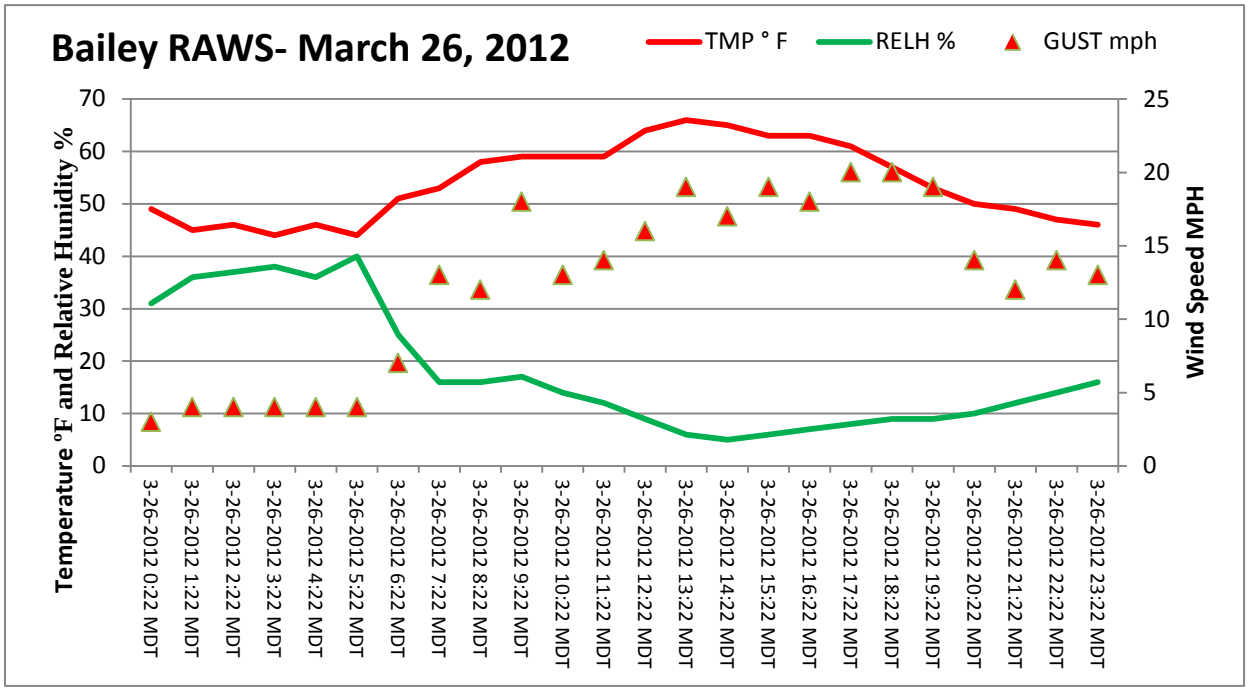


Figure 23. *Bailey RAWS Temperature °F, Relative Humidity %, and Wind Gusts (MPH) for Monday March 26, 2012. Notice the increase in temperature, drop in relative humidity and wind gusts that increase in speeds between 1222 MDT and 1322 MDT, though not as dramatic as Polhemus.*

Critical Fire Weather (Pre-Frontal) conditions (strong and gusty southwest wind, warm temperatures, single digit relative humidity, and unstable atmospheric conditions (Haines 6) continued through 1800 MDT. The Lower North Fork smoke plume (convective column) first became apparent on 1-KM resolution satellite imagery around 1645 MDT and very conspicuous around 1732 MDT (Figure 24.), an obvious increase in fire behavior.

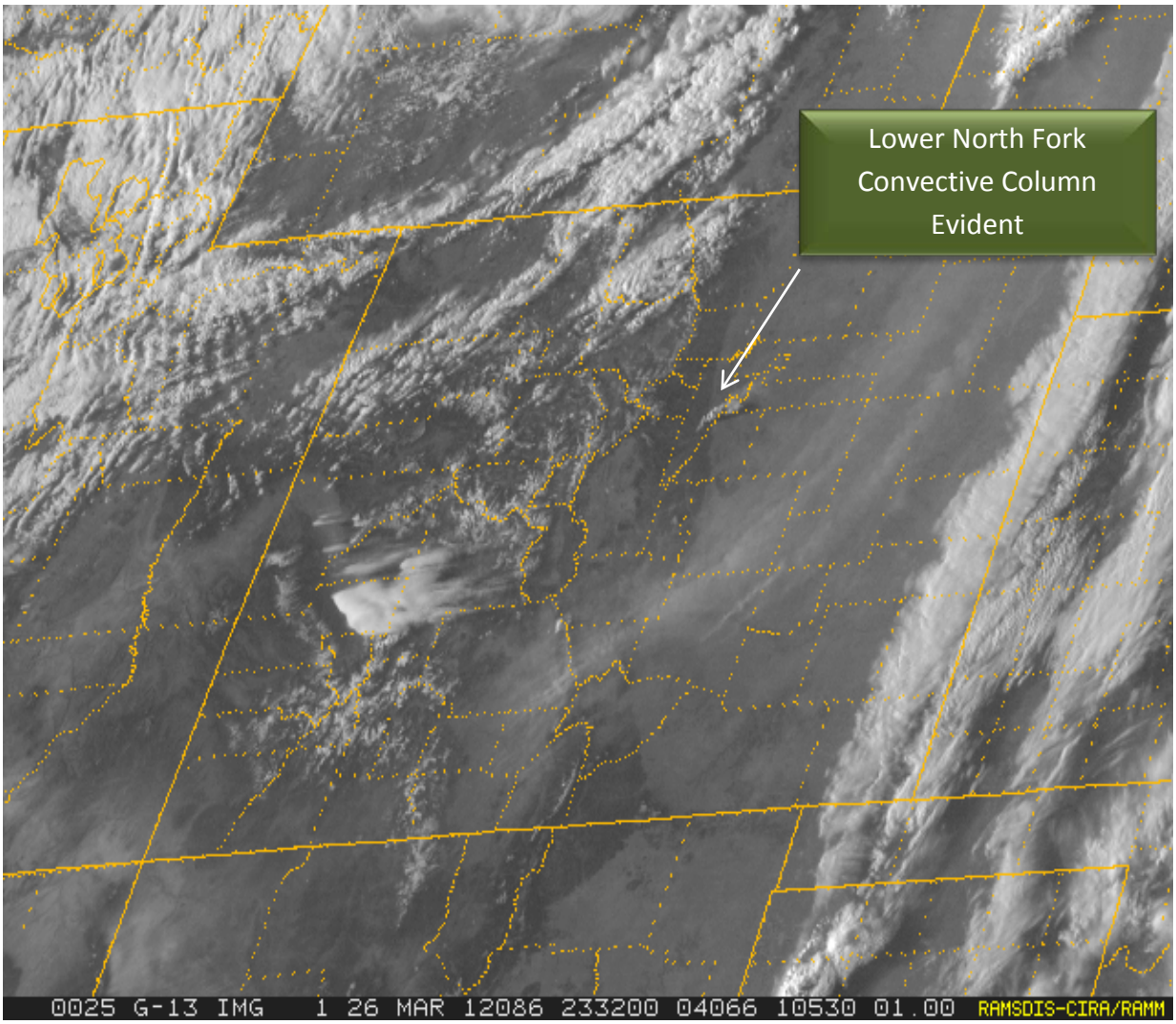


Figure 24. *1-KM Visible Image at 2332Z (1732 MDT) on Monday, March 26, 2012. Lower North Fork convective column is evident, indicative of an increased fire behavior. . Image obtained from Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA).*

Still photography (Figure 25) during this 45 minute window also verified satellite trends, with a bulbous convective column and pyro-cumulus (indicative of unstable atmospheric conditions). Other images around 1725 MDT also showed the column tilted or bent-over toward the east northeast consistent with strong winds that had developed over the area early in the afternoon.

Figure 25. *Still image of the Lower North Fork convective column with pyro-cumulus between 1700 and 1730 MDT (Source Unknown).*

Forecasts and Outlooks Issued-

National Weather Service Boulder Area Forecast Discussions:

Area Forecast Discussions issued by the Boulder National Weather Service highlighted increasing southwesterly wind, warm temperatures, and high fire danger for Monday, March 26, 2012, as early as Tuesday, March 20, 2012. Subsequent Area Forecast Discussions continued to highlight increasing wind and dryness through the event (Monday, March 26, 2012)

National Weather Service Fire Weather Planning Forecast (FWF) for Colorado Fire Weather Zone 216:

Forecasts Issued on Tuesday March 20, 2012 and Wednesday, March 21, 2012

The Fire Weather Planning Forecast (FWFs) issued on March 20th and 21st by the Boulder National Weather Service Office did not incorporate extended periods beyond day 5, and therefore did not included forecasts for Monday, March 26, 2012.

Forecast Issued on Thursday, March 22, 2012

The Fire Weather Planning Forecast (FWF) issued on Thursday, March 22, 2012 at 0409 MDT was the first issuance to include the extended period of Monday, March 26, 2012. The discussion stated:

SOUTHWESTERLY FLOW ALOFT WILL KICK IN SATURDAY CONTINUING THROUGH MONDAY

The extended forecast for Monday, March 26, 2012 (Lower North Fork Incident) was:

.MONDAY...PARTLY CLOUDY. LOWS AROUND 40. HIGHS IN THE MID 60S. SOUTHWEST WINDS 9-15 MPH.

Forecast Issued on Friday, March 23, 2012

The Fire Weather Planning Forecast (FWF) issued on Friday, March 23, 2012 at 0406 MDT highlighted increasing winds in the discussion:

LONG TERM DISCUSSION...SATURDAY THROUGH TUESDAY...SOUTHWESTERLY FLOW ALOFT IS EXPECTED ON SATURDAY AND SUNDAY. BY MONDAY IT WILL INCREASE WITH INCREASED LOW LEVEL WINDS AS WELL.

The extended forecast for Monday, March 26, 2012 (Lower North Fork Incident) was:

.MONDAY...PARTLY CLOUDY. LOWS AROUND 40. HIGHS IN THE LOWER 60S. SOUTHWEST WINDS 13-20 MPH.

Forecast Issued on Saturday, March 24, 2012

The Fire Weather Planning Forecast (FWF) issued on Saturday, March 24, 2012 at 0523 MDT highlighted increasing winds for Monday, March 26, 2012 in the discussion:

FAIRLY STRONG LOW LEVEL WINDS ARE EXPECTED MONDAY...SO FIRE DANGER WILL BE WORSE.

The extended forecast for Monday, March 26, 2012 (Lower North Fork Incident) was:

.MONDAY...BREEZY. PARTLY CLOUDY. HIGHS IN THE LOWER 60S. SOUTHWEST WINDS 16-26 MPH.

Forecast Issued on Sunday, March 25, 2012 at 0526 MDT

The Fire Weather Planning Forecast (FWF) issued on Sunday, March 25, 2012 at 0526 MDT included a Fire Weather Watch for Monday, March 26, 2012 for STRONG WINDS and LOW RELATIVE HUMDITY.

LONG TERM DISCUSSION...MONDAY THROUGH THURSDAY...PRETTY STRONG SOUTHERLY FLOW ALOFT WILL COVER THE AREA MONDAY...WITH A WEAK UPPER TROUGH TO MOVE ACROSS LATE IN THE DAY AND EVENING.

The forecast for Monday, March 26, 2012 (Lower North Fork Incident) was:

```
.MONDAY...
SKY/WEATHER.........MOSTLY SUNNY UNTIL 1200...THEN PARTLY
                    CLOUDY(35-45%).
MAX TEMPERATURE.....57-67.
   24 HR TREND......7-10 DEGREES COOLER.
MIN HUMIDITY........8-18%.
   24 HR TREND......LITTLE CHANGE.
20-FOOT WINDS.......
   VALLEYS/LWR SLOPES...SOUTHWEST 9-15 MPH WITH GUSTS TO 30 MPH
                        INCREASING TO 22-32 MPH WITH GUSTS TO 55
                        MPH IN THE AFTERNOON.
   RIDGES/UPR SLOPES....SOUTHWEST 11-17 MPH WITH GUSTS TO 40 MPH
                        INCREASING TO 24-36 MPH WITH GUSTS TO 60
                        MPH IN THE AFTERNOON.
HAINES INDEX........3 VERY LOW.
LAL.................1.
CWR.................0 PERCENT.
10K FT FREE WINDS...SOUTHWEST 65-75 MPH.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 0700...THEN 9500-
10500
                    FT AGL.
TRANSPORT WINDS.....SOUTHWEST 15-20 MPH UNTIL 0900. 45-55 MPH
                    AFTER 1400.
SMOKE DISPERSAL.....POOR UNTIL 1000. EXCELLENT AFTER 1500.
```

Forecast Issued on Sunday, March 25, 2012 at 1519 MDT

The Fire Weather Planning Forecast (FWF) issued on Sunday, March 25, 2012 at 1519 MDT upgraded the Fire Weather Watch for Monday, March 26, 2012 to a RED FLAG WARNING for STRONG WINDS and LOW RELATIVE HUMDITY.

.DISCUSSION...TONIGHT AND MONDAY...SOUTHWEST FLOW WILL INCREASE TONIGHT AND MONDAY AS AN UPPER LEVEL TROUGH MOVES ACROSS THE CENTRAL ROCKIES. THIS SYSTEM WILL BRING VERY WINDY CONDITIONS MONDAY. SOUTHWEST WINDS WILL INCREASE DURING THE MORNING. BY AFTERNOON...GUSTS TO 50 MPH WILL BE POSSIBLE. WINDS WILL SHIFT TO WEST LATE MONDAY AFTERNOON BEHIND A COLD FRONT. THESE WINDS COMBINED WITH RELATIVE HUMIDITIES VALUES AROUND 10 PERCENT AND DRY FUELS WILL RESULT IN A VERY HIGH POTENTIAL FOR RAPID FIRE GROWTH.

The forecast for Monday, March 26, 2012 (Lower North Fork Incident) was:

```
.MONDAY...
SKY/WEATHER.........PARTLY CLOUDY(40-50%).
MAX TEMPERATURE.....56-66.
   24 HR TREND......4-7 DEGREES COOLER.
MIN HUMIDITY........9-19%.
   24 HR TREND......LITTLE CHANGE.
20-FOOT WINDS.......
   VALLEYS/LWR SLOPES...SOUTHWEST 8-14 MPH WITH GUSTS TO 30 MPH
                        INCREASING TO 22-32 MPH WITH GUSTS TO 55
                        MPH IN THE AFTERNOON.
   RIDGES/UPR SLOPES....SOUTHWEST 11-17 MPH WITH GUSTS TO 40 MPH
                        INCREASING TO 23-33 MPH WITH GUSTS TO 55
                        MPH IN THE AFTERNOON.
HAINES INDEX........3 VERY LOW.
LAL.................1.
CWR.................0 PERCENT.
10K FT FREE WINDS...SOUTHWEST 70-80 MPH.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 0700...THEN 9500-
10500
                    FT AGL.
TRANSPORT WINDS.....SOUTHWEST 15-20 MPH UNTIL 0800. AROUND 55
MPH
                    AFTER 1600.
SMOKE DISPERSAL.....POOR UNTIL 0800...THEN VERY GOOD UNTIL
1000...
                    THEN EXCELLENT.
```

Forecast Issued on Monday, March 26, 2012 at 0551 MDT

The Fire Weather Planning Forecast (FWF) issued on Monday, March 26, 2012 at 0551 MDT included a RED FLAG WARNING for STRONG WINDS and LOW RELATIVE HUMDITY FROM 10 AM UNTIL 7 PM.

