# Snow Nets for Avalanche Protection

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Statewide Project Engineer's Conference
Lake Chelan, Washington
October 15, 2013



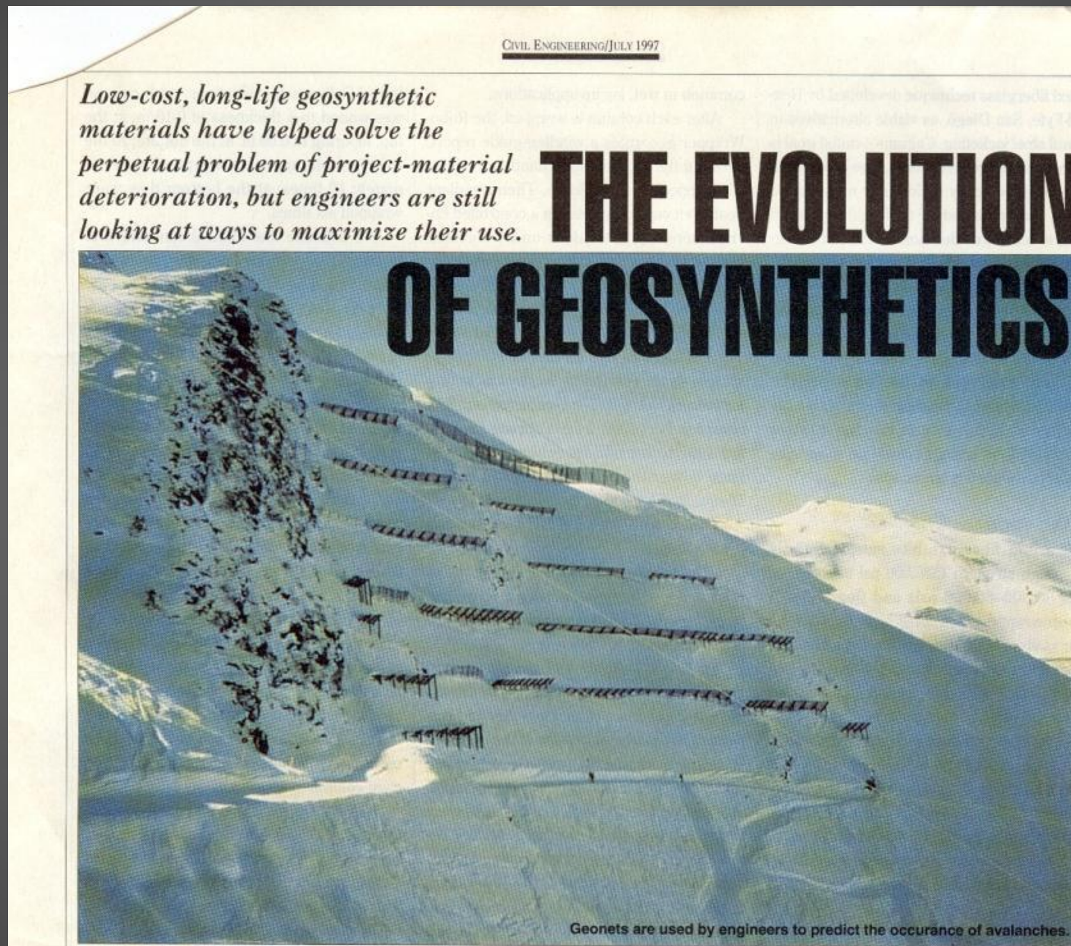



# Outline

- Origins in Europe
- Rigid vs. Flexible
- USA Applications
- Design Parameters
- I-90 Snoqualmie Pass East
  - Climate & Site Conditions
  - Project Challenges
  - Instrumentation & Outlook
- Questions

*"Bald Knob"*
*I-90 Snoqualmie Pass East*
*Photo: Hi Tech Rockfall*

# Misconceptions



CIVIL ENGINEERING/JULY 1997

*Low-cost, long-life geosynthetic materials have helped solve the perpetual problem of project-material deterioration, but engineers are still looking at ways to maximize their use.*

**THE EVOLUTION OF GEOSYNTHETICS**

Geonets are used by engineers to predict the occurance of avalanches.

"Geonets are used by engineers to predict the occurrence of avalanches."

