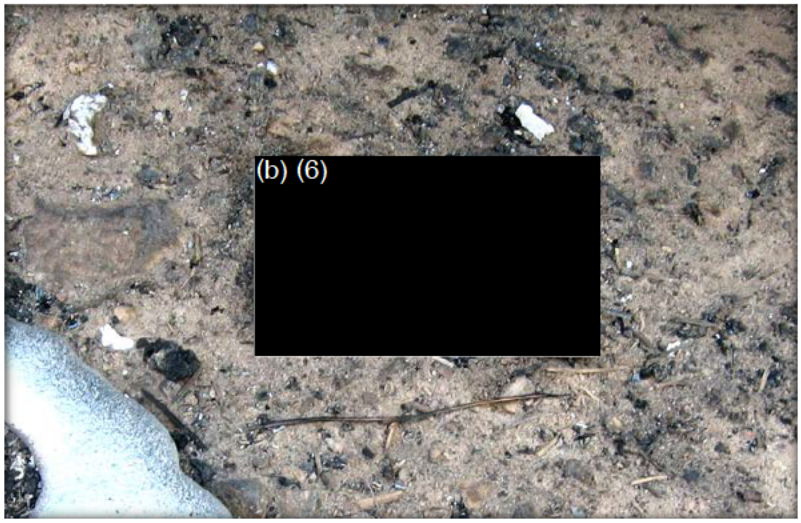
Coal Canyon Fire

August 11, 2011



Serious Accident Investigation Report

Hell Canyon Ranger District
Black Hills National Forest
South Dakota

Contents

Executive Summary

On August 11, 2011, at approximately 1330, U.S. Forest Service, South Dakota State, and Volunteer Fire Department personnel responded to a fire in Coal Canyon on the Black Hills National Forest.

During initial attack, the Incident Commander (IC) formulated a plan: use hose lay and hand line to work up from the heel on the right flank, and use the helicopter to make bucket drops along the left flank. *As additional resources arrived, the IC, perceiving the increasing complexity, requested a type 3 organization through dispatch. Shortly after, as fire behavior increased and compromised an egress route out of the fire area, fire entrapped and overran firefighters attempting escape.*

One firefighter died, two received serious burns, and two received minor burns. Two firefighters were entrapped in the engine; one remained entrapped and died; the other escaped and was transported to the Rapid City Regional Hospital. The third firefighter, who was overrun by fire while on foot, was transported to a Greeley, Colorado Burn Center. Two other firefighters received minor burns during rescue efforts; they were treated at local hospitals and released.

A national Serious Accident Investigation (SAI) Team conducted a review of events surrounding this accident. The team consisted of employees from the Forest Service, State of South Dakota, and State of Colorado. They worked to identify conditions and events leading to the entrapment, in an effort to help the greater wildland fire community learn from this incident and help prevent accidents of this kind in the future. Team members visited the site, listened to recorded dispatch audio, interviewed individuals associated with the incident, reviewed fire weather and behavior, and examined available written records and physical evidence.

Introduction

Purpose

The purpose of this report is to present the facts proximal to the accident and share the Team's analysis in a way that enhances the reliability and resilience of Federal, State, and Local wildland fire organizations. The intent is to spur discussion and learning for those in the fire and safety community at all levels.

Background

This incident involved fire resources assigned to the Coal Canyon Fire on the Hell Canyon Ranger District, part of the South Zone of the Black Hills National Forest.

Fire management within the South Zone of the Black Hills is coordinated among the Black Hills National Forest (BKF), Nebraska National Forest (NBF), South Dakota State Division of Wildland Fire Suppression (SDS), Bureau of Land Management, National Park Service, and career and volunteer fire departments (fig. 1). The South Zone area includes Custer, Hot Springs, Edgemont, Argyle, Pringle, Minnekahta, and

Cascade along with Newcastle, WY. The Northern Great Plains Interagency Dispatch Center (GPC) processes Federal and State resource requests. Local fire departments are dispatched through the appropriate county 911-dispatch center with mutual aid assistance from surrounding counties as requested.

These fire resources form part of the interagency wildland fire community in southwestern South Dakota. Area wildland fire management exemplifies robust interagency cooperation, which has developed over the past decade or more. This interagency cooperation is a result of deep commitment and sustained efforts of leaders from the various agencies. Cooperation is practiced at all levels—from those in top leadership positions to initial attack firefighters on the ground.

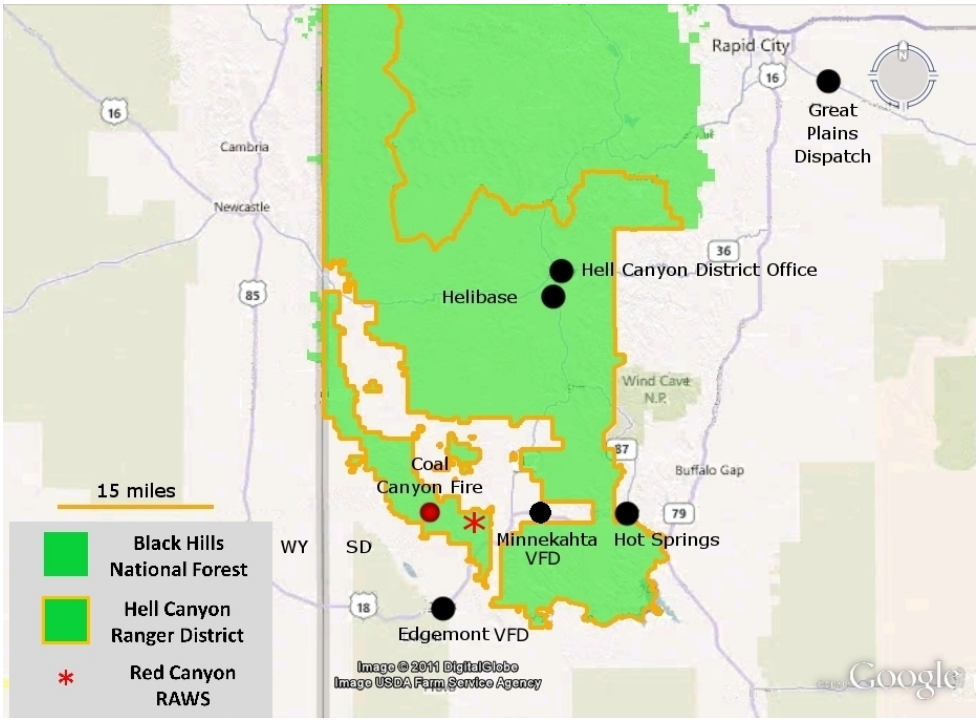


Figure 1. Map showing locations of wildland fire resources serving the South Zone of the Black Hills National Forest.

Interagency training contributes to successful interagency outcomes and relationships. Numerous live fire exercises and classroom training courses are offered each year. Live fire training opportunities are primarily provided by South Dakota Wildland Fire Suppression and occur across the State. The Forest Service conducts tabletop tactical decision games and numerous 200 and 300 level courses. All agencies are welcomed and encouraged to attend, with participants from not only South Dakota but also surrounding states.

Training managers conduct live fire training schools to simulate actual incident conditions. They use all functions of the Incident Command System, and provide trainees with excellent opportunities to achieve training goals and complete task books. Notably, *live fire exercises in recent*

> *"We have a solid interagency relationship"*
> —BKF Fire Management Officer

years have included scenarios of an incident within an incident (IWI) using actual life flight capability. This training builds mutual respect among firefighters from cooperating agencies, and sets the stage for working together and communicating effectively within the Incident Command structure while on incidents.

The preplanned interagency dispatch response level is a three-tiered response based on the area's predicted ERC. The Hell Canyon Ranger District fire organization has a standing daily morning briefing to discuss pertinent issues, such as staffing, resources available, forecasted weather, lightning activity, and Six minutes for Safety. Great Plains dispatch reads morning fire weather, response levels, National Fire Danger Rating observations, and daily staffing. These briefings are broadcast via radio, which provides an opportunity for Federal, State, and local career and rural volunteer fire resources to monitor the briefing each day.

