

How Much Can it Cost to Remediate a Large Landslide?

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Surface areas of large landslides range from 2 to 20 acres, and efforts to improve the stability of landslides this size can be overwhelming. Before discussing remedial costs, large landslides need to be investigated and engineered one step at a time to minimize the potential for setbacks to the owner and/or the consultant. A phased approach helps the owner of the landslide understand if remediation is feasible and what the potential costs could be. It allows sufficient geotechnical data to be gathered, determines the appropriate remediation technique for both landslide and owner, and sets the stage for engineering design and construction. A cookie cutter approach does not work: every large landslide is unique.

The costs to treat a large landslide are dictated by geometry, site considerations, and the methods that are used to improve the balance of forces within the landslide. Potential methods can involve drainage, earthwork and structures. Drainage techniques often include trenching, relief wells and horizontal drains. Earthwork techniques may include unloading, buttresses and key trenches. Structural techniques for large slides are typically large diameter piles with tieback anchors. A phased approach would determine which technique is appropriate for any given landslide.

Costs for treating a large landslide can range from hundreds of thousands of dollars to many millions. For comparison, consider an 800-foot wide and 60-foot deep slide. Horizontal drains are relatively inexpensive at \$15 to \$20 per foot of installed drain; however, the number of drains and lengths add up and costs can quickly reach hundreds of thousands of dollars or more. Earthwork quantities for a rock shear key in an 800-foot wide slide could be on the order of 150,000 to 200,000 cubic yards. Prices of \$3 to \$20 per cubic yard for materials that range from waste soil to quality rockfill result in potential costs for construction of a shear key that could be on the order of \$2 to \$3 million. Conventional soldier pile tieback walls are usually inadequate for remediation of landslides this deep, and a wall of 3- to 4-foot diameter shear piles with tiebacks may be more suitable. Considering that construction costs could range from \$400 to \$500 per foot for a 4-foot diameter pile, an 800-foot long shear pile wall could cost on the order of \$3 to \$4 million.

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Presented by Charlie Hammond, C.E.G.
(with help from M.Meyer, A.Vessely,
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Presentation Outline

- What is 'large'
- Engineering analysis
- Cost versus Risk
- Treatment methods to compare
- Ballpark construction costs
- Slide remediation examples

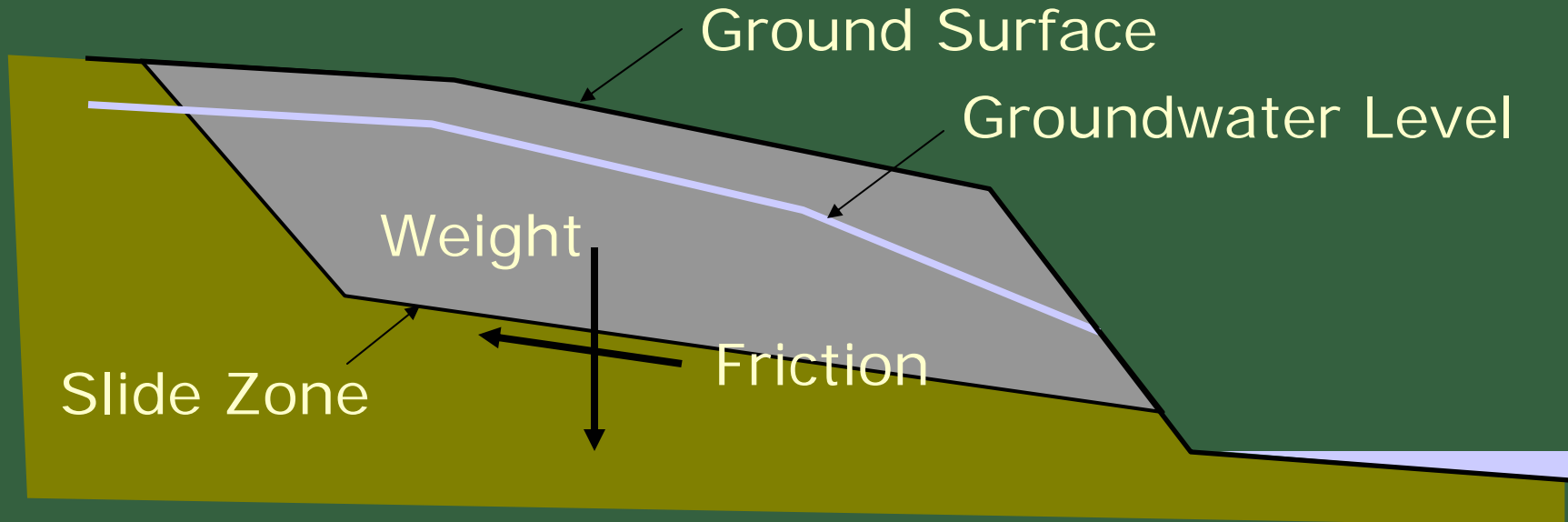
What is large?

