Analyses, Design, and Construction of Flexible Debris Flow Barriers in a Narrow Canyon

KANE GeoTech, Inc.
Geoengineering Consultants

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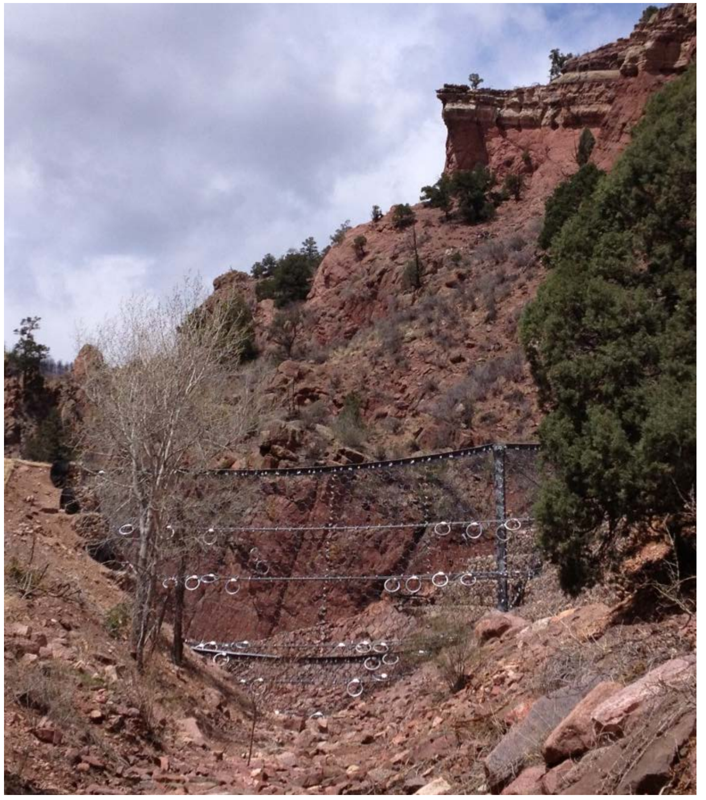

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Acknowledgements

KANE GeoTech, Inc.
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- Derek Strickler, The Navigators

  Colorado Springs, Colorado
- Midwest Rockfall, Inc.