ASCE Civil Engineering Magazine, June 1997

# Primary Use in Europe:

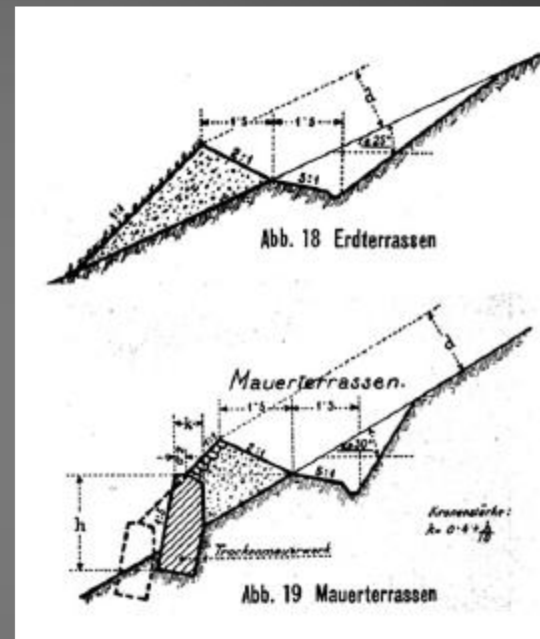
Protect Villages

- Andermatt,Switz.
- Davos, Switz.
- Galtur, Austria

Andermatt, Switzerland
Photo: Michael Falser

Galtur, Austria

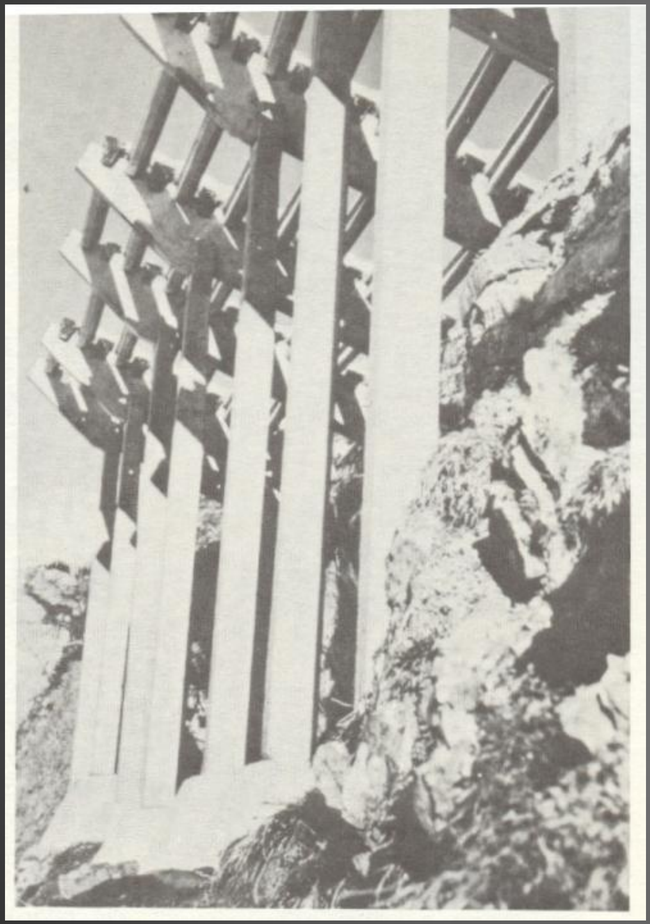
# Walls/benches




K. Imhof 1912
*Lawinenverbauungen*

Photos: Michael S. Falser, 2007
*Historische Lawinenschutzlandschaften*

# Early Structures

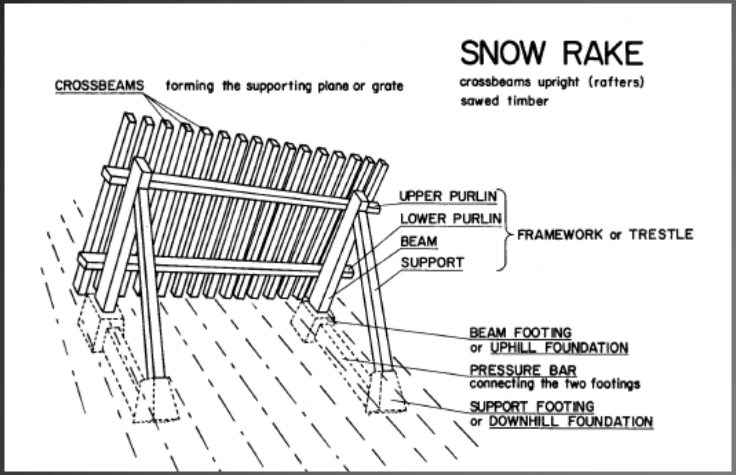


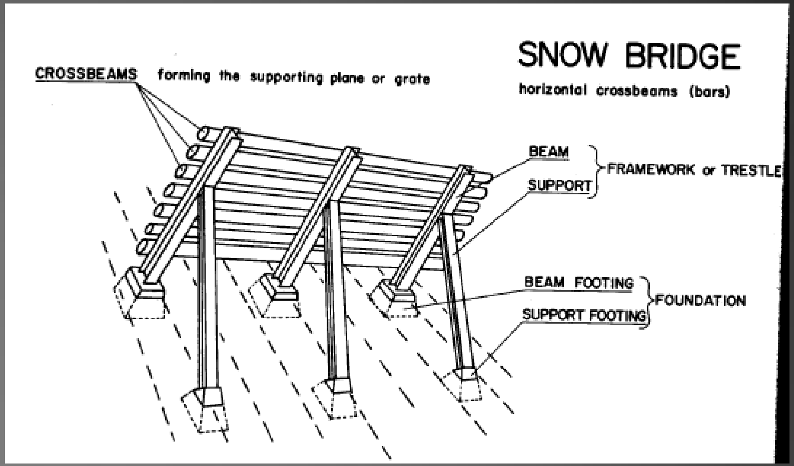
Pre-stressed Concrete
1966 photo by Frutiger & Martinelli
St. Antonien-Castels, Switz.

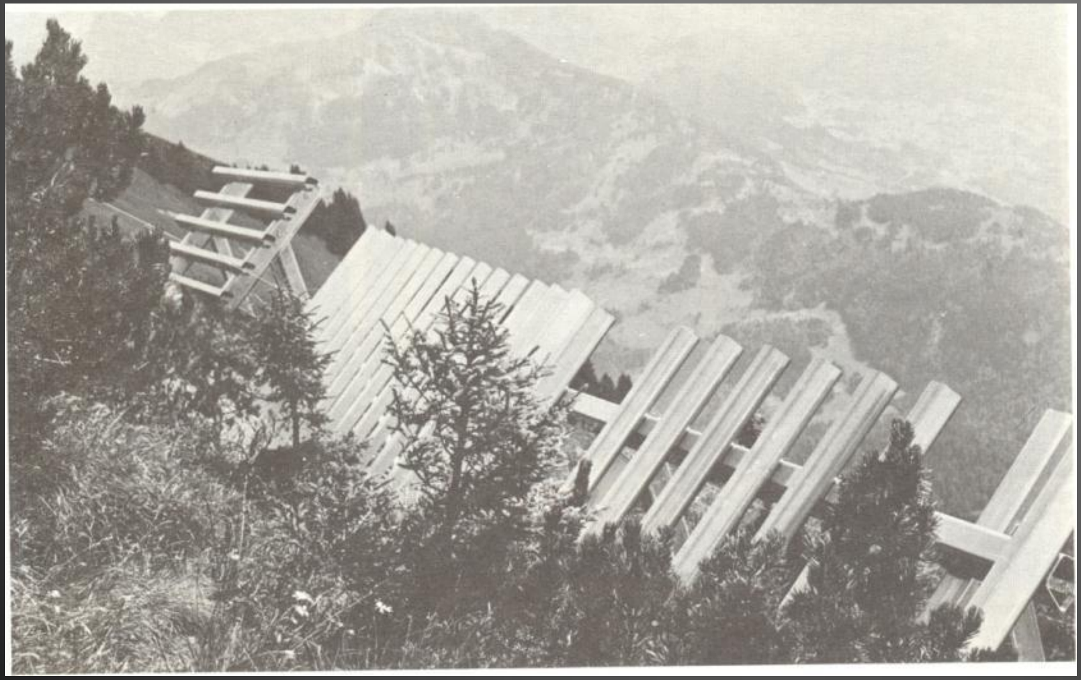
Aluminum Frame with
Wood Cross Members
1959 photo by Wagner & Hopf
Mattstock Avalanche
Amden, Switz.

