United States
Department of
Agriculture

Forest Service

Engineering Staff

Washington, DC

Engineering Field Notes

Volume 30
May–August
1998

Engineering Technical Information System

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Coconino National Forest Bridge Inspection and Maintenance Trailer

Robert H. Powell, P.E.
Highway Engineer
Coconino National Forest

Each national forest is mandated by law to inspect every bridge within its boundaries on a 2-year cycle. These inspections require qualified personnel to evaluate critical structural and safety-related elements of the structure and to document those findings.

With recent reductions in funding and personnel, some national forests have had difficulty meeting the mandated inspection schedule. Hiring consultants, bringing inspectors in from other forests or Regions, or hiring State transportation department personnel has eased the inspection dilemma, but none of these have the time or the ability to correct deficiencies, especially safety-related deficiencies, at or near the time of inspection.

Such inspections have been dutifully carried out on the Coconino National Forest year after year. Report after report has documented deficiencies, deterioration, and wear and tear to varying degrees. Serious defects such as impact damage, severe deck deterioration, or scour problems, and some minor work like missing object markers were moved into the budget and work planning process and eventually corrected. Taking care of all deficiencies listed for all bridges has been continually hampered by lack of funding, lag time in planning and budgeting, and other, “higher” priorities. If the bridge was functioning and the deficiencies were not too severe, bridge work generally went on the back burner, left to be documented again in the next round of inspections.

It became increasingly apparent after a few inspection cycles that minor documented deficiencies were becoming bigger and bigger problems. Funding for repair of bigger problems was getting more difficult to find as maintenance budgets were reduced. Liability was increasing. Documenting the same deficiency over and over again seemed to be just building a legal case for a plaintiff in the event of a lawsuit. It was time to stop doing business as usual.

It became apparent to us that the solution was to have the ability to fix all safety-related maintenance items and do other minor repairs for investment protection and cosmetic purposes at the time of inspection. The “tool” we devised is the bridge inspection and maintenance trailer (see figure 1).

In 1995, we completed a review of past inspection reports, in which every repair item was identified and categorized. From that we compiled a list of tools and materials needed to do the repairs. It was decided that a 14-foot tandem-axle trailer would be large enough to house the tools and still be

Figure 1. *Coconino National Forest's bridge inspection trailer*

maneuverable enough to get to all bridge locations. Money was set aside in the fiscal year 1996 budget for purchase of the trailer and its components (see figure 2 for a listing of tools and materials and figure 3 for a trailer schematic). The trailer was tested on a small number of bridges in the fall of 1996 on the Coconino with what we felt was great success.

We found that all safety-related maintenance items such as repair and replacement of object markers, brushing, deck cleaning, approach pothole filling, removal of encroaching vegetation, and opening of drains could be done quite efficiently at the time of inspection. In addition, investment-protection items such as concrete patching of impacted or spelled curbs and decks, guardrail repair and painting, and tightening of loose bolts was also possible, with a total time spent at each facility in the neighborhood of 1 to 3 hours. Major items such as approach paving, large foundation deterioration or scour problems, full guardrail replacement, deck overlays, or concrete injection repairs would be documented for later force-account or contract work.

The initial trial runs showed that a typical Forest Service highway bridge could be inspected and have minor repairs done on site at the time of inspection for approximately $200 per bridge, including salary for three Forest Service employees, travel costs, and materials. This cost was less than what was being charged by the State transportation department for just the inspection report.

It also became apparent that such a portable unit could be utilized on more than just one forest. We were already coordinating with the adjacent Kaibab

General Support Items

Generator (5,000-watt minimum)

Compressor (sized to match air tools)

Air hose—100 foot with reel (2 each)

Power washer—1,250 psi

Water pump—120 volt, 30 psi (for garden hose)

Water tank—30 to 50 gallon

Shelving system—6 feet tall by 4 feet wide (4 units) (shelves must have containment edges)

Impact wrench with sockets, deep wall, large and small

Skill saw

Electric drill, heavy duty, with concrete and wood bits

Portable drill

Cut-off tool, electric or air driven (for bolts)

Extension cords, 100 foot, heavy duty outdoor (2 each)

Gas can, 5 gallon, safety type with pump (for generator)

Hose reel with 100-foot garden hose with spray nozzle

Mark III pump with hose, fittings, and nozzle

Hacksaw

Handsaw

Hydraulic jack (3 ton)

Long chisel/digger bar

Wrecking bar

Rubber mat (for trailer floor)

Nonskid tape (for ramp)

Fire extinguisher

First-aid kit

Various sizes of containers with lids (for storage of loose items)

Bungee cords

Carpenter's level

Nut, bolt, and screw assortment

Tool box containing assortment of sockets, wrenches, pliers, hammers, screwdrivers, chisels, wire brushes, etc.

Delineation and Visibility

Type II delineators—20 each left and right side

Signposts—30 minimum

Post puller

Post pounder

Sign hardware—nuts, bolts, washers, etc.

"Narrow Bridge" signs

Brush hook, sandvik, pruning shears

Small chainsaw

8-inch PVC pipe (for signpost storage), 8 foot length (3 each)

Inspection Items

Personal protective gear

Extension ladder—20 foot

Rubber wader boots

Appropriate warning signs, such as "Workers Ahead"; cones

Laptop computer, digital camera, printer

Deck/Superstructure/Substructure

Mud/ice scraper with 5-foot handle

Multisurface push broom

Scoop shovels (2 each)

Spray bottle (for concrete patching)

Various trowels

Mixing tray (for concrete patch)

Small water container (2 quart)

Wood sealer and patch

Concrete and deck patch materials

Painting

Paint, 5 gallons each color, latex and oil base

Plastic buckets for paint and cleanup

Assorted brushes

Rollers—3 inch and 6 inch, with extension handles

Disposable roller refills

Paint thinner

Air sprayer with attachments and hoses

Long mixing rod (attach to drill for mixing paint)

Roller pan with disposable trays

Miscellaneous

Rags

Waterless hand cleaner

Tow chain

Water cooler—5 gallon

Plumber's tape (for securing items to floor or wall)

Plywood (for walls)

Assorted wood and sheet-metal screws

Figure 2. *Bridge inspection trailer materials*

Figure 3. *Schematic of bridge inspection trailer*

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Figure 3. *Schematic of bridge inspection trailer (continued)*

National Forest to do their inspections, but could such an asset be valuable beyond that?

In 1997, with the help and coordination of Region 3 Structural Engineer Rich Miller, we were able to travel to two additional national forests in New Mexico. Over a 2-week period, working 12-hour days with three people, we were able to complete inspections and do numerous repairs on more than 60 bridges. Documentation included the inspection report, photo log, delineation of items repaired as well as those remaining, and a work summary matrix for all structures. Cost, again including salary, travel and per diem, and materials, was just over $200 per structure. In all of 1997, including the bridges inspected on the Coconino and Kaibab National Forests, 103 structures were inspected and safety-related repairs were completed on four national forests in two States. That accounts for more than a third of the bridges in Region 3.

At this time we believe that trailer inspection units such as the one we have put together on the Coconino are effective within a radius of about 500 miles of their home base. More remote and scattered bridges will affect the unit cost, but we believe such inspections and repairs can be made even in these cases for no more than $300 per bridge.

Initial cost of the trailer and its contents was approximately $11,000. We are working to complete our onsite capability by adding a laptop computer, portable color printer, and digital camera that will allow us to do the inspection, make repairs, and produce the inspection report and photo log before leaving the site. Additional cost for these items is approximately $4,600. When you consider the cost of one lawsuit or claim that could result from a lack of safety-related maintenance, or the cost of replacing an abutment or deck because some minor investment-protection maintenance was not done in a timely manner, this solution becomes extremely cost-effective.

For additional information or assistance in setting up a bridge maintenance trailer, please contact Robert Powell in the Coconino National Forest Supervisor's Office.

The Relative Effects of Landslides Resulting From Episodic Storms on a Low-Volume Road System in Northern Idaho

Douglas E. McClelland, USDA Forest Service, Missoula, MT.

Dr. Randy B. Foltz, USDA Forest Service, Moscow, ID.

Dr. C. Michael Falter, University of Idaho, Moscow, ID.

W. Dale Wilson, Consultant, Orofino, ID.

Dr. Terrance Cundy, Potlatch Corporation, Lewiston, ID.

Dr. Robert L. Schuster, U.S. Geological Survey, Denver, CO.

Jim Saurbier, USDA Forest Service, Missoula. MT.

Craig Rabe, University of Idaho, Moscow, ID.

Ron Heinemann, USDA Forest Service, Orofino, ID.

