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## **Accident Investigation Factual Report**

Snag Falling Accident  
Frank Church WFU – Missouri Ridge Fire  
Payette National Forest, Krassel Ranger District  
Intermountain Region  
McCall, Idaho

**Date of Accident:**

September 6, 2005

# Accident Investigation Factual Report

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Snag Falling Accident

**Location:** Krassel Ranger District, Payette National Forest

**Date of Accident:** September 6, 2005

## Investigation Team Leader:

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Northern Rockies

  
Signature

  
Date

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## Executive Summary

A snag falling accident occurred on September 6, 2005, at 1158, on the 6,500-acre Missouri Ridge Wildland Fire Use (WFU) Fire, which was part of the 40,000-acre Frank Church WFU complex that started on August 1, 2005. The Missouri Ridge Fire was located on the Krassel Ranger District, Payette National Forest, approximately 50 miles northeast of McCall, Idaho.

Several overhead, firefighters, and the sawyer involved in a snag falling accident were stationed out of the remote Johnson Creek Campground spike camp and helibase. The injured sawyer is a forest service employee and was the designated Division Supervisor (DIVS) on the Missouri Ridge Fire. On the day of the accident, the DIVS assumed the role of a Class C sawyer and coordinator for three sets of sawyers assigned to manage hazard tree along a section of indirect saw line.

The indirect saw line, which ran from Missouri Creek up a ridge, was built 3 weeks prior, as part of a system of control lines/action points identified in the Wildland Fire Implementation Plan and Incident Action Plan. The decision to manage hazard trees at this time was based on a concern by line supervisors and a safety officer about the increased risk to firefighters exposed to snags while running a hose lay and sprinkler system recently established along this saw line. The hose lay was introduced in preparation for a possible burn out operation intended to check a part of the fire now nearing the saw line. Access to this section of saw line from the spike camp required motor vehicle travel on a forest gravel road and an approximately 1-mile hike up a designated forest trail.

A sawyer was struck on the E6 by the top section of a snag which broke off while he was attempting to fall it with a chain saw. The snag was 120 feet tall, 21 inches diameter breast height (d.b.h.), and naturally leaning into a larger green tree. The sawyer was step-cutting the lower sections from the snag base, in an effort to lower and position it so it would fall free to the ground. As the second section was cut and released, a 20-foot long, 41-pound top section snapped back and fell down striking the sawyer while he was standing next to the base of the snag.

The sawyer sustained a E6 injury from the broken top which impacted the top, front part of his hardhat. Injuries included a E6  
E6

A swamper who was working with the injured sawyer immediately provided emergency first-aid and activated medical evacuation procedures. Several firefighters carried the sawyer on a backboard down the trail to a forest service vehicle. Following a short drive, the injured firefighter was delivered to an emergency landing area and loaded onto a waiting Life Flight helicopter which flew him to Saint Alphonsus Regional Medical Center in Boise, Idaho. The sawyer was subsequently released from the hospital to recover from his injuries.

# I. Narrative

## A. Overview

A snag falling accident occurred on September 6, 2005, at 1158, on the 6,500-acre Missouri Ridge Wildland Fire Use (WFU) Fire, which was part of the 40,000-acre Frank Church WFU complex that started on August 1, 2005. The Missouri Ridge Fire was located on the Krassel Ranger District, Payette National Forest, approximately 50 miles northeast of McCall, Idaho.

A sawyer was struck on the <sup>E6</sup> by the top section of the snag which broke off while he was attempting to fall it with a chain saw. The snag was 120 feet tall, 21 inches d.b.h., and naturally leaning into a larger green tree. The sawyer was step-cutting the lower sections from the snag base, in an effort to lower and move it toward the base of the green tree so it would fall to the ground. As the second section was cut and released, a 20foot long, 41-pound top section snapped back and fell down striking the sawyer standing next to the base of the snag.

The sawyer sustained a <sup>E6</sup> injury from the broken top which impacted the top, front part of his hardhat. Injuries included a <sup>E6</sup>

<sup>E6</sup>

A swamper working with the injured sawyer immediately provided emergency first-aid and activated medical evacuation procedures. The sawyer was transported by a Life Flight emergency medical helicopter to Saint Alphonsus Regional Medical Center in Boise, Idaho.

## B. Sequence of Events Associated with the Accident

**Note:** Times shown in the italic are approximate. Although they are based upon witness statements and evidence they are estimates developed by the investigation team when multiple parties provided different times for activities/events or no times were provided.

<u>Date/Time</u>	<u>Activity/Event</u>
August 1	The Missouri Ridge Fire started.
August 31	A Type II Fire Use Management Team relieved the previously assigned IMT and took over the fire.
September 1	The swamper was assigned to the Missouri Ridge Wildland fire Use.
September 3	The sawyer was assigned to the Frank Church WFU, Missouri Ridge Fire.

