# Association of Conservation Engineers
# 52nd Annual Conference

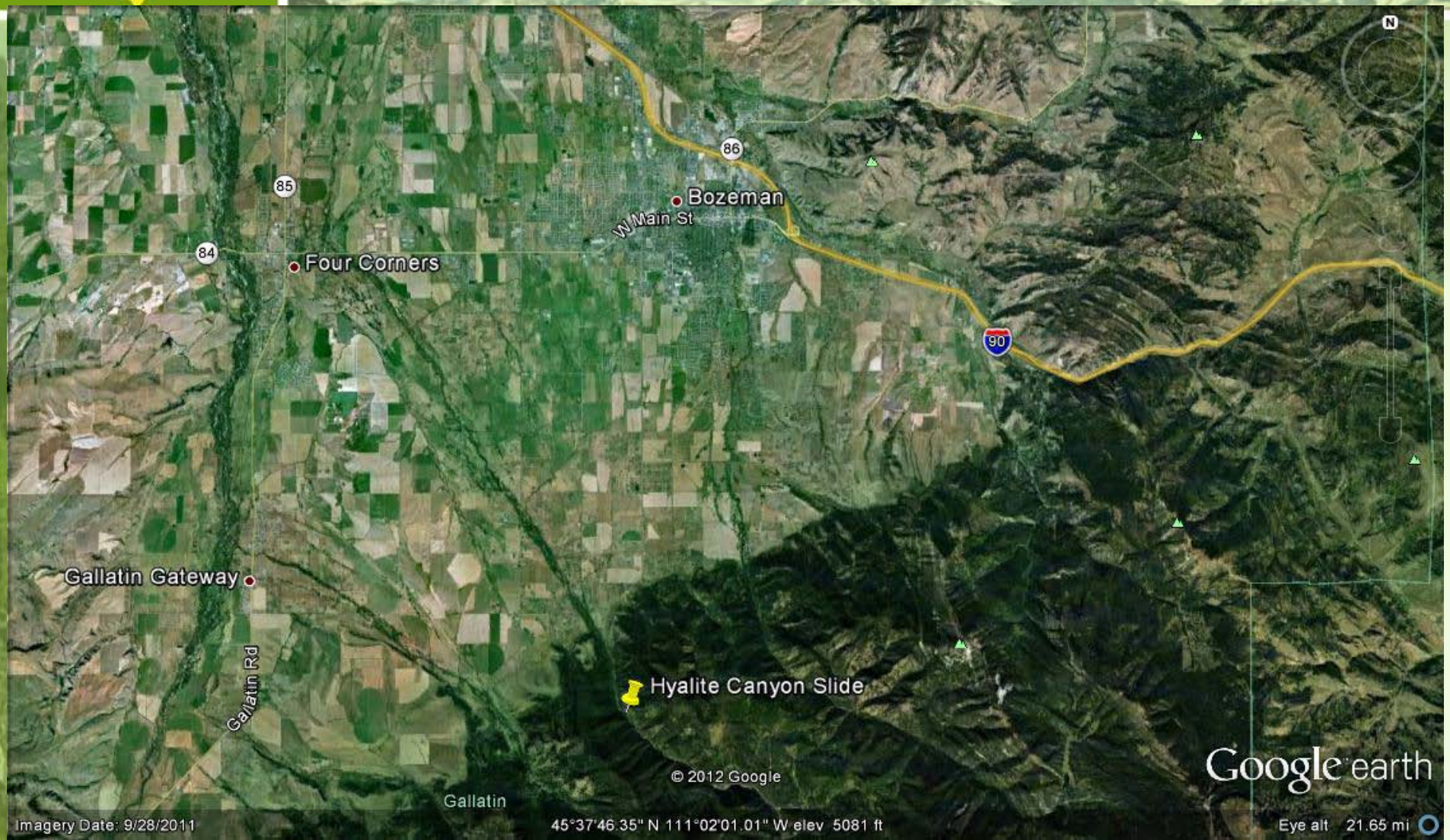

## Stabilization of an Infinite Slope Failure Utilizing Hollow Bar Soil Nails with Long-Term Monitoring Plan
## September 2013

Presented By: Christopher “Chud” Lundgreen, EIT
Regional Geotechnical/Pavements Engineer
Northern Region, USDA Forest Service

# Outline

- Site location and problem description
- Slide materials and geometry
- Mitigation measures
- Monitoring plan
- Summary

# Location


86
85
84
90
Bozeman
W Main St
Four Corners
Gallatin Gateway
Gallatin Rd
Hyalite Canyon Slide
Gallatin
© 2012 Google
Google earth
Imagery Date: 9/28/2011
45°37'46.35" N 111°02'01.01" W elev 5081 ft
Eye alt 21.65 mi

# Hyalite Canyon Slide, Gallatin NF

- Slide was triggered in 2007
  - Part of an old (geologic) bedrock slide
  - Slide is a shallow infinite slope failure
  - Material moved every spring with substantial groundwater at the slump
- Situated in the Hyalite Creek Drainage
- Upstream of Bozeman water treatment plant that provides 30%-40% of water supply
- Most recreated Forest Service area in the region

# Slide View From Satellite

# Seismic Refraction Summary

**Table 1: Seismic Model Layers, Velocities, and Material**

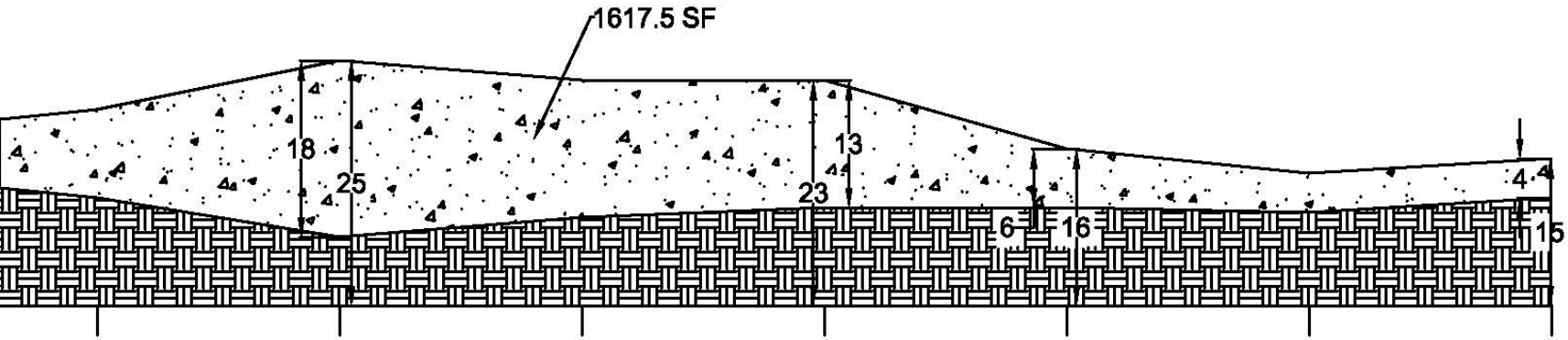
| Layer | Velocity (fps) | Material Type |
|---|---|---|
| 1 | 1,150 - 1,675 | Surficial soil, silt, clay, highly weathered bedrock |
| 2 | 7,150 - 8,200 | Moderately weathered to marginally competent bedrock |
| 3 | 12,075 (+) | Highly competent bedrock |

It should be noted that calculated P-wave velocities are averages for a particular spread and layer. There may be localized areas within a particular layer where the actual P-wave velocity is higher or lower than the value presented.