Abstract

In late November and early December of 1995 and in February 1996, northern Idaho was hit by heavy rains on a deep snowpack, resulting in two flood and landslide events of historic magnitude. Each of these storm events was larger than the most recent significant storm, which occurred in January 1974. The Forest Service initiated a study to survey and analyze the effects of the landslides on the Clearwater National Forest, including the impacts to the aquatic ecosystem. The results of this study were compared with the estimated average natural sediment due to landslides to evaluate the incremental impacts of these recent episodic landslides. They were also compared with the results of a study conducted on the landslides resulting from the January 1974 storm event to determine if the landscape was responding more severely to large storms as a result of Forest Service management activities over the past 21 years. The general results of this study indicate that, of the Forest Service management activities, roads are the major contributor; however, they contribute less sediment than natural landslides. The total resultant sediment appears to be within the transport capacity of the aquatic system, and the landslide response in 1974 was similar to the 1995–96 response. The results of the aquatic ecosystem study were generally mixed, with some habitat parameters indicating degradation, some unchanged, and some improved as a result of flooding or flooding with landslide sediment.

Introduction

In late November and early December of 1995 and in February 1996, northern Idaho was hit by heavy rains on a deep snowpack, resulting in two flood and landslide events of historical magnitude—each the largest since January 1974. Many low-lying areas were evacuated, and there was extensive public and private property damage (U.S. Geological Survey 1996). Fifteen northern Idaho counties, including Clearwater County, were declared flood disaster areas. The Forest Service initiated a study to survey and study the effects of landslides on the Clearwater National Forest, including impacts to the aquatic ecosystem. The final report of this study is the two-part *Assessment of the 1995 and 1996 Floods and Landslides on the Clearwater National Forest* (McClelland et al. 1997; Falter and Rabe 1997). This article summarizes that final report.

Study Area

The Clearwater National Forest is located in Clearwater, Benewah, Shoshone, Idaho, Lewis, and Latah counties in north central Idaho (see figure 1). It lies west of the Montana border and is bounded on three sides by four other national forests: the Lolo in Montana, the Bitterroot in Montana and Idaho, the Nez Perce in Idaho, and the St. Joe in Idaho. The forest boundary encompasses all or major portions of the drainages of the North and Middle Forks of the Clearwater River, the Lochsa River, and the Palouse River, which are all part of the Columbia River system.

Methods

Landslide Assessment

Field and aerial photo inventories were necessary to obtain complete coverage of the Clearwater. The entire forest (with the exception of the Palouse district and the Selway Bitterroot Wilderness) was flown in July 1996 at a scale of 1:15840.

A threshold landslide volume of 19.1 cubic meters (25 cubic yards) was established because of the difficulty of estimating landslide volumes from

Figure 1. *Location map*

aerial photography and also the difficulty of field measurement of the typical debris slides, which alternately scoured and deposited material as the slide progressed downslope. Because of these volume measurement problems, the landslide volumes were grouped in volume ranges. Estimating the sediment delivered to a stream was more difficult because some of the sediment was likely removed by spring runoff. Sediment delivered was grouped in percent-delivered ranges.

Volume estimates from field-surveyed landslides were used to calibrate aerial photo volume estimates on approximately 10 percent of the aerial photo interpreted landslides. An Oregon State Forestry Department study of landslides in western Oregon found that locating landslides through aerial photography in forested areas significantly undercounts the number of landslides occurring under a dense tree canopy (Dent et al. 1997). Based on the experience of the author performing the aerial photo interpretation and another author's experience in that area of western Oregon, the canopy cover on the Clearwater should not have interfered significantly with landslide identification.

Landslides were classified into four land-use categories of road, timber harvest, fire, or natural. The road category was defined as a landslide originating between the top of a road cut and 30.5 meters (100 feet) below the base of the road fill. Landslides attributed to timber harvest include landslides on areas varying from recent clearcuts to 50-year-old timber stands. Fire was considered the land use if the area had been burned by a wildfire during the preceding 10 years. A landslide not originating in any of these three categories was considered of natural origin.

Stream Assessment

Two sets of comparisons were made to estimate stream response to the 1995–96 landslides:

- Comparison of 5 stream-habitat parameters across 16 streams that had been surveyed annually prior to these storm events and therefore provided a temporal, or before and after, comparison.
- Comparison of 44 stream-habitat and biota parameters across 35 stream reaches that had experienced flood and landslide impacts, or had experienced flooding only because all of the streams on the Clearwater had at least experienced the flooding.

The first comparison was achieved by comparing 1996 post-landslide conditions with parameters surveyed in the early 1990's on identical stream reaches, while the second comparison was based only on data collected in 1996.

Results

Storm and Flood Conditions

The Clearwater River drainage experiences periodic floods and landslide events. Major floods occurred in 1919, 1933, 1948, 1964, 1968, and 1974, with streamflow records for all but the 1919 event.

The vast majority of the landslides of the winter of 1995–96 resulted from a series of storms in late November and early December and early February. The total precipitation on the Clearwater for the November-December series was approximately 200 percent of average, with approximately 152.4 millimeters (6 inches) of precipitation in 6 days. The February series averaged 114.3 millimeters (4.5 inches) of precipitation in 6 days.

Streamflows for the February event were higher due to more snowmelt. High flows were not as severe in the two drainages at higher elevations (Lochsa and Selway) as in the drainages at lower elevations (Clearwater and North Fork Clearwater). Some streams experienced their largest flow on record, depending on elevation, snowpack, and drainage location.

Additional landslides did occur during the spring snowmelt, although the streamflow rates were not unusually high.

Landslide Assessment

A summary of the data gleaned from the landslide study database is presented in figures 2 through 4 and tables 1 through 8. Landslide risk factors of geologic parent material, landform, elevation, hillslope aspect, and hillslope steepness were distilled from the data analysis.

The volume estimates given in the figures and tables are the authors' best estimates. Both total and delivered volumes for each land use were given ranges during the analyses. The best estimate of the total volume displaced was 535,500 cubic meters (700,000 cubic yards) with a range of 306,000 cubic meters (400,000 cubic yards) to 688,500 cubic meters (900,000 cubic yards). The best estimate of the volume delivered to streams was 306,000 cubic meters (400,000 cubic yards) with a range of 229,500 cubic meters (300,000 cubic yards) to 535,500 cubic meters (700,000 cubic yards). Two large landslides that were judged to be natural had a combined volume of 229,500 cubic meters (300,000 cubic yards) and contributed 43 percent of the total estimated landslide volume.

Based on the authors' observations, a majority of the landslides in the less than 10 percent delivery category did not actually deliver sediment to a stream or floodplain. It should be noted that the minimum volume threshold of 19.1 cubic meters (25 cubic yards) should not have introduced a significant error in total volume since even 1,000 additional 19.1-cubic-meter (25-cubic-yard) landslides would have represented only 19,100 cubic meters (25,000 cubic yards), or less than 4 percent of the best estimate of total landslide yardage for the 1995–96 events.

The timber harvest landslide data include landslides on areas with 40- to 50-year-old stands of regenerated timber that should have fully recovered root strength (Sidle et al. 1985).

A possible reason for the low incidence of fire-associated landslides was that the Clearwater had experienced few wildfires over the past 10 years at elevations below 1,524 meters (5,000 feet) on unstable landforms.

From table 1 it is seen that Border and Batholith parent materials accounted for 84 percent of the landslides for all land uses.

Table 2 indicates that 94 percent of all landslides occurred below 1,524 meters (5,000 feet) elevation, which coincides with an abrupt change in soil and landforming processes on the Clearwater. The soil-forming processes are primarily driven by chemical weathering below 1,524 meters (5,000 feet)

