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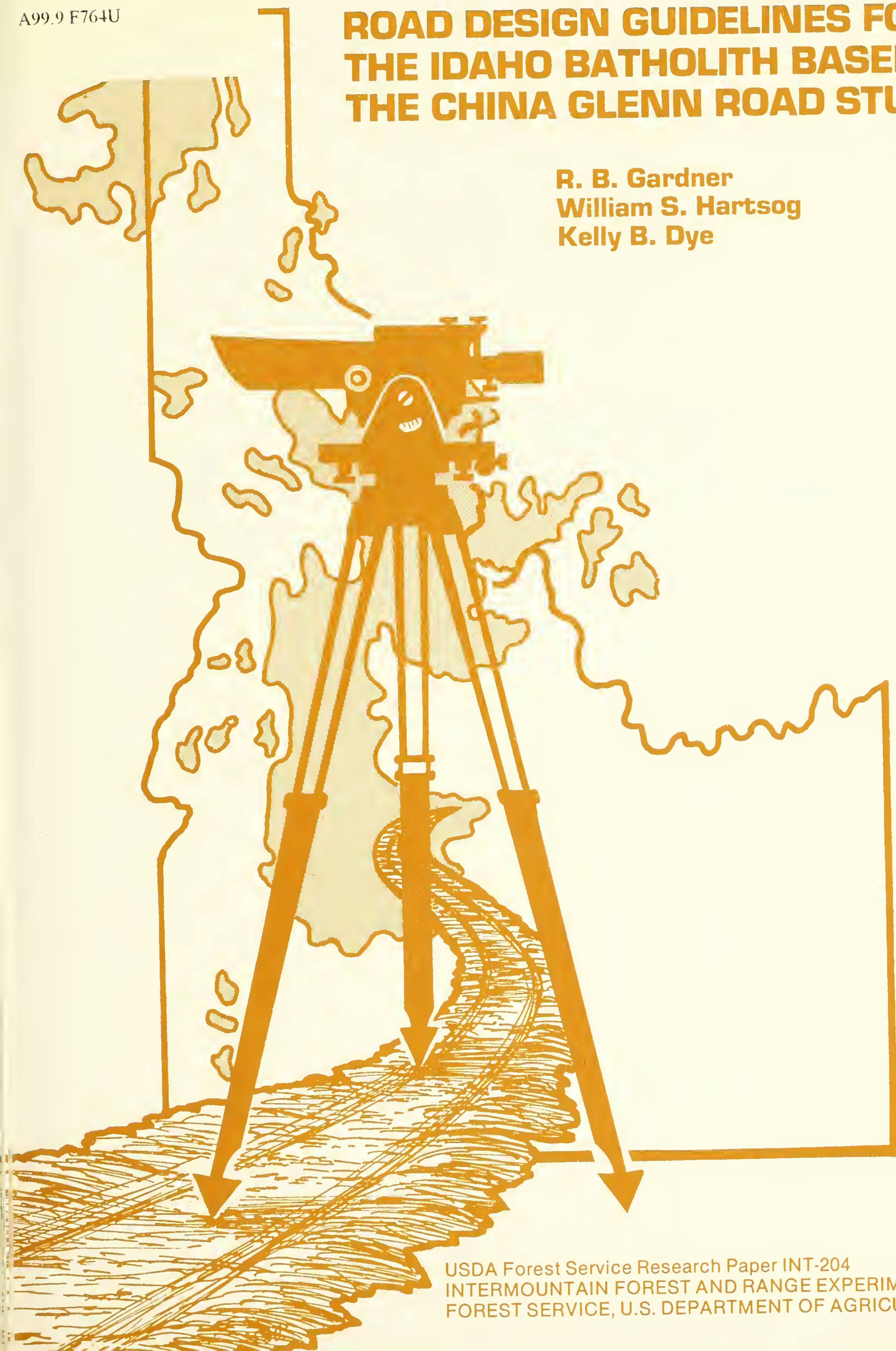

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RESEARCH SUMMARY

Erosion caused by road construction on the steep, fragile, decomposed granitic soils of the Idaho Batholith resulted in a 1965 moratorium on road construction in the South Fork of the Salmon River and its tributaries.

In 1970, the China Glenn Road was built to salvage trees attacked by the Douglas-fir beetle and protect the residual stand. It was constructed well back of the river-break zone on slopes averaging 40-50 percent. A key objective was to build a road with as little environmental impact as possible. A single-lane (12-foot (3.66 m)) road following the contour without a ditch, and with special design features, has proved adequate for logging, with little adverse impact.

