Informational Summary Report of Serious or Near Serious CAL FIRE Injuries, Illnesses and Accidents

GREEN SHEET

Burn Over Fatalities

July 26, 2018

Carr Incident

18-CA-SHU-007808

18-CA-SHU-007962

California Northern Region

SUMMARY

On July 26, 2018, a private dozer operator (Dozer 1) and Marin County Engine Company (ENG1) were assigned to the Carr Fire in Shasta County, California. At approximately 5:30 p.m., the fire transitioned from a fuel dominated fire to a wind-driven fire, resulting in a combination of increased fire behavior and extraordinary fire weather conditions. During the progression of the fire's rapid spread through Old Shasta, Keswick, and into the City of Redding, firefighters were engaged in rescues, evacuations, structure defense, and suppression operations. As the wildland fire advanced into the City of Redding, Redding Fire Department personnel and apparatus responded, including a Fire Prevention Inspector (FPI1). Within a timeframe of approximately 1 hour and 50 minutes, covering a 3-mile expanse, the following events transpired: Dozer 1 was burned over while improving dozerline; ENG1 firefighters suffered minor burn injuries while engaged in structure defense; and FPI1 was caught in a fire tornado while engaged in community protection. Dozer 1 and FPI1 suffered fatal injuries.

CONDITIONS

The following conditions provide an overview of the changing fire environment leading up to and including the events on July 26, 2018.

Weather Observations

Mule Mountain RAWS is approximately 4 miles from the accident sites at an elevation of 2,044 feet. On July 26, at 6:00 p.m., the RAWS site recorded 111°F with relative humidities lowering to 7%. Gusty west-northwest winds picked up during the late afternoon and evening hours. Gusts as high as 21 mph were recorded.

Weather Narrative

The northern Sacramento Valley has been plagued by abnormally dry conditions since last fall. As of July 26, 2018, the Redding airport was 14.09 inches behind normal for the water year (58% of normal since October 1st). The last significant rain event occurred on May 25, 2018, leaving June and July without measurable precipitation.

On July 25, breezy conditions developed in the evening in response to a persistent thermal low over the northern Sacramento Valley. Thermal lows are areas of low pressure produced primarily by warm surface temperatures. Winds were downslope (west-northwest) off the coastal range and ran strongest along aligned drainages. These winds were especially enhanced due to the strength of the thermal low and its associated hot temperatures in the valley, and the increasing cooler and denser airmass toward the coast.

July 26 was a record hot day. The Redding airport tied its daily record at 113°, while relative humidity was in the single digits. Conversely, temperatures along the coast were 5° below normal in Eureka (59°). This created an enhanced thermal gradient due to the 54° temperature difference between the coast and the valley. The thermal low in the valley developed throughout the day. Following the hottest period of the day, gusty downslope winds developed off the coastal range toward Redding.

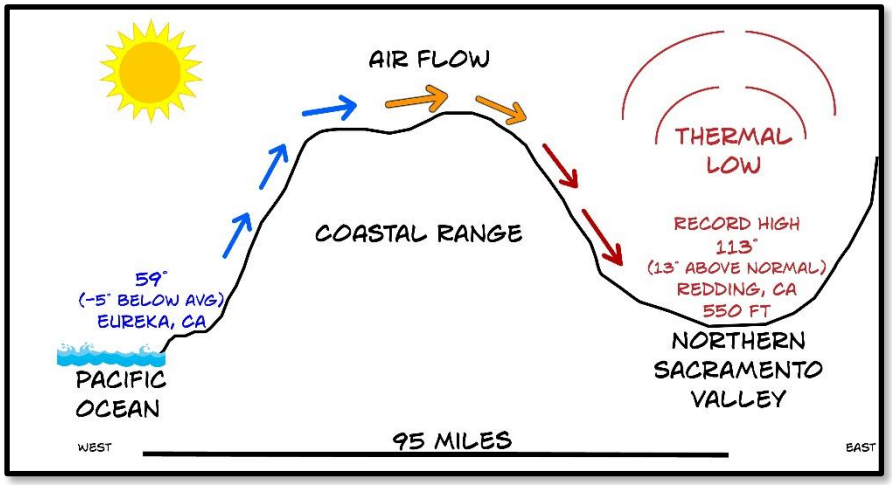


Figure1- As the sun sets and temperatures cool, the thermal low in the Sacramento Valley begins to fill by drawing air from surrounding areas. The western portion of the valley draws progressively cooler and denser air from over the coastal range. This results in increased winds due to downsloping, and increased temperatures due compressional warming of the airmass.

Fuel Types
The general area is characterized by mixed conifer-California black oak at higher elevations progressing down to knobcone pine and manzanita intermixed with annual grasses at the lower elevations. Fuel types adjacent to the western edge of Redding are primarily composed of pockets of manzanita with oak woodland and an annual grass understory.

Fire Behavior
On July 23, 2018, the Carr Fire started in the Whiskeytown Lake National Recreation Area, along Highway 299 near the Oak Bottom Marina, and burned northerly through French Gulch. Fire behavior was moderate, and suppression actions were primarily successful along Highway 299 and within the community of French Gulch. Fire spread was primarily influenced by topography and fuels.

