City of Ketchum

CITY COUNCIL MEETING AGENDA MEMO

Meeting Date:	December 16, 2024	Staff Member/Dept:	Seth Martin – Fire

Agenda Item: Review results of the Urban Avalanche Analysis.

Recommended Motion:

No motion is needed.

Reasons for Recommendation:

- The City of Ketchum and surrounding areas have had conflicts with avalanches well back into the days of active mining at the end of the 19th century. Large avalanche cycles at lower elevations have seemingly increased in frequency in the past 20 years as urban development and infrastructure have also increasingly encroached into avalanche terrain. Mid-winter and late winter rain events have also become more common as the earth's climate warms. Wildfires have changed the landscape to a large degree around Sun Valley and have influenced the anchoring of the snowpack, not to mention its resilience to warming events. Overall, it appears that the risk of avalanches impacting the residents and visitors to Ketchum has significantly increased in the 21st Century.
- This study is one of the first steps in a multi-tiered process aimed at equipping emergency managers with tools that will better help predict and plan for avalanche risks and make more informed decisions regarding evacuations and repopulation decisions after an evacuation.

Policy Analysis and Background (non-consent items only):

Sustainability Impact:

None

Financial Impact:

None OR Adequate funds exist in account:	None

Attachments:

1. Urban Avalanche Analysis

Wood River Valley Urban Avalanche Analysis

Report Follow Up

December 16 & 17, 2024

DHA
Avalanche Safety

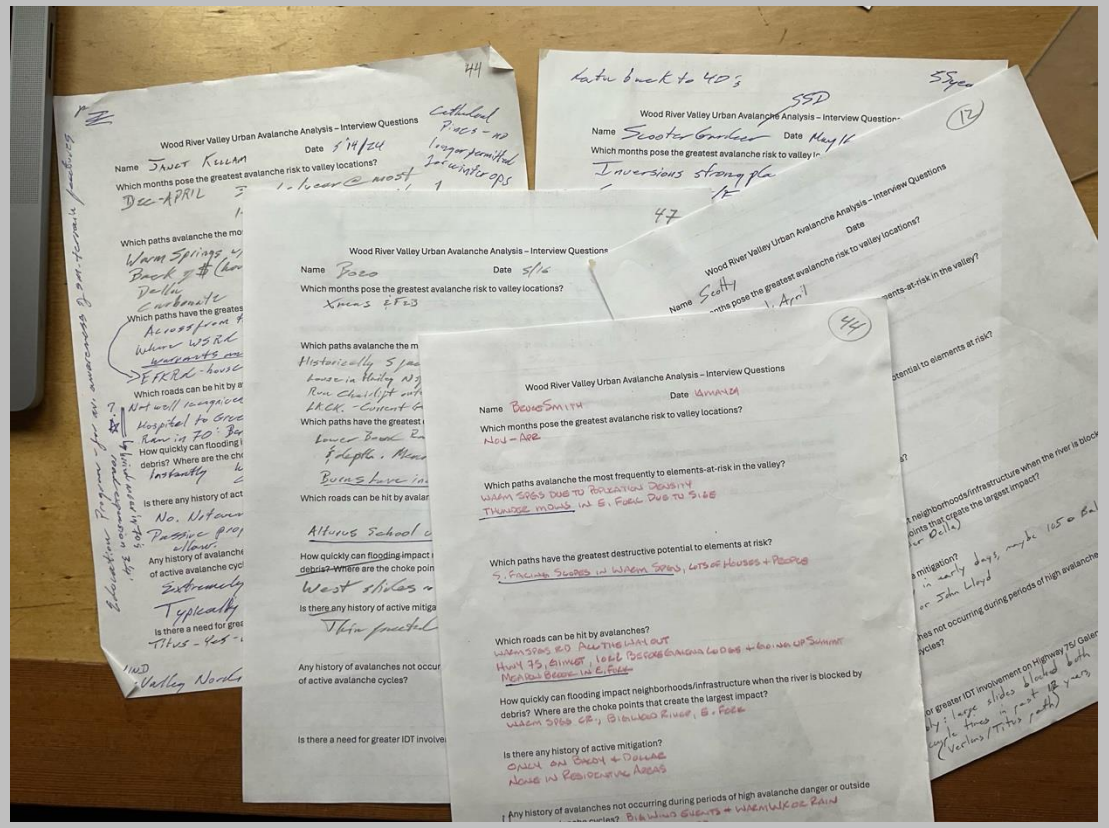
Deliverables

- GIS shape files – 152 mapped slide paths
- Avalanche Occurrence Database – Approx. 130 events
- Avalanche Atlases – 238 pages
- Avalanche Hazard Index – Sage, Hillside, Warm Springs, and ID 75 – 7 road segments
- Report summarizing methods, results, and recommendations – 82 pages