  Henderson, Colorado
- John Kalejta, Geobrugg Geohazards Solutions

  Rocky Mountains Region

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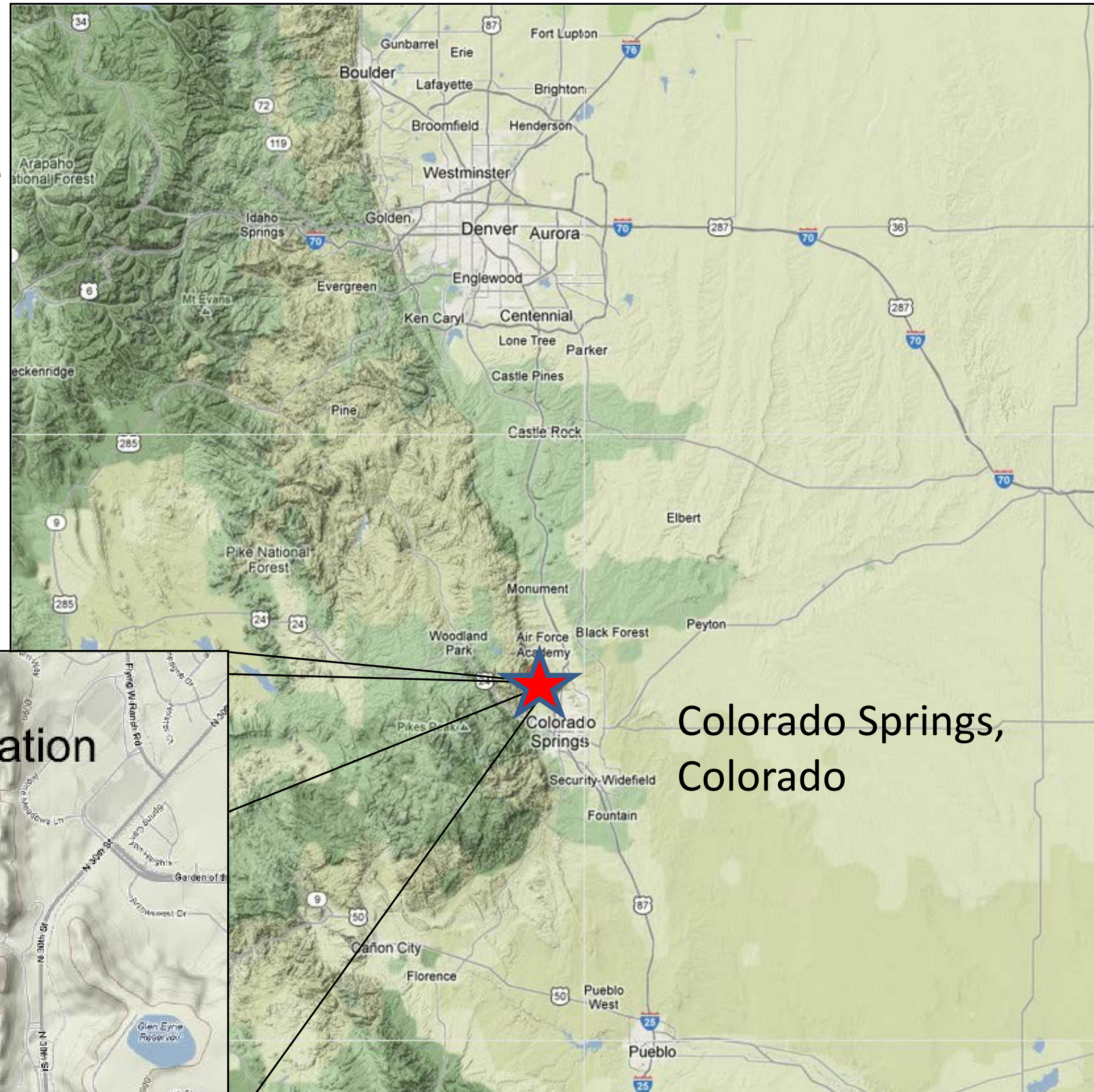
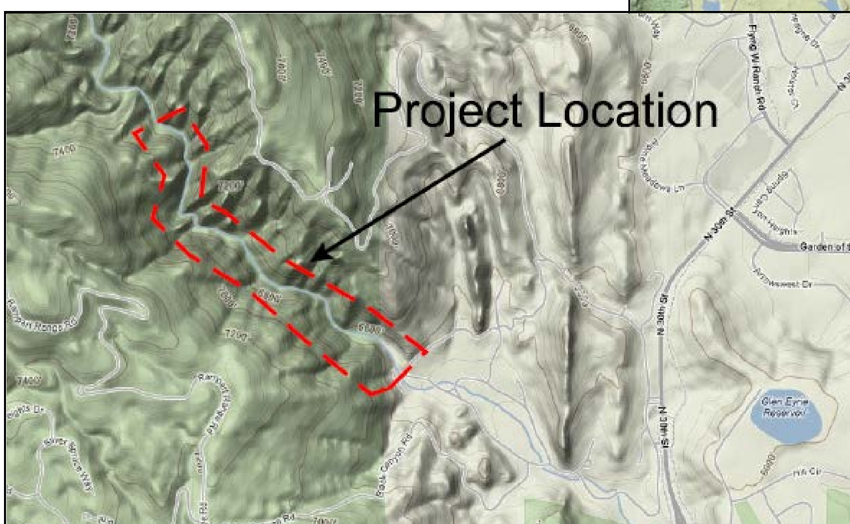
Introduction