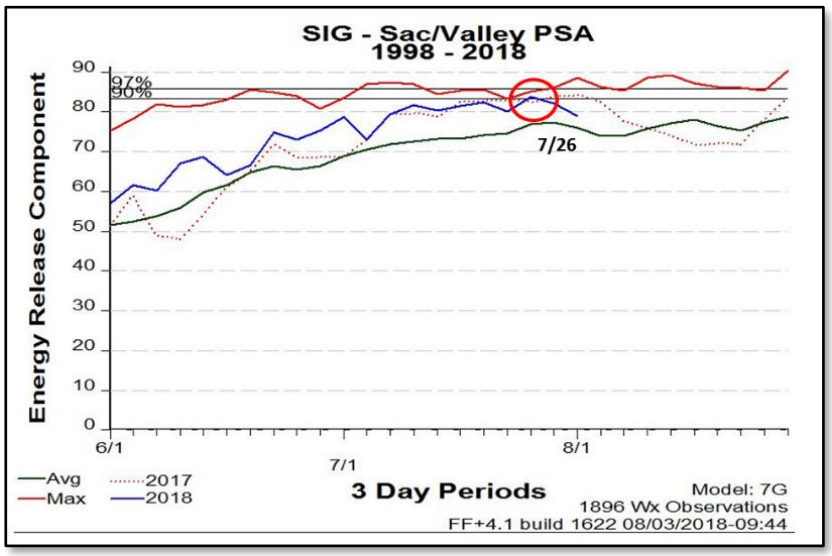


Figure 2- Energy Release Component values were near record highs for this time of year. 1,000-hour dead fuel moistures were also near record lows for this time of year.

On July 24, at approximately 5:00 p.m., west winds surfaced over the upper ridgetops, pushing uncontained portions of the fire 2.5 miles to the east in approximately 6 hours.

On July 25, at approximately 5:00 p.m., west winds resurfaced, pushing the fire east an additional 2 miles in approximately 7 hours. The fire also progressed southerly 2 miles down the Whiskey Creek drainage back to Whiskeytown Lake.

Around midnight on July 26, westerly winds again developed and the fire travelled 8 miles in 7 hours progressing southeast from Whiskeytown Lake National Recreation Area and easterly past Old Shasta. Fire spread was due to a combination of wind-driven and fuels-driven runs.

During the day on July 26, fire behavior moderated under a ridge of high pressure with little wind. The fire was mainly fuels-driven with slope runs. At approximately 5:30 p.m., west winds resurfaced, pushing the fire rapidly to the east. Major fire runs occurred in more than one location, and the fire was observed moving at 2.5 miles per hour with spot fires becoming established over one mile ahead of the main fire front.

Additionally, a large fire plume developed over the area, reaching approximately 40,000 feet in height.

Fire Tornado

A large fire tornado was one of the primary causes of the entrapment and death of FPI1 on July 26, 2018. The fire tornado was a large rotating fire plume that was roughly 1000 feet in diameter at its base. Winds at the base of the fire tornado reached speeds in the range of 136-165 mph (EF-3 tornado strength), as indicated by wind damage to large oak trees, scouring of the ground surface, damage to roofs of houses, and lofting of large steel power line support towers, vehicles, and a steel marine shipping container within ½ mile of the entrapment site. The strong winds caused the fire to burn all live vegetation less than 1 inch in diameter and fully consume any dead biomass. Peak gas temperatures likely exceeded 2,700 °F.

Current understanding of how large fire tornados form and propagate suggests that necessary factors include high energy release rates, sources of vorticity (rotating air), and low to moderate general winds. All of these factors were present in the area of Buenaventura Boulevard on July 26. Observations from witnesses and other evidence suggest that either several fire tornados occurred at different locations and times, or one fire tornado formed and then periodically weakened and strengthened causing several separate damage areas.

Assessment of air flow in the area using a weather prediction model indicates it is likely that large amounts of vorticity were present due to a hydraulic jump phenomenon. The phenomenon creating hydraulic jumps can best be understood when observing water travelling down a dam spillway. As fast moving water flows down a spillway, a breaking wave forms when the high-speed water impacts the slower moving pool of water at the spillway's base. The breaking wave is called a hydraulic jump, and results in increased turbulence and vorticity. Hydraulic jumps occur in atmospheric conditions as well.

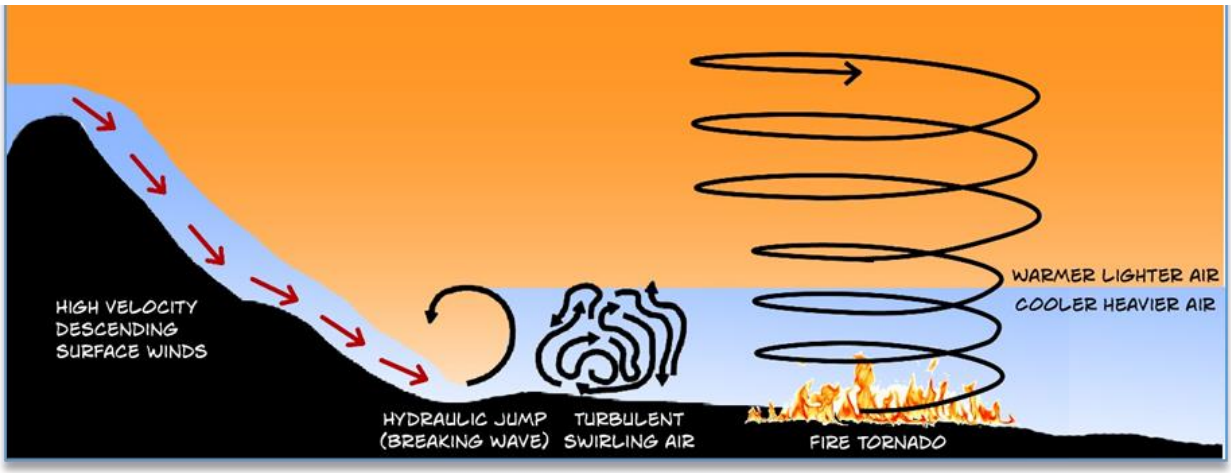


Figure 3- Hydraulic jump illustration

It is generally recognized by local residents in Shasta County that northwest downslope winds coming out of the terrain around the Whiskeytown National Recreational Area often form in the evening. This is due to thermal and pressure differences between the coast and the valley, which cause downslope winds, accelerating cool winds. These winds impact a stationary airmass in the valley floor causing an atmospheric hydraulic jump. Computer simulations of large scale atmospheric flow for this area support this conclusion.