- Consider a 'large' slide is about 100,000 to 1,000,000 square feet (about 2 to 23 acre surface area)
- For comparison, think of a slide 600 feet wide by 800 feet long (480,000 square feet)
- and 60 feet thick (about 1,000,000 cubic yards)

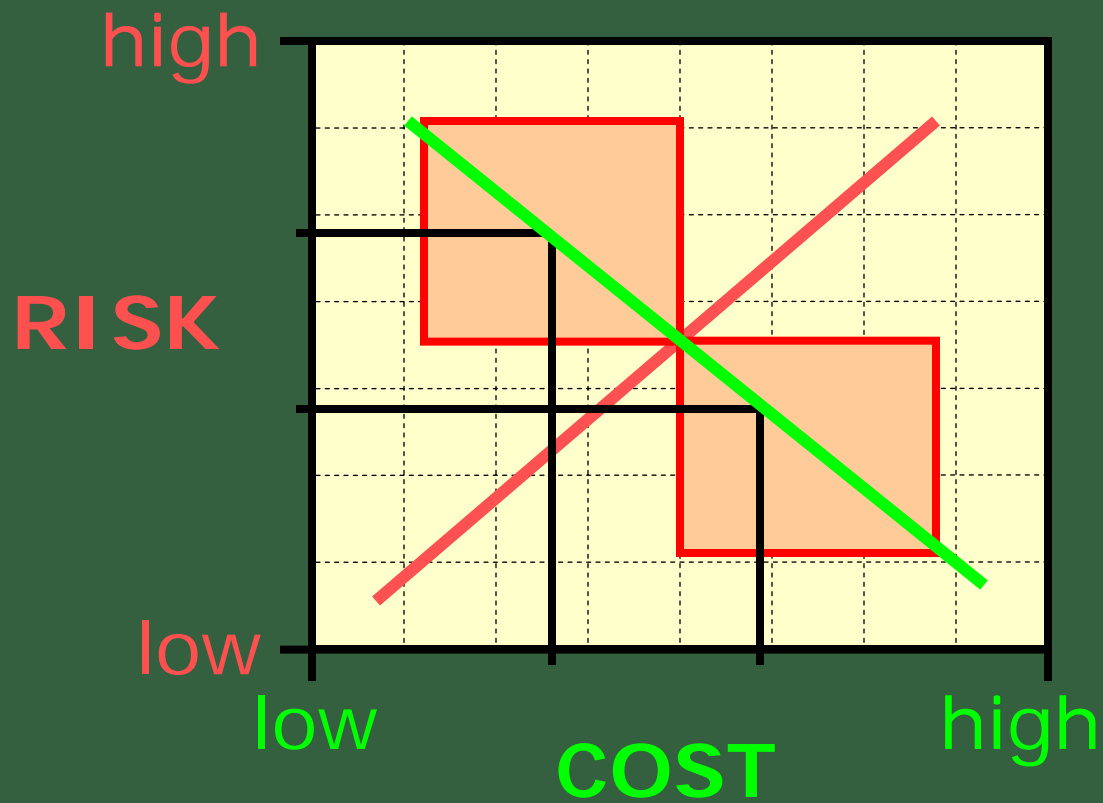
Engineering (Stability) Analysis

A landslide is constrained by:

- Driving forces (weight and water pressure)
- Resisting forces (friction)