<b>Date/Time</b>	<b>Activity/Event</b>
September 4	The IAP division assignment for the operational period on this day called for the installation of sprinkler/hose lay system to support possible burn out operation along an established saw line where the injury occurred.
September 5	Objectives included monitor hand line and mop-up activity with emphasis on west and northwest flanks.
September 6	
0600	The morning briefing occurred at Johnson Spike Camp/Helibase with all the members of the division. The plan to engage three sets of sawyers was initiated and agreed upon by all involved overhead working and spiked out of Johnson Helibase. The objectives were communicated by the sawyer to all saw teams. The decision to snag the line at this time was driven by a growing concern more firefighters would be exposed to hazard trees while engaged in suppressing the fire's slow advance towards the established control line/action point.
1100	The sawyer and swamper arrived on the division after hiking in from the trailhead 31.
1150	The sawyer felled four trees before attempting to fall the snag (number 5) associated with the accident.
	A near miss/close call occurred when sawyer cut tree number 3, prior to the accident. The sawyer cut down a 9-inch d.b.h., approximately 50-foot tall snag that was naturally hung up in an adjacent live tree. Midway through this cutting operation, a top part of the snag broke out (5-foot section in length) and fell to the ground near the sawyer.
1155	Prior to cutting snag number 5, the sawyer directed the swamper to stand in a secure location approximately 50 feet behind and slightly uphill from the sawyer next to a large tree that could be used for safe cover.
1158	While cutting the snag, the sawyer was struck by the top that broke off while he was standing approximately 6 feet from where the base of the snag was positioned when cut.

Date/Time	Activity/Event
1158	The snag top impacted on the top ridge of the hardhat near the front. The swamper immediately came to sawyer's aid and observed he was sitting slumped over with his hardhat still on his head and his face touching his knees. The swamper then checked and found a strong and consistent pulse. The swamper promptly radioed for help.
1159	The swamper found the sawyer.  E6
1200	An EMT from the upper saw team arrived and assumed emergency care for the patient. An EMT from the lower saw team arrived shortly after first EMT and assisted.
1202	Air ambulance was requested through dispatch from Johnson Spike Camp/Helibase.
1205	<p>The sawyer regained consciousness.</p> <p>Two firefighters rappelled into trailhead # 31 with a back board and trauma kit, then hiked the medical equipment into the accident site.</p> <p>Additional fire personnel in the area were sent to the accident site to help with evacuation.</p> <p>The sawyer was immobilized on backboard with C collar and carried out on trail 31 with assistance from assigned interagency hotshot crew.</p>
	The sawyer was transported up FS Road 340 in a Forest Service vehicle to the emergency landing site.
1315	Life Flight helicopter lands at Johnson Helibase.
1345	The Life Flight helicopter took off from Johnson Helibase and flies with paramedics to an emergency landing site where the sawyer is being picked up.
1420	The sawyer is loaded into the life flight helicopter and transported to St. Alphonsus Regional Medical Center in Boise, Idaho.

<u>Date/Time</u>	<u>Activity/Event</u>
1417	All fire personnel come off the fireline and meet at the trail head.
1700	An after Action Review conducted back at Johnson Spike Camp/Helibase by involved personnel.

## **C. Incident Analysis**

### **1. Assignment**

The Missouri Ridge Wildland Fire Use (WFU) Fire, which was part of the 40,000-acre Frank Church WFU complex, started on August 1, 2005. The Type II Fire Use Management Team in charge of the fire on the day of the accident was assigned to manage the complex on August 31, 2005.

The sawyer was assigned to the complex and the Missouri Ridge Fire on September 3, 2005, as a division supervisor (DIVS) and he also had a trainee assigned to him. On the day of the accident, the sawyer transitioned his role from division supervisor to sawyer and the trainee assumed general DIVS responsibilities.

The sawyer worked on one of three sets of saw teams and served as the point-of-contact/supervisor in charge of the felling operations along a saw line.

The swamper was assigned to the fire on September 1, 2005, and was a member of the Zion Fire Use Module Helicopter. As a B sawyer, the swamper was assigned to work with the injured sawyer on the day of the accident.

Both the sawyer and swamper were working the established IAP operational period of 0600-1800.

The sawyer and swamper were stationed at Johnson Creek Campground spike camp and helibase.

The Wildland Fire Implementation Plan established the management action points used in the IAP and called for holding the fire if it reached this point which occurred on September 3, 2005. The establishment of these action points is consistent with the National Wildland Fire Implementation Guide.

### **2. Weather**

The forecasted weather on the day of the accident called for a warming and drying trend through midweek, light northwest winds, an inversion breaking around 1100-1200 hours, clear skies with good visibility, and Haines Index of 4.

The observed weather on the day of the accident was consistent with the forecast.

### 3. Physical environment

Slope was 40 to 55 percent with a small flat area at base of snag. The ground/footing surface was dry and the area around the base of the snag was unburned.

The snag was about 10 feet within the saw line. The indirect saw line (no hand/scratch line) was approximately 50 feet wide and lightly cleared of surface fuels. The saw line ran from the Missouri Creek drainage bottom to the ridgeline approximately 1,800 feet. The snag involved was about midway up the slope. Elevation at accident site was 6,756 feet.

The spruce snag was the fifth tree the sawyer cut that day. The snag was predominately free of any bark with limited branches in the upslope portion of tree. It was 21 inches in d.b.h. and 120 feet tall. The top section that struck the sawyer was 20 feet long, 6 inches in diameter at the large end and weighted 41 pounds.

The material from the base of the snag to upper portion was mostly solid and sound. The snag had a rotted root system which caused it to lean into an adjacent larger (34 d.b.h.), taller live green Douglas-fir tree. The snag was leaning upslope (approximately 15-20 degree angle) into the fir tree located 28 feet directly above on the slope. The material/wood at the location where the top broke off the snag was defective.

The single, primary escape route was cleared and free of notable obstructions.

### 4. Equipment

The sawyer was wearing all PPE required for chain saw and firefighting operations except the hardhat did not meet Forest Service standards required for firefighting operations.