Picture 1- Example of swirling air generated by turbulence (Carr Fire burning down to Sacramento River).
Click here to view video

Theoretical and experimental research shows that atmospheric hydraulic jump conditions cause very large increases in wind turbulence and vorticity. This likely provided the rotational air necessary for formation of the fire tornado.

Regardless of the primary factors that caused the fire tornado, the resultant fire behavior was unpredictable and unusual. It surprised many highly experienced firefighters. The rotating vertical plume appeared and behaved in many aspects like an EF-3 scale tornado.

Road Conditions
Dozer 1 was mid-slope travelling downhill on a previously constructed dozer line when the burn over occurred.

FPI1 was driving on Buenaventura Boulevard between Lake Keswick Estates and the Land Park/Stanford Hills Subdivisions when the accident occurred. Buenaventura Boulevard is a one-way-in, one-way-out paved road that terminates at Land Park and Stanford Hills.

Structural Features
Marin County Engine 1 (ENG1) was engaged in defense of a single-family residential structure within a rural area of Shasta County.

Make/Model of Equipment
2002 John Deere 700H LT with Open Cab (Dozer 1)
2016 Ford F-150 Crew Cab Pickup Truck (FPI1)

SEQUENCE OF EVENTS

*****The following sequence of events chronicle three separate incidents which occurred on the Carr fire during the early evening hours of July 26, 2018.*****

On July 23, 2018, at approximately 1:14 p.m., the CAL FIRE Redding Emergency Command Center dispatched a vegetation fire near Whiskeytown Lake in Shasta County, California. Due to the location of the fire within the Whiskeytown National Recreation Area, Unified Command was established between CAL FIRE and the National Park Service. As the fire increased in size and complexity, a decision was made to order a CAL FIRE Incident Management Team (IMT). On July 26, 2018, at 6:00 a.m., the IMT assumed command of the incident.

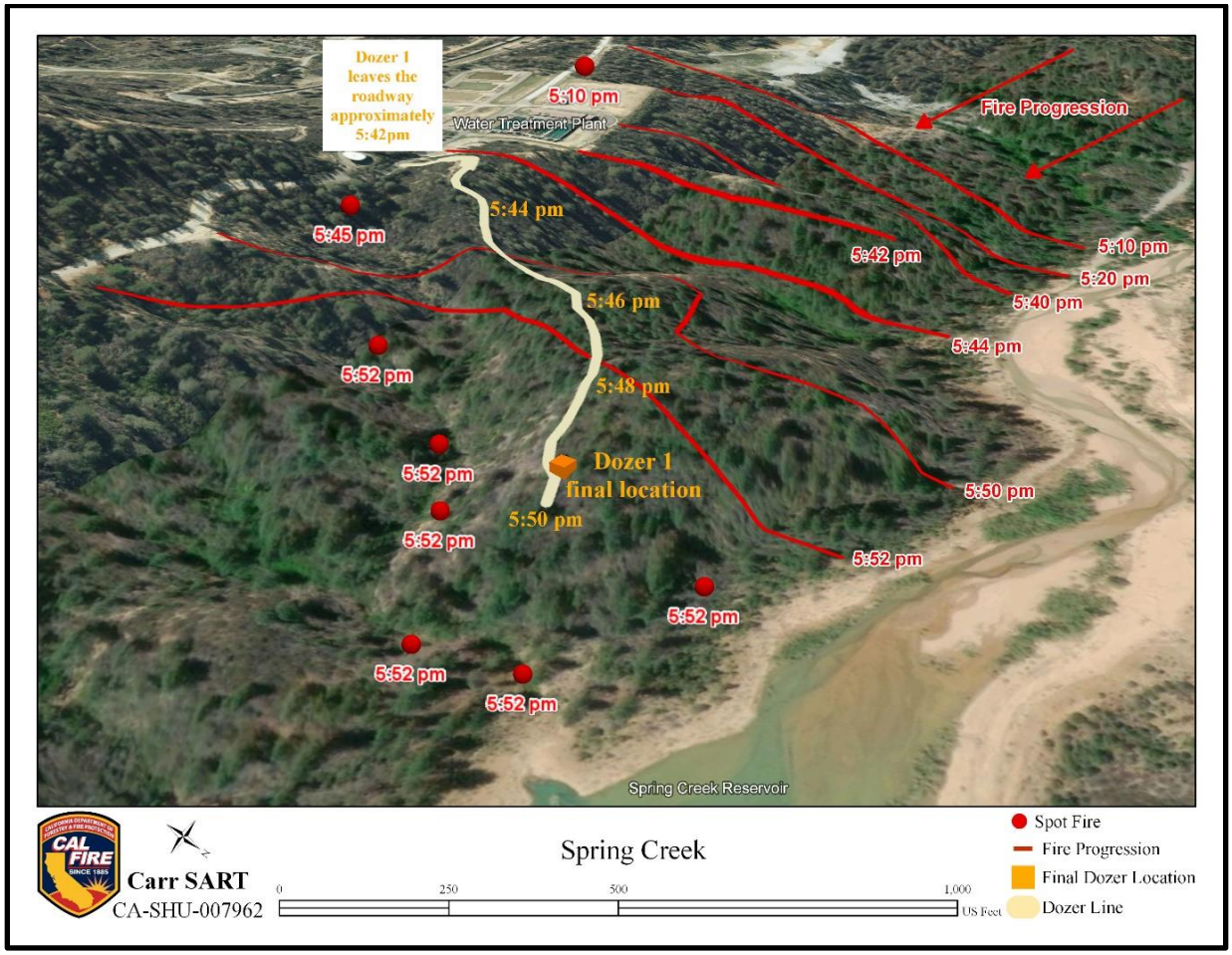
Spring Creek (Dozer 1)
On July 26, 2018, at approximately 5:00 a.m., one CAL FIRE dozer and two private dozers were assigned in Division O (DIV O) to explore contingency line options in the area of the Buckeye Water Treatment Plant. Due to mechanical issues with one of the private dozers, the CAL FIRE dozer and the second private dozer began constructing line east of the water treatment plant down toward Spring Creek Reservoir.