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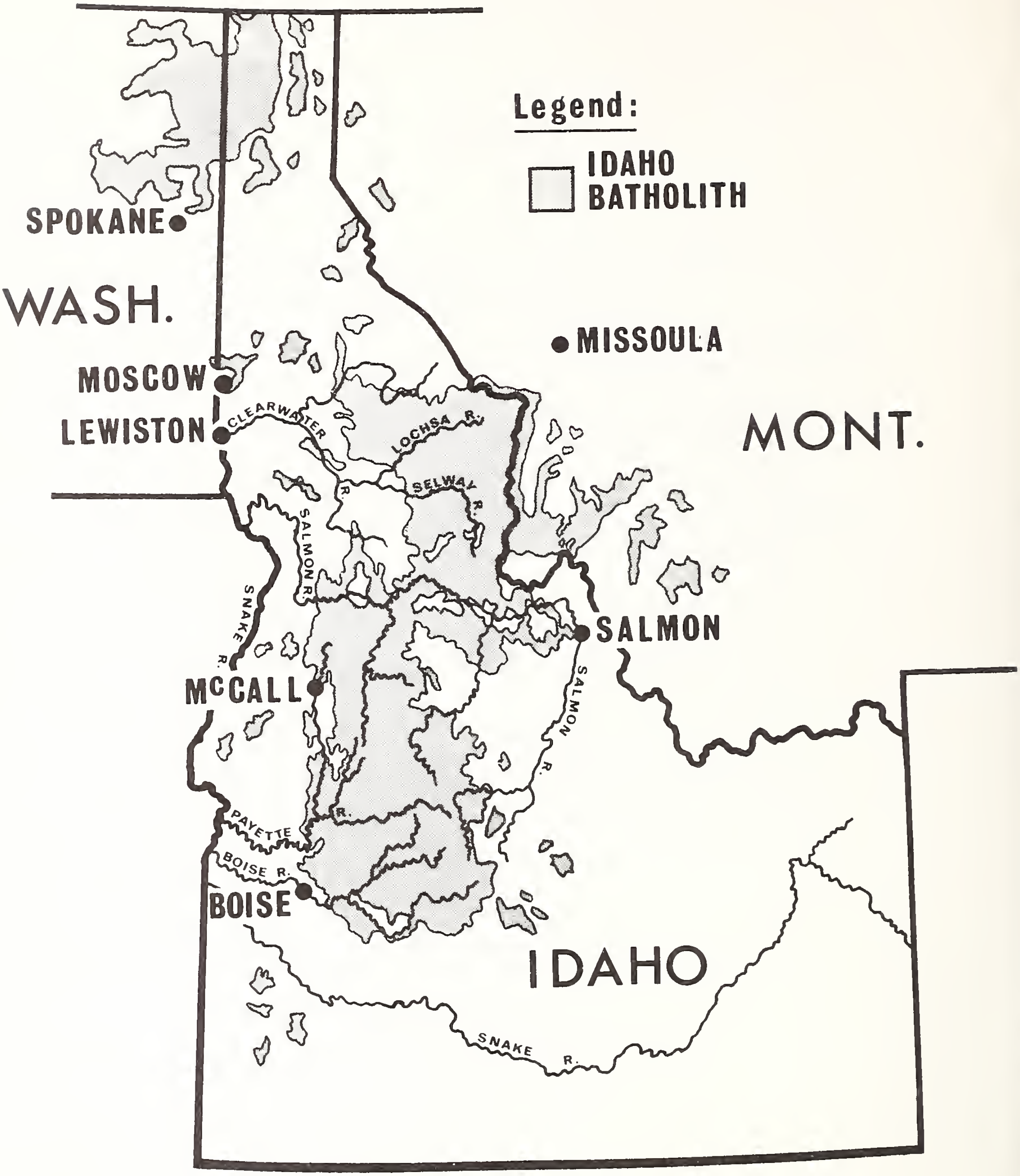

Figure 1.--The Idaho Batholith.

INTRODUCTION

The fragile, steep, decomposed granitic slopes of the Idaho Batholith (fig. 1) present many special problems for the construction and maintenance of stable forest roads. Some early recognition of this (1958) resulted in a joint administrative-research study by the Intermountain Region and Intermountain Forest and Range Experiment Station, both of the Forest Service, U.S. Department of Agriculture. The study was in Zena Creek on the Payette National Forest and was designed to help determine if the steep slopes could be logged economically with tolerable impacts on the environment.

Although there was an awareness that roads could contribute significant volumes of sediment, especially during critical periods of runoff, the results proved to be more serious than anticipated. Studies following road construction (1958-60) in Zena Creek by Haupt and others (1963), Gonsior and Gardner (1971), and Megahan and Kidd (1972) document the impacts of the road construction. Excessive erosion occurred the first year or two on both insloped and outsloped roads. Later in December of 1964 and April 1965, rain-on-snow storms produced extensive damage, this time from road slope failures.

As a result of these experiences, a moratorium on road construction in the South Fork of the Salmon River drainage was declared in 1965 until research and experimentation could better identify the problems and develop methods for reducing impacts to acceptable levels.

In 1969, an entomological detection flight in the South Fork drainage found a large and expanding population of Douglas-fir beetle (*Dendroctonus pseudotsugae* (Hopk.)) that had already damaged many trees and threatened many others. A decision was made to build the China Glenn Road into the infected area to salvage the bug-killed material and protect the residual stand. This road could be built well back from the river-break zone and in much less sensitive terrain than the Zena Creek roads. Also, the design would incorporate criteria that were known from experience to reduce impacts, including what was learned in Zena Creek.

The engineers and resource managers both desired to build a road that would serve the needs of the loggers, but not inflict excessive damage on the land and water resources. This report (1) reviews the initial design and performance of the China Glenn Road as reported by Hartsog and Gonsior in 1973, (2) describes the redesign of the second section of the road, (3) compares the guidelines used on the first and second sections of the road, and (4) gives a list of suggested road design principles to be used in the Idaho Batholith.