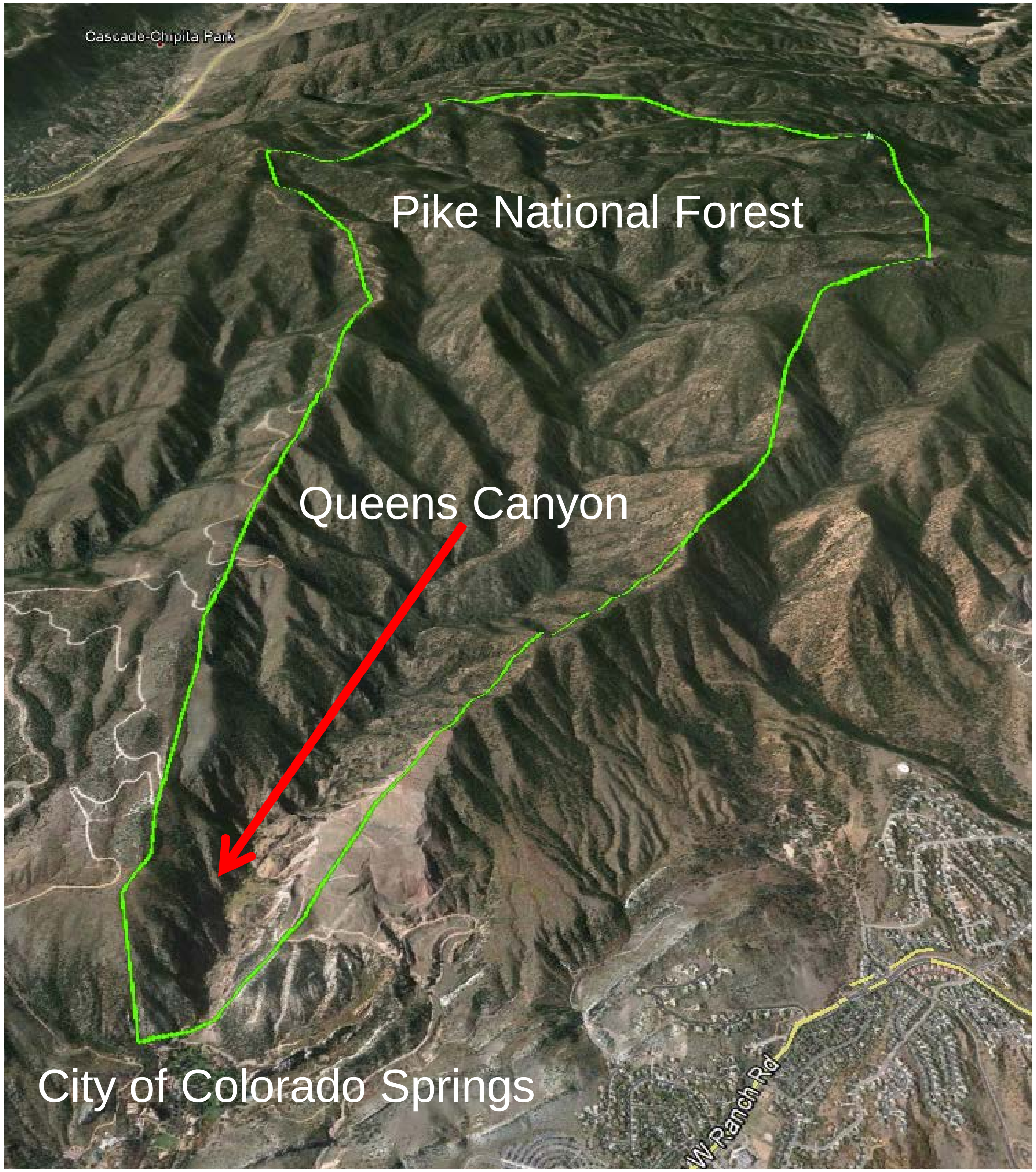
- Colorado Springs, Colorado
- Rocky Mountains Front Range
- Camp Creek Watershed
  - (11.2 square miles)
- Private Property
- Between USFS and City land





Site Description

- Camp Creek Watershed
  - 11.2 square miles
- Severely burned by the Waldo Canyon Fire Summer 2012
- Upper Watershed- USFS Property
- Queens Canyon- Private Property
- Lower Watershed- City of Colorado Springs



Waldo Canyon Fire

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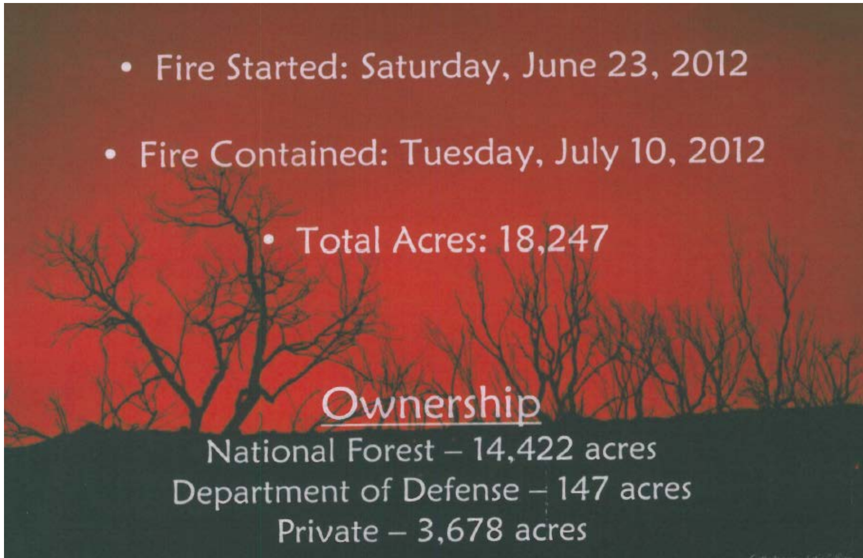