As the dozers constructed line, the area became too steep and overgrown to tie in with the reservoir. The dozers completed approximately 1,220 feet of line before stopping approximately 500 feet above Spring Creek. The CAL FIRE dozer operator communicated to the Division Supervisor that the line would not be viable and was incomplete.

At approximately 7:00 a.m., a briefing occurred for the day shift operational period resources at the Carr Incident Command Post. In attendance were personnel assigned to a private hire dozer (Dozer 1) including the owner, transport driver, and operator who had arrived at the incident base earlier that night. Following the briefing, Dozer 1 remained at the Incident Base in Anderson, California pending an assignment.

At approximately 3:00 p.m., Dozer 1 responded to Division V, a Division formed earlier in the day following the morning operational briefing. Dozer 1 was given instructions to proceed to the intersection of Benson Drive and Rock Creek Road. Upon arrival, the Division Supervisor (DIVS V) directed the dozer transport to the Buckeye Water Treatment Plant. DIVS V told Dozer 1 he would be working for a CAL FIRE Handcrew Strike Team Leader (CREW1 Leader).

At approximately 5:00 p.m., Dozer 1 arrived at the water treatment plant and unloaded from the transport. The dozer operator put on Personal Protective Equipment. He then conducted a radio check and confirmed he was on the assigned tactical frequency. During this time fire behavior was moderate with isolated torching.



Aerial overview sequencing approximate timelines of events.

At approximately 5:30 p.m., Dozer 1 drove east on the water treatment plant access road and had a face-to-face meeting with CREW1 Leader. CREW1 Leader instructed Dozer 1 to improve dozer line from the road down toward Spring Creek Reservoir. Prior to departing, CREW1 Leader warned Dozer 1 not to proceed down the dozer line if it was unsafe or if Dozer 1 was uncomfortable with the assignment. (CREW 1 Leader was unaware this stretch of dozer line was the contingency line previously abandoned by the CAL FIRE dozer earlier in the morning.)

After the assignment was given to Dozer 1, CREW1 Leader drove west back to Benson Drive in order to update DIVS V on the operational plan. Within the vicinity of the water treatment plant, there were a total of two handcrews and seven engines working. At approximately 5:40 p.m., as Dozer 1 drove east past the water treatment plant, the fire was increasing in intensity east of Benson Drive with isolated torching and spotting. Additionally, winds were increasing from the west-northwest.

Dozer 1 turned off the water treatment access road and proceeded down the existing dozer line toward Spring Creek Reservoir. Around this same time, firefighters at the water treatment plant noticed a rapid increase in fire activity.

Picture 2 taken at 5:44 p.m.- Travel route of Dozer 1 up water treatment plant access road to dozer line.

At approximately 5:44 p.m., the fire jumped the top of the dozer line near the access road (picture 2). Multiple spot fires became established in the area. Approximately two minutes later, CREW1 Leader returned to the water treatment plant and asked where Dozer 1 was located. CREW1 Leader was told that Dozer 1 had proceeded down the dozer line. CREW1 Leader made several attempts over the radio to contact Dozer 1 in order to tell him to “get out of there”.

Two firefighters from a local government engine strike team were positioned near the top of the dozer line and recognized the urgency of the situation. They attempted to chase Dozer 1 on foot, but were unable to make access due to increasing fire activity.

CREW1 Leader was finally able to establish radio contact with Dozer 1. Dozer 1 stated he could not get out because he was cut off by the fire, and he would push down instead. Sometime between 5:46 p.m. and 5:50 p.m., radio traffic was heard from Dozer 1 that he was on a bench attempting to make a safety zone. Dozer 1 was also requesting water drops.

At approximately 5:50 p.m., a CAL FIRE Helicopter (Copter 1) began making numerous water drops through the smoke in and around Dozer 1’s last known location. Copter 1 notified the Helicopter Coordinator (HLCO) of Dozer 1’s situation, and HLCO assigned three more helicopters to drop water in the area. HLCO noticed a dramatic increase in fire behavior; however, the helicopters continued to make water drops as conditions worsened. At approximately 6:08 p.m., Copter 1 was forced to land due to a temperature warning light resulting from the high atmospheric temperatures. Approximately 30 minutes later, Copter 1 returned to service and continued to drop water on Dozer 1’s location.

Picture 3 taken at 6:08 p.m.- Fire activity looking east down water treatment plant access road.

CREW1 Leader attempted to contact Dozer 1 several more times on the radio without a response. Due to increased fire activity, CREW1 Leader and a CAL FIRE Engine Strike Team Leader (STEN1) exited the area to the east. At approximately 6:10 p.m., CREW1 Leader and STEN1 had a face-to-face meeting with DIVS V and advised the Division Supervisor of the burn over. At approximately 6:13 p.m., DIVS V advised Branch III of the burn over.