Field Visit

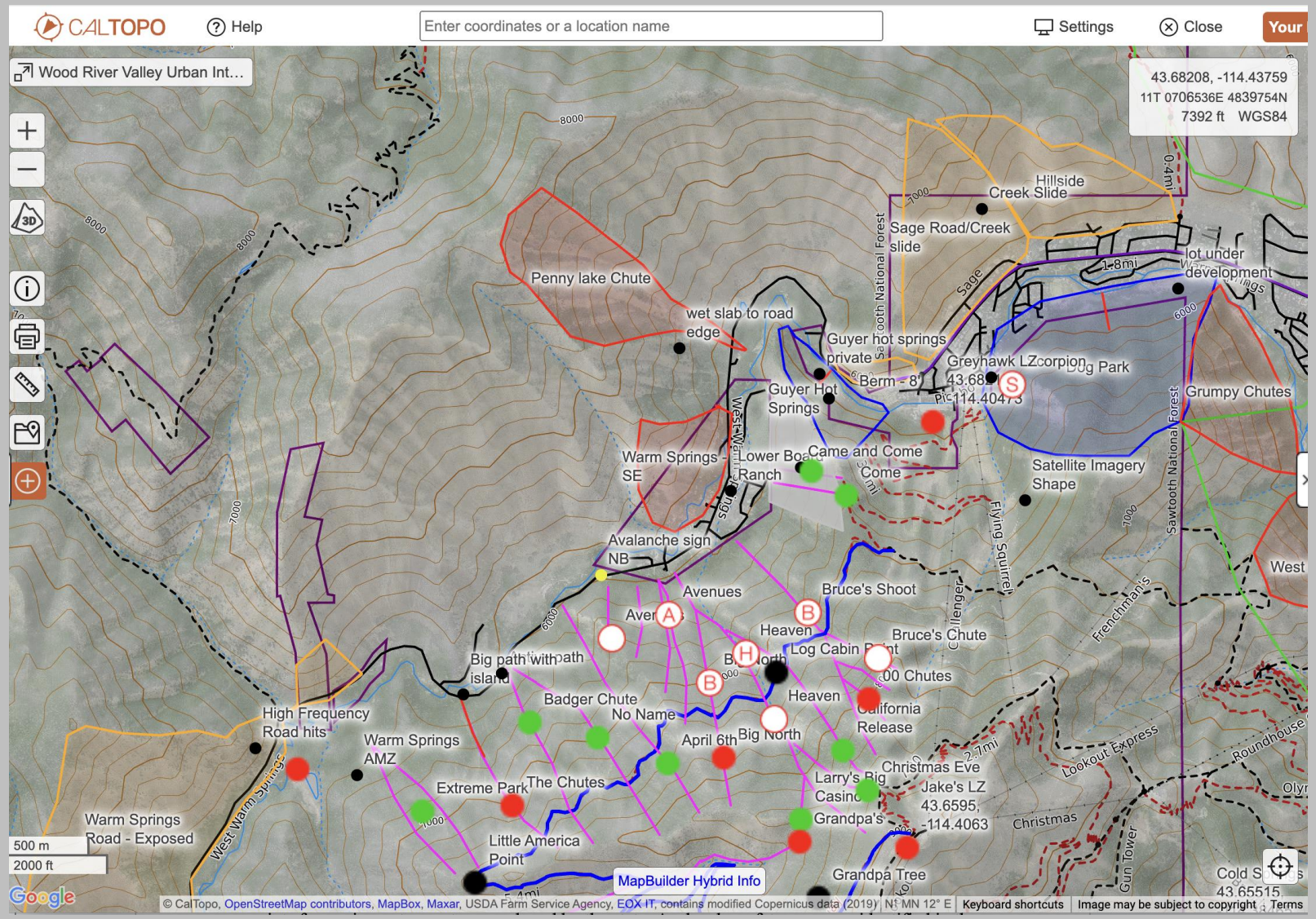
Methods Overview

Field Visit



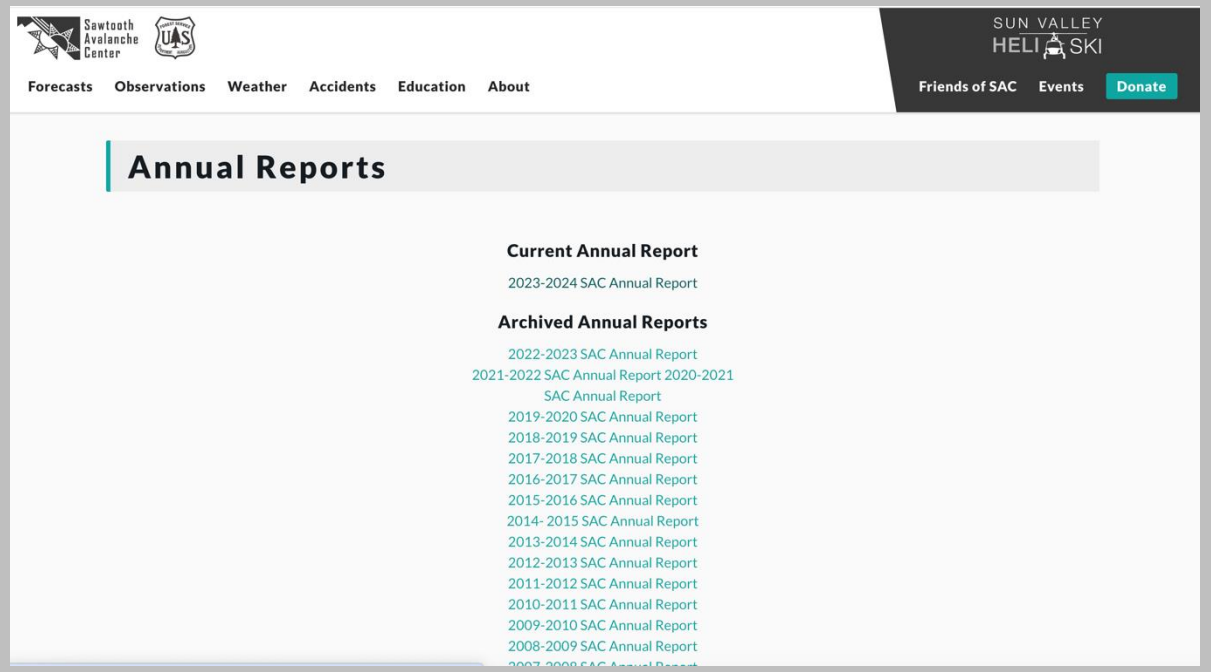
Methods Overview

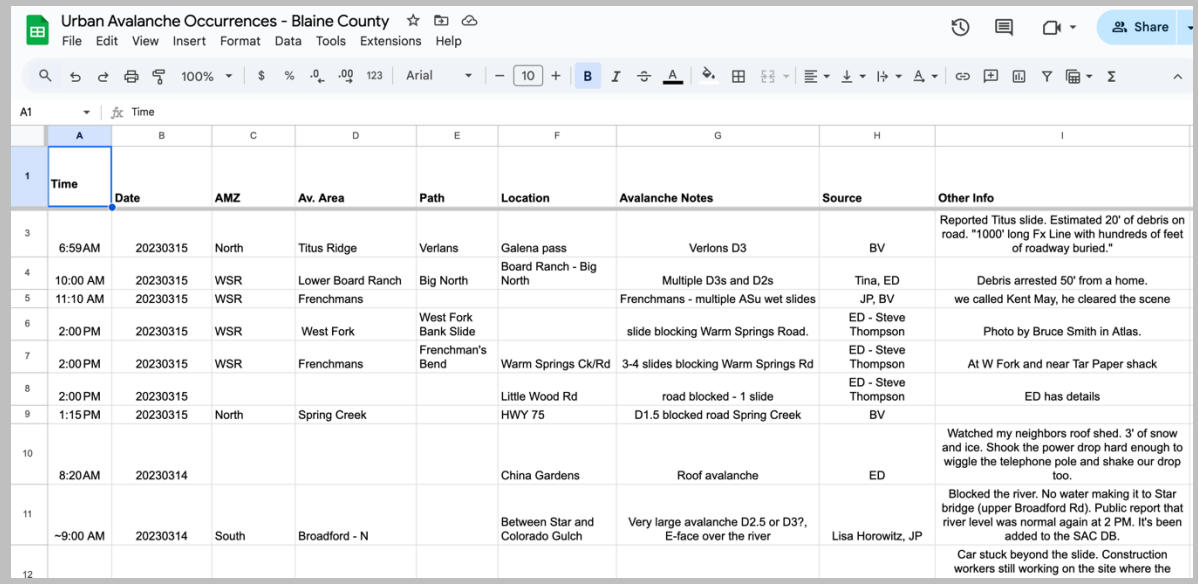
Field Visit



Methods Overview

Avalanche Occurrences



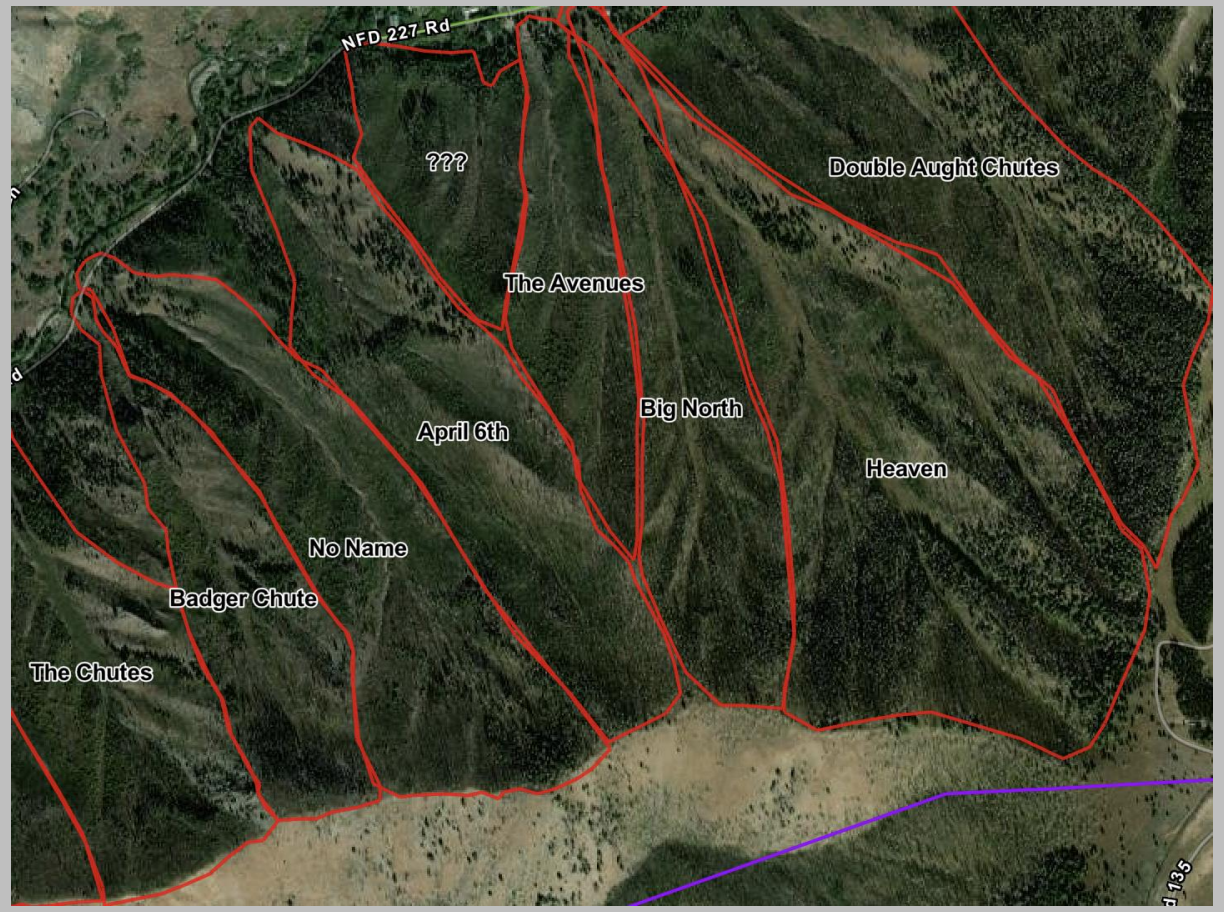


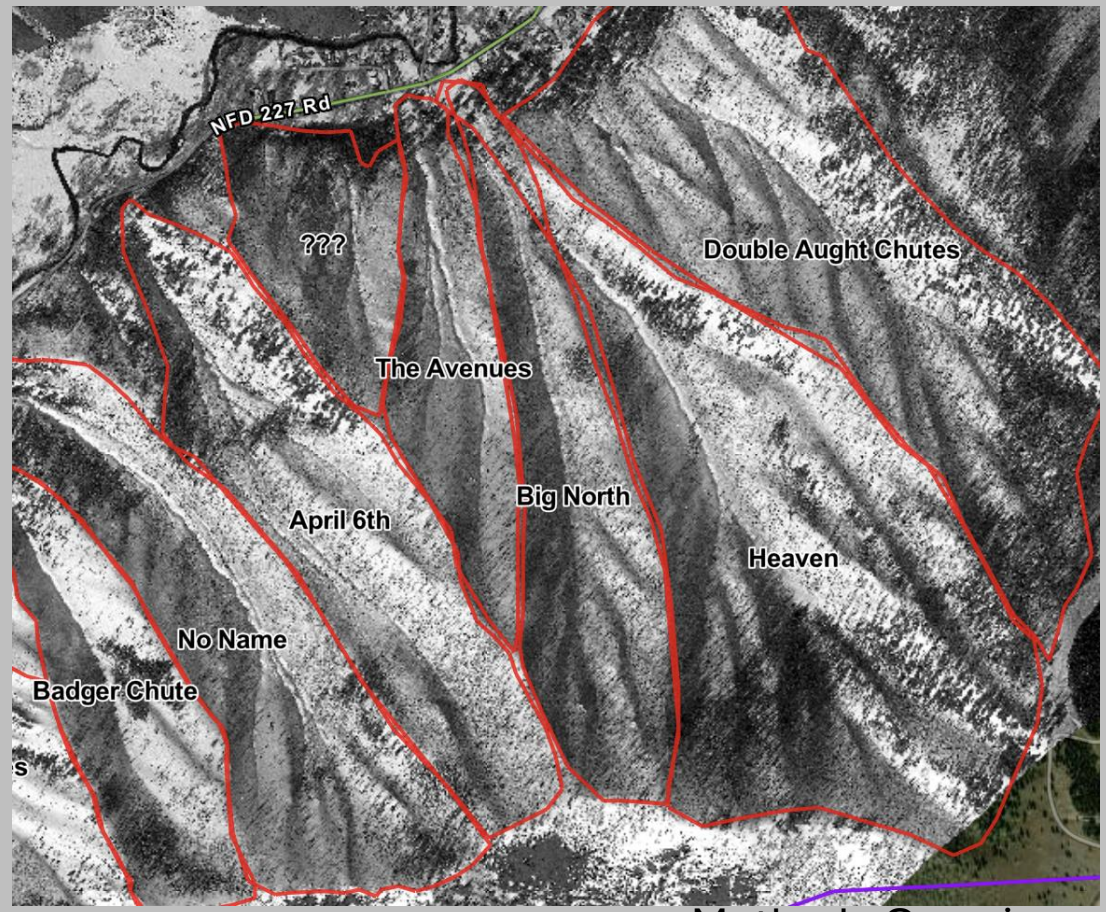
	A	B	C	D	E	F	G	H	I
1	Time	Date	AMZ	Av. Area	Path	Location	Avalanche Notes	Source	Other Info
3	6:59AM	20230315	North	Titus Ridge	Verlans	Galena pass	Verlons D3	BV	Reported Titus slide. Estimated 20' of debris on road. "1000' long Fx Line with hundreds of feet of roadway buried."
4	10:00 AM	20230315	WSR	Lower Board Ranch	Big North	Board Ranch - Big North	Multiple D3s and D2s	Tina, ED	Debris arrested 50' from a home.
5	11:10 AM	20230315	WSR	Frenchmans			Frenchmans - multiple ASu wet slides	JP, BV	we called Kent May, he cleared the scene
6	2:00 PM	20230315	WSR	West Fork	West Fork Bank Slide		slide blocking Warm Springs Road.	ED - Steve Thompson	Photo by Bruce Smith in Atlas.
7	2:00 PM	20230315	WSR	Frenchmans	Frenchman's Bend	Warm Springs Ck/Rd	3-4 slides blocking Warm Springs Rd	ED - Steve Thompson	At W Fork and near Tar Paper shack
8	2:00 PM	20230315				Little Wood Rd	road blocked - 1 slide	ED - Steve Thompson	ED has details
9	1:15 PM	20230315	North	Spring Creek		HWY 75	D1.5 blocked road Spring Creek	BV	
10	8:20AM	20230314				China Gardens	Roof avalanche	ED	Watched my neighbors roof shed. 3' of snow and ice. Shook the power drop hard enough to wiggle the telephone pole and shake our drop too.
11	~9:00 AM	20230314	South	Broadford - N		Between Star and Colorado Gulch	Very large avalanche D2.5 or D3?, E-face over the river	Lisa Horowitz, JP	Blocked the river. No water making it to Star bridge (upper Broadford Rd). Public report that river level was normal again at 2 PM. It's been added to the SAC DB.
12									Car stuck beyond the slide. Construction workers still working on the site where the

+ Interviews + Wood River Journal + Snowy Torrents + Wilbur, Mears, and Wilson Studies