The helmet used by the sawyer, a Bullard Model 502 (fiberglass), does not meet the Interagency (PPE) Standards for Fire and Fire Aviation Operations nor adheres with required NFPA 1977 (Protective Clothing and Equipment for Wildland Fire Fighting) standards.

The power saw used was a Stihl MS 440 with 24 inch bar and was in good running condition.

No warning device such as a whistle or air horn were in the possession of or used by the swamper.

The helicopter assigned as the primary ship for medical evacuation in the IAP did not have a backboard or stretcher on board. A backboard was immediately provided during the emergency by another helicopter module located at the Johnson Helibase.

### 5. Qualifications and training

The sawyer is a qualified C-certifier sawyer, falling boss and designated as the Eb Forest Chain Saw Program Manager. The sawyer was certified as a C-faller in May 1997 and was certified as a C-certifier on May 24, 2002. Then he was re-certified as a C-

certifier on September 23, 2003 and also on April 4, 2005. He also attended a regional workshop on falling on February 9, 2005 presented by the Intermountain Regional Chainsaw Program Manager. The sawyer is also a qualified division supervisor (DIVS) and was initially assigned in this role on the Missouri Ridge Fire.

The sawyer's first aid and CPR was current with the last training received May 2005.

The swamper was certified as a B-faller on June 28, 2005. The swamper's basic first aid/CPR training certification expired in June 2005.

## **6. Communications**

Based on discussions between DIVS (the injured sawyer) and DIVS trainee, the trainee was assigned and served as the primary point of contact for the daily operational decisions and ongoing communications with other assigned personnel on that division for the day of the accident. The DIVS assumed sawyer duties for saw line on day of accident due to his existing C class chain saw qualifications, and the fact that there were few advanced sawyers available.

The objective communicated to the saw teams at the morning briefing at Johnson Helibase on the day of the accident called for felling hazard trees within one tree length of saw line.

## **7. Risk Management**

Three saw teams were assigned to fell hazard trees. The top saw team was comprised of a B-faller, swamper/EMT, and an EMT helitack crew member. They were assigned to the upper location in order to direct any helicopter bucket work if needed, cut predominately smaller material in area, and provide strategic EMT coverage. The bottom saw team was comprised of a C-faller/EMT and helitack crew member/swamper. They were assigned the lower location to manage more complex/large saw material and provide strategic EMT coverage. The injured sawyer and swamper were positioned between the other two teams.

The direction provided in the IAP regarding options to manage and mitigate exposures hazard trees was limited to the following brief statement found in the 215A: "Snags: Shallow-rooted trees will continue to fall as the root systems burn. Be heads up at all times. Line supervisors on the Missouri Ridge need to consider moving personnel off the line away from snags."

No warning device such as a whistle or air horn were in the possession of or used by the swamper working with the injured sawyer.

Detailed instruction on felling/cutting techniques prescribed to safely cut hang ups is absent from the S-212 and MTDC chain saw training courses.

Swamper/spotter roles, responsibilities and qualifications covered in the S-212 Wildland Fire Chain Saw Training course, Fireline Handbook, and Health and Safety Code Handbook are not clear or consistent.

## 8. Injuries to Personnel

The sawyer sustained <sup>E6</sup> injury from the impact to the front part of his hardhat. The injuries included a <sup>E6</sup>

## 9. Property Damage

The hardhat sustained a small indentation and crack, and the liner remained secure and intact. The hardhat was sent to the Missoula Technology and Development Center (MTDC) for formal equipment analysis.

## 10. Survivability

A single/primary escape route away from the base of the tree was adequately cleared of down material and free of notable obstructions.

## 11. Adherence to standards

The helmet used by the sawyer, a Bullard Model 502 (fiberglass), does not meet the Interagency (PPE) Standards for Fire and Fire Aviation Operations, nor adheres to required NFPA 1977 (Protective Clothing and Equipment for Wildland Fire Fighting) standards.

The sawyer serves as the designated Forest Chain Saw Training and Certification Program Manager for the Payette National Forest.

The sawyer is currently certified as a C-Certifier under the Intermountain Region chain saw training/certification program.

The sawyer is qualified as Division Supervisor, and Class C Sawyer.

The sawyer first aid and CPR was current as of May 2005.

The swamper is red card qualified for Class B Sawyer.

The swamper's basic first aid/CPR training certification expired June 2005.

The sawyer and swamper did not have any warning device.