.DISCUSSION...TODAY AND TONIGHT...
VERY DANGEROUS FIRE WEATHER CONDITIONS WILL DEVELOP TODAY AS AN UPPER LEVEL TROUGH MOVES FROM NEVADA INTO THE NORTHERN ROCKIES. STRONG SOUTH TO SOUTHWEST WINDS WILL DEVELOP AHEAD OF THE TROUGH BY MIDDAY WITH SHALLOW MOISTURE MIXING OUT. THIS WILL RESULT IN LOW RELATIVE HUMIDITIES. IN ADDITION...VERY DEEP MIXING WILL ALLOW FOR EXCELLENT VENTILATION OF ANY FIRES THAT START. A COLD FRONT WILL MOVE ACROSS THE AREA DURING THE AFTERNOON...WITH WINDS SHIFTING TO A MORE WESTERLY DIRECTION. HUMIDITIES WILL EVENTUALLY INCREASE WITH SOME COOLING BEHIND THE FRONT THIS

EVENING...BUT A MOUNTAIN WAVE WILL KEEP VERY STRONG WINDS GOING OVER THE EAST SLOPES OF THE FRONT RANGE.

IN ADDITION TO THE AREAS COVERED BY THE RED FLAG WARNING...THE MOUNTAIN PARKS WILL ALSO HAVE WARM...DRY...AND VERY WINDY CONDITIONS TODAY. FUELS IN THESE AREAS ARE NOT AS DRY AS AT LOWER ELEVATIONS...BUT RAPID GROWTH OF ANY FIRE THAT DOES START IS ALSO POSSIBLE IN THESE AREAS.

The forecast for Monday (Today), March 26, 2012 (Lower North Fork Incident) was:

```
...RED FLAG WARNING IN EFFECT FROM 10 AM THIS MORNING TO 7 PM
MDT THIS EVENING FOR STRONG WINDS AND VERY LOW HUMIDITY...

.TODAY...
SKY/WEATHER.........MOSTLY CLOUDY(50-60%) UNTIL 1200...THEN
PARTLY
                    CLOUDY(40-50%).
MAX TEMPERATURE.....56-66.
   24 HR TREND......4-7 DEGREES COOLER.
MIN HUMIDITY........10-20%.
   24 HR TREND......2-4% DRIER.
20-FOOT WINDS.......
   VALLEYS/LWR SLOPES...SOUTHWEST 8-13 MPH WITH GUSTS TO 25 MPH
                        INCREASING TO 22-32 MPH WITH GUSTS TO 60
                        MPH IN THE AFTERNOON.
   RIDGES/UPR SLOPES....SOUTHWEST 9-15 MPH WITH GUSTS TO 30 MPH
                        INCREASING TO 23-33 MPH WITH GUSTS TO 60
                        MPH IN THE AFTERNOON.
HAINES INDEX........3 VERY LOW.
LAL.................1.
CWR.................0 PERCENT.
10K FT FREE WINDS...SOUTHWEST 65-75 MPH.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 0700...THEN 8500-
9500
                    FT AGL.
TRANSPORT WINDS.....SOUTHWEST 15-20 MPH UNTIL 0900. AROUND 60
MPH
                    AFTER 1600.
SMOKE DISPERSAL.....POOR UNTIL 1000...THEN GOOD UNTIL
1100...THEN
                    EXCELLENT.
```

Forecast Issued on Monday, March 26, 2012 at 1542 MDT

The Fire Weather Planning Forecast (FWF) issued on Monday, March 26, 2012 at 1542 MDT continued a RED FLAG WARNING for STRONG WINDS and LOW RELATIVE HUMDITY UNTIL 7 PM.

.DISCUSSION...TONIGHT AND TUESDAY...THE STRONG SOUTHWEST WINDS WILL BEGIN TO DECREASE EARLY THIS EVENING AS WINDS SHIFT MORE WEST AND NORTHWEST. WINDS WILL FURTHER DECREASE LATER TONIGHT ALONG WITH SLOWLY IMPROVING HUMIDITIES. TUESDAY...WINDS WILL BE MUCH LIGHTER WITH COOLER TEMPERATURES. THE WINDS WILL REMAIN STRONG TONIGHT OVER THE MOUNTAINS AND NORTHERN FRONT RANGE FOOTHILLS WITH GUSTS UP TO 70 MPH.

The forecast for Monday Evening, March 26, 2012 (Lower North Fork Incident) was:

```
...RED FLAG WARNING IN EFFECT UNTIL 7 PM MDT THIS EVENING...

.TONIGHT...
SKY/WEATHER.........MOSTLY CLEAR.
MIN TEMPERATURE.....33-41.
   24 HR TREND......2-4 DEGREES COOLER.
MAX HUMIDITY........28-38%.
   24 HR TREND......35-50% DRIER.
20-FOOT WINDS.......
   VALLEYS/LWR SLOPES...WEST 24-36 MPH WITH GUSTS TO 60 MPH
                        DECREASING TO 12-18 MPH WITH GUSTS TO 50
                        MPH AFTER MIDNIGHT.
   RIDGES/UPR SLOPES....WEST 28-39 MPH DECREASING TO 15-25 MPH
                        AFTER MIDNIGHT. GUSTS UP TO 60 MPH.
HAINES INDEX........3 VERY LOW.
LAL.................1.
CWR.................0 PERCENT.
10K FT FREE WINDS...WEST 65-75 MPH.
MIXING HEIGHT.......6000-7000 FT AGL.
TRANSPORT WINDS.....WEST AROUND 55 MPH UNTIL 2400...THEN AROUND
40
                    MPH.
SMOKE DISPERSAL.....EXCELLENT UNTIL 2400...THEN VERY GOOD.
```

Forecast Issued on Monday, March 26, 2012 at 1751 MDT

The Fire Weather Planning Forecast (FWF) issued on Monday, March 26, 2012 at 1751 MDT to extend RED FLAG WARNING for STRONG WINDS and LOW RELATIVE HUMDITY UNTIL 9 PM.

```
...RED FLAG WARNING IN EFFECT FOR STRONG GUSTY WINDS...VERY LOW
```

```
HUMIDITIES...AND DRY FUELS UNTIL 9 PM MDT TONIGHT FOR THE FRONT
RANGE FOOTHILLS AND PLAINS OF NORTHEAST COLORADO...FIRE WEATHER
ZONES 215 AND 216...AND 238 THROUGH 251...

.DISCUSSION...TONIGHT AND TUESDAY...
RED FLAG CONDITIONS WILL LIKELY CONTINUE ANOTHER FEW HOURS WITH
STRONG LOW LEVEL PRESSURE GRADIENT AND SUBSIDENCE. IN
ADDITION...HUMIDITY RECOVER WILL BE SLOW DUE TO A VERY DRY
AIRMASS IN PLACE...SO HAVE EXTENDED THE RED FLAG WARNING TIL 9
PM. IT IS POSSIBLE WE'LL NEED TO EXTEND THE FOOTHILLS WARNING
EVEN FURTHER TONIGHT WITH GUSTY WINDS CONTINUING...BUT
HUMIDITIES DO GRADUALLY IMPROVE AND WINDS SHOULD BE MORE
CONFINED TO TYPICAL MOUNTAIN WAVE FAVORED AREAS.
```

The forecast for Monday Evening, March 26, 2012 (Lower North Fork Incident) was:

```
...RED FLAG WARNING IN EFFECT UNTIL 9 PM MDT THIS EVENING FOR
STRONG
GUSTY WINDS...VERY LOW HUMIDITIES...AND DRY FUELS...

.TONIGHT...
SKY/WEATHER.........MOSTLY CLEAR.
MIN TEMPERATURE.....33-41.
   24 HR TREND......2-4 DEGREES COOLER.
MAX HUMIDITY........26-36%.
   24 HR TREND......35-50% DRIER.
20-FOOT WINDS.......
   VALLEYS/LWR SLOPES...WEST 20-30 MPH WITH GUSTS TO 45 MPH...
    DECREASING TO 10 TO 20 MPH WITH GUSTS TO 30 MPH.
   RIDGES/UPR SLOPES....WEST 23-38 MPH WITH GUSTS TO 60 MPH.
HAINES INDEX........3 VERY LOW.
LAL.................1.
CWR.................0 PERCENT.
10K FT FREE WINDS...WEST 65-75 MPH.
MIXING HEIGHT.......6000-7000 FT AGL.
TRANSPORT WINDS.....WEST AROUND 55 MPH UNTIL 2400...THEN AROUND
40
                    MPH.
SMOKE DISPERSAL.....EXCELLENT UNTIL 2400...THEN VERY GOOD.
```

National Weather Service Boulder Fire Weather Watch and Red Flag Warnings:

A Fire Weather Watch was issued by the Boulder National Weather Service Office on Saturday, March 24, 2012 209 PM **for** Monday, March 26th, 2012 from 1200 (Noon) MDT to 1900 MDT,

highlighting increasing winds (Southwest 20 to 30 mph with gusts up to around 45 mph), and low humidity (6%), including fire weather zone 216 that encompasses Lower North Fork unit.

The **Fire Weather Watch** for Monday, March 26th was upgraded to a **Red Flag Warning** by the Boulder National Weather Service office on Sunday, March 25, 2012 at 1215 MDT, highlighting a west to southwest wind of 25 to 35 mph and gusts up to 65 mph, including fire weather zone 216 that encompasses Lower North Fork unit.

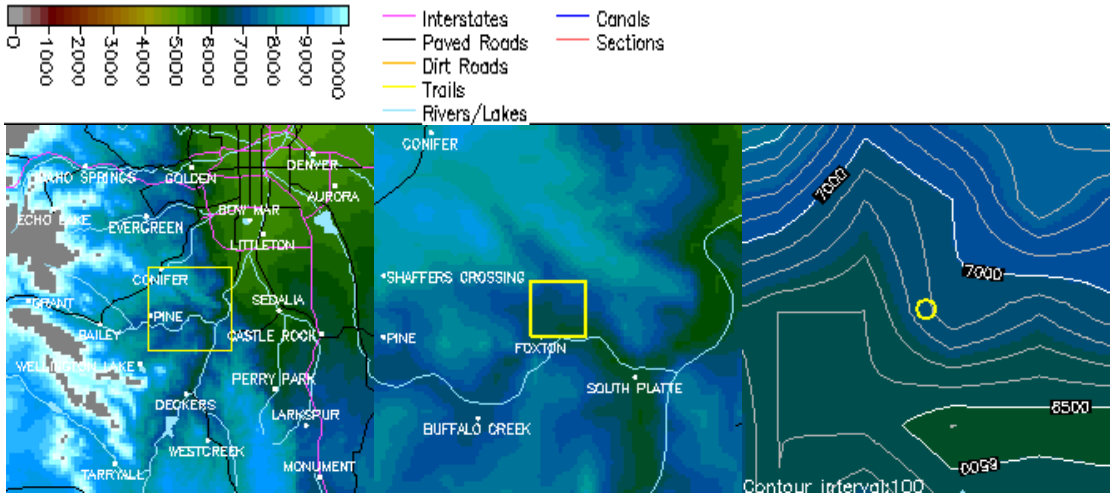
The **Red Flag Warning** was in effect for Monday, March 26, 2012 from 10 AM until 7 PM highlighting a west to southwest wind of 25 to 35 mph, gusts up to 60 mph and low humidity including fire weather zone 216 that encompasses Lower North Fork unit.

The **Red Flag Warning** was updated at 1736 MDT on Monday, March 26, 2012 and extended until 2100 MDT west wind of 20 to 30 mph, gusts up to 50 mph and low humidity including fire weather zone 216 that encompasses Lower North Fork unit.

National Weather Service Boulder Spot Forecasts:

A Spot (Site-Specific) Forecast was requested on Sunday, March 18, 2012 at 1530 MDT for blacklining operation on Monday.

Lower North Fork Rx (Proposed ignition time: 1000 MDT 3/19/12)
(Requested: 1415 MDT 3/18/12)
Forecast complete at 1530 MDT 3/18/12
Requested by: CSFS - GLDS



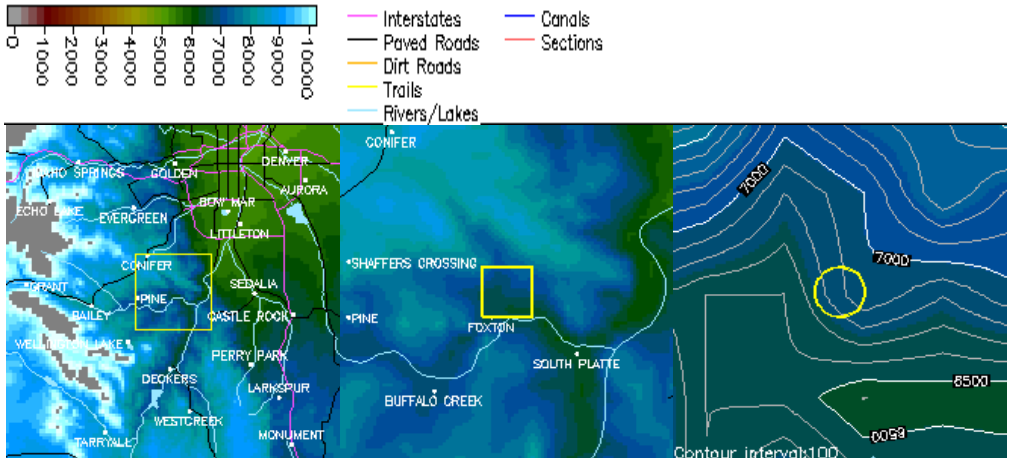
```
.DISCUSSION...THE STRONG UPPER LEVEL DISTURBANCE WILL BE OVER COLORADO
THROUGH MONDAY WITH A SLIGHT CHANCE OF RAIN AND SNOW SHOWERS. TEMPERATURES
WILL BE MUCH COOLER WITH SLIGHTLY HIGHER HUMIDITY LEVELS. THE SOUTWEST WINDS
TONIGHT WILL SHIFT TO THE NORTHWEST ON MONDAY AS THE DISTURBANCE SLOWLY MOVES
EAST.

.MONDAY...
SKY/WEATHER.........MOSTLY CLOUDY. SLIGHT CHANCE OF SNOW. SLIGHT
                     CHANCE OF RAIN AFTER 1200.
MAX TEMPERATURE.....45.
MIN HUMIDITY........16%.
20-FOOT WINDS.......NORTHWEST WINDS 6-12 MPH WITH GUSTS TO 20 MPH
                     UNTIL 1500...THEN NORTH 6-10 MPH.
TRANSPORT WINDS.....WEST 13-24 MPH UNTIL 1200...THEN 8-12 MPH.
MIXING HEIGHT.......5600-6600 FT AGL UNTIL 1000. 12800-13800 FT AGL
                     AFTER 1200.
SMOKE DISPERSAL.....VERY GOOD.
HAINES INDEX........2 VERY LOW.
```

A Spot (Site-Specific) Forecast for the Lower North Fork burn was requested on Wednesday, March 21, 2012 at 1417 MDT) and issued by the Boulder NWS at 0454 MDT on Thursday, March 22, 2012. Temperature, Relative Humidity and 20-ft winds were accurate and validated by on-site observations taken on the Lower North Fork Unit.

