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Road Obliteration

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The fiscal year 1991 Appropriations language included something new—authorization to use up to $5 million of road maintenance funds for the obliteration of roads no longer needed. This has added a significant new tool for Forest managers to obliterate roads not needed to implement the Forest Plans. Most Forest Plans identify the elimination of unneeded roads as part of the desired future condition. For some years, a Comptroller General's letter has prohibited the Forest Service from using Forest road funds for road obliteration.

Congress added this authorization instead of making an additional $5 million reduction in the road maintenance appropriation as some congressional members had proposed. Accordingly, while many Forests may still have additional road maintenance needs, we expect to report that this authorization was in fact used to obliterate roads. Certainly, road maintenance funds are not the only tool available for road obliteration; others include the following:

(1) The Federal Facilities Compliance Program can identify nonpoint pollution projects for obliterating unneeded roads that cause erosion problems, usually with Soil and Water funds.

(2) Timber sales can be designed to obliterate unneeded roads, or they can provide funds to obliterate unneeded roads after they have been used for Knutson-Vandenberg or brush disposal work.

(3) Unneeded roads can be obliterated as part of fire rehabilitation work.

(4) Trail funds can be used to convert an unneeded road to a trail.

Leveraging any of these funding opportunities through cooperative partnerships and involving volunteers can improve accomplishment while providing a positive Forest management image.

The preparation of a road obliteration plan is essential for prioritizing work and for identifying funding and partnership opportunities. The plan should also identify the nature of the work necessary to accomplish the obliteration. In some areas, the mechanical stabilization of slopes, the correction of erosion problems, and the planting of vegetation may be necessary. In other areas, managing access and allowing natural revegetation may be sufficient.

Area closures, signing, ditches, barriers, or other traffic management strategies may be necessary.

The monitoring of road obliteration projects will verify that the environmental protection and traffic management measures worked as planned. Once traffic is naturally precluded, signs and barriers can be removed.

This new congressional authorization to obliterate roads with road maintenance funds may be used on either system or nonsystem roads. Under the authorization, the unit costs of obliteration will not be tracked. However, miles of system roads obliterated (under any authorization or combination of methods) will be reported as part of the total road system accomplishment report to Congress. The Forest Service hopes that Congress will continue this authorization in the future.

Roadway Surface-Water Deflectors

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Introduction

Finding an effective, low-cost, low-maintenance method to deflect surface water off roadways is a never-ending struggle. Drain dips work well on grades less than 7 or 8 percent. However, on steeper grades, drain dips can be a rather abrupt change in road grade, and they have a tendency to be filled in by traffic and routine maintenance. The traditional open-top culverts also have their drawbacks, such as requiring frequent cleaning and being damaged by graders.

In 1984, at the Region 1 road maintenance meeting in Missoula, Jim Stackhouse of the Bonners Ferry Ranger District, Idaho Panhandle National Forests, gave a presentation on using an old conveyor belt to divert water off roadways. By 1987, they found that the used belting did not work well, so they switched to ½-inch by 6-inch skirtboard rubber, which is sandwiched between 2-inch lumber, with the top edge of the wood buried approximately 1 inch below road level and the rubber exposed about 2½ inches. This was an improvement, but it did not hold up well to blading or heavy winter traffic. At last contact, they were not using the conveyor belts very extensively.

Background

In 1985, this author also began experimenting with a conveyor belt. Some of the first installations were on the Mayo Gulch Road 4227 near St. Regis. This is a road with very erosive sandy soil and had 6-inch and deeper gullies over most of the roadway (figure 1).

The water bars were constructed through force account and installed by a contractor. Various types, thickness, and width of material were tried; remnants were purchased from a conveyor belt supplier. All the material was new. Some of the belt was PVC, while other parts consisted of two or three laminations of nylon or rayon sandwiched between layers of rubber. The total thickness ranged from about 5⁄16 inch to ½ inch. Because the belting was remnants, the width varied, including widths of 3, 6, 8, 10, and 12 inches. The 3-inch material was used with the 6-inch material, with the 3-inch being used as filler directly under the 6-inch. The belt was then sandwiched between 2-by-6, 2-by-8, or 2-by-10 treated timber, leaving 2½ or 3 ½ inches of belt projecting above the treated timber, and nailed with 20 "d" nails at 15- to 18-inch centers. A 2 by 6 was laid flat underneath the sandwiched belt and treated timber. All treated timber members were 20 feet long.

The road was graded before the installation of the surface-water deflectors. The contractor used a small backhoe for excavation and backfilled using a vibratory compactor (figure 2).

Several problems have developed with the early installations. The PVC belting, while very durable, has a tendency not to rebound well under traffic; it ends up parallel to the road grade. This has been a problem with the rubber-laminated type also, although not to the extent of the PVC. After about 5 years and three or four gradings, the 6-inch belting that was installed above the 3-inch belting and sandwiched between 2-by-6 treated timber began to rip out during grading. On other installations that had heavy winter hauling, the top of the belt began to fray and, in some situations, delaminate (figure 3). According to one supplier, the reason for the delamination was the plies being constructed of nylon instead of rayon. Another problem resulted from installation on grades less than approximately 6 percent, where traffic wheel ruts tend to cause the water to pond on the upgrade side, resulting in potholes (figure 4).

Design & Construction

The latest installation is shown in figure 5. Allowing joints in the treated timber makes the timber easier to obtain. Burying the treated timber 3 to 4 inches helps protect the timber from damage during grading. Using 12-inch-wide belt leaves 2½ to 3½ inches of belt exposed above the roadway. If much more belt is exposed, it tends to curl over too much when subject to traffic. Any less exposure is not adequate to keep water from going over the top, particularly as wheel ruts develop. Also, less belt exposed would make it more difficult for the grader operator to see it while maintaining the road.

All of the installations have been on existing roads. The preferred time to locate the installation is after a recent rain, when drainage patterns are more apparent. Also, the Forest Service Engineering Handbook guide for maximum spacing of drainage culverts can be used. When feasible, one should try to locate a water bar immediately above a grade pitch. For the outlet, it is

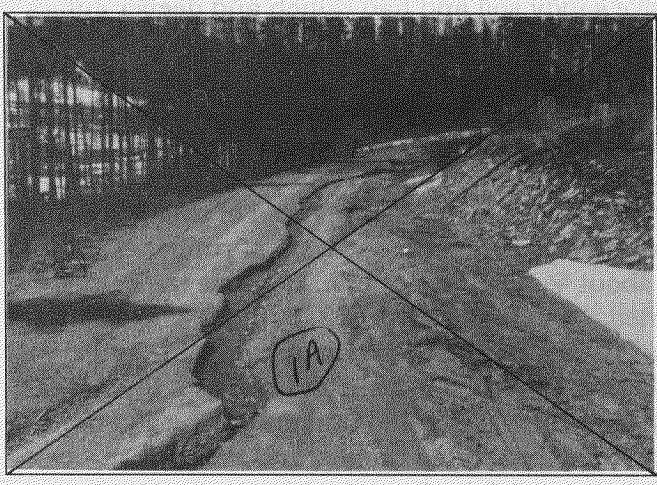

Figure 1.—Surface erosion from spring runoff (Crusher Road 18269).

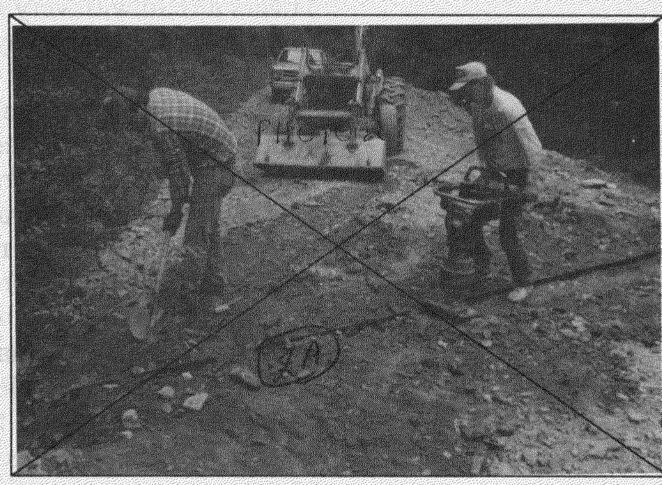

Figure 2.—Installation of a surface-water deflector (Graves Creek Road 367).

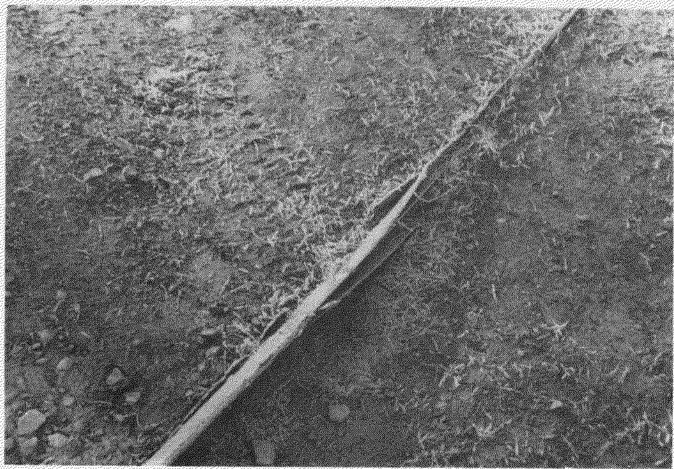

Figure 3.—Delamination and fraying of belt after several seasons of winter haul (Combest Road 508).

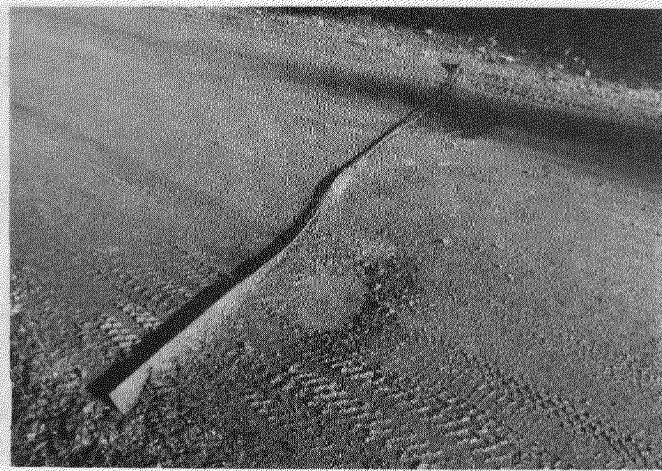

Figure 4.—Potholes.

best to find a site where bank erosion is not a problem, preferably a low fill or a site with sufficient rock or vegetation to dissipate the water. Rarely has it been necessary to use riprap on a maintenance installation. However, there have been installations on new construction where the outlet has washed part of the embankment away. In these situations, riprap, filter cloth, and/or a downspot may be necessary. Erosion next to the belt has not been a significant problem as long as the spacing is adequate.

One location where the water bars have been particularly useful is immediately upgrade from cattleguards (figure 6). On the Lolo National Forest, there are several cattleguard installations where erosion down the road surface has a tendency to fill in the cattleguard. One or more water bars above the cattleguard can significantly reduce cleaning out cattleguards.

The installation has been as specified in Forest Service Standard Specification 557 Timber Structures, supplemented by a Special Project Specification (figure 7).

Cost

For the last several contracts, this author has been furnishing the conveyor belt and requiring the contractor to furnish the treated timber, construction, and installation. The last three contracts that have included surface-water deflectors have had low bidder prices of $5.00, $20.00, and $9.00 per foot, respectively. This last price ($9.00 per foot) seems the most reasonable.

Cost for a two-ply conveyor belt, 1/4 inch by 12 inches, costs approximately $3.50 per foot. The same-sized rubber skirting costs about $2.50 per foot. A typical installation should cost approximately $250.

Figure 5.—Recent installation.

Figure 6.—Installation above cattleguard (note leadoff ditch).

Conclusion

Surface-water deflectors constructed of treated timber and a conveyor belt can effectively reduce erosion on roadways. They are best suited for medium- to low-traffic volumes, with grades steeper than 6 percent. Continued experimentation is necessary to find a material that will stay upright and resist abrasion from traffic, particularly winter hauling.