## II. Maps, Illustrations, and Photographs

### A. Vicinity and Accident Sketch Maps

Figure 1 – Vicinity Map

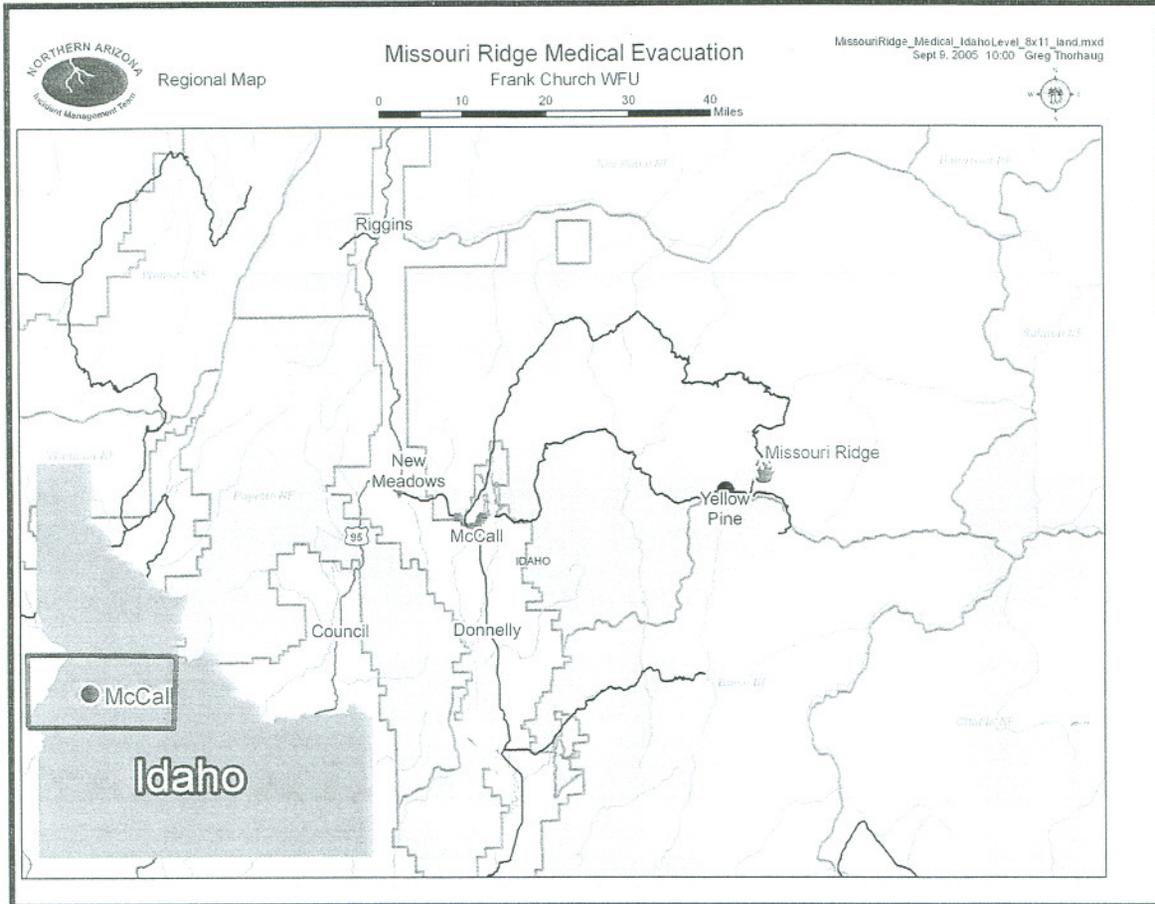


Figure 2 – Map of Frank Church WFU and Missouri Ridge Fire