The Accident

Just after 1300 on August 11, 2011, resources representing four agencies from federal, state, and rural volunteer fire management entities respond to the Coal Canyon Fire on the Black Hills National Forest. These resources include a helitack crew with their type 3 helicopter, two rural volunteer type 6 engines, two South Dakota State type 6 engines, three Forest Service type 6 engines, and one Forest Service type 4 engine.

The initial resources on scene—two helitack crewmembers, two rural volunteers, and three state engine crewmembers—establish command and report the fire to be 1 to 2 acres, burning with 1- to 3-foot flames in a draw bottom about 100 feet below a mid-slope road. The fire is most active in non-continuous grass and timber on the left flank, which is on a south aspect. On the right flank, below the road on the north aspect, less active fire burns in heavy, brushy fuels. Thick fuels restrict visibility around most of the fire. Winds are light and variable.

As resources continue to arrive, firefighters on scene plumb the fire's heel in the canyon bottom to reinforce their anchor point, and then progress uphill along the right flank with hand line followed by a hose lay. Bucket drops from the helicopter help cool the heel and left flank.

Incident command changes hands twice within the first hour, as more experienced personnel arrive. Ultimately, an IC (b), (b) (6) and a firefighter designated to serve as (b) (6)(b) (6)(b) (6) form the leadership over the incident. As additional engines approach the immediate fire area, these three decide that conditions along the road warrant moving all the engines, except for the first two that arrived, up and out of the canyon. They would stage the engines in a meadow above, form a hand crew, and hike into the fire. Although not feeling immediately threatened by fire behavior, they feel there are too many engines on a narrow mid-slope road with uncertain egress below and with smoke in the draw. All engines, except for the first two (Engines 1 and 2), turn around where the road crosses through a draw on a sharp curve; they drive out the way they came in and head to the meadow.

The IC(b) and (b) (6) begin scouting the fire together and meet face-to-face with personnel on scene while (b) coordinates the turnaround, engine staging, and hand crew formation. The IC(b) feels the established tactical plan is sound. He communicates this to resources on the fire, as well as his initial control objectives: keep the fire between the ingress road on the fire's right flank and the open ridge on the left flank.

After hiking down to the canyon bottom near the anchor point, the (b) (6) hikes back toward the right flank, and the IC(b) goes up the left flank for a better vantage point and to get a sense of whether they will be able to hold the fire on the ridge. (b) has already moved down to the right flank to check on progress. By the time the IC(b) makes it to the ridgeline, the hand crew communicates their ingress is cut off due to fire, and (b) communicates that they are past the point of keeping the fire below the road as initially intended. The fire has crossed the road above the draw where the engines turned around.

As (b) walks back toward Engines 1 and 2 on the right flank, he finds a spot fire above the road in front of the hand line. E2 discontinues hose lay operations and pulls their engine forward a short distance to engage the spot. About this time, the IC(b) radios the Duty Officer and discusses the changing conditions on the fire and, perceiving the increasing complexity, requests a type 3 organization. The IC(b) also ends the (b) (6) assignment for the (b) (6) and takes back full control of the fire (Note: this narrative will continue to refer to him as "(b) (6) to avoid confusion).

Figure 2. Photo showing the location of E2 stuck on the road in the draw at the apex of the sharp curve.

As E2 works on the spot fire, (b) hikes back up the road toward the draw. He sees at least two more spots above the road and thinks, *"This canyon's going to go."* (See figures 2 & 3) He hikes back toward

E2 and E1, and he radios, *"Back the engines down the road."* Moments later, (b) walks down to and past E2 and tells the driver, *"Back up!"* An E2 crewmember, who is standing behind the engine sees trees torching close to the road beside the engine, says to (b) , *"It's too hot!"* (b) points up the road and shouts back, *"It's hotter up there! Back Up!"* (b) continues to walk down the road passing a torching tree below the road and shielding himself from the heat by tilting his hardhat and holding his hand to his face. (b) continues down the road another 40 to 50 feet toward E1. E1 is backing down the road and stops about 150 feet from the spot fires. (b) checks the hose line down toward the heel to see if it is holding.

(b) is expecting to see E2 backing towards him. He sees a large tree torching just below the road and between himself and E2. At some point after (b) passed E2, the E2 crew leader jumps into the passenger seat of E2. With the flame and smoke from the torching tree, the E2 crew leader and driver lose sight of all firefighters, including the third E2 crewmember (who is still behind the engine working the hard line). E2 drives pulls forward and drives up the road.

(b) turns to see the back of E2 disappear into the smoke as the engine drives away. The third E2 crewmember is standing between the main fire and the spot fire above the road. He drops the nozzle and looks around, then drops face down into the road and protects his airway. Immediately, a burst of heat, fire, and smoke curl over the road where he was standing. The flames dissipate. (b) runs up the road, grabs the third E2 crewmember by his belt, pulls him up, and sends him running down the road towards E1.

E2 drives around the sharp curve and through the draw and then confronts a wall of fire crossing the

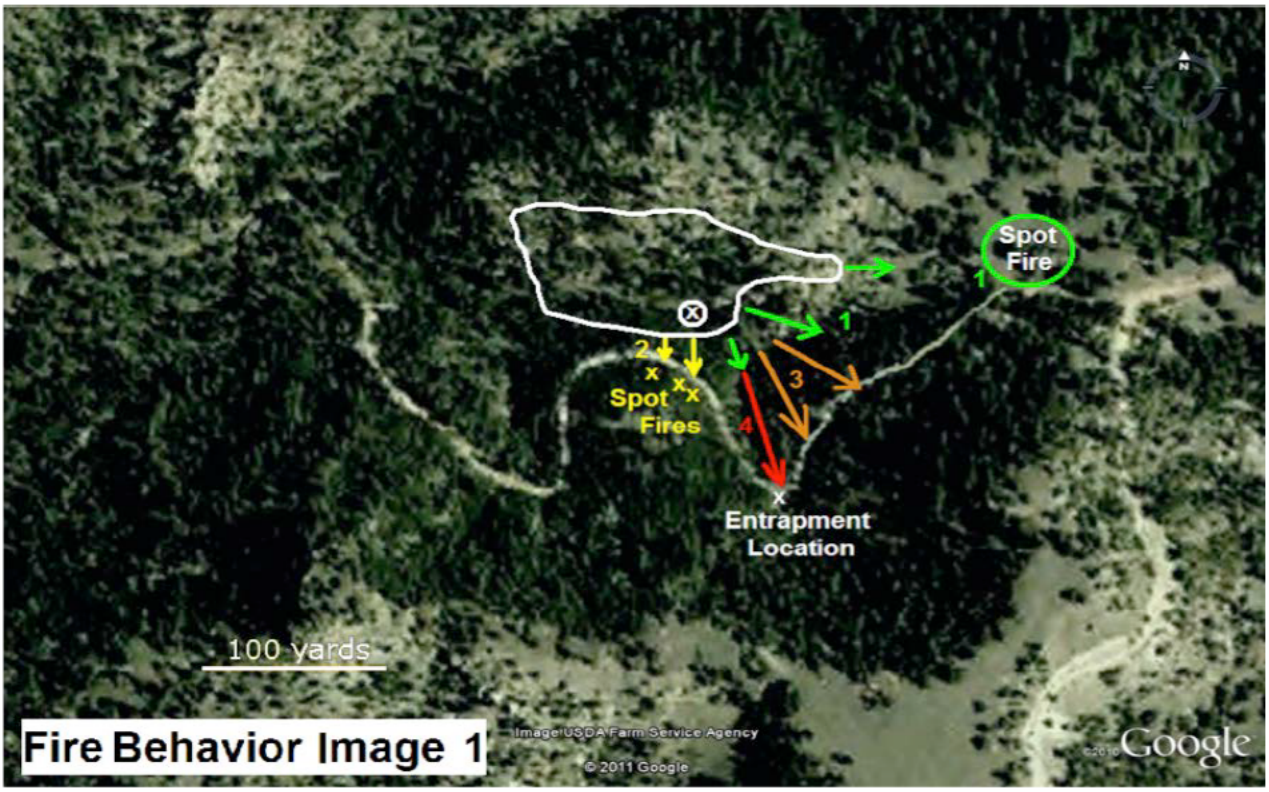


Figure 3. Fire progression on the right flank (from Fire Behavior Analysis, Appendix B): The spotting at (1) blocks (b) progress up the road. Then, at (2), he finds spots above the road near the western edge of the fire. E2 works these spots and later drives forward from here. Their escape is cut off by fire over the road (3), so they pull back. The vehicle gets stuck in the turnaround spot in the draw, and fire runs through the draw (4).