REVIEW OF THE INITIAL DESIGN AND PERFORMANCE OF THE CHINA GLENN ROAD

Although it is standard practice to utilize a multidisciplinary approach for the planning of transportation systems, the China Glenn road received extra attention because it was the first road constructed in the Batholith since the moratorium was imposed. The China Glenn Road thus became a test of some principles that needed verification and a learning experience for those interested in road construction methods in the Batholith.

Because of the necessity for quick action required to protect the stand and the short lead time given the research group, there was not enough time to set up detailed research experiments to help evaluate the results. However, one study of settlement of a through fill was attempted without conclusive results. The engineering research staff in Bozeman, Montana, was invited to participate in reviewing the proposed design and make suggestions based on their experience in Zena Creek. They were also involved in observing construction and helping to evaluate the results.

Location and Design

The major objective of location and design was to reduce impacts as much as possible and still provide reasonable service to the traffic. Access to the general area was provided by an existing system road.

Because of the desire to reduce impacts, a 12-foot-wide (3.66 m) (without ditch), single-lane road with turnouts, a 90-foot (27.36 m) minimum radius of curvature, and maximum grade of 10 percent constituted the basic design criteria (grade averages 2.7 percent). Fill slopes were designed on a minimum slope of 1-1/2:1, and cut slopes generally 1:1. When natural ground slope was 55 percent or greater, full bench construction was used (fig. 2). This was done to help avoid long sliver fills (fig. 3). Soil testing showed that it was possible to achieve the desired compaction with the construction equipment and normal traffic use. (The decomposed granitic material in the entire South Fork has very similar characteristics and, therefore, has similar reactions to the forces of water and traffic use.)

Two general land types were encountered--weakly dissected mountain slope land, deep sandy soil; and moderately dissected mountain slope land, moderately deep sandy soil. In a system used to classify soil and land types in the Idaho Batholith, they are mapped and classified as 120a and 120b, respectively.[1]

Water control, of course, is vital to stability. Care was taken to try to prevent any significant volume of water from developing on the road by the use of outsloping, grade breaks, and culverts for natural drainage channels--culverts were installed in virtually every draw.

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[1] Thompson, Richard A., Paul E. Skabelund, and Norbert C. Kulesza. 1973. Soil-hydrologic reconnaissance, McCall Ranger District, Payette National Forest.

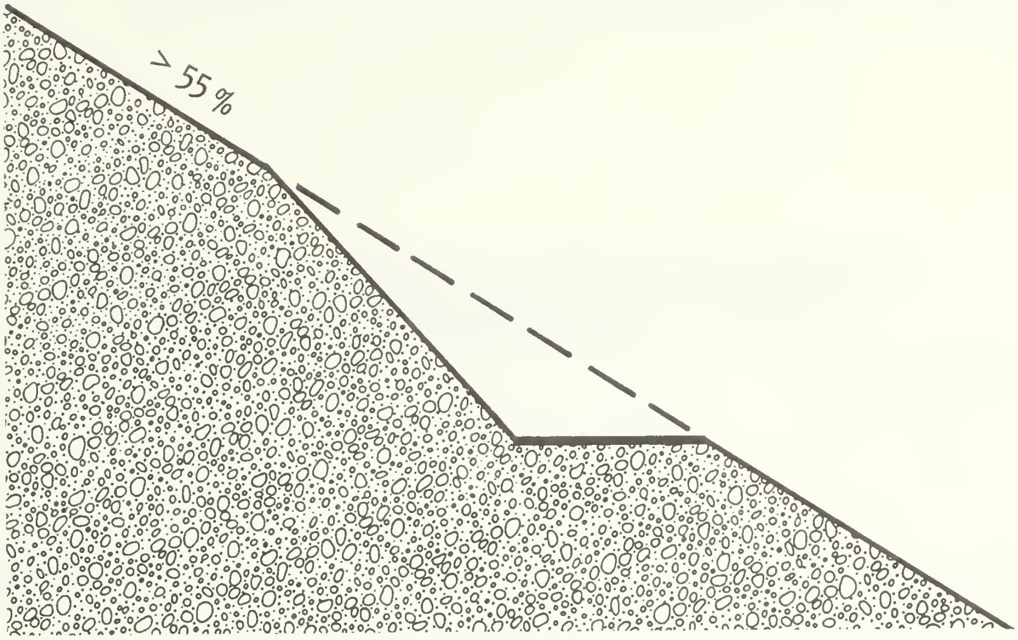

Figure 2.--Full bench.