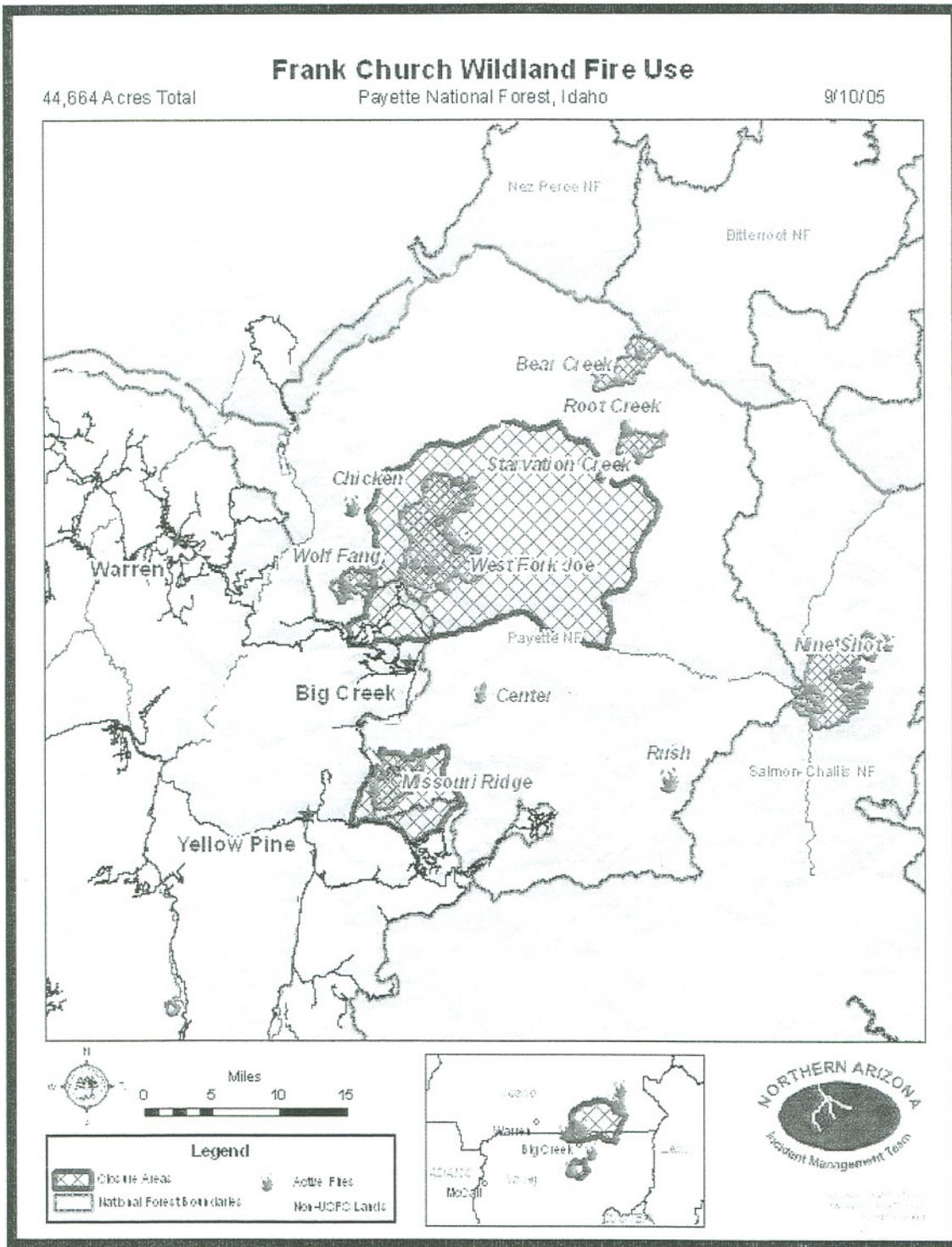
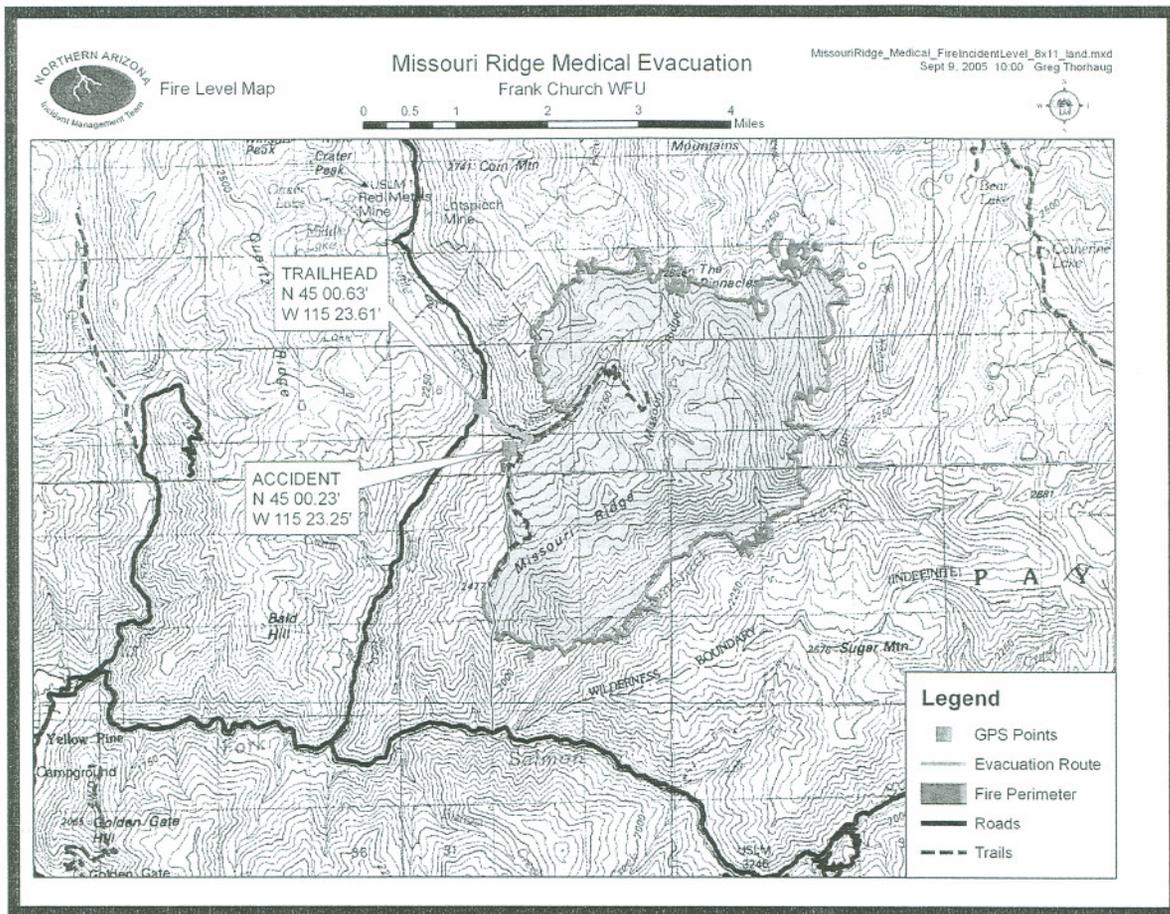
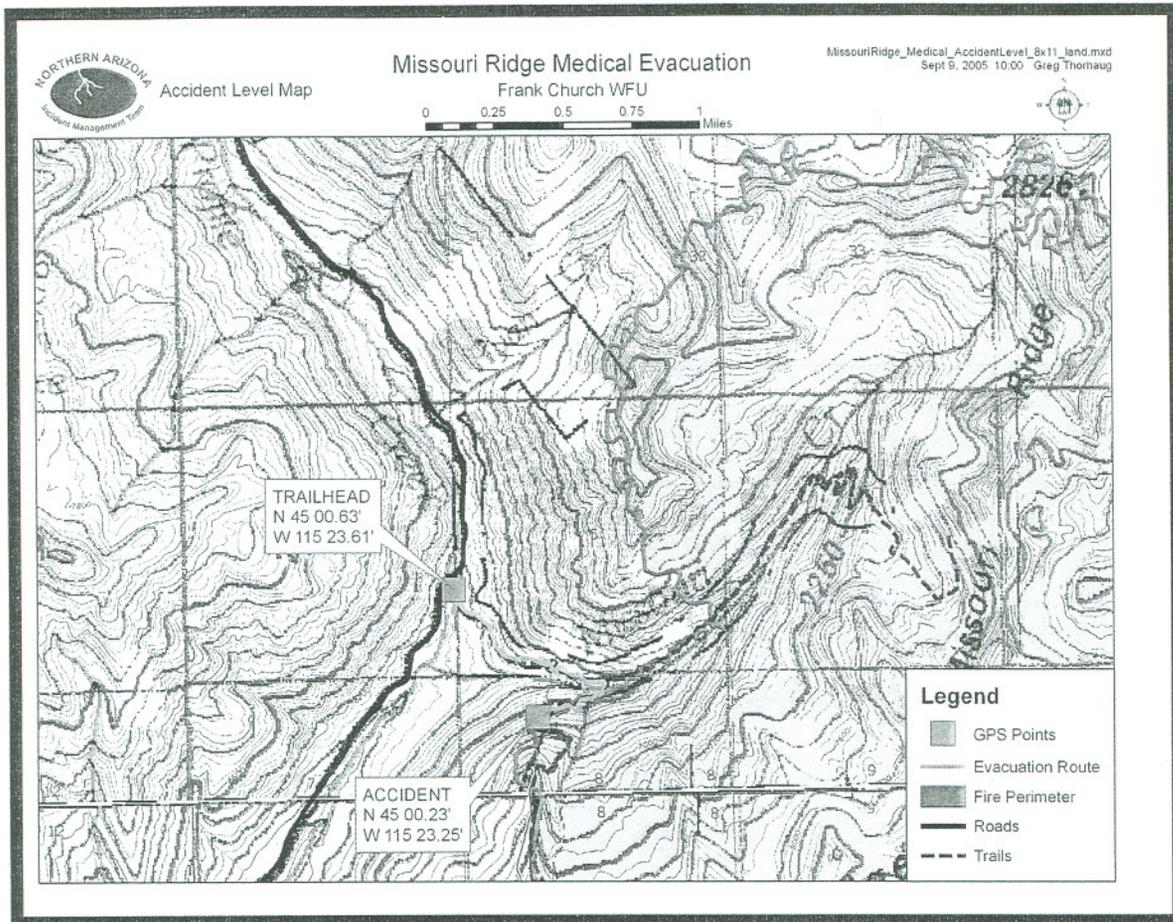