road. The driver starts backing up, goes less than 80 feet, when, in the dense smoke, he backs into a cut bank. The vehicle engine cuts out. E2 is now stuck in the middle of the sharp curve and in the middle of the draw. Flames are bending directly at the engine. Both occupants feel it is too hot to try to exit the vehicle. The crew leader has his fire shelter out, and the driver struggles to access his. The crew leader drapes his own shelter over both of them. Flames engulf the engine, and flammable items on the engine catch fire. The E2 crew leader makes at least two Mayday calls and requests bucket drops from the helicopter.

The (b) (6) and (b) converge on the road near the spot fires. They know the situation is critical. The IC (b), working his way from the left flank around the heel toward the road, requests life flight response through dispatch. Dispatch also mobilizes two ground ambulances.

At some point, (b) establishes radio contact with one of the firefighters in E2, who reports that they are in the draw. Battling heat and dense smoke, (b) (6) and (b) make multiple attempts to reach E2 on foot. (b) (6) pulls his fire shelter and uses it as a heat shield during these attempts.

The (b) (6) makes it to within 30 feet of the engine but the intense heat drives him to stop and kneel behind his fire shelter. Convective heat is channeling up the narrow draw, directly at E2 (See figure 4). Equipment in the back of the engine is now on fire. Paint on the vehicle's hood is aflame, yet the inside of the cab is still survivable. A tire blows, and (b) (6) within 40 feet of the engine, retreats. Both (b) (b) and (b) make additional attempts to reach the engine for rescue. After one of the attempts, (b) (6) collapses from exhaustion.

(b) (6) tells (b) that if E2 firefighters can make it 15 feet down the road, they can get out of there. (b) walks back toward the fire near E2 and makes radio contact with someone in E2. He says that if they can make it out of the engine—they need to get just 50 feet back down the road where they'll be okay. The driver and crew leader decide to run for it. (b) inches toward E2. With only a couple of feet of visibility in the dense smoke, he feels his feet catch the end of E2's hard line, 35 feet of which had trailed behind as E2 drove off. As he looks up, he sees E2's driver

Figure 4. Aerial view showing how far rescue attempts reached while trying to come to E2's aid.

outside (maybe 5 feet) running from the engine. The heat pushes the driver back toward the cut bank. He stumbles over the hard line and his hard hat falls off, but he keeps his footing. He runs into (b) then (b) (6) and continues toward E1.

Meanwhile, the helicopter has been trying to make bucket drops on the burning engine, but (b) (6) cannot find E2 through the dense smoke. He makes three slow passes along the road, and on the fourth pass, (b) (6) estimates the location of the engine and drops on the thickest smoke. The drop lands upslope from the engine.

(b) (6) and (b) go back down to E1 where the two injured crewmembers are receiving treatment and report the current situation to the IC (b). (b) (6) asks the E1 crew to drive forward to reach E2 with their engine, in hopes of rescuing the E2 crew leader. The E1 firefighters start their pump and drive up to within a few feet of the burning vehicle. The captain and driver take turns working the nozzle. They shoot water directly into the cab and see remnants of a fire shelter. Flames have fully engulfed the inside of the cab. They mutually decide to withdraw because the water had no affect on the intense heat.

It cannot be known with certainty, but it is believed that the crew leader of E2 inhaled as he was hit by an intense burst of superheated gases and flames and was killed almost instantly. This burst of heat may have missed the driver by only seconds, or he may have been holding his breath as he passed through it.

Analysis and Conclusion

This tragedy was the result of the chance conjunction of events, especially lethal erratic local fire behavior and unexpected combinations of normal human variability. The SAI team concluded that the convergence of these events—in a very specific way and with very specific timing—quickly narrowed the firefighters' margin of maneuvering to safety. Slight differences in any number of factors could have led to drastically different results (far more severe or far less severe).

Up until the accident, the firefighting professionals involved in the Coal Canyon Fire reasoned the risks of engaging and suppressing this fire to be relatively low and the benefits of direct suppression to be worth this low risk. After considerable review of the incident, including the leadership, qualifications, training, interagency cooperation, fuels, weather, the organization, and local policies, the SAI team has concluded that the judgments and decisions of the firefighters involved in the Coal Canyon Fire were appropriate.

Firefighters all performed within the leaders' intent and scope of duty, as defined by their respective organizations. The team did not find any reckless actions or egregious violations of policy or protocol. In fact, the SAI Team found the actions of the firefighters involved with the Coal Canyon Fire to be fully consistent with local and national policy and meeting the intent of leadership expectations. Many decisions and actions on the Coal Canyon Fire were manifestly heroic, demonstrating the best of wildland fire professionalism. Following are two specific actions that connect to the outcome, along with a brief explanation of how these decisions would have appeared reasonable to firefighters in context:

1. **Driving forward rather than backward:** Given the firefighters' knowledge and perception of the situation at the time, this option appeared to be the best for getting to safety. When the driver and crew leader had to act, they saw flame and smoke behind them with a clearer path in front of them**.**
2. **Going direct rather than burning off the mid-slope road:** There are risks and tradeoffs associated with both tactics. Based on their expectation of fire behavior and available resources, firefighters judged their best move for managing risk was to try to suppress the fire while small. Even with this decision, they believed they would have more than enough time to maneuver to safety should the fire change unexpectedly.

Doctrine, national policy, and interagency policy are clear that protection of human life is the overriding priority of fire management and that no resource or facility is worth the loss of a human life. It is also clear that almost all fire management activities involve an acceptance of some level of risk to human life, especially to the lives of firefighters. The Coal Canyon Fire was clearly and certainly not worth the life of a young firefighter. However, *low risk* is not *no risk*. Because of the unpredictability of fire behavior and innumerable human factors, some risks cannot be calculated; they can only be estimated, and much of this estimation is intuitive.

Recommendations

How should the agencies and the firefighting community react to this analysis and conclusion? The best and most appropriate response is rigorous dialog and learning. After the release of this report, the team will produce separate documents focused on learning from this tragedy. Those documents will provide an **Expanded Narrative** and an in-depth **Discussion and Analysis** around human variability, risk management and resilience, as well as additional considerations and recommendations.

Passing the Story Along

The link below accesses a Google Earth presentation, which gives a brief overview of the Coal Canyon Fire and provides. This presentation can aid in learning and sharing and is suitable for self-study and discussion. Download and open the zip file, which contains the Google Earth file and a facilitator's how-to guide. Once Google Earth is installed, double-click on the CoalCanyonFire.kmz file to begin.

Coal Canyon Fire Depiction Using Google Earth (http://wildfirelessons.net/documents/CoalCanyon.zip)

> To view the file: download it, load it into Google Earth, and follow the prompts. The user must have Google Earth installed; this software may be downloaded free of charge from http://www.google.com/earth/download/ge/

Continuous Improvement

In addition to learning from the tragedy at Coal Canyon, wildland fire-management organizations must strive to learn from how they study and present such accidents to the fire community. Help us continuously improve by providing your feedback regarding the Coal Canyon Serious Accident Investigation and associated learning tools. Please follow the link below and fill out the brief questionnaire. Your anonymous responses will help us improve this process and better serve the fire community.