Photos source: Perla & Martinelli, 1978
USDA Avalanche Handbook 489

# Orientation

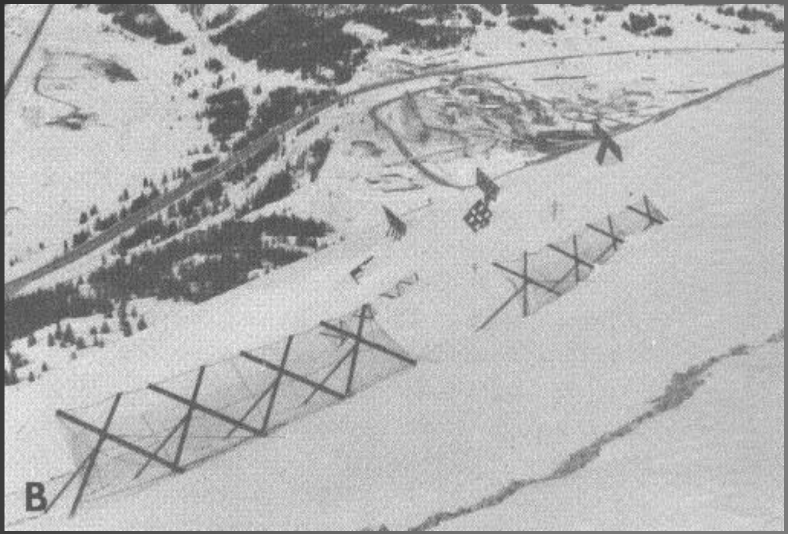


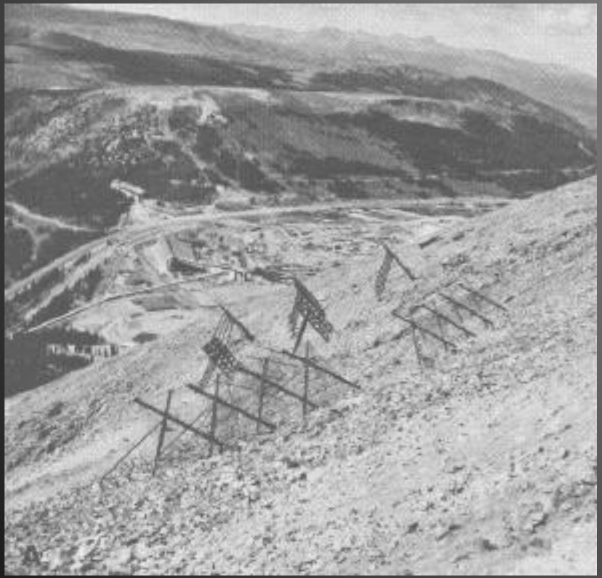



Perla & Martinelli,
USDA Avalanche
Handbook 489

# Snow Nets in USA



Climax Molybdenum Mine
Lake County, Colorado
Source: Frutiger & Martinelli, USFS, 1966

# Sunlight Ridge

## Mt. Crested Butte, Colorado

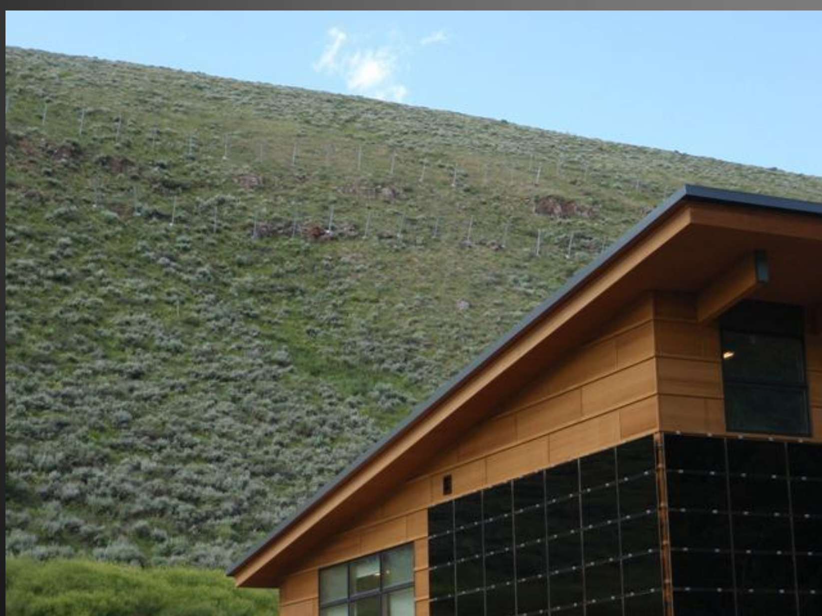
- Protects Condos
- 1989 child fatality
- Concrete wall in 1996
- Snow nets in 2006
- Dk 3.0m 1500 ft. length
- Cost “just over $1 million”
- 2007 Avalanche Maps revised
- Deep snow in January 2008

# Teton Science School

## Jackson, Wyoming

- Dk=3.0m nets
- Short slope
- Preventative measure
- Low visual impact

Art Mears photo



# Alpental Subdivision
Snoqualmie Pass, WA

- 4.0 meter Geobrugg snow nets
- Installed after tree logging
- Contractor: Janod, Quebec, Canada
- Cost overruns due to unforeseen poor ground anchor conditions

# WYDOT - US 89/191

## MP 151 Jackson, Wyo.

- 8000 ADT (winter)
- Avg. Return Period 0.7 yrs.
- Replaced “Wind Sails” (from 2002)
- USFS Critical Big Game Habitat
- NEPA process
- Built in 2012-13
- $2.3 million
- Reforestation component

Photos courtesy of
TLC Tree and Landscape Co.

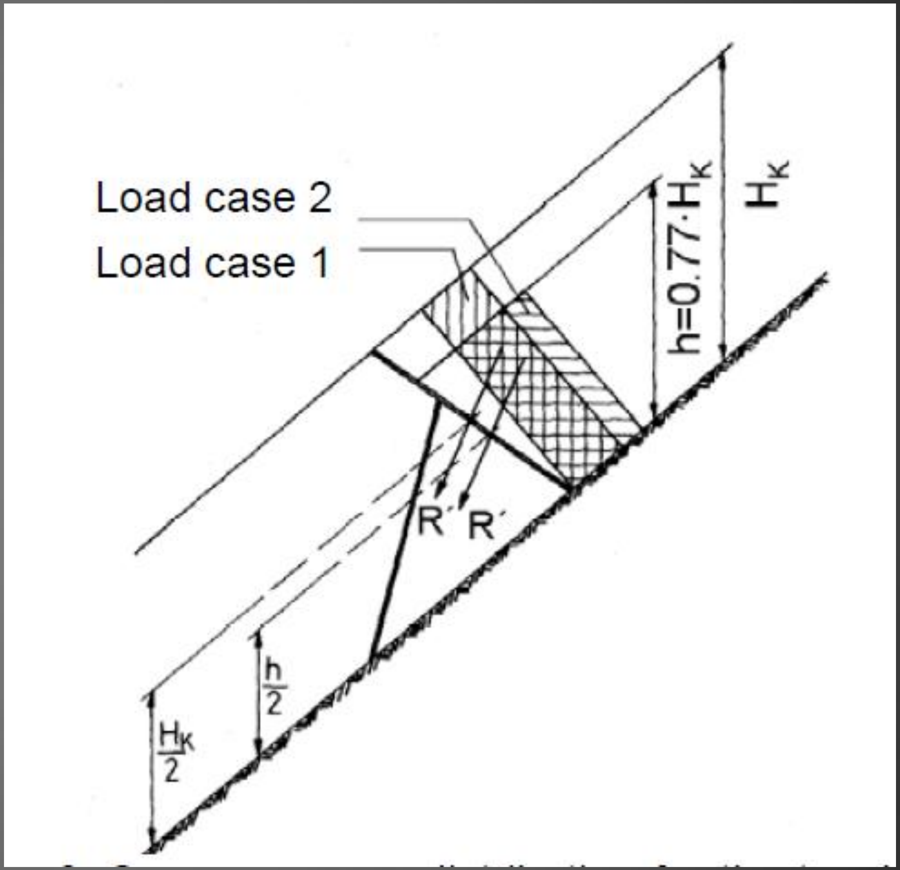
# The Canyons – Park City, Utah
## Vela "Umbrella" Nets