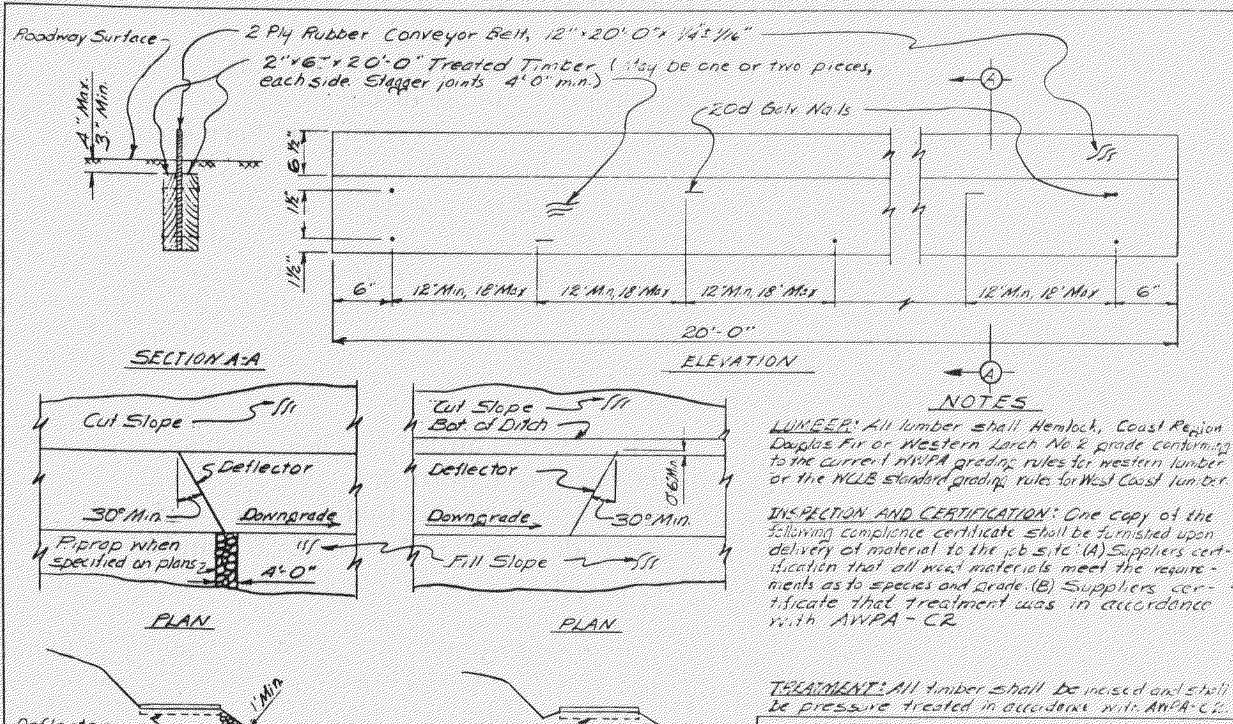

Figure 7.—Roadway surface-water deflector specifications.

Why Weight, Rate, & Calculate Decisionmaking Is Unsound—A Challenge to the "Rational Method"

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Introduction

A common method for choosing among mutually exclusive alternatives is to do the following:

(1) Determine the factors that make a difference in the decision.

(2) Weigh the factors relative to their importance.

(3) Rate the alternatives so as to reflect how well they support the factors.

(4) Multiply the weights of the factors by the ratings of the alternatives.

(5) Total the points for each alternative.

(6) Choose the alternative with the greatest point total.

Does this sound rational? It is called "the rational method of decisionmaking." However, it is *not sound.* This weight, rate, and calculate (WRC) method is full of opportunities for error and leads people toward making unsound decisions, while they think they are doing everything correctly. What is wrong with WRC is that it leads people into making a series of "unanchored" judgments. For example, suppose you meet someone you know well on your way to work. You say, "Hi, how are you?" He or she answers, "Fine, how are you doing?" You probably reply, "Okay, nice day isn't it." Then the two of you discuss the weather in more generalities.

Talking in generalities and filling in the blanks (making assumptions) about what others mean are normal in daily conversations. It is done to survive in society. Yet, did you ever stop to think just how vague that talk actually is? What did you mean when you asked, "How are you?" How is your health? Your cholesterol level and blood pressure? Or did you mean to ask about a financial situation? Is your bank account up or down? Or did you really ask the person about his or her relationship with a supervisor? Did he or she do well on a performance rating?

Indeed, one may be asking, "How are you?," and meaning one thing (health), while the other person may be answering, "Fine," and meaning something else (the relationship with the boss is on the upswing). This is acceptable in small talk conversation, but it is *not* in making serious decisions. In decisionmaking, people must "anchor" their statements to the relevant facts, not to assumptions that are made in response to generalities.

Examples of WRC: Unsound Decisionmaking

Factors *are* generalities. When someone feels that one factor is more important than another and gives them different weights, specific assumptions about general categories are being made. Error is being introduced into the decisionmaking! For example, suppose that you are selecting a design proposal, one from several submitted by consulting engineers, for a bridge that will be built above a deep ravine in mountainous terrain. In your opinion, in making this decision, which of the following factors would be most important: economics, safety, or esthetics?

More than 90 percent of the respondents to this question answer "safety." Why? Because they fill in the blanks. From the information given, they picture vehicles tumbling off the bridge into the ravine so safety has to be the most important consideration. What they were not told is that all the designs meet the State safety standards. In fact, there is actually very little difference in the designs relating to safety. The *difference* in the safety attributes of one design proposal versus another is very small and *unimportant;* therefore, it has very little to do with the decision.

When applying this example to WRC, safety is given 10 points because it is considered the most important. Then, with the small differences in safety, the alternatives and all rated very good—8, 9, and 10. The weights are multiplied by the rates and a 20-point spread between one alternative and another is introduced, where in fact there should have been no weight given to the unimportant differences.

An illustration of the levels of abstraction used in language will help explain why it is important to weigh only the importance of the differences between alternatives. See the diagram in figure 1.

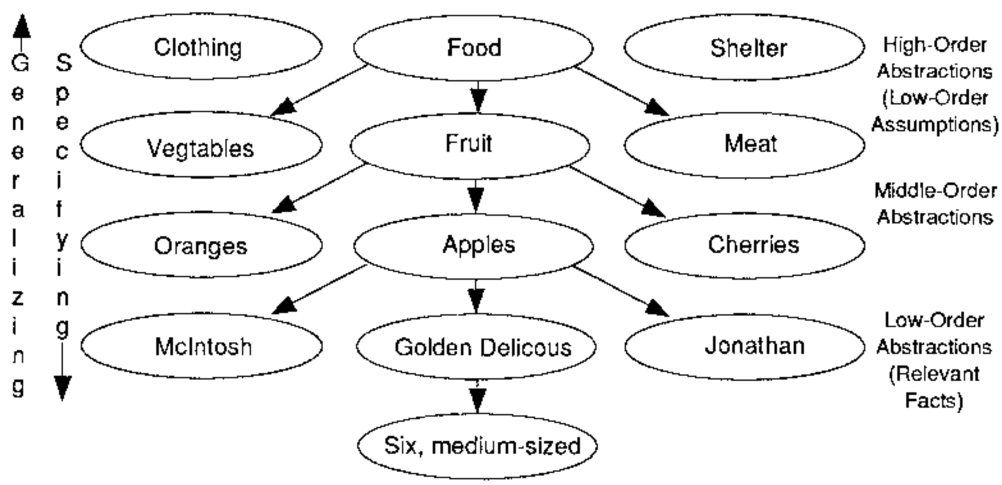

Figure 1.—Levels of abstraction with common English words.

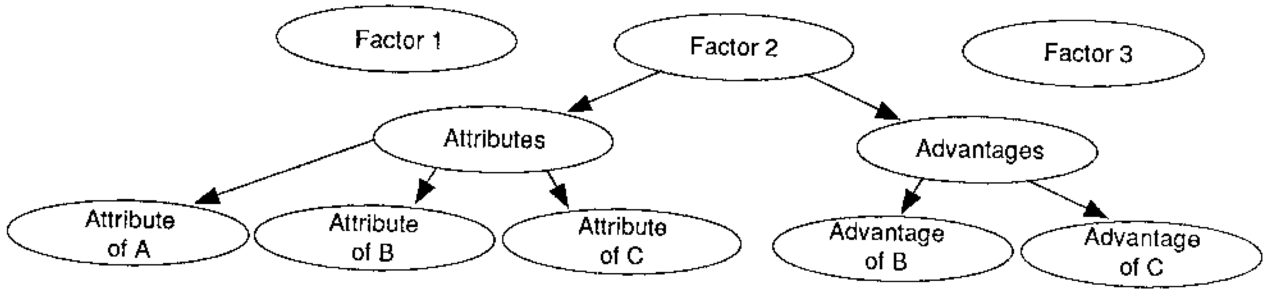

Figure 2.—Levels of abstraction in decisionmaking.

If you were asked to go to the store and get six medium-sized golden delicious apples, you would probably return with six medium-sized golden delicious apples. However, if you were asked to go to the store to get food, what are the chances you would bring home six medium-sized golden delicious apples? You would have a better chance if fruit was asked for and an even better chance if it was apples. However, unless you are asked to get six medium-sized golden delicious apples, the chances of you getting exactly that are slim.

The broad categories of food, clothing, and shelter are high-order abstractions. To answer how important one is versus another (or any other specific question) one has to make some assumptions. From where do the assumptions come? They come from past experiences and present imaginations, which may not have anything to do with the current decision. These would be "low-order" assumptions.

Factors are high-order abstractions. To ask how important a particular factor is, one makes a low-order assumption, filling in the blanks as to what one thinks it means in relation to the decision. What are the chances of guessing correctly? Again, the chances are slim.

The levels of abstraction in decisionmaking are shown in figure 2. In this example, within factor 2, the attribute of A is the least preferred attribute and the advantages of B and C are shown.

Factors, again, are those broad categories that make a difference in the decision. An attribute is a characteristic (quality or quantity) of an alternative or a proposal. In each factor, there is one attribute for each alternative. An advantage is a favorable dissimilarity (in quality) or a favorable difference (in quantity) between two alternatives. The "importance of an advantage" equates to how much one is willing to pay for apples.

In 1887 Wellington, a railroad economist stated, "No increase of expenditure over the unavoidable minimum is expedient or justifiable, however great the probable profits and value of an enterprise as a whole, unless the *increase* can with reasonable certainty be counted on to be, in itself, a profitable investment." Even though it is narrow in its application, this statement laid the basis for understanding that one has to pay attention to the differences in alternatives when making decisions.

Grant and Ireson, in *Principles of Engineering Economy*, simplified the idea by stating, "It is only prospective differences among alternatives that are relevant in their comparison." They also said, "Over the years, many published formulas for the solution of problems in Engineering Economy have given dangerously misleading guidance to decision makers because the authors of the formulas have not recognized this concept." This statement applies to the WRC methods.

Bruce Bishop in his award-winning 1969 report, *Socio-Economic and Community Factors in Planning Urban Freeways*, stated, "Decisions must be based on the differences among alternatives." He also stressed the subjective side of decisionmaking. Decisions are value laden—that is, the decision depends not only on objective facts, but also on the viewpoint of the decisionmakers.

To highlight the subjective side of decisionmaking, Jim Suhr, in 1976, added three words (in italics) to Bishop's statement: "Decisions must be based on the *importance of the* differences among alternatives" (italics added). To simplify and clarify decisionmaking, and to adopt a positive view in the decisionmaking process, Suhr once again improved on the fundamental rule of decisionmaking by stating, *"Decisions should be based on the importance of advantages."*

Sound Decisionmaking

Notice how that last statement fits within the levels of abstraction. By basing the decision on the importance of advantages, one is addressing relevant facts rather than low-order assumptions and has a basis for making sound decisions.

Compare the following steps of sound decisionmaking with those of WRC on the first page of this article:

(1) Determine the factors that make a difference in the decision.

(2) Determine the attributes of each alternative for each factor.

(3) Decide the least preferred attribute for each factor.

(4) Using the least preferred attributes as references, decide the advantages of all the rest of the attributes for each factor.

(5) Select the most important advantage in each factor and the most important of the most important advantages (paramount advantage).

(6) Assign the paramount advantage a convenient number (10, 100, and so on) and weigh all of the rest of the advantages based on their importance as compared with the paramount advantage.

(7) Total the points for each alternative.

(8) Choose the alternative with the greatest point total.

The method above comes from a decisionmaking system called Choosing by Advantages (CBA). It was developed by Jim Suhr, Management Methods Engineer in the Regional Office of Region 4, Ogden Utah.

CBA is for all types of money and nonmoney decisions, from the simplest to the most complex. The system has different methods for addressing different types of decisions—such as choosing between mutually exclusive alternatives or among nonexclusive proposals or addressing equal-cost and different-cost alternatives or proposals. For most decisions, the CBA methods are much simpler than explained above; and for very simple decisions, the methods are extremely simple.

What has been explained here is just to whet the reader's appetite for doing things right—making sound decisions. If you are interested in learning more about CBA, contact a qualified CBA instructor or facilitator. It could not only affect the way you make decisions at work, but could influence your entire life. After all, what we make of our lives is a result of our decisions.

History of Engineering Book Published

Because of continued interest at the Regional Engineers' meetings and the growing emphasis on the Centennial and Forest Service history, *The History of Engineering in the Forest Service (A Compilation of History and Memoirs, 1905–1989)* was published in October 1990. This history includes the previous volume published in 1969 plus accounts from more recent retirees. As many Engineering retirees as possible were given the chance to participate; the contributions of those who did are appreciated. The book is an interesting and colorful account of the personal experiences of those who worked for Engineering in the Forest Service.

Copies were sent to each Regional Engineer, the retirees who contributed, and the Washington Office. If you would like a copy, please contact your Regional Engineering Office.

Chainlink Retaining Walls—Alternative Facings & Forming Can Save Money

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Introduction

This past year, the Siskiyou National Forest constructed two modified chainlink walls. They differed from previous designs in their forming methods and facing. One wall was faced with native logs; the second was formed with hay bales. Both are permanent, cost-effective, easy-to-construct, and environmentally appealing structures.

In 1978, the first chainlink walls were installed as a demonstration project on the Siskiyou National Forest. The largest chainlink structure to date is a 25-foot-high, 2,026-square-foot wall constructed in 1984.