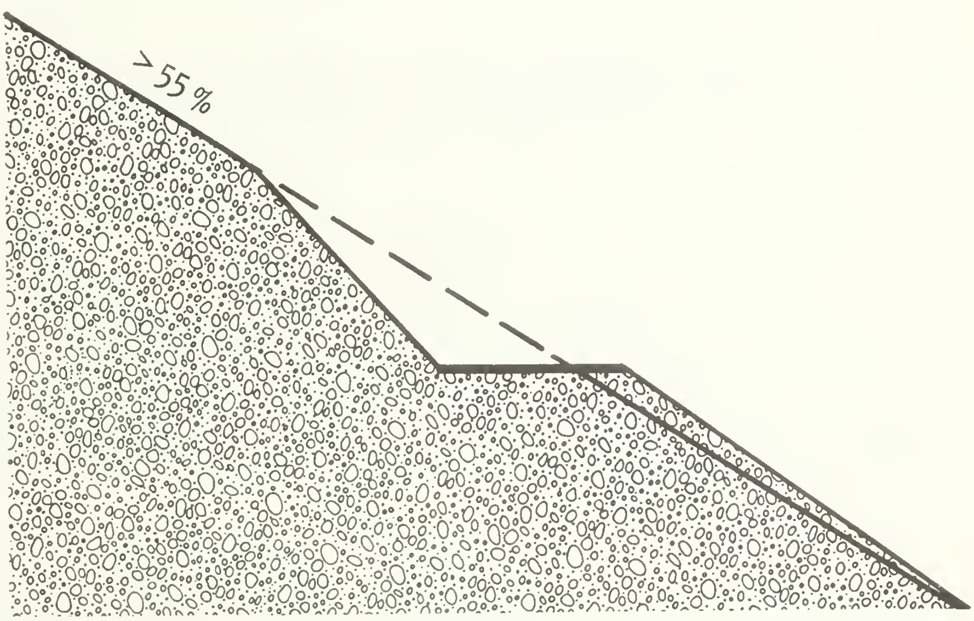

Figure 3.--Sliver fill.

The above describes the basic parameters and the general philosophy of design. The following sections cover observations made during and after the first year's construction, decisions, about design changes following those observations, the results of these design changes, and recommendations, and guidelines for future design of roads in the Batholith.

CONSTRUCTION/PERFORMANCE — FIRST 2.25 MILES (3.62 KM)

Construction

Construction began the last week of July 1970 and continued into September. About 2.25 miles (3.62 km) of the total of 3.48 miles (5.60 km) were completed the first year.

An important point to mention about the road in general, before some detailed observations, is that land managers' and engineers' backgrounds give them a somewhat different ability to visualize, from looking at a set of road plans, what the final product might look like on the ground. There were some differences between the results envisioned by the land managers and actual results on the first section constructed. How these concerns were accommodated in the design of the second section will be the subject of further discussion later. (Perhaps the developing use of computer graphics will help alleviate this problem in the future.)

Because some design changes were made after the first year of construction, it is necessary to separate some of the observations of results. Because the clearing operation was essentially the same for the entire job, it is discussed first.

Clearing

Clearing a right-of-way on slopes averaging 40-50 percent is a difficult operation, especially while trying to protect the environment and the integrity of the road. To gain reasonable access to operate with the equipment available, a pioneer road was built, as is the custom. The construction of a pioneer road constitutes probably the most troublesome problem of the whole operation. The difficulty lies in the problem of preventing slash and unmerchantable logs (merchantable logs are decked outside of the right-of-way) that will be burned from ending up in the road fill or having excessive quantities of loose soil mixed in with the slash piled at the toe of the fill. The operator in this case was reasonably careful, and the results were about as good as can be expected using present equipment and methods.

Customarily, slash is burned. Here, the slash at the toe of the fills was not burned the first year after construction, and it acted as an efficient trap for sediment from the fill slopes. This brings into question what the most desirable disposition of slash might be when there is a potential beneficial use for it--to be discussed more later. This is the extent of the observations of clearing for which some recommendations will be made in the Conclusions.