Methods Overview

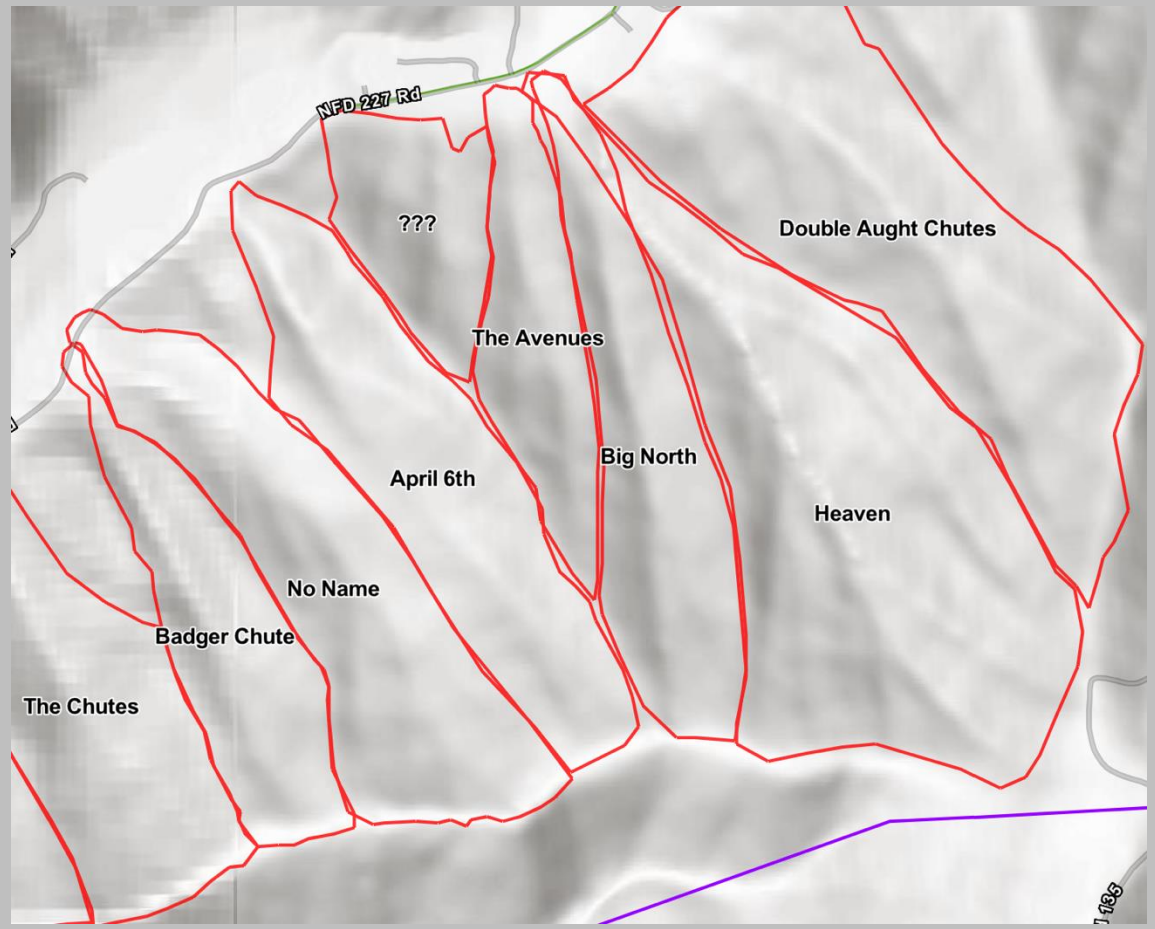
Path Mapping – Winter Imagery

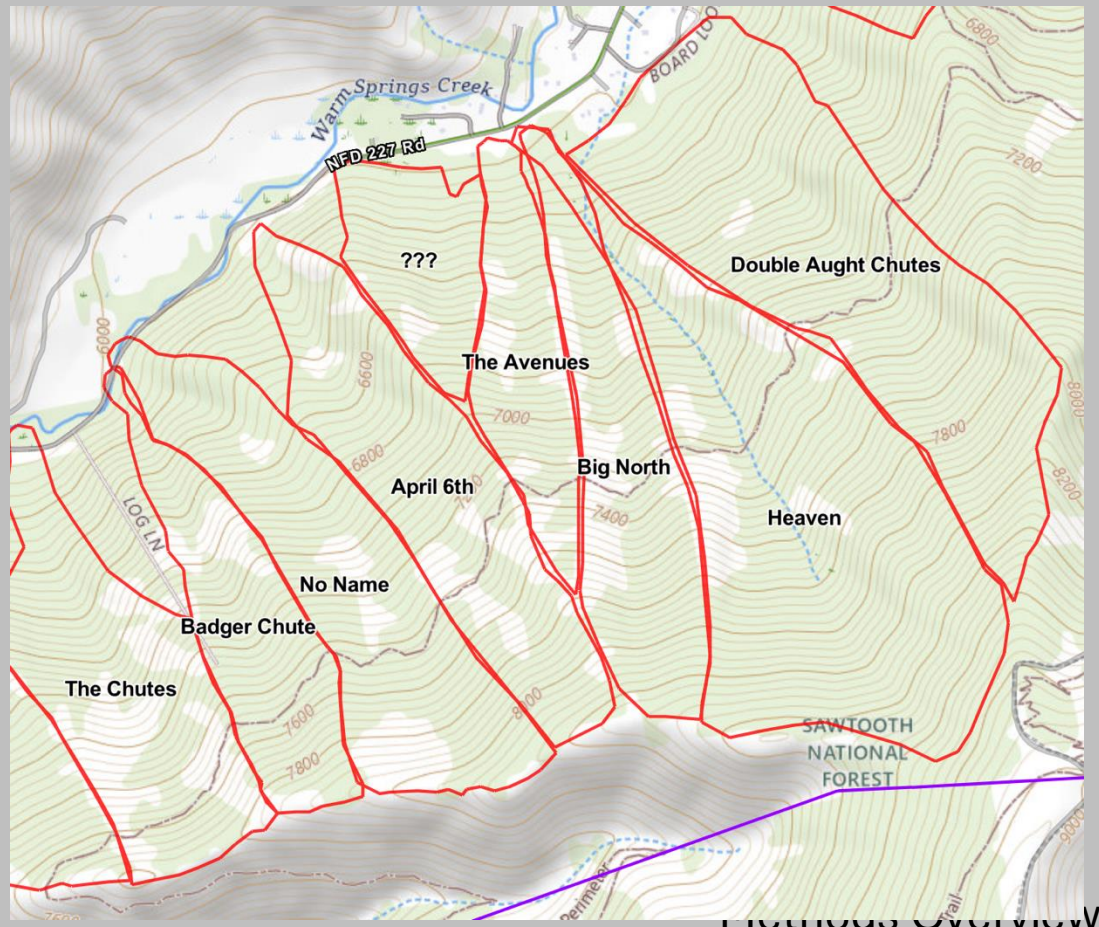




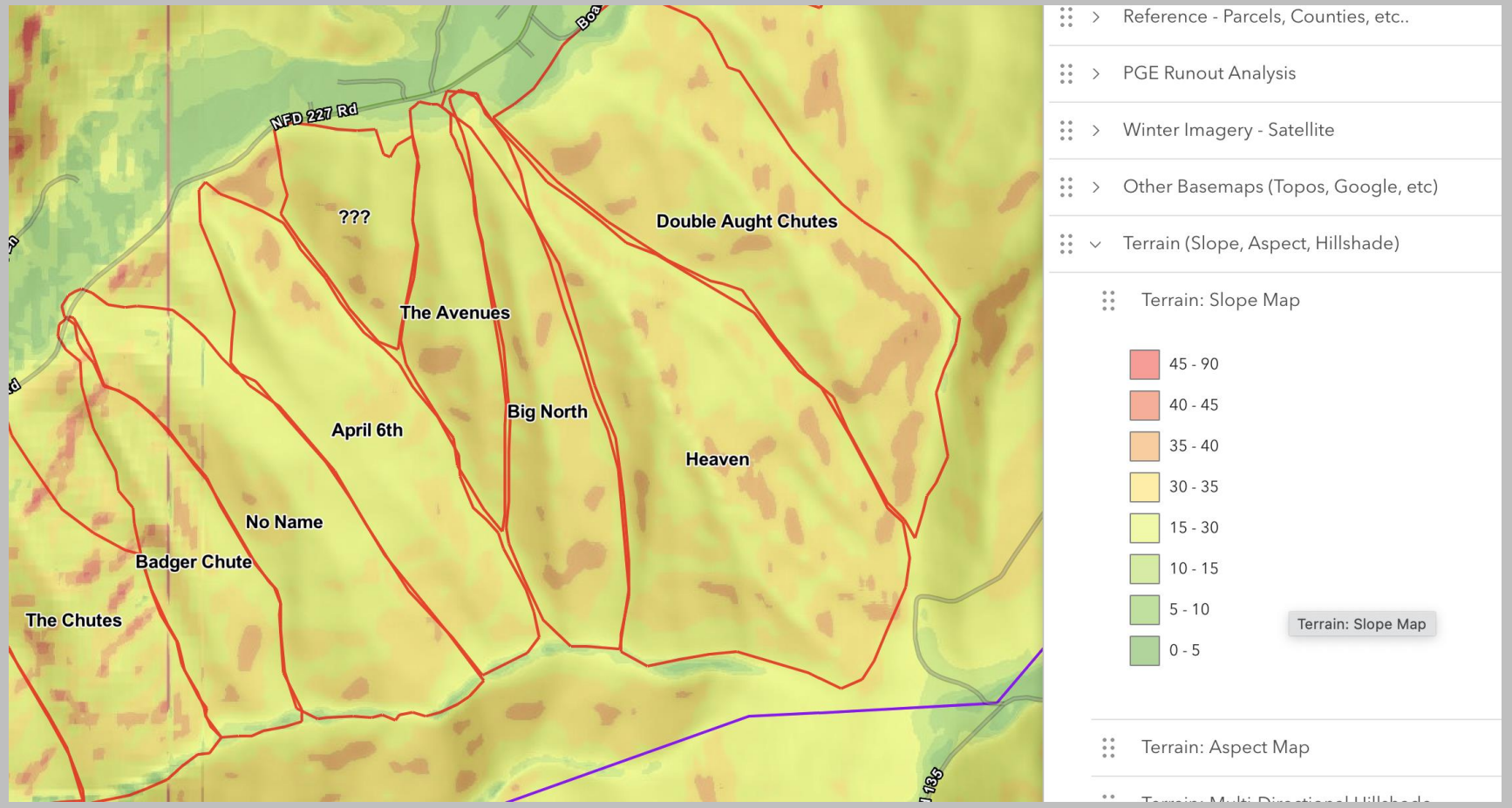
Methods Overview

Path Mapping – Directional Hillshade



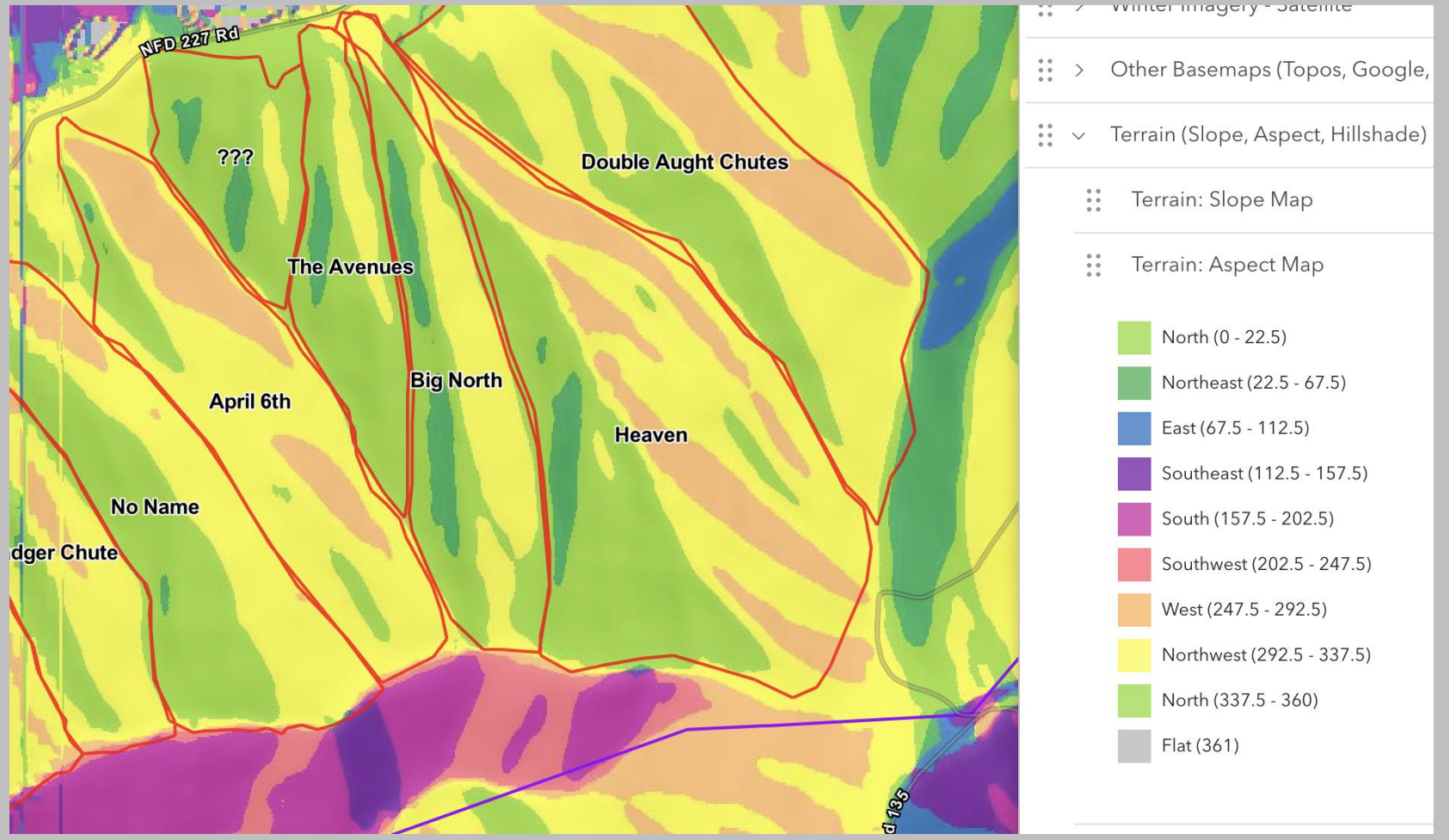


Path Mapping – Slope Angle



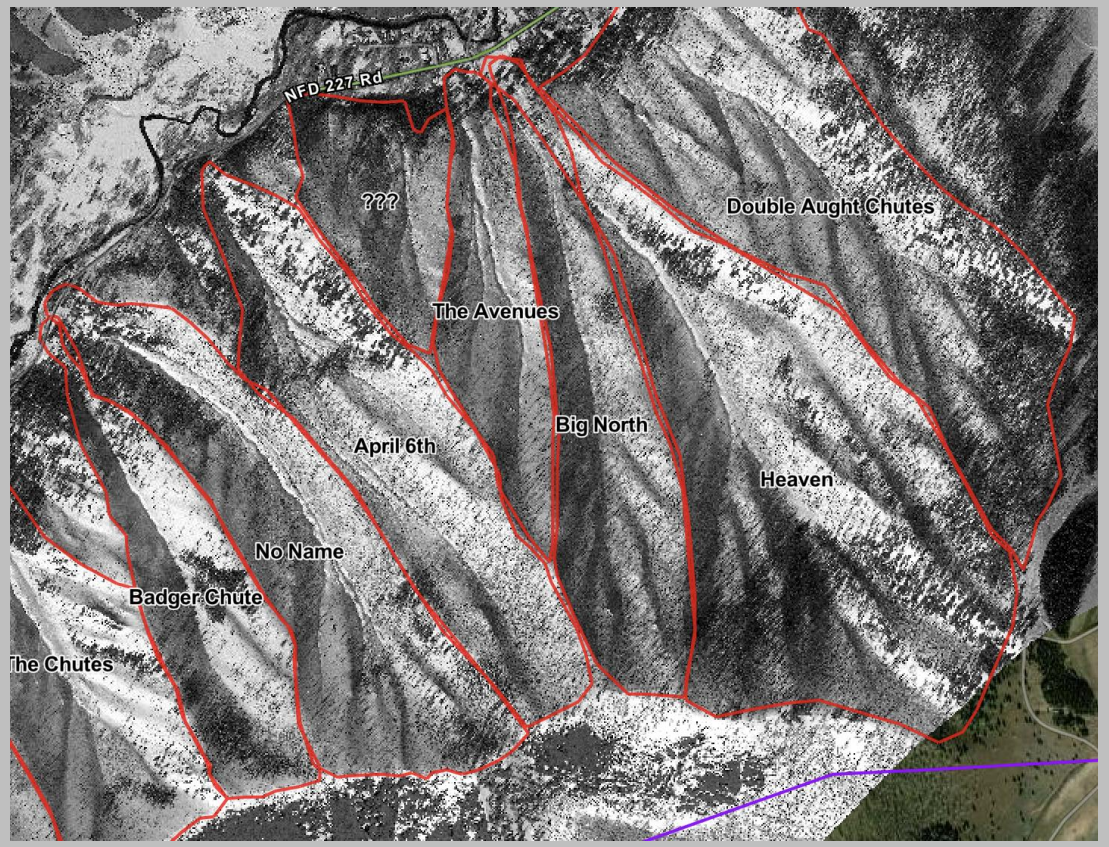
Methods Overview

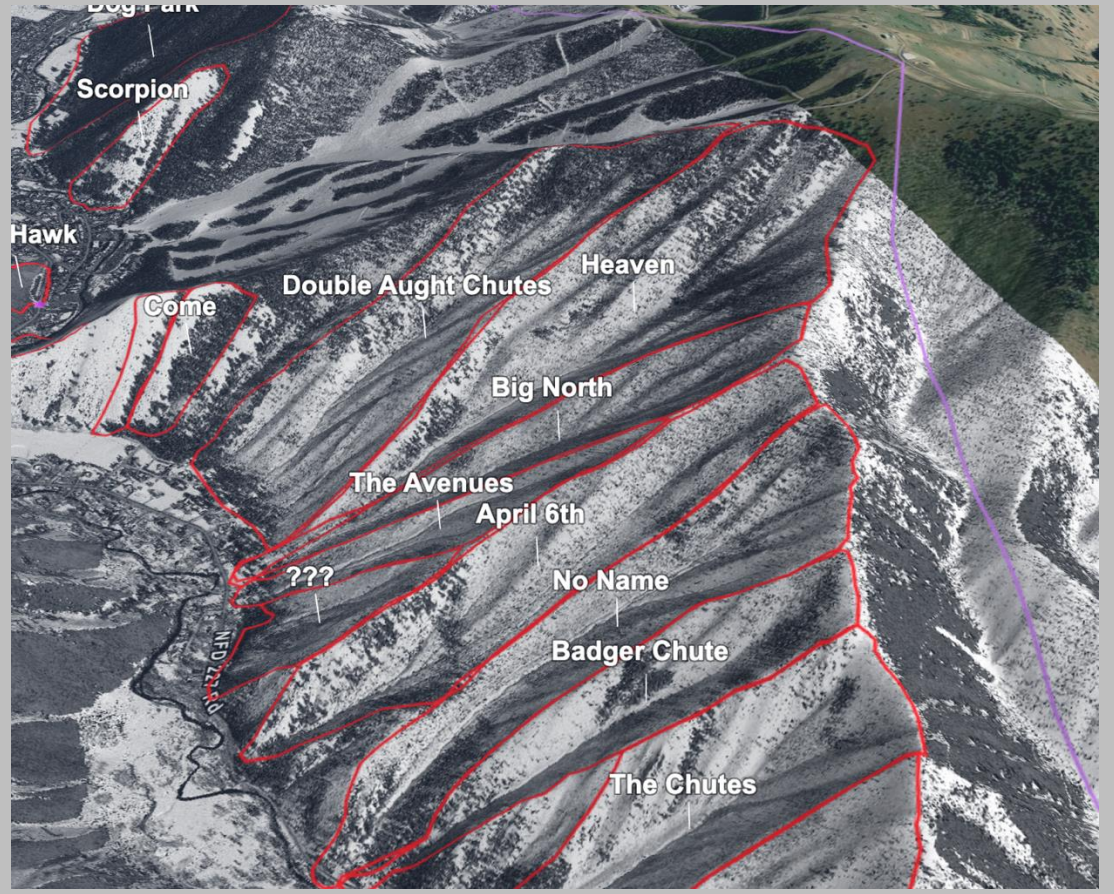
Path Mapping – Aspect



Methods Overview

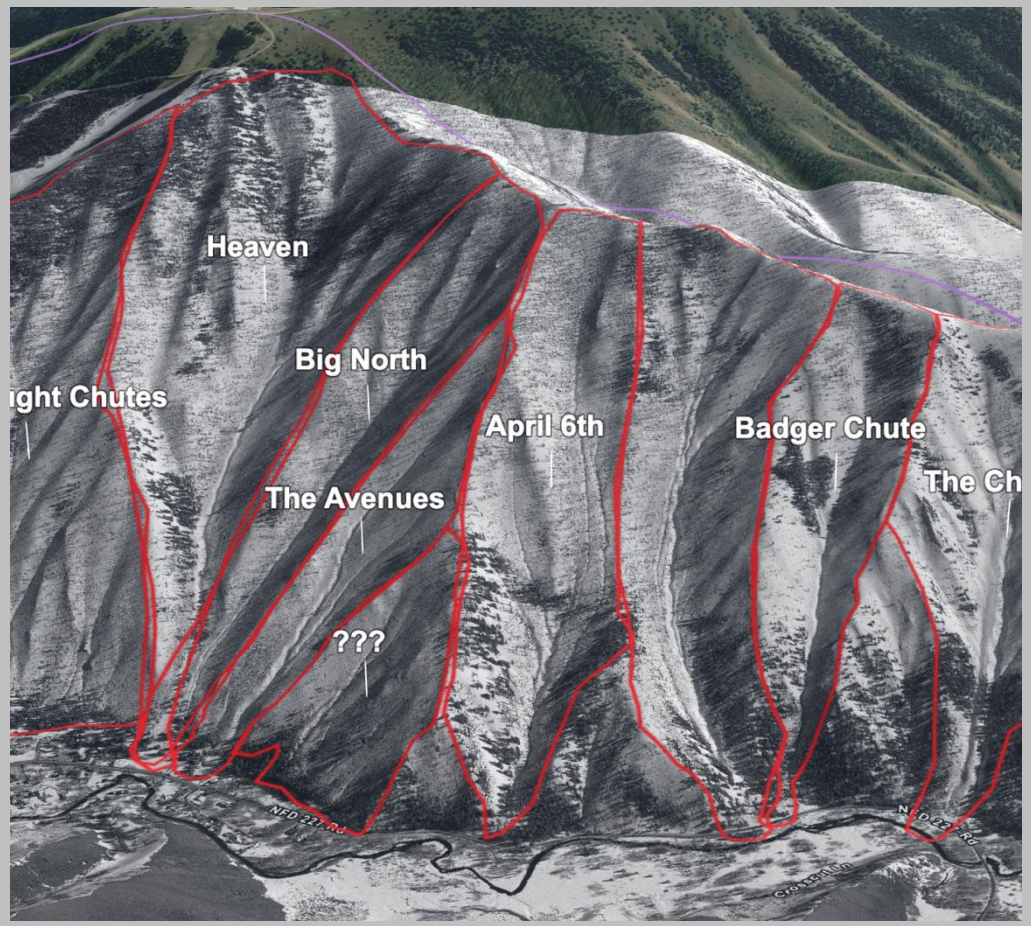
Path Mapping - 3D Rotation

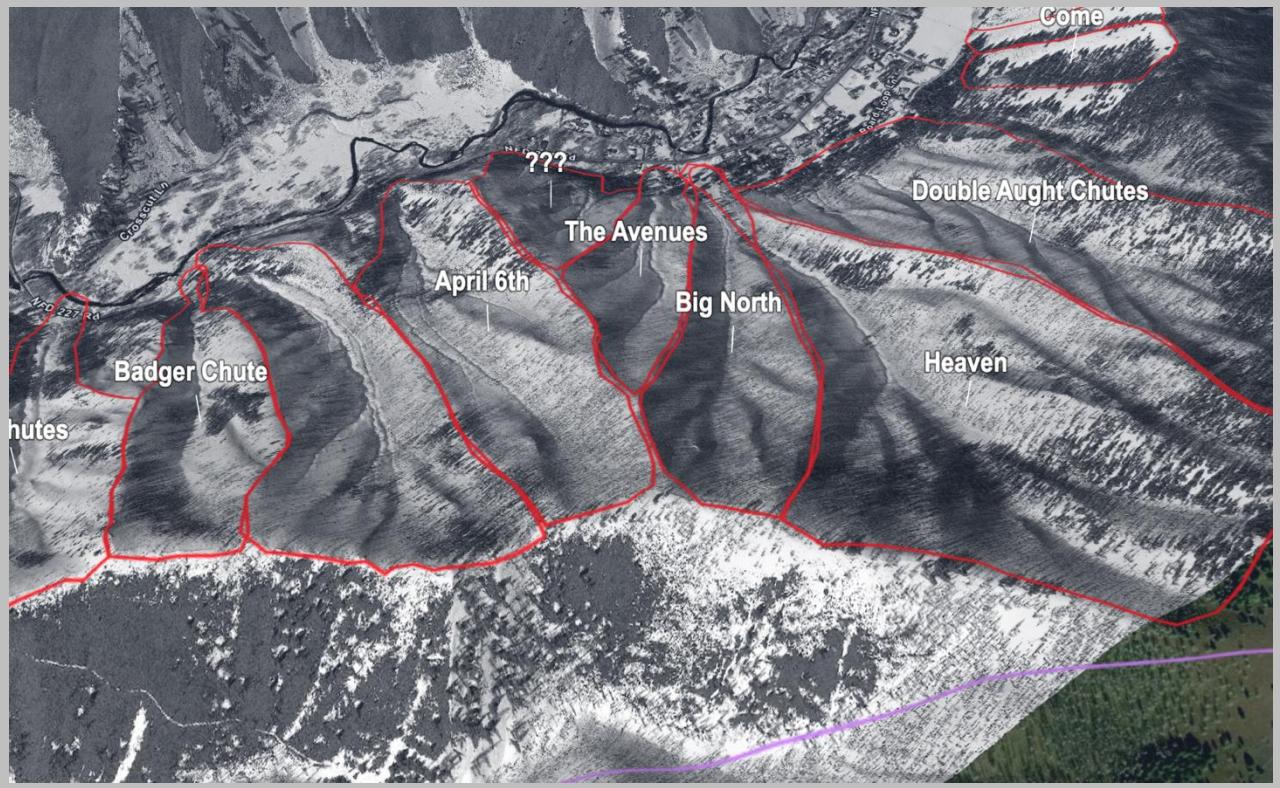




Methods Overview

Path Mapping - 3D Rotation





Methods Overview

AHI – Baseline Info (GIS, WADT, Frequency…)

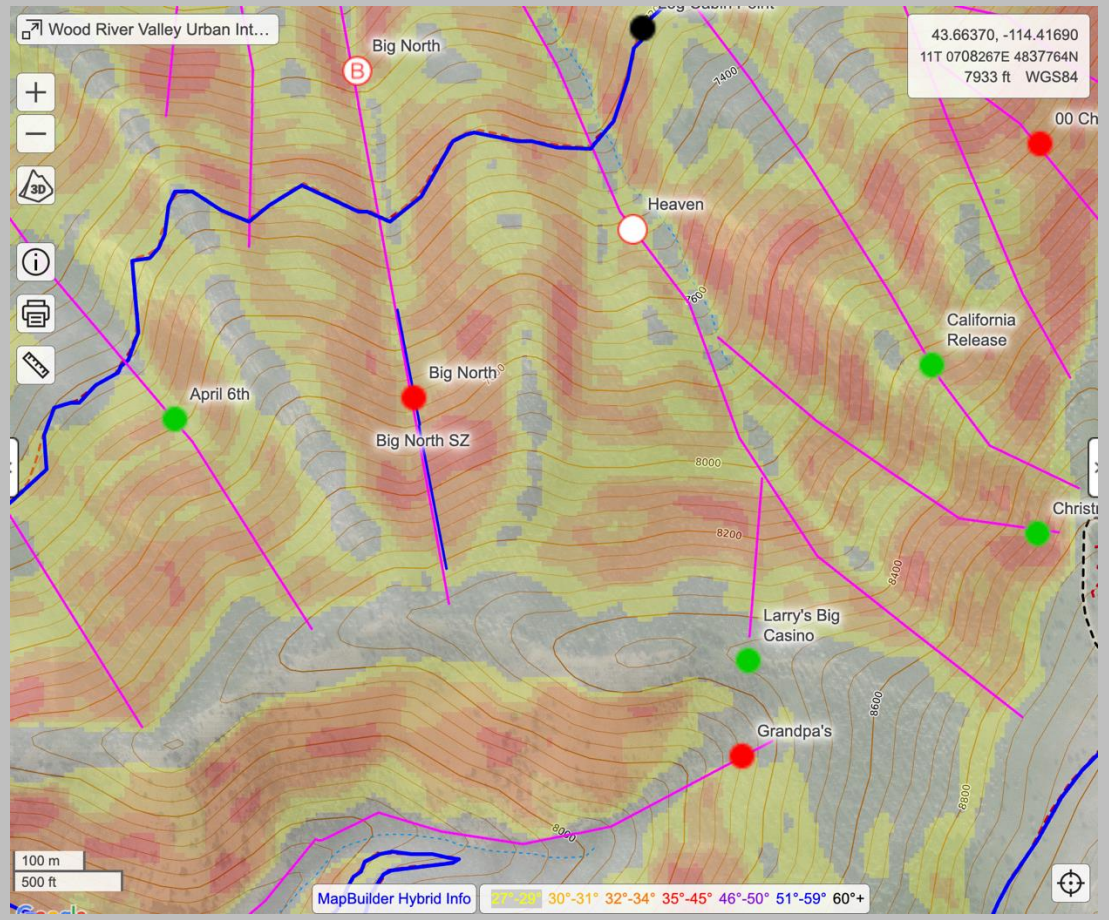
Wood River Valley AHI: ID75-SNR to Galen	WADT	Cars/day	Ratio
	Total	285	
	Cars	282	0.99
	Buses	3	0.01

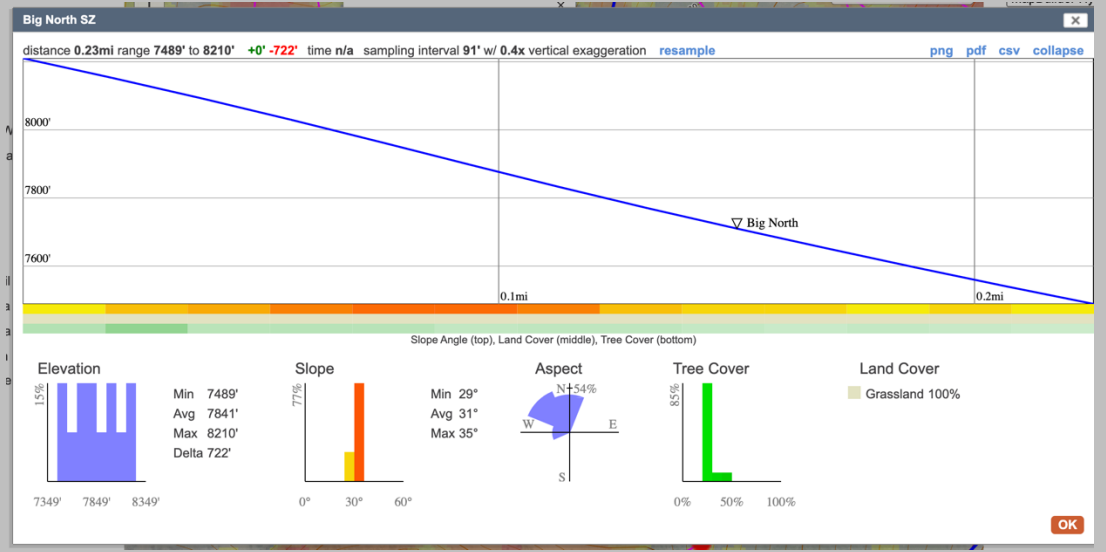
Deep														
								Total				Moving	Car	Bus
		Annual	Return	Avg.	Lmax	Encounter probability		Encounter	Q Factor	Q Factor	Total	AHI	Ratio	Ratio
Path #	Name	Frequency	Period	length (m)	(m)	Car	Buses	Probability	Cars	Trucks				