After a clearing in the smoke, HLCO noticed Dozer 1 was engulfed with fire. HLCO did not observe any sign of a shelter deployment. After fire intensity decreased, two Fire Captains (FC1 and FC2) from the handcrew strike team attempted to approach Dozer 1's location, but they were forced to turn around due to heat and smoke. At approximately 7:00 p.m., FC1 was able to make access down the dozer line. FC1 confirmed that the dozer operator suffered fatal injuries during the burn over.

Picture 4- The final resting place of Dozer 1.

George Street (ENG1)

Fire activity continued to increase with spot fires and increasing winds from the west-northwest. Prior to the Dozer 1 burn over, approximately 1.25 miles to the southeast of the water treatment plant, a Marin County Engine Strike Team was engaged in structure defense on Division Y. The engines were working in the area of Rock Creek Road and George Street. At approximately 6:45 p.m., the Marin County Engine Strike Team Leader (STEN2) notified his resources of increased fire behavior, wind speeds, and spot fires.

A Marin County Engine Company (ENG1) scouted a house on George Street in preparation for structure defense operations. The ENG1 Fire Apparatus Engineer (FAE1) briefed his two Firefighters (FF1 and FF2). FAE1, FF1, and FF2 removed brush from around the house, extended a hose line off ENG1, and prepared for a defensive firing operation. All three crew members indicated the fire was at least 1000' away from them when they began their preparations.

At approximately 7:05 p.m., ENG1 personnel experienced increased heat, smoke, spot fires, and area ignition of the ornamental brush near the house and driveway. FF1 and FF2 dropped their tools and retreated toward ENG1, stopping for shelter behind an outbuilding. FF1 and FF2 noticed the hose flaps burning on the back of the fire engine as well as duff burning underneath. FAE1 retreated directly to ENG1 and received burns to the back of his hands as he reached up for the door handle. FAE1 entered ENG1 and activated the air horn. FAE1 repositioned ENG1 to provide safer

entrance for FF1 and FF2. As FF1 and FF2 made their way back to the fire engine, they suffered minor burns to their faces.

Once FF1 and FF2 were back in ENG1, FAE1 made several attempts to exit the property, but ultimately had to wait for the fire front to pass. ENG1 exited down George Street to Rock Creek Road where they met Marin County Engine 2 (ENG2) at a nearby house. ENG2 personnel provided medical care to the injured crew members, and Marin County Engine 3 (ENG3) personnel handled communications for the medical response.

At approximately 7:27 p.m., ENG3 contacted Carr Communications and advised of an Incident Within an Incident (IWI). ENG1 personnel were eventually transported by paramedic units to Mercy Hospital. FAE1 suffered minor burns to his hands. FF1 and FF2 suffered minor burns to their faces. Following evaluation, FAE1 and FF1 were cleared to full duty. FF2 was also released, but referred to the UC Davis Burn Center for follow up treatment.

Buenaventura (FPI1)
The Carr Fire continued progressing east toward the City of Redding. Redding Fire Department personnel and apparatus had been monitoring the fire's spread throughout the day and began mobilizing as the fire front approached the city.

At approximately 6:00 p.m., a CAL FIRE Contingency Group Supervisor (SUP1) observed fire activity increasing as the fire front burned east toward the Sacramento River. Additionally, SUP1 was monitoring the progress of three private dozers (Dozer 2, Dozer 3, and Dozer 4). These dozers were assigned to construct contingency line along the western edge of Redding, from the Sacramento River to the Land Park Subdivision. At approximately 6:30 p.m., upon completion of the contingency line, SUP1 directed the dozers to head north along Buenaventura Boulevard toward Keswick Dam Road.

At 6:38 p.m., the Carr Air Tactical Group Supervisor, advised Branch III to evacuate Market Street and Buenaventura Boulevard, among other areas threatened by the fire. At 6:43 p.m., Branch IV advised Branch III the fire was going to cross the Sacramento River.

At approximately 6:59 p.m., a Redding Fire Engine (ENG4) was directed to stage at Land Park. At this time, a second Redding Fire Engine (ENG5) observed a smoke column developing northwest of Land Park.

At approximately 7:17 p.m., ENG4 drove south on Buenaventura Boulevard toward the Land Park and Stanford Hills Subdivision. As they travelled along Buenaventura Boulevard, ENG4 firefighters observed a spot fire growing to their west. ENG4 reported the spot fire to a Redding Battalion Chief (BC1). During this time, numerous spot fires had already become established on the east side of the Sacramento River.

Following the arrival of ENG4 at Land Park and Stanford Hills, additional Redding Fire Department resources began evacuating residents and preparing for structure defense operations. At 7:23 p.m., the fire front began to crest the hill and advance toward their location.

Picture 5- Helicopter Coordinator looking southeast at fire tornado over Lake Keswick Estates. Click here to view video

It was around this time when a large rotating plume of smoke was observed developing north of Land Park near Buenaventura Boulevard. The swirling winds at the base of the plume dramatically increased fire intensity. The rotating plume continued to intensify until it developed into a fire tornado. Winds dramatically increased near the fire tornado, and embers were lofted in many directions. The fire front exhibited erratic and rapid growth during this period.

Firefighters were forced to use the intersection of Sutro Mine Road and Buenaventura Boulevard as a temporary refuge area while the fire actively burned around their location. Additionally, civilian evacuees were staged at this location by Redding firefighters.

At approximately 7:35 p.m., FPI1 responded to Land Park from a nearby fire station. (Earlier in the day, FPI1 returned to work due to the fire. Throughout the day, FPI1 was conducting welfare checks and interfaced with other Redding firefighters at Salt Creek Heights in western Redding.)