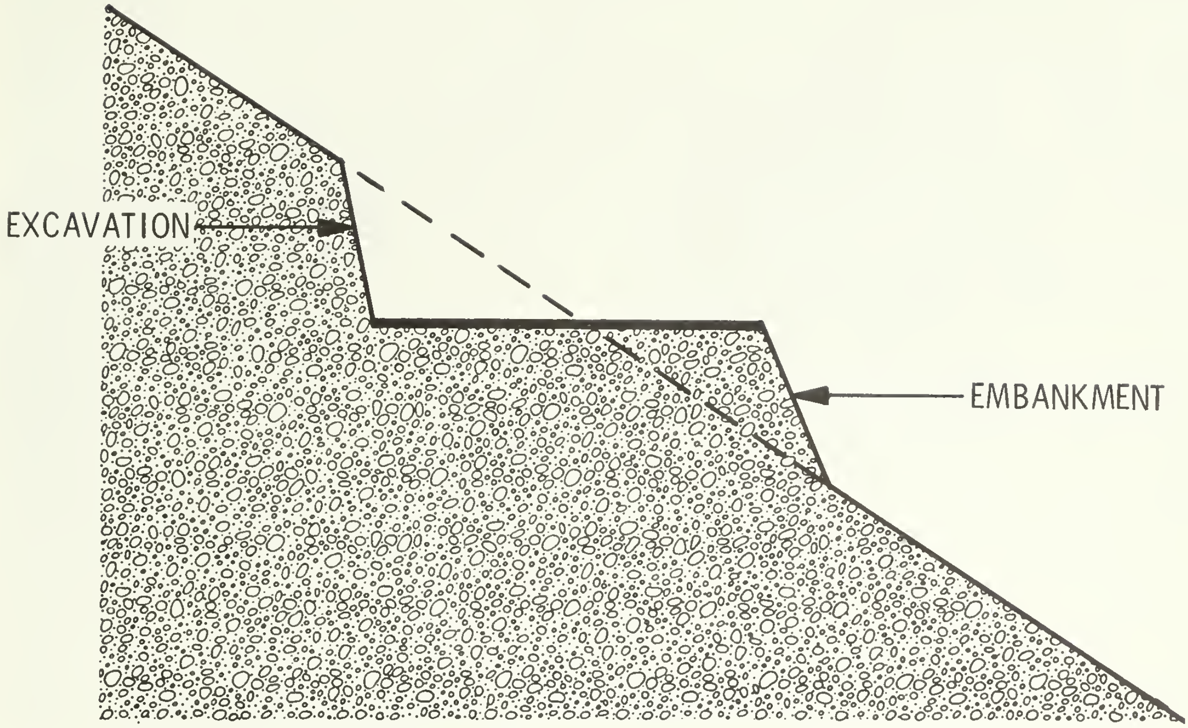

Figure 4.--Sidecast section.

Grading and Drainage

Grading refers to the earthmoving and placement operations that were primarily accomplished with "U" dozers. (A U-shaped dozer blade facilitates drifting material between balance points.) Because this was essentially a contour road, most of the road was constructed by sidecasting excavation to provide embankment, as seen in figure 4. Balance points were generally fairly closely spaced, and material from ridges was readily available for through fills crossing draws.

A D-8 cat with a 14-foot (4.27-m) blade was used to move most of the excavation, and herein lies a problem common to constructing any 12-foot-wide (3.66-m) subgrades with large equipment. It is virtually impossible to obtain good compaction for much of the embankment because the 11.5-foot (3.51-m) (outside span) tracks remain essentially in the same position on the road. Also, it isn't possible to compact the area near the toe or often to even work the material out to the fill stake. This results in some of the fills being on slopes slightly greater than the design slope of 1-1/2:1.

The drainage design of outsloping, grade breaks, and culverts in almost every draw was carried out according to plan. However, the culverts proved to be somewhat over-designed with many not carrying any water even during the 4-day, Labor Day weekend storm. The storm produced 2-3 inches (5.1-7.6 cm) of rain.

Performance

Control of subsurface and surface water flows is the key to stability from erosion and mass failure. As discussed earlier, outsloping, grade breaks, dips, and adequate drainage for natural channels were designed for this purpose. Contouring into draws, to the extent possible with 90-foot (27.36-m) minimum radius, helped keep through fill heights down. Employing these techniques produced a road that has functioned very well considering the difficult soils of the Batholith. In fact, the following photos and discussions show basic stability remains 6 years after construction without any maintenance for the past 5 years.

Outsloping/Insloping/Grade Breaks/Berms

In figures 5 and 6, it is apparent that control of surface water has been maintained by the judicious use of outsloping, design dips, and breaks in grade. In figures 7 and 8, insloping was used with berms to direct surface water to the cross-drain culverts. Although the road is primarily an outsloped road, there were occasions when water could not be carried to a full bench section or transition point from fill to cut to be dispersed on natural ground. When this occurred, as shown in figures 7 and 8, insloping and berms were used. Because of the difficulty of maintaining berms, and the extra road width required for their use, they were employed only when other means could not be used.

Fill-and-Cut Slopes

Since most of the sidecast fill slopes are short (less than 20 feet (6.10 m) long) and they are built on natural ground slopes of 50 percent or less, there have not been any failures, even through some slopes are steeper than 1-1/2:1. Part of the success of fill slope stability to date can be attributed to the fact that good drainage has prevented any of the fills from becoming saturated.

Figure 5.--Outsloped section with dip (built after construction).

Figure 6.--Break in grade, with dip followed by turnout on outslope section.

Figure 7.--Inslope to culvert for cross drainage at break in grade.

Figure 8.--Insloping to dip with berms controlling flow.

In figure 9, a typical section of stable sidecast fill is shown.

Since natural ground slope seldom exceeded 50 percent, it was generally possible to use 1:1 backslopes for cuts without opening up excessively long raw slopes. (When slopes exceeded 55 percent, full bench construction was used to eliminate sliver fills.) Figure 10 shows a typical section of cut slope that is relatively short and obviously stable.

Culverts

No culverts have failed to date and none are expected to fail. However, culverts in some small draws have not carried any water to date.

Revegetation

The revegetation success with cut slopes has been generally good, and fill slopes excellent (fig. 9 and 11). Seeding specifications are given in the following tabulation:

Revegetation--Grass Specification

Seed	*Percent*
Intermediate wheat	50
Smooth brome	15
Timothy	15
Orchardgrass	15
White clover	5

(In addition, 2-year ponderosa pine stock was planted on through fills to enhance stability on a 5- by 5-foot (1.52- by 1.52-m) spacing using an auger with good success.)

Figure 9.--Typical section of stable, sidecast fill.

Figure 10.--Typical section of stable 1:1 cut slope.

Figure 11.--Revegetation of cut-and-fill slopes.