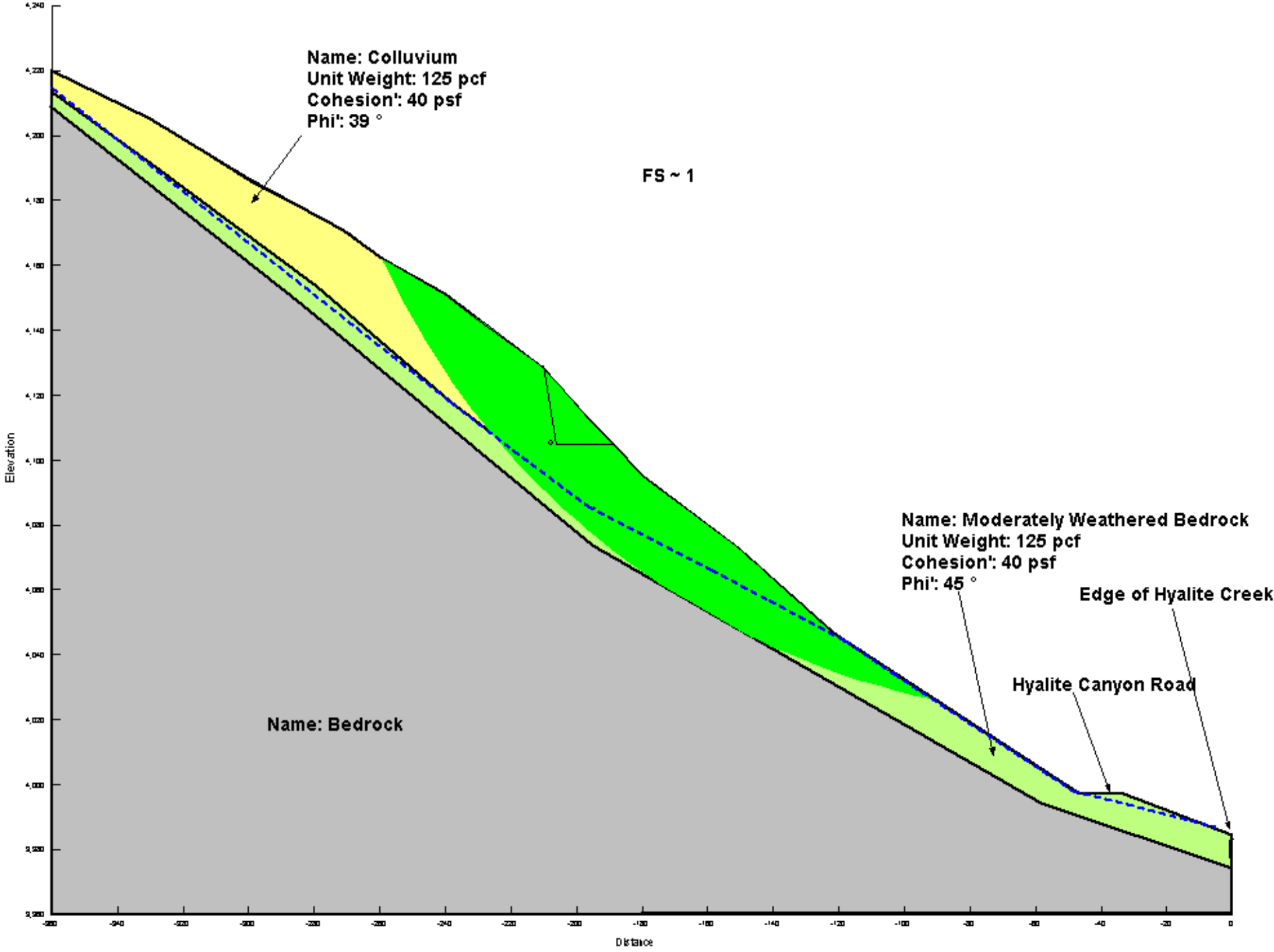
**Table 2: Summary of Derived Seismic Velocities and Layer Depths**

| Line No | Layer 1 Velocity (fps) | Layer 2 Velocity (fps) | Layer 3 Velocity (fps) | Depth to top of Layer 2 (feet) | Depth to top of Layer 3 (feet) |
|---|---|---|---|---|---|
| 1 | 1,150 | 7,150 | | 17 - 32 | |
| 2 | 1,350 | 7,150 | | 20 - 37 | |
| 3 | 1,200 | 8,200 | | 29 - 44 | |
| 5 | 1,200 | 7,750 | | 16 - 22 | |
| 6 | 1,675 | 7,150 | 12,075 | 2 - 4 | 9 - 31 |