At approximately 7:35 p.m., the fire burned into Stanford Hills and Land Park. At approximately 7:38 p.m., a CAL FIRE Prevention Captain (PREV1) observed a fire tornado near Buenaventura Boulevard looking north from Land Park. One minute later, Dozer 2, Dozer 3 and Dozer 4, who were located just north of Land Park, used cut banks on Buenaventura Boulevard as temporary shelter from the fire front.

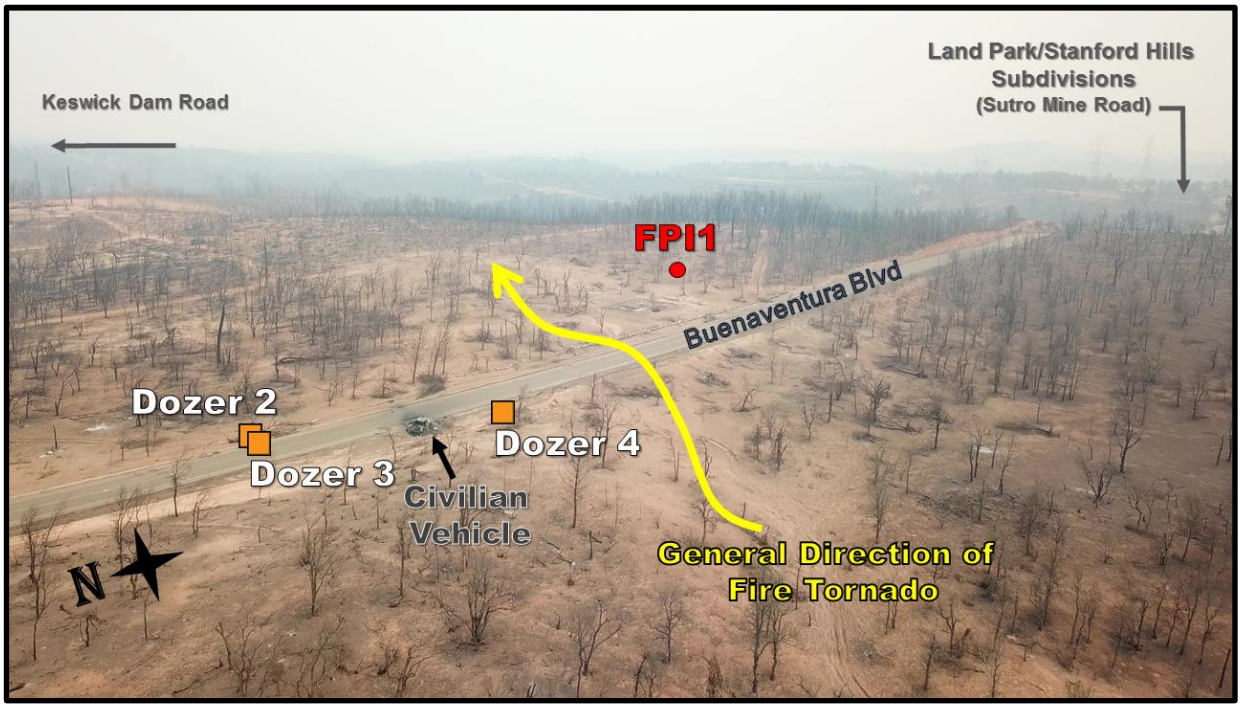
At approximately 7:39 p.m., FPI1 was driving south on Buenaventura Boulevard toward Land Park. At 7:40 p.m., FPI1 radioed a ‘mayday’ on a Redding FD 800 Mhz frequency. FPI1 identified himself by his radio call sign, and stated that he needed a water drop and was getting burned over. This was immediately followed by a second ‘priority traffic’ transmission by FPI1 on Redding FD Tac 1 (VHF). FPI1 stated he was in the middle of the road, was getting burned over, and needed a water drop.

The crew on ENG4, as well as other Redding Fire Department personnel, heard the priority traffic call from FPI1. ENG4 Captain called FPI1 on Tac Net in order to determine FPI1's location. There was no response.

ENG4 Captain exited the fire engine and faced-to-faced with BC1. ENG4 Captain confirmed with BC1 that he heard FPI1's priority radio traffic. Since FPI1's location was unknown, Shasta Communications (SHASCOM) worked to locate him by 'pinging' his cell phone.

Picture 6- ENG4 looking north from Buenaventura and Sutro Mine Road at fire tornado. Click here to view video

At 7:47 p.m., SUP1 travelled north on Buenaventura Boulevard, leading some civilian evacuees out of Land Park and Stanford Hills. When SUP1 arrived at the intersection of Keswick Dam Road and Buenaventura Boulevard, a resident advised SUP1 that the resident's family was still at home in Stanford Hills. SUP1 returned back to Stanford Hills in order evacuate the resident's family members. During this time the fire tornado was seen approaching the River Ridge Subdivision east of Buenaventura Boulevard.



Buenaventura Incident overview depicting general location of resources following passage of fire front and fire tornado.

At approximately 8:02 p.m., Dozer 2, Dozer 3 and Dozer 4 continued northbound on Buenaventura Boulevard toward Keswick Dam Road. Approximately one-half of a mile from Land Park, all three dozers were violently impacted by flying debris, rocks, embers, smoke, and intense heat. The flying material shattered windows on all three dozers. As hot air entered the cab of Dozer 2, the operator repositioned the dozer and parked next to Dozer 3. When Dozer 3's windows shattered, airborne glass entered the operator's eyes. Dozer 3 stopped on Buenaventura Boulevard and deployed his fire curtains.