Summary

The usual problems with clearing in steep terrain and construction of narrow, single-lane roads with equipment large enough to efficiently perform the job were encountered. However, since the construction was completed, the performance of the road to date has been good for the difficult conditions in the Batholith.

The general design philosophy was effective in attaining control of water and producing a stable road. However, the designers and research cooperators both felt that some lessons had been learned that could be applied and should be tried for the balance of the road to be constructed the following year.

The next section of the report will discuss the redesign and performance of the second section of the China Glenn Road.

REDESIGN AND PERFORMANCE OF THE SECOND SECTION OF ROAD

The key point that prompted a redesign of the second section was the difference in the final appearance of the road from what was visualized by the resource managers. The primary concern was the area opened up by construction of the road. Two other important points were:

--a modified dip design, that would have less effect on trucks negotiating it than the standard design, would provide adequate control of surface flow, and

--fewer culverts were needed for minor draws than originally designed.

Because the China Glenn Road was a multiple use road, the minimum standard practice for safety and other guidelines were used for the original design. These guidelines are not hard and fast rules, but were developed over the years and are established practice. The original design employed such common practices as minimum radius of curvature of 90 feet (27.36 m), minimum backslopes of 1:1 in common material, and a generally sustained grade. These standards, as viewed by the engineers, would produce a road with no more impact than necessary to maintain reasonably safe standards for a system road. The resource managers visualized a road that would meet the absolute minimum needs for removing timber from the area. It was felt that a compromise between these views was a reasonable goal to try to attain for the second section.

Following is a discussion of the guidelines and criteria used for the redesign.

Guidelines for Redesign

It is seldom possible to design a road that achieves all of the major objectives of all concerned; therefore, it is usually necessary to determine objectives that have priority and to modify other desirable objectives. In the case of the China Glenn redesign, the primary objective for the design of the second section was protection of soil and water resources.

To better protect these resources, the designers attempted to improve the redesign in the following ways: (1) expose a minimum of soil to the effects of weathering and erosion (especially from runoff and raindrop impact erosion), (2) control runoff water during, as well as after construction, and (3) disrupt natural drainage patterns as little as possible.

Road travel surface width is determined by minimum use needs; therefore, the exposed soil surface sections of the road prism that can be reduced are sometimes confined to the cut-and-fill slopes. Often little can be done to reduce the quantity of soil exposed on granitic fill slopes as oversteepening could lead to more serious problems, such as failure of the fill. However, construction of cut slopes as steep as feasible and fitting the road horizontal and vertical alinement to the contour of the land were methods to be emphasized to reduce soil exposure and thus keep excavation volumes to a minimum.

Guidelines for Cut Slopes

It was decided to try near-vertical cut slopes as long as they did not exceed 6 feet (1.83 m) in height, otherwise a 1:1 slope was used. It was felt that if a 6-foot vertical slope sloughed, it would not result in much infringement on the travel surface. Since the timber adjacent to the road was to be logged the same season that the road was constructed, all logging truck traffic would take place before any spring sloughing could occur. The type of traffic anticipated after the first spring would be normal management and recreational traffic, which would not require the full orignal width (12 feet (3.66 m)).

Guidelines for Grade and Alinement

Horizontal and vertical alinements were adjusted to obtain as many balanced sidecast sections as possible. The balanced sidecast road requires a minimum of earth movement and is especially efficient on steep sidehills.

The China Glenn Road is generally located on terrain that made it possible to roll the vertical alinement in conjunction with adjusting the horizontal alinement to obtain a balance between cut-and-fill. (Often in mountainous terrain, steep grades do not allow rolling the vertical alinement, and attempts to keep the earthwork balanced have to be made by adjusting the horizontal alinement only.) Two advantages of being able to roll the grade are: first, the earthwork can be held at a near balance condition while maintaining a better horizontal alinement; and second, the rolling grade helps provide drainage control and allows the road to better fit the natural drainage patterns of the area.

Guidelines for Clearing

Right-of-way clearing was restricted to help control sliver fills.

The first section of the China Glenn Road was cleared in accordance with "good" sight distance criteria for logging road construction. Horizontal clearing limits were set at 10 feet (3.05 m) beyond the top of cut banks and 5 feet (1.52 m) beyond the toe of fills, or 16 feet (4.88 m) each side of centerline, whichever was greater.

It was decided to allow fills to build up to a maximum height of 2 feet (0.61 m) on the trunks of the trees along the toe of the fills (as long as this point was at least 16 feet (4.88 m) from the road centerline).

Another design change was to pile slash of 4 inches (10.1 cm) or less diameter along and below the lower edge of the fill. The slash would act as a catchment to help contain any eroded fill material. Placing living or dead material along the toe that may end up supporting part of an embankment is not considered good engineering practice; however, after considering the nature of the intended use and the characteristics of the area, the advantages of using a slash catchment seemed to outweigh the disadvantages.

Guidelines for Turnouts

Turnouts were installed at locations that minimized earthwork. Desirable locations for turnouts are gentle slopes. When earthwork is minimized, esthetic impacts and erosion are reduced. Turnout locations, of course, should always be located with consideration for sight distance and safety. This guideline was followed on the original road and the redesign, so there were no appreciable differences in this case. (There were 11 turnouts in the 6,500 feet (1,976 m) of the redesign.)