Lower North Fork Rx (Proposed ignition time: 1030 MDT 3/22/12) (Requested: 1417 MDT 3/21/12)

Forecast complete at 454 MDT 3/22/12

Requested by: CSFS - GLDS



.DISCUSSION...THERE WILL BE SOME HIGH LEVEL CLOUDS OVER THE AREA THROUGH AFTERNOON BUT IT WILL REMAIN DRY. WINDS SHOULD BE NORTHEAST IN THE 6-12 MPH RANGE WITH DISPERSAL BECOMING GOOD AFTER 1200.

ON FRIDAY IT WILL REMAIN DRY WITH SOUTHWEST WINDS IN THE MORNING BECOMING EAST IN THE AFTERNOON. DISPERSAL WILL BE POOR THROUGH THE DAY.

```
.TODAY...
SKY/WEATHER.........PARTLY CLOUDY.
MAX TEMPERATURE.....61.
MIN HUMIDITY........25%.
20-FOOT WINDS.......NORTHEAST WINDS 6-12 MPH.
TRANSPORT WINDS.....NORTH 12-20 MPH.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 0800. 5400-6400 FT AGL
                    AFTER 1200.
SMOKE DISPERSAL.....POOR UNTIL 1000...THEN FAIR UNTIL 1200...THEN
                    GOOD.
HAINES INDEX........3 VERY LOW.
```

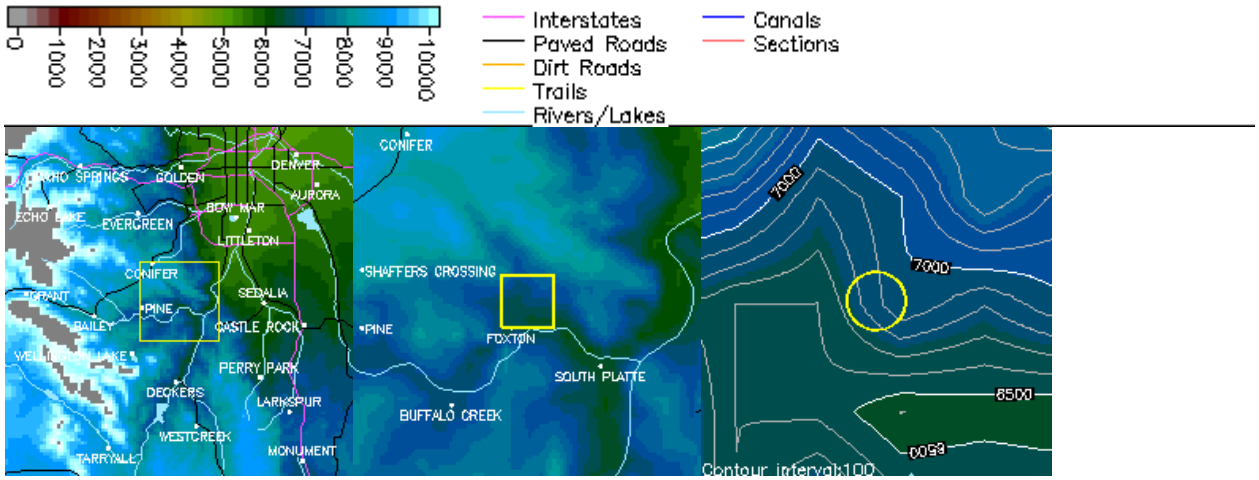
An additional Spot (Site-Specific) Forecast for the Lower North Fork burn was requested on Thursday, March 22, 2012 at 1935 MDT) for Friday, March 23, 2012.

Lower North Fork Unit 4 (Proposed ignition time: 900 MDT 3/23/12)

(Requested: 1935 MDT 3/22/12)

Forecast complete at 416 MDT 3/23/12

Requested by: CSFS - GLDS



DISCUSSION...IT WILL BE CLEAR THROUGH THE AFTERNOON WITH LIGHT WINDS AND POOR DISPERSAL MUCH OF THE DAY.

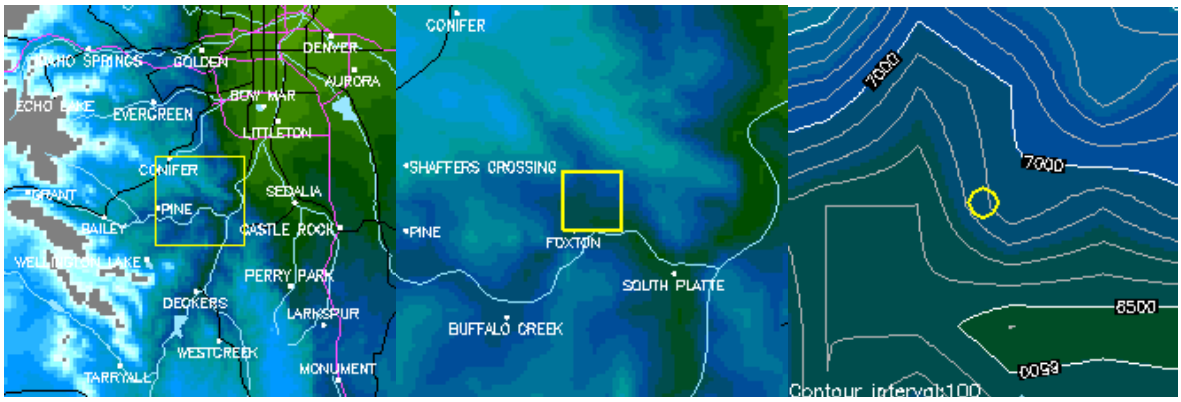
```
.TODAY...
SKY/WEATHER.........MOSTLY SUNNY.
MAX TEMPERATURE.....72.
MIN HUMIDITY........17%.
20-FOOT WINDS.......SOUTHWEST WINDS 6-7 MPH UNTIL 1200...THEN
                    SOUTHEAST.
TRANSPORT WINDS.....SOUTHWEST 4-8 MPH.
MIXING HEIGHT.......BELOW 1000 FT AGL UNTIL 1000. 5600-6600 FT AGL
                    AFTER 1200.
SMOKE DISPERSAL.....POOR UNTIL 1500....THEN FAIR.
HAINES INDEX........3 VERY LOW.
```

The next Spot (Site-Specific) Forecast for the Lower North Fork Unit was requested by fire officials on Monday, March 22, 2012 at 1501 MDT and issued by the Boulder NWS at 2102 MDT, Monday, March 26, 2012.

Lower North Fork (WILDFIRE) (Requested: 1501 MDT 3/26/12)

Forecast complete at 2102 MDT 3/26/12

Requested by: Jefferson County Fire Management




```
.DISCUSSION...WINDS WILL BE SOUTHWEST AT 10 TO 20 MPH WITH A FEW GUSTS TO 30
MPH OVER THE HIGHER RIDGES.  WINDS MAY SHIFT TO THE SOUTH BY 6 AM WITH SPEEDS
IN THE 6-12 MPH RANGE AND THEN BECOME SOUTHEAST BY NOON.  MAX HUMIDITY
RECOVERY OVERNIGHT WILL ONLY BE AROUND 35%.

.REST OF TONIGHT...
SKY/WEATHER.........MOSTLY CLEAR.
MIN TEMPERATURE.....36.
MAX HUMIDITY........35%.
20-FOOT WINDS.......SOUTHWEST WINDS 12-22 MPH WITH GUSTS TO 30 MPH.
TRANSPORT WINDS.....WEST 36-56 MPH UNTIL 2400...THEN 13-24 MPH.
MIXING HEIGHT.......3000-4000 FT AGL UNTIL 2300...THEN 2000-2400 FT
                    AGL.
SMOKE DISPERSAL.....EXCELLENT UNTIL 2100. POOR AFTER 0500.
HAINES INDEX........4 LOW.
```

Haines Forecasts and Manual Calculations:

Haines forecast of 3-very low was forecast on March 25th and 26th. Manual calculations using observed data for the Denver (DNR) upper air sounding produced a Haines of 6-High for the afternoon of the 25th, and morning and afternoon of the 26th .

Rocky Mountain Area Predictive Services Outlooks:

7-Day Significant Fire Potential Outlook-

This outlook combine's forecast fuel dryness with significant weather triggers to identify high risk areas for new large fires or large fire growth on existing fires for the purpose of *national* resource movement and allocation. Rocky Mountain Area Predictive Services 7-Day Fire Potential Outlook issued on Wednesday March 21, 2012 (Figure 26) included a "High Risk" for strong wind (among other factors) along the Colorado Front Range and eastern Plains for Day 6, Monday, March 26th, 2012.

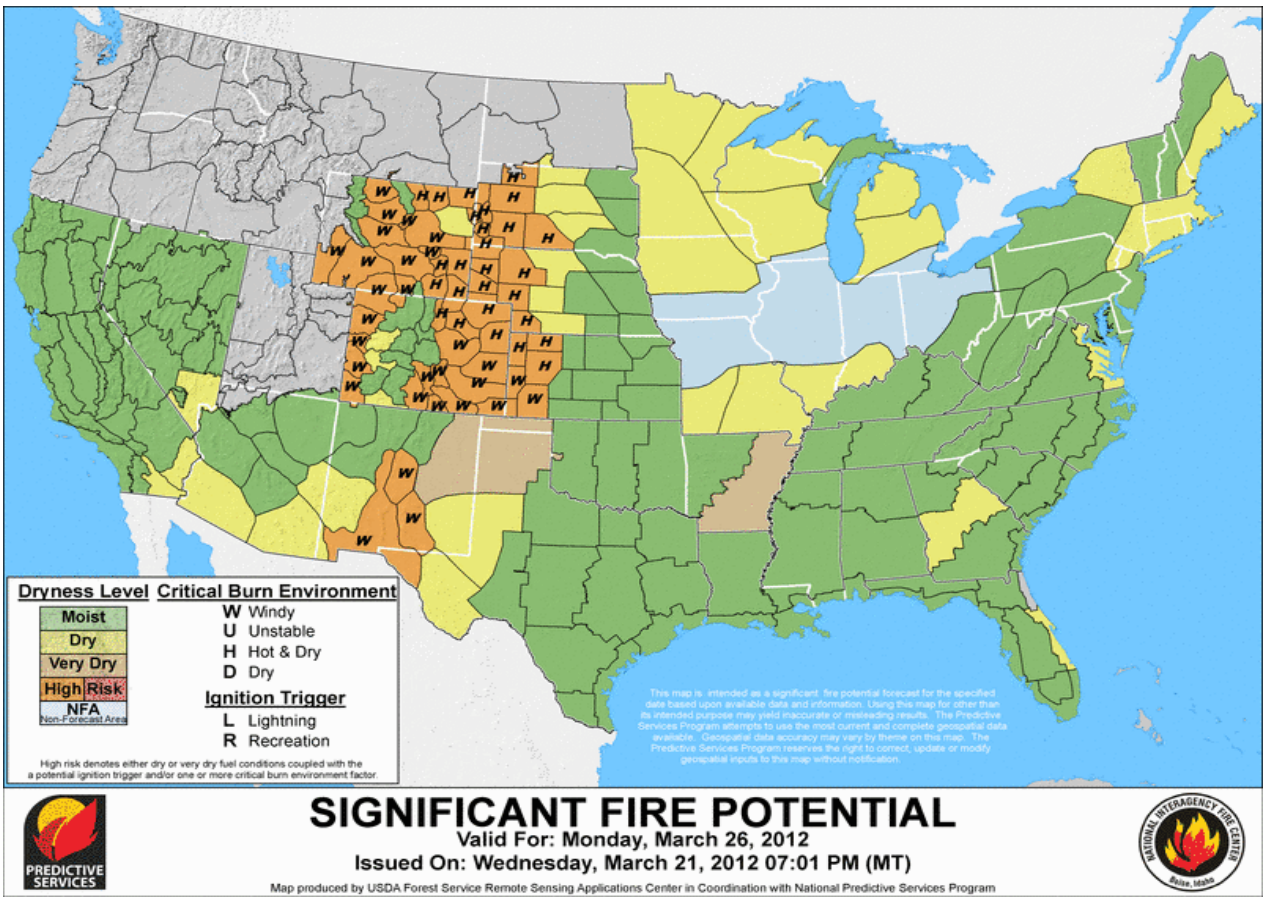


Figure 26. *Predictive Services 7-Day Significant Fire Potential issued Wednesday, March 21, 2012 and valid for Monday, March 26, 2012. Orange colors indicate "High Risk" for Critical Burn Environment.*

Locally (Rocky Mountain Area) Derived Fire Potential Outlooks-

In addition to providing data to the national fire potential outlook (Figure 26), Rocky Mountain Area Predictive Service produces weather and fuel dryness outlooks and corresponding large fire risk for the Rocky Mountain Area (Wyoming, Colorado, South Dakota, Kanas and Nebraska) for days 1 through 7. Different descriptors are used to convey large fire risk, but are utilized for the same purpose as national level (Determine long-range regional resource demand and allocation). Figure 27 and 28 are daily fire potential outlooks issued by Rocky Mountain Area Predictive Services on Wednesday, March 21, 2012 and Friday, March 22, 2012, respectively. The outlooks shown were valid for Monday, March 26, 2012.