Figure 3 – Map of Missouri Ridge Fire and Accident Location



Map of evacuation route from accident site on saw line along Trail 031 to trailhead at Road 340

Figure 4 –Missouri Ridge Fire Medical Evacuation Route Map



Map of evacuation route from accident site on saw line along Trail 031 to trailhead at Road 340.

Accident Site Photographs

*Photograph 1*



Post accident photo of snag looking uphill.

*Photograph 2*



**Post accident photo of snag showing limb and hung-up top.**

*Photograph 3*



**Accident site showing ground fuels, slope, and broken snag top.**

*Photograph 4*



**First and second sections cut from base of snag.**

*Photograph 5*



**The 20-foot long broken top that struck the sawyer. Person in red hardhat in a sitting position is shown in the location where the sawyer was struck.**

*Photograph 6*

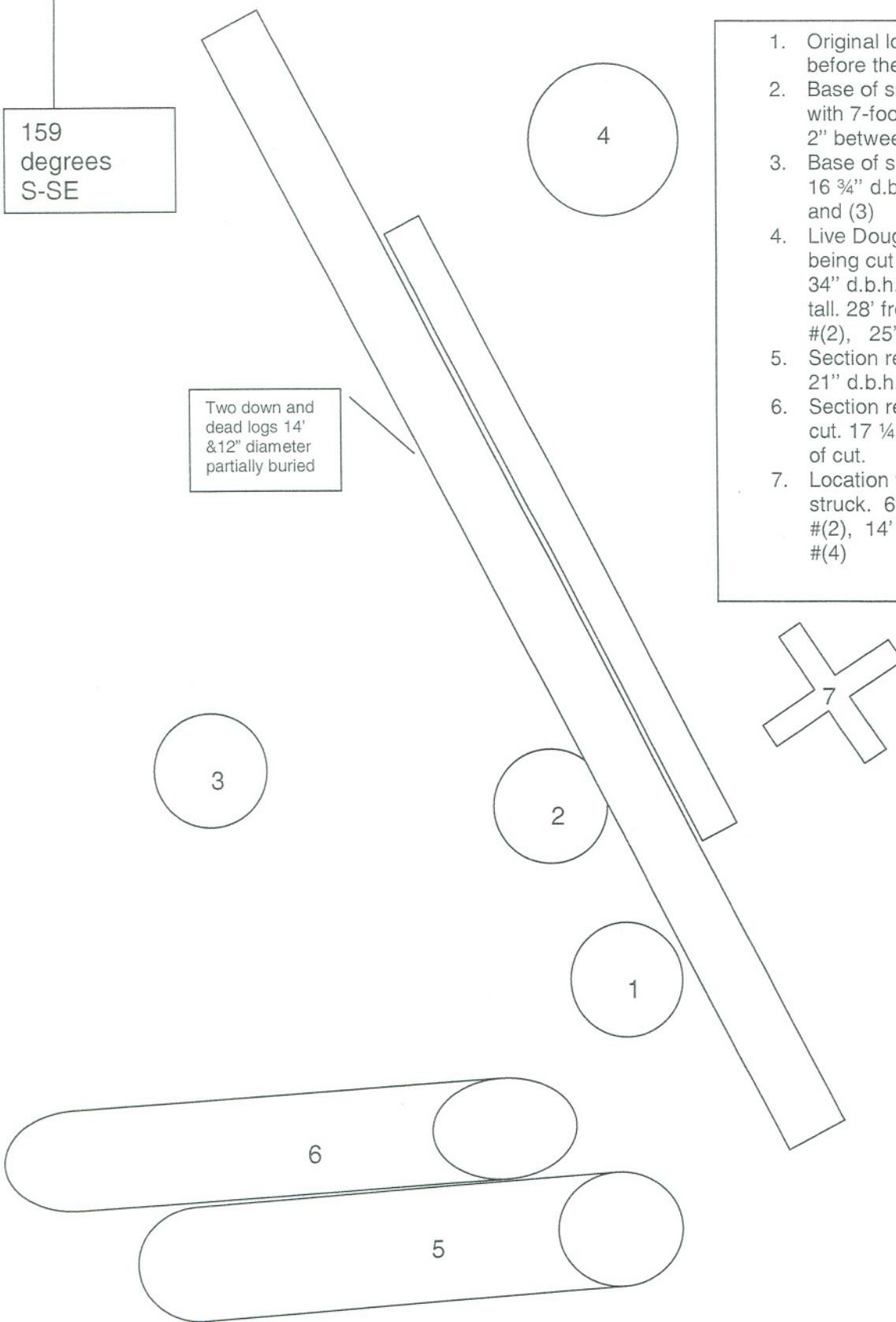


Close up of material defect in the top where it broke off the snag.

159  
degrees  
S-SE

Two down and  
dead logs 14'  
& 12" diameter  
partially buried

1. Original location of snag base before the first cut
2. Base of snag after the first cut with 7-foot section removed. 4' 2" between (1) and (2)
3. Base of snag after second cut. 16 3/4" d.b.h., 7' between (2) and (3)
4. Live Douglas-fir that snag being cut was hung up in. 34" d.b.h. approximately 110' tall. 28' from #(1), 25'4" from #(2), 25' from #(7)
5. Section removed after first cut. 21" d.b.h., 7' long
6. Section removed after second cut. 17 1/4" diameter at height of cut.
7. Location where sawyer was struck. 6' from #(1), 5'6" from #(2), 14' from #(3), 25' from #(4)



Sketch diagram of cutting sequence

*Photograph 7*



**Scene of firefighters involved in emergency medical care and evacuation of injured sawyer.**

*Photograph 8*



**Injured sawyer being loaded for transport by Life Flight helicopter.**

### **III. Findings**

#### **A. Environmental Conditions**

##### ***Findings:***

1. The slope at the site of the accident was 40 to 55 percent with a small flat area at the base of snag. Winds were calm, sky was clear, visibility was good, and ground/footing surface was dry. Elevation at the accident site was 6,756 feet. (RF) = Record File (RF - 10)
2. The area in the vicinity of the snag was unburned. The accident site is on an indirect saw line approximately 50 feet wide and was lightly cleared of surface fuels (without a hand/scratch line). (RF-10)
3. The spruce snag that struck the sawyer was: predominately barkless with limited branches in the upper/upslope portion of tree; 21 inches in d.b.h. and 120 feet tall; mostly solid and sound and appeared to have been dead for a long time; had a rotten root system that naturally caused it to lean/fall/hang-up in an adjacent larger (34 d.b.h.) live/green Douglas-fir tree; leaning upslope (approximately 15-20 degree angle) into the larger/taller fir tree located approximately 28 feet directly above on the slope; defective at the top where it broke off; the size of the piece that struck him was 20 feet long, 6 inches in diameter at large end, and weighted 41 pounds. (RF-23)
4. A single, primary escape route was adequately cleared and free of notable obstructions. (RF-8)

#### **B. Equipment**

##### ***Findings:***

5. The sawyer was wearing all PPE required for chain saw and firefighting operations, except the hardhat was not to standards. (RF-21 and 30)
6. The hardhat used by the sawyer, a Bullard Model 502 (fiberglass), does not meet the Interagency (PPE) Standards for Fire and Fire Aviation Operations nor adheres with required NFPA 1977 (Protective Clothing and Equipment for Wildland Fire Fighting) standards. (RF-30 and 38)
7. The power saw, a Stihl MS 440 with 24 inch bar was in good running condition, and common size/type used for the material being cut. (RF-21)
8. No warning device such as a whistle or air horn was in possession or used by the swamper/spotter. (RF-21)
9. The helicopter assigned as the primary ship for medical evacuation in the IAP did not have a backboard or stretcher stored on board. A backboard was immediately provided during the emergency by another helicopter module located at the Johnson Helibase. (RF – 21)

## C. Human Factors (People and Management)

### Management

#### *Findings:*

10. The sawyer was initially assigned as DIVS for the Frank Church WFU Complex and Missouri Ridge Fire on September 3. (RF-11)

11. Based on a working agreement between DIVS and DIVS trainee, the DIVS trainee served as the primary point-of-contact for the daily operational decisions and ongoing communications with other assigned personnel on the division for the day of the accident. (RF-21)

12. DIVS assumed sawyer duties for the saw line on day of accident due to his existing C-faller chain saw qualifications, and the fact that there were few advanced sawyers available. (RF-21)