Guidelines for Drainage

The need to control runoff during construction was demonstrated by the Labor Day storm of 1970 (described in the first report in this paper), which damaged the first section of the road before it was completed.

The general objective was to control runoff water during, as well as after, construction by installing corrugated metal pipe, roadway dips, and an alternating outslope-inslope road surface as needed to take advantage of stable surfaces for discharging water.

Drainage for live water and draws was provided by appropriately sized, corrugated metal pipe, and cross drainage was provided by dips constructed in the roadway. Drainage control was basically the same for both the original and the redesign. However, the redesign was adjusted as a result of experience gained after the first section was constructed. For example, less drainage for draws was called for in the redesigned section because it was found that many of the culverts on the first section didn't carry water either during the Labor Day storm or during spring runoff. The dry culverts were in small draws that are common to the area. Because infiltration (natural permeability) is generally good in the Batholith, overland flow is uncommon outside of ephemeral streams.

Dips were not included in the original portion of the road's design grade because they can be troublesome for the logging trucks to negotiate. Truck drivers dislike dips constructed as specified by the Forest Service standard design because the dips deflect the trucks off the road during slick road conditions and also impose a twisting stress on trailer frames. Dips used in the redesign were modified to reduce the sliding hazard and stresses on trucks. The first modification consisted of keeping the dip the same depth across its full width, relying completely on the normal 3-5 percent outslope or inslope to keep the dips drained. The second modification was to make the dips perpendicular to the centerline of the road rather than skewed. This allows all the wheels on the same axle to negotiate the dips evenly, thereby eliminating the twisting action on the trailer frames. The dips were 1 foot (0.30 m) deep and 100 feet (30.40 m) long. The profile of a typical dip is shown in figure 12.

The 1-foot (0.30-m) depth is measured between the elevation of the dip bottom and the elevation of the downgrade end of the dip 35 feet (10.69 m) away. The vertical height between the dip's bottom and the projected sustained grade varies according to the magnitude of the grade. The height for the above example in figure 12 is 2.98 feet (0.91 m). It can easily be seen that as the grade increases, so does the impact of these dips to the road user. The dips, as described, caused no apparent distress to logging truck traffic.

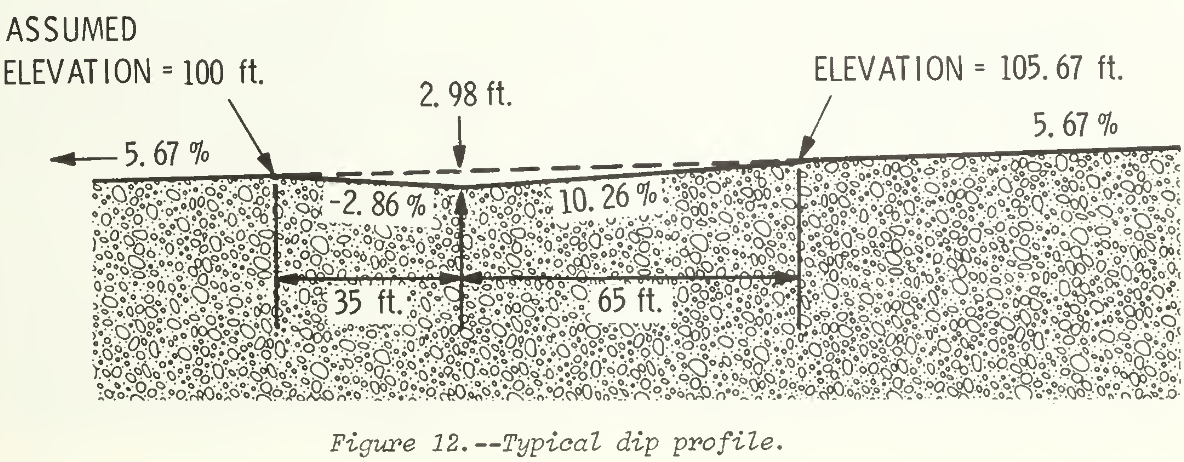

Figure 12.--Typical dip profile.

COMPARISON OF THE GUIDELINES USED ON FIRST AND SECOND SECTIONS OF THE CHINA GLENN ROAD

There are no quantitative measurements of impacts on either section of road, and opinions differ between observers. However, there are some obvious differences in some of the parameters that undoubtedly had some effect on impacts.

Construction

The second year's construction began July 1, 1971, and was completed in mid-September.

Clearing

The problems associated with clearing were discussed in the first section of the report and were generally the same for the second section.

Total clearing area for the redesign was 6.61 acres (2.68 ha), which was 26 percent less than the original design. Of this 6.61 acres (2.68 ha), 83 percent occurred inside the minimum clearing limits of 16 feet (4.88 m) each side of centerline. Eleven percent was outside minimum clearing limits on the cut side of the road, and only 6 percent occurred outside minimum clearing limits on the fill side. Through fills over stream crossings are included in this 6 percent, which indicates that most sliver fills of the type found on the original design were eliminated.