- Individual Units
- Single Anchor
- Relatively New
- Considered for I-90

Photos from Vela

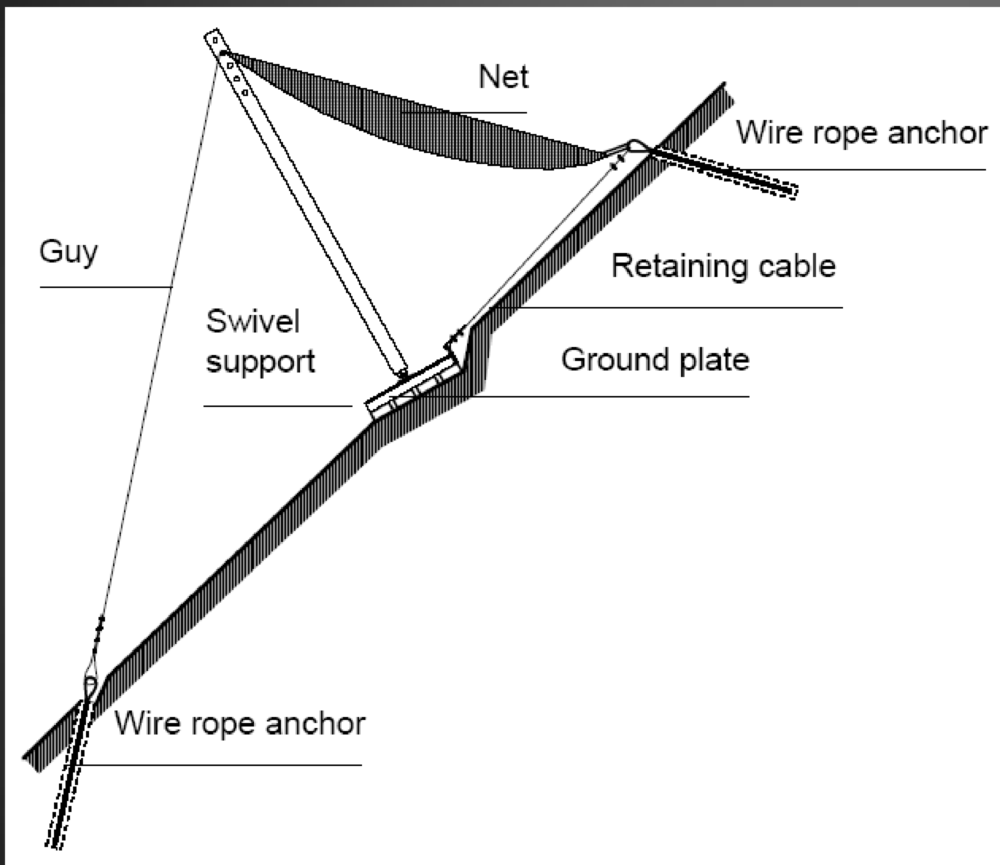
# Design

- Creep
- Glide
- Factors
  - Snow height
  - Ground roughness
    - (glide factor)
  - Snow density
  - Terrain shape
  - Slope angle



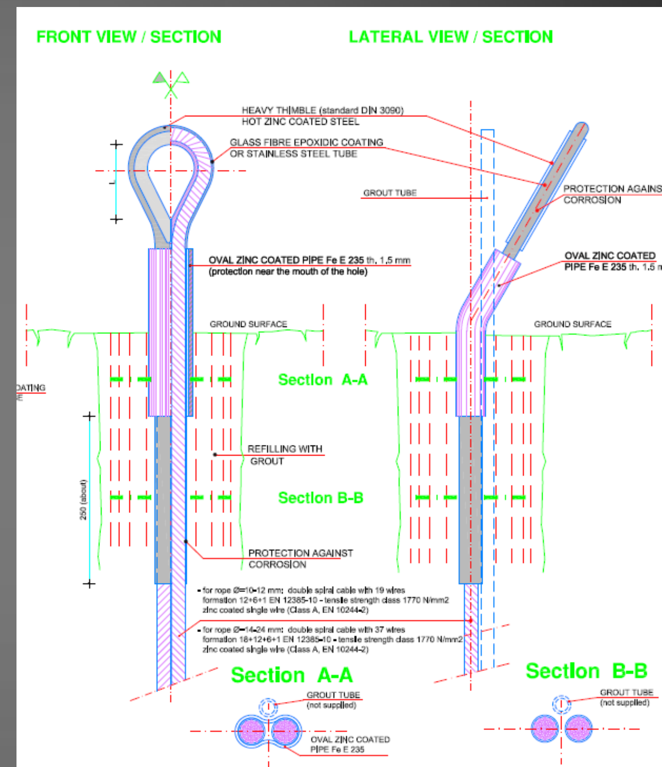

Source: 2009 Swiss Guidelines
By Stefen Margreth, SLF

# Snow Nets




Profile

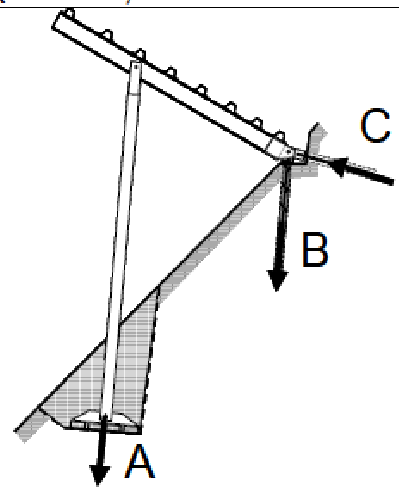
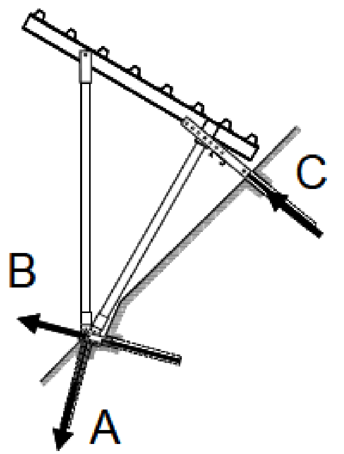
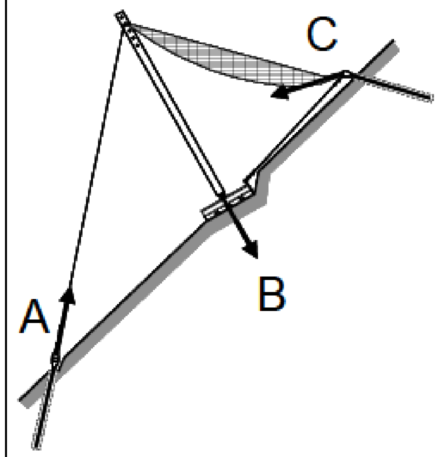
Source: Figure 31, 2007 Swiss Guidelines