1	Galena Pass Bank Slide #1	0.03	33	235	335	0.0016	0.0000	0.00	10.0	10.0	0.29	0.015	0.990	0.010
2	Galena Pass Bank Slide #2	0.03	33	73	104	0.0010	0.0000	0.00	10.0	10.0		0.010	0.990	0.010
3	Galena Pass Bank Slide #3	0.03	33	48	68	0.0009	0.0000	0.00	10.0	10.0		0.009	0.990	0.010
4	Galena Pass Bank Slide #4	0.03	33	55	79	0.0009	0.0000	0.00	10.0	10.0		0.009	0.990	0.010
5	Galena Pass Bank Slide #5	0.03	33	147	210	0.0012	0.0000	0.00	10.0	10.0		0.012	0.990	0.010
6	Galena Pass Bank Slide #6	0.03	33	168	240	0.0013	0.0000	0.00	10.0	10.0		0.013	0.990	0.010
7	Galena Pass Bank Slide #7	0.03	33	88	125	0.0010	0.0000	0.00	10.0	10.0		0.010	0.990	0.010
8	Galena Pass Bank Slide #8	0.00	1000	86	123	0.0000	0.0000	0.00	10.0	10.0		0.000	0.990	0.010
9	Galena Pass Bank Slide #9	0.03	33	82	117	0.0010	0.0000	0.00	10.0	10.0		0.010	0.990	0.010
10	Galena Pass Bank Slide #10	0.03	33	125	178	0.0012	0.0000	0.00	10.0	10.0		0.011	0.990	0.010
11	Titus Redge	0.30	3	233	333	0.0171	0.0002	0.02	10.0	10.0		0.170	0.990	0.010
12	Galena Pass Bank Slide #11a	0.01	100	95	135	0.0003	0.0000	0.00	10.0	10.0		0.003	0.990	0.010
13	Galena Pass Bank Slide #11b	0.03	33	281	401	0.0017	0.0000	0.00	10.0	10.0		0.017	0.990	0.010