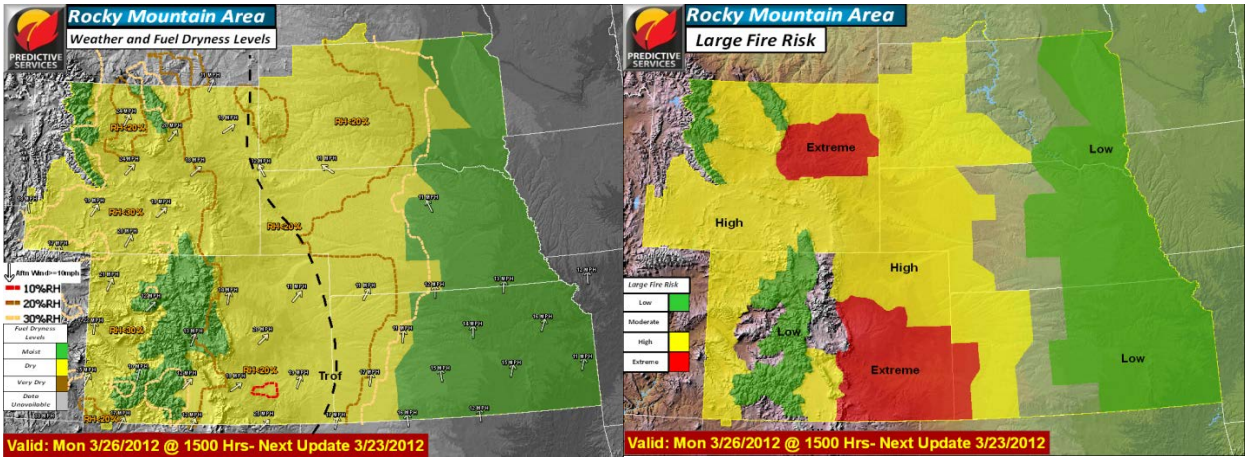


Figure 27. *Rocky Mountain Area Daily Fire Potential Maps issued Wednesday, March 21, 2012 and was valid for Monday, March 26, 2012. Weather and fuel dryness forecast (left) indicated widespread increasing winds and low humidity. The corresponding large fire risk (right) outlook showed "high" to "extreme"*

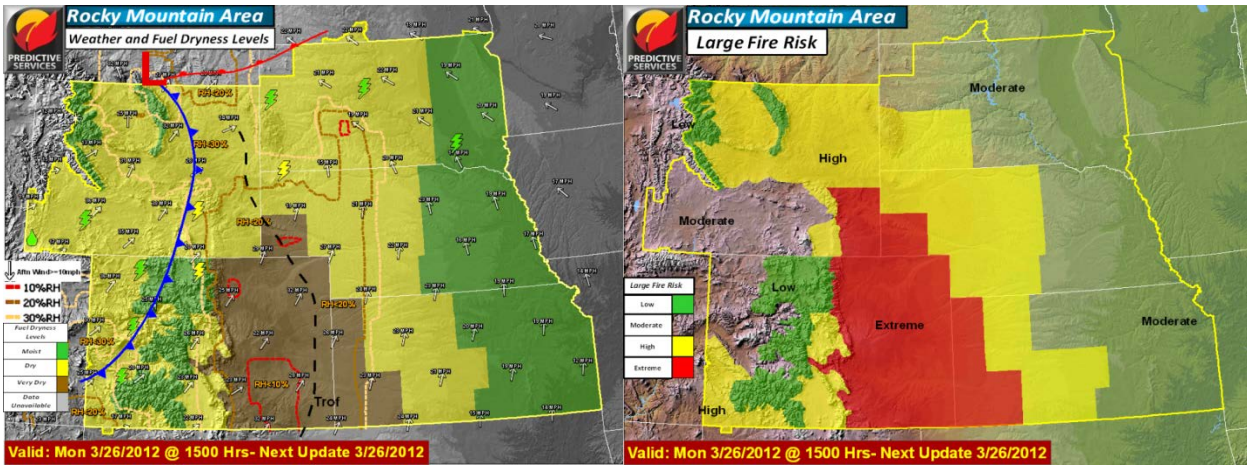


Figure 28. *Rocky Mountain Area Daily Fire Potential Maps issued Friday, March 23, 2012 and was valid for Monday, March 26, 2012. Weather and fuel dryness forecast (left) indicated widespread increasing winds and low humidity. The corresponding large fire risk (right) outlook showed "high" to "extreme" indices.*

The overall climatological and meteorological factors that contributed to rapid fire growth of Lower North Fork include:

1. Record warmth and dryness during the month of March (short-term drought conditions)
2. Rapid depletion of snowpack gained in February, exposing fuels to prolonged warm temperatures, low humidity and wind.
3. Air mass change (warm, dry, and unstable) beginning March 23rd
4. Rapidly changing weather conditions (temperatures, relative humidity, wind, and instability) following decrease in cloud cover and dry air push from the west.
5. A decrease in cloud cover resulted in increased vertical mixing between the air mass at the surface and aloft, allowing stronger winds to surface.
6. Pre-Frontal conditions (Above Average Temperature, Low Humidity, Strong and Gusty Winds, Unstable Atmospheric Conditions, Haines Index of 6, Poor Overnight Relative Humidity Recovery)

Data Collection and Considerations

Data collection and considered for this analysis includes:

- NOAA- National Weather Service Boulder Fire Weather Planning Forecast (FWF)
- NOAA- National Weather Service Boulder Spot Forecasts (Site Specific Forecasts)
- NOAA- National Weather Service Radiosonde Data for DNR (Denver)
- NOAA- National Weather Service Cooperative Observer Data
- NOAA- National Climate Data Center Archived Upper Charts
- NOAA- Hydrologic Prediction Center (HPC) Data
- Rocky Mountain Area Predictive Service 7-Day Outlook
- Rocky Mountain Area Predictive Service Daily Fire Potential Outlooks
- Department of Agriculture Natural Resource Conservation Service (NRCS)
- Archived U.S. Forest Service Remote Automated Weather Station (RAWS) Data
- USDA-United States Drought Monitor
- Colorado State University Cooperative Institute for Research in the Atmosphere
- University of Wyoming- Archived Upper Air Data

Fire Behavior

Wildland fire behavior is determined by the interaction of the primary components of the fire environment – fuels, weather, and topography. Topography is variable over space, and fuels and weather vary with both space and time. This variation is both short-term (within a day or between several days) and long-term (seasonality).

Topography

Topography includes any topographic feature or characteristic that influences fire behavior. Three major components of topography – elevation, slope, and aspect – have direct influences on fire behavior. Further, Terrain features, such as ridges, valleys, and saddles, influence fire behavior by channeling winds, often with an accompanied changes in speed and direction at the surface, and localized eddying effects.

Elevation

Elevation can influence fire behavior due to variation of temperature and relative humidity at different elevations. Lower elevations are generally warmer and drier than higher elevations, all things being equal. The area in the vicinity of Unit 4a ranges in elevation from 6,365 feet near the river to feet 7,060 at DP4 (Figure 29).

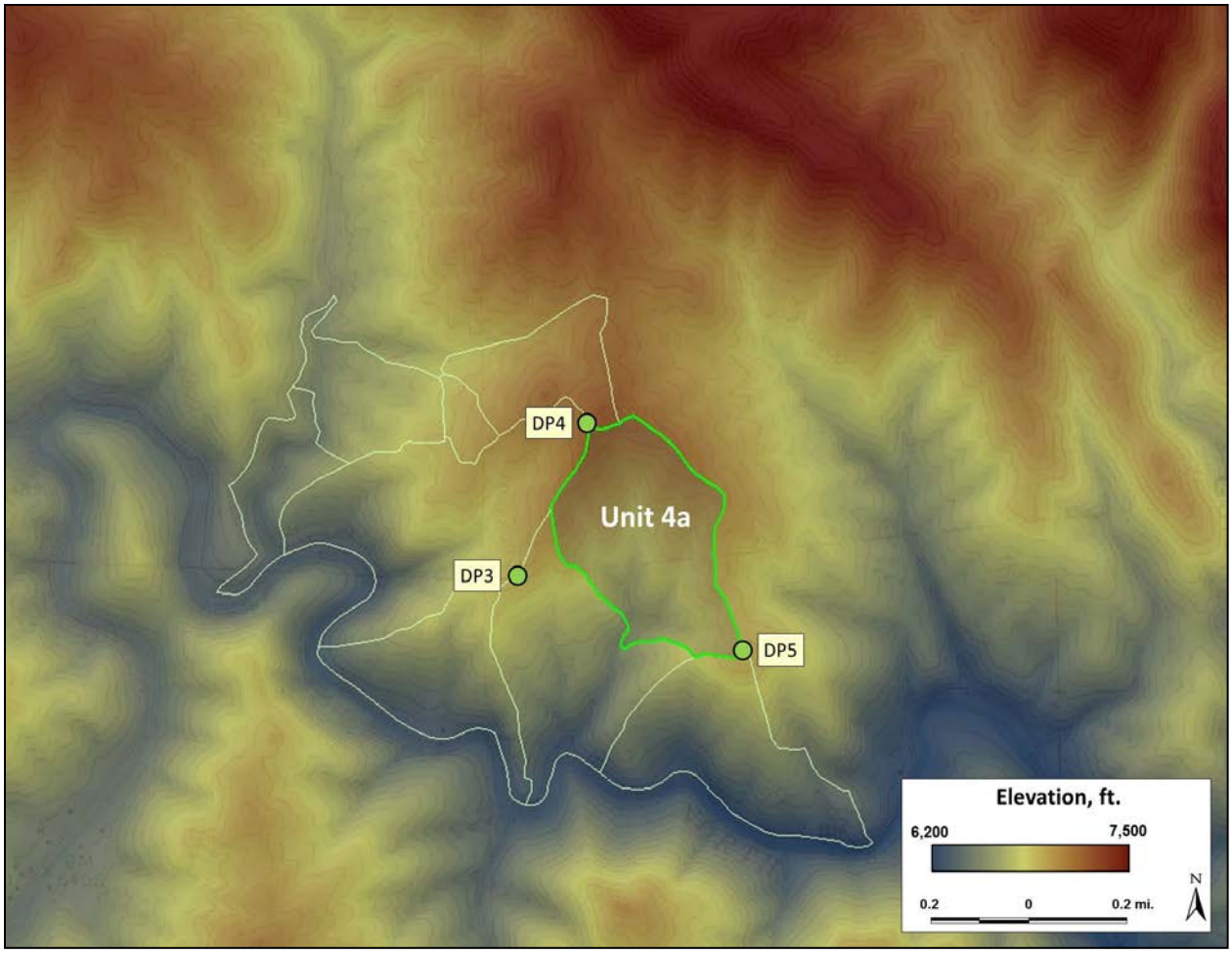


Figure 29. *Elevation in proximity to Unit 4a. Key reference locations are noted.*

Slope

Slope steepness influences fire behavior by generally accelerating (upslope) or slowing (downslope) fire spread. Slope and wind frequently interact to influence fire behavior. Wind aligned with slope (upslope winds) results in an acceleration of fire spread beyond wind or slope alone. Wind blowing downhill can reduce the uphill spread rate of fire, and with sufficient wind speeds, can overpower the impact of slope and drive fire spread downhill. From descriptions by personnel on Unit 4a on March 26, 2012, and examination of post-fire burn pattern indicators, this appears to have happened during the initial spread of the third spot fire near DP5.

Slope steepness on Unit 4a ranges from nearly flat (1.8%) to 85%. The average slope of Unit 4a is 36%. Over a broader area, slope also varies greatly. A map of the slope in the vicinity of Unit 4a is shown in Figure 30.

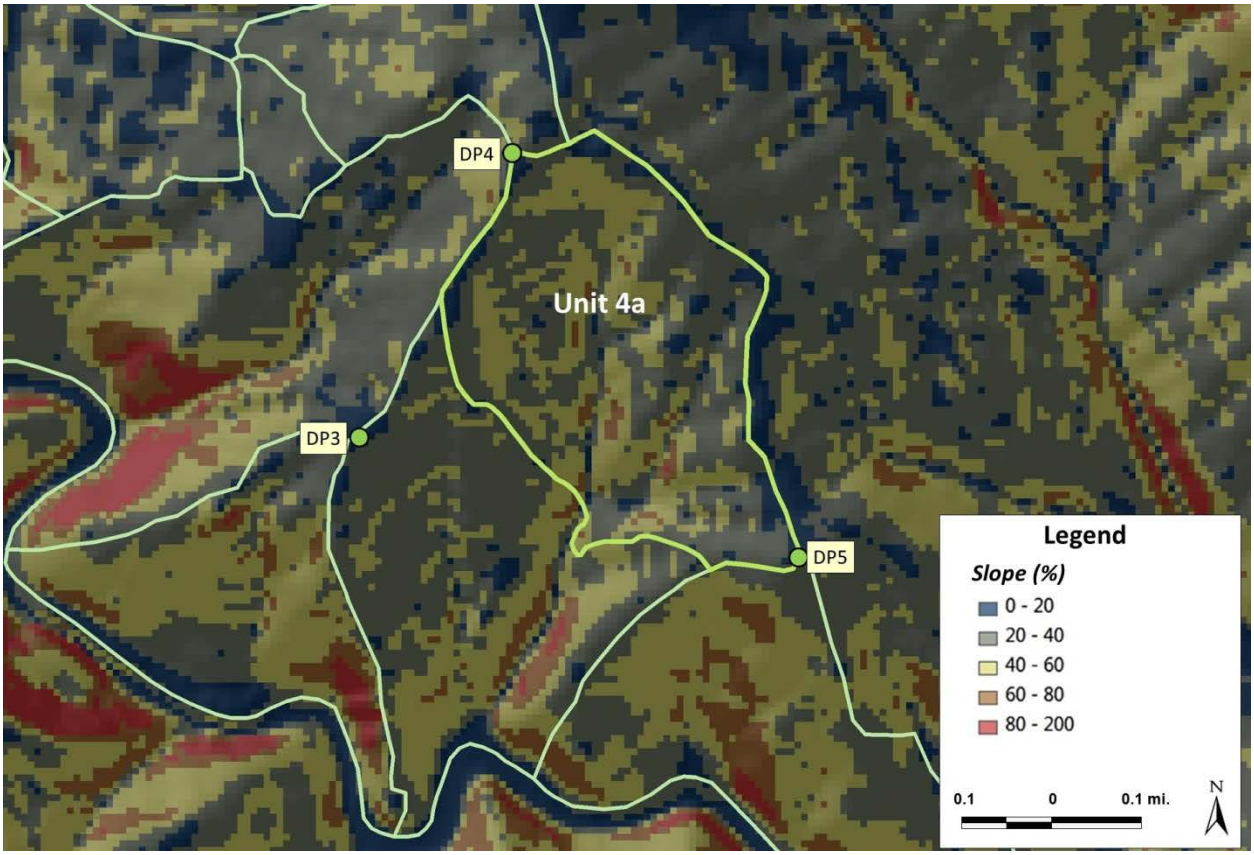


Figure 30. *Slope in the vicinity of Unit 4a, in percent.*

Aspect

Aspect is the direction a slope faces and is expressed as compass direction (degrees). Aspect influences fire behavior in the short-term by differential heating during the day, and in the longer term by affecting the fuel type and loading.

South- and southwestern aspects are typically warmer and drier and tend to have lighter fuel loadings. Conversely, more northerly aspects tend to be cooler and moister and have heavier fuel loadings. This was evident in Unit 4a, where drier aspects had open ponderosa pine stands with a light grass understory and cooler aspects had denser mixed conifer stands (ponderosa pine and Douglas-fir) with significant understory fuels (Figure 31).