13. The injured sawyer functioned as one of three sets of sawyers assigned to snag the saw line, and was the supervisor in charge of the felling operations. (RF-21)

14. The saw line (no handline), initially completed on August 23, was located outside the wilderness boundary, and follows Wildland Fire Implementation Plan established by a previous Incident Management Team assigned to the WFU. (RF-5)

15. Monitoring and use of helicopter bucket drops as needed to cool hot spots had been the primary tactic used to check the fire advance towards the saw line prior to September 4. (RF-11)

16. The IAP division assignments for the operational period September 4 was updated from previous shift and called for the installation of sprinkler/hose lay system to support possible burn out operation along saw line. (RF-11 and 21)

17. The plan to engage three sets of sawyers was initiated and agreed upon by all involved line supervisors and a safety officer working out of Johnson Creek spike camp and helibase. (RF-21)

18. The decision to snag the line at this time was driven by a growing concern more firefighters would be exposed to hazard trees while engaged in suppressing the fire moving towards the established control line/action point (RF-21)

19. The objective communicated to the saw teams at the morning briefing on the day of the accident called for felling of hazard trees within one tree length of saw line. (RF-21)

20. The saw team members were positioned in such a fashion as to provide EMT coverage along the saw line. (RF-21)

21. The current S-212 Wildland Fire and MTDC Chain Saw Training Courses briefly mentions "special hazard like leaners and snags". Detailed instruction on felling/cutting techniques and procedures prescribed to safely cut and mitigate hang ups is absent. (RF-24)

22. The S-212 Wildland Fire Chain Saw Training course, Fireline Handbook, and Health and Safety Code Handbook provides different direction regarding roles, responsibilities, and qualifications of swamper, lookouts, and observer, therefore, it is not applied as a standard practice. (RF-24, 36, and 37)

## ***People***

### ***Findings:***

23. The sawyer had cut down four hazard trees prior to the accident. (RF-21)

24. A near miss/close call occurred when sawyer cut a 9-inch d.b.h., tree 3, prior to the accident. The sawyer cut down the approximately 50-foot tall snag that was naturally hung up in an adjacent live tree. Several sections (fence posts/wafers) had to be cut out before the tree came free and fell. Midway through this cutting operation, a top part of the snag broke out (5-foot section in length) and fell to the ground near the sawyer. (RF-21)

25. Following this event, the swamper talked to sawyer about the near miss. The swamper indicated that in the future she would yell a warning in the event of falling material and the sawyer would then hug/move into the bole of tree. (RF-21)

26. The sawyer made two cuts in tree 5 before being struck by top of tree. (RF-21 and 29)

27. The sawyer positioned the swamper in a secure location approximately 50 feet behind and slightly uphill from the sawyer next to a large tree that could be used for safe cover. (RF-21 and 29)

28. The swamper had a view of the top one-fourth of the snag. (RF-21 and 29)

29. The sawyer's first step down cutting maneuver successfully put a 7-foot section on the ground. (RF-21 and 29)

30. The techniques used to complete the step-down maneuver included one kerf cut on the top side and second release cut on the bottom side. (RF- 21 and 29)

31. The sawyer's second step-down cutting effort resulted in an 8-foot section going to the ground at the same time the top snapped back and fell. (RF-21 and 29)

32. The sawyer was struck approximately 6 feet from where the snag base was positioned when it was cut. (RF-21 and 29)
33. In the time it took the swamper to shout the sawyer's last name twice (about 3 seconds) the top fell and struck the sawyer who was not looking up and did not hear the warning. (RF-21)
34. The snag top impacted indirectly on the top ridge of the hardhat near the front. (RF-27 and 30)
35. The swamper immediately came to sawyer's aid and observed he was sitting slumped over with his hardhat still on his head and his face touching his knees. The swamper then checked and found a strong and consistent pulse. (RF-21)
36. The swamper promptly radioed for help. (RF-21)
37. The swamper found the sawyer *ED* (RF-21)
38. An EMT from the upper saw team arrived within approximately 2 minutes and assumed emergency care for the patient. A second EMT arrived to assist a few minutes after the first arrived. (RF-19, 17, 21)
39. The swamper then looked through sawyer's pack for a wallet or other potential source for medical information given the sawyer did not have medical identification bracelet or necklace. (RF-21)
40. The sawyer regained consciousness at 1205. (RF-21)
41. Helitack repelled in a backboard, oxygen, and first-aid supplies. (RF-17, 19, 21)
42. Sawyer was immobilized on backboard with C collar, and then carried out Trail 31 with assistance from an interagency hotshot crew. (RF-21)
43. Sawyer was transported up Road 340 in a Forest Service vehicle to the helicopter emergency landing site. (RF-21)
44. Life Flight helicopter landed with paramedics and transported the injured sawyer to St. Alphonsus Regional Medical Center. (RF-19, 21)

## Training and Qualifications

### *Findings:*

45. Sawyer serves as the designated Forest Chain Saw Training and Certification Program Manager for the <sup>Eb</sup> (RF-6)
46. Sawyer is currently certified as a C-Certifier under the Intermountain Region chain saw training/certification program. (RF- 6)
47. Sawyer is red card qualified as Division Supervisor, Felling Boss, and Class C Sawyer. (RF-6)
48. Swamper is red card qualified for Class B Sawyer. (RF-6)
49. Swamper's basic first aid/CPR training certification expired June 2005. (RF-21)