README | Chart1 | Chart2_SUM2 | Overall hazard | Powder | Light | Deep | Plunging | A_WaitingTraffic | StoppingDist | Summary | +

Methods Overview

Atlas Buildout - Angles





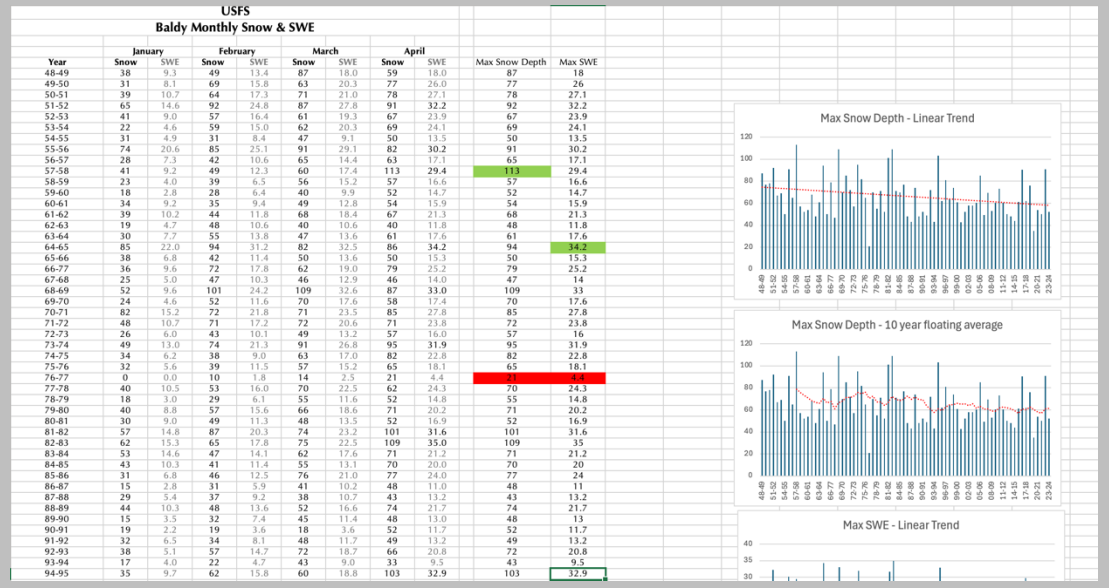
Methods Overview

Atlas Buildout - Frequencies

WSR								
path_count	PathName	Fx'er FREQ estimation	Atlas FREQ	AHI Freq Light	Return Interval Light (years)	AHI Freq Deep	Return Interval Deep(years)	Fx'er Notes
1	Grumpy Chutes	0.01					100	
2	Dog Park	0.3					3	
3	Hill Side	0.1 to 0.3		0.1	10	0.03	33	Capable of D4
4	Creek Slide	0.1 to 0.3		0.1	10	0.03	33	
5	Sage Road High	0.1 to 0.3		0.1	10	0.03	33	
6	Sage Road Low			0.1	10	0.03	33	
7	Scorpion	0.3					3	
8	Gray Hawk			0.1	10	0.03	33	
9	Guyer Hot Springs		0.1				10	
10	Penny Lake	0.1		0.3	3	0.1	10	
11	Double Aught Chutes		U				U	
12	Heaven		0.03				33	
13	Big North			0.3	3	0.1	10	Capable of D4
14	The Avenues			0.1	10	0.03	33	
15	???			0.01	100	0.01	100	
16	April 6th			0.03	33	0.03	33	
17	No Name			0.03	33	0.03	33	
18	Badger Chute			0.03	33	0.03	33	
19	The Chutes			0.03	33	0.03	33	
20	West Fork Bank Slide			0.3	3	0.1	10	
21	Frenchmans Bend #1	1.0 to 0.3		0.1	10	0.03	33	R2/R3 and D2 to D3 will hit road
22	Frenchmans Bend #2			0.1	10	0.03	33	
23	Frenchmans Bend #3			0.1	10	0.03	33	
24	Frenchmans Bend #4			0.1	10	0.1	10	
25	Frenchmans Bend #5			0.3	3	0.1	10	
26	Frenchmans Bend #6			0.01	100	0.01	100	
27	Frenchmans Bend #7			0.3	3	0.1	10	
28	Frenchmans Bend #8			0.3	3	0.1	10	
29	Frenchmans Bend #9			0.01	100	0.003	333	
30	Frenchmans Bend #10			0.3	3	0.3	3	
31	Frenchmans Bend #11			0.05	20	0.05	20	

Methods Overview

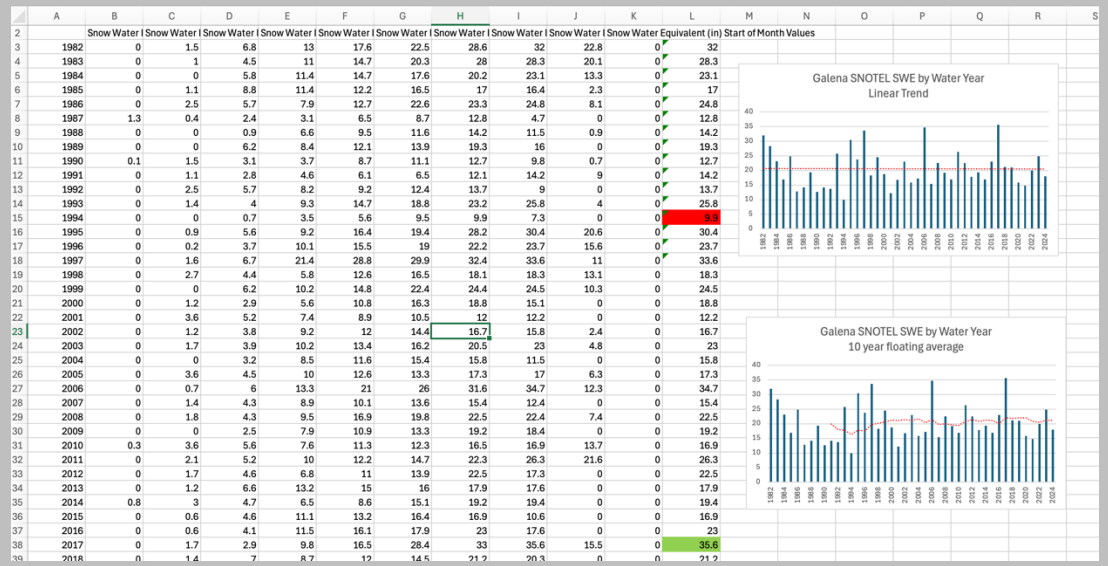
Final Report – Climatology Analysis



USFS

Baldy Monthly Snow & SWE

	January		February		March		April			
Year	Snow	SWE	Snow	SWE	Snow	SWE	Snow	SWE	Max Snow Depth	Max SWE
48-49	38	9.3	49	13.4	87	18.0	59	18.0	87	18
49-50	31	8.1	69	15.8	63	20.3	77	26.0	77	26
50-51	39	10.7	64	17.3	71	21.0	78	27.1	78	27.1
51-52	65	14.6	92	24.8	87	27.8	91	32.2	92	32.2
52-53	41	9.0	57	16.4	61	19.3	67	23.9	67	23.9
53-54	22	4.6	59	15.0	62	20.3	69	24.1	69	24.1
54-55	31	4.9	31	8.4	47	9.1	50	13.5	50	13.5
55-56	74	20.6	85	25.1	91	29.1	82	30.2	91	30.2
56-57	28	7.3	42	10.6	65	14.4	63	17.1	65	17.1
57-58	41	9.2	49	12.3	60	17.4	113	29.4	113	29.4
58-59	23	4.0	39	6.5	56	15.2	57	16.6	57	16.6
59-60	18	2.8	28	6.4	40	9.9	52	14.7	52	14.7
60-61	34	9.2	35	9.4	49	12.8	54	15.9	54	15.9
61-62	39	10.2	44	11.8	68	18.4	67	21.3	68	21.3
62-63	19	4.7	48	10.6	40	10.6	40	11.8	48	11.8
63-64	30	7.7	55	13.8	47	13.6	61	17.6	61	17.6
64-65	85	22.0	94	31.2	82	32.5	86	34.2	94	34.2
65-66	38	6.8	42	11.4	50	13.6	50	15.3	50	15.3
66-77	36	9.6	72	17.8	62	19.0	79	25.2	79	25.2
67-68	25	5.0	47	10.3	46	12.9	46	14.0	47	14
68-69	52	9.6	101	24.2	109	32.6	87	33.0	109	33
69-70	24	4.6	52	11.6	70	17.6	58	17.4	70	17.6
70-71	82	15.2	72	21.8	71	23.5	85	27.8	85	27.8
71-72	48	10.7	71	17.2	72	20.6	71	23.8	72	23.8
72-73	26	6.0	43	10.1	49	13.2	57	16.0	57	16
73-74	49	13.0	74	21.3	91	26.8	95	31.9	95	31.9
74-75	34	6.2	38	9.0	63	17.0	82	22.8	82	22.8
75-76	32	5.6	39	11.5	57	15.2	65	18.1	65	18.1
76-77	0	0.0	10	1.8	14	2.5	21	4.4	21	4.4
77-78	40	10.5	53	16.0	70	22.5	62	24.3	70	24.3
78-79	18	3.0	29	6.1	55	11.6	52	14.8	55	14.8
79-80	40	8.8	57	15.6	66	18.6	71	20.2	71	20.2
80-81	30	9.0	49	11.3	48	13.5	52	16.9	52	16.9
81-82	57	14.8	87	20.3	74	23.2	101	31.6	101	31.6
82-83	62	15.3	65	17.8	75	22.5	109	35.0	109	35
83-84	53	14.6	47	14.1	62	17.6	71	21.2	71	21.2
84-85	43	10.3	41	11.4	55	13.1	70	20.0	70	20
85-86	31	6.8	46	12.5	76	21.0	77	24.0	77	24
86-87	15	2.8	31	5.9	41	10.2	48	11.0	48	11
87-88	29	5.4	37	9.2	38	10.7	43	13.2	43	13.2
88-89	44	10.3	48	13.6	52	16.6	74	21.7	74	21.7
89-90	15	3.5	32	7.4	45	11.4	48	13.0	48	13
90-91	19	2.2	19	3.6	18	3.6	52	11.7	52	11.7
91-92	32	6.5	34	8.1	48	11.7	49	13.2	49	13.2
92-93	38	5.1	57	14.7	72	18.7	66	20.8	72	20.8
93-94	17	4.0	22	4.7	43	9.0	33	9.5	43	9.5
94-95	35	9.7	62	15.8	60	18.8	103	32.9	103	32.9



	Snow Water Equivalent (in) Start of Month Values											
	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	Snow Water	
1982	0	1.5	6.8	13	17.6	22.5	28.6	32	22.8	0	32	
1983	0	1	4.5	11	14.7	20.3	28	28.3	20.1	0	28.3	
1984	0	0	5.8	11.4	14.7	17.6	20.2	23.1	13.3	0	23.1	
1985	0	1.1	8.8	11.4	12.2	16.5	17	16.4	2.3	0	17	
1986	0	2.5	5.7	7.9	12.7	22.6	23.3	24.8	8.1	0	24.8	
1987	1.3	0.4	2.4	3.1	6.5	8.7	12.8	4.7	0	0	12.8	
1988	0	0	0.9	6.6	9.5	11.6	14.2	11.5	0.9	0	14.2	
1989	0	0	6.2	8.4	12.1	13.9	19.3	16	0	0	19.3	
1990	0.1	1.5	3.1	3.7	8.7	11.1	12.7	9.8	0.7	0	12.7	
1991	0	1.1	2.8	4.6	6.1	6.5	12.1	14.2	9	0	14.2	
1992	0	2.5	5.7	8.2	9.2	12.4	13.7	9	0	0	13.7	
1993	0	1.4	4	9.3	14.7	18.8	23.2	25.8	4	0	25.8	
1994	0	0	0.7	3.5	5.6	9.5	9.9	7.3	0	0	9.9	
1995	0	0.9	5.6	9.2	16.4	19.4	28.2	30.4	20.6	0	30.4	
1996	0	0.2	3.7	10.1	15.5	19	22.2	23.7	15.6	0	23.7	
1997	0	1.6	6.7	21.4	28.8	29.9	32.4	33.6	11	0	33.6	
1998	0	2.7	4.4	5.8	12.6	16.5	18.1	18.3	13.1	0	18.3	
1999	0	0	6.2	10.2	14.8	22.4	24.4	24.5	10.3	0	24.5	
2000	0	1.2	2.9	5.6	10.8	16.3	18.8	15.1	0	0	18.8	
2001	0	3.6	5.2	7.4	8.9	10.5	12	12.2	0	0	12.2	
2002	0	1.2	3.8	9.2	12	14.4	16.7	15.8	2.4	0	16.7	
2003	0	1.7	3.9	10.2	13.4	16.2	20.5	23	4.8	0	23	
2004	0	0	3.2	8.5	11.6	15.4	15.8	11.5	0	0	15.8	
2005	0	3.6	4.5	10	12.6	13.3	17.3	17	6.3	0	17.3	
2006	0	0.7	6	13.3	21	26	31.6	34.7	12.3	0	34.7	
2007	0	1.4	4.3	8.9	10.1	13.6	15.4	12.4	0	0	15.4	
2008	0	1.8	4.3	9.5	16.9	19.8	22.5	22.4	7.4	0	22.5	
2009	0	0	2.5	7.9	10.9	13.3	19.2	18.4	0	0	19.2	
2010	0.3	3.6	5.6	7.6	11.3	12.3	16.5	16.9	13.7	0	16.9	
2011	0	2.1	5.2	10	12.2	14.7	22.3	26.3	21.6	0	26.3	
2012	0	1.7	4.6	6.8	11	13.9	22.5	17.3	0	0	22.5	
2013	0	1.2	6.6	13.2	15	16	17.9	17.6	0	0	17.9	
2014	0.8	3	4.7	6.5	8.6	15.1	19.2	19.4	0	0	19.4	
2015	0	0.6	4.6	11.1	13.2	16.4	16.9	10.6	0	0	16.9	
2016	0	0.6	4.1	11.5	16.1	17.9	23	17.6	0	0	23	
2017	0	1.7	2.9	9.8	16.5	28.4	33	35.6	15.5	0	35.6	
2018	0	1.4	7	8.7	12	14.5	21.2	20.3	0	0	21.2	