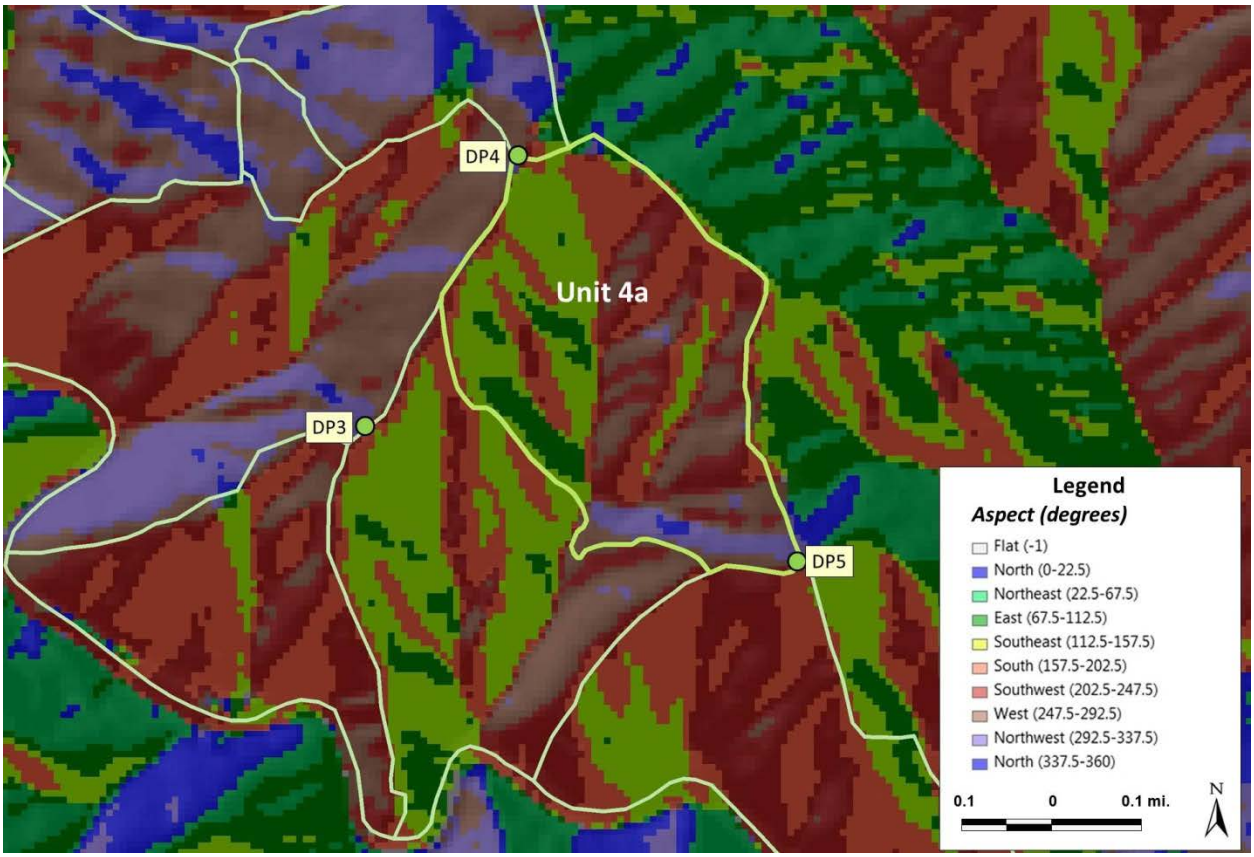


Figure 31. *Aspect in the vicinity of Unit 4a, in degrees.*

Fuels

Fuels within Unit 4a, include open ponderosa pine with light grass understory and denser mixed ponderosa pine/Douglas-fir stands with timber litter understory. Significant portions of the unit were masticated fuels resulting from mechanical treatment of woody fuels. In the two draws in the southern portion of the unit, fuels had not been mechanically treated due to access limitations by mechanical equipment.

Outside of Unit 4a, fuels varied. In Unit 1 and the upper portion of Unit 3, surface fuels were largely absent due to prescribed burning the previous year. To the north and northeast of Unit 4a, fuels were similar to those on the northern portion of Unit 4a – mechanically treated fuels with interspersed grass under open ponderosa pine. South of Unit 4a, fuels were similar to the lower portion of 4a – dense ponderosa pine/Douglas-fir stands on more northerly aspects, with open ponderosa pine and light grass on more southerly aspects. Surface fuels had been mechanically treated in a significant portion of the area north, east, and south of Unit 4a. This mechanical treatment altered surface fuels, breaking up larger pieces of woody debris and reducing the fuel bed depth. Figure 32 shows the extent of the areas that had been mechanically treated prior to March 22, 2012

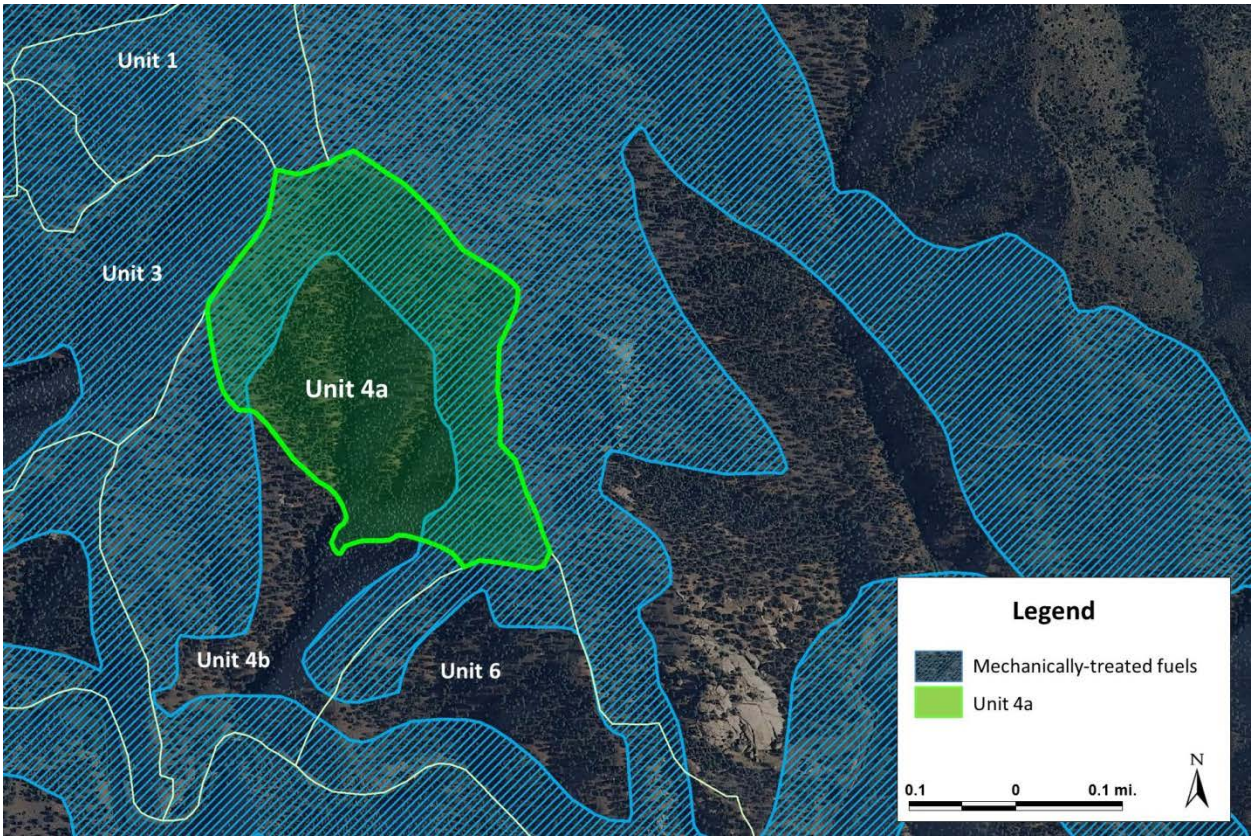


Figure 32. *Extent of mechanically-treated (masticated) fuels in the vicinity of Unit 4a. The interior of Unit 4a had not been treated due to equipment accessibility limitations.*

Weather

Weather Station Data

Three weather stations were used for information and analysis in this report: Bailey RAWS (BAWC2), Polhemus RAWS (POLC2), and the HOBO portable weather station located on-site on Unit 4a, about 800 feet up the ridge from DP3. RAWS stations record wind speed and direction at a standard height of 20 feet above the ground. The HOBO portable weather station had wind sensors at a height of about 6 feet.

Detailed information about these RAWS, and the data from these RAWS, is discussed in the Fire Weather section of this document. The locations of individual weather stations discussed in this document are shown in Figure 33.

Figure 33. *Weather stations (RAWS and the HOBO station) at sites representative of weather on Unit 4a. Respective distances of RAWS from Unit 4a are 7.25 mi. (Bailey) and 13.25 mi. (Polhemus).*

For assessment of on-site weather conditions on Unit 4a, weather observations taken by personnel on site were compared to hourly weather data logged at the Bailey and Polhemus RAWS from March 22-26, 2012. These are the two RAWS stations in closest proximity to Unit 4a, and provided the best representation of on-site conditions.

The HOBO portable weather station was not functioning properly during this time period so was not relied on for on-site weather. There were four sensors on the HOBO station – temperature, relative humidity, wind speed (anemometer), and wind direction (wind vane). From examination of the data from the HOBO station, it appeared the anemometer was the only sensor working properly during this time period. Comparison of wind speed data from the HOBO station to the Bailey and Polhemus RAWS data indicated the anemometer was working properly and providing a reasonable assessment of on-site winds. Therefore, the HOBO portable station, in conjunction with on-site weather observations (see Figures 7, 8, and 11), and data from the Bailey and Polhemus RAWS, was used solely for assessment of on-site wind speeds.

Weather Station Site Characteristics

The elevation and general site characteristics of each RAWS, and the HOBO portable station, are summarized in the table below. The location and site characteristics of each station are summarized in Figures 34-36.

Station	Elev. (ft.)	Distance to Unit 4a (mi.)	Site Characteristics	Use in this Report and Appendix
Bailey RAWS	7,982	7.25	Broad, open site; mid-elevation	Approximation of on-site temperature and RH at Unit 4a
Polhemus RAWS	8,683	13.25	Ridge top	Ridge top winds in the area
HOBO Portable	7,000	On-site	Mid-slope ridgetop on west perimeter of Unit 4a	Assessment of on-site winds

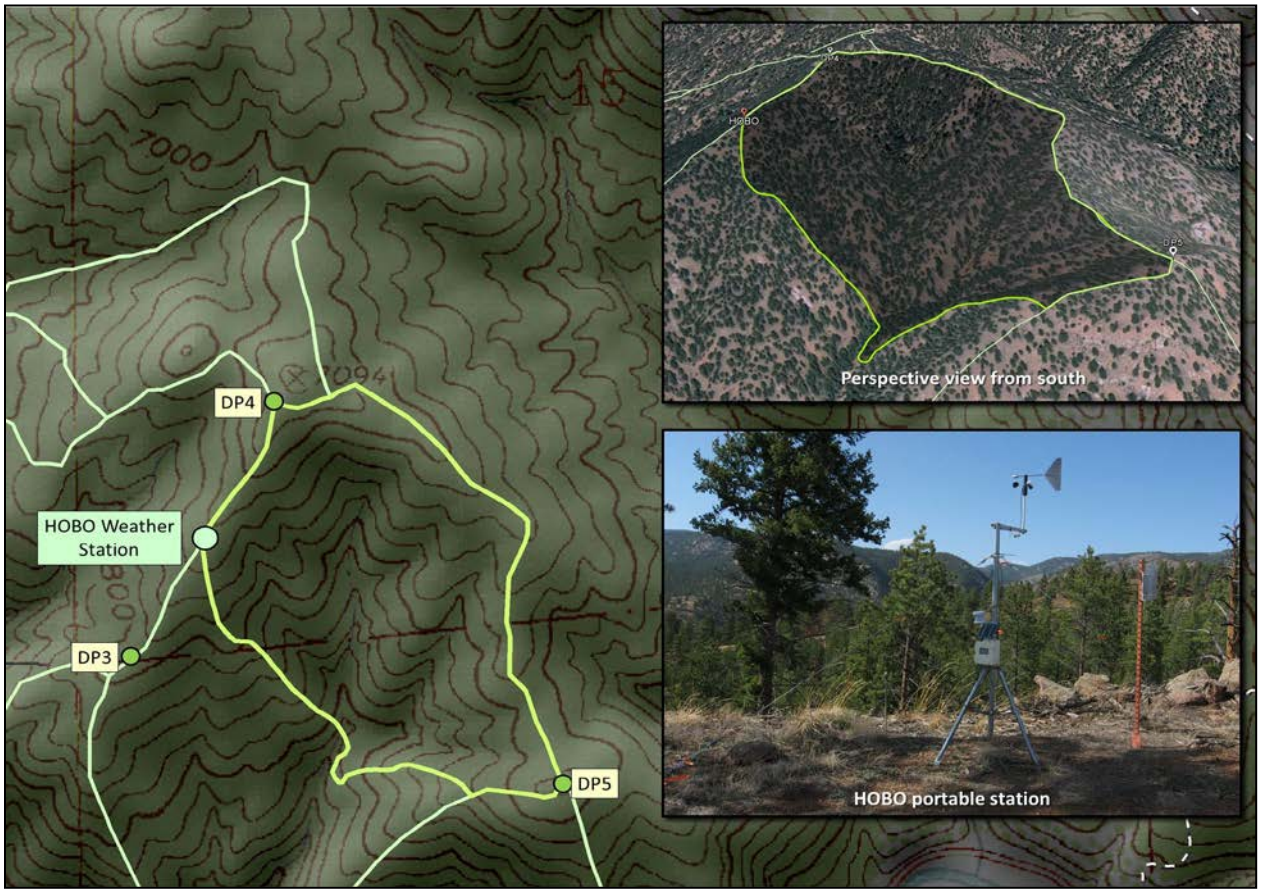


Figure 34. *Location and local site characteristics of the HOBO portable weather station between DP3 and DP4 on Unit 4a.*

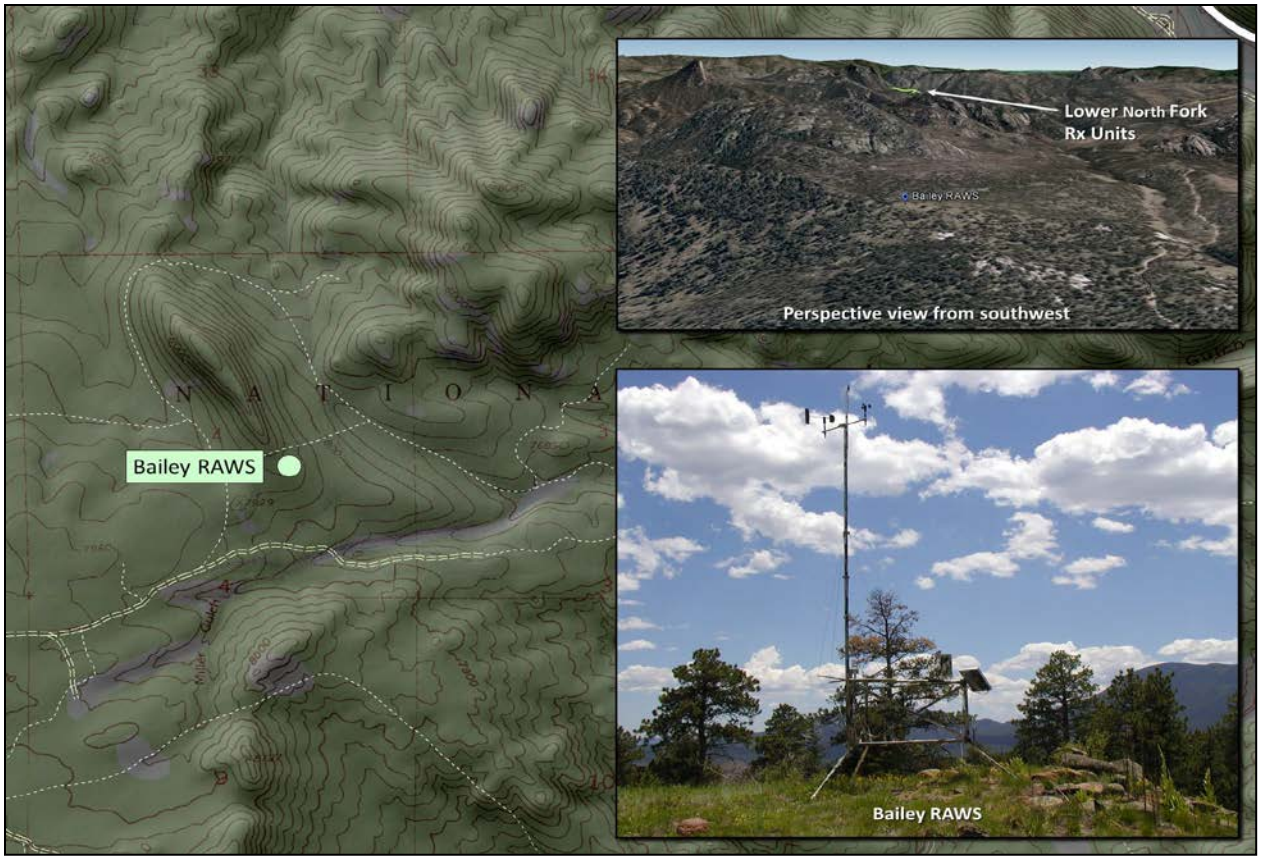


Figure 35. *Location and local terrain/site characteristics of the Bailey RAWS.*

Figure 36. *Location and local terrain characteristics of the Polheums RAWS.*

Seasonal Severity

Assessment of Seasonal Severity on the Colorado Front Range

Two NFDRS (National Fire Danger Rating System) indices are typically used for assessing seasonal conditions in the Front Range of Colorado: ERC (Energy Release Component) and 1000-hour fuel moisture. These two indices provide useful information about seasonal severity and long term drying trends, are a source of information used for pre-suppression and operational planning.