Design

General

Drawings and specifications for walls up to 15 feet high and backdrains are included in the appendix to this article. Three types are included: wire-faced walls, log-faced walls, and walls with bales used for forming. Grid lengths are specified for three typical backfill soil types. The design assumes that backfill material is drained and nonplastic.

If water is encountered or anticipated, a drain is recommended along the backslope. A standard backdrain detail with specifications was developed for reinforced soil walls and is available for inclusion with any wall design.

Erosion is a concern on all walls. Typical details may include cross-drains, curbs, paving, and insloping the roadway.

Delineators, berms, and/or guardrails are typically added for traffic control. A typical wall face is set back from the edge of the travelway by 4 to 5 feet to allow the placement of a guardrail, the construction of a shoulder, and the reduction of the live-load forces on the facing.

In lieu of chainlink fabric, designers may use a geogrid or high-strength fabric. Many of the commercially available fabrics are superior to chainlink in costs, ease of handling, and resistance to corrosion. Their design properties also vary. Designers need to consider ultimate strength, soil shear stress interaction, creep, and ultraviolet deterioration, in addition to physical characteristics such as direction of primary axis, available widths, and delivery time. Chainlink designs must be modified before substituting other geotextiles.

Paving over chainlink walls is the best way to control erosion. Because walls often settle slightly their first winter, one should either pave the following season or plan for a minor skin patch over the completed wall.

Chainlink Wall With Log Facing

A chainlink wall with log facing was constructed on Hungry Hall Road, Powers Ranger District. The wall repaired a logging road fill failure. The repair was expedient and cost-effective; it demonstrated the use of logs for facing. See figures 1 and 2.

Timing was critical. The timber purchaser intended to move a large yarder to a landing beyond the failure within a week. The repair desired could be temporary, must prevent any additional material from entering the drainage below, should be constructible by the purchaser's crews, and, to avoid litigation and bad press, needed to be expedient.

A log-faced wall option appealed to everyone. The purchaser felt he could build it in less than 2 days. The technology was simple, the materials were

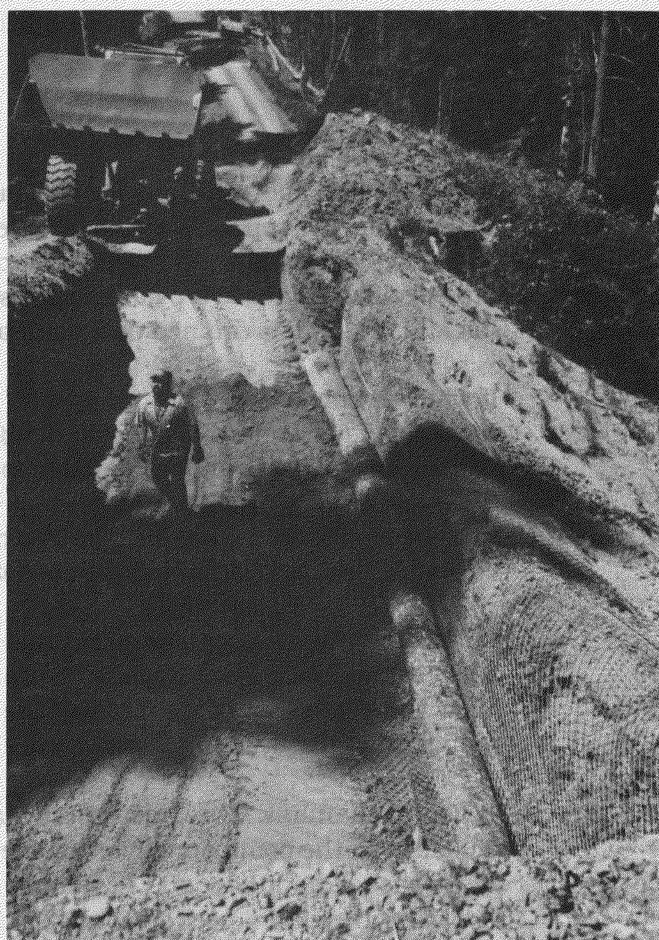


Figure 1.—Placing fabric and logs for chainlink wall with log facing.

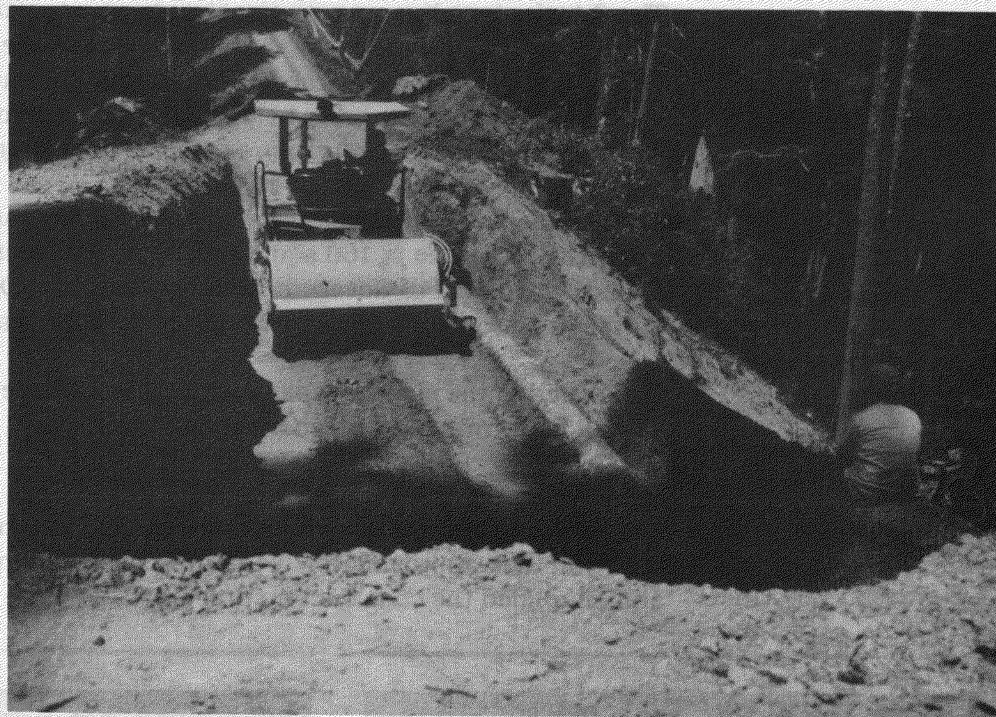


Figure 2.—During compaction of the fill for the wall with log facing, construction equipment can work directly against face.

available, the costs were reasonable, and the site could be seeded. The design is considered a permanent repair.

The completed log wall is 50 feet long and 8 feet high. Five logs form a near-vertical face. The wall *was* constructed in 2 days. The first day, the contractor mobilized his equipment and excavated to an approved foundation. The second day, he constructed the wall and surfaced the road with pit-run material salvaged from the existing road and adjacent rock outcrops. The contracted cost to the Government was $3,500.

Chainlink Wall With Hay Bale Facing

A chainlink wall formed with hay bales was constructed on a logging road near Humbug Mountain on the Powers Ranger District. The wall is a typical chainlink wall in every way, except for the method of forming. The wall was constructed using hay bales along the face of the wall to act as forms for building the chainlink wall inside. This forming method greatly simplified the construction procedures. The bales do not support traffic and are placed below the traveled way, avoiding the appearance of a wide shoulder. See figure 3 through 6.

Forming with bales reduces sedimentation and improves visuals. The bales retain fines in the fill, while vegetation develops along the face. Within several months, the bales sprout, with grass growing on the entire wall face. The wall looks like a steep slope covered with grass.

The wall is stepped 6 inches per bale with a finished slope ratio of 0.4 to 1.0. The 6-inch steps line up with the strings on a typical bale. Control is a matter of placing bales along the strings of the bales below. The bales are secured with chicken wire wrapped around the face and stakes driven through the bales to the soil or bales below. This combination develops the lateral strength required for compactors to work directly against the bales.

The completed Humbug Mountain wall is 30 feet long at the top and 8 feet high. The total area is 160 square feet. The contracted cost was $1,300, not including the cost of Government-furnished wire. Overlaps and cutting required approximately 30 percent more wire than was originally estimated.

Constructing the slope steeper will not affect the design. Bales should work as well for forming in a steeper configuration.

Construction

The Humbug Mountain wall was constructed in 6 hours, while the Hungry Hall wall took approximately 14 hours. The following procedures expedited and simplified the construction process:

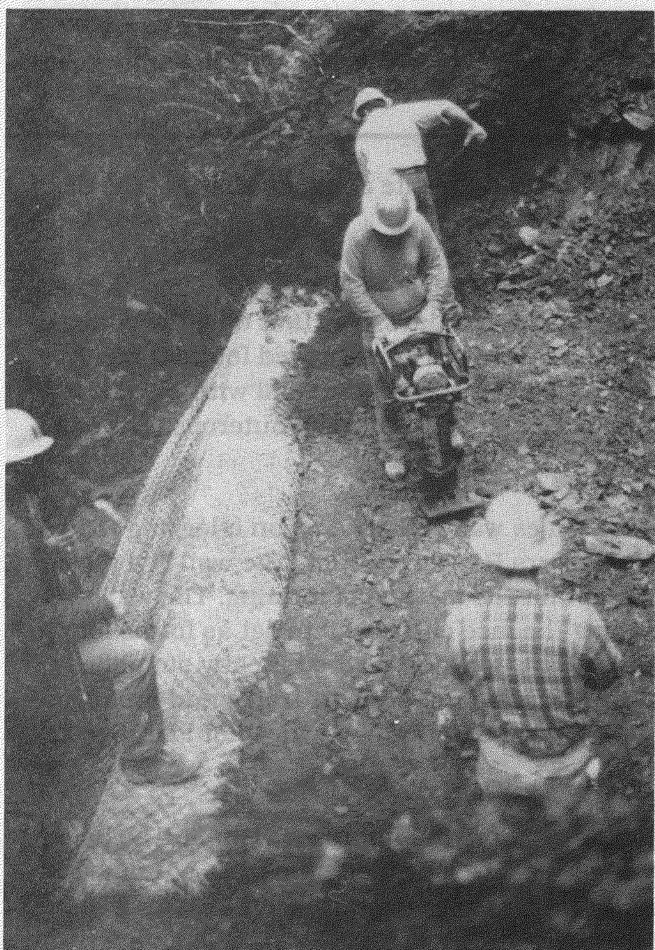


Figure 3.—Compaction next to face for the wall with hay bale facing.

Figure 4.—Placing and staking fabric for the wall with hay bale facing.

(1) Survey control was simple. All controls were references to a stringline placed along the face of the wall at the elevation of the finished road grade. The footing of the wall was located by measurements from the stringline. A level rod held vertically was used for this purpose. The outside edge was established from the wall geometry.

(2) Tolerances were consistent with the design. The foundation was leveled within a tenth of a foot under the face. The remainder of the foundation was allowed to vary as much as a half foot.

(3) The grade of the wall is parallel to the road grade rather than level. Steps are not designed in the top layer.

(4) The height and spacing of the top layer were field-adjusted to match the road grade. Typically, the top of a wall is slightly skewed to the road grade despite the best of intentions. The top of the last layer was set to the desired stringline offset without exceeding the maximum spacing on the plans.

Figure 5.—Using a hay bale wall, the completed roadway prior to grading.

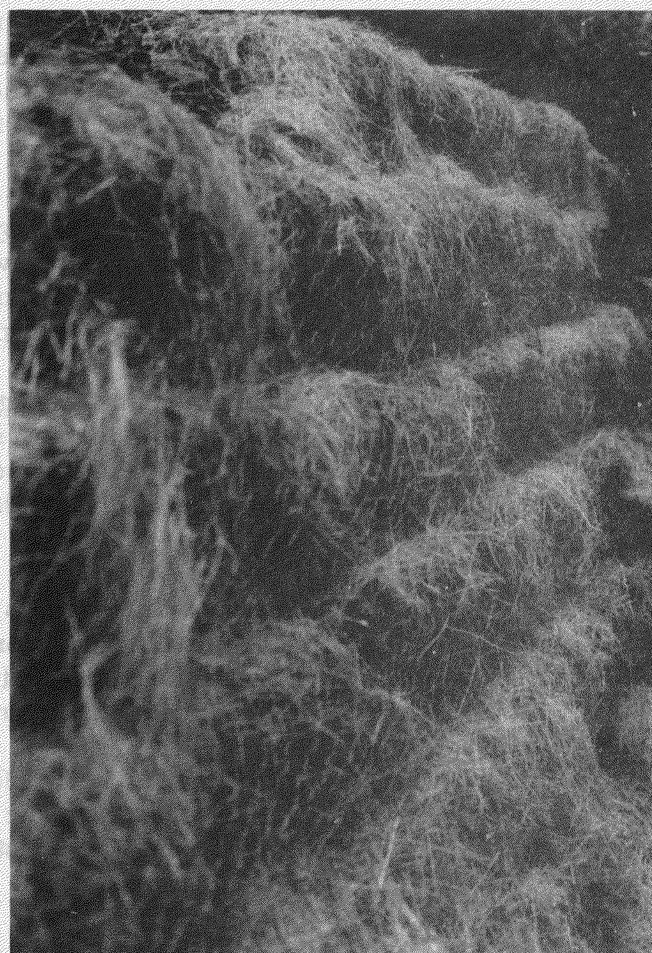


Figure 6.—Completed face of the hay bale wall.