Methods Overview

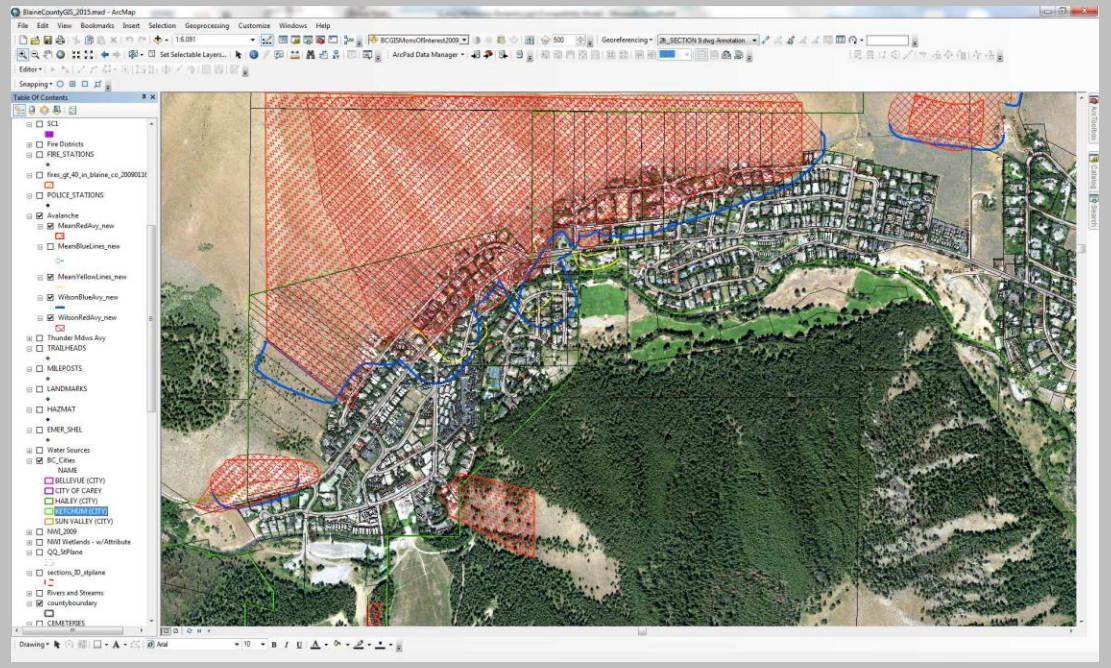
Final Report - Signage

- Avalanche Area Signage

Next Steps

Final Report – Public Access Overlays

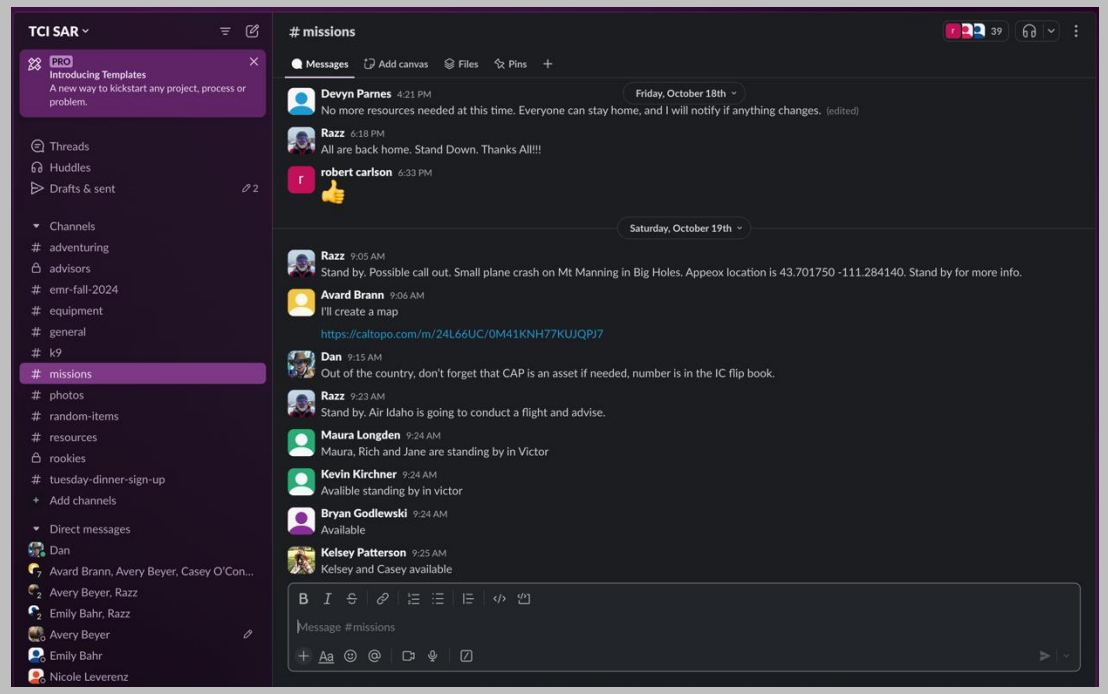
- Shareable GIS layers – avalanche paths and R/B Zones



Next Steps

Final Report – Communication within the County

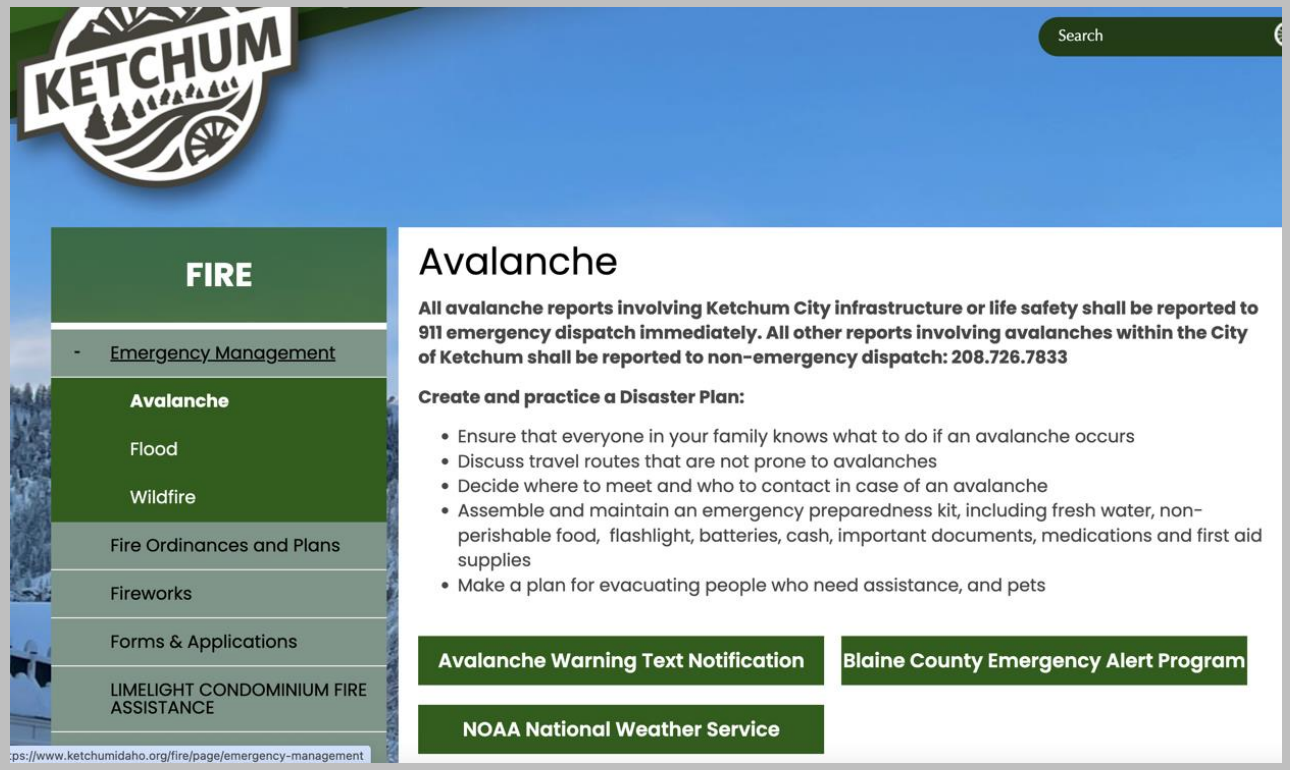
- Creation of common communication platforms – for internal use amongst EMS, SAC, etc.



Next Steps

Final Report –Communication to the Public

- Unified efforts on an information website for the Wood River Valley



Next Steps

Final Report – Communication with ITD

- Push District 4 to start logging avalanche observations.
- Communicate Planned Closures
- Share information from local forecasters to ITD and vise versa
- Mitigation prior to road clearing on Galena Summit.
- Training /Awareness for workers.
- RACS/SZ Fencing for Titus Ridge
- Statewide Avalanche Program Manager/Supervisor

Next Steps

Final Report – Avalanche Commission

- A committee and hierarchy that can make important decisions quickly.

Avalanches Sunday morning on Della Mtn W of Hailey blocked the Big Wood River, temporarily diverting it onto War Eagle Rd near Heagle Park. Photo: City of Hailey

Next Steps

Final Report – Emergency Response Plan AKA Avalanche Safety Plan

- Closures to Public Recreation Zones threatened by Avalanches.
- Road Closures
- Shelter in place orders
- Evacuations
- Communication Language and conduits.

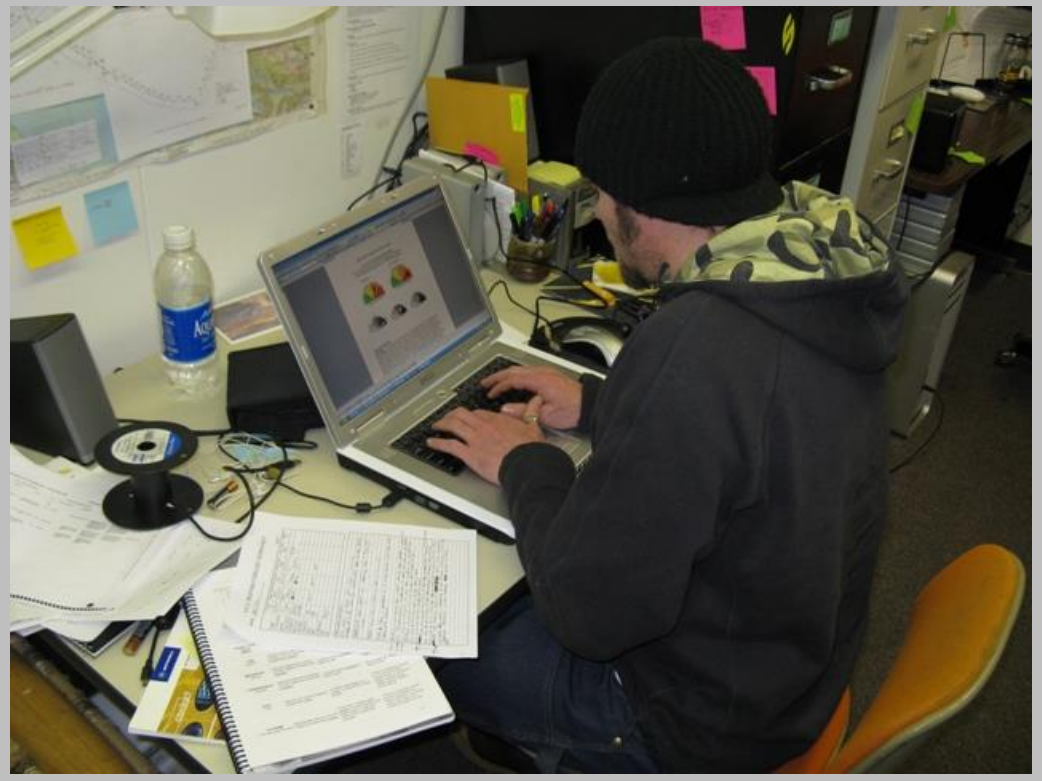
Next Steps

Emergency Preparedness - Training

- Multi-Agency – ALL who may be called upon
- Realistic – Uncertainty will always be part of reality
- Consistent
  Annual – Field based exercise
  Semi-Annual – Table Top Response Exercise
- Expense should be mostly covered by existing training budgets

Final Report – Urban-focused Avalanche Forecasting Program

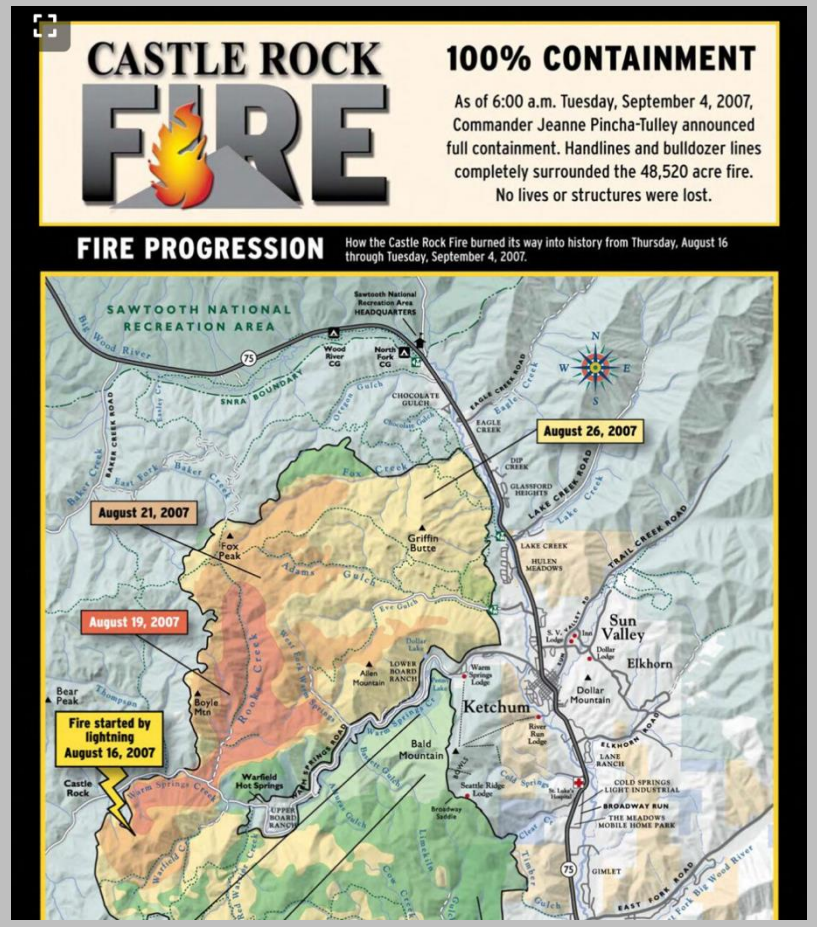
- Partnership with SAC/USFS ?
- Needs to be scalable from zero to hero with only 5-day notice
- Language of communication – advisory, watch, warning?
- Recommendations that can be easily made
- Closures/Evacuations communicated through Nixel alerts or something like it.
- Greatest challenge of urban cycles is not when they start, but when they effectively end.