Figure 2. *Landslide location map*

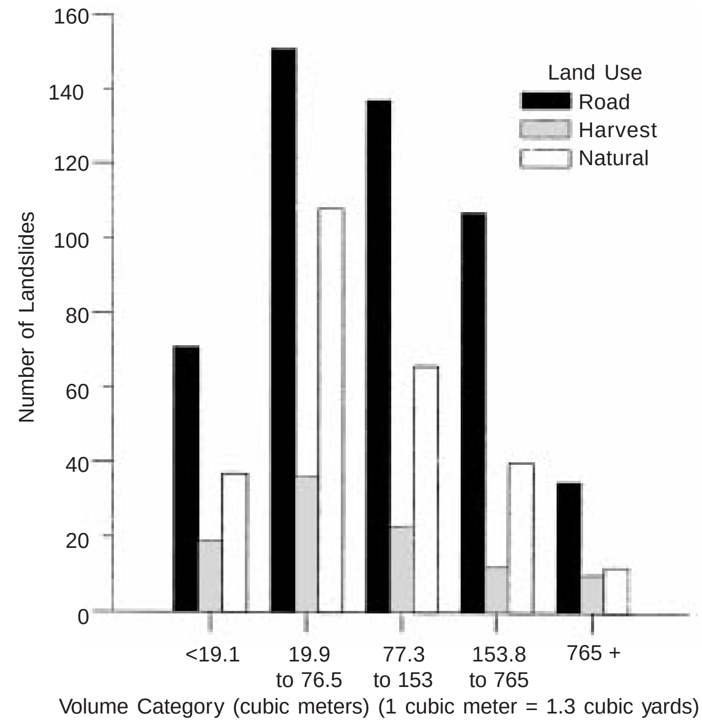

Figure 3. *Number of landslides by size and land use*

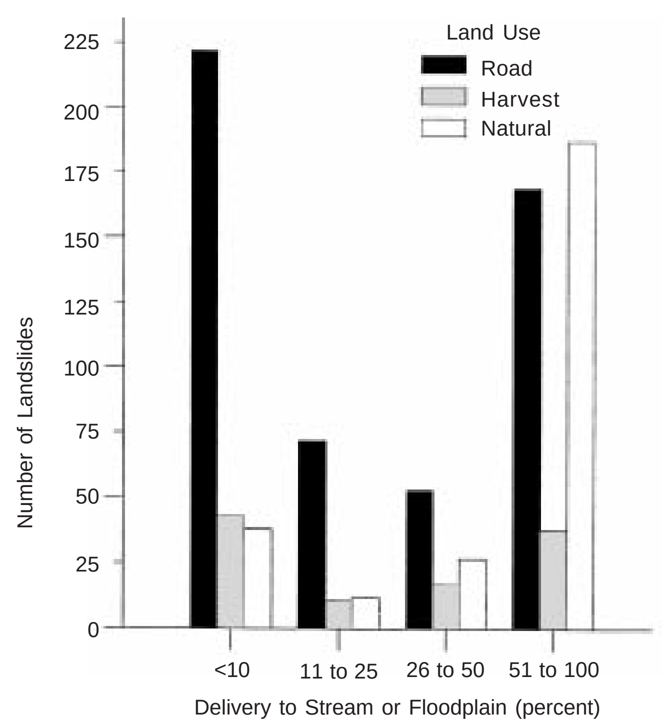

Figure 4. *Delivery of sediment to stream or floodplain by land use*

Table 1. Number of Landslides by Geologic Parent Material and Land Use

Parent Material	Percent on CNF	Total Landslides No.	Total Landslides per 1,000 ha	Road-Associated Landslides No.	Road-Associated Landslides % of Roads on CNF	Road-Associated Landslides per km	Timber Harvest Area Landslides	Natural Area Landslides
Border	25	407	2.2	263	40	0.10	44	99
Batholith	39	358	1.3	163	43	0.06	42	150
Belt	14	90	0.89	69	12	0.09	17	4
Alluvium	8	6	0.10	4	2	0.04	2	0
Basalt	2	4	0.07	4	2	****	0	0
No data		42		19			5	14
Total	88	907		522			110	267

1 hectare (ha) = 2.47 acres
Note: Road, harvest, and natural landslides do not equal the total of 907 because two landslides were fire related and six were not classified as to land use.
Batholith consists primarily of granitics, which are commonly deeply weathered and have grussic soils.
Border are high-grade metamorphic rocks with interbedded schists, gneisses, impure quartzites, and pegmatites. They typically are deeply weathered, with 10- to 20-percent mica, and have low cohesionless strength.
Belt rocks are weakly metamorphosed, containing clean quartzites, argillites, siltites, and carbonates. They typically contain a large percentage of angular particles, which increases shear strength.
Basalts are layered volcanics that vary from hard weakly weathered to extensively weathered. They typically are fine grained and cohesive.
Alluvium results from surface erosion and deposition over geologic time and is dominated by ancient deposits associated with basalt flows. These lands have old, well developed silty soils and commonly have seasonally perched groundwater tables over fragipans. They range in size from fine silts to coarse gravels, cobbles, and boulders.

and physical weathering with frost churning above 1,524 meters (5,000 feet) elevation, which suggests that these storm and landslide events are an integral part of the geomorphic process and result in a landscape susceptible to landslides.

The most landslide-prone slope aspects of south through west are consistent with the normal winter storm track into northern Idaho from the Pacific Ocean. The slopes with these aspects also receive the highest solar-energy input, resulting in warmer, wetter snowpacks that are available for melting by a relatively warm, wet storm.

Table 5 indicates that the breaklands and mass wasting landforms are most susceptible to landslides, which is not surprising because the breaklands are generally very steep and the mass wasting landform is intrinsically unstable.

Historical Comparison

A comparison was made with the last significant storm and landslide event on the Clearwater, in 1974, which was reported by Megahan et al. (1978). The purpose of the comparison was to evaluate if the landslide effects were generally proportional to the storm events or if the landscape response was becoming increasingly severe.

The authors estimated that the total precipitation plus snowmelt was approximately the same for both the January 1974 and February 1996

Table 2. Landslide Occurrence by Elevation and Land Use

Elevation Range (meters)	Percent Elevation on CNF	Number of Landslides	Landslides per 1,000 ha	Number of Road-Associated Landslides	Number of Timber Harvest Area Landslides	Number of Natural Area Landslides
<610	1	20	4.08	11	5	4
610 to 762	2	29	2.20	14	6	9
762 to 914	3	81	3.66	24	5	51
914 to 1,067	6	184	4.09	115	20	47
1,067 to 1,219	11	203	2.75	127	19	53
1,219 to 1,372	14	206	2.08	139	31	35
1,372 to 1,524	16	137	1.22	73	21	43
1,524 to 1,676	16	32	0.31	13	2	17
1,676 to 1,829	14	5	0.12	1	0	4
1,829 to 1,981	17	1	0.00	0	0	2
No Data		9		5	1	3
Total	100	907		522	110	267

1 meter = 3.28 feet
1 hectare (ha) = 2.47 acres
Note: Road, harvest, and natural landslides do not equal the total of 907 because two landslides were fire related and six were not classified as to land use.

events. The average total precipitation on the Clearwater for the November-December 1995 plus the February 1996 storms was approximately 266.7 millimeters (10.55 inches) versus approximately 76.2 millimeters (3.0 inches) for the January 1974 event.

From table 6, it can be seen that the average landslide was larger in 1974 than in 1995–96, but the total volume, volume delivered to streams, and percentage of landslide volume delivered to stream channels were greater in 1995–96, with approximately 38 percent of the volume delivered from the two large natural landslides.

Table 8 indicates that road, harvest, and natural plus fire-associated landslide incident rates are remarkably close for the 1974 and 1995–96 flood and landslide episodes.

Natural Background Sediment Rate

Wilson et al. (1982) reported an average annual sediment yield of 85.6 kN/sq. km/year (25 tons/sq. mi/year) for undisturbed drainages on the Clearwater. The natural sediment yield resulted from in-channel transport of material that had originated from surface erosion of fire-denuded landscapes and natural mass wasting. Wilson et al. estimated the natural sediment loading as 70 percent from erosion of landscapes denuded by historic fires and 80 percent from natural landslides.

Table 3. Landslide Occurrence by Aspect and Land Use

Hillslope Aspect	Percent on CNF	Number of Landslides	Landslides per 1,000 ha	Number of Landslides: Road-Related Landslides	Number of Landslides: Timber Harvest Area Landslides	Number of Landslides: Natural Area Landslides
North	11	39	0.52	21	7	10
Northeast	11	40	0.52	25	11	3
East	13	78	0.89	46	1	29
Southeast	13	86	0.94	47	8	30
South	12	200	2.47	94	25	80
Southwest	12	187	2.20	100	21	65
West	15	187	1.83	127	26	34
Northwest	14	75	0.77	52	9	14
No Data		15		10	2	2
Total	100	907		522	110	267

1 hectare (ha) = 2.47 acres
Note: Road, harvest, and natural landslides do not equal the total of 907 because two landslides were fire related and six were not classified as to land use.

Table 4. Number of Landslides by Hillside Steepness and Land Use

Hillside Steepness (percent)	Percent on CNF	Number of Landslides	Landslides per 1,000 ha	Number of Landslides: Road-Related Landslides	Number of Landslides: Timber Harvest Area Landslides	Number of Landslides: Natural Area Landslides
<20	19	6	0.05	5	0	1
21 to 25	9	6	0.10	4	1	1
26 to 30	10	15	0.20	10	2	3
31 to 35	11	23	0.30	19	2	2
36 to 40	10	66	0.91	52	7	6
41 to 45	10	70	1.06	57	9	4
46 to 50	8	105	1.80	57	19	25
51 to 55	7	71	1.46	42	15	14
>56	15	527	4.94	262	55	205
No Data		18		14	0	2
Total	100	907		522	110	267

1 hectare (ha) = 2.47 acres
Note: Road, harvest, and natural landslides do not equal the total of 907 because two landslides were fire related and six were not classified as to land use.