# Drill Logs

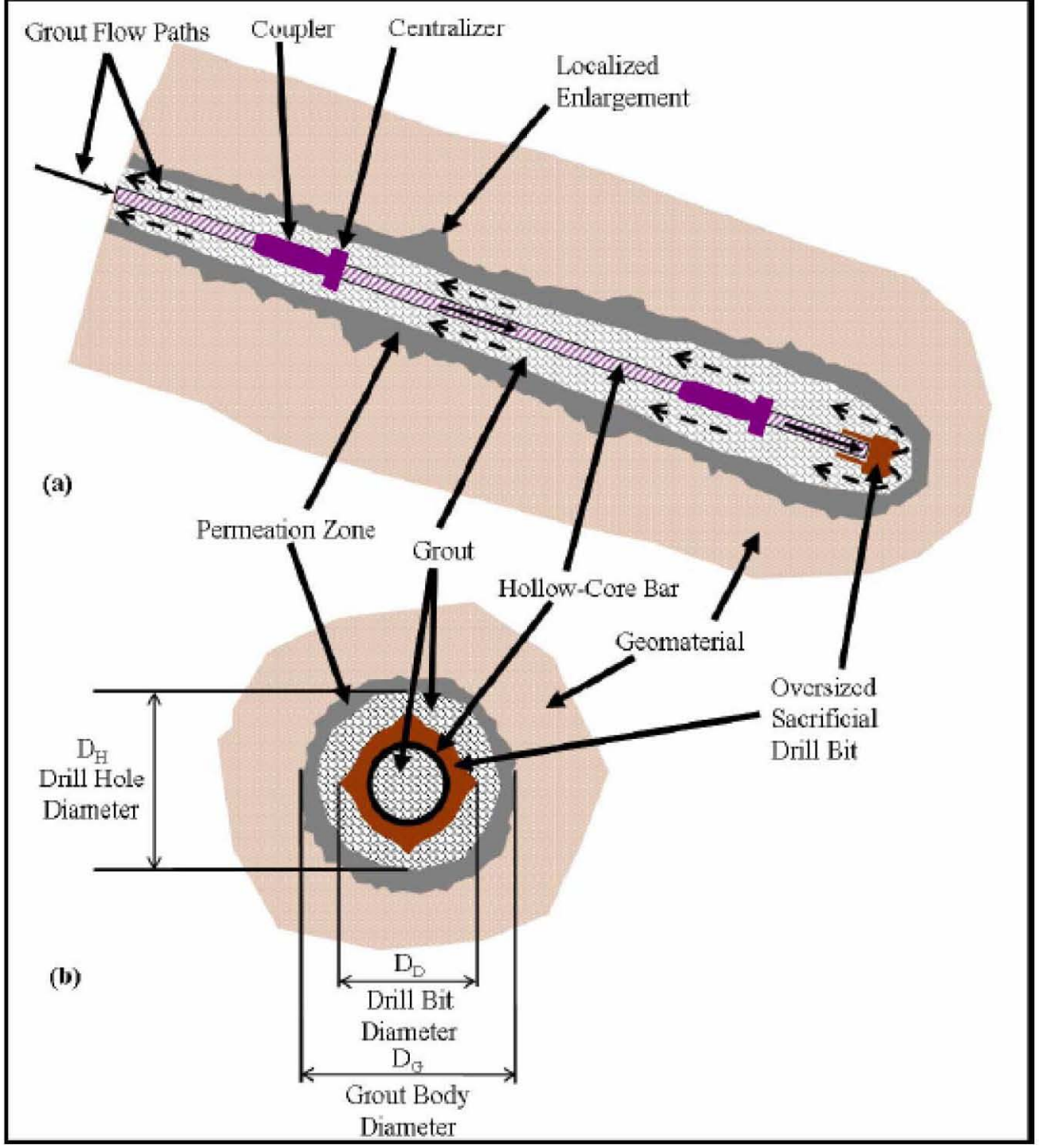


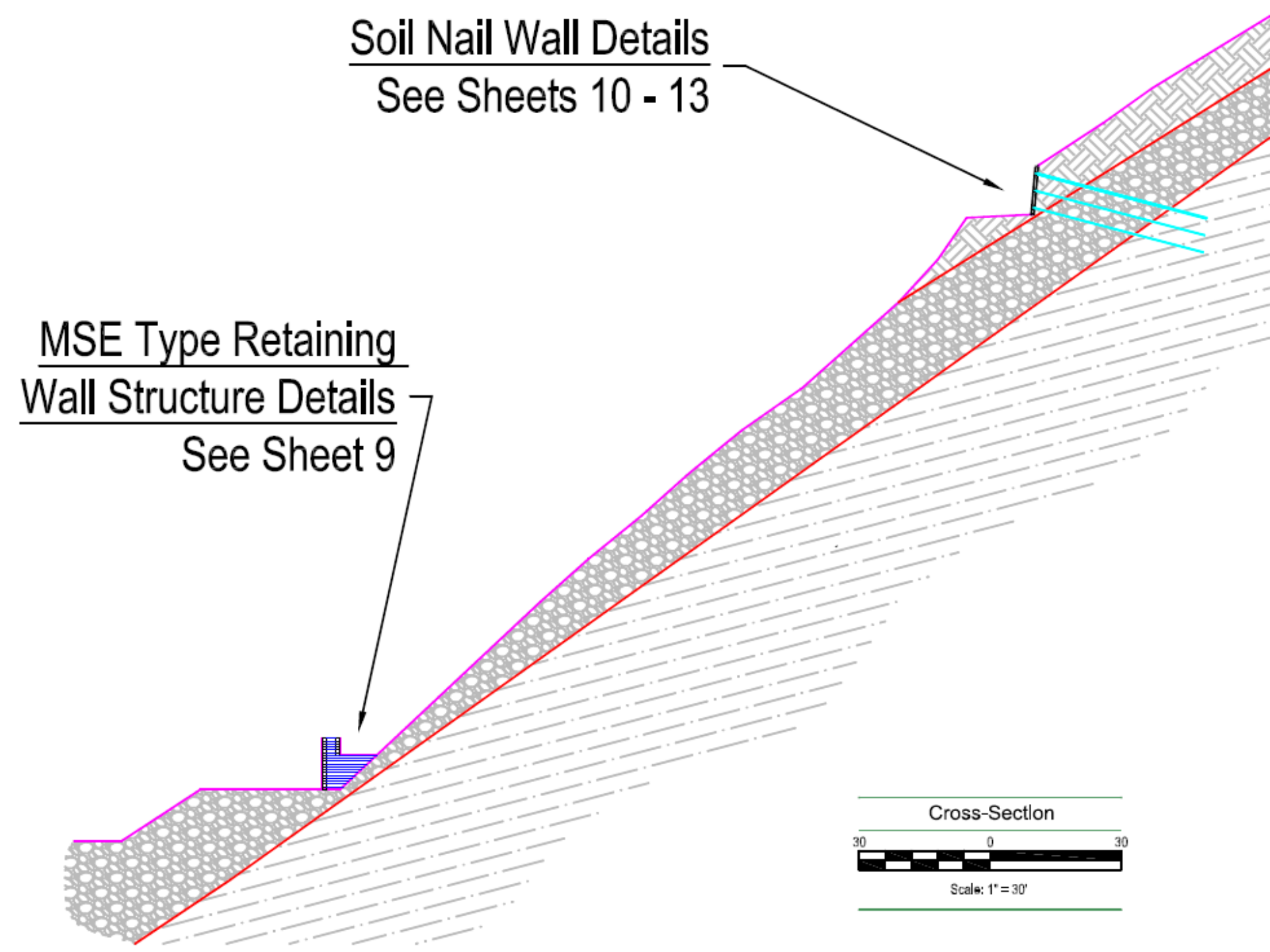

| 0-8 Colluvium (loose) 8 to 40 Mod. Weathered Rock (very dense) | 0-9 Colluvium (very loose) 9 to 13 Highly Weathered Rock (dense) 13 to 21 Soil (loose) 21 to 40 Mod. Weathered Rock (very dense) | 0-8 Colluvium (very loose) 8 to 24 Highly Weathered Rock (dense) 24 to 35 Soil (loose) 35 to 37 Mod. Weathered Rock (very dense) 37-40 Rock | 0-20 Colluvium (very loose) 20 to 26 Highly Weathered Rock (dense) 26 to 33 Soil (loose) 33 to40 Mod. Weathered Rock (very dense) | 0-20 Colluvium (very loose) 20 to 30 Highly Weathered Rock (dense) 30 to 33 Soil (loose) 33 to 36 Mod. Weathered Rock (very dense) 36-40 Rock | 0-22 Colluvium (very loose) 22 to 27 Mod. Weathered Rock (very dense) 27-33 Rock | 0-18 Colluvium (very loose) 18 to 22 Mod. Weathered Rock (very dense) 22-28 Rock |
|---|---|---|---|---|---|---|


Name: Colluvium
Unit Weight: 125 pcf
Cohesion': 40 psf
Phi': 39 °
FS ~ 1
Name: Moderately Weathered Bedrock
Unit Weight: 125 pcf
Cohesion': 40 psf
Phi': 45 °
Edge of Hyalite Creek
Hyalite Canyon Road
Name: Bedrock
Elevation
Distance