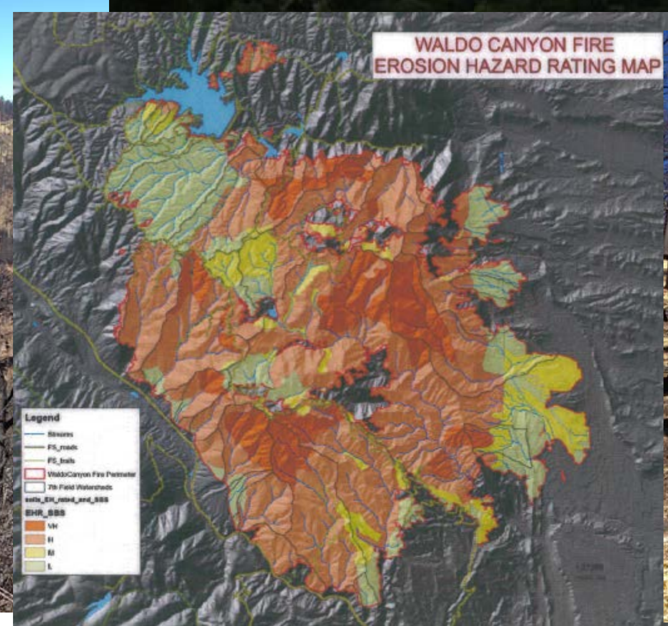

Post-Fire GeoHazards

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Manitou Springs Mudflow Event

Post Waldo Canyon Fire

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Pikes Peak Granite

Phase 1 Investigation

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Channel morphology and gradient dictates available volume of storage!

Potential Debris Flow Barrier sites are identified in the project area.

Sites are chosen based upon:

- storage potential for debris
- protection of critical infrastructure
- ability to clean-out

Phase 2 Design

Using the results from the field investigation and USGS report on Waldo Canyon Fire:

- Volume of expected debris are determined
- Geological characteristics of debris flows are determined
- Geobrugg DEBFLOW software is utilized to analyze loading of debris flow barriers

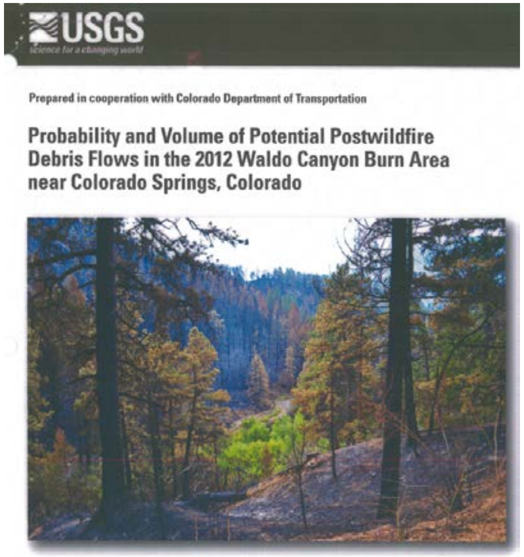

Table 2: Probability of a debris flow initiating during a 10 year storm (a 10% chance of occurrence in a given year) (Design Storm)

Drainage or Subwatershed with High Probabilities	Probability *based on Initial BS	Volume (m3)
10 (N-Douglas)	41	57,000
12 (L -Queens Canyon)	45	>100,000
13 (K – Williams)	54	77,000
14 (H – Waldo)	53	48,000
15 (G – unnamed)	74	14,000

The USGS estimated a total debris flow volume of >100,000 m^3 for a 10 year storm event!