Table 5. Number of Landslides by Landform and Land Use

Landform	Percent on CNF	Number of Landslides	Landslides per 1,000 ha	Road-Related Landslides No.	Road-Related Landslides per km	Number of Timber Harvest Landslides	Number of Natural Area Landslides
Breaklands	24	507	2.77	247	0.20	51	192
Mountain Slopes	15	149	1.33	106	0.04	24	20
Mountain Ridge	18	38	0.27	23	0.02	6	11
Gentle Hills	25	87	0.47	77	0.02	4	3
Mass Wasting	2	64	4.25	42	0.25	15	7
Valley	2	26	1.73	16	0.04	6	3
Total	86	871*		511		106	236

1 hectare (ha) = 2.47 acres; 1 kilometer (km) = 0.62 miles
*The landforms shown do not include all landforms on the Clearwater National Forest that had landslides.
Landforms are used by the Clearwater to aggregate areas with common local relief, vegetative patterns, slope shape, slope gradient, and low-order stream characteristics.
Breaklands are oversteepened slopes resulting from uplifting of the land surface and subsequent downcutting of rivers and streams. Hillslopes often exceed 60 percent and bedrock is moderately to weakly weathered.
Mountain Slopes have been formed by fluvial and colluvial processes. Ridges are generally convex and sideslopes straight. Hillslopes range from 35 to 60 percent and bedrock weathering is variable with weakly to moderately developed soils.
Mountain Ridges are broad convex slopes commonly occurring above mountain slopes and adjacent to steep glaciated terrain. They are primarily formed by physical weathering and periglacial frost churning. Hillslopes range from 5 to 40 percent. Soils contain a large percentage of coarse fragments and are highly permeable.
Gentle Hills consist primarily of gently to moderately sloping hills with relief less than 300 feet. Hillslopes are 20 to 40 percent with deep soils and extensively weathered bedrock.
Mass Wasting landforms contain historic rotational and translational landslides resulting in hummocky topography with 20- to 60-percent sideslopes.
Valley landforms include both recent terraces and high terrace remnants, debris fans, and colluvium. Hillslopes are typically up to 30 percent on terraces and fans, and up to 60 percent on toeslopes and eroded faces of terrace remnants.

In a personal communication, Nick Gerhardt, Nez Perce National Forest hydrologist, reported obtaining an average annual sediment yield of 92.7 kN/sq. km/year (27 tons/sq. mi/year) for the Selway River drainage near its confluence with the Lochsa River. The Selway River drainage had little timber harvest and few roads above the sampling location, so these results should approximate the natural background sediment rate. The value agrees closely with the estimate in Wilson et al.

Based on an area of 675,000 hectares (l .667 million acres) for this study and a sediment density of 17.46 kN/cubic meter (110 pcf), the natural background rate due to natural landslides was estimated to be 30,600 cubic meters (40,000 cubic yards) per year. Table 6 gives the incremental sediment delivery to streams above the natural baseline for the 1974 and 1995–96 landslide events. The total sediment delivered for the 1974 and 1995–96 events was approximately 3 to 10 times the annual natural background landslide sediment.

Table 6. Landslide Characteristics—Comparison Between 1974 Study and 1995–96 Study

Year	Number of Landslides	Average Size (m^3)	Total Volume (m^3)	Delivered Volume (m^3)	Delivery (%)	Sediment Loading Ratio/Natural Background
1974	214	1,262	270,000	86,000	32	2.8
1995–96 Total	907	589	535,000	306,000	57	10.0
1995–96 Roads	522	369	193,000	76,000	25	2.5
1995–96 Natural	267	1,183	316,000	217,000	71	7.1
1995–96 Harvests	110	243	27,000	12,000	4	0.4

1 cubic meter (m^3) = 1.31 cubic yards
Note that the 1974 study covered 80 percent of the 1995–96 study area.

Table 7. Landslide Parent Material—Comparison Between 1974 Study and 1995–96 Study

Parent Material	1974 (%)	1995–96 (%)	1974 (no./km^2)	1995–96 (no./km^2)
Border	53	45	0.14	0.24
Batholith	21	39	0.06	0.14
Belt	22	10	0.13	0.10
Other	4	6	0.09	0.07
Total	100	100		

1 square kilometer (km^2) = 0 39 square miles

It was recognized that sediment loading to the streams across the Clearwater was not uniform and that the relative long-term impacts on fisheries from chronic, spatially continuous sediment loading would be different than episodic, spatially patchy sediment loading. The relative impacts of chronic, spatially continuous versus episodic, spatially patchy sediment loading was beyond the scope of this study. The value of 10 times the background rate of sediment loading assumed the sediment was uniformly spread over the Clearwater basin, which it clearly was not. Some watersheds were heavily impacted while others were largely unaffected by the landslides, which is evident from figure 2. Analysis of the sediment delivery for selected watersheds found that the sediment delivered varied from 5 to 270 times the background rate for selected watersheds with high landslide rates. The highest rate was for a single drainage that contained a single 153,000-cubic-meter (200,000-cubic-yard) landslide. A random

Table 8. Landslides by Land Use—Comparison Between 1974 Study and 1995–96 Study

Land Use	1974 (%)	1995–96 (%)
Roads	58	57
Natural	3*	29
Harvest	12	12
Fire	27	2**
Total	100	100

*In complete survey of Clearwater National Forest.
**Very small acreage burned in recent years in area impacted by storm.

selection of 10 percent of the named watersheds across the Clearwater gave a range of 0.04 to 9.7 times the estimated background rate.

It is evident that the variation was observed across the range of scales, from the size of a channel confluence to the size of a river basin. The impact variations range from sediment inundation to sediment impoverishment, where landslides have essentially scoured a channel to bedrock.

Evaluation of Current Road Construction Standards

The road construction practices observed by the authors varied from sidecast construction, prone to fill failures, to roads that had been located by geotechnical personnel to avoid landslide hazards and that were adequately designed and constructed. The authors reviewed 9.65 kilometers (6 miles) of roads constructed in problematic landtypes where the necessary skills were applied to location, design, and construction. The authors found no road-related landslides where adequate geotechnical input had been used.

Evaluation of Road-Obliteration Projects

The authors reviewed 9.65 km (6 miles) of obliterated roads. The treatments ranged from merely closing the road to traffic to full recontouring (pulling the fillslopes onto the road surface to restore the slope to the original contours). At the time of the 1995–96 events, the obliteration program had treated 59.5 kilometers (37 miles) of historically unstable roads. Based on the general results of this study, 10 landslides would have been predicted for 9.65 km (6 miles) of road on those landforms. The authors were not aware of any road-associated landslides occurring on the treated roads. Slides did occur on adjacent untreated roads on the same landforms. Based on these observations, it was concluded that road obliteration has successfully reduced road-related landslides.

Stream Response

Stream responses to the flood and landslide events were found to be largely dependent on landform, parent material, and stream size. Landslides and floodflows negatively impacted small streams by significantly widening their channels and scouring out acting large organic debris. Small streams did, however, show a reduced level of cobble embeddedness and increased average depth compared with conditions before the events.

Large streams were negatively impacted by landslides and floodflows through stream channel widening and increased levels of cobble embeddedness compared with historic conditions. There were no significant improvements to large stream channels when comparing pre-event and post-event conditions on the same stream reach. General comparisons of flood-only stream reaches to flood and landslide reaches showed that the flood and landslide reaches had, on the average, significantly lower width-to-depth ratios and greater pool area, yet had decreased channel stability as indicated by the Pfankuch index. Flood and landslide reaches were generally deemed "less habitable" for benthic macroinvertebrates than reaches impacted only by floodflows.

The existence of a road within a drainage was not found to be consistently related to the level of landslide impacts to streams.

Recommendations to Reduce Landslides

The following recommendations are made to reduce landslides resulting from roads and timber harvest on the Clearwater, based upon the observations of the 1995–96 inventory of the landslides, the authors' field reviews, and the authors' collective experiences.

Roads. A systematic inventory of the road network should the completed. The inventory should include information on all construction, reconstruction, maintenance, decommissioning, and use activities on the roads. The inventory, together with a Geographic Information System (GIS) screening predicated on the five landslide risk factors identified in this study, will allow location, prescription, and prioritization of roads for maintenance, reconstruction, or decommissioning.