Coal Canyon SAI Feedback Questionnaire (for use by federal employees only)

Appendix A – Chronology of Events

August 11, 2011

Fire start date and time: Lightning strike, July 27, 2011, at 1722.

Approx Time	Event
Initial Dispatch	
1303	County 911 center pages out Volunteer Fire Department.
1309*	Helo1 is dispatched to fire by Great Plains Dispatch (GPC).
1310*	E2 and E3 are ordered to respond to the fire.
1319*	Helo1 notifies GPC that they are en route, eta 9.5 minutes
1328*	Helo1 estimates size at ¼ to ½ acre and requests two additional type 6 engines.
1328*	GPC dispatches E5. *Note: This SAI report designates engines as E1 through E8, based on order of arrival (not order of dispatch).*
Initial Action on the Fire	
1333*	Helo1 orders a hand crew.
1335	E1 establishes radio contact with E2 and advises them on best access.
1340*	Helo1 lands to drop off two crewmembers, who walk down toward the fire.
1342	Helo1 guides E2 toward the fire.
1344	Helo1 contacts GPC, orders two additional type 6 engines, asks about status of SEAT (unavailable), notifies will set up a helibase and attach bucket.
1350	E1 is on scene.
1350*	Helo1 crewmembers arrive at the western edge of the fire and tie in with E1 and E2.
1351*	One of the Helo1 crewmembers takes command as IC(b) (6). The group discusses tactics and escape plans. The engines turn around to face the direction they came in. E2 parks near the fire's western edge; E1 parks approximately 70 yards behind them.
1406*	IC(b) (6) reports fire size up to GPC. The Coal Canyon fire is 1½ acres with flame lengths 0 to 3 feet.
1409*	E3 arrives. E3 crew cuts a turnaround spot where the road goes through a draw and backs toward E2. E3 crew leader ties in with E2.
1411*	E4 arrives on scene.
1413*	Command channel switched to Cicero repeater.
1417*	Incident Commander role transfers between IC(b) (6), then to an IC(b) (6) and (b) (6)
1420	E5 arrives. Engines driving down Road 318 get congested at the turnaround spot in the draw.
1422	At the western edge of the fire, E2 begins to lay hose and E1 starts digging line along the right flank from the anchor point up toward Road 318. Helo1 crewmembers cut line on the

Approx Time	Event
	right flank and direct bucket drops along the left flank.
Vehicle Bottleneck	
1425*	E7 Captain is identified as the incoming IC(b), keeps E3 Captain as (b) (6)
1425*	(b) (6) and IC(b) establish contact, "We're down in the canyon dealing with the bottleneck," sa(b) (6) to the incoming IC(b) who is above the bottleneck of engines.
1425	Engines E3, E4, E5, E6, and E7 converge near the draw that will later become the entrapment site. The engines turn around, move, and park 400 yards east of the fire.
1429	IC(b) appoints an (b) (6). They, along with (b) (6) begin developing plans, scouting the fire, and moving down the road toward the western edge.
Immediately Before Accident	
1440~	(b) scouts along Road 318. He walks back up the road and discovers fire has crossed road near the main drainage. Torching trees block the hand crew's ingress from the meadow. On the left flank, (b) (6) has turned around and is heading toward Road 318. IC(b) continues scouting along the left flank.
1450	(b) finds a spot above the road, in front of E1's hand line. He orders E2 to disconnect from hoselay down right flank, pull forward, and engage the spot with water. E2 pulls forward and engages the spot. (b) moves back up the road to check the draw.
1450	E1 starts building hand line on spots above road.
1500-1503	ICT(—standing at a lookout location on left flank—orders an IC(, based on fire behavior and increasing complexity. He ends the (b) (6) assignment for the (b) (6)
1502	As(b) walks down Road 318 toward E2, he finds more spots above road in front of them. He directs all resources on Road 318 to pull back behind the western edge of the fire. A tree torches below the road and behind E2. (b) repeats his direction as he walks past E2 and towards E1. He checks the western edge of the fire as E1 pulls back.
1502	E2 crew leader returns from above the road where he was working on the spot fire. He joins the driver who is already in the engine.
Incident Within Incident	
1503	E2 drives forward.
1503	The third E2 crewmember is standing behind E2, between the spots and the main fire. He drops to the ground just as a wave of heat passes.
1504	E2 drives past the draw and is met by a wall of flame.
1504~	(b) (6) emerges on road from below.
1505	E2 reverses, then tries to turn around at wide spot, in the draw. Surrounded by heavy fire and smoke, the vehicle's engine cuts out. E2 crew leader has pulled out his fire shelter, the driver has difficulty accessing his. Crew leader pulls his shelter over driver and they share. They make a Mayday distress call on tactical channel and make contact with (b)
Rescue	
1505	E2 tries to contact Helo1 to request a bucket drop. Helo1 crewmember hears request and relays to Helo1 on A/G. Helo1 makes several passes along the road, attempting to locate

Approx Time	Event
	the engine.
1507	(b) reaches E2 crewmember lying on the ground, pulls him to his feet, and starts him running back towards E1.
1510*	IC (b) requests life flight response.
1512*	GPC notifies IC (b) they have also ordered ground ambulances. IC (b) notifies GPC that (b) has been assigned command of the incident within an incident (IWI).
1510	(b) and (b) (6) make multiple efforts to rescue E2.
1511	(b) makes radio contact with E2 and tells them to get out of the engine and run back towards E1.
1511	E2 crewmember escapes from E2 and runs to E1 with the assistance of (b) and (b) (6) First aid to two E2 crewmembers begins.
1511-1520	(b) (6) and (b) make repeated attempts (for a total of 10) to approach E2 to rescue the E2 crew leader. Helo1 makes four passes and is unable to locate E2. He drops water on the heaviest smoke in the drainage. Helo1 begins to reload for a second drop. (b) (6) requests E1 to move their engine towards to E2 to see if they can rescue the E2 crew leader, who is still in the engine. E1 drives to E2, which is fully engulfed by flame. E1 sprays water on the engine and into the cab, until driven back by heat and smoke.
Treatment and Transport of Injured	
1525	E1 backs down Road 318 and continues administering first aid to the injured crewmembers of E2. IC (b) arrives at road, and orders Helo1 to reconfigure for a medivac.
1525	Helo1 crewmembers begin to scout, then construct, an emergency landing zone.
1530*	(b) orders a South Dakota National Guard hoist-capable helicopter for extraction.
1543	(b) determines that the fire has subsided enough for E1 to drive out on Road 318.
1550	IC (b) orders Helo1 crewmembers to cease construction of helicopter landing zone and return to E1.
1600	E1 loads the injured firefighters. All personnel depart to the staging area. (b) and (b) (6) follow on foot. Injured firefighters arrive at the awaiting life flight helicopters.
1610	IC (b) command transfers to District (b) (6)(b) (6)(b) (6)(b) (6) upon arrival at the meadow.
1615*	E2 crewmembers are loaded into a life flight helicopter and leave for Rapid City.
1645*	Life flight helicopters arrive at hospital in Rapid City.

* Denotes times taken from dispatch records. Other records are approximate.

Appendix B – Fire Behavior Analysis

Topography

The fire was lightning-caused, and it ignited in a steep box canyon on the lower quarter of the slope. The canyon has intersecting gullies that form a network in the bottom of the drainage. Slopes range from 30% to 40%. The canyon runs generally east–west, and the road that traverses the canyon is about one-third of the way up from the canyon bottom and the south side of the canyon, with a northern exposure.

The engine entrapment occurred where the road goes through a narrow steep drainage/chimney. This chimney funneled the fire so that it spread rapidly up the hill with high intensity.

Climate

During the winter of 2010–2011, the Black Hills received a significantly above average snowpack. Above average precipitation persisted through the spring in the form of rain. These conditions created higher-than-normal soil moisture and delayed green-up by several weeks. The summer drying/curing process had begun, but it was later than normal.