Dozer 4 became disoriented when impacted by the flying debris. As a result, the dozer hit a civilian vehicle that was stopped along Buenaventura Boulevard. The impact caused the dozer operator to land on the floor of his cab. The dozer continued to travel until it came to rest against a tree. Once stopped, the operator tried to drop the fire curtains. Due to burn injuries on his hands, he was unable to manipulate the straps, and had to cut the straps with a razor knife to deploy the curtains. He successfully dropped three out of the four curtains. The operator then deployed a fire shelter. In order to escape the intense heat, he exited the cab and sought refuge under the dozer, but saw a tree blocking his route. When the dozer operator reentered the cab, he saw emergency vehicle lights on Buenaventura Boulevard. He ran up to the vehicle where PREV1 directed him into the backseat. Once in the pickup truck, the dozer operator noticed there was also a civilian in the vehicle.

Picture 7- Final resting location of Dozer 2, Dozer 3, Dozer 4 and the civilian vehicle on Buenaventura Blvd.

Prior to the rescue of the Dozer 4 operator, at approximately 8:01 p.m., PREV1 and SUP1 exited north on Buenaventura Boulevard from Land Park and Stanford Hills. SUP1 was now travelling back out of the subdivision with the evacuated family members.

Both PREV1 and SUP1 drove slowly, due to the heavy smoke conditions. Both vehicles were in close proximity to each other. As they approached the general area where the three dozers were stopped, PREV1 saw a civilian vehicle on fire. SUP1 passed PREV1 as he slowed to a stop. SUP1 continued north approximately 150 feet when both of their pickup trucks were suddenly impacted by flying debris, rocks and embers.

SUP1's vehicle began to shake violently, and the passenger windows shattered. SUP1 ducked down to avoid being hit by flying debris and he momentarily drove off the road. SUP1 regained control of his vehicle, drove back onto the road, and exited the area to the north.

Picture 8- Damage to PREV1 pickup truck. Note shattered windows and dents to body of the vehicle.

As PREV1 slowly approached the burning vehicle, he felt his pickup truck get “pushed” from the west. All the windows in his pickup truck except the windshield shattered. PREV1 took refuge in his vehicle. Approximately 30 seconds later PREV1 observed a male civilian attempting to get in his pickup truck. PREV1 directed the civilian to get in the back seat. Moments later, PREV1 saw a second individual (Dozer 4 operator) running toward him wrapped in a fire shelter. PREV1 directed the dozer operator into the back seat. PREV1 asked if they were injured. The dozer operator indicated that his hands were burned. PREV1 notified Redding ECC that he had a burn victim.

At approximately 8:14 p.m., PREV1 returned to the intersection of Sutro Mine Road and Buenaventura Boulevard. ENG4 began treating the burn injuries suffered by Dozer 4 operator. BC1 assisted the civilian.

At approximately 8:15 p.m., SUP1 located a California Highway Patrol vehicle on Keswick Dam Road and transferred the civilians to the officer.

Minutes later, a dozer tender operator who was staged at Land Park drove his pickup truck north on Buenaventura Boulevard and located Dozer 2 and Dozer 3. He evacuated both operators out of the area.

At 8:45 p.m., Redding Fire Department personnel safely escorted a caravan of residents out of Land Park and Stanford Hills.

In the very early morning hours of June 27, 2018, FPI1 was located east of Buenaventura Boulevard by Redding Fire Department personnel.

INJURIES/DAMAGES

1. FPI1 suffered fatal traumatic injuries when entrapped in a fire tornado while engaged in community protection operations.
2. Dozer 1 operator suffered fatal thermal injuries. The operator's fire shelter was located behind the dozer's seat and the fire curtains were not deployed.
3. Dozer 3 operator suffered from smoke inhalation and glass in his eyes. Dozer 3 operator did not have eye protection.
4. Dozer 4 operator suffered burns to his hands, neck and back. Dozer 4 operator was not wearing gloves.
5. FAE1 received minor burns to his hands. FF1 and FF2 received minor burns to their faces. FAE1 was not wearing gloves. FF1's shroud was not down. FF2 had his shroud down but not secured.

SAFETY ISSUES FOR REVIEW

1. Move as far away as possible to a safe location when fire tornados are observed. This is a high-risk event that can have severe consequences for humans and property.
2. Be aware that fire tornados can retain their energy and remain rotating for tens of minutes as they move over the terrain. Their path is highly unpredictable, and they can move independent of the fire. They can cause significant impact damage due to entrainment of rocks and debris, as well as ignition across wide areas and profuse spotting. Firefighters can be injured or killed from exposure to flames and flying debris.
3. Be aware that winds along a fire tornado's base can be very high due to the vertical movement of air and gases in the core of the rotating plume, creating a very strong indraft at the tornado's base. This indraft can be a significant threat to human safety, especially to pilots flying aircraft in the area.
4. Maintain constant communications with supervisors and adjoining forces; ensure hazards are communicated as they develop.
5. Maintain awareness of fire weather and behavior during operational work periods. Be aware of changing conditions around your work location.
6. Wear and utilize all appropriate PPE.
7. Maintain accountability of personnel at all times.
8. Post lookouts when actively engaged in fire suppression operations.
9. Establish safety zones and make them known.
10. Maintain and monitor escape routes at all times.
11. Be familiar with protocols for an Incident Within an Incident (IWI).