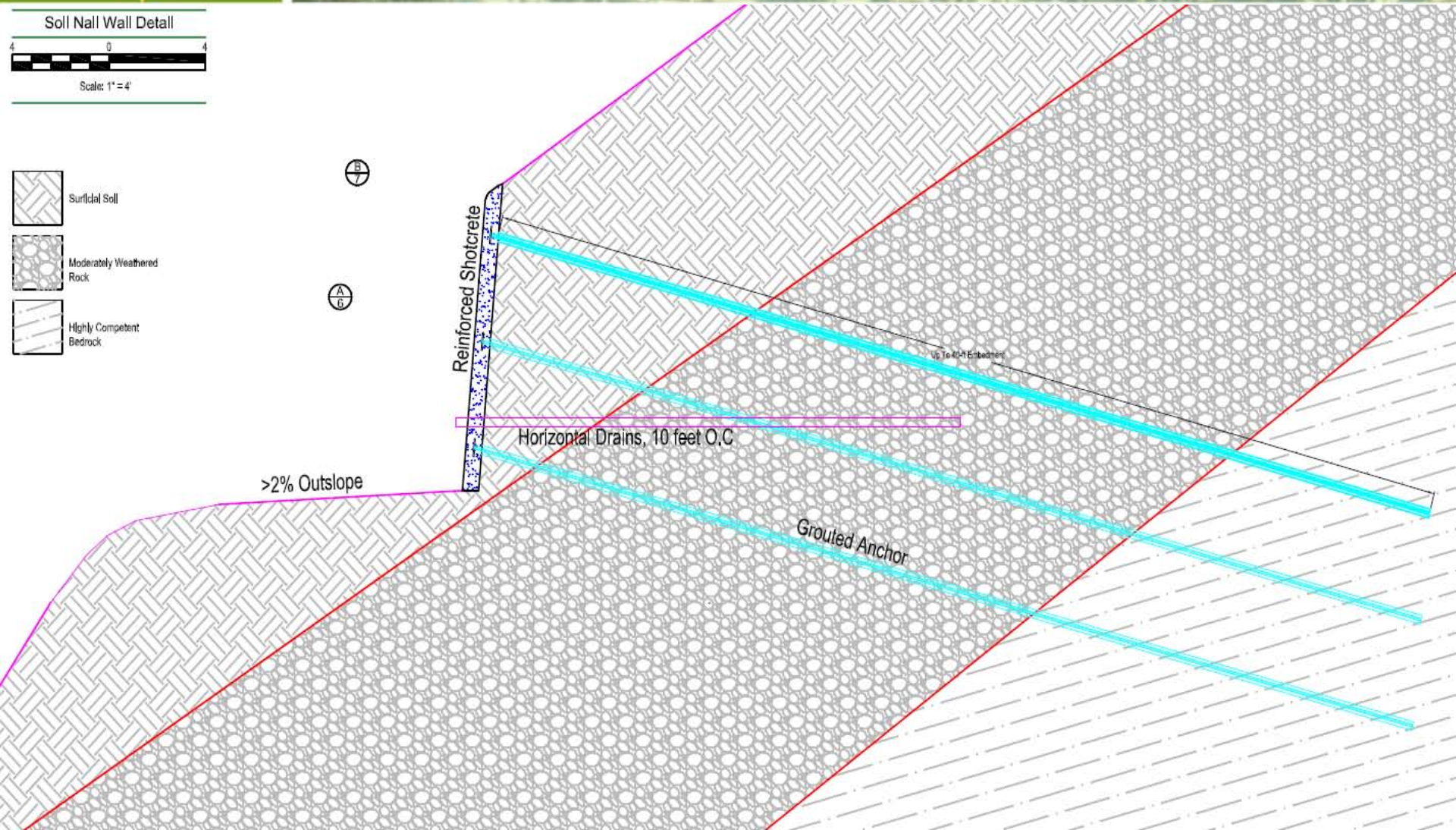
# Mitigation

- The solution decided upon was to soil nail the active portion of the slope near the top.
  - 303 hollow bar soil nails (HBSN)
    - 51 mm diameter hollow core allows for simultaneous grouting and drilling
    - 40 feet deep
    - $15^{o}$ from horizontal, allows tension to be utilized instead of relying completely on shear strength of steel
  - 65 micropiles
    - 30 feet deep
- Geosynthetic Reinforced Soil (GRS) wall constructed at the bottom for debris catchment purposes.
  - Form of MSE wall
  - 8 inch lifts with fabric reinforcement
  - CMU block facing