Table 1.—Cost summary: detailed.

	Humbug Mountain hay bale forming (160 square feet)	*Hungry Hall log facing (400 square feet)*
Mobilization	Not required	$1,100
Hay bales and stakes	$ 100	n/a
Chainlink (Government-furnished)	1,000	1,800
Equipment and labor	1,200	2,400
Logs (Government-furnished)	n/a	500
Subtotal	$2,300	$5,800
Cost per square foot of wall	$14.74	$14.50

(5) In-place material for backfill should be used provided it is nonplastic. The savings in haul and borrow will more than compensate for the extra fabric length and compactive effort.

Detailed Cost Summary

The detailed cost summaries for the Humbug Mountain and Hungry Hall walls are in Table 1. Previously, chainlink walls have cost between $22 and $25 per square foot. The cost savings here reflect improved designs and procedures and the use of in-place material for backfill.

Maintenance

Chainlink walls are easy to maintain. In the past 10 years, only two repairs were reported. Riprap was placed on the sideslope of one wall to repair surface erosion. Resurfacing and grading repaired a second wall after a grader operator inadvertently pulled up a section of wire.

The maintenance on log-faced walls is minor. In approximately 10 years, the logs will begin to rot. A slight settlement of the face is anticipated, requiring minor grading and some additional surfacing. The road behind the wall will remain intact and stable. Vegetation growing on the rotted logs will restabilize the face.

Forming with hay bales will not affect maintenance. Some settlement of the face during the first months is anticipated as the hay loses its strength and evolves into a grass mat. The inner wall may develop slight surface bulges. Routine maintenance grading will correct any settlement.

The estimated design life of chainlink walls is 50 to 100 years, depending on the corrosiveness of the backfill material. Log facing or bale forming will not affect the life. The oldest walls, constructed in 1978, have not shown any signs of corrosion.

Other Uses

In addition to road repairs, log-faced chainlink walls are applicable for stabilizing landings. Yarders can work without damaging the facing of the walls.

The ease of installation and log components appeal to most timber operators. The walls are well suited for work adjacent to streams, such as temporary bridge abutments and fills along streams.

The walls with hay bale forming are applicable for erosion-control structures, recreation area structures, and streambank stabilization. Recreation specialists will appreciate the ease of force account construction.

Specifications & Drawings

Standard specifications for reinforced soil walls and backdrains are included in the appendix. They include the following new features:

(1) Payment is by square foot of wall or square yard of backdrain and includes all materials, select borrow, and drainage works within the wall area. Work outside the walls, such as downpipe and guardrail, is not included.

(2) The configuration and quantity of a completed wall can vary up to 15 percent under the variations-in-quantities clause. Engineers can adjust the foundation to match ground conditions as a work order adjustment rather than as a change order. The administration is consistent with the design intent.

(3) Two options are allowed for backdrains.

The following standard drawings are included in the appendix for chainlink walls and backdrains (AutoCAD files are available on request):

(1) Chainlink wall with wire facing.

(2) Chainlink wall with log facing.

(3) Chainlink wall with bale facing.

(4) Forming method—chainlink wall with wire facing.

(5) Backdrain for reinforced soil—retaining wall.

(6) Chainlink wall general notes.

Conclusions

The experiences with chainlink walls on the Siskiyou National Forest lead to the following conclusions:

(1) Chainlink walls are an excellent choice today for Forest roads and recreation projects with a demonstrated cost advantage on small projects.

(2) Hay bales function well for forming. The grass-covered slopes are attractive. The hay reduces sedimentation and acts as an organic filter.

DRAFT PROPOSAL

SPECIAL PROJECT SPECIFICATION
REINFORCED SOIL WALLS

SECTION 642 REINFORCED SOIL WALLS

DESCRIPTION

642.01 **Work.** This work shall consist of furnishing and installing reinforced soil retaining wall(s) complete with soil reinforcement fabric, facing and hardware. Work shall include all excavation, embankment and backfill. Wall options permissible for specific projects shall be as SHOWN ON THE DRAWINGS.

MATERIALS

642.02 **Geogrid.** Geogrids are polypropolene or polyester grid structure geotextiles specifically fabricated for use as soil reinforcement. Material shall meet the requirements of section 720, Type 1, Function G. The maximum tensile strength or type of fabric shall be as SHOWN ON THE DRAWINGS. Mats must have 70% open area to allow for soil to soil contact.

642.03 **Welded Wire.** The welded wire fabric shall meet the requirements of ASTM A-185 and ASTM A-82. The maximum tensile strength requirements or size, shall be as SHOWN ON THE DRAWINGS. The fabric shall be galvanized at the rate of 0.4 ounces per square foot.

642.04 **Chain Link Fabric.** Chain link fabric shall be two inch mesh fencing material made from 9 gage wire, helically wound, and interwoven in such a manner as to provide a continuous mesh without knots or ties. All fabric material shall conform to the requirements of AASHTO M-181, Type I, with Class B coating and Knuckled Selvage.

642.05 **Treated Timbers.** Treated timbers shall meet the requirements of the following subsections.

Structural Timber and Lumber	716.01
Preservative Treatment	716.02

642.06 **Landscape Timbers.** Landscape timbers shall be No. 1 graded railroad ties or treated timbers as noted above.

642.07 **Masonry Units.** Modular blocks specifically designed for use as a retaining wall. Materials shall comply with manufactures specifications in addition to the following: ASTM C90, ASTM C140, ASTM C145-75.

642.08 Proprietary Wall Systems. Materials shall comply with manufactures recommendations except for those as noted above in which case the materials shall be equal or better.

642.09 Log Faced Walls: Logs shall be barked and trimmed . Limbs shall be cut flush with truck. Trees used for logs will be marked by engineer prior to cutting operations when designated as goverment furnished.. The minimum and maximum diameter of logs used for wall facing shall be as SHOWN ON DRAWINGS.

642.10 Government Furnished Materials: When SHOWN ON DRAWINGS , Materials for construction of the wall shall be government furnished. Contractor is responsible for delivering the materials to the construction site from the designated pickup location SHOWN ON THE DRAWINGS.

642.11 Backfill. Backfill material shall be granular in nature and shall meet the following gradations and plasticity requirements:

Sieve Size	Percent Passing
6 inch	100
3 inch	75 to 100
No. 200	0 to 15

Plasticity Index (P.I.) shall not exceed 6.

The backfill shall be free of organic matter, soft clayey soils, rock of poor durability, or bituminous material. Suitable on site material shall be used as backfill as APPROVED BY THE ENGINEER.

642.12 Certification. A manufacturer's certification shall be furnished to the Engineer upon delivery of the reinforcement material. In addition to submittal requirements of section 720, the contractor shall furnish certification of product tensile strengths at breaking, 2% strain and 5% strain for reinforcement materials not SHOWN ON THE DRAWINGS.

642.13 **Soil Reinforcements.** Soil Reinforcements shall be laid at the proper elevation and alignment as SHOWN ON THE DRAWINGS.

Soil Reinforcements shall be oriented such that the maximum tensile strength available is in the direction as SHOWN ON THE DRAWINGS.

Splicing of reinforcements is not anticipated in the direction perpendicular to the primary reinforcement. In the direction of primary reinforcement a minimum overlap of 48 inches is required.

Soil reinforcements shall be installed in accordance with manufacturers recommendation for their intended purpose. A copy of those recommendations shall be included with project submittals when requested by the Engineer.

Extreme care should be taken to prevent wrinkle development and/or slippage of reinforcement during fill placement and spreading. Geogrids and chainlink will require stretching and staking to mobilize their desired strengths. A plan must be submitted by the contractor indicating how he proposes to accomplish this prior to his beginning work.

Tracked construction equipment shall not operate directly upon the reinforcement material. A minimum fill thickness of 6 inches is required prior to operation of tracked vehicles over the fabric. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the fabric.

Precise and accurate installation of the initial mats is very important. A small grade change can drastically affect the elevation of the top of the wall. The elevation tolerance for the finished top of the wall is +/-0.3 feet from design values. The variance from design and/or manufactures recommendations for vertical tolerance shall not exceed +/-0.1 foot per 10 feet of wall height, and shall be such that the designed width of the road shall not be reduced.

642.14 **Field Adjustments.** The final limits and configuration of the wall may vary depending on the foundation materials encountered during excavation. Final foundation limits will be as approved by the Engineer before placement of any backfill material.

Notification will be given to the Engineer at least 48 hours prior to beginning work to facilitate a timely inspection of the foundation.

Over excavation of foundations beyond approved limits shall be repaired by contractor at no additional cost to the government.

642.15 Excavation. Excavation shall be in accordance with Section 206. Excavated material shall be considered suitable for backfill when in compliance with section 642.11 and approved by the Engineer.

Unsuitable material shall be disposed of as SHOWN ON THE DRAWINGS

Excavation shall be approved by the Engineer before placement of any backfill material.

642.16 Performance. The contractor shall notify the Engineer at least 48 hours prior to beginning of work.

It will be the contractors responsibility to maintain the offset markers and bench mark and all construction stakes necessary to control the work.

A 3 to 4 inches layer of granular backfill shall be placed as per the manufactures recommendations or as SHOWN ON THE DRAWINGS over the entire length of the completed excavation as a leveling course prior to placing the first mats of any wall section. This material is incidental to other work.

642.17 Backfilling. Excavated areas shall be backfilled with approved material placed in horizontal layers, not exceeding 9 inches loose measure in depth. Each layer shall be compacted in accordance with subsection 203.15 (b), Method 4. Sheepsfoot and pneumatic tire rollers shall not be used to obtain compaction. Portable vibratory compaction equipment shall be used as APPROVED BY THE ENGINEER. On chainlink and geogrid walls backfill shall be placed from the wall face inward to insure that the reinforcing fabric remains taut.

MEASUREMENT

642.18 Method. The Method of Measurement will be designated in the SCHEDULE OF ITEMS and measured in accordance with section 106.

Payment will be based on the contract unit price per square foot, vertical frontal area of wall completed in place and accepted.

PAYMENT

642.19 Basis. The accepted quantities will be paid for in accordance with section 106 at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS.

Payment will be made under:

PAY ITEM	PAY UNIT
642 (01) Reinforced Soil Wall	SQ.FT.

SPECIAL PROJECT SPECIFICATION

612

SECTION 612 - BACKSLOPE DRAIN

612.01 **Work**

This work shall consist of furnishing and installing backslope drainage systems. Contractor has option of two alternative backslope drain systems as SHOWN ON THE DRAWINGS. Materials used in systems vary between options. They may include using woven plastic filter cloth, drainage core, pipe, pipe connections, and drainrock in accordance with these specifications and as SHOWN ON THE DRAWINGS.

MATERIALS

612.02 **Geotextiles.** Geotextiles shall meet the requirements of section 720, Function Type (E). A sample of the material and the manufacturers specifications, including Equivalent Opening Size (EOS), Percent Open Area; and Permeability shall be provided to the Forest Service, for approval, a minimum of 10 days prior to incorporating into construction.

612.03 **Drainage Core.** The drainage core shall be an impermeable polymeric sheet with a 3-dimensional corrugated or waffle-like structure which provides flow channels for the water. The drainage core shall meet the following MINIMUM specifications:

Thickness: .75 inches.
Compressive Strength: 4300 pounds per square foot.
Flow 5 gallons/minute/foot width.

Specifications and samples of proposed material shall be provided to the Forest Service, for approval, a minimum of 10 days prior to incorporating into construction.

612.04 **Pipe.** Drain pipe and couplings shall meet the requirements of AASHTO M-252. Drain Pipe diameter is SHOWN ON THE DRAWINGS. Outlet pipe shall be nonperforated pipe of like type and diameter.

612.05 Backslope Drain System. The geotextile does not have to be bonded to the drainage core but shall be pinned and stretched sufficiently taut to prevent bunching during installation. The number of sides of the core to becovered with the geotextile will be SHOWN ON THE DRAWINGS.

CONSTRUCTION

612.06 Assembly of Backslope Drainage System. The system shall be assembled as SHOWN ON THE DRAWINGS. The drainage pipe shall be installed in contact with the bottom of the drainage core. The drainage pipe shall be encased in geotextile. The geotextiles shall be overlapped a minimum of 4 inches at each joint in the geotextile and drainage core. The overlap shall be secured with 3-inch safety pins or roofing nails with push nuts spaced no more than 3 feet on center. The overlap may also be secured by sewing. The Engineer will approve the assembly prior to installation.

612.08 Installation of Backslope Drainage System. The geotextile shall be placed and secured sufficiently taut with spikes on the slope and shall have overlaps as per 612.06. The drainage core shall be placed and pinned in place to develope a shingle effect with 4-inch overlaps.

After the installation has been inspected and approved by the Engineer, backfill material may be placed. Backfilling shall be done in uniform layers not exceeding 1 foot loose thickness. The degree of compaction required is SHOWN ON THE DRAWINGS. Backfill shall not contain material larger than 6 inches in greatest dimension, and shall be carefully placed by methods that will not cause damage to the drainage system. Any damaged materials shall be replaced or repaired by the Contractor.