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CLIMATE REPORT
NATIONAL WEATHER SERVICE RAPID CITY SD
231 AM MDT FRI AUG 12 2011


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...THE CUSTER COUNTY AIRPORT SD CLIMATE SUMMARY FOR AUGUST 11 2011...

CLIMATE NORMAL PERIOD 1981 TO 2010
CLIMATE RECORD PERIOD 9999 TO 9999


WEATHER ITEM   OBSERVED TIME   NORMAL DEPARTURE LAST
                VALUE   (LST)  VALUE  FROM      YEAR
                                       NORMAL
................................................
TEMPERATURE (F)
 YESTERDAY
  MAXIMUM         81    121 PM  79      2        88
  MINIMUM         48   1254 AM  51     -3        51
  AVERAGE         65            65      0        70

PRECIPITATION (IN)
  YESTERDAY        T             0.07  -0.07     0.00
  MONTH TO DATE    2.78          0.74   2.04     0.77
  SINCE JUN 1      7.51          6.40   1.11     7.30
  SINCE JAN 1     17.39         13.51   3.88    16.23
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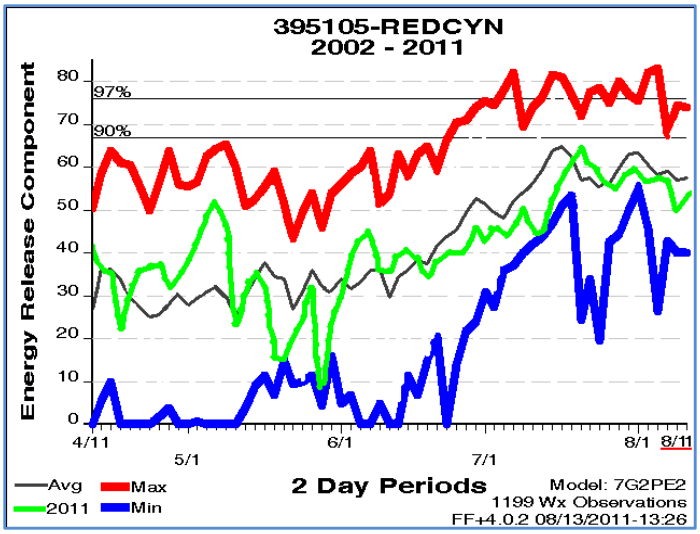
Energy Release Component, ERC, is a measure of the overall dryness/flammability of both live and dead fuels. Higher ERC measurements mean higher potential fire intensity. The Red Canyon Remote Automated Weather Station (RAWS) Fuel Model G ERC for the fire area was 54 that day while the historical average for that date is 58.



Fuels

On the north aspect, the entrapment site, the trees are primarily ponderosa pine ranging from saplings to pole-sized. Density varies from a moderate density in the larger trees to a high density in the saplings. There are also Rocky Mountain junipers in the drainage bottoms. On the slopes outside of the gullies, there is a uniform duff layer caused by ponderosa pine needle-cast. The gullies have heavy live and dead fuel concentrations on the bottom and light to no fuel loadings on the side. There is a light grass component on the site and on the north aspect where the majority of this grass was still green. There have been no timber harvests or fuels treatment on the site, resulting in high stand density and a low down-dead woody fuel loading. On the south aspect, the quantity of fuels decrease and the grass fuels were almost completely cured.

Weather

The conditions forecasted in the morning National Weather Service Fire Weather Forecast for the southern Black Hills were:

- Maximum temperature: 77-87°
- Minimum humidity: 26-40%
- Winds south: 5 to 10 mph, shifting to the west 5 to 15 mph in the afternoon

The observed afternoon weather at the Red Canyon RAWS was:

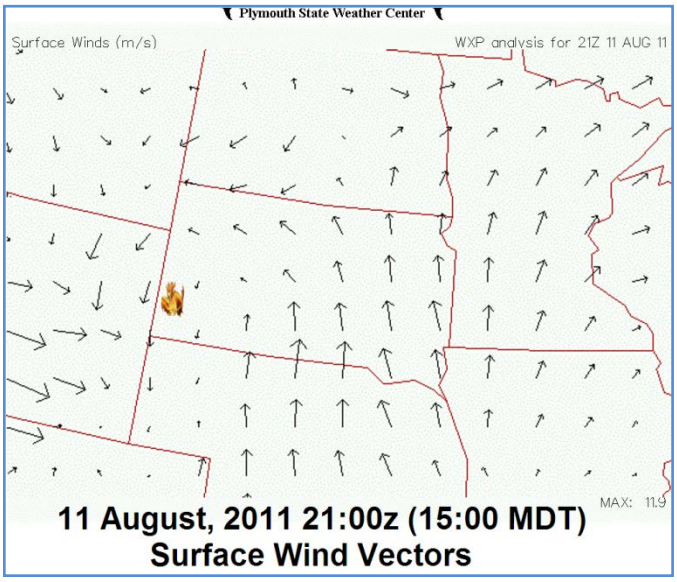
- Maximum temperature: 92°
- Minimum humidity: 16%
- Winds south: 4 to 8 mph, gusting to 20 mph

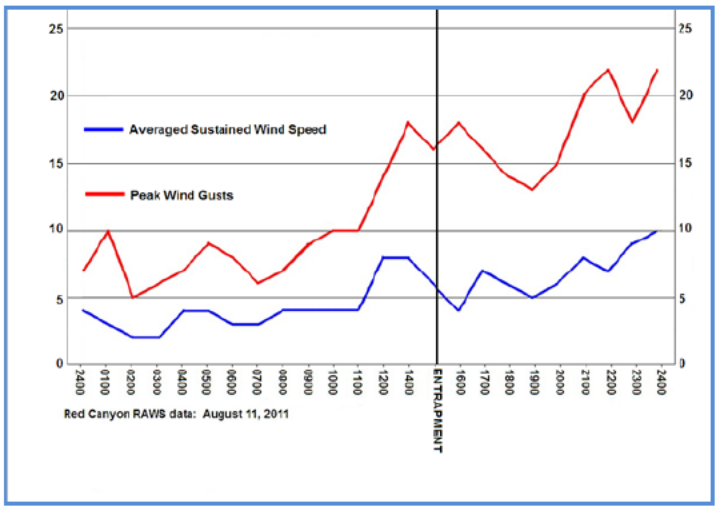
A predicted weather disturbance to the west had resulted in a Red Flag Warning for eastern Wyoming, but those conditions were not forecast to extend into western South Dakota. Weather observations near the fire indicate that a Red Flag Warning was not warranted.

There were no reports of any weather observations taken on site until a spot weather forecast was requested at 19:22.

At the time of the entrapment, the fire was located in the center of a low-pressure system and under an associated dry line.

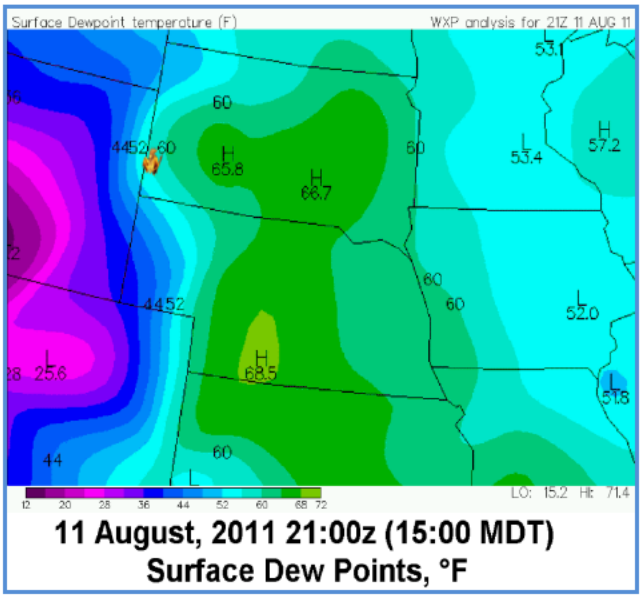
Being in the center of a low-pressure system is somewhat analogous to being in "the eye of a storm." It is the center of a vortex and winds tend to be light and variable.