Grading and Drainage

The same equipment was used for both sections of the road, and the same general difficulties encountered on section 1 also apply to section 2. There was one important difference in construction for section 2--the dips were staked and built as the grade was constructed. This was done to control drainage during construction. Another advantage to this practice is that the dips are compacted with the rest of the road and therefore are more stable.

Outsloping/Insloping/Rolling Grade/Dips/Berms

The difference between the two sections of road in these categories is primarily the use of grade rolling and the dip design in the second section discussed earlier. In figure 13, a transition section (inslope to outslope) is shown. This is an example of good design working well, controlling flow. Figure 14 shows a dip in a section of sustained outsloped grade. The appearance of the unmaintained road surface shows that drainage has been adequately controlled.

Figure 13.--Transition from outslope to inslope just past the curve is an example of good design functioning well.

Figure 14.--Dip near the end of a section of outsloped road on a sustained grade.

Fill-and-Cut Slopes

Both fill-and-cut slope heights are less in section 2 because of the vertical cuts used for slopes 6 feet (1.83 m) and under and more rolling of grades and contouring. The advantages of contouring and grade rolling to generally reduce cut-and-fill heights are obvious. However, opinion is divided on the use of vertical cut slopes. The general problem of designing vertical cut slopes is much the same as it has always been--short vertical slopes function quite well in the better drained soils that also exhibit some cohesiveness, and not so well in the poorer drained, heavier soils. The problem is in identifying these situations before the slopes are built. Batholith soils are usually well drained and low in silt content, except in or near draws where soils are deeper. These areas are where the problems occur.

When cut heights are very short on uniformly sloping sidehills, vertical slopes generally work well, as seen in figure 15. In situations that are obviously well drained, but when soil depths are fairly deep, they may still work satisfactorily, as seen in figure 16. For cuts steeper than 1:1 in some of the deeper, well-drained slopes, structural stability may be retained, but sloughing can become a problem, especially when cornice conditions begin to form at the interface of the cut and natural ground, as seen in figure 17. Figure 18 shows what can happen to cuts steeper than 1:1 in the deeper soils that are not as well drained. The crack seen in the picture is a planar failure that has resulted in a section of the cut slumping toward the road.

Use of vertical slopes for cuts of 6 feet (1.83 m) or less is still being debated. The design of cut slopes obviously is difficult and requires the use of all available information and skill. Seismic traverses were attempted in 1970 to help with the design, but the material is generally such a heterogeneous mixture that the investigations were inconclusive and abandoned. Therefore, on-the-ground inspection and judgment had to be used.

Figure 15.--Short, stable vertical backslopes on uniformly sloping terrain.

Figure 16.--Transition from 3/4:1 to vertical backslopes going away from the camera.

Figure 17.--Cut slope near maximum height of 6 feet (1.83 m)--structurally stable, but prone to sloughing. A cornice is beginning to build at the top of the cut.

Figure 18.--Crack in a cut slope that is near the 6-foot (1.83-m) maximum height.

Culverts

Culverts were eliminated from minor draws. All culvert drainage is functioning satisfactorily on both sections.

Revegetation

No changes were made in revegetation, and the success was good for fill slopes on both sections. One of the disadvantages of vertical backslopes is that they cannot be seeded or planted. However, for the short slopes, natural vegetation usually invades from above as seen in figure 15.

CONCLUSIONS AND RECOMMENDATIONS

There is strong evidence that the effort to minimize environmental and esthetic impact produced good results. Although quantitative data are not available to give a better measure of the success, subjective evaluation of results leaves little doubt.

The discussion and photos in the preceding sections show quite conclusively that the road has produced little sedimentation and has maintained its basic integrity without any maintenance since its last use in 1971.

Strict adherence to the following principles will usually produce good results for reducing road impacts in the Batholith and elsewhere.

--Reduce road travel widths to the minimum needed to accommodate the traffic and other uses such as logging equipment.

--Contour and roll grades to disrupt natural drainage patterns as little as possible and reduce cut-and-fill slope heights. This will greatly reduce the potential for the buildup of waterflows.

--Carefully locate and design turnouts where the terrain is favorable to reduce overall impact of cuts and fills.

--Use dips where needed for cross drainage, but construct perpendicular to the traffic to reduce impacts on traffic use--also, construct dips along with the grading operation to control water during construction.

--Use insloping, outsloping, grade breaks, dips, and berm designs carefully and effectively as demonstrated to control water on single-lane roads without a ditch.

--Consider the use of slash as a barrier to sediment movement from fill slopes.

--Consider the use of reduced clearing widths to reduce the total area opened up by right-of-way clearing.

--Always revegetate the first year following construction to help stabilize the raw cut-and-fill slopes.

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In 1970, the China Glenn Road was built to salvage trees attacked by the Douglas-fir beetle and protect the residual stand.

KEYWORDS: road construction, design standards, fragile soils, erosion.

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Erosion caused by road construction on the steep, fragile, decomposed granitic soils of the Idaho Batholith resulted in a 1965 moratorium on road construction in the South Fork of the Salmon River and its tributaries.

In 1970, the China Glenn Road was built to salvage trees attacked by the Douglas-fir beetle and protect the residual stand.

KEYWORDS: road construction, design standards, fragile soils, erosion.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
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