METHOD OF MEASUREMENT

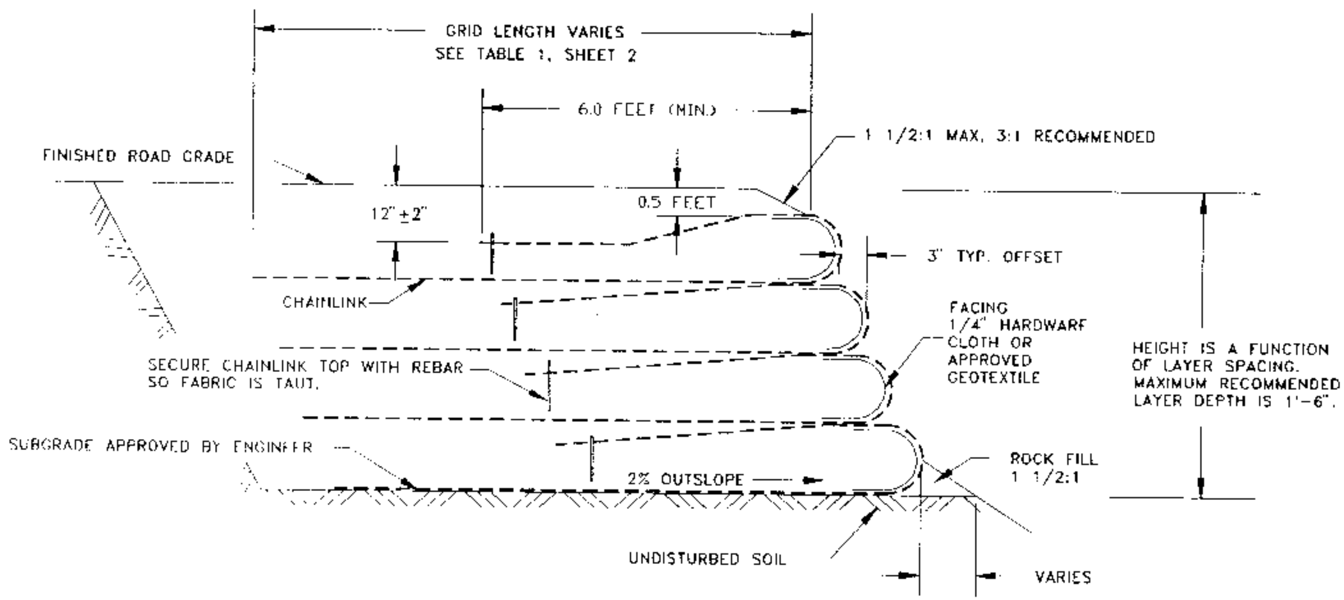
612.10 Method. The method of measurement will be DESIGNATED in the SCHEDULE OF ITEMS and measured in accordance with Section 106. Measurement for Prefabricated Underdrain will be made along slope lines.

BASIS OF PAYMENT

612.11 Basis. The accepted quantities will be paid for in accordance with Section 106 at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS. Payment for Prefabricated Underdrain includes geotextile, core, and perforated pipe.

Payment will be made under:

Pay Item	Pay Unit
612(01) Prefabricated Underdrain	S.Y.



CONSTRUCTION SEQUENCE

1) STRINGLINE EDGE OF SHOULDER.
2) EXCAVATE TO THE APPROVED SUBGRADE, DEPTH IS A FUNCTION OF LAYER SPACING, BASE OF WALL IS AT THE SAME SLOPE AS THE ROAD GRADE.
3) PLACE APPROVED FORMING.
4) PLACE CHAINLINK ON BOTTOM LIFT, OVERLAP 12" AT SPLICES.
5) PLACE 1/4" GALVANIZED HARDWARE CLOTH OR APPROVED GEOTEXTILE AGAINST THE CHAINLINK AT THE FACE.
6) PLACE BACKFILL IN COMPACTED LIFTS TO TOP OF FORMING AND LEVEL OF OVERLAP.
7) PULL CHAINLINK TOP BACK, SECURE IN PLACE & COMPACT FILL TO BASE OF NEXT LAYER.
8) BEGIN NEXT LIFT.

MATERIALS

CHAINLINK: SEE SHEET #2 NOTE #2
BACKFILL: SELECT GRANULAR MATERIAL FROM EXCAVATION AND/OR APPROVED BORROW SITE.
STAKES: 1/2 INCH DIA. REBAR OR 1"X1" WOOD STAKES
FORMING: METHOD APPROVED BY ENGINEER.
FACING: 1/4" GALVANIZED HARDWARE CLOTH OR APPROVED GEOTEXTILE

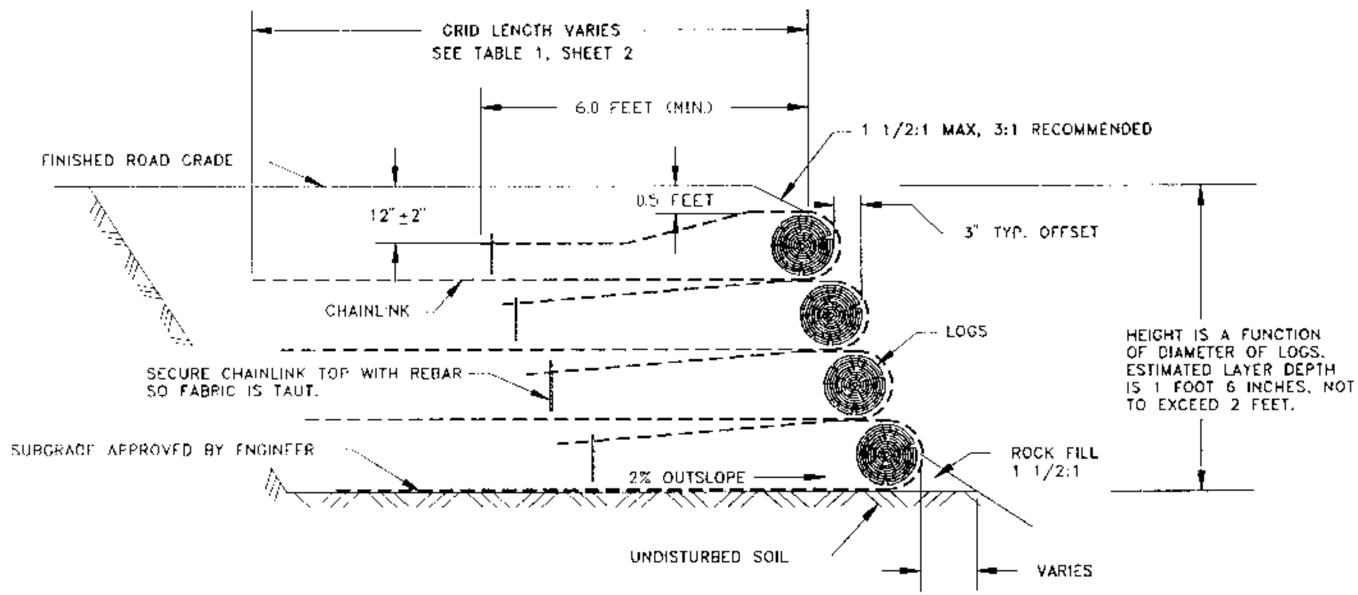
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
SISKIYOU NATIONAL FOREST
THE PACIFIC NORTHWEST REGION

DESIGNED DON PORIOR
REVIEWED RICHARD VAN DYKE
SUBMITTED

DRAWING BY
DATE DEC. 1990
ACAD NAME CHAINWAL

CHAINLINK WALL WITH WIRE FACING

SHT 1
OF



CONSTRUCTION SEQUENCE

1) STRINGLINE EDGE OF SHOULDER.
2) EXCAVATE TO THE APPROVED SUBGRADE. DEPTH IS A FUNCTION OF LOG DIAMETER. BASE OF WALL IS AT THE SAME SLOPE AS THE ROAD GRADE.
3) PLACE CHAINLINK ON BOTTOM LIFT, OVERLAP 12" AT SPLICES.
4) PLACE LOG OVER CHAINLINK ALONG FACE. KEY LOG INTO FILL ON BOTH SIDES.
5) PLACE AND COMPACT FILL AGAINST LOGS IN LIFTS.
6) BEGIN NEXT LAYER, OFFSET BASE INTO SIDESLOPES AS NEEDED.

MATERIALS

CHAINLINK: SEE SHEET #2 NOTE #2
BACKFILL: SELECT GRANULAR MATERIAL FROM EXCAVATION AND/OR APPROVED BORROW SITE.
STAKES: 1/2 INCH DIA. REBAR OR 1"X1" WOOD STAKES

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CHAINLINK WALL WITH LOG FACING

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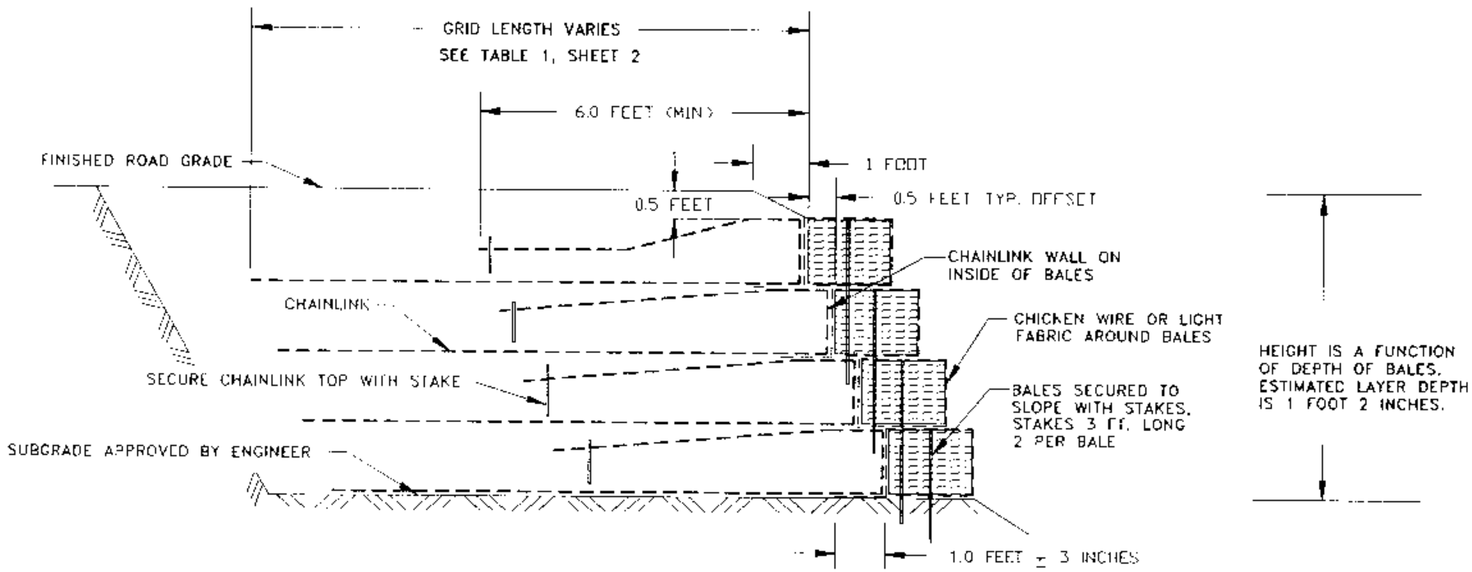
REVIEWED RICHARD VAN DYKE
SUBMITTED
DRAWING BY
DATE DEC. 1990
ACAD NAME LOGWALL

SHT 1 OF



CONSTRUCTION SEQUENCE

1) PLACE LIGHT FABRIC ALONG FACE (5 FEET WIDE).
2) PLACE BALES ALONG FACE ON LIGHT FABRIC.
3) STAKE BALES TO SOIL BELOW, WRAP BALES & SECURE FABRIC.
4) PLACE CHAINLINK ON FOUNDATION FLUSH WITH EDGE OF BALES. LAP CHAINLINK OVER TOP OF BALES (TEMPORARY). OVERLAP ADJACENT PANELS 12" AT FACE.
5) PLACE BACKFILL IN COMPACTED LIFTS TO THE TOP OF THE BALE.
6) PULL CHAINLINK TOP BACK, SECURE IN PLACE & PLACE IN FILL.
7) COMPACT FILL FLUSH TO TOP OF BALES.
8) BEGIN NEXT LIFT.

MATERIALS

CHAINLINK:	SEE SHEET #2 NOTE #2.
BACKFILL:	SELECT GRANULAR MATERIAL FROM EXCAVATION AND/OR APPROVED BORROW SOURCE.
STAKES:	1"x1" WOOD STAKES
BALES:	GRASS, HAY, OR STRAW BALES.
LIGHT FABRIC:	ANY OPENING MESH LIGHT FABRIC SUCH AS CHICKEN WIRE 5 FT. MINIMUM WIDTH.