Next Steps

Final Report – Avalanche Hazard Zoning Updates

- The changing climate with a changing landscape.
- Engineering for houses in terrain that had previously no avalanche occurrences may be inadequate for current conditions



Next Steps

Final Report – Avalanche Hazard Zoning Consistency

- Property Rights – Above All

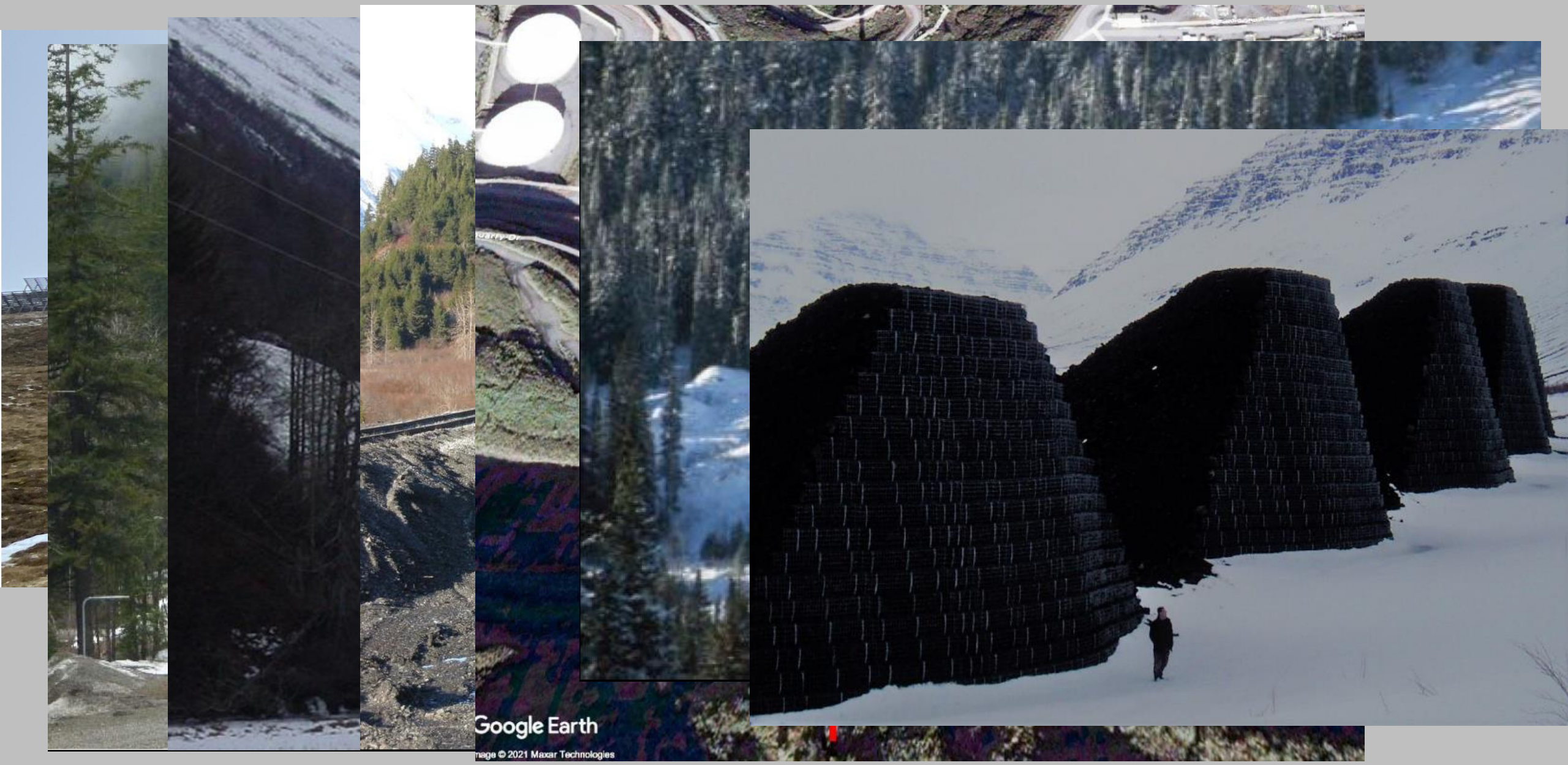
- Public Safety – First and Foremost

Next Steps

DHA's perception of greatest risk

- Motorists* and maintenance workers under Galena Summit
- Motorists*, PEDESTRIANS and maintenance workers traveling on Warm Springs Road (including bus shelters)
- Recreationists (including school children) in Parks, adjacent to Schools, Penny Hill, Quigley…
- Private Properties – particularly LBR, Backside $, and Gimlet Hill, Della Neighborhoods
- Worker Exposure (WSR and neighborhoods)
- First Responders

Permanent Measures



Permanent Measures – continued

What can SAC, ITD, Ketchum, Blaine County, Sun Valley, Hailey, and Bellevue do?

Just about anything they put their minds to, and have time for, and have buy-in for.

What can DHA do for WRV ?

- Ideas from other urban avalanche forecasting programs.
- Design and structure for an urban avalanche forecasting program.
- Public messaging recommendations.
- Avalanche Response Plan – Framework and suggestions.
- Communication with ITD.
- Permanent mitigation measures recommendations

What can DHA do for WRV ?

- Add Table of Contents to all Atlases*
- Work with Bruce Smith to refine avalanche frequencies and runout zones to higher accuracy.
- Add any omitted slopes that could impact the urban interface. (Easley Faces above Harriman Trail, Owl Creek?, “Behind Hospital”…)

KETCHUM

BLAINE COUNTY

IDAHO

Teamwork · Integrity · Excellence

DHA

Avalanche Safety

Mount Jumbo Avalanche Accident
Missoula, Montana

Date: 2014-02-28
Submitted By: Steve Karkanen, Director, West Central Montana Avalanche Center (WCMAC)
Location: Mount Jumbo, City of Missoula Conservation District Open Space Land (inside Missoula City Limits)
State: MT
Country: USA
Fatalities: 1
Injuries: 2
Summary: 1 snowboarder caught and self arrested, 1 child caught and partially buried, 1 child caught and fully buried, recovered with injuries, 2 residents fully buried and recovered with injuries, 1 later died from injuries.
Classification: HS-ARu-D3.5-R4-S,O
Coordinates: N 46.8739 X W -113.9639 (at mid-crown)

*** FULL REPORT FROM THE WCMAC ***

View report and photos online at: www.missoulaavalanche.org

SYNOPSIS

On February 28, 2014 at approximately 1615 hrs, a snowboarder triggered a hard slab avalanche on a west facing, 35 degree slope of Mount Jumbo, located within the Missoula City limits on Missoula Conservation District land.

The snowboarder was caught by the avalanche but able to self arrest by digging in with the edge of his board and using his arms and fingers to grab the bed surface as the snow passed by.

The avalanche entrained most of the available snow in the fetch zone and accelerated as it advanced over a terrain convexity halfway down the track.

At the base of the ravine, the avalanche caught two children, Phoenix and Coral Scoles-Coburn, ages 8 and 10, who were playing in their backyard as it slammed into and destroyed a two story wood frame home. The two residents of the home, Fred Allendorf, 66, and his wife Michel Colville, 68, were inside the house when it was hit.

The two children saw and heard the avalanche coming down the ravine and ran downslope toward their home. Both were caught and carried several feet before coming to rest next to their home. Coral was partially buried, up to her armpits, and was able to dig herself out quickly. Phoenix was completely buried next to the house about 3 feet deep.

Fred and Michel were together in their home and were also completely buried under several feet of snow and debris from their destroyed home.

At 1618, Missoula City Fire, Police, Missoula County Sheriff, MT Highway Patrol units and local EMS teams were dispatched. A large contingent of well equipped neighbors with avalanche rescue gear soon began arriving on scene.

Rescue coordination was complicated by live power lines, broken natural gas lines and the very real possibility of another avalanche. The crown was not visible from the valley floor due to the mid-slope convexity and extreme weather that blocked visibility.

Spot probing began and a probe line formed near the home just below Phoenix's last seen point. Phoenix described being in the dark and unable to move his arms after being buried. He stated that he tried eating and chewing away at the snow until he became so tired that he fell asleep.

He was located 3-4 feet deep by a probe strike after approximately 55 minutes at 1709 hrs. When extricated from the snow, he was unresponsive. Rescue breaths were given and he was immediately transported by ground ambulance to Saint Patrick Hospital's Emergency Department.

Rescue efforts then concentrated on spot probing and digging in areas directly below the last known location of Allendorf and Colville. A neighbor showed rescue teams the probable location on the remaining foundation of where the couple may have been on a Friday afternoon.

Probe teams were directed to concentrate on possible catchment features on the fall line below this area of the house. A probe strike was confirmed and Allendorf was located at 1758 hrs in a cavity under a brick chimney and a wall or roof partition approximately 4 feet deep. He was responsive and able to inform rescuers that his wife was 3 feet from him when the house was hit.

He was extricated and transported by ground ambulance to Saint Patrick Hospital's Emergency Department.

At 1907 hrs, Colville was located by a responding neighbor with a probe. An earlier probe detected a soft spot where a sofa was removed. This location was re-probed after a few minutes and a probe strike confirmed as Colville. She was approximately 25 feet below her husbands location 2-3 feet deep.

Colville was breathing but unresponsive. Extricated at 1914 hrs, she was transported to Saint Patrick Hospital's Emergency Department in critical condition. She died on March 3 from traumatic injuries.

Three other homes, several vehicles and an apartment building were also damaged by the avalanche.

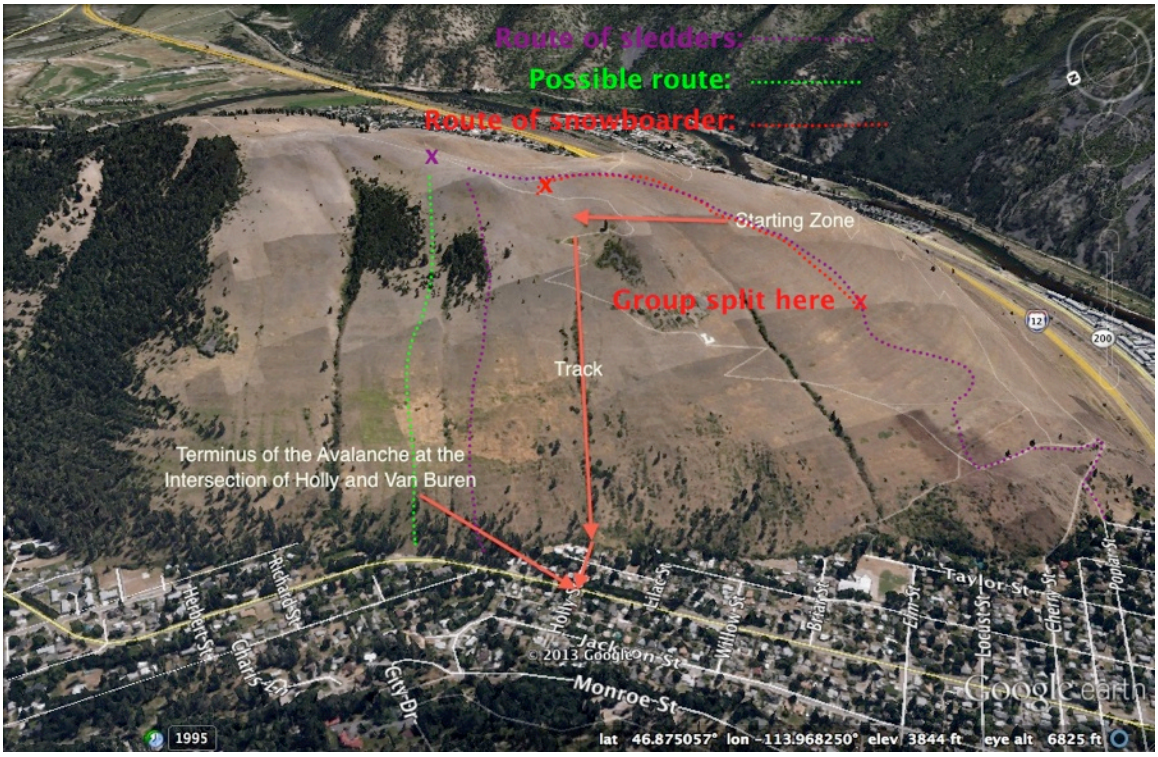
Events leading up to the avalanche

4 friends, ages 13-27, wanting to take advantage of a rare day when schools were closed, decided to snowboard or ski the untracked west face of Mount Jumbo. Earlier storms had deposited enough snow on the low elevation terrain in the mountains surrounding Missoula to allow for unique skiing and riding opportunities within walking distance of many residents. Near record snowfall was recorded by NOAA Weather Service Missoula Office at the Missoula airport during February. Mount Sentinel, above the University of Montana and south of Mount Jumbo, had been skied and ridden earlier in the week and was heavily tracked.