Cost versus Risk

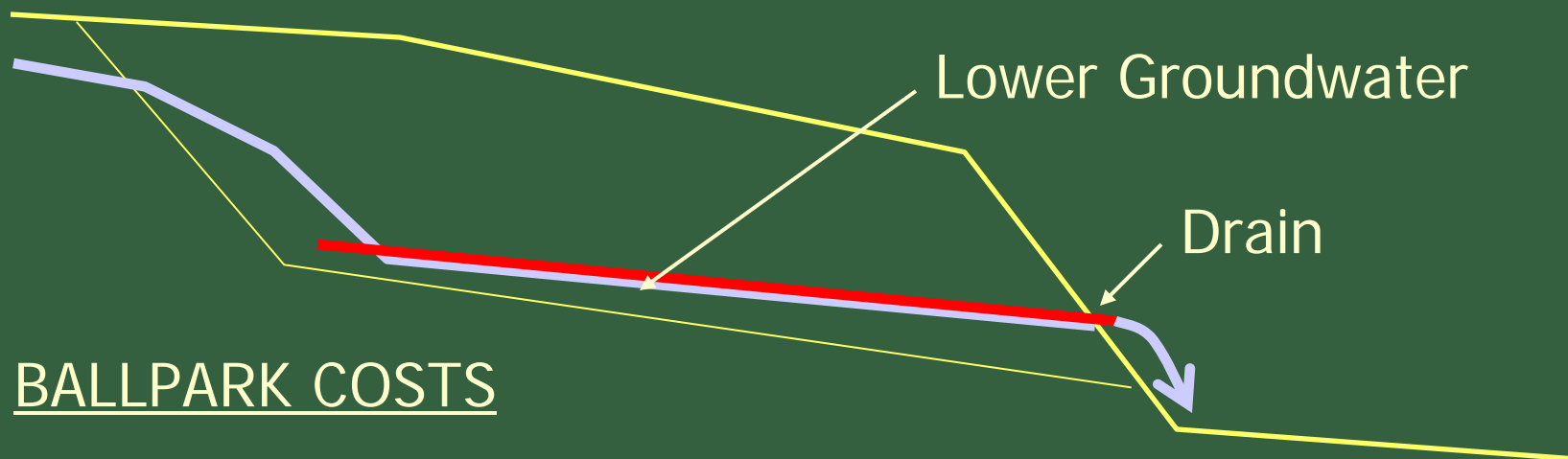


Treatment Methods to Compare

- Drainage (Horizontal Drains)
- Earthwork (Key Trench)
- Structural (Shear Piles)
- Maintenance

Horizontal Drains

Goal: Lower the water level to decrease water pressure and increase soil friction



BALLPARK COSTS

CONSTRUCTION (500 ft long drains)

30 drains @ \$15 to \$20 per ft

\$225,000 to \$300,000

60 drains " " " " " "