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CHAINLINK WALL WITH BALE FACING

DESIGNED DON PORIOR
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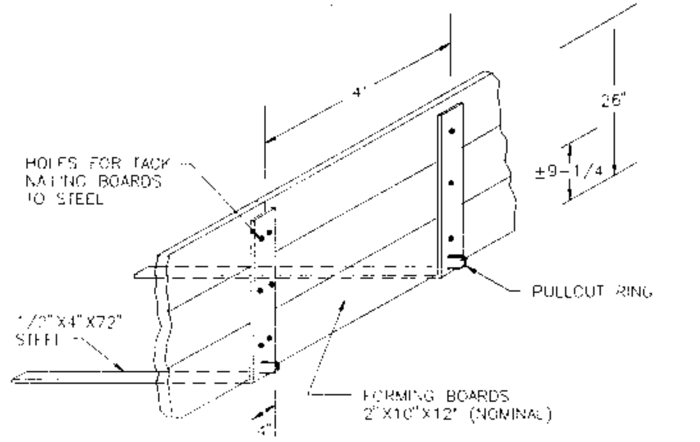
SUBMITTED
DRAWING BY
DATE DEC. 1990
ACAD NAME HAYWALL
SHT 1 OF

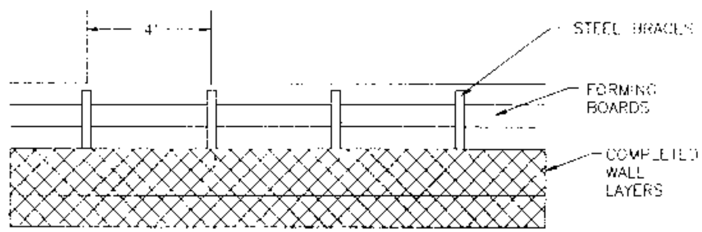
RECOMMENDED CONSTRUCTION SEQUENCE

CONTRACTOR IS NOT REQUIRED TO FOLLOW THIS METHOD AND SEQUENCE

1. EXCAVATE TO THE DESIGN DEPTHS AND GRADE
2. WHILE EXCAVATION IS PROCEEDING, MAKE UP AND LABEL THE REQUIRED NUMBER AND LENGTHS OF CHAINLINK PANELS
3. ALIGN AND SPACE THE REQUIRED NUMBER OF STEEL BRACES ON THE GRADED EXCAVATION.
4. NAIL THE REQUIRED NUMBER OF BOARDS TO THE INSIDE OF THE BRACES USING DOUBLE HEADED NAILS
5. LAY OUT THE PANELS OF CHAINLINK WITH THE REQUIRED EMBEDMENT. OVERLAP ADJACENT PANELS A MINIMUM OF 1 FOOT AND TIE WIRE THEM TOGETHER. THE CHAINLINK SHOULD BE IN CONTACT WITH THE WOOD FORM FROM TOP TO BOTTOM. THE REMAINDER OF THE CHAINLINK IS THEN DRAPED OVER THE TOP OF THE FORM.
6. PLACE 1/4" GALVANIZED HARDWARE CLOTH OR APPROVED GEOTEXTILE AGAINST THE FACE FORM TIGHTLY AGAINST THE BOTTOM OF THE FACE
7. AT THE FACE OF THE WALL, PLACE AND COMPACT THE BACKFILL USING A MECHANICAL TAMPER.
8. FOLD BACK THE CHAINLINK FABRIC THAT IS DRAPED OVER THE TOP OF THE FORM AND THE DRAIN CLOTH. COMPLETE BACKFILLING AND COMPACTING THE LAYER TO REQUIRED HEIGHT
9. PULL THE NAILS FROM THE FORMS. REMOVE THE STEEL BRACES INDIVIDUALLY BY ATTACHING A CHAIN TO THE PULLOUT RING AND SLIDING THE BRACES OUT WITH A BACKHOE
10. ALIGN AND SPACE THE REQUIRED NUMBER OF STEEL BRACES FOR THE NEXT LAYER. REPEAT STEPS 4 TO 10 UNTIL THE WALL IS COMPLETED.

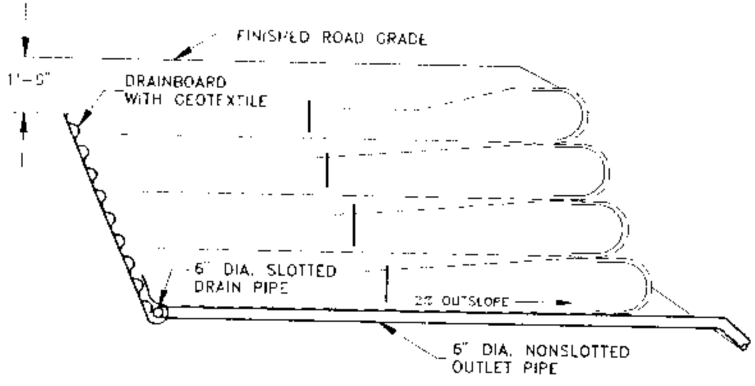


BRACING DETAIL

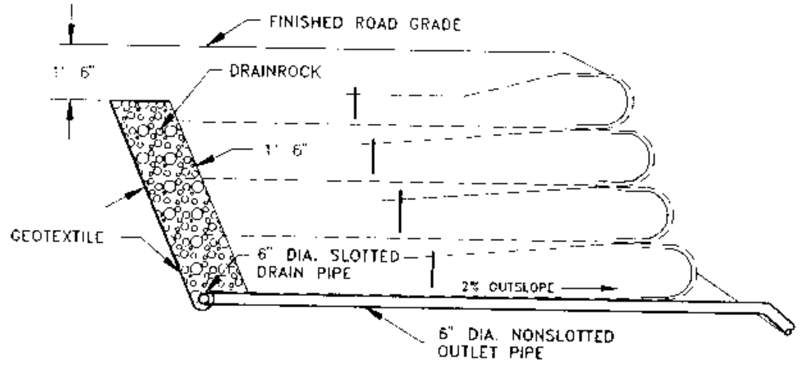


FRONT ELEVATION VIEW

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE SISKIYOU NATIONAL FOREST THE PACIFIC NORTHWEST REGION	FORMING METHOD CHAINLINK WALL WIRE FACING
DESIGNED DON PORIOR REVIEWED RICHARD VAN DYKE SUBMITTED	DRAWING BY DATE DEC. 1990 ACAD NAME FORMMETH
	SHT 3 OF



PREFABRICATED BACKDRAIN



AGGREGATE BACKDRAIN

GENERAL NOTES

1. WHEN REQUIRED BY THE ENGINEER, BACKDRAIN SHALL BE EXTENDED AROUND SIDES OF EXCAVATION.
2. CONTRACTOR HAS THE OPTION TO INSTALL EITHER PREFABRICATED OR AGGREGATE BACKDRAIN.

MATERIALS

DRAIN ROCK:	100% PASSING 3" - 0-3% PASSING #4.
GEOTEXTILE:	TYPE 3, FUNCTION E
DRAIN BOARD:	3-DIMENSIONAL WAFFLE BOARD CONSTRUCTION WITH FLOW CHANNELS ON BOTH SIDES. MIRADRAIN 4000 OR APPROVED EQUAL.
DRAIN PIPE:	CORRUGATED POLYETHYLENE (PE) DRAINAGE PIPE.

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DRAWING BY
DATE DEC. 1990
ACAD NAME BACKDRN

BACKDRAIN
RETAINING WALL

SHT
OF

GENERAL NOTES

1. Maximum spacing between lifts shall not exceed 2 feet.
2. Chainlink fabric shall be a nine gage wire, Type I, knuckled salvage.
3. Wall shall be placed on undisturbed soil or rock. The foundation must be approved by the engineer.
4. Design Values:
   Long Term Allowable
   Strength of Chainlink ...... 2200 lbs
   Coefficent of Soil Shear
   Stress Interaction............ 0.65
   Uniform Surcharge on Wall ... 150 lbs./sq.ft.
   Bulk Unit Weight of Soil
   In Backfill......................... 125 lbs./sq.ft.
   Minimum Factor of Safety
   Internal Stability.............. 1.5
   Minimum Factor of Safety
   External Stability.............. 2.0
5. A 10 foot minimum grid length is recommended for ease of construction.
6. The foundation shall be leveled to ±0.10 ft of approved subgrade elevation under the face. The remainder of the foundation shall be within ±0.50 ft.

TABLE 1

MINIMUM GRID LENGTH (FT.)

HEIGHT OF WALL H (FEET)	BACKFILL SOIL TYPES I $\phi=37^{\circ}$	II $\phi=33^{\circ}$	III $\phi=27^{\circ}$
0–6	6.0	6.0	6.5
8	6.5	6.5	8.0
10	7.0	7.0	9.5
12	8.0	8.5	11.0
15	10.0	10.0	13.0
	(See Note #5)		

SOIL TYPE I: Unified Soil Classification, GW, GP, SW, SP. Assumed internal angle of friciton 37 degrees.

SOIL TYPE II: Unified Soil Classification GM, SM. Assumed internal angle of friciton 33 degrees.

SOIL TYPE III: Unified Soil Classification SC, GC, ML, CL-ML. Assumed internal angle of friction 27 degrees.

SOIL TYPE IV: Unified Soil Classification, CL, OL, MH, CH. These soils are not suitable for backfill without special testing and design considerations.

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE SISKIYOU NATIONAL FOREST THE PACIFIC NORTHWEST REGION	CHAINLINK WALL GENERAL NOTES
DESIGNED DON PONIOR REVIEWED RICHARD VAN DYKE SUBMITTED DRAWING BY DATE DEC. 1990 ACAD NAME SOILNOTE	SHT 2 OF

Bradford Quarry Volume Determination

Greg Visconty
Engineering Geologist
Siskiyou National Forest, Region 6

Objective

The Bradford Quarry is located on private land near Goldbeach, Oregon. From about 1965 to 1988, the Forest Service authorized contract entry into this pit for "in-Service" aggregate use, with the owner's permission. Recently, the owner requested being paid, as per agreement, for the rock removed from his land, but records were not kept through most of the quarry activities. A determination of the total volume of rock removed needed to be done.

The following three methods were considered for this volume determination:

(1) Measure the roads that were rocked from this pit (considerable confusion still exists because there are no written records).

(2) Survey the pit, visually estimate what it looked like in 1964, and estimate the volume removed.

(3) Use an AP190 analytical stereoplotter, which would allow three-dimensional digitizing of aerial photographs of the pit from before and after all the quarry excavations.

The stereoplotter was chosen because it was the most accurate method available.

Procedure

Aerial Photography

Two sets of aerial photographs were used for the project: one from 1964 and one from 1986. Both sets were 1:12,000 scale. The 1964 photographs predated any rock removal and were used as the base for digitizing. However, the vegetative cover and the photograph scale prevented acceptable digitizing accuracy around the base of the rock outcrop. The outcrop was fully cleared on the 1986 photographs, so these photographs were used for the base, digitizing only the unexcavated areas around the base of the pit. These data were stored separately. Next, the excavated areas on the north and south ends of the pit on the 1986 photographs were digitized and also stored separately. The perimeters of these excavated areas were transferred to the 1964 photographs by hand, and the original surfaces over the excavated areas were digitized on the 1964 photographs. All three data sets were combined to form two data sets: one for the preexcavation surface and the other for the postexcavation surface.

SURFER

The two data files were entered into the SURFER software program to produce grid files of the surfaces digitized for 1964 and 1986 (figures 1 and 2, respectively). These grid files are used to produce topographical maps and three-dimensional views of digitized data. The grid files themselves are generated using complex mathematical equations, and the user has control over how the data are manipulated by the program. Both data files were processed in SURFER under identical formats. The 1986 surface was compared to the actual current pit configuration to determine the accuracy of the processing format. The following stipulations were used:

(1) *Grid size.* The size was cut to 75 columns by 75 columns (later cut to 75 by 50).

(2) *Method.* The method was krieging.

(3) *Search.* This was a normal, radius 80 search, with the number of nearest points being 10. (These last two values will necessarily change, depending on the concentration of data in the data file. They can be arrived at by trial and error until the resulting surface view resembles the actual surface feature that was digitized. Further accuracy should be field-checked.)

(4) *Limits.* This was default to data limits. (When comparing two separate data files, as in this project, one must ensure that the limits are identical.)

Once this process was completed, the surface grid files were overlayed in the "Utility" subprogram of SURFER to determine the volume difference between the two. If "Cut-and-Fills" is chosen as the output of the volume determination, the program will list (in cubic data units) how much material was removed and how much was added. If the digitizing and processing methods are precise, the volume of material added should be zero.

The volume of rock removed from this pit was 66,000 yards, with an indicated fill of approximately 1,400 yards. The method had an error rate of approximately 2 percent.

Conclusion

The precision of the project was within acceptable limits, but the accuracy of the work could only be estimated by comparing the surface view of the current outcrop condition with the actual outcrop. This comparison was acceptable considering the small scale of the available aerial photographs.