ERC and 1000-hour Timelag Fuel Moisture: Definitions

The National Wildfire Coordinating Group (NWCG) describes ERC and 1000-hour fuel moisture as follows:

"The Energy Release Component is a number related to the available energy (BTU) per unit area (square foot) within the flaming front at the head of a fire. Daily variations in ERC are due to changes in moisture content of the various fuels present, both live and dead. Since this number represents the potential "heat release" per unit area in the flaming zone, it can provide guidance to several important fire activities. It may also be considered a composite fuel moisture value as it reflects the contribution that all live and dead fuels have to potential fire intensity. The ERC is a cumulative or "build-up" type of index. As live fuels cure and dead fuels dry, the ERC values get higher thus providing a good reflection of drought conditions. The scale is open-ended or unlimited and, as with other NFDRS components, is relative. Conditions producing an ERC value of 24 represent a potential heat release twice that of conditions resulting in an ERC value of 12.

"As a reflection of its composite fuel moisture nature, the ERC becomes a relatively stable evaluation tool for planning decisions that might need to be made 24 to 72 hours ahead of an expected fire decision or action. Since wind and slope do not enter into the ERC calculation, the daily variation will be relatively small. The 1000-hr timelag fuel moisture (TLFM) is a primary entry into the ERC calculation through its effect on both living and dead fuel moisture inputs. There may be a tendency to use the 1000-hr TLFM as a separate "index" for drought considerations. A word of caution - any use of the 1000-hr TLFM as a separate "index" must be preceded by an analysis of historical fire weather data to identify critical levels of 1000-hr TLFM. A better tool for measurement of drought conditions is the ERC since it considers both dead and live fuel moistures." Source: http://fam.nwcg.gov/fam-web/pocketcards/erc.htm

Seasonal Adjustments for RAWS

Calculation of ongoing NFDRS indices throughout the year involves setting a "Greenup" and "Freeze" date of year, as well as setting a "Wet Flag" in daily observations, for each RAWS. The

Greenup and Freeze dates denote the availability of live fuels to burn as influenced by seasonal changes. The Wet Flag setting denotes that dead fuels are wet and less available to burn, and is typically set when there is snow cover and/or a long-duration precipitation event. Both these settings impart the influence of changing seasonal differences in fuel conditions into the NFDRS calculations, and impact the ERC and 1000-hour fuel moisture index trends.

Impacts of setting the Wet Flag in Shoulder Seasons

Optimum prescribed burning conditions often occur during the "shoulder seasons" of the year – spring and fall. Depending on the seasonal trends, the typical summer fire season can also extend early or late in the year. However, the Wet Flag is often set for many RAWS during the spring in anticipation of the upcoming summer season. This has the effect of re-setting the NFDRS indices as if they were wet and starting a new drying cycle. If the dead fuels were already dry, setting the Wet Flag during this time can lead to unreliable assessments of the actual seasonal severity.

This was the case for a number of RAWS in the Front Range of Colorado in March, 2012. See Figure 37 for illustration. On March 12, the Wet Flag was set for a number of RAWS in the Front Range, including Bailey and Cheesman, and was kept in place through March 24. This led to inaccurate NFDRS indices, and unrealistic wetting trends, being reported for these stations for this time period.

This Wet Flag setting has been a wide-spread issue with RAWS inputs to NFDRS for a number of years. In fact, a "SAFENET" – report of unsafe situation in wildland fire operations – was submitted on March 30, 2012 for just this issue (Figure 38). The 1000-hour fuel moisture and ERC trends for a number of weeks had been indicative of a steady drying trend.

This problem was subsequently corrected in early April, but had caused erroneous NFDRS indices to be reported for the latter half of March (Figures 39 and 40). During the course of this Review, fire personnel from federal, state, and local agencies expressed similar ongoing concerns about inaccuracies in local NFDRS indices.

	StationID	ObsDate	Type	SOW	Temp(F)	RH	24hr Precip	Duration	Wind Speed	Direction	Azimuth	Max Temp	Min Temp	Max RH	Min RH	WetFlag
16,595	052001	03/01/12 13:00	0	3	26	70	0.00	0	3	2	101	45	26	76	17	0
16,596	052001	03/02/12 13:00	0	3	20	65	0.00	0	3	2	70	26	9	98	43	0
16,597	052001	03/03/12 13:00	0	0	36	23	0.00	0	5	6	277	36	13	65	22	0
16,598	052001	03/04/12 13:00	0	0	54	13	0.00	0	3	6	255	54	31	40	13	0
16,599	052001	03/05/12 13:00	0	0	58	9	0.00	0	4	6	288	58	31	35	8	0
16,600	052001	03/06/12 13:00	0	0	59	7	0.00	0	8	6	255	59	39	19	5	0
16,601	052001	03/07/12 13:00	0	4	23	99	0.00	0	2	2	74	59	23	100	6	0
16,602	052001	03/08/12 13:00	0	0	40	29	0.00	0	3	2	101	40	17	100	27	0
16,603	052001	03/09/12 13:00	0	0	53	10	0.00	0	3	2	87	53	21	39	10	0
16,604	052001	03/10/12 13:00	0	2	54	19	0.00	0	4	4	161	57	27	29	9	0
16,605	052001	03/11/12 13:00	0	2	55	14	0.00	0	2	7	295	58	29	89	12	0
16,606	052001	03/12/12 13:00	0	1	56	11	0.00	0	2	8	341	58	36	30	10	1
16,607	052001	03/13/12 13:00	0	1	62	7	0.00	0	5	5	244	62	34	31	7	1
16,608	052001	03/14/12 13:00	0	0	62	5	0.00	0	5	6	249	62	36	22	5	1
16,609	052001	03/15/12 13:00	0	1	61	14	0.00	0	3	5	218	62	39	21	4	1
16,610	052001	03/16/12 13:00	0	0	65	9	0.00	0	4	5	242	65	35	47	9	1
16,611	052001	03/17/12 13:00	0	1	62	6	0.00	0	5	6	249	67	40	25	6	1
16,612	052001	03/18/12 13:00	0	3	54	17	0.00	0	6	4	178	64	42	26	5	1
16,613	052001	03/19/12 13:00	0	1	39	11	0.00	0	2	8	359	55	22	67	10	1
16,614	052001	03/20/12 13:00	0	0	40	25	0.00	0	4	2	81	41	18	78	11	1
16,615	052001	03/21/12 13:00	0	0	51	22	0.00	0	4	1	44	52	20	44	20	1
16,616	052001	03/23/12 13:00	0	0	70	9	0.00	0	4	2	110	70	30	47	9	1
16,617	052001	03/24/12 13:00	0	1	63	13	0.00	0	5	1	65	73	39	33	7	1
16,618	052001	03/25/12 13:00	0	1	69	7	0.00	0	5	6	276	71	36	65	7	0
16,619	052001	03/26/12 13:00	0	0	65	5	0.00	0	8	5	238	71	44	40	5	0
16,620	052001	03/27/12 13:00	0	1	64	6	0.00	0	5	5	230	66	39	25	5	0
16,621	052001	03/28/12 13:00	0	1	66	9	0.00	0	4	5	232	66	34	39	6	1
16,622	052001	03/29/12 13:00	0	0	63	7	0.00	0	4	7	297	66	40	24	7	0

Figure 37. *Data from the Bailey RAWS (Station ID 52001) from March 01 through March 30 showing the Wet Flag enabled (value set to "1") for March 12-24. Once the Wet Flag was removed (value set to "0"), the ERC and 1000-hour fuel moisture once again began to show a drying trend in the graphs*

SAFENET

Wildland Fire Safety & Health Reporting Network

Report unsafe situations in all wildland fire operations.

ID # 8SXM6ASAFE

REPORTED BY

Name : *(Optional)*
Phone : *(Optional)*
EMail : *(Optional)*
Date Reported : 04/01/2012
Agency/Organization : Other
State Agency :
Other Agency : RMA Interagency Fire

EVENT

Event Date : 03/30/2012
Local Time : 3:00 PM
Incident Name : N/A
Incident Number : N/A
State : CO
Jurisdiction : USFS
Local Unit : Pike National Forest

Incident Type : Wildland; Prescribed; Fuel Treatment
Incident Activity : Readiness/Preparedness
Stage of Incident : Other

Position Title : Predictive Services
Task :
Management Level : 1
Resources Involved : Fire Personnel

CONTRIBUTING FACTORS

Contributing Factors : Human Factors
Human Factors : Decision Making; Leadership; Performance; Risk Assessment; Situational Awareness
Other Factors : N/A

NARRATIVE

Describe in detail what happened including the concern or potential issue, the environment (weather, terrain, fire behavior, etc), and the resulting safety/health issue.

Inaccurate NFDRS indices from unit RAWS (i.e. Bailey and Cheeseman)

Systemic and chronic problems continue with the Rocky Mountain Area WIMS-RAWS-NFDRS program. Poor quality control and incorrect 1300 "O" type observation input has resulted in inaccurate NFDRS indices output (i.e. ERC, 1000-hr fuel moisture, fire danger, etc.) across portions of the Central/Southern Front Range of Colorado, an area that has experienced large fire activity this Spring.

Current NFDRS indices at the Bailey and Cheeseman RAWS are reporting 1000-hr fuel moistures greater than 25% and below average ERC's (near 10). This area has experienced record heat, low humidity, loss of snow cover, and has received little if any moisture during the last 30 days. Data quality problems could be a result of inconsistent and/or invalid usage of the "Wet Flag" parameter for much of March 2012.

These indices are typically utilized for planning and decisions related to prescribed burns, wildland fire preparedness and wildland fire suppression efforts by multi-jurisdiction (local, state, federal)fire managers. Erroneously moist NFDRS fuel indices WILL: 1. Create a false sense of security; 2. Provide an inaccurate portrayal of the current fire risk or situation; 3. Provide an inaccurate portrayal of anticipated fire behavior; 4. Impact planning and decisions related to firefighter operations; and 5. Negatively impact both firefighter and public safety.

IMMEDIATE ACTION TAKEN

Reporting Individual : please describe actions you took to correct or mitigate the unsafe/unheathful event.
Photos, particularly for equipment related issues, may be attached. Please do not exceed 5 pictures and compress photos for the smallest file size that illustrates the particular concern. Photos are subject to the same sanitization criteria as SAFENETS.

ATTACHMENTS:
#1
#2
#3
#4
#5

Figure 38. *SafeNet filed March 30, 2012 regarding NFDRS indices from local RAWS units, including Bailey.*

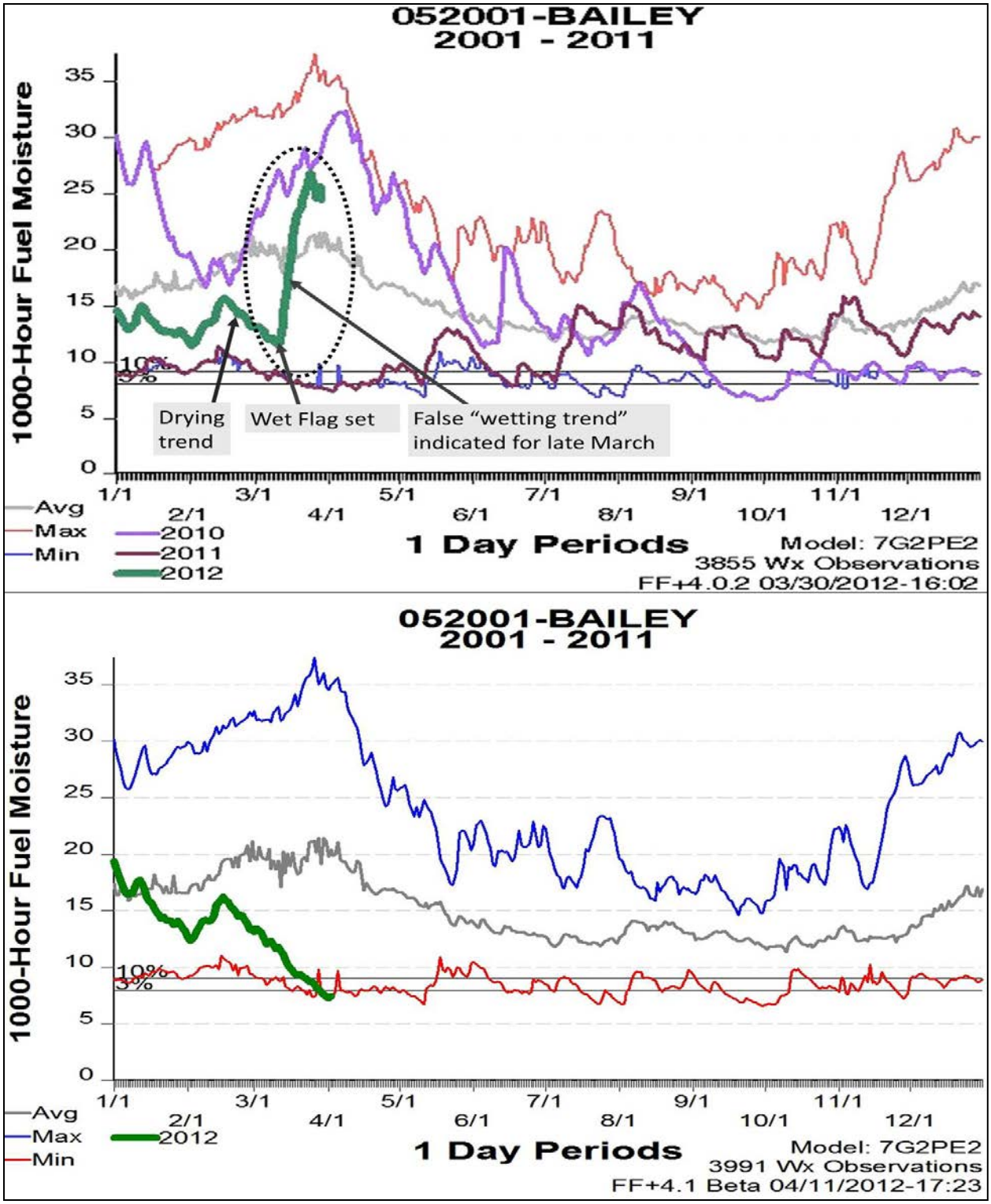


Figure 39. *NFDRS graph of 1000-hour fuel moisture trends for the Bailey RAWS using data generated with the wet flag set mid-March (top) and the same data with the wet flag removed (lower). The impact of setting the Wet Flag is evident by the sudden and dramatic drop in the reported 1000-hour fuel moisture (top, circle). Note that only the upper graph was available prior to March 30, 2012.*