\$450,000 to \$600,000

ENGINEERING

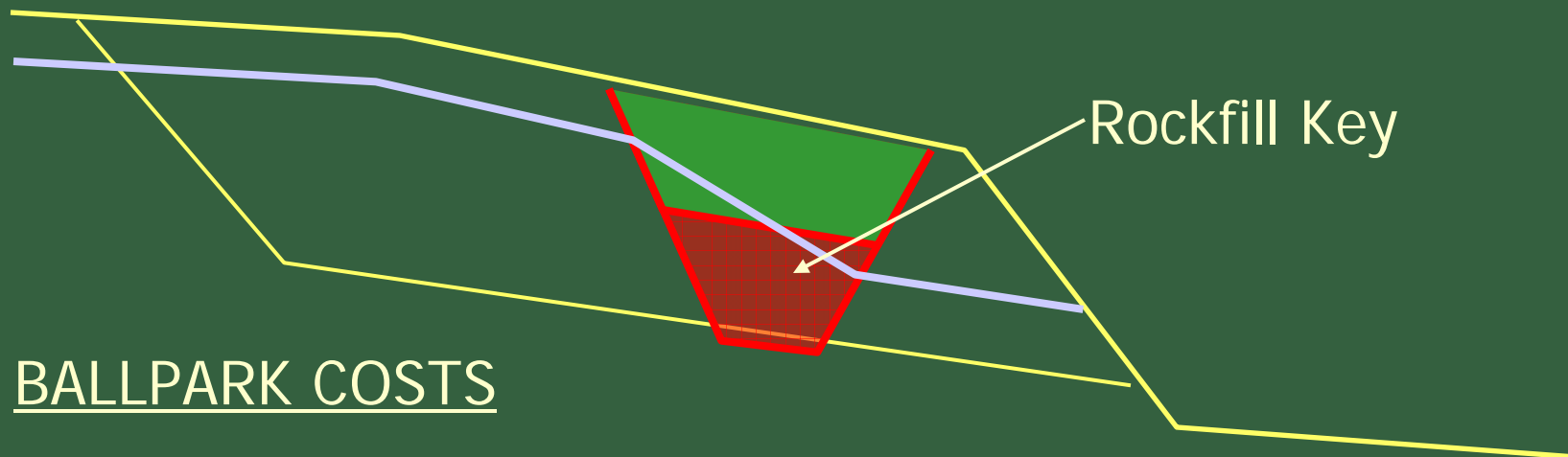
\$100,000 to \$200,000

RISK OF FUTURE MOVEMENT

LOW TO HIGH

Key Trench

Goal: Increase resisting force with high strength rockfill



BALLPARK COSTS

CONSTRUCTION (600 ft long shear key)

20 ft wide key @ \$5 to \$15 per yard \$1.5 million

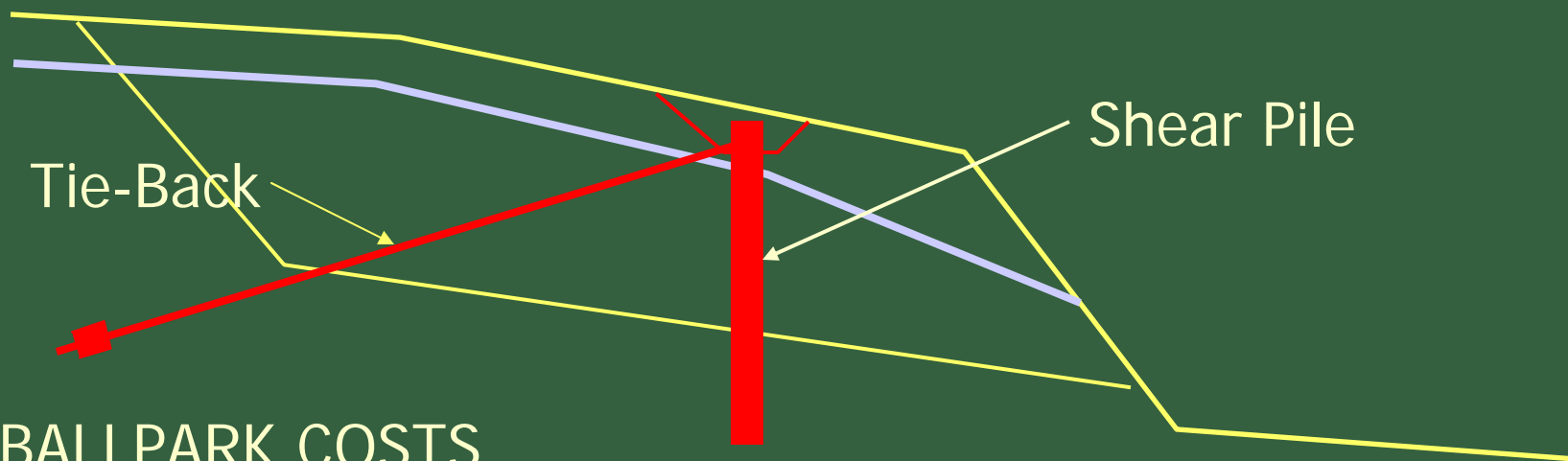
40 ft wide key " " " " " " \$2 million

ENGINEERING \$0.2 to \$0.6 million

RISK OF FUTURE MOVEMENT LOW

Shear Piles (Tied-Back)

Goal: Increase resisting forces with a row (or buried wall) of tied-back shear piles