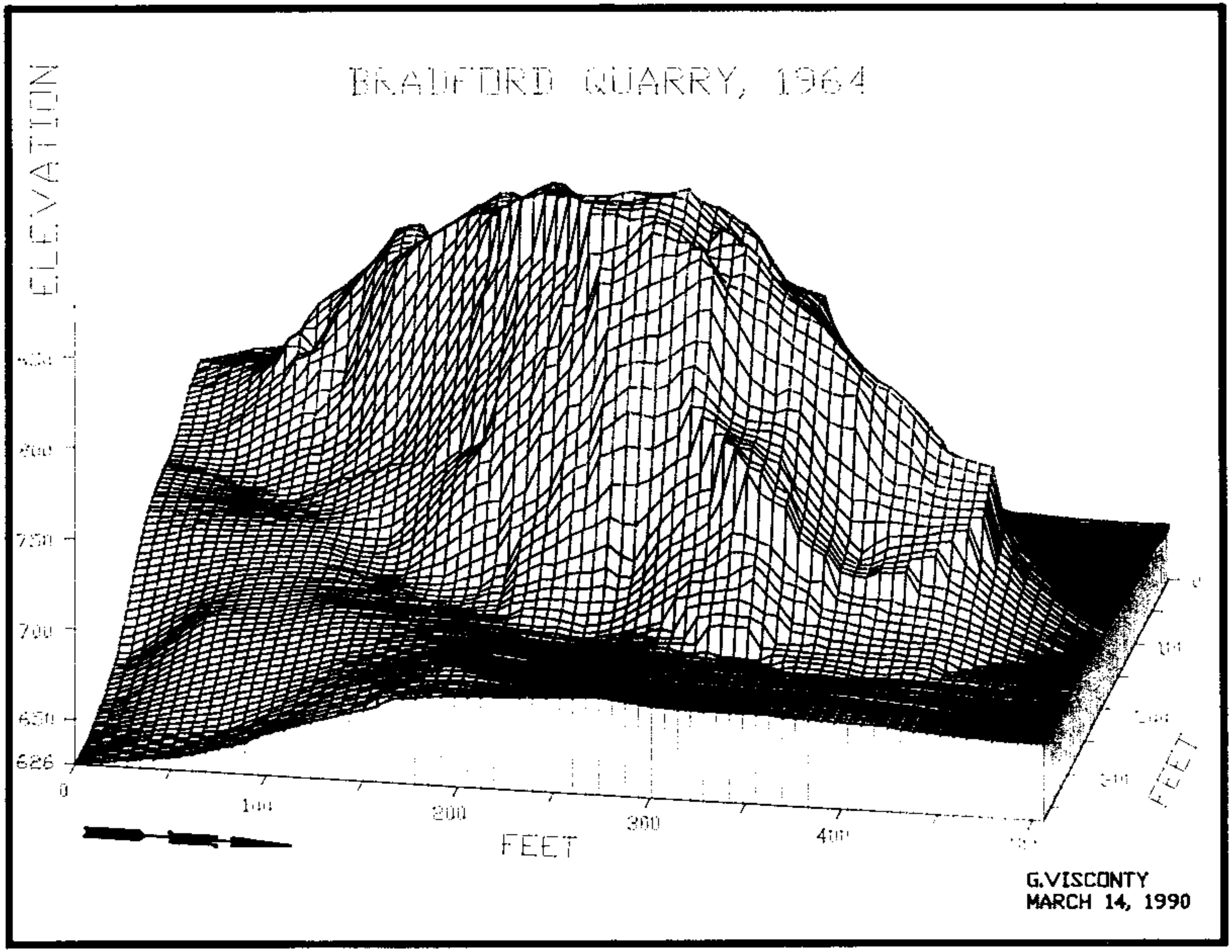

Figure 1.—Grid file of the surfaces for 1964.

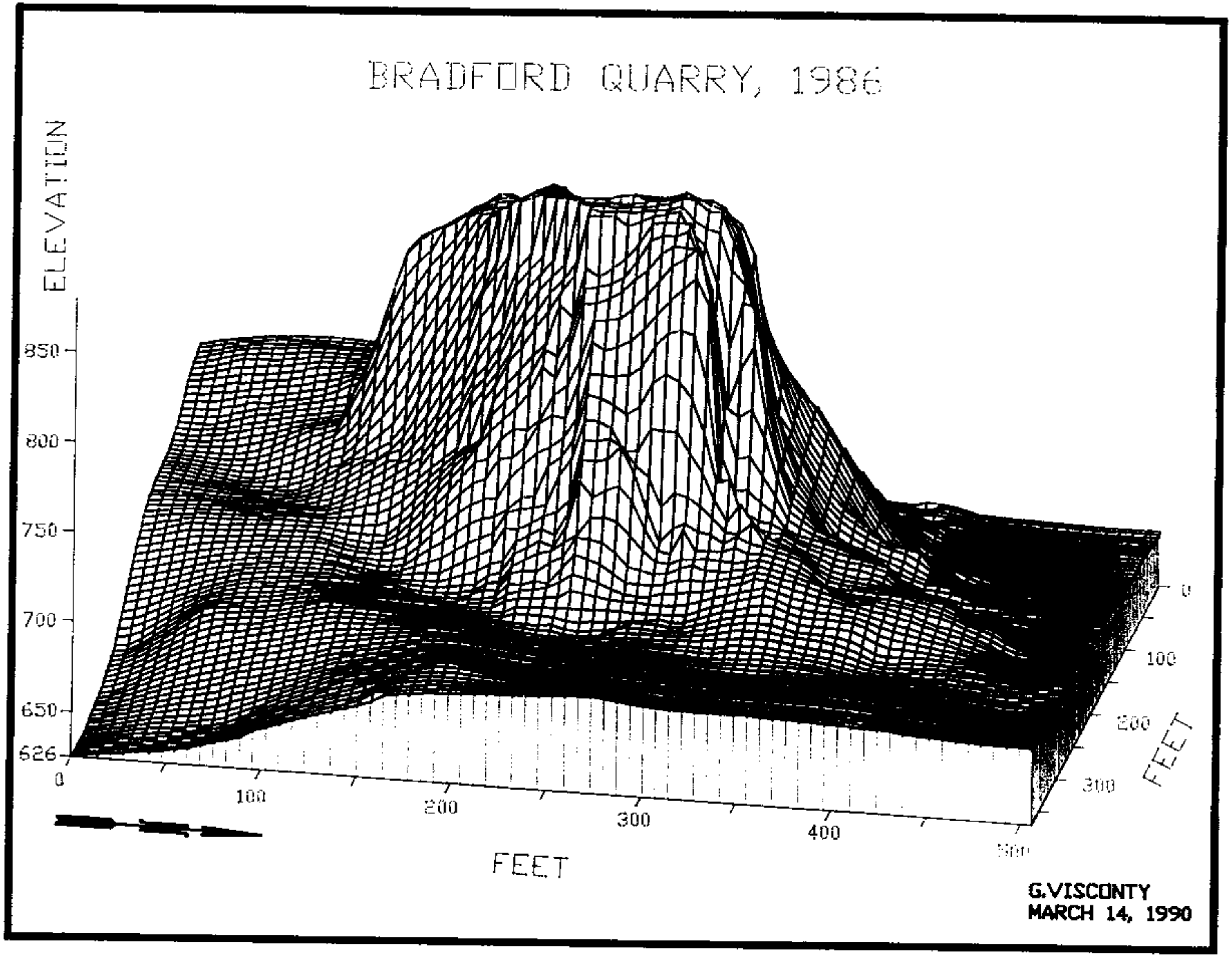

Figure 2.—Grid file of the surfaces for 1986.

Using Autolisp To Compute Design Quantities in AutoCAD Drawings

Tom Strassmaier
Civil Engineer (retired)
Mt. Hood National Forest, Region 6

Introduction

This article might be considered a followup to the July-August *Engineering Field Notes* article "Increasing Productivity by Preparing Road Plans With CADD." The message in that article was that production can be greatly increased, versus manual drafting methods, through designing application packages tailored to specific needs. This is done by creating prototype drawings; blocking and inserting often-used graphics; writing custom menus, macros, and batch processing routines; and so forth.

While that article was helpful, it is possible to do much more when automating the drafting process in AutoCAD by writing "Autolisp" routines that operate both within menus and as external files, which can be "loaded" as needed. (Autolisp is an AutoCAD program language.) Some examples would be: (1) to show spot surfacing areas in a plan with hatching created by "picking" two corners of a box and (2) to use keyboard entries to insert a culvert symbol at the correct station and skew angle with descriptive text.

However, there is an added dimension that can be explored with Autolisp. With a few additional keystrokes, the operator can produce design quantities at the same time.

Background

Figure 1 shows an unedited prototype road plan diagram. It is not a line diagram because the traveled-way edges are shown so that more detail can be added to the drawing. The legend appears on the first sheet only. Note the empty "Sheet Quantities" table along the left margin. The "T" intersection shown at station 0+00 is the default intersection graphic.

Figure 2 is an example of how the same drawing would appear after editing. A custom menu (not shown) provides the interface to the macros and Autolisp routines that do the work.

Some examples of drafting enhancements can be seen in Figure 2. The "T" intersection has been replaced by a "Y"-type intersection. This was done with a single selection from an icon menu (made possible with an Autolisp selection set function). Culvert symbols are inserted with a macro. The variable data in the culvert description tables (that is, station, diameter, and length) are input with block attribute prompts. The typical section number bubble (the "2" in the circle in figures 2 and 3) is controlled with an Autolisp routine that also trims out the underlying centerline as the symbols are created.

While drafting enhancements of this type are very useful, the routines that also perform routine design computations can be even more so. Examples of Autolisp design outputs are shown in Figures 2 through 6 by the hatched areas representing application areas for various subgrade, surfacing, and paving requirements. The operator moves through the drawing using the transparent pan and zoom functions and defining each application area, one by one, with a pick box. The operator then is prompted at each area for design variables (slopes, widths, depths, and so on). The programs compute design quantities for each area, and the areas are hatched, dimensioned (in some cases), and labeled. When the input is complete, the quantities are placed in the "Sheet Quantities" table, along with the pay item number and unit of measurement. The table is constructed, item by item, in a unique layer for later extraction to Lotus, as desired.

The Autolisp routines that control these activities allow for much flexibility. Constants can be changed. Variables can be added or made constant, or vice versa. Number-rounding can be adjusted, and so forth.

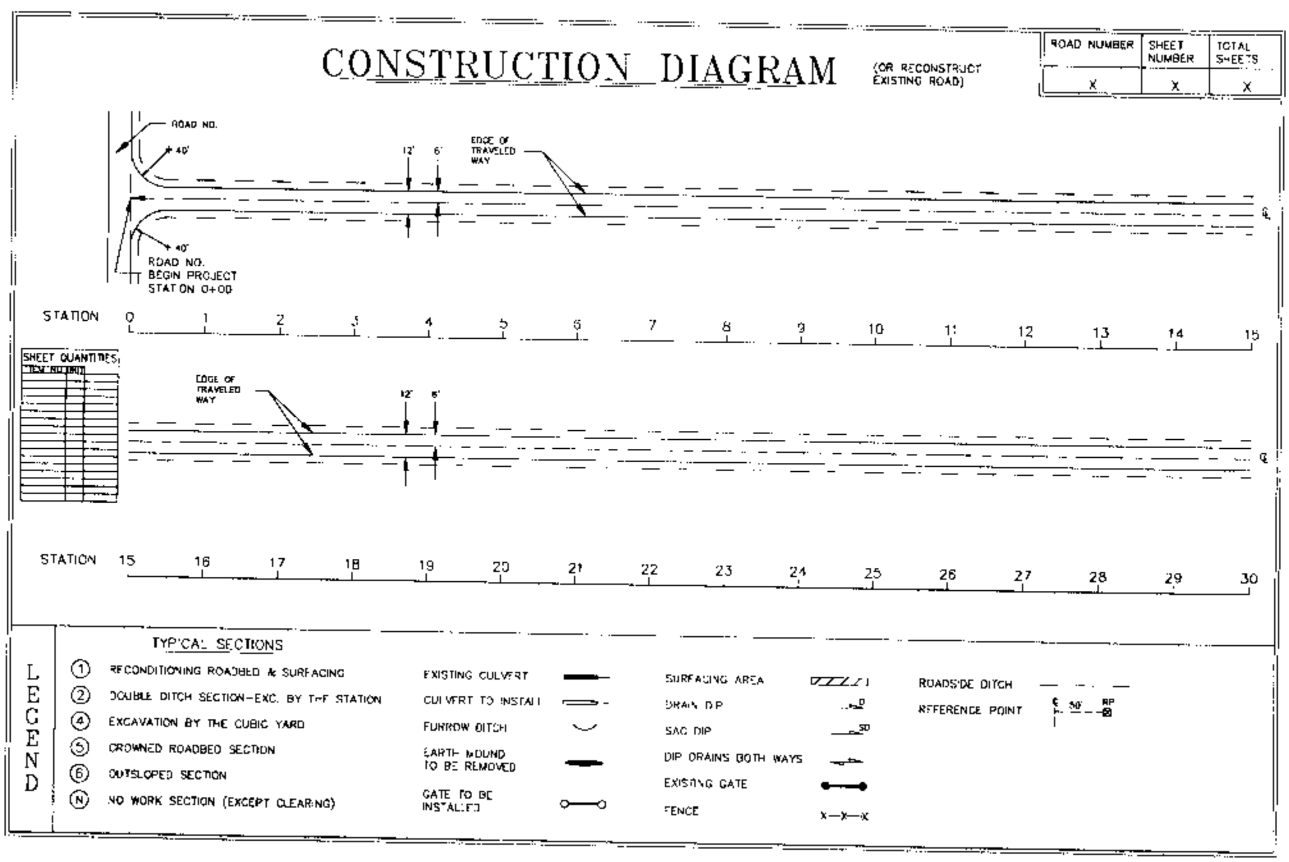

Figure 1.—Unedited prototype road plan diagram.