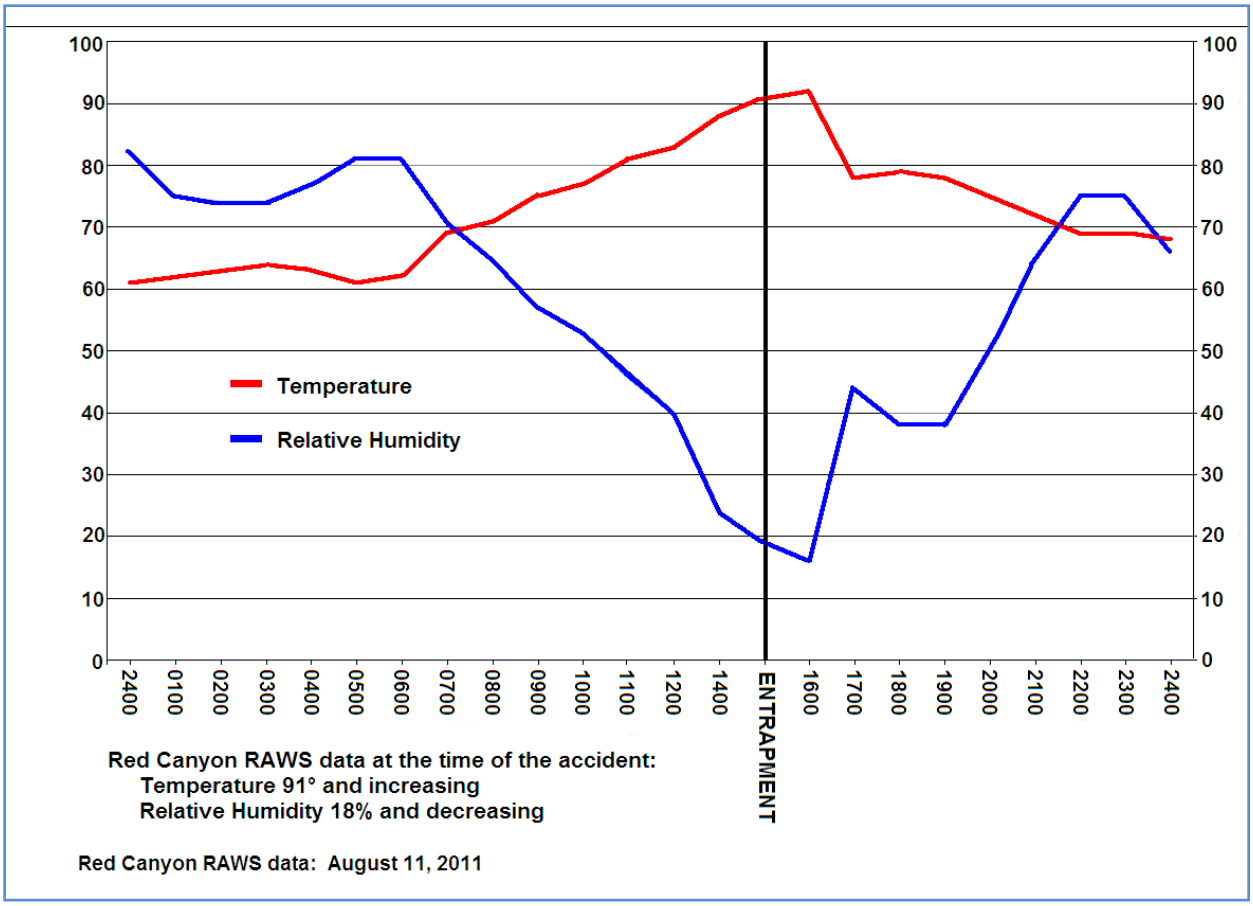




General winds reported as being light to moderate up slope, up valley. Firefighters at the opposite end of the fire from the entrapment did not notice significant wind conditions. The helicopter (b) reported that winds above the surface were never strong or gusty, even when he was flying over the fire during the entrapment. All of the strong winds reported were on the surface and in the immediate vicinity of single-tree or group torching, or near the entrapment chimney.

A "dry line" is a boundary separating moist and dry air masses. It typically lies north-south across the central and southern high Plains states, where it separates moist air from the Gulf of Mexico (to the east) and dry desert air from the southwestern states (to the west). The dry line typically advances eastward during the afternoon and retreats westward at night. The movement of a dry line over the fire area accelerated the decrease in the relative humidity and fine fuel moistures, and the increase in fire activity.





Firefighters reported seeing smoke from the fire rising slowly until approximately 14:00. After that time, the smoke started to rise more rapidly and fire intensities increased. This indicates decreasing atmospheric stability and increasing surface ventilation.

None of the firefighters interviewed reported noticing anything unusual or unique about the weather conditions.

Fire Behavior

The fire was ignited by lightning on July 27, 2011. The fire escaped detection until August 11, when warmer, drier weather caused the fire to start spreading. The initial size-up from the helicopter was:

- ¾ to 1 acre,
- Fuel models 9 and 2,
- Flame lengths of 1 to 3 feet,
- White to gray smoke, and
- Spread potential moderate to high.

Firefighters reported light-colored smoke slowly rising from the fire until around 14:00. Then, fire activity increased, the smoke became darker, and the surface winds increased going upslope.

The fire spread was primarily a combination of surface spread and single-tree and jackpot torching. The only area with a sustained crown run was from the bottom of the entrapment chimney to the top of the ridge. This run was narrow and slope driven. (This area reburned the next day, which altered the burn patterns on the ground.)

Estimated Fire Spread Progression

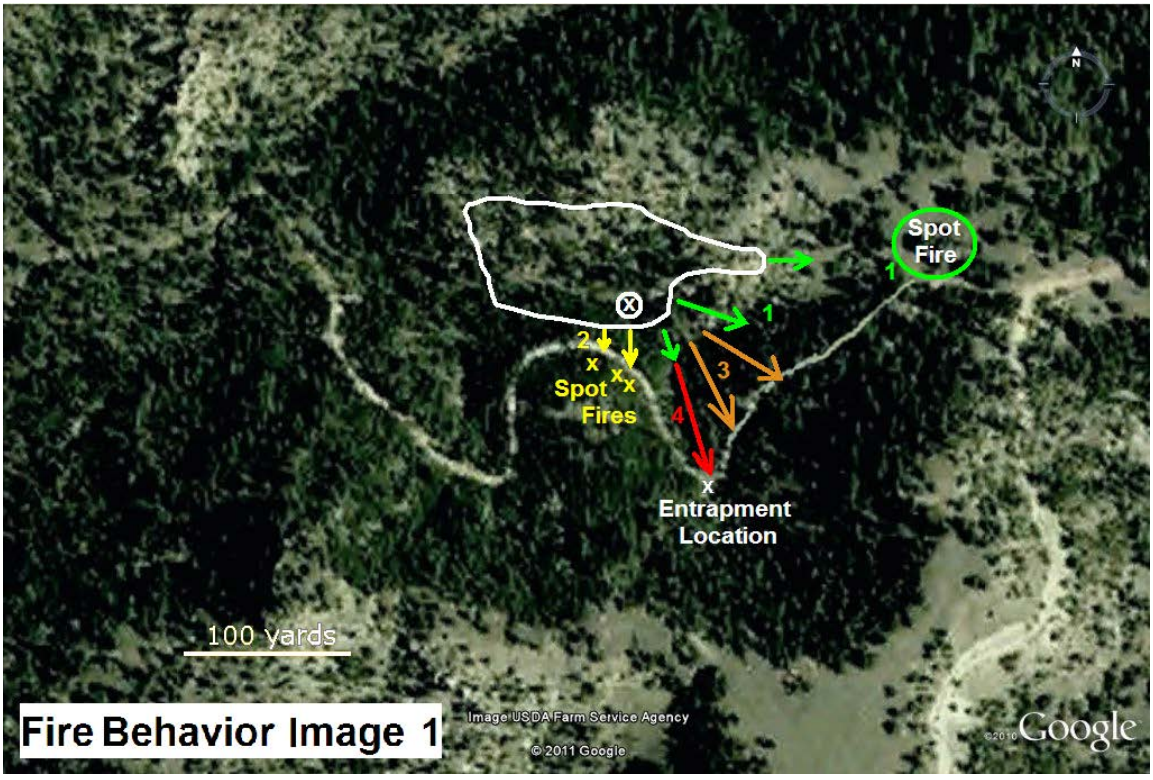
The following two images illustrate the progression of fire spread on the right flank. The white outline represents the estimated perimeter during the arrival of the initial attack units. Initially the fire was reported to be primarily creeping with 1- to 3-foot flames. Following is the estimated timeline for following fire behavior images:

1440 Fire activity increases in the bottom of the canyon, and a spot fire develops east of the fire.

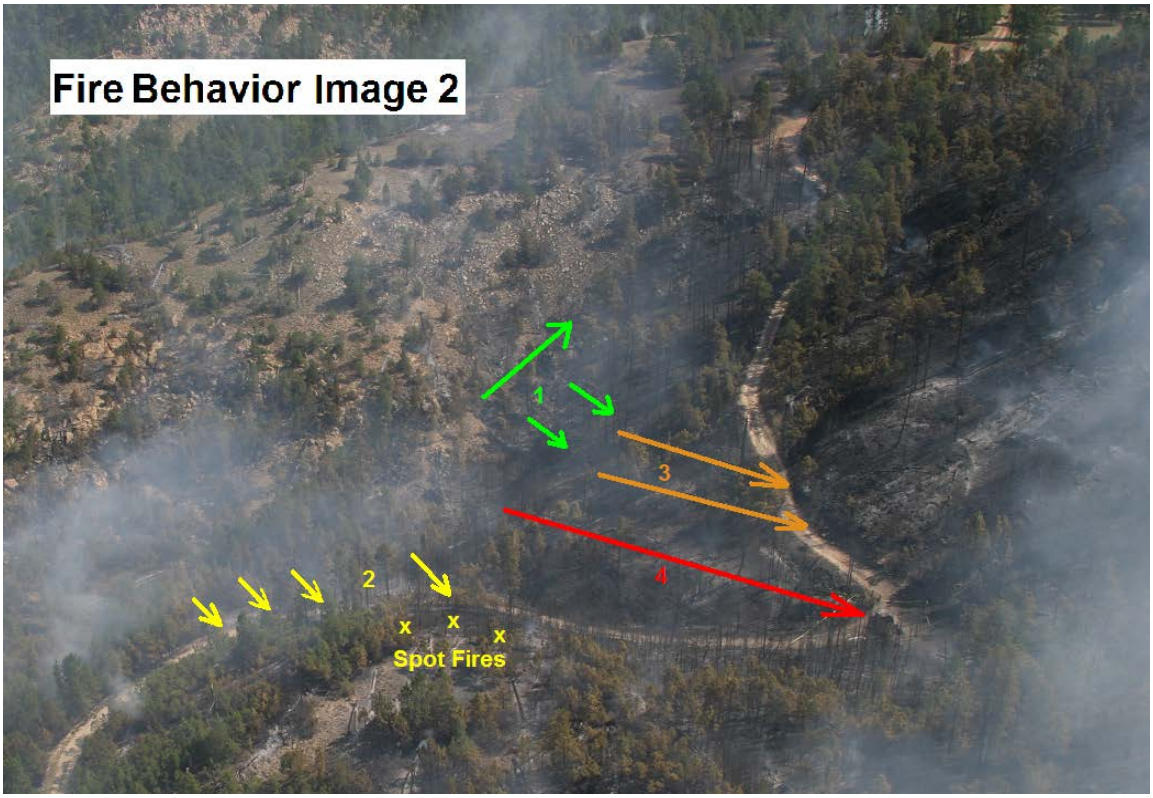
1450 The fire becomes active near the road on the south end of the fire. Several spot fires occur near the road. At the same time, the fire progresses northward along the drainage bottom.

1503 The fire flares up below the road at the bottom of the steep pitch, making the road unusable as an egress.

1505 The fire in the bottom of the chimney moves into the crown and crosses the road at the location of the entrapment.



Fire Behavior Image 1



Analysis

When the initial attack resources arrived on the fire, the behavior they observed was described as benign fire behavior. As the day went on, the air and fuel temperatures increased, relative humidity and fine fuel moistures decreased, and the diurnal wind speeds increased. These factors combined to increase fire intensities. As the fire intensities increased, the increase was localized and in pulses. There is no evidence of a single major fire run or event that could be characterized as a transition into large-scale extreme fire behavior. Personnel on other parts of the fire, including two that were less than one tenth of a mile from the entrapment, felt comfortable with their safety, and were confused when they learned that an engine was in trouble.

The engine entrapment occurred where the road crosses a steep narrow gully mid-slope. This gully served to channel hot gasses upslope, which increased the fire's intensity and rate of spread. This type of topographic feature is referred to as a "chimney" and the acceleration of a fire in that type of terrain is known by wildland firefighters as the "chimney effect."

The fire behavior prior to the entrapment was a series of flare-ups, single-tree torching, group torching, short-range spotting, and, just prior to the entrapment, short-crown runs. The fire movement up the chimney was the most intense behavior observed that day. The lack of an overpowering wind event resulted in fire spread and intensity caused by diurnal winds, topography, and fuels. This resulted in pulsating condition with no constant fire behavior. One firefighter described it as "calm to angry and then back to calm."

Appendix C – Personal Protective Equipment Analysis

This report is based on witness statements, photographs, examination of the entrapment site, and examination of the equipment found or used at the entrapment site.

Entrapment Site

Engine 2 – E2 Crew Leader and E2 Driver

This site was exposed to high intensity, long duration heat produced by the vegetative flame front through the draw and the ensuing vehicle fire. The E2 crew leader shared a fire shelter with E2 driver inside the cab of E2 for 5 to 6 minutes before E2 driver exited the engine.

Third E2 Crewmember

The third E2 crewmember was lying across the road at a 45° angle with his head facing the draw and his feet towards the road cut bank. This roadbed site was exposed to mostly high intensity radiant heat. Directly below and above the spot where the crewmember lay for 3 to 4 minutes without deploying his fire shelter, tree crowns of short ponderosa pine were consumed by fire.

Area where the third E2 crewmember laid face down on the roadbed. Notice the torched trees both below and above the road.

Fire Shelters

E2 Crew Leader: The crew leader was found with his fire shelter wrapped around him. He was lying across the front seat of E2; his upper body was on the driver's side. Evidence of delaminated aluminum foil and silica cloth was found throughout the shelter. Most of the aluminum foil and fiberglass material of the shelter had burned away; much of the silica cloth remained intact, but some of the cloth was brittle.

E2 Driver: His fire shelter, accordion folded in the same shape as when packaged, was found on the floor of the driver's side of E2. The shelter's PVC bag had burned away, much of the shelter's aluminum foil had melted away, and much of the fiberglass inside the shelter was brittle. The exposed edges of the silica cloth were brittle; the inside folds remained intact.

Third E2 Crewmember: His fire shelter was found inside his fireline pack that was located on the road next to where he lay down.

(b) (6) He deployed his fire shelter to attempt rescue; he made numerous attempts to reach E2 while using the shelter. He reported that he shook open the shelter, put it over his head, and held it to his side. No signs of heat or structural damage were found on the shelter, and he reported no issues occurred when deploying the shelter.

(b) His fire shelter was found on the road near E2 crewmember. He reported that the fire shelter fell from his fireline pack (Wolfpack brand). He believes it fell out when he picked up the E2 crewmember. The shelter subsequently was run over by E1 during its attempted rescue.