Double spiral cable anchor

(Maccaferri/Kane Geotech)

# Typical Loads

| |  |  |  |
|---|---|---|---|
| Snow pressure | 93 kN/m' | 93 kN/m' | 85 kN/m' (5.8 kips/ft) |
| Pressure force (+) Tension force (-) | +261 kN (A) | +365 kN (A) | -81 kN (A) (-18 kips) |
| | +115 kN (B) | -44 kN (B) | +255 kN (B) (57 kips) |
| | -182 kN (C) | -169 kN (C) | -322 kN (C) (-72 kips) |

for Dk=4.0, N=2.5, fc=1.1 slope 45 deg. intermediate section

Source: Stefan Margreth, ISSW 2008 Whistler, BC, Canada

# I-90 Snoqualmie Pass East

- 30,000 ADT
- 58,000 ADT peak weekends
- 35 million tons of freight/year
- Cost of Closures
  (120 hrs/yr average)
- Snow Nets (3 sites)
- Other mitigation
  bridge, ditch/wall systems

# I-90 Snoqualmie Pass East

# I-90 Snow Nets

## <u>Quantities:</u>

- Slide Curve –3693 l.f.
- E. S. Minus 1 – 540 l.f.
- Bald Knob – 103 l.f.
- Totals
  - 4.0 m 1941 l.f.
  - 3.5 m 1148 l.f.
  - <u>3.0 m 1247 l.f.</u>

TOTAL = 4336 l.f.

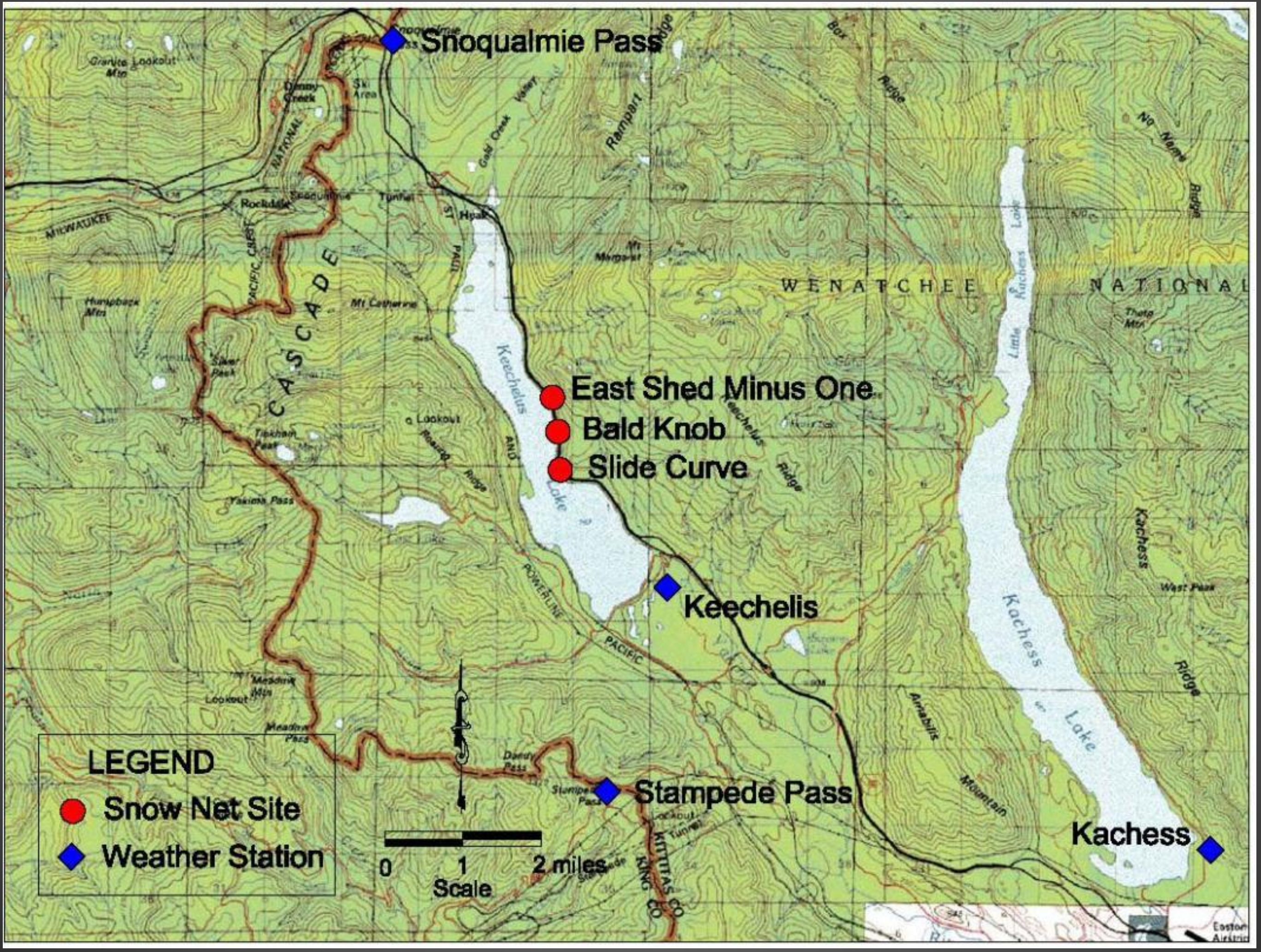
## <u>Preliminary Construction Cost:</u>

Engineer's Est.: $10.0 million
Bid Award: $6.0 million
Change Orders: $2.9 million
Total Cost: $8.9 million