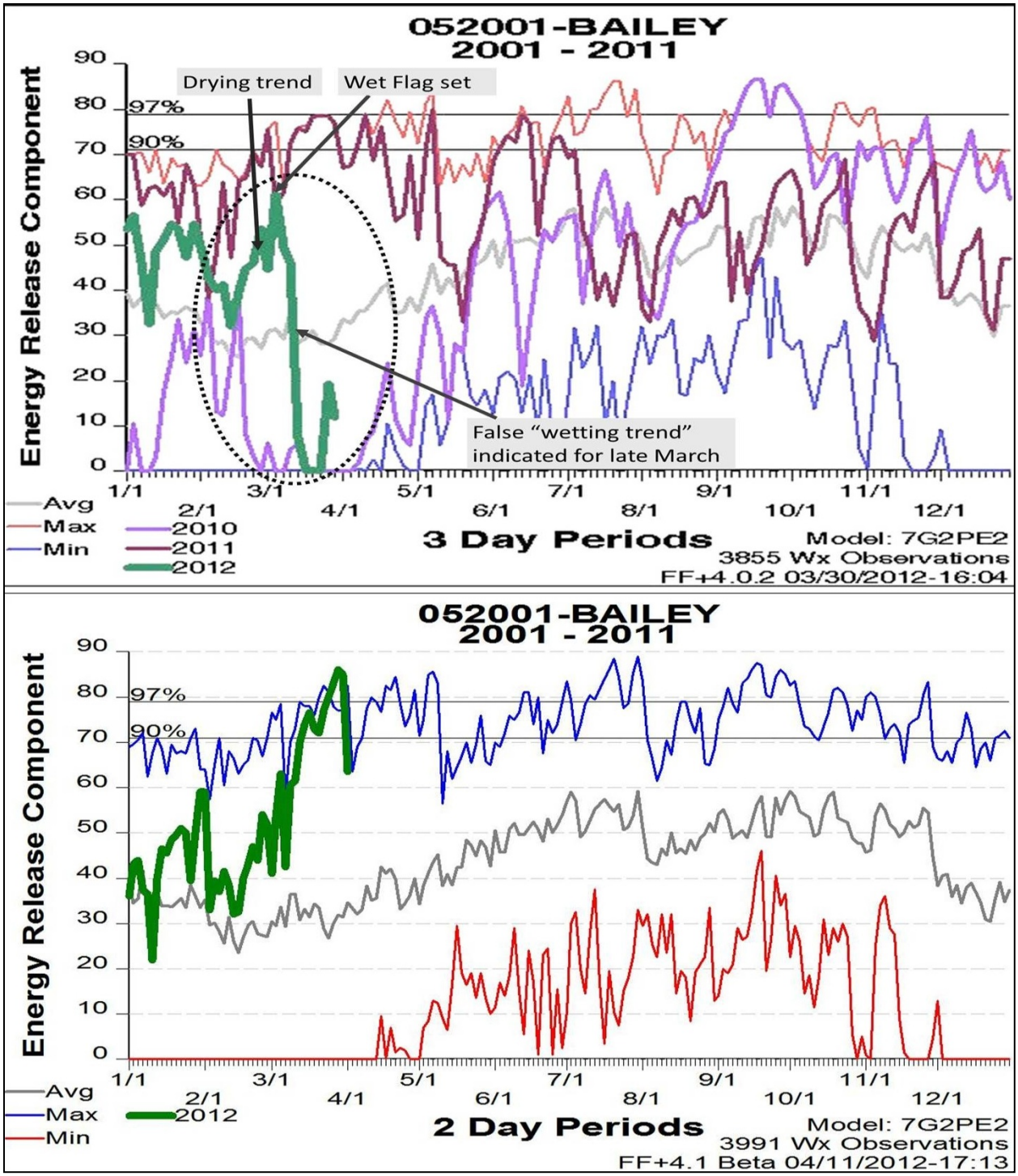


Figure 40. *NFDRS graph of ERC trends for the Bailey RAWS using data generated with the Wet Flag set mid-March (top) and the same data with the wet flag removed (lower). The impact of setting the Wet Flag is again evident by the sudden and dramatic drop in the reported 1000-hour fuel moisture (top, circle). Note: the sudden drop in ERC on April 02 in the corrected data (lower) is likely due to the Wet Flag being re-set on April 02, 2012, as there was precipitation in the area April 02-03. Also, it should be noted that only the upper graph was available prior to March 30, 2012.*

Fire Behavior

Gridded Winds

For the purpose of assessing the local winds near the surface on March 26, 2012, a CFD-based (computational fluid dynamics) program, WindWizard, was employed. WindWizard uses CFD algorithms with enhancements to tailor it to wildland fire applications. WindWizard acts as a "virtual wind tunnel," conforming strong synoptic winds aloft to local terrain features. Local terrain is represented by a digital terrain model, with settings to adjust for surface roughness by specifying the predominant vegetation as grass, brush, or forest. The output from WindWizard is a grid of regularly-spaced points representing wind speed and direction at a user-specified resolution. These wind grids are generated as ArcMap-format shapefiles, Google Earth KMZ files, and ASCII grids for use in wildland fire modeling programs such as FARSITE and FlamMap. See http://www.firemodels.org/index.php/windwizard-introduction/windwizard-overview for an overview of WindWizard.

For this report, Windwizard was used to simulate the surface winds on March 26, 2012, to assess local channeling of winds by ridges, valleys and draws in and around Unit 4a. The speed and intensity of actual winds aloft were estimated using data from the Polhemus RAWS, which is situated on a high-elevation, exposed ridgetop site. These ridgetop winds were then used to determine the appropriate input for winds aloft as an input to WindWizard. Wind speeds from the HOBO weather station were found to be consistent with those recorded at the Polhemus RAWS and provided an additional validation of the wind grid outputs.

The end result (Figures 41-43) shows simulated local wind patterns on Unit 4a that are consistent with what personnel on the ground reported on the upper (north) perimeter of the unit as winds increased through the day on March 26, In particular, the winds simulated for 1300h show winds intensifying and aligning with the slope and draw below where two spot fires were discovered below DP4, and winds simulated for 1400h show the same phenomenon where the third spot fire was discovered near DP5. It should be noted that the surface wind grids produced by WindWizard are for speed and direction at 20 feet above the surface (similar to those measured by RAWS). Where forest canopy is present, wind speeds near the ground would be reduced somewhat.

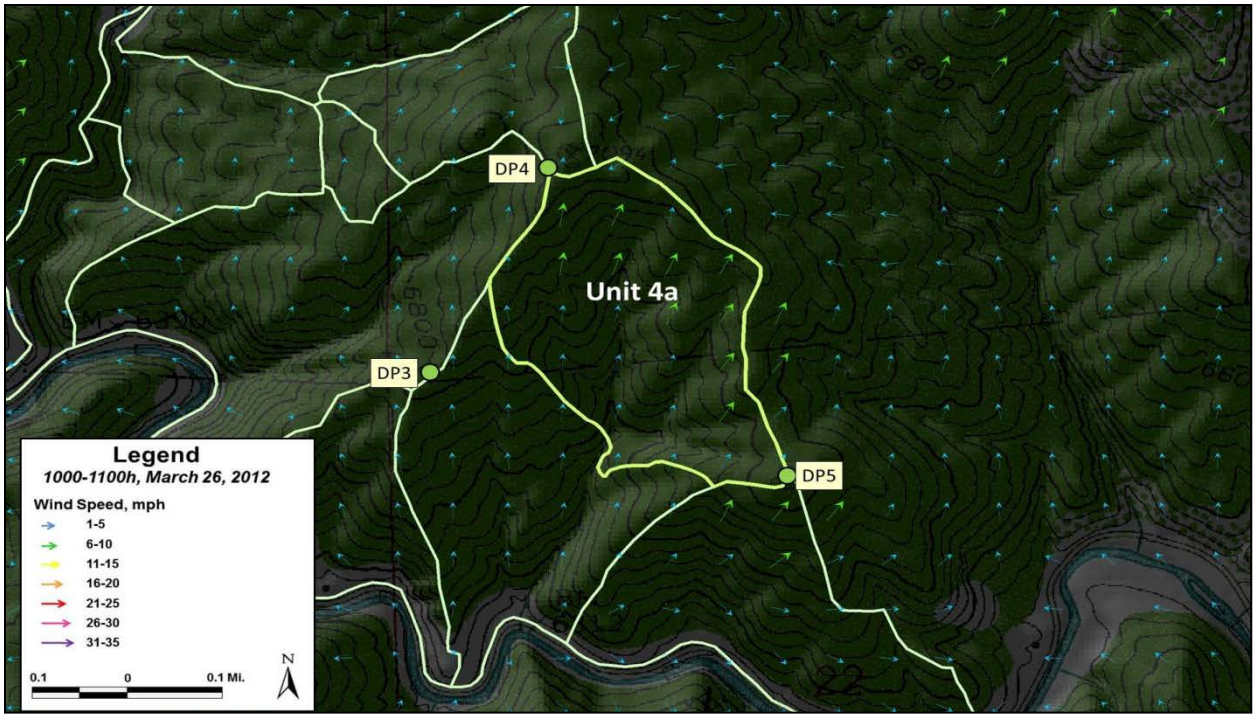


Figure 41. *Simulated surface winds for conditions at 1100h on March 26, 2012. Wind speeds are consistent with those recorded by the HOBO station and observations of personnel on the site.*

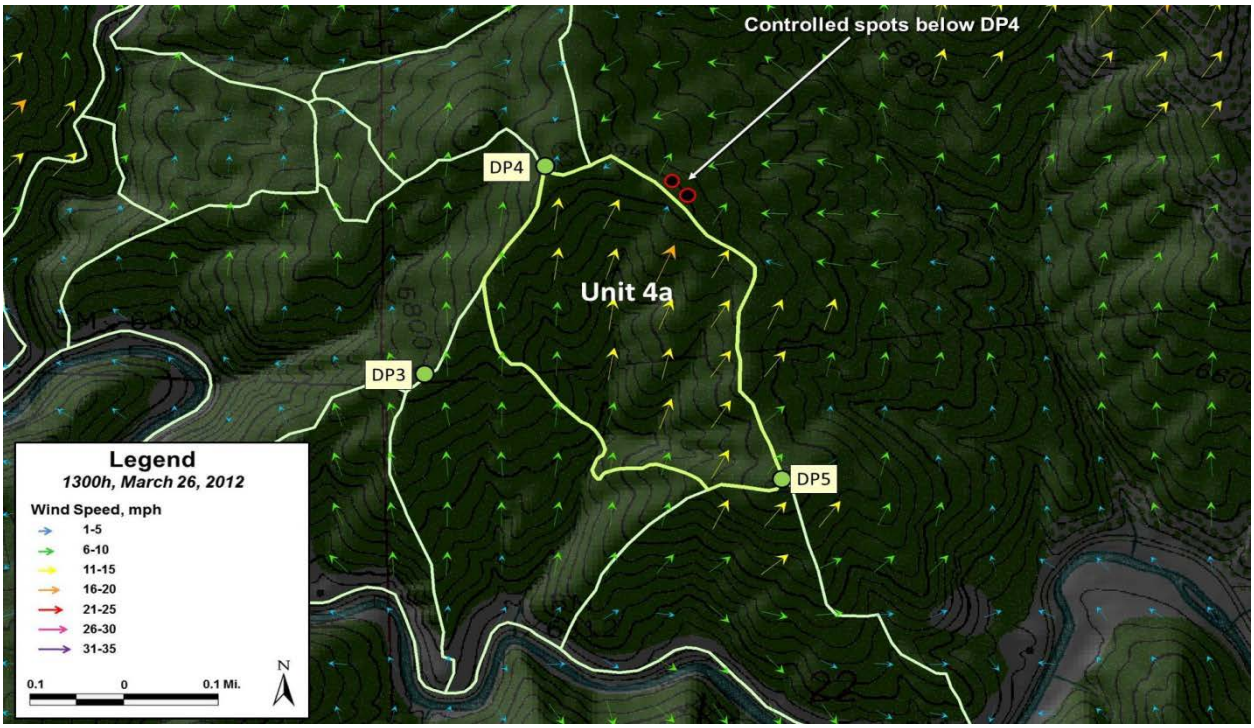


Figure 42. *Simulated surface winds for conditions at 1300h on March 26, 2012. Winds are increasing and channeling up the major draws in Unit 4a. The two spot fires below (east of) DP4 are indicated; simulated winds show alignment with terrain within the unit below this area.*

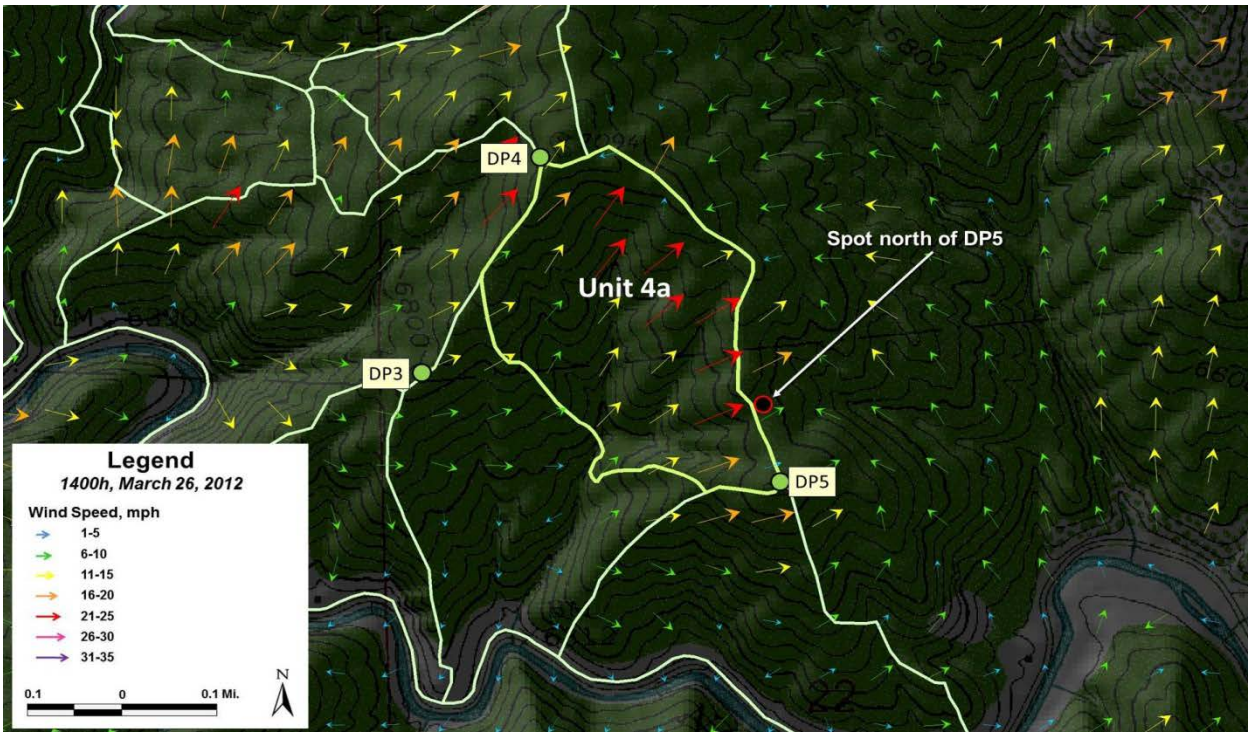


Figure 43. *Simulated surface winds for conditions at 1400h on March 26, 2012. The wind speed has intensified since 1300h and become more westerly. The third spot fire north of DP5 is shown. Simulated winds in this scenario show stronger winds that are in alignment with terrain – notably the draw below (west of) the control line where the spot fire occurred.*

Short-Range Surface Spotting

On the afternoon of March 26, 2012, personnel patrolling Unit 4a noticed fire spread by short range spotting in previously-burned areas when winds became strong at the surface. This resulted in the progression of fire across the surface, upslope toward the northern and eastern perimeter, and led to spot fires across the line. Each person independently described the spread as surface-borne embers in strong winds near the ground surface that spotted a few feet downwind, ignited new spots, which then repeated the process. This steady "leap-frog" spot fire spread enabled fire progression through areas where most of the surface fuels had been consumed, where what remained was largely duff that had not been consumed yet appeared cold. It is an unusual phenomenon for which there is no applicable fire spread model, and as such this type of fire spread is not readily predictable.