The decision to maintain or decommission a road should be based on the maintenance required, transportation system needs, and potential environmental risks. Longer maintenance intervals require more conservative maintenance or decommissioning prescriptions. For any road permanently closed to vehicle use, culverts should be removed and provisions made to ensure control of surface water. For a closed road, the maintenance interval might be many years—although periodic inspections will still be needed to assess the road prism stability unless the road prism has been recontoured.

The rate of occurrence of landslides on new roads can also be reduced by GIS screening of the project areas using the five landslide risk indicators and then scrupulously adhering to appropriate design and construction practices. The following practices should be observed:

- Avoid the high-risk areas where possible.
- Avoid fills on slopes steeper than 55 percent or full-bench and end-haul if it is necessary to have the road located on a slope steeper than 55 percent.
- Perform geotechnical investigations to either avoid the landslide hazards or to obtain low-risk designs to mitigate the effects of the hazards, particularly in areas where there is the potential for high groundwater levels.

- Because a vast majority of road-related landslides in the study were found to have been fill failures, the road should be designed to control surface flows and thus to avoid discharging accumulations of water on fills or other areas that have potential to fail because of the addition of water. The design should include backup drainage design features. In the event that culverts, ditches, or other drainage features fail to handle the water, these backup features will direct the overflow to areas of least impact rather than onto large fills or other potentially unstable areas.

- Construction of critical fills should include subexcavation of weak foundation materials and adequate compaction to improve the fill stability, reduce settlement deformation, and resist erosion.

Harvest Areas. Although landslide rates from timber harvest areas were not large in the 1995–96 study, others (Sidle et al. 1985) have found them to be significant, with the important factor being loss of root strength. The five landslide indicators can be used to identify high-risk portions of areas considered for timber harvest. Timber harvest treatments that maintain root strength can be used to reduce landslide hazards.

Summary and Conclusions

1. Of the 907 landslides on the Clearwater National Forest in this study, 58 percent were road related, 29 percent were natural, and 12 percent were associated with timber harvest. The total landslide volume was estimated to be 535,500 cubic meters (700,000 cubic yards), of which 306,000 cubic meters (400,000 cubic yards) were delivered to streams.

2. Five landslide indicators that can be used to delineate high-risk areas were identified in this study: geologic parent material, elevation, slope aspect, hillside steepness, and landform.

3. The findings of this study were similar to those of a 1974 study on the Clearwater. The total landslide volume delivered to streams in the 1974 event was approximately three times the natural annual landslide background sediment rate. The 1995–96 events delivered a total of 10 times the natural annual landslide background rate, with natural landslides contributing 70 percent of the sediment delivered to stream channels.

4. Evaluation of landslide effects was confounded by stream size; for example, smaller streams were in steeper terrain and therefore had more energy and scouring capability. Stream channels and banks were destabilized after landslides, but channels generally became deeper, wider, and more unstable and had larger stream channel particle sizes following landslides. Larger streams had lower gradients and less energy, resulting in more deposition as well as less stable channels and banks following the flood and landslide flows.

5. Study results emphasized the value of conducting evaluations on identical reaches of streams before and after the flood and landslide events. Comparison of parameters between paired streams or among clusters of streams with similar characteristics (where impacts occurred in some and not in others) is frustrated by the very large range of variation of parameters among different streams.

6. The Clearwater's road-obliteration program appears to have been effective in reducing road-related landslides.

7. The five landslide risk indicators identified in the study can be used to highlight high-hazard areas. For new roads, the indicators can be used to avoid high-hazard areas or to develop site-specific road designs and specifications. For existing roads, the indicators can help prioritize maintenance and suggest appropriate management ranging from year-round use to complete recontouring. For planned timber harvest units, the five indicators can be used to avoid unstable areas or assist in the planning of timber harvest activities to minimize the risk of landslide.

Author Addresses and Telephone Numbers

Douglas E. McClelland, USDA Forest Service, P.O. Box 7669, Missoula, MT 59807. Phone: (406) 329-3351, Fax: (406) 329-3198

Dr. Randy B. Foltz, USDA Forest Service, 1221 S. Main, Moscow, ID 83843. Phone: (208) 883-2312, Fax: (208) 883-2318.

Dr. C. Michael Falter, University of Idaho, Moscow, ID 83844-1136. Phone: (208) 885-7123, Fax: (208) 885-7123.

W. Dale Wilson, Consultant, 11830 Marquette Court, Orofino, ID 83544. Phone: (208) 476-5481.

Dr. Terrance Cundy, Potlatch Corporation, P.O. Box 1016, Lewiston, ID 83501-1016. Phone: (208) 799-4135, Fax: (208) 799-1707.

Dr. Robert L. Schuster, U.S. Geological Survey, P.O. Box 25046. Denver, CO 80225. Phone: (303) 273-8617, Fax: (303) 273-8600.

Jim Saurbier, USDA Forest Service, P.O. Box 7669, Missoula, MT 59807. Phone: (406) 329-3335, Fax: (406) 329-3198.

Craig Rabe, University of Idaho, Moscow, ID 83844-1136. Phone: (208) 885-7123, Fax: (208) 885-7123.

Ron Heinemann, USDA Forest Service, 12730 Highway 12, Orofino, ID 83544. Phone: (208) 476-4541, Fax: 476-8329.

Acknowledgments

Many individuals helped to make this report possible. The authors would like to acknowledge the contributions of the landslide and aquatic field crews, very ably lead by Craig Rabe (aquatics) and Ron Heinemann (landslide), who spent a summer field season climbing slopes and wading swollen streams collecting the data this report is based upon. Landslide crew members were Justin Iverson, Craig Steel, Eric Tanner, and Van Weisz. Aquatic crew members were Cam Albee and Brent Clark. The Clearwater National Forest employees were all very responsive and helpful in their administrative support of the study and in supplying background information for development of the databases. In particular, the authors would like to thank Ed Lozar, Erwin Brooks, Dick Jones, Pat Murphy, Brooks Beegle, and Gayle Howard. David Hall and Paul Swetik at the Forest Service's Rocky Mountain Research Station provided invaluable computer expertise. Walt Megahan deserves special acknowledgment for answering numerous questions.

The authors also gratefully acknowledge peer reviews by Mary Donato, Nick Gerhardt, James H. Hardcastle, Jim McKean, Walt F. Megahan, Keith Mills, Larry Morrison, Jim Padgett, Bill Powell, Bill Putnam, Jim Sheldon, and Beverly C. Wemple.

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Application of Methods for Estimating the Bearing Capacity of Spread Footings in Bridge Approach Fills

Douglas E. McClelland
Geotechnical/Dams Engineering
Missoula Technology and Development Center

Abstract

The Northern Region of the Forest Service has used various methods to estimate the allowable bearing capacity of spread footings placed in bridge approach fills (SFIF's). The limitations, design guidelines, and Forest Service policy for use are discussed. The results from current state-of-the-art procedures are compared with cruder estimates that used truncated failure surfaces and slope stability methods. An example case history is used to demonstrate the application of the various methods.

Introduction

Region 1 of the Forest Service began placing spread footings in bridge approach fills in the early 1980's, with six to eight constructed by the mid-l980's. The general configuration of a spread footing in an approach fill (SFIF) is shown in figure 1. A Forest Service Regional policy was written to follow the 1987 AASHTO Standard Specifications for Highway Bridges (AASHTO 1987), which allowed footings set significantly above the streambed in "special cases." The policy allows SFIF's primarily on lower volume, single-lane bridges crossing streams where the stream channel is

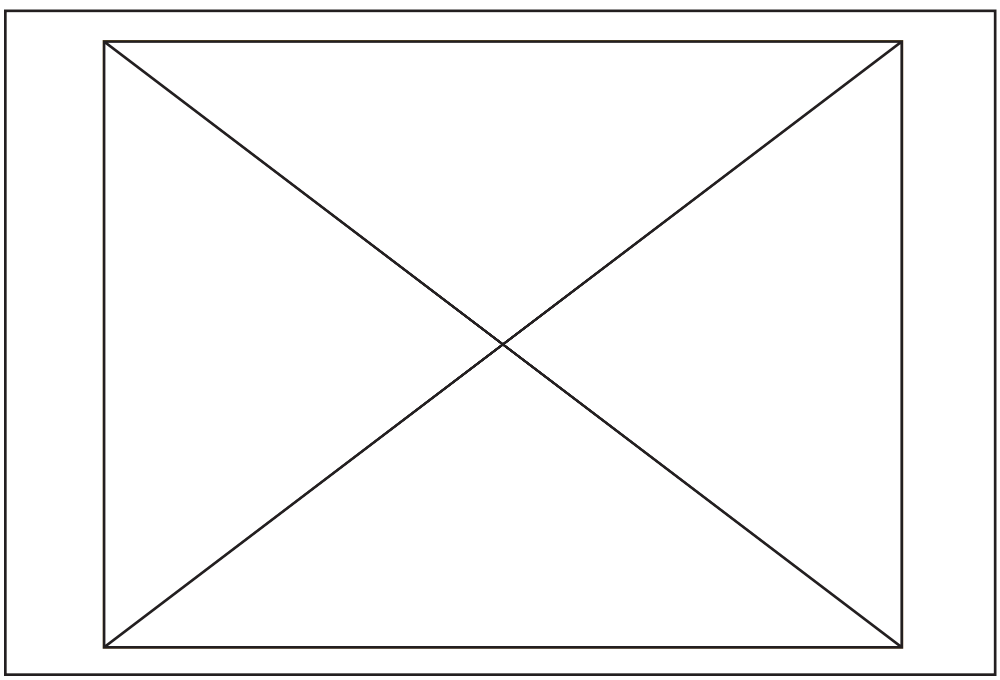

Figure 1. *Definition of terms*

straight and stable, has low potential for scour, and will not accumulate significant debris and ice. In addition, where SFIF's are used, the riprap should be a minimum of one class larger than would normally be specified, and additional conservative design measures should be taken to prevent scour.