The friends met at a home in the lower Rattlesnake and opted to hike Jumbo since Sentinel had already been tracked up. 1 person had a snowboard available, the others took small plastic sleds. Their intention was to hike to the summit, ride down the untracked west face, walk back to the same home where they planned to take a shuttle vehicle to the trailhead to retrieve their first vehicle.

None of the group has any previous avalanche training or carried rescue equipment and have no applicable winter backcountry travel experience beyond in-bounds skiing and riding at the local resorts. They carried a small shovel with them in case one of their vehicles got stuck.

They parked at the Poplar Street trailhead and initially followed the trail system part way up the mountain until they lost the trail in the new snow. The snowboarder described having to break through several drifts where the historic shoreline created small lee zones but no signs of instability such as collapse noise or fracture propagations. They made their way up the southwest face, avoiding the deeper pockets of snow and eventually found bare ground making it easier to hike.



Google Earth View of Mount Jumbo

The wind was making travel difficult with the snowboard acting like a sail so at about the halfway point, the group split with the 3 sledders continuing toward the summit. (see figure 1)

The sledders planned to hike to the summit and meet the snowboarder at the base of the mountain. They all described the wind as severe at the ridge top with poor visibility from the blowing and drifting snow. The snowboarder was several hundred feet behind the sledders when they began their descent next to a large group of trees. (**Note**: The actual descent route of the sledders has not been confirmed as of 5/13/14. The information shown on the map is based on a personal conversation with the snowboarder and a telephone conversation with one of the sledders.)

The snowboarder reached a point above the slide path and opted not to push toward the summit as the wind was making travel difficult at best. He strapped on his board, entered the slide path at the highest point where there was adequate snow, and immediately fell. He got back up and noticed movement in his peripheral vision and realized he was being carried downslope by an avalanche. He was at the top of the slab and able to self arrest by digging in with the edge of his board and using his arms and fingers to grab the bed surface as the snow passed by. A terrain convexity prevented him from seeing where the avalanche stopped.

The sledders were near the base of the mountain to the north of the slide path. At least one of them saw a powder cloud and heard the avalanche slam into the home. They immediately went to the site and began digging for the buried child. Shortly after this the snowboarder walked down

the slide path and also assisted with the initial rescue effort. All 4 left the scene after talking with responding police officers and were later interviewed by Missoula City Police detectives at the Police Department.

Avalanche Classification: HS-ARu-D3.5-R4-S,O

Description:
HS: A hard slab avalanche.
ARu: Triggered unintentionally by a snowboarder.
D3.5: The destructive force (D) destroyed a house, several cars and damaged several other structures.
R4: The avalanche was large but did not involve the maximum area.
S,O: A surface wind slab initially released at the recent storm snow interface and stepped down to the ice crust at ground level.

Avalanche dimensions

Coordinates: N 46.8739 X W -113.9639 (mid-crown)
Aspect: 294 degrees
Crown elevation: 4480 feet
Terminus: 3280 feet
Vertical drop: 1200 feet
Crown width: 658 feet
Depth: 2.5 feet, Max: 4 feet
Average depth: 3 feet
Slope steepness at crown: 38+ degrees
Average: 35
Distance from crown to terminus: 2200 feet
Average slope steepness: 35 degrees
Maximum steepness at convexity: Estimated at 40 degrees
Alpha Angle at terminus: 30 degrees

Weather and Snowpack

Near record snowfall amounts were recorded in the Missoula Valley during the week before the avalanche. On February 24 and 25, skies cleared and temperatures moderated.

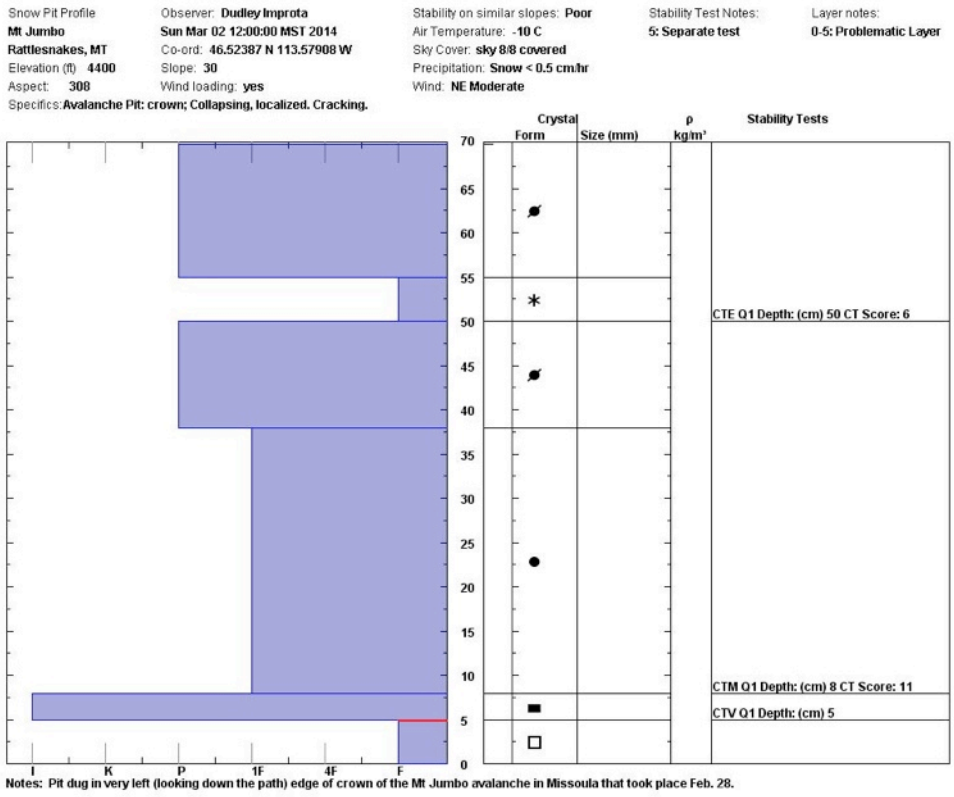
Temperatures above freezing and several hours of sun melted down most of the mountain's snow which then froze hard as temperatures plummeted with the arrival of an arctic air mass.

A rare blizzard warning was issued for Missoula with several inches of snow and high east winds forecast for the area. By the afternoon of February 28, the area received several inches of snow and strong east winds loaded fetch zones high on the mountain. Turbulent winds also heavily cross loaded the ravines leading to the valley floor. The high wind formed sensitive wind slabs on what under normal conditions is a wind scoured slope.

On Sunday, March 2, avalanche specialists Dudley Improta and David Williams, from the West Central Montana Avalanche Center in Missoula were given special permission to enter the Mount Jumbo closure area to conduct a stability assessment of the avalanche path and adjacent terrain.

As they travelled to the site, they reported localized collapsing, whoompfing and fracture propagations in pockets of wind drifted snow. They were careful not to cross any snowfield that connected to steeper terrain. They were able to walk on bare ground for much of their tour.

At the crown, they found a weak snow structure (see profile) with a pencil hard wind slab overlying a fist hard layer of cold snow sandwiched between the hard surface layer and a pencil to 1 finger hard slab on top of the ice layer that formed during the sunny warm days earlier in the week. Large facets were at ground level.

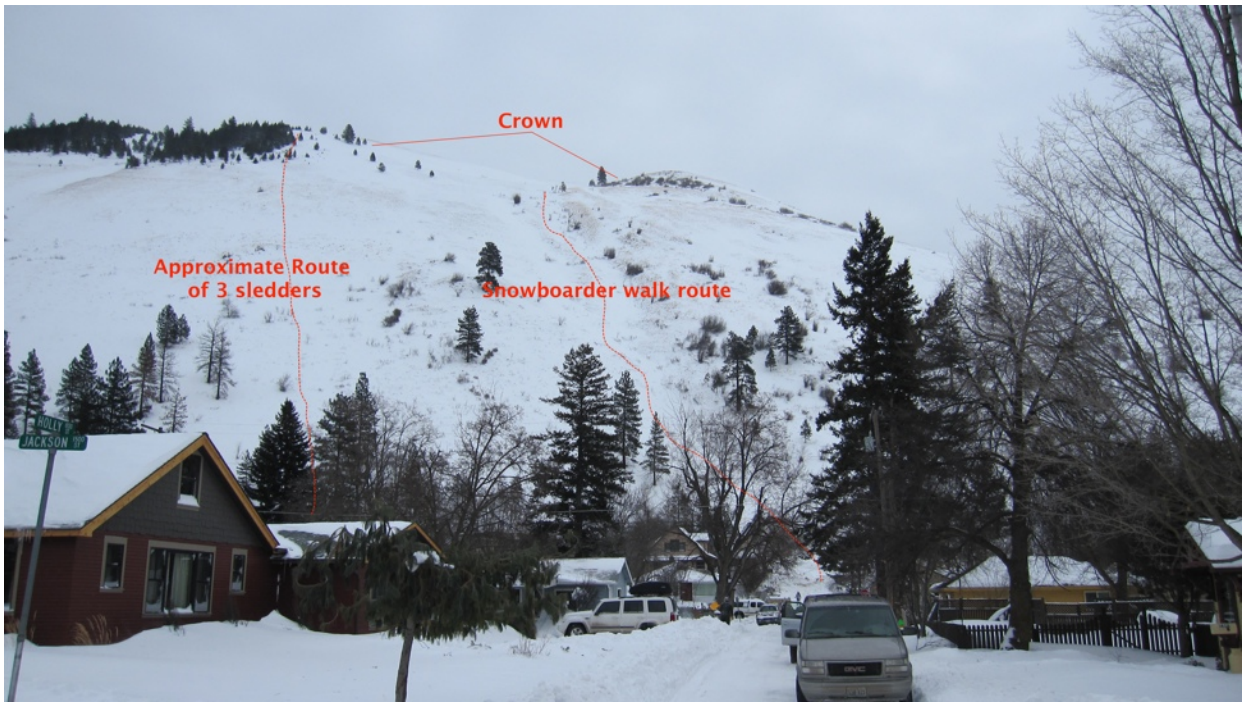


Snow Pit Profile (crown profile) March 2, 2014

Considering the crown profile, the description of how the avalanche was triggered and other observations made by Improta and Williams, we believe the snow initially failed on the pencil hard wind slab then stepped down to involve the remaining slab to the ground facets/ice layer.

This is a complex accident investigation involving multiple agencies and witnesses.

The American Avalanche Association's Avalanche Accident Report Long Form will be submitted to the National Avalanche Center and Colorado Avalanche Information Center once our findings are complete. Please direct any questions to info@missoulaavalanche.org.



View from Jackson and Holly Street Intersection

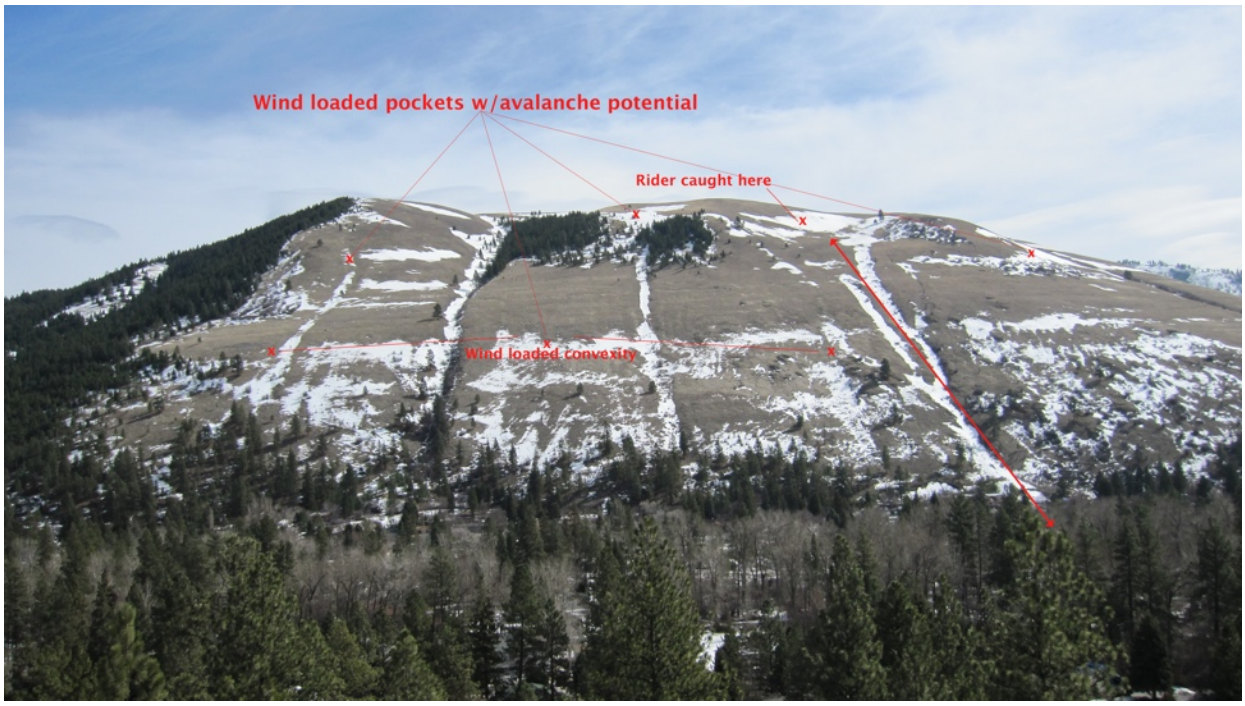
View of the starting zone

View of the crown and upper path

Looking downslope from the foundation of the destroyed home

Terminus of the path at the Intersection of Holly and Van Buren

Dudley Improta conducting crown profile on March 2



View of fetch areas and ravines on Mt Jumbo