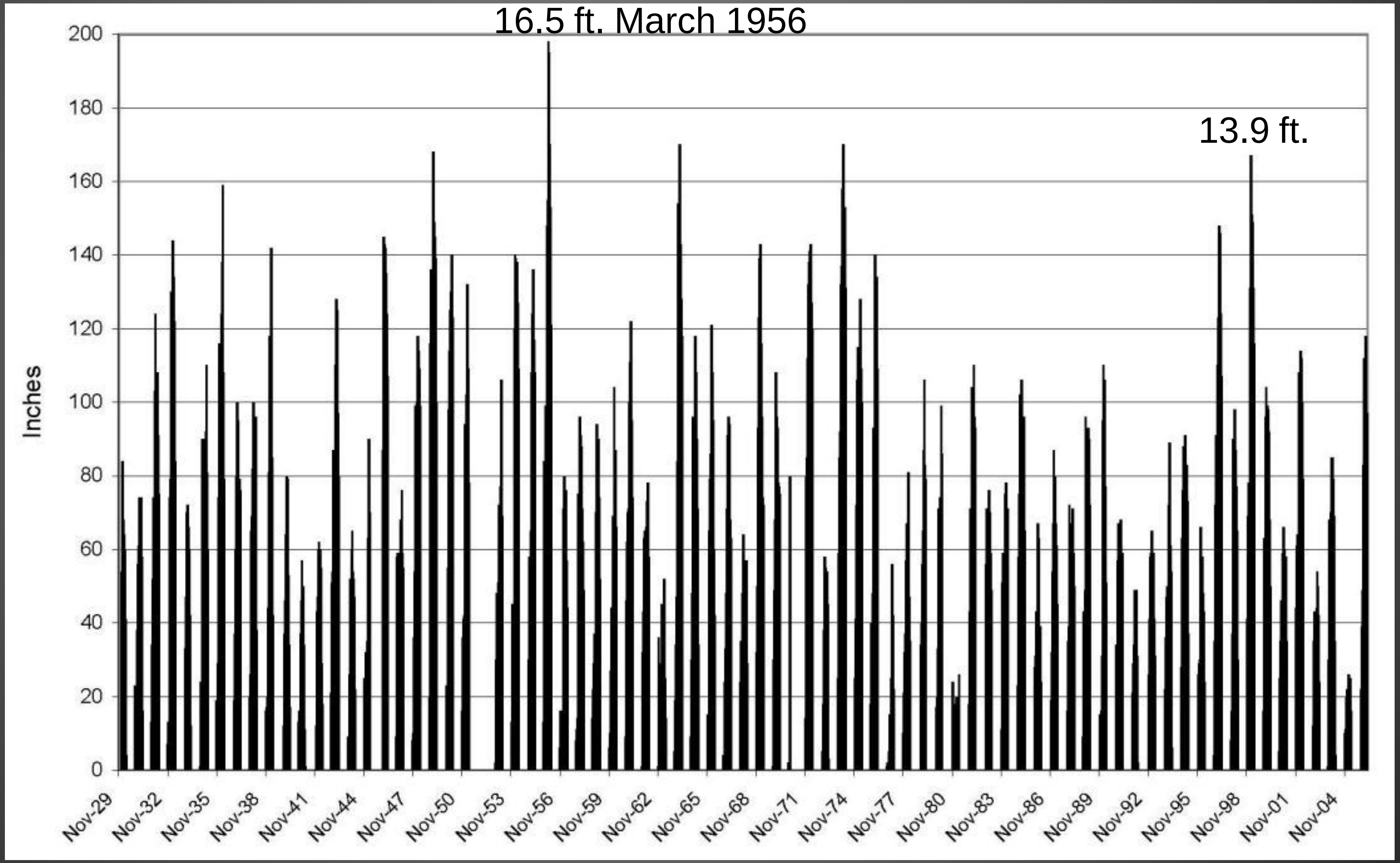
Unit cost: $2053/ft
$6732/m

Not included: Training, spare parts, instrumentation.

# Weather Stations



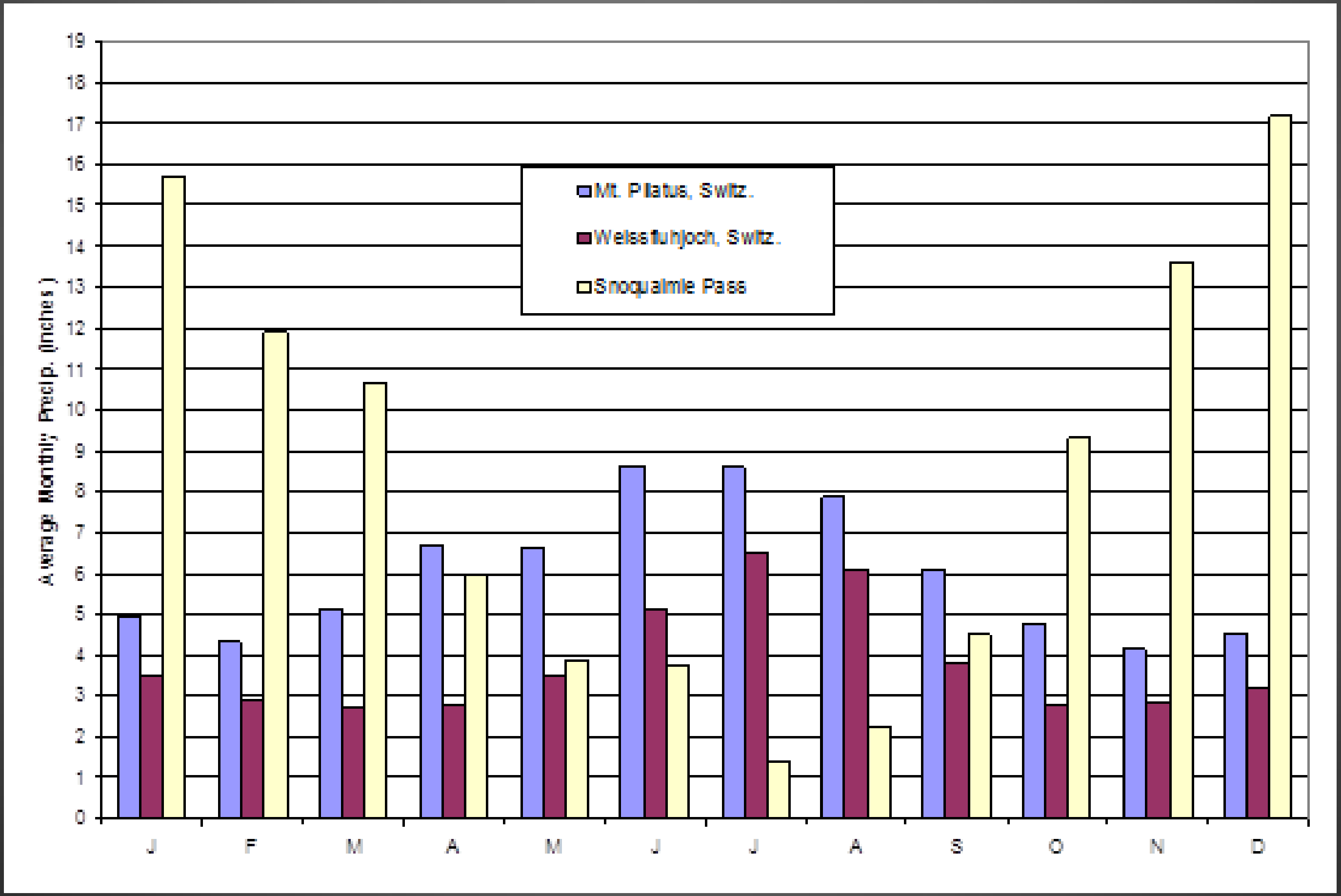
# Snoqualmie Pass Snow Depth



# Design Climate

## Washington Cascades vs. Swiss Alps

1. Total Precipitation
2. Seasonal Differences
3. Temperatures
4. Rain-on-snow



# Slide Curve

- 3.0m, 3.5m & 4.0m heights
- High density snow
- Variable ground conditions
- Instrumentation
- Re-Forestation