The primary reason for using SFIF's is economics, with a typical cost reduction of approximately $20,000 per bridge for Forest Service applications over the alternatives of placing the footing on piles through the fill. Because the Forest Service has approximately 7,600 bridges nationwide and replaces roughly 50 per year, use of SFIF's under appropriate conditions has the potential to provide significant cost savings. For the typical Region 1 bridge, the cost of placing a longer superstructure on footings supported by piles is approximately the same as a shorter bridge with retaining-wall abutments, so the estimated net savings with SFIF's is the incremental cost of placing piles through the fill.

The 1996 AASHTO Standard Specifications for Highway Bridges (AASHTO 1996) has a specific section on footings in fills and includes design guidelines for determining the reduced bearing capacity. In addition, it is recommended that the global stability of the slope be considered. For global stability, factors of safety that depend on whether the design soil parameters are determined from in-situ tests, laboratory tests, or some other source are suggested. These AASHTO guidelines for reduced bearing capacity are based on Meyerhof (1957), which recent model tests have shown to be not conservative, as demonstrated in the example below.

Previous Studies

DiMillio (1982) reported on an extensive study of the performance of 148 Washington Department of Transportation (WDOT) bridges that had been constructed with SFIF's. It was concluded that the SFIF's provided a satisfactory alternative to pile foundations, especially where the embankments are well constructed with good-quality borrow materials.

Holtz and White (1992) conducted a survey of the advantages and disadvantages of SFIF's. The primary advantage was cost. The primary disadvantages were scour protection, allowable bearing capacity and settlement predictions, seismic response, and potential retrofitting problems with, for example, widening an underpass constructed on SFIF's.

Considerations for Forest Service Applications

The use of SFIF's in Forest Service applications has fewer disadvantages and some additional advantages over general highway applications. As indicated in the Region 1 policy on SFIF's, scour is a definite consideration in the steep mountainous environment of Montana and northern Idaho.

In general, lifeline risks are relatively small in Forest Service applications because the vast majority of the roads do not access significant population. The risk cost is also relatively small because most applications are on single-lane roads with structures less than 15 meters (50 feet) in length.

Because most Forest Service roads are either native or aggregate surfaced, allowable bridge settlements can be significantly larger than those involving roads that are asphalt or portland cement surfaced, and the potential for expensive infrastructure expansion affecting an SFIF structure is negligible in comparison with an urban area.

A significant advantage in Forest Service applications is that most future bridges will be replacements for existing structures with existing seasoned approach fills. If the loading imposed by the SFIF's exceeds the capacity of the in-situ fill material, then subexcavation and replacement with reinforced soil or higher quality borrow or aggregate can be specified.

Another significant advantage in Forest Service applications is that the construction and environmental impacts of simply placing a longer superstructure on SFIF's as opposed to spread footings 1.2 to 1.8 meters (4 to 6 feet) below a low streambed are minimal. In addition, use of SFIF's allows trapezoidal stream channels that significantly reduce scour and that resource specialists feel have less environmental impact than rectangular stream channels that result from retaining-wall abutment bridges.

A large majority of the applicable foundation soils in Region 1 are cohesionless, with real or apparent cohesions of less than 4.8 kPa (100 psf). The lack of cohesion greatly simplifies loading-rate and settlement problems.

Review of Methods for Estimating Bearing Capacity

For the initial use of SFIF's in Region 1, the reduced bearing capacity was estimated by the classic Meyerhof (1957) method and Bowles's method in his second edition (Bowles 1982). As noted in the example, both methods appear to overestimate the bearing capacity of SFIF's.

Meyerhof

For cohesionless soils, Meyerhof's (1957) method reduces to:

$$q = \gamma B N_{\gamma q}/2$$

where

q	=	ultimate bearing capacity, kPa (ksf)
B	=	footing width, meters (ft)
γ	=	foundation soil density, kN/m^3 (pcf)
$N_{\gamma q}$	=	figure 2 bearing capacity factor

with figure 2 presenting his applicable design chart. Note that the figure is applicable only up to $D/B = 1$; for ϕ from 30 to 40 degrees; and slopes up to 40 degrees. Within these constraints, interpolation can be used to obtain the appropriate bearing capacity factor $N_{\gamma q}$.

Bowles

For the cohesionless case, Bowles's (1982) method reduces to:

$$q = q' N_q' + \tfrac{1}{2}\gamma B N_\gamma$$

where

$q' = D\gamma$
N_q' is from table 1
N_γ is uncorrected from Hansen's value

Figure 2. *Bearing capacity factors for strip foundation on top of slope of cohesionless material (after Meyerhof et al.)*

Bowles's table is applicable from the surface at D/B = 0 to 1.5; for ϕ from 0 to 40 degrees; and slopes up to 60 degrees. The appropriate values of N_q' are obtained from table 1 by interpolation.

The N_q' values in table 1 are essentially flat-ground N_q values reduced in proportion to the truncated confinement area between the sloped surface and horizontal ground.

On later projects, the author became aware of additional methods for estimating the bearing capacity in SFIF's. Use of the various methods provided a range of bearing capacity values upon which to make a professional judgment.

Winterkorn and Fang

Winterkorn and Fang (1975) contained an earlier method by Bowles which combined force equilibrium with the notion of truncated or reduced confinement. Figure 3 outlines the method with the application demonstrated in the example.

Table 1. Bowles method (1982) bearing-capacity factors N'_c, N'_q for footings on ($b/B = 0$) or adjacent to a slope

Figure 3. *Bowles (1975) method (after Winterkorn and Fang)*

Shields

In 1977, Shields (1977) found from model loading tests on cohesionless soils that the analytical methods which assumed plane-strain shear strength greatly overestimated the bearing capacity which is indicated in the example. Shield's model tests were performed on compact and dense sands using 0.3-meter-wide continuous strip footings at various locations within the slope. His results are given in figures 4 and 5, which give combined $N_{\gamma q}$ values for use in the following bearing capacity equation:

$$q = \tfrac{1}{2}\gamma B N_{\gamma q}$$

Figure 4. *Contours of experimental $N_{\gamma q}$ values in compact sand (after Shields et al.)*

Figure 5. *Contours of experimental* $N_{\gamma q}$ *values in dense sand (after Shields at al.)*

Log Spiral Method

The author had also used a graphical analysis with a log spiral failure surface which is illustrated in figure 6. Two failure surfaces were evaluated: one exiting the slope at 45–ϕ/2, shown as point B, and the other the truncation of the horizontal failure surface, shown as point A.

Figure 6. *Log spiral method*

Slope Stability Method

The computer program XSTABL Version 5.0 (Sharma 1994) was used to compute global stability as well as to compute a reduced bearing capacity for comparison with the values obtained by the other methods. The slope stability approach degenerates to the reduced bearing capacity case when the proposed slope failure surface intersects the base of the footing, which should not be a surprise since nature does not make the decision to fail by bearing capacity one day and slope stability the next. Figure 7 gives the results of the XSTABL analysis for the example problem.

Figure 7. *Bearing capacity estimate through slope stability analysis*

Shields

In 1990, Shields (1990) reported results from centrifuge testing on cohesionless soils such as sand and normally consolidated clay. The information was presented as a percentage of the flat ground bearing capacity. The method essentially computes $N_{\gamma q}$ using Gemperline's (1988) proposed equation and uses that value in Meyerhof s bearing capacity equation for flat ground:

$$q = \tfrac{1}{2}\gamma B N_{\gamma q}$$

Figures 8 and 9 give the percentages of flat ground bearing capacity for 1½:1 and 2:1 slopes. The reduced bearing capacity for the slope is obtained by multiplying the q from the above equation by the percentage from those figures. Note that the percentages are over 100 percent where the effect of footing burial exceeds the effect of proximity to the slope. The units of B are inches in the equation.