INCIDENTAL ISSUES/LESSONS LEARNED

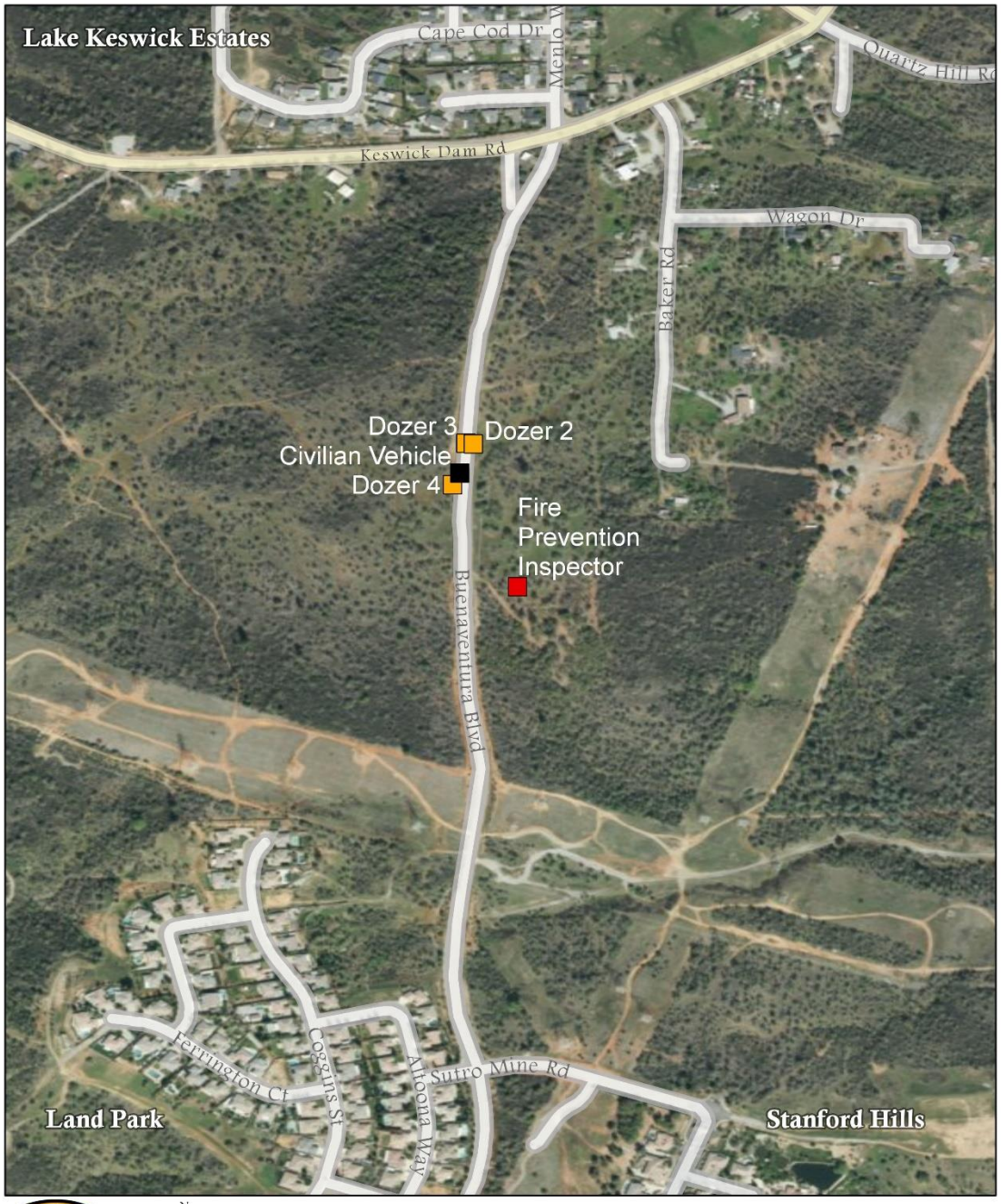
1. Firefighters must recognize the wildland firefighting environment is becoming more extreme due to a combination of a changing climate, overly dense and

dry fuels, changing weather patterns, and continued growth of communities into fire prone landscapes.

2. Just because a fire plume displays some rotation, a large fire tornado is not imminent; however, additional vigilance is warranted. Some rotation is visible in most large fire plumes.
3. Once a fire tornado appears to dissipate, it may redevelop and result in additional injuries and damage.
4. Conditions that likely contributed to the formation of this fire tornado include: highly flammable fuels, low to moderate general winds, localized areas of high vorticity and turbulence, and the presence of an atmospheric hydraulic jump.
5. Rapidly expanding wildland fires into urban areas are becoming more common. Decision points should be identified and implemented early.

AERIAL OVERVIEW OF ACCIDENT LOCATIONS

BEUNAVENTURA OVERVIEW MAP



ADDITIONAL VIDEO LINKS AND PUBLICATIONS

Links to the videos in this Green Sheet can be located here:

- Fire Engine video of fire tornado:
- https://calfire.box.com/s/7z61vrl2esxe4t9q9zml6edevcdl61wb

- Helicopter video of fire tornado:
- https://calfire.box.com/s/2fl9bb4sml0jg8t1mtsm0lgcsu0nx979

- Keswick Dam video:
- https://calfire.box.com/s/si2xp3m5mlbheh5odf3dxu54rf20yjds

Links to additional websites, video and publications:

- Carr Fire 360 Aerial Views by Redding City GIS:
- http://redding.maps.arcgis.com/apps/webappviewer/index.html?id=2b5e92ade03a40cb8e1b3f1027245c0f

- National Weather Service Explanation of EF- Scale Rating:
- https://www.weather.gov/hun/efscale_explanation

- Missoula Fire Sciences Laboratory - Fire whirl training video:
- https://www.youtube.com/watch?v=wEpW24WIgR8

- 2008 Indians Fire entrapment video:
- https://www.youtube.com/watch?v=Dd6udYmLvBQ

- Publication on the current state of knowledge on extreme fire behavior:
- https://www.fs.usda.gov/treesearch/pubs/39553

- Scientific paper about vortices in fires:
- http://downloads.hindawi.com/journals/jc/2011/984363.pdf