BALLPARK COSTS

CONSTRUCTION (75 ft deep piles w/ tie-backs)

120, 2 ft dia piles on 5 ft centers @ \$215 per ft \$2 million

75, 4 ft dia piles on 8 ft centers @ \$490 per ft \$2.8 million

ENGINEERING

\$0.5 to \$0.9 million

RISK OF FUTURE MOVEMENT

LOW

Maintenance

- Applicable for creeping translational block slides
- Utility repair, road and ditch patching, etc
- Facility repair
- Monitoring
- Water management (surface and ground)

BALLPARK COSTS

ANNUAL MAINTENANCE OF INFRASTRUCTURE

(how many monitor and repair visits per year ?) \$20,000 ?

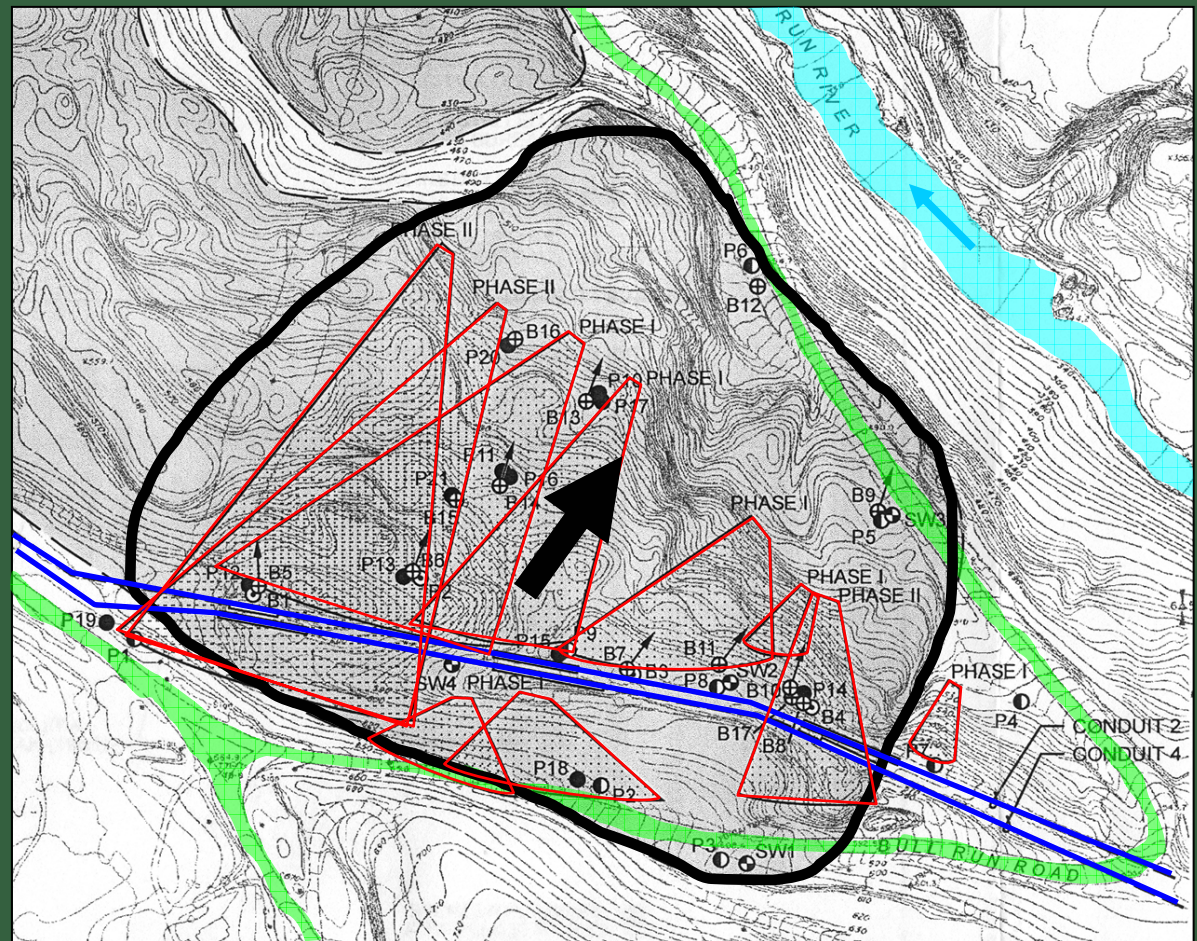
(over 20 years ?) \$400,000 ?