Figure 8. *Suggested design for 26.6° slope (after Shields et al.)*

Figure 9. *Suggested design for 33.7° slope (after Shields et al.)*

Example

The first use of an SFIF in Region 1 was on the Flathead National Forest in northwest Montana in 1982. A relatively weak layer of loose to medium-dense silt was located during the subsurface investigation. The weaker material was subexcavated and replaced with a silty gravel.

The replacement silty gravel (GM) was estimated to have a density of 21.4 kN/m^3 (135 pcf) at the specified density of 95 percent of AASHTO T-180, and the strength parameter $\phi = 40°$ with negligible cohesion, c.

A cross-sectional view of the proposed structure and subsurface materials is shown in figure 10.

Figure 10. *Example application*

For the initial designs, the Meyerhof and Bowles methods were used. These gave ultimate bearing capacities of 1,170 kPa (24.3 ksf) and 1,645 kPa (34.4 ksf), respectively. The analyses are summarized below.

Meyerhof (1957) method:

As shown in figure 2, for $\phi = 40°$, B = 0.91m, D/B = 1, b/B = 1 and $\beta = 26.6°$ (2:1 slope), $N\gamma q \approx 120$.

For $q = 0.5\gamma B N_{\gamma q}$

$q = (0.5)(21.4)(0.91)(120)$

q = 1,170 kPa (24.3 ksf)

Bowles (1982) method:

Interpolating from table 1 for $\phi = 40°$, $\beta = 26.6°$, D/B = 1 and b/B = 1, $N_q' = 45.2$ and using Hansen (1970)

$N_\gamma = 1.5(N_q - 1)\tan\phi$ where

$$\begin{aligned} N_q &= \text{Meyerhof's } N_q \\ &= e^{(\pi\tan\phi)}\tan^2(45 + \phi/2) \\ &= 64.2 \end{aligned}$$

$N_\gamma = 79.5$

$q = (21.4)(0.91)(45.2) + ½(21.4)(0.91)(79.5) = 1{,}645$ kPa (34.4 ksf)

For comparison with later methods, Bowles method in Winterkorn and Fang (1975):

From figure 3 for truncated slope:

$\Sigma F_h = 0$

$R_1\cos\theta_1 + R_2\cos\theta_2 + R_3\cos\theta_3 + R_4\cos\theta_4 - N_1\sin\theta_1 - N_2\sin\theta_2 - N_3\sin\theta_3 - N_4\sin\theta_4 = 0$

q_u = 541 kPa (11.3 ksf)

For level ground: add $N_5\sin\theta_5 + R_5\cos\theta_5$ = 14,678 N/m (3,300.0 lb_f)

q_u = 838 kPa (17.5 ksf)

For a slope reduction factor of 541 kPa/838 kPa = 0.65

Shields (1977) method:

For ϕ = 40°, D/B = 1, b/B = 1, figure 4 gives $N_{\gamma q}$ = 75

$q = \frac{1}{2}\gamma B N_{\gamma q}$

q = (½)(21,429)(0.91)(75)

q = 731.3 kPa (15.2 ksf)

Log spiral method (figure 6):

Case I: Truncated failure plane with slope exit at point A

$\Sigma F_h = 0$

$R_1\cos\theta_1 + R_2\cos\theta_2 + R_3\cos\theta_3 + R_4\cos\theta_4 + R_5\cos\theta_5 + R_6\cos\theta_6 + R_7\cos\theta_7 - N_1\sin\theta_1 - N_2\sin\theta_2 - N_3\sin\theta_3 - N_4\sin\theta_4 - N_5\sin\theta_5 - N_6\sin\theta_6 - N_7\sin\theta_7 = 0$

$0.59q_u$ = 474 kPa (9.9 ksf)

q_u = 804 kPa (16.8 ksf)

Case II: Log spiral with slope exit at point B:

$\Sigma F_h = 0$

Same as above except use slice W_9 in place of W_5, W_6, and W_7.

$R_1\cos\theta_1 + R_2\cos\theta_2 + R_3\cos\theta_3 + R_4\cos\theta_4 + R_9\cos\theta_9 - N_1\sin\theta_1 - N_2\sin\theta_2 - N_3\sin\theta_3 - N_4\sin\theta_4 - N_9\sin\theta_9 = 0$

$0.59q_u$ = 552 kPa (11.5 ksf)

q_u = 934 kPa (19.5 ksf)

Case III: Log spiral without slope

$\Sigma F_h = 0$

Same as case I except add $R_8 \cos\theta_8 + N_8 \sin\theta_8$

$$q_u \cong 1{,}890 \text{ kPa } (39.5 \text{ ksf})$$

which gives slope reduction factors of 804 kPa/1,890 kPa = 0.43 for case I and 934 kPa/1,890 kPa = 0.49 for case II.

Slope stability method:

As shown in figure 7, using the slope stability program XSTABL, the bearing capacity or surface pressure at the location of the footing would be 720 kPa (15 ksf) for a factor of safety = 0.999.

Shields (1990) method:

$q = \frac{1}{2}\gamma B N_{\gamma q}$, with $N_{\gamma q}$ determined from the Gemperline equation

$$N_{\gamma qr} = (10^{(0.1159\phi - 2.386)})(10^{(0.34 - 0.2\log_{10} B)})$$

$$= 5.11$$

q = (0.5)(21.4)(914mm)(5.11) = 594 (12.4) × 95% (from figure 8)
and B = 3 ft = 36 inches = 914 mm

q = 565 kPa (11.8 ksf)

The values for the reduced bearing capacity are summarized below:

Method	**Bearing Capacity (kPa)**
Meyerhof (1957)	1,163 (24.3 ksf)
Bowles (1982)	1,647 (34.4 ksf)
Bowles (1975) (Winterkorn and Fang)	541 (11.3 ksf)
Shields (1977)	731 (15.2 ksf)
Log spiral with truncated flat grid exit angle on slope at point A	804 (16.8 ksf)
Log spiral with 4 – ϕ 2 exit angle on slope at point B	934 (19.5 ksf)
Slope stability with XSTABL program	720 (15.0 ksf) with FS = 0.999
Shields (1990)	565 (11 8 ksf

Comparison of the above bearing capacity estimates illustrates that the Meyerhof (1957) and Bowles (1982) procedures used in the initial Forest Service applications overestimated the available bearing capacity. The factor of safety of 2.5, the probable underestimation of the foundation shear strength parameter ϕ, and the neglect of any real or apparent cohesion in the foundation silty gravel soil must have compensated for the overestimation of the bearing capacity because no foundation problems have occurred. The slope stability and log spiral procedures also give similar values.

The relatively conservative value of the Bowles method in Winterkorn and Fang (1975) may be due to the less realistic failure surface that truncates the available resisting soil wedge.

In conclusion, the more recent estimates of reduced bearing capacity for SFIF's have been made using the Shields 1977 and 1990 methods with no apparent problems. The Shields 1990 method is easiest to apply and has the best empirical basis. It is recommended that the Shields 1990 method be used to estimate the reduced bearing capacities for SFIF's.

Within the discussed constraints, and particularly in Forest Service applications, use of SFIF's is often a cost-effective foundation alternative. A cost savings of $20,000 per bridge is particularly significant with reduced budgets and increasing bridge replacement needs.

Acknowledgments

The author would like to thank the following USDA Forest Service employees: Nelson Hernandez for suggesting this paper, John Kattell for review of the paper, and particularly Linda Lanham for her AutoCAD drawing of the figures. Dr. Joseph Bowles and Dr. Donald Shields provided valuable review and interest in development of the paper.

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Funding Energy Conservation Projects: An Overview

Steve Oravetz
Project Leader
Missoula Technology and Development Center

Several funding options are available to finance Federal energy conservation projects, none of which require large capital outlays on the part of agencies. These options are direct appropriations, energy savings performance contracting (ESPC), utility incentives, and combinations of the three options. Energy projects can be paid for from energy savings at very low net cost. The Forest Service is eligible for these funds, and we can learn from the success of other Regions. Most of the information shown here can be found on the Internet at the World Wide Web home page:

http://www.eren.doc.gov/femp/financing.html

Direct Appropriations

Historically, Federal appropriations have provided the bulk of energy efficiency financing for Government agencies. Direct appropriations allow the Government to retain all of the savings from cost-effective renovations. Because the Government's appropriated funds come from tax revenues or bonds, the "cost" to appropriate these funds is lower than the cost to borrow money from a bank or a financial institution. This approach also enables the agency to implement an energy efficiency project with minimal contractual obligations. However, with the current emphasis on reducing the Federal Government's appropriations, projects may not be fully funded or may be delayed. Funding for specific projects may be rejected if the payback period is too long.