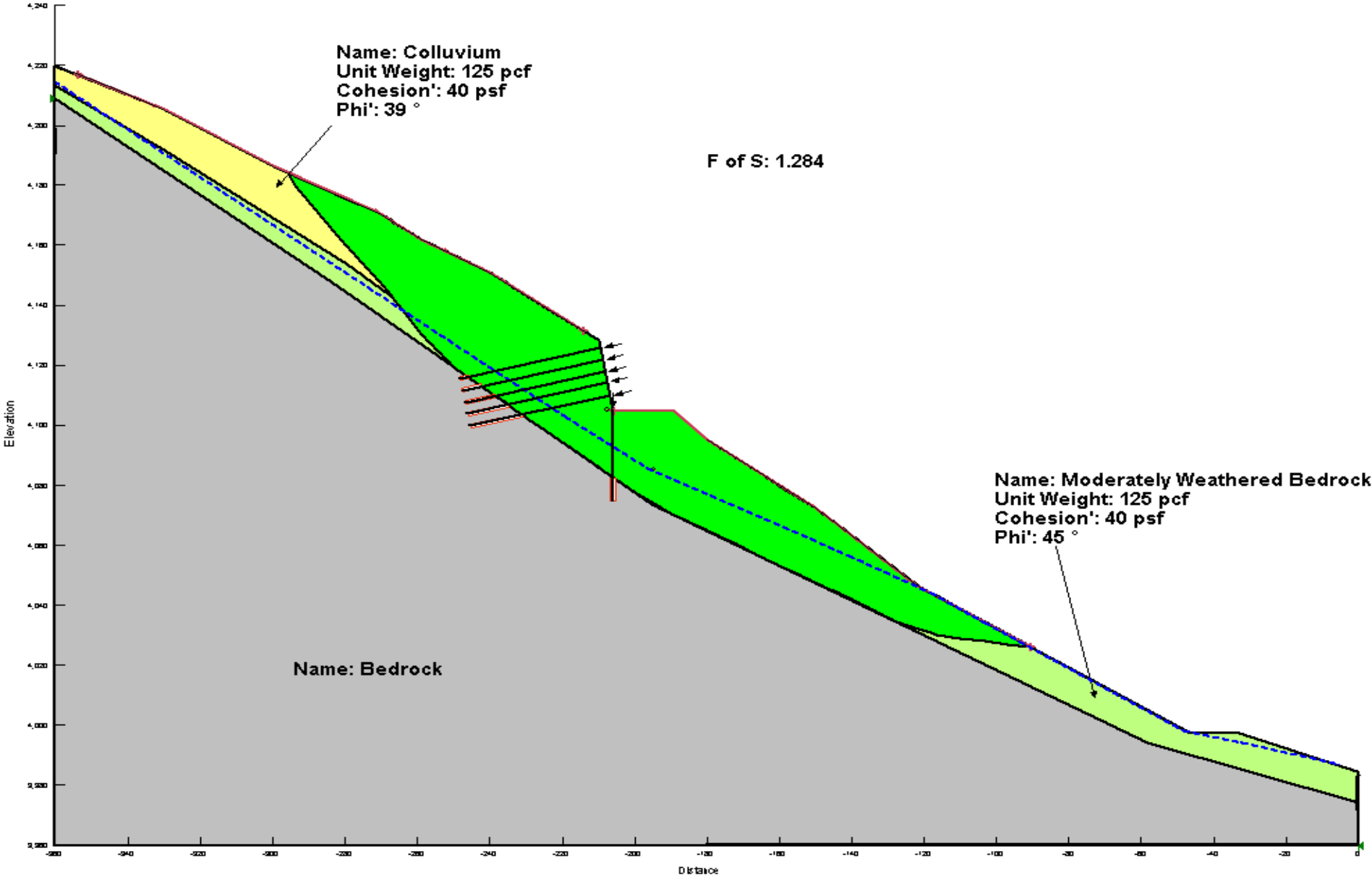

Grout Flow Paths
Coupler
Centralizer
Localized Enlargement
(a)
Permeation Zone
Grout
Hollow-Core Bar
Geomaterial
Oversized Sacrificial Drill Bit
$D_H$ Drill Hole Diameter
(b)
$D_D$ Drill Bit Diameter
$D_G$ Grout Body Diameter


Soil Nail Wall Details
See Sheets 10 - 13
MSE Type Retaining
Wall Structure Details
See Sheet 9
Cross-Section
30
0
30
Scale: 1" = 30'

# Cross Section



1.284


Name: Colluvium
Unit Weight: 125 pcf
Cohesion': 40 psf
Phi': 39 °
F of S: 1.284
Name: Moderately Weathered Bedrock
Unit Weight: 125 pcf
Cohesion': 40 psf
Phi': 45 °
Name: Bedrock
Elevation
Distance