Photos: John Stimberis, WSDOT

# Upper Slide Curve

- High Glide Factor
- Greater Snow Depth
- Artificial Roughening

# Surface Roughening

Photos: Stefan Margreth
SLF Swiss Federal Institute for
Snow and Avalanches

# Bald Knob

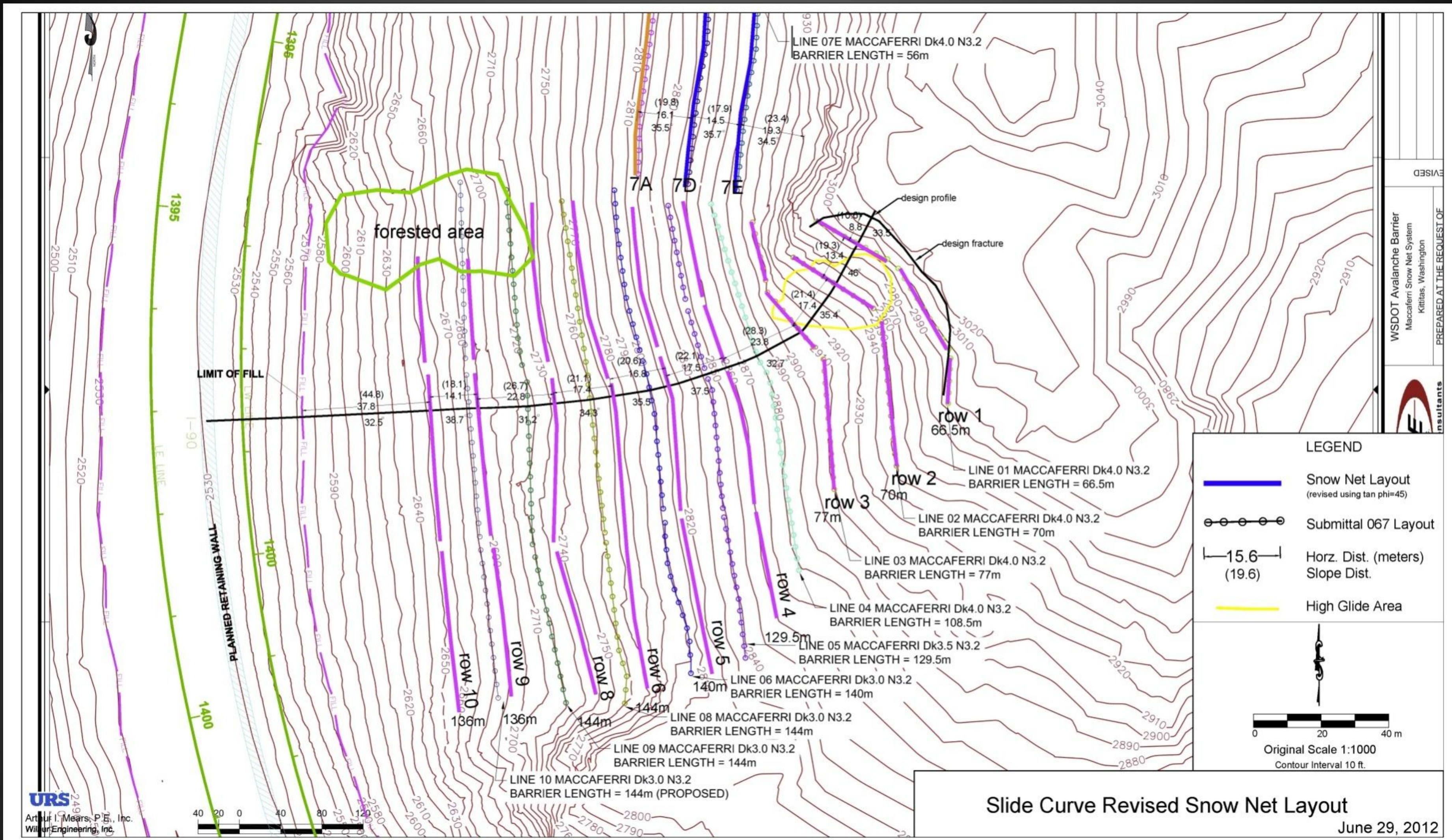
Smooth Rock – High Glide Factor
Convex Slope

# East Shed Minus One

- Smooth Rock (High Glide Factor)
- Lower Elevation
- Water Flow at base of snowpack