Energy Savings Performance Contracting

ESPC allows energy service companies to assume the capital costs of installing new energy-efficient equipment. The energy service company guarantees a fixed amount of energy cost savings over the life of the contract (up to 25 years), and is paid directly from those cost savings. Agencies retain any remaining energy cost savings. Energy cost savings refer to any reduction in the cost of energy used in federally owned buildings. The ESPC contract determines how to establish the base cost and the share of energy cost savings each year. The contract also specifies how to determine the value of such savings, which may vary from year to year. Energy cost savings may result from the lease or purchase of operating equipment, increased efficiency of existing equipment, or altered operations and maintenance. Savings may also result from cogeneration or heat recovery that improves the efficiency of existing energy sources.

Super Energy Savings Performance Contract

To make it easier for agencies to use ESPC, the Federal Energy Management Program has developed an "Energy Savings Performance Contract," or Super ESPC, based on the Indefinite Delivery – Indefinite Quantity provision of the Federal Acquisition Regulation. Super ESPC's are broad-area contracts (for example, agency-wide or regional) that allow agencies to

Utility Incentives—An Example From Region 1

Region 1 of the Forest Service and Montana Power Company have developed an energy conservation program for Forest Service facilities that use Montana Power utilities. The program is based on the existing Montana Power/GSA area-wide energy services contract. Projects will provide retrofits of motors and electrical, HVAC, and water supply equipment without initial investment by the Forest Service and will reduce the cost of utilities and maintenance. This program requires a small amount of participation by Forest Service employees to help Montana Power determine the scope of work, lead pre-bid tours, negotiate, and perform inspections.

To take advantage of the program, a Forest Service unit must have an electrical power account with Montana Power. The unit makes an initial inquiry about the program with Montana Power using third-party financing. Financiers prefer projects worth at least $1 million, so several forests or stations may have to be considered together for a project to be economically feasible. Montana Power researches several years of electrical, gas, and water consumption; performs an onsite energy audit; and discusses usage with the site tenants.

After the audit has been completed, Montana Power sends the unit a written proposal, including cost estimates. Montana Power and the unit review the proposal and decide what work will be included in the project. Montana Power invites potential subcontractors to bid on the work. When the bids are received, Montana Power negotiates with a warranted Forest Service contracting officer to determine the final scope of work, the cost, and the project's payback period.

The total project cost includes the construction cost as well as the cost of financing interest, overhead and profit, and audits. Any rebates received for energy-efficient equipment are deducted from the project costs. The total cost is amortized over a mutually acceptable period. Annual cost savings are expected to approximately equal the annual payment due Montana Power on September 30 each year. The expected cost savings will be realized only after the entire retrofit is completed and operating properly. During construction, the unit budget must include both the regular utility payments and the annual payment due the contractor.

A delivery order is written on the existing Montana Power/GSA contract. The paperwork contains the delivery order, authorization, scope of work, financial data, and any modifications to the GSA contract.

A prework meeting is held to determine the project work schedule. The Forest Service provides contracting officer and contracting officer's representative functions for the contract, but most of the contract duties are the responsibility of Montana Power.

For further information, contact Jane A. Kipp, Architect, Region 1 at (406) 329-4952, or Mike Blinn, Contracting Officer, Region 1 at (406) 329-3756.

negotiate site-specific ESPC's with an energy service company without having to start the contracting process from scratch. In this way, agencies can effectively "piggyback" their own ESPC projects onto a broader "Super ESPC," saving time as well as energy and money. This process is now being used at the Pacific Northwest Research Station in Corvalis, OR.

Utility Incentives

While the pending deregulation of the utility industry has created a great deal of uncertainty, it has also created the perfect environment for public-private partnerships between Government agencies and utility companies. Utilities often offer financial or other incentives to their customers to install energy-efficient equipment or to construct more energy-efficient buildings. Reducing demand or load growth may be more cost-effective than constructing a new powerplant or upgrading transmission and distribution systems. In addition, investor-owned and regulated utilities commonly receive approval from regulatory commissions to earn incentives or profits on efficiency investments. Incentive programs provide a technical resource or funding source that can be leveraged to help the Forest Service implement an energy project. In such partnerships, utilities cover the capital costs of new equipment in consideration of the energy savings the retrofits will produce. In some cases, utilities may enter into an ESPC with an outside company or arrange another form of third-party financing. In any event, the net cost to the agency acquiring the new technology remains minimal, and the agency also benefits from the "one-stop shopping" that a utility partnership provides. This article includes an example of such a partnership developed by Region 1 in Missoula, MT.

Combinations of the Three Types of Financing

Using a combination of the three financing methods may be the best strategy for reducing energy costs. For example, combining utility incentives with an ESPC may eliminate the need for direct appropriations when installing energy-efficient chillers. If a facility uses a renewable energy technology such as a solar thermal system, the system's cost may exceed the agency's maximum payback period. Combining agency funds with a grant may improve the project's economics.

An agency with limited technical and procurement staff could apply for a grant to pay for a facility audit and technical support for an ESPC solicitation. Information on these grants and on reimbursable assistance is available at the Federal Energy Management Program's World Wide Web homepage at the Internet address:

http://www.eren.doe.gov/femp/techasst_form.html

Test Your ESPC Potential

To see if your facility qualifies for an ESPC, use the screening test on the following pages.

Please send comments to:
webmaster: femp@nrel,nrel.gov

or Steve Oravetz at MTDC
IBM: soravetz/wo,mtde

Does Your Facility Need an ESPC?

Agency Initial Screening Test

The Federal Energy Management Program prepared this screening test for a single facility, or for a combination of facilities. The more square footage an ESPC covers, the more economical this type of contracting is to you and the Federal Government.

Please circle either 1, 2, 3, or 4, then add up your score and compare with the table on the next page.

The average electric rate for your facility(ies) is:

Less than $0.05/kwh	$0.06-0.10/kwh	$0.11-0.15//kwh	Greater than $0.16/kwh
1	2	3	4

The total square footage of the facility(ies) you want to retrofit is:

Less than 50,000	50,000 to 100,000	100,000 to 500,000	Greater than 500,000
1	2	3	4

The total annual energy bill (all fuels) for these facility(ies) is:

Less than $50,000	$50,000 to $200,000	$200,000 to $500,000	Greater than $500,000
1	2	3	4

Are all buildings in one location?

No	N/A	N/A	Yes
1			4

How many buildings are included?

75 or more	31 to 74	16 to 30	1 to 15
1	2	3	4

The age of the buildings you want to retrofit is:

Less than 5 years	5 to 10 years	10 to 20 years	Greater than 20 years
1	2	3	4

Years since lighting upgrade:

Less than 5 years	5 to 10 years	10 to 15 years	Greater than 15 years
1	2	3	4

Years since HVAC upgrade:

Less than 5 years	5 to 10 years	10 to 15 years	Greater than 15 years
1	2	3	4

Is Your Facility a Good ESPC Candidate?

Add up the numbers you circled on the previous page.

Scoring:

7 to 10	Savings potential is low and your facility is not a good candidate for an ESPC. Perhaps your utility has a financing program that could help fund your project.
11 to 15	Your facility may benefit from the use of an ESPC as long as the solicitation and contracting process is not costly. You should consider using a Department of Energy FEMP Energy Savings Performance Contract (Super ESPC).
16 to 20	Your facility is a good candidate for an ESPC. Here, too, if solicitation and contracting costs are held to a minimum, the greater the benefit to your facility. Using the FEMP Super ESPC may still be your best option.
21 to 28	Your facility is an excellent candidate for an ESPC. You should consider the FEMP Super ESPC, but if the potential is exceptionally large, developing your own request for proposal (RFP) may actually provide you with the best results.

Simple payback: if you haven't previously retrofitted your buildings and the systems are fairly old, you could use a projected 20-percent cost savings in your utility bill as a rule of thumb. Calculate the simple payback of the project by taking the estimated project cost and dividing that number by the annual cost savings from your utility bill. This is the number of years it would take to recover the project cost if using appropriated Federal funds. Is the number between 3 and 10 years? If so, your project could be a good ESPC prospect if other factors are positive.

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Regional Information Coordinators should send material for publication and direct any questions, comments, or recommendations to the following address:

FOREST SERVICE—USDA
Engineering Staff—Washington Office
ATTN: Sonja Beavers, Editor
Kitty Hutchinson, Assistant Editor
201 14th Street SW
Washington, DC 20250

Telephone: (202) 205-1421

Volume 30
May–August 1998

Engineering Field Notes