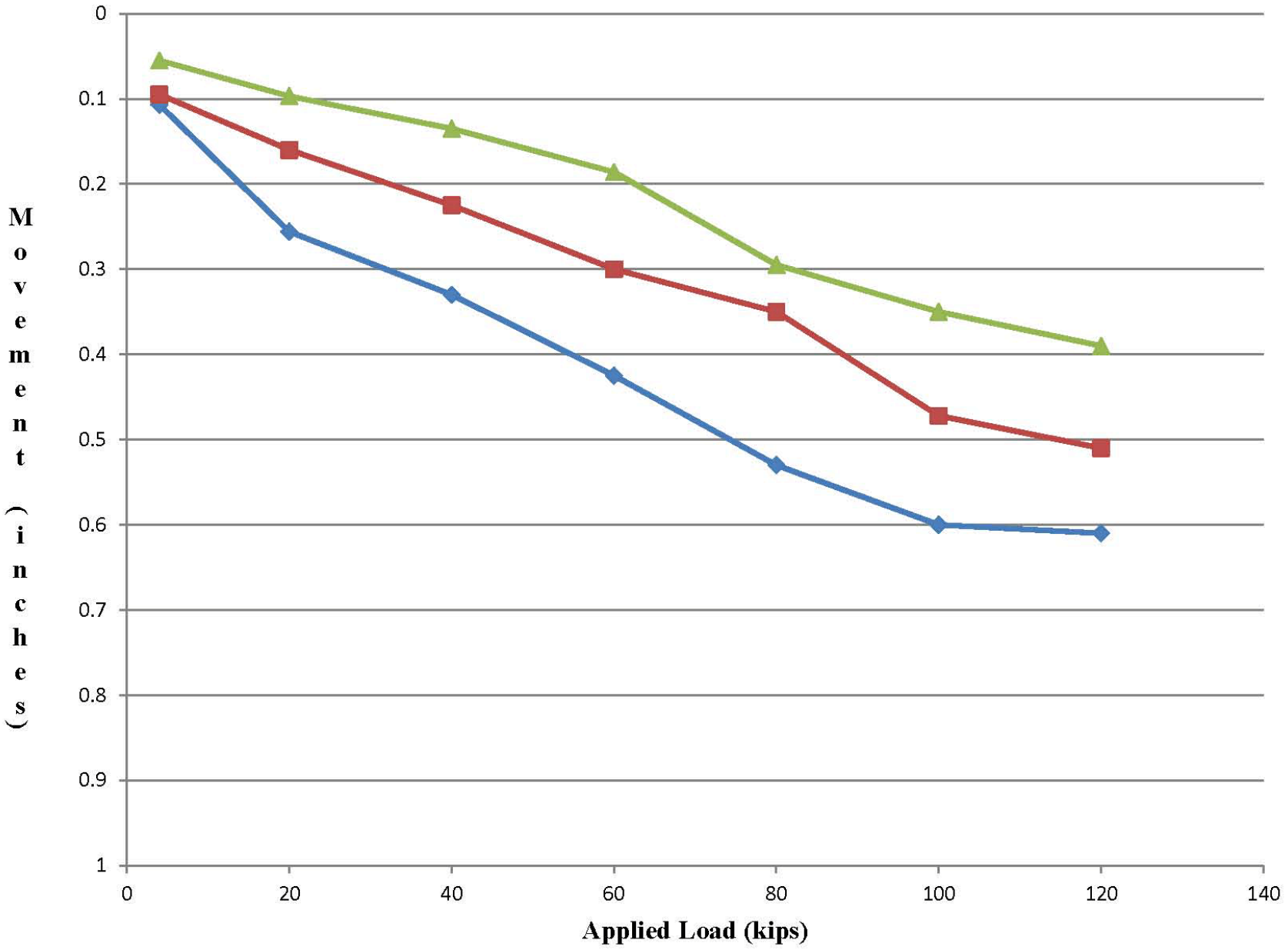
# Slide View From Satellite


10.22.2010 14:25


Mounted nail
Grout injection orifice
Bit
Threaded joints
10.22.2010 14:25


11.11.2010 11:20

# Hyalite Canyon Slide Proof Test Results




09.14.2011 16:38


Genie
12.07.2010 14:59

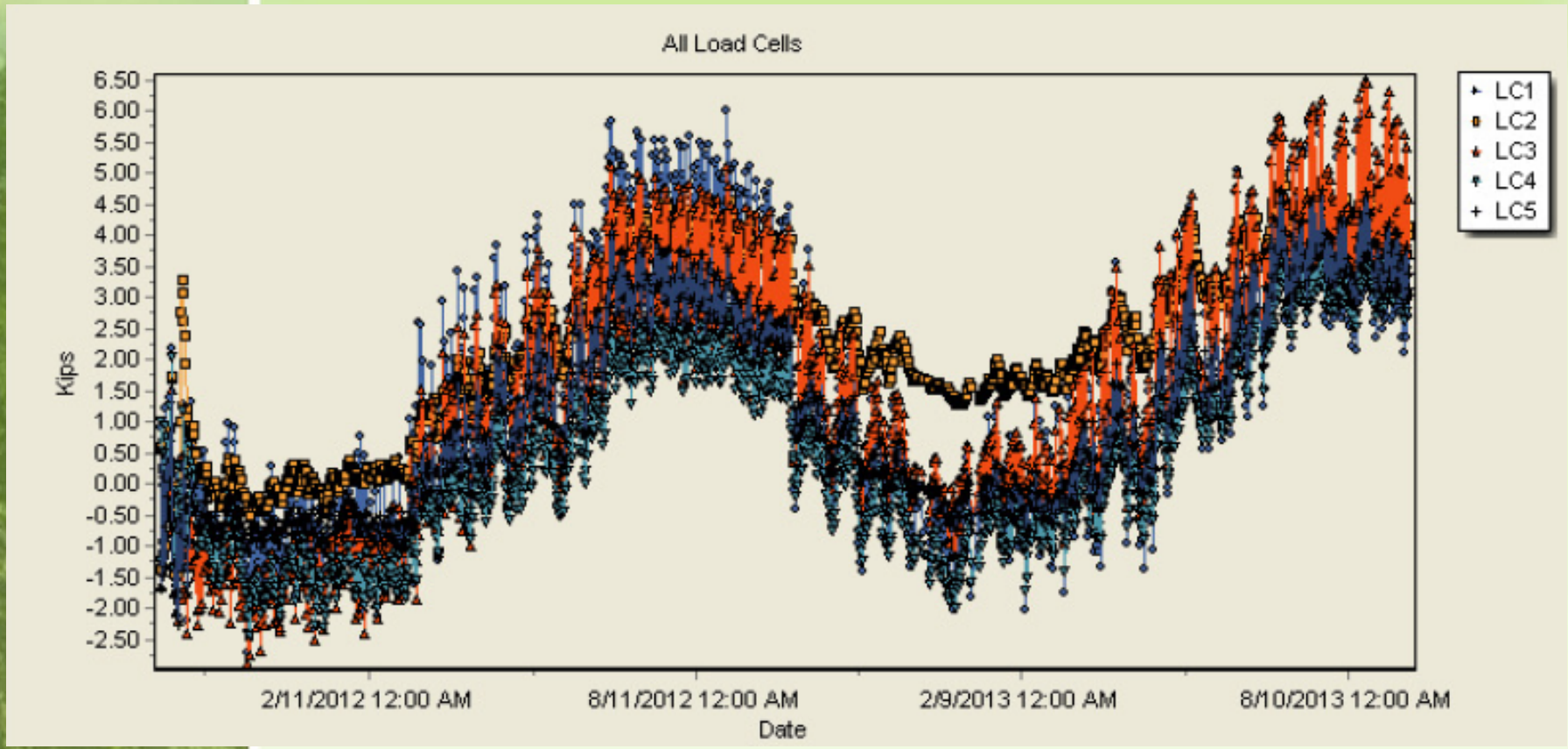

10.13.2011 14:12

# Instrumentation and Monitoring

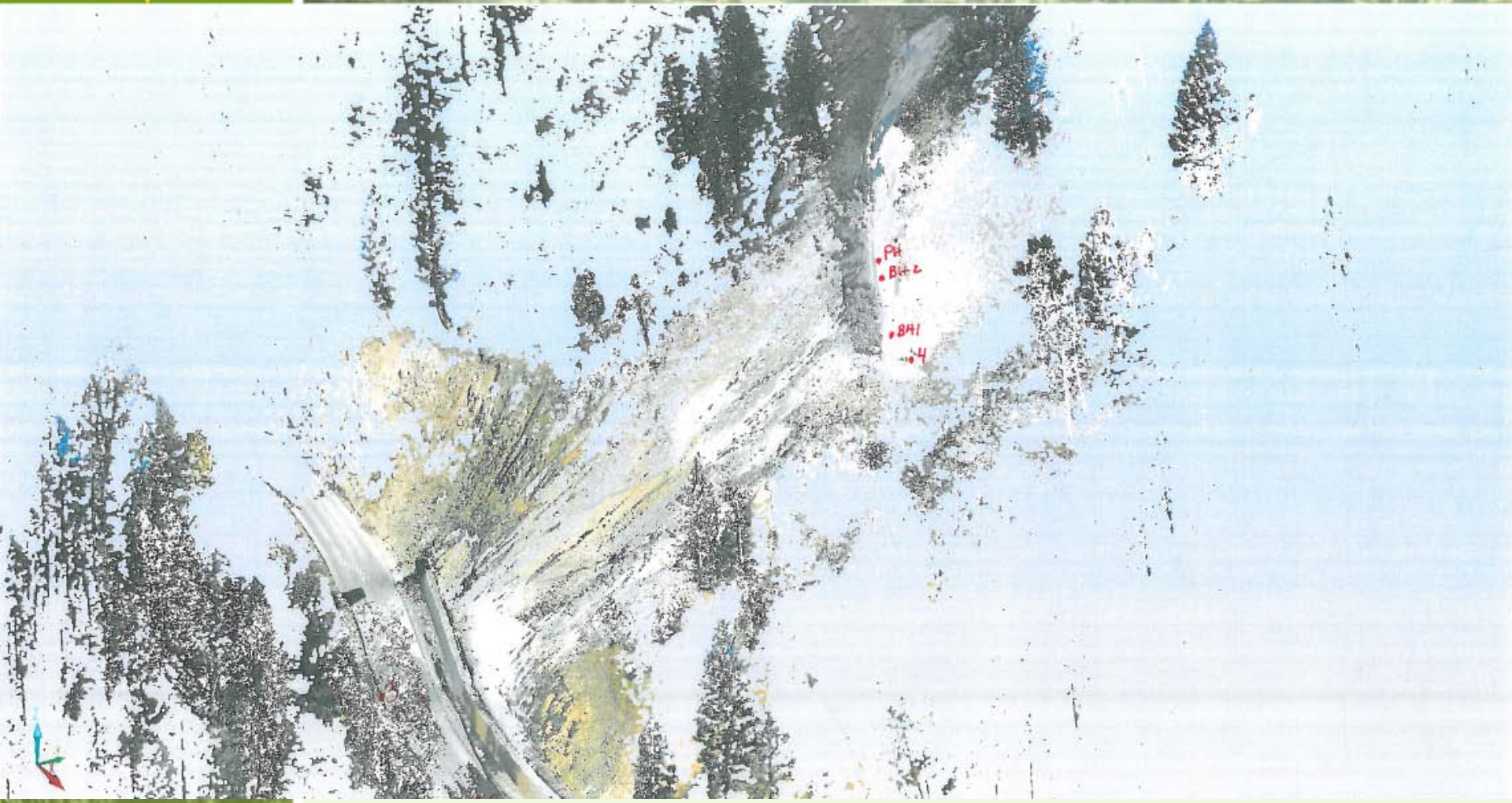
- 5 Vibrating Wire Load Cells
- 2 Vibrating Wire Piezometers
  - 15’ and 24.5’ below grade
- 2 Slope Inclinometer Casings
  - Each 40 feet below grade
  - Require use of external slope inclinometer torpedo
- Able to take remote readings from the load cells and piezometers