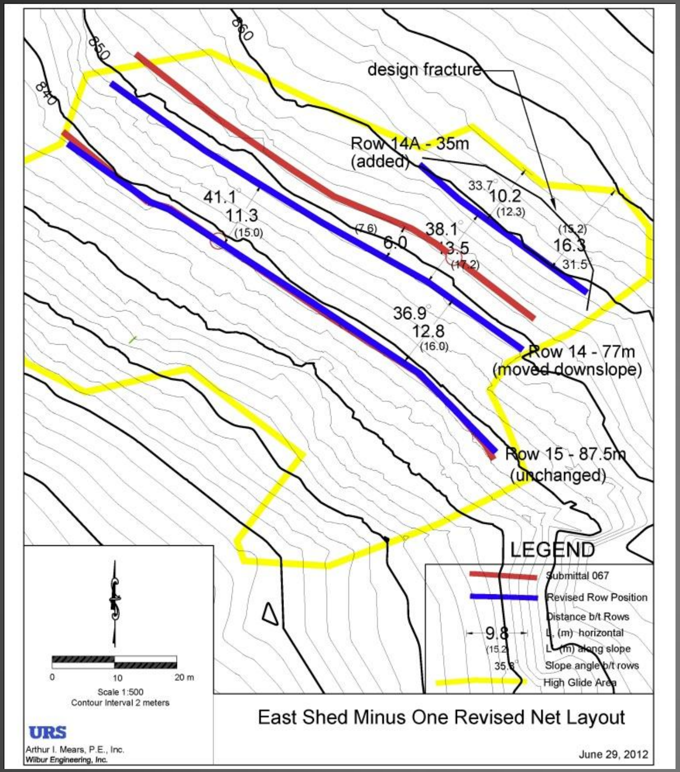
# East Shed Minus One

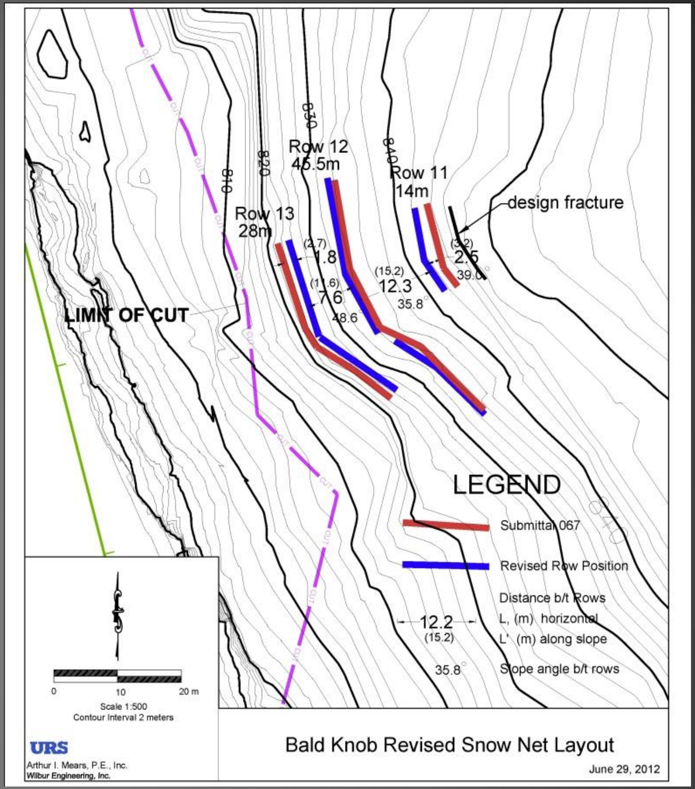
Photos: High Tech Rockfall, Inc.




# Slide Curve

## Iterative Design Process




East Shed Minus One

Bald Knob

# Project Challenges

- Snow Conditions
- Variable Ground Conditions
- Limited Geotechnical Data
- Technical Specifications
- Limited Experience
  - Designers
  - Contractors
  - Owner

Slide Curve
Boulder Field

# Addressing Challenges

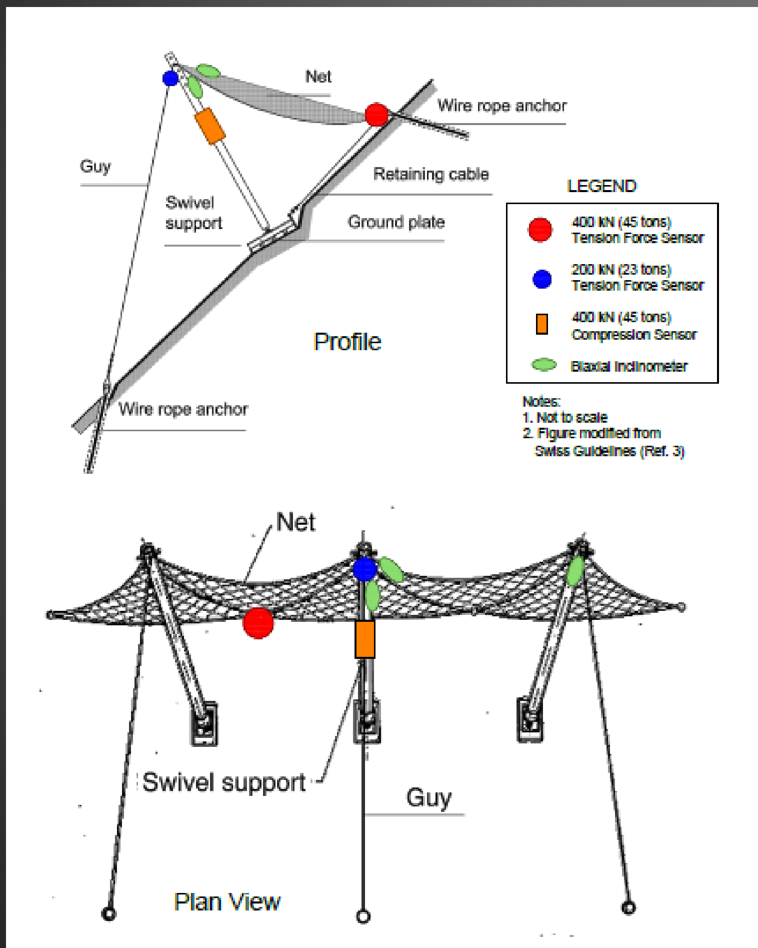
- European Expertise
- Geotechnical Consultant
- Iterative Design Layout
- Artificial Surface Roughening
- Upsizing Snow Net Heights
- Incorporate New Data (2009 ROS*)
- Comprehensive Anchor Testing

Roberto Castaldini, Dr. Ing.
Studio Tecnico di Ingegneria
Verona, Italy

KANE GeoTech, Inc.
Geoengineering Consultants

* Rain-on-snow - *January 2009 event was classified as an extreme event, with a return period in excess of 100 yrs.*

# Snow Net Instrumentation




1. Uphill Anchor Tension
2. Post Compression
3. Post Inclination
4. Downhill Cable Tension

# Inspections

| Types of Inspection | L1 Level 1 Inspection | L2 Level 2 Inspection | SL2 Special Level 2 Inspection | L3 Level 3 Inspection |
|---|---|---|---|---|
| **Periods** | Key structure: annually<br>Standard structure: at least every 5 years | all structures: before end of guarantee<br>Key structure: every 5 years | Key structure: after extreme events | all structures:<br>in vase of need |
| **Methods** | visual | visual | | advanced methods |
| **Executed by** | Lumbermen | Experts | | Experts (interdisciplinary) |
| **Result** | Level 1 minutes | Level 2 minutes | | Level 3 minutes |

From **Florian Rudolf-Miklau, Wolfgang Schilcher, Johann Kessler and Jürgen Suda**
Life Cycle Management for Technical Avalanche Protection Systems, Egilsstaðir, Iceland, 2008

## Iceland Snow Nets

Damaged due to insufficient lateral support
Photo: Tómas Jóhannesson

## Austria Snow Bridges

Damaged by avalanche
Photo: Florian Rudolf-Miklau

# Outlook

- Highway Closure Reduction
- Forecasting & Control Resources
- Summer Maintenance
- Structure Retirements
- Structure Replacements
- Costs vs. Benefits

Slide Curve
Photo: John Stimberis, WSDOT

# Snow Nets
# Take-away

- Starting Zone Structures (snow nets and/or snow bridges) are a very effective passive avalanche defense
- Costs depends on size of starting zone, snow depth, ground conditions, land availability
- Eliminates decision making during extreme snow conditions
- Frees up avalanche forecast/control resources during winter big storms
- Inspections & Maintenance are required to achieve typical design life of 80 years

# *Thank You!*


John Scurlock, Photographer/Pilot

# *Questions?*