DEBFLOW Software

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Using field data and literature references:

- Input parameters are chosen for debris flow analyses
- DEBFLOW software models static and dynamic characteristics of debris flows and outputs a design barrier size

GT12-26 | Glen Eyrle Debris Flow Barriers | Site S-2 Channel

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Input Parameters

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	granular	no load case	no load case	
Density of the debris flow material	ρ =	2000			[kg/m³]
Specific weight of the debris flow material	γ =	19.6			[kN/m³]
Water content	ω =	0.39			-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	1000			[m³]
Number of surges	N=	9			-
Volume per surge (average)	V_N =	111			[m³]
Volume of first surge (recommended)	$V_{N1,rec}$ =	167			[m³]
Volume of first surge (chosen)	V_{N1} =	170			[m³]

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{p,rec}$ =	7.4			[m³/s]
Peak discharge (chosen)	Q_p =	7			[m³/s]

Safety factor

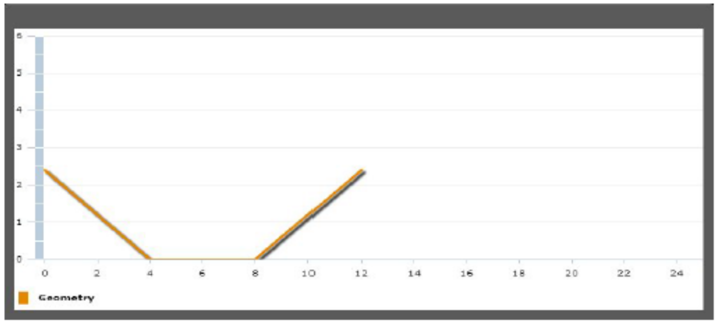
Global safety factor	SF =	1.4

GT12-26 | Glen Eyrle Debris Flow Barriers | Site S-2 Channel

Barrier Location No. 1

Geometry of barrier location

System height	$H_{0.1}$ =	2.4	[m]
Width of torrent on the level of the bottom support ropes	$b_{u.1}$ =	4	[m]
Width of torrent on the level of the top support ropes	$b_{o.1}$ =	12	[m]
Distance to the next barrier upstream	$L_{0.1}$ =	500	[m]



Torrent inclination and retention volume

System height of the filled barrier	$H_{1.1}$ =	1.8	[m]	
Average torrent inclination upstream of the barrier	$I_{z.1}$ =	14	[%]	8°
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{z.1.rec}$ =	9.3	[%]	5°
Deposition inclination of filled barrier (chosen)	$I'_{z.1}$ =	9	[%]	
Angle between ring net and river bed	ξ=	87.0	[o]	
Length of deposited material behind barrier	L_1 =	36.5	[m]	
Retention volume	$V_{r.1}$ =	262	[m³]	

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	V1,base =	2.7			[m/s]
Front velocity according to Strickler (v1>vstr)	vstr =	2.9			[m/s]
Impact velocity at barrier location (chosen,max. v-value)	V1 =	2.9			[m/s]
Flow height	$h_{fl.1}$ =	0.6			[m]
Recommended max. basal opening height (acc. to Wendeler)	$h_{d.1}$<=	0.4[m]			

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX080-H4
Max. system height	$H_{o.max}$ =	4.4 [m]
Max. system width above	$b_{o.max}$ =	15 [m]
Max. system width below	$b_{u.max}$ =	8 [m]
Proof of system height and system width		fulfilled !

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.80			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{Dyn.1}$ =	24			[kN/(m*h_{fl})]
Resistance against dynamic loading	$RD_{dyn.1}$ =	60			[kN/(m*h_{fl})]