Injuries and Personal Protective Equipment

E2 Crew Leader

It was reported that the E2 crew leader was fully equipped with all required personal protective equipment (PPE).

E2 Driver

Injuries: The E2 Driver received 4 square inches of second-degree burn to the back of his left hand. He reported that he was not wearing his gloves because he was driving. His hair and beard were singed.

Shirt: Compliant and certified to NFPA 1977, 2005 edition

- Manufacturer: Western Shelter Systems/Crew Boss
- Material: Nomex IIIA, 6 oz
- Size: XL
- Condition: Lower right sleeve showed two areas of dye sublimation (2 square inches total)

Pants: U.S. Forest Service specification 5100-92

- Date of manufacture: Not legible
- Size 36 – 40 X 30
- Condition: ½-inch and ¼-inch spots of dye sublimation on the lower right leg, exposed thread ends, exposed thread ends of a blown seam, fabric fuzz from waistband to knees, and medial edges of rear pocket showed dye sublimation—condition of the pants is estimated as similar to what might result from a one-second flash fire

Boots: Hawthorne, leather

- Condition: No signs of heat

Hardhat: Bullard 911H

- Condition: Hardhat was embedded within molten metal that drained from the burned remains of the engine.

Dye sublimation (orange color) of the fabric fuzz and edges of rear pockets.

Third E2 Crewmember

Injuries: The third E2 crewmember's total burns equal 13% of body surface

- Back of left arm from wrist to shoulder blade received second- and third-degree burns
- Right elbow received second- and third-degree burns
- Lower legs and calf area received second- and third-degree burns
- Inner thigh left leg received narrow strip of second-degree burn
- Hips received small area of second-degree burn
- Face and nose received first- and second-degree burns
- Thumb and first finger received small area second-degree burn

Shirt: U.S. Forest Service specification 5100-91D

- Date of manufacture: Not legible
- Material: 98% Aramid blend, 2% anti-stat
- Size: Medium
- Condition: Material of the back of the left arm from the cuff to the shoulder showed areas of dye sublimation and scorch; material on the right elbow showed dye sublimation

Pants: Compliant and certified to NFPA 1977, 2005 edition

- Manufacturer: Barrier Wear, Inc.
- Date of manufacture: 08/2007
- Material: Kevlar/Nomex (Aramid) blend, rip-stop weave
- Size: Medium/32
- Condition: Lateral lower left pants leg showed a 24-square-inch area of dye sublimation; lateral thigh of left pants leg showed 28 square inches of dye sublimation

Gloves: U.S. Forest Service specification 6170-5C

- Size: Medium

- Condition: Leather showed no signs of heat; gloves were still soft and pliable

Boots: Logger style, compliant and certified to NFPA 1977, 2005 edition

- Manufacturer: White's Boots, Inc.
- Date of manufacture: 2010

Condition: Showed no signs of heat

Dye sublimation (orange color) on the left side of pants.

Dye sublimation and scorch on the back of the entire left arm and right elbow of shirt.

(b) (6)

Injuries: The IC (b) received blisters on his nose, left cheek, and left side of jaw area. He reported that he received these injuries during his first attempt to reach E2. He made this first rescue attempt without using his fire shelter; he made subsequent rescue attempts using his fire shelter for protection.

Shirt: U.S. Forest Service specification 5100-91

- Date of manufacture: Not legible
- Material: Aramid blend 98%, 2% anti-stat
- Condition: Dirty

Pants: U.S. Forest Service specification 5100-92M, Type II

- Date of manufacture: 2010

- Material: Para-aramid blend (60/40 Kevlar/Nomex IIIA)
- Size: 32 – 36 Regular
- Condition: Lower right leg showed a small (½ inch) spot of full thickness dye sublimation inside a 1 square inch area of surface dye sublimation

Hardhat: Bullard 911H

- Compliant and certified to NFPA 1977
- Condition: Showed signs of heat–left side of the hardhat brim received enough heat to soften and droop slightly

Gloves: U.S. Forest Service specification 6170-5D

- Condition: No signs of heat

There is a slight droop of the brim of (b) (6) *hardhat caused by the high heat environment of the rescue attempts.*

(b) (6)

During the rescue attempts, (b) reported he was wearing all required PPE. He was medically evaluated later; he did not suffer any burn injuries. He did report that he had a few small ember spots of dye sublimation on his FR pants. (b) also reported that his fire shelter fell out of his fireline pack onto the road during rescue attempts. The fire shelter eventually was run over by E1; it was recovered later.

E1 Driver

During the rescue attempts, he received first-degree burn to the left side of his face, his left arm, and the left side of his back. He reported that in the high-stress environment, he forgot to pull down his face/neck shroud from the top of his hardhat (shirt, pants, face/neck shroud, gloves, and hardhat show no signs of heat).

Material—Conditions and Corresponding Temperatures:	
Silica cloth–brittle	Estimated 2,000 °F
Fiberglass–brittle	1,350 to 1,610 °F
Aluminum foil–melt	1,220 °F
Foil/Shelter cloth bond–delamination	500 °F
Aramid cloth–char	824 °F
Aramid cloth–stiff/brittle	710 °F
Aramid cloth dye–sublimation	450 °F
Hardhat polycarbonate–softens	325 °F

Discussion

(b) (6) reported that earlier in 2011, (b) (6)(b) (6)(b) (6) of the fire shelter deployment section of beginner firefighter training. He had demonstrated practice fire shelter deployment many times (b) (6) (b) (6) and had become very skilled at the task. During his rescue attempts, he deployed his fire shelter quickly and easily.

Recommendations

Recommended policy for equipment operators and drivers: Because work gloves are not designed for fine motor skills, equipment operators and drivers should be able to wear flame-resistant flight gloves during fire operations.

Firefighters need to be aware that if they deploy fire shelters inside a vehicle, they need to plan for a possible escape from the vehicle at some point. They may be able to escape the area, or they may need to deploy their fire shelters on the ground. These movements may expose firefighters to extreme air temperatures, temperatures that may damage their airway. Firefighters should take and hold a deep breath before making such movements.

Additional study is needed to determine guidance on how to deploy a fire shelter inside a vehicle.

Appendix D – SAI Team Members

Coal Canyon Fire Accident Investigation Report
Hell Canyon Ranger District,
Black Hills National Forest, South Dakota
August 11, 2011

Charles L. Myers: Investigation Team Leader/Regional Forester, FS, Region 9

Randy Draeger: Chief Investigator/Senior Safety Advisor, FS, Region 4

Investigation Team Members:

Antoine Dixon: Team Leader Trainee/National Director, FS, Job Corps

Cliff Dahl: State of South Dakota Liaison/Fire Technical Specialist, South Dakota Department of Public Safety**,** Deputy State Fire Marshall; Captain, Rapid Valley Volunteer Fire Department

Jim Saveland: Human Performance–Fire Technical Specialist/Program Manager for Human Factors and Risk Management, FS, Rocky Mountain Research Station

Brad Mayhew: Organizational Learning and Human Performance, Fire Technical Specialist, Writer/Editor/FS, Los Padres National Forest

Gary Brown: Fire Operations/FS, Fire Staff Officer, Payette National Forest, Region 4

Tony Petrilli: Personal Protective Equipment/FS, Missoula Technology and Development Center

Ben Murphy: GIS, Fire Technical Specialist/FS, Lolo Hotshots–Geospatial Equipment and Technology Application Group, Lolo National Forest

Erin Newman: Documentation Specialist/FS, Fire and Aviation Management, Washington

Karen Mora: Union Representative–Editor/Acting NFFE Local President 927–FS, EMC Publishing Arts, Washington Office Detached

Tim Foley: Fire Behavior Analyst, Colorado State Forest Service

Acknowledgments: The SAIT would like to thank the employees of Black Hills National Forest and the R2 Safety Office for their support to the team during this difficult tragedy. The team would also like to thank Steve Holdsambeck and Larry Sutton for providing advice, council and vision in the development of the report.