Fire Behavior Potential for March 26

In order to examine factors that led to increased fire activity, spotting, and rapid fire spread of fire outside Unit 4a, several fire behavior projections were run. These used a program called FlamMap to show potential fire behavior for the area. FlamMap is a computer program that displays potential fire behavior across a landscape, given inputs for a specific time. FlamMap

incorporates existing fire behavior models for surface fire spread (Rothermel, Andrews, Nelson) and crown fire spread (Rothermel, VanWagner). For further information about FlamMap, see http://www.firemodels.org/index.php/national-systems/flammap.

As inputs to FlamMap, GIS layers depicting fuel and terrain were obtained from the LANDFIRE archive (http://www.landfire.gov/). Though the LANDFIRE fuels information does not reflect the mechanically treated fuels, it does include some slash fuels within the area examined. Wind inputs for FlamMap consisted of the wind grids from WindWizard for specific times on March 26 as previously discussed. Weather inputs (temperature, relative humidity) were estimated from the Bailey RAWS data.

These analyses are not intended to be a depiction of the actual fire behavior that occurred on March 26. Rather, they are provided to give a comparison of potential fire behavior under the changing weather conditions that occurred on March 26 to help illustrate factors leading to more aggressive fire spread that afternoon.

Potential Flame Length

Flame length is directly related to heat intensity – the great the flame length, the more heat is produced at the flaming front. The depiction of potential flame length in Figure 44 is shown for categories depicting limitations of fire suppression resources. Flame lengths less than 4 feet can be directly attacked by firefighters with hand tools. Flame lengths up to 8 feet can be directly attacked with equipment (engines or dozers). Above 8 feet, only indirect attack is possible, and with increased flame length, there is increased potential for large fire growth

In Figure 44, flame lengths modeled for 1100h conditions (left) are consistent with what was observed and documented during ignition on March 22, under moderate winds, temperature, and RH. For 1400h conditions, the potential flame length shown has changed dramatically. This is a reflection of the increased winds, and warmer, drier conditions that predisposed the area to significantly more intense burning conditions.

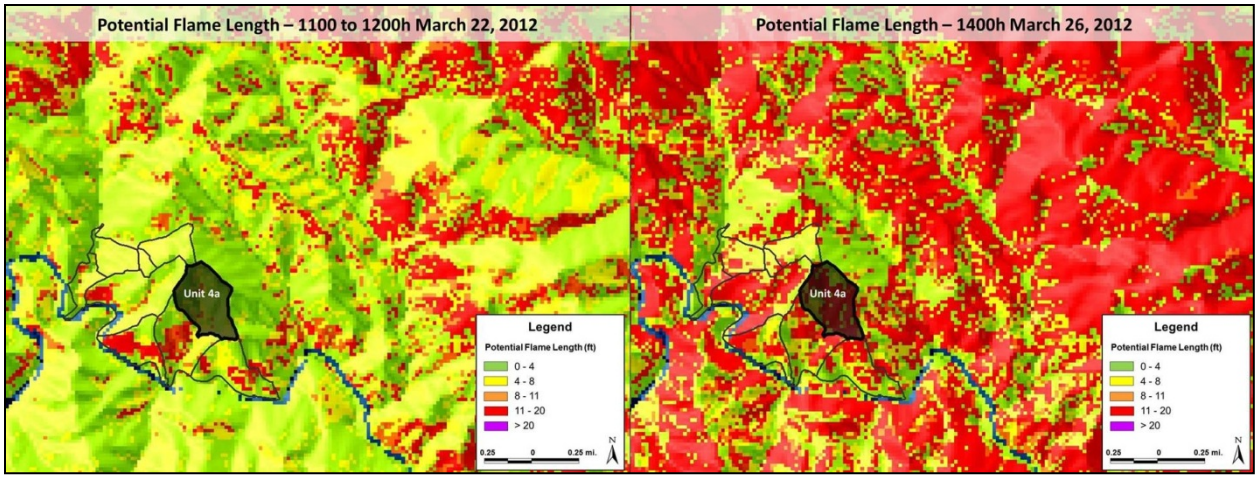


Figure 44. *Potential flame length under 1100h conditions (left) compared to 1400h conditions (right).*

Potential Crown Fire

Crown fire is the spread of fire through tree canopies (crowns). Crown fire can be either passive (torching only) or active (sustained runs through the crowns). Increased surface fire intensity can pre-heat crown fuels, making them more susceptible to crown fire. Additionally, significant surface fuels can facilitate spread of fire into crown fuels.

Potential crown fire modeled for 1100h and 1400h on March 26, 2012 is shown in Figure 45. Crown fire modeled for 1100h conditions is consistent with what was observed and documented during ignition on March 22, 2012 under moderate winds, temperature, and RH. Under that scenario, simulated crown fire was limited to torching (passive crown fire), with no sustained runs through the tree canopy. By comparison, during ignition, occasional single-tree torching was observed, and there were no sustained runs through the tree canopy.

For 1400h conditions, many areas show potential for sustained crown fire runs – notably the southeast portion of Unit 4a where there were denser mixed conifer stands, and east and northeast of Unit 4 where the fire did make sustained crown fire runs later in the afternoon.

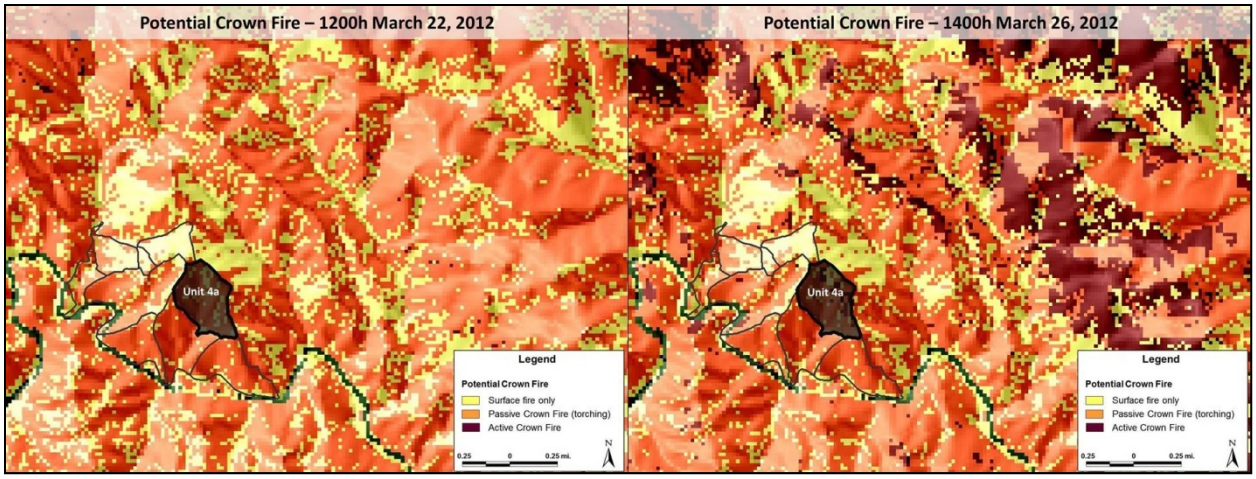


Figure 45. *Potential crown fire under 1100h conditions (left) compared to 1400h conditions (right). Passive crown fire denotes torching, while active crown fire denotes sustained runs through crown fuels.*

BEHAVE "CONTAIN" Modeling

To determine the effectiveness of additional fire suppression resources on March 26, 2012, as discussed in the Report, several modeling scenarios were run using the CONTAIN module of BEHAVE Plus. Assumptions and inputs to this modeling, and a description of outputs obtained from CONTAIN, are shown in Figure 46. A summary of the modeling results is shown in Figure 47. In all but one scenario (4 engines, 10% slope), the fire exceeded capabilities of suppression resources.

Fire Control Modeling

- **Model Used**: Behave fire spread model
- **Inputs:** conditions found at 1:00 PM on Lower North Fork Prescribed Fire, March 26, 2012
- **Assumptions:**
  - standard crew size of 3 personnel
  - line production rate of 12 ch/hr/engine for 1 hour
  - head attack, 1/10 acre at detection, 6 minute response
- **Outputs:** Estimates whether the spot fire could be caught with 1 Engine, 2 Engines, or 4 Engines

Figure 46. *Summary of inputs, assumptions, and outputs for fire behavior modeling to determine effectiveness of additional fire suppression resources on March 26. Modeling was done using the "CONTAIN" module of BEHAVE Plus*.

Fire Control Modeling Results

Fire Behavior Outputs	
10% Slope	35% Slope
Spread Rate – 23 ch/h	Spread Rate – 25 ch/h
Flame Length – 4.8 ft	Flame Length – 5 ft

Scenario	Slope Class	Contain Status	Contain Area
1 Engine	10% Slope 35% Slope	Escaped Escaped	N/A N/A
2 Engines	10% Slope 35% Slope	Escaped Escaped	N/A N/A
4 Engines	10% Slope 35% Slope	Contained Escaped	0.8 acre N/A

Figure 47. *Summary of results from fire behavior modeling performed to determine effectiveness of additional fire suppression resources on March 26. Modeling was done using the "CONTAIN" module of BEHAVE Plus*.

The following tables provide details of the BEHAVE runs:

BehavePlus 4.0.0 (Build 276)
Containment Scenario #1 - 1 Engine, 6 min. Response Thu, Apr 12, 2012 at 15:01:01

Input Worksheet

Inputs: SURFACE, CONTAIN

Input Variables	Units	Input Value(s)
Fuel/Vegetation, Surface/Understory		
Fuel Model		9
Fuel Moisture		

1-h Moisture	%	4
10-h Moisture	%	6
100-h Moisture	%	8
Live Herbaceous Moisture	%	
Live Woody Moisture	%	

Weather

20-ft Wind Speed (upslope)	mi/h	20
Wind Adjustment Factor		.4

Terrain

Slope Steepness	%	10, 35

Fire

Fire Size at Report	ac	.1

Suppression

Suppression Tactic		Head
Line Construction Offset	ch	0
Resource Line Production Rate	ch/h	12
Resource Arrival Time	h	.1
Resource Duration	h	1

Notes

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Suppression input is for a single resource [CONTAIN]; multiple values can be entered for any input variable.

Results

Slope	ROS (max)	Flame Length	Contain Status	Time from Report	Contain Area	Fireline Constructed
%	ch/h	ft		h	ac	ch
10	22.7	4.8	Escaped	0.1	-1.0	0.0
35	24.5	5.0	Escaped	0.1	-1.0	0.0

BehavePlus 4.0.0 (Build 276)

Containment Scenario #2 - 2 Engines, 6 min. Response

Thu, Apr 12, 2012 at 14:55:29

Input Worksheet

Inputs: SURFACE, CONTAIN

Input Variables	Units	Input Value(s)
Fuel/Vegetation, Surface/Understory		
Fuel Model		9
Fuel Moisture		
1-h Moisture	%	4
10-h Moisture	%	6
100-h Moisture	%	8
Live Herbaceous Moisture	%	
Live Woody Moisture	%	
Weather		
20-ft Wind Speed (upslope)	mi/h	20
Wind Adjustment Factor		.4
Terrain		
Slope Steepness	%	10, 35
Fire		
Fire Size at Report	ac	.1
Suppression		

Suppression Tactic		Head
Line Construction Offset	ch	0
Resource Line Production Rate	ch/h	24
Resource Arrival Time	h	.1
Resource Duration	h	1

Notes

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Suppression input is for a single resource [CONTAIN]; multiple values can be entered for any input variable.

Results

Slope	ROS (max)	Flame Length	Contain Status	Time from Report	Contain Area	Fireline Constructed
%	ch/h	ft		h	ac	ch
10	22.7	4.8	Escaped	0.1	-1.0	0.0
35	24.5	5.0	Escaped	0.1	-1.0	0.0

End

BehavePlus 4.0.0 (Build 276)

Containment Scenario #3 - 4 Engines, 6 min. Response

Thu, Apr 12, 2012 at 15:01:28

Input Worksheet

Inputs: SURFACE, CONTAIN

Input Variables	Units	Input Value(s)
Fuel/Vegetation, Surface/Understory		
Fuel Model		9
Fuel Moisture		
1-h Moisture	%	4
10-h Moisture	%	6
100-h Moisture	%	8
Live Herbaceous Moisture	%	
Live Woody Moisture	%	
Weather		
20-ft Wind Speed (upslope)	mi/h	20
Wind Adjustment Factor		.4
Terrain		
Slope Steepness	%	10, 35
Fire		
Fire Size at Report	ac	.1

Suppression

Suppression Tactic		Head
Line Construction Offset	ch	0
Resource Line Production Rate	ch/h	48
Resource Arrival Time	h	.1
Resource Duration	h	1

Notes

Run Option Notes

Maximum reliable effective wind speed limit IS imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Suppression input is for a single resource [CONTAIN]; multiple values can be entered for any input variable.

Results

Slope	ROS (max)	Flame Length	Contain Status	Time from Report	Contain Area	Fireline Constructed
%	ch/h	ft		h	ac	ch
10	22.7	4.8	Contained	0.3	0.8	11.5
35	24.5	5.0	Escaped	0.1	-1.0	0.0

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