Phase 2 Results

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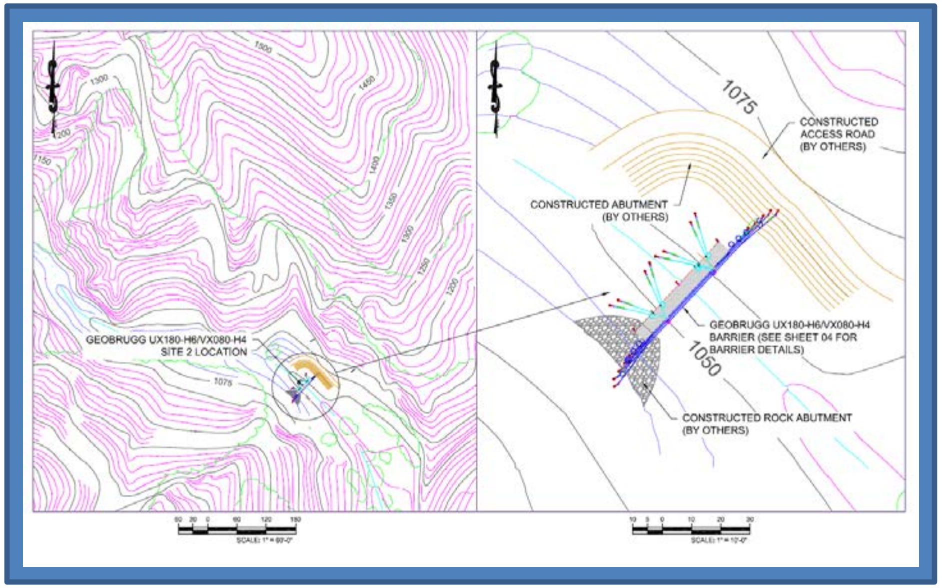
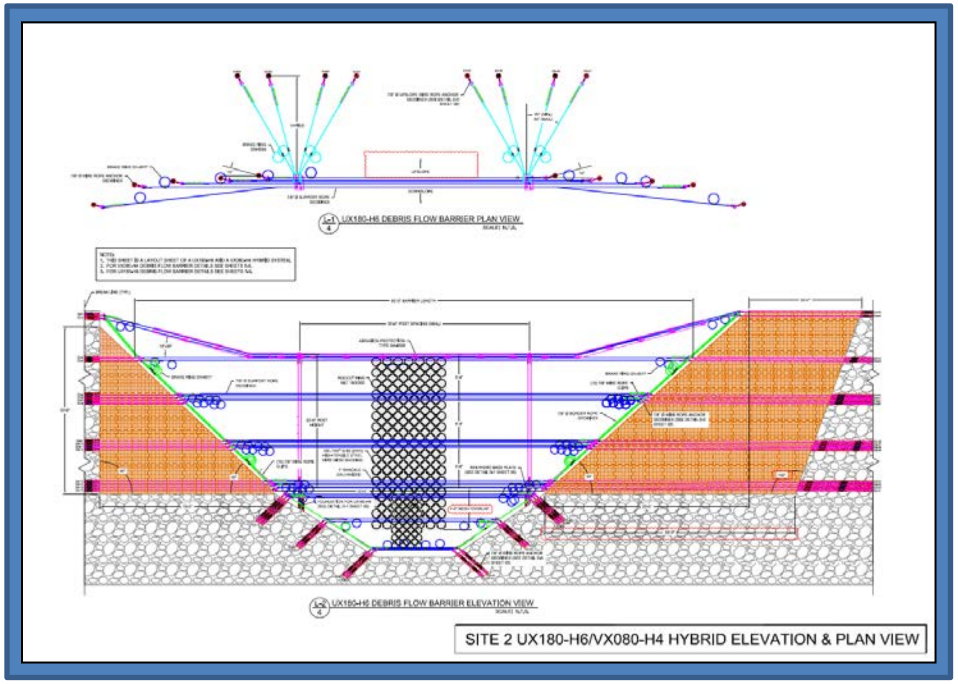
- 2 Barrier Locations were chosen for construction
- *KANE* GeoTech produced engineered drawings for Geobrugg UX and VX debris flow barriers
- Client put the project out to bid
- Pre Bid meeting held to familiarize contractors with project, stress tight completion timeframe
- Project awarded to Midwest Rockfall, Inc. on January 30
- Final Completion Deadline: March 30





Construction Begins

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Helicopter Transport of Materials and Equipment

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Helicopter Transport of Materials and Equipment

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Anchor Drilling

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Grouting Anchors

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Anchor Pull Testing

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Anchor Pull Testing

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Assembly of Barriers

Assembly of Barriers

Completion – Site 2 UX120-H6 Debris Flow Barrier

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Completion - Site 2 UX180-H6 & VX080-H4 Debris Flow Barriers

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Successful Retention of Debris Flow

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Successful Retention of Debris Flow

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Conclusion

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A planned, phased approach enabled timely, effective completion:

- A thorough initial investigation produced engineered drawings and bid documents
- Rapid selection of a qualified contractor and daily oversight
  - Debris flow mitigation systems installed on time and before spring rains
- On-site engineer's representative
  - Allowed effective testing of anchors
  - Kept costs low for the contractor and client


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Thanks for your attention!