10:42
08.30.2011 16:54

# Load Cell Data

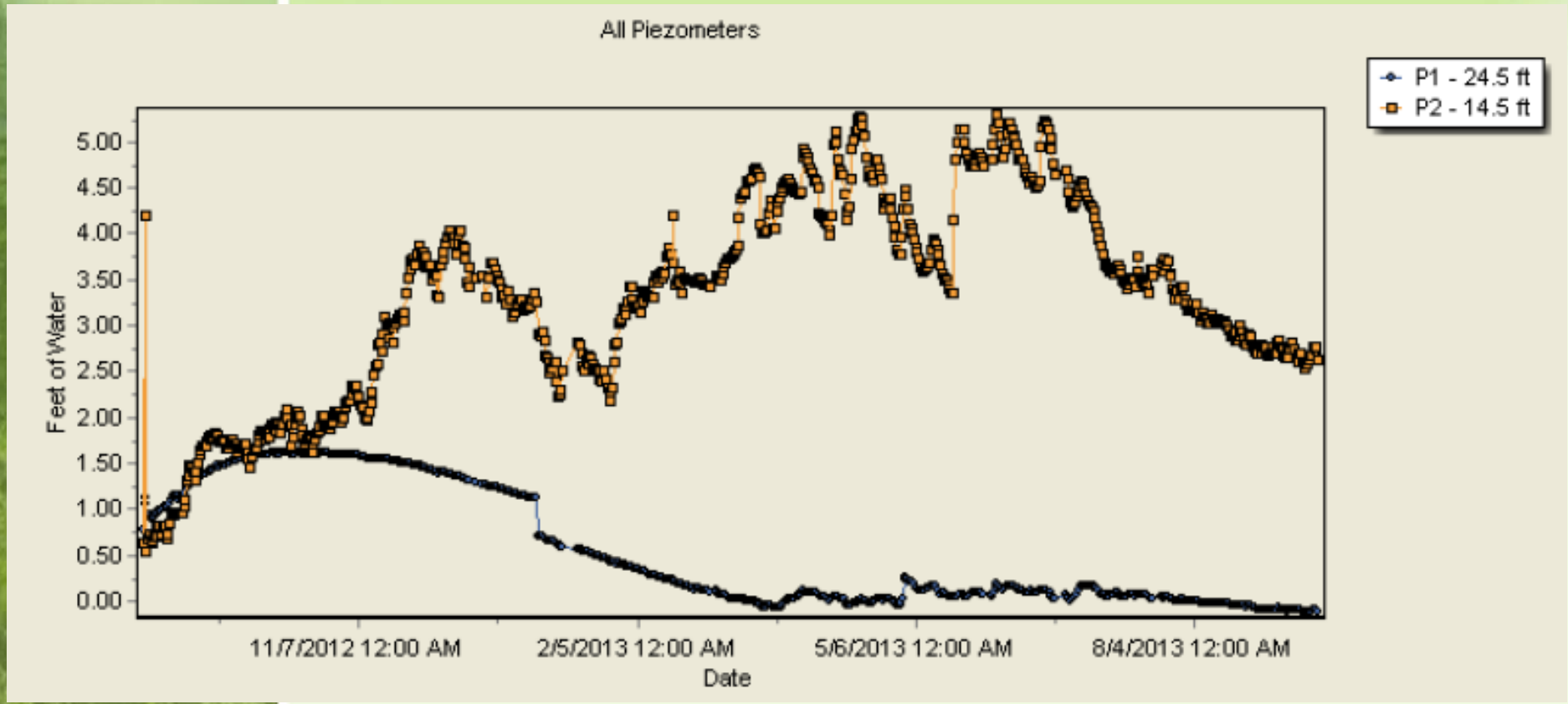


# Scanner Survey



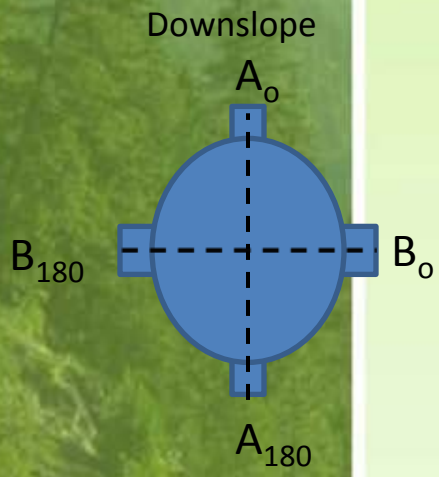

GEOKON
Model Number
Serial Number
Geotechnical Instrumentation - Made in the U.S.A.
0 kPa
CE
08.28.2012 19:00