RISK OF CONTINUED MOVEMENT

ALWAYS

Ditch Camp Slide (Sandy, OR)

- 1,200 ft wide, 900 ft long, 30 to 50 ft deep
- 29,000 feet of horizontal drains
- Construction Cost (1997-98): \$400,000
- Result: Satisfactory Stability



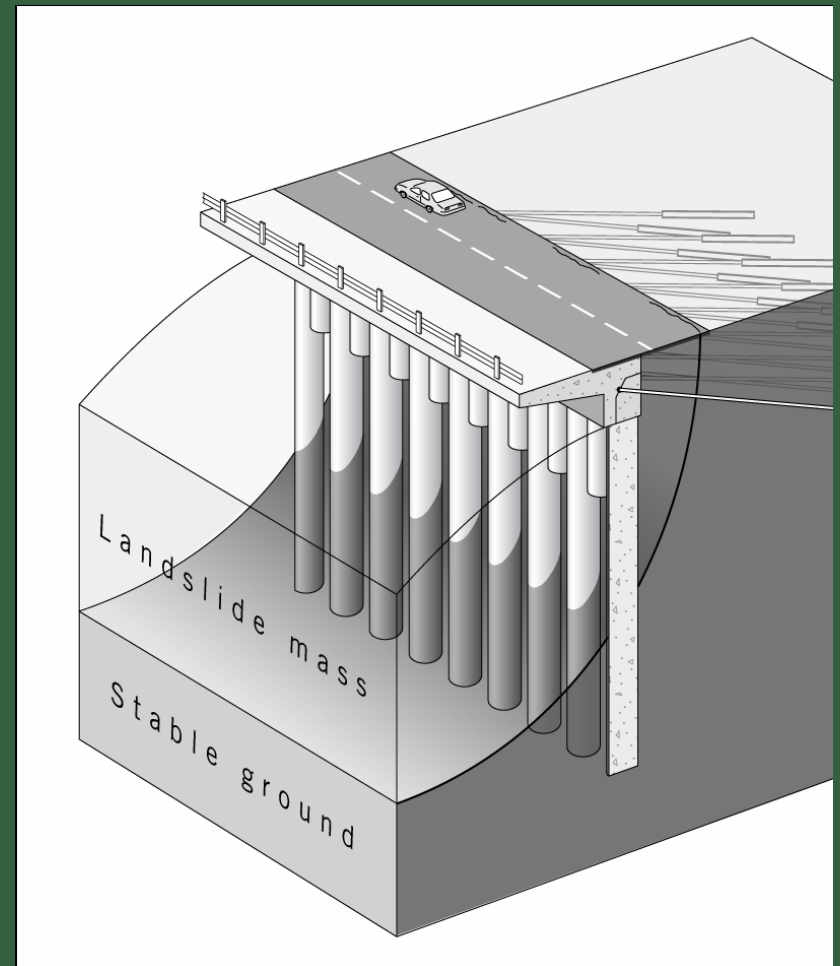
Scenic Loop Highway Slide (Pacific City, OR)

- 850 ft wide, 500 ft long, 40 to 50 ft deep
- 9,000 feet of horizontal drains
- 45,000 cubic yard shear key
- 750 feet of trench drains
- 1,000 feet of highway relocation
- Construction Cost (1999): \$1.5 million
- Result:
Good
Stability



Goat Lick Slide (Glacier Nat'l Park, MT)

- 220 ft wide, 420 ft long, 30 to 45 ft deep
- 1,670 liner feet of 4-foot diameter shear pile
- 53 tie-backs
- Cantilever bridge
- Construction Cost (1993): \$1.5 million
- Result: Good Stability



In Conclusion

- Large landslides can be 2 to 25 acres in size
- Cost and risk evaluation
- Cost could range from \$0.3 to \$4 million
- Understanding 'risk', client communication, and confidence in engineering makes the difference between "nothing can be done about it" and success