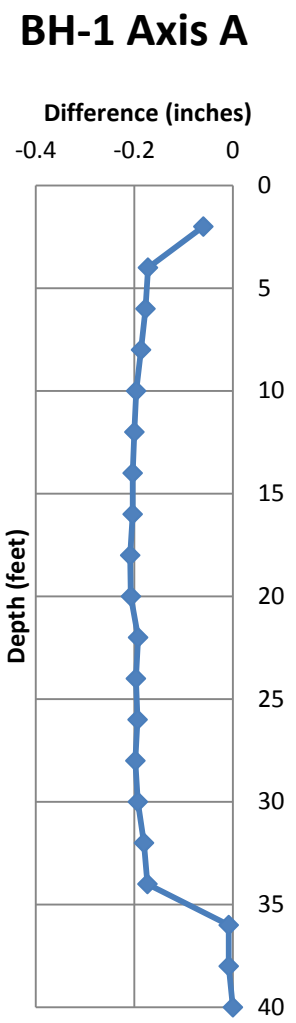
# Piezometer Data

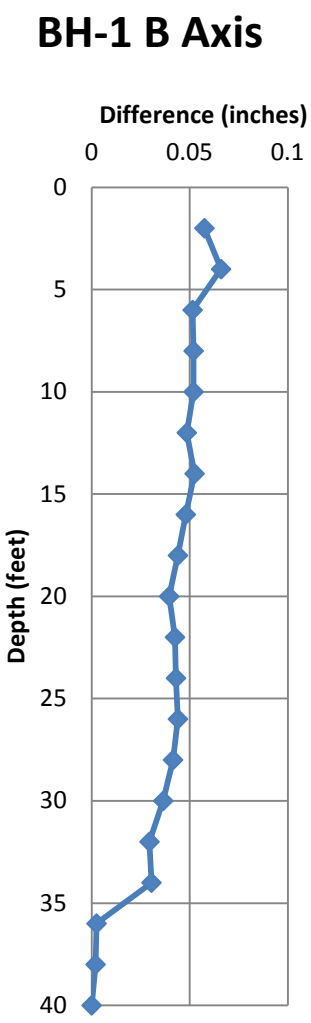


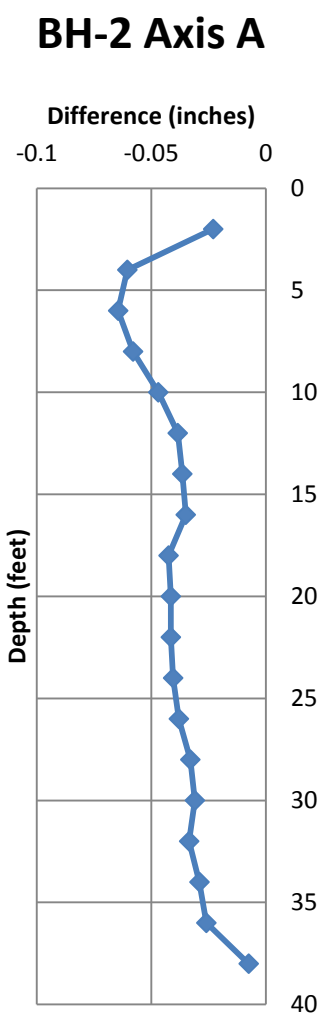

08.28.2012 13:20

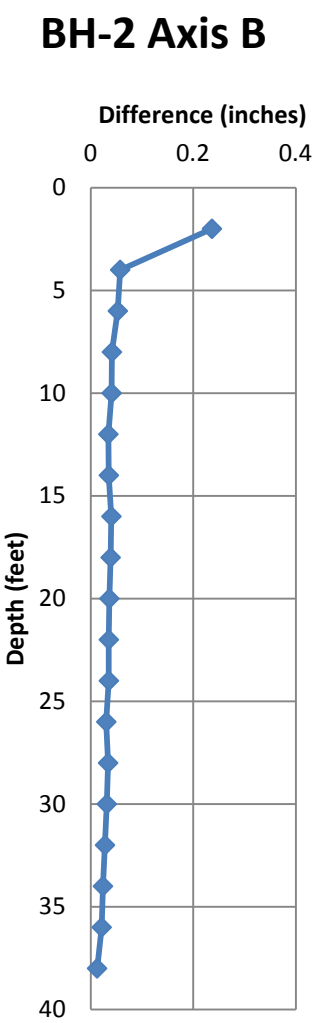
# Slope Inclinometer Data



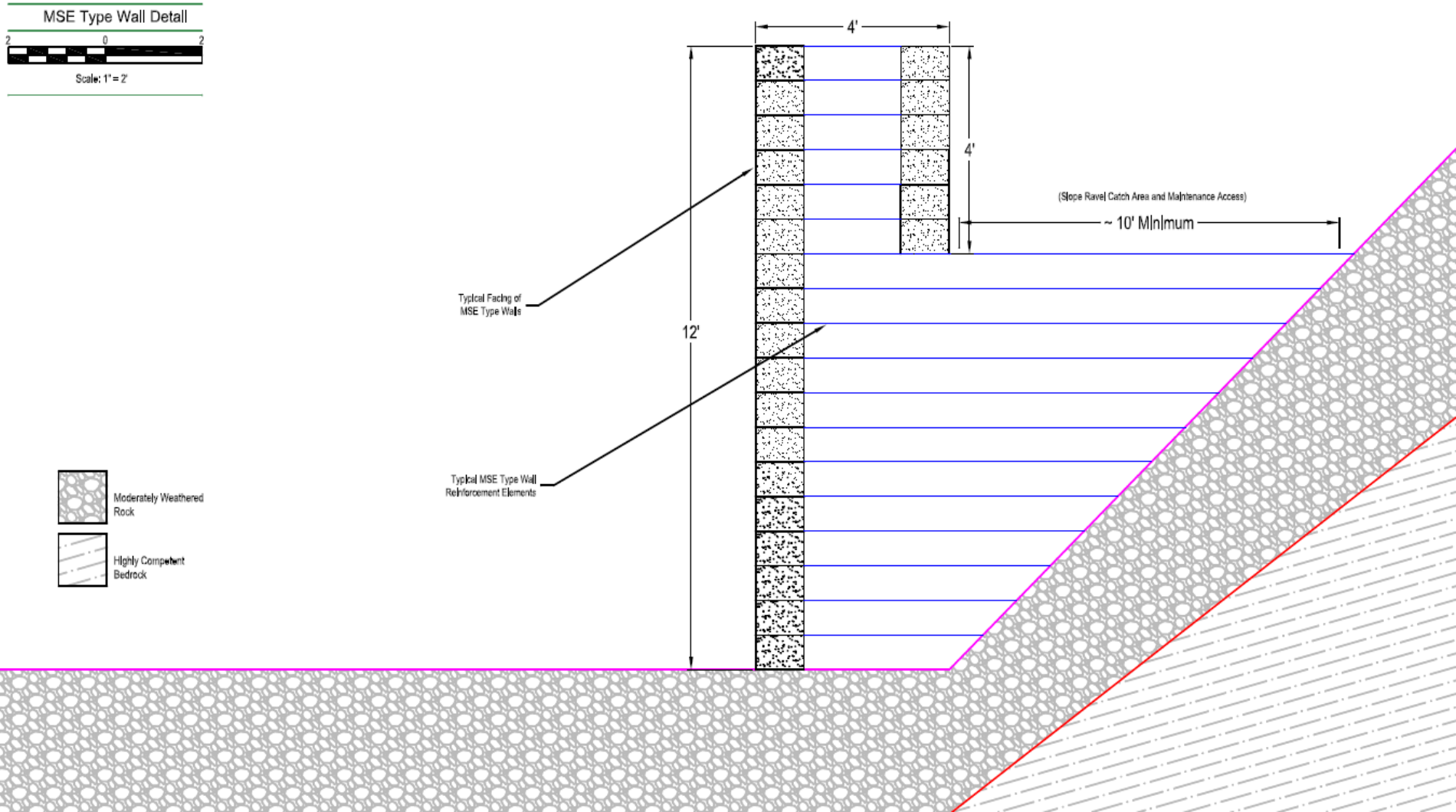



# GRS Wall


MSE Type Wall Detail
2 0 2
Scale: 1" = 2'
4'
4'
12'
(Slope Ravel Catch Area and Maintenance Access)
~ 10' Minimum
Typical Facing of MSE Type Walls
Typical MSE Type Wall Reinforcement Elements
Moderately Weathered Rock
Highly Competent Bedrock


Leveling is extremely important
07 . 14 . 2011 14:47


07.14.2011 16:25


07.21.2011 15:10


07.21.2011 15:11


08.30.2011 17:17


08.30.2011 17:20

# Summary

- HBSN's were installed with a shotcrete facing to mitigate the failing slope.
- GRS wall was constructed as a catchment structure due to high profile and usage of site.
- Remote monitoring plan with load cells and piezometers were put in place to monitor changes.
  - The value of monitoring is the ability to see changes over the long and short term.
  - Trends so far reflect what is seasonally expected.

# Acknowledgments


- Geostabilization
  - Cameron Lobato, P.E.
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- Axis Drilling, Inc.
  - Lyle Ballenger
- DJ&A, P.C.
  - Mike Jensen, P.E., Principal
  - Vaughn Anderson, P.E. (retired)
  - Chris Anderson, P.E. , Principal
- Contracting Officer
  - Gary Stephens
- Gallatin National Forest
  - Jonathan Kempff, P.E., Forest Engineer
  - Jeff Hiedeman, Field Technician
  - Grant Morrison, EIT
- USDA Forest Service, Northern Region Geotechnical Engineers
  - Bill Vischer, P.E. (retired)
  - Ed Rose


Thank you!