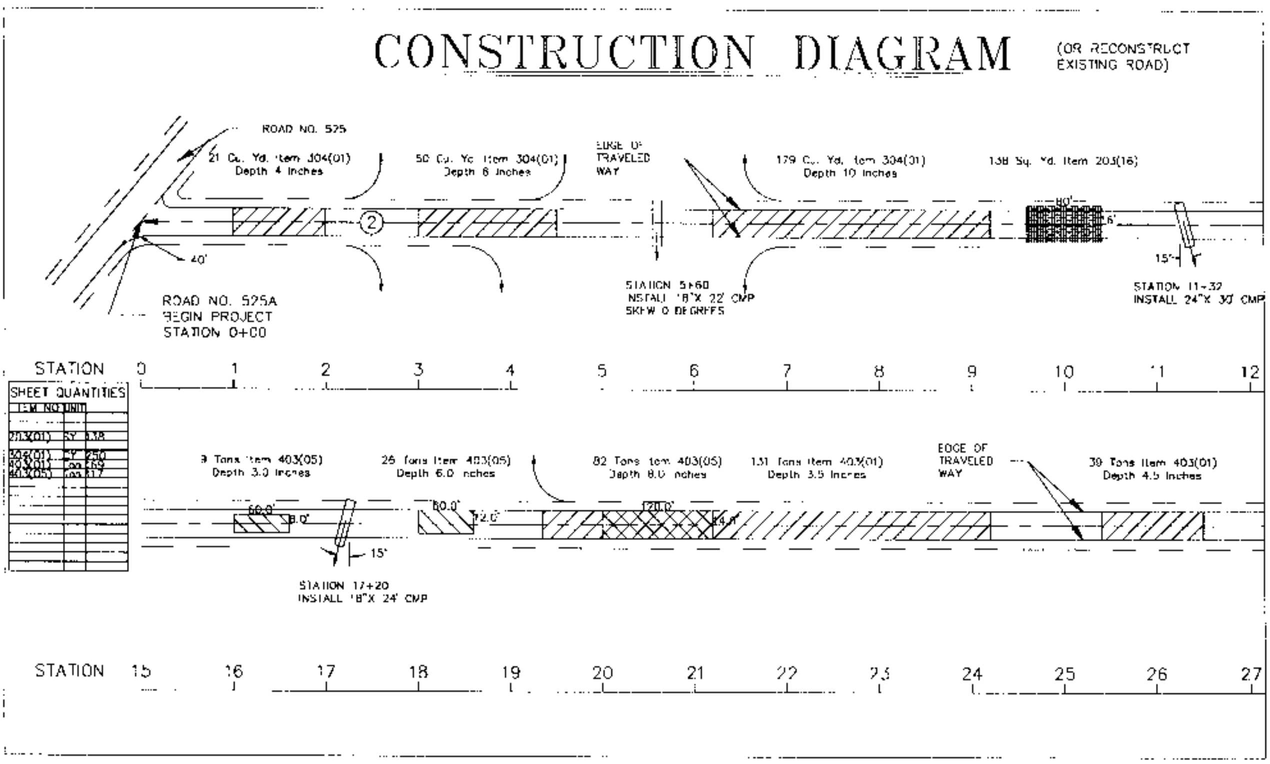

Figure 2.—Edited version of diagram shown in figure 1.

Developed & Tested Autolisp Routines

PAVE_1.LSP SPOT SURFACING

All of these routines are initiated from a submenu in the AutoCAD User Interface pulldowns. The user is prompted for a one-time entry of the pay item number, then to pick the lower-left and upper-right corners of the first application area and to enter the width, depth, and shoulder slopes. The program responds by drawing a polyline around the application area, drawing two vertical edge lines, hatching the area, erasing the polyline to avoid overplotting the road edges (leaving the edge lines), computing the quantity ("21 Cu. Yd." in figure 3), printing a description centered and above the area, and prompting to pick the corners of the next area. This repeats, as shown by the three examples in figures 3 and 4, until terminated, at which time the total accumulated quantity and other data are placed in the "Sheet Quantities" table (figure 7). A swell factor of 1.33 was used in the volume calculations. This can be changed or made a variable.

A detailed description of this routine is given in figure 8, and the Autolisp file is included as figure 9. This routine can also be used for continuous surfacing.

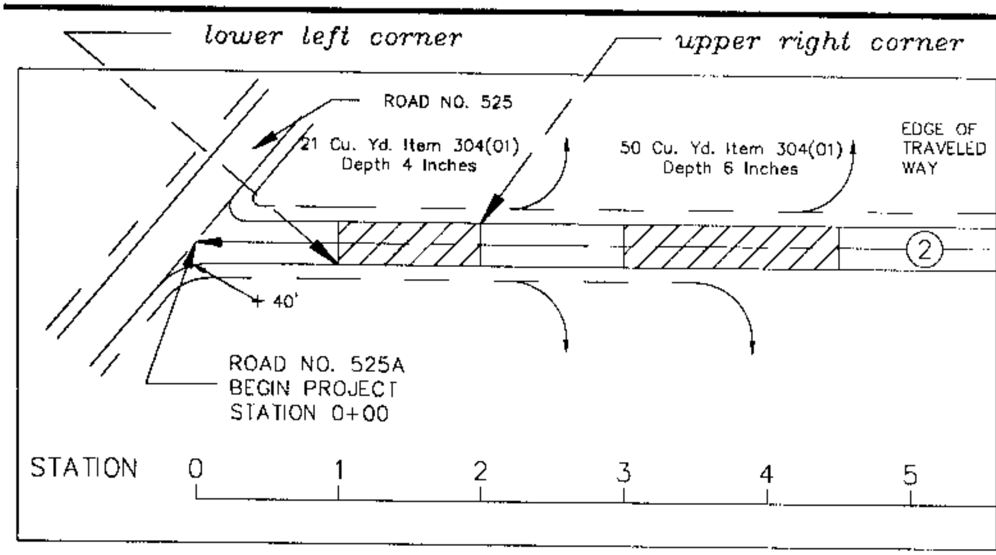

Figure 3.—Sample of Autolisp design output.

SUB.LSP SUBGRADE TREATMENT (Fabrics)

This program is similar to PAVE_1.LSP. The outputs are in square yards. There are no depth and slope variables. A different hatch pattern is used. The length and width dimensions are drawn. An example is shown in figure 4. Again, the total quantity and other data are placed in the table (figure 7).

PAVE_3.LSP PAVEMENT INLAY (Patching)

In this routine, a vertical edge slope is assumed, outputs are in tons, depth is again in variable, the inlay areas are dimensioned, and the hatch pattern is ANSI 31 at 90-degree rotation. Three examples are shown in figure 5.

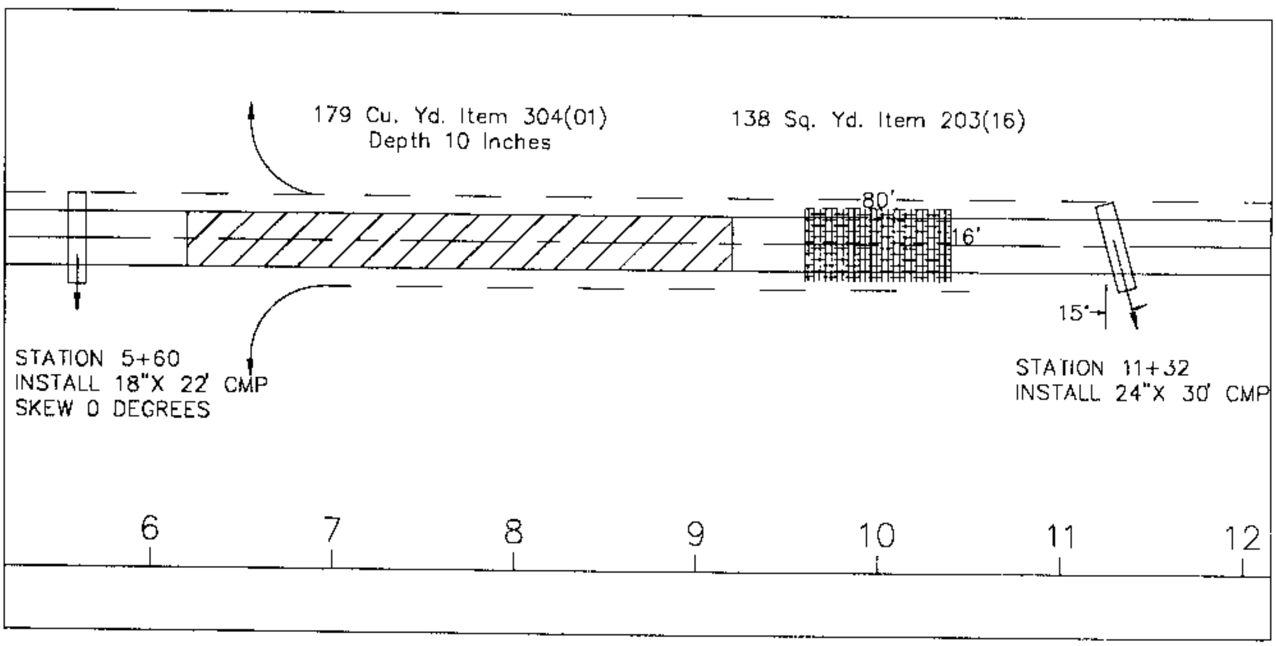

Figure 4.—Sample of Autolisp design output.

PAVE_2.LSP
PAVEMENT OVERLAY

This routine is similar to PAVE_1.LSP. The outputs are in tons. The slope variable is retained because in Region 6 mat edges are sometimes sloped. One should use 0.001 for a vertical edge. The unit weight is calculated at "110#/SqYd/in." This can easily be a variable. Other features, such as beginning and ending station labels, can be added. Three examples of this application are shown in figures 5 and 6. In the one place where a patch is overlain (figure 5), a cross-hatch effect occurs because the patch areas were hatched at 90 degrees.

Autolisp Routines To Be Developed

Aggregate Paving

A routine will be developed for aggregate and paving items with variable width sections and transition sections, such as with turnouts, curve widening, and curves at intersections. This will require the operator to first outline the areas as polylines. During operation, the designer will be prompted to pick the polyline segments and then draw the endlines. The volume computations will be correct because a vertical slope will be applied to the ends and the specified slope to the edges.

Campground & Parking Lot Construction or Restoration

Several programs will be written for campground and parking lot construction or restoration; such as the following:

(1) *Aggregate and pavement quantities.* The operator will first outline areas of common depth and shoulder slope; then the program will operate much as in the routine above. Accurate quantities will be developed when evaluating adjacent sections with differing depths and slopes. A slope can be forced at the outside sections by entering a zero value for the end lines. Individual areas will not be labeled.

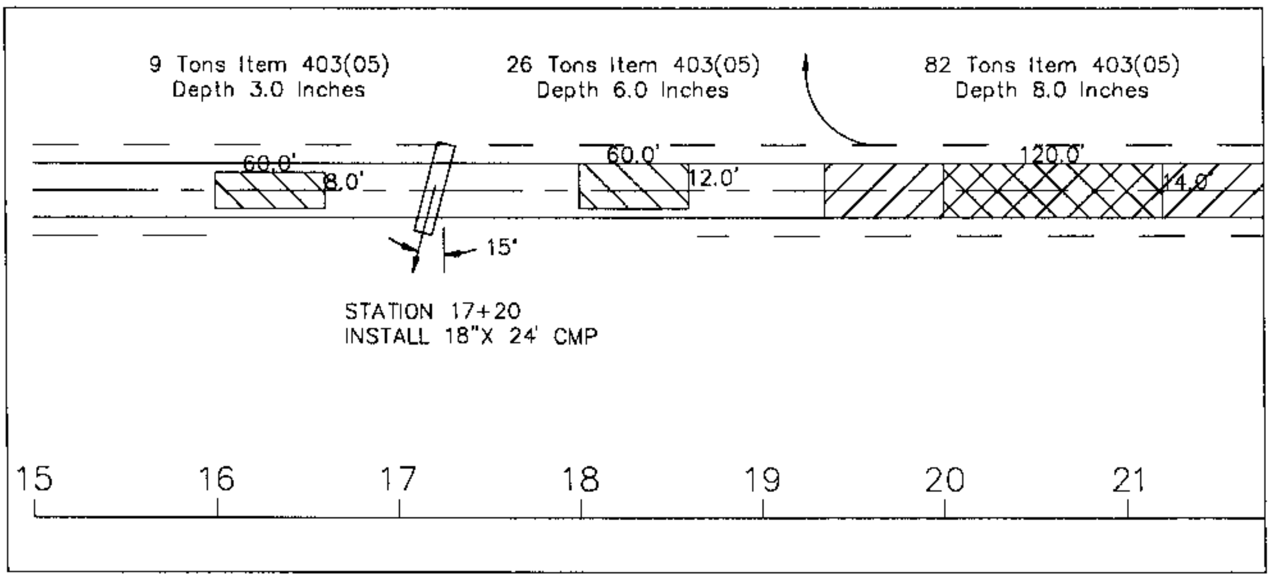

Figure 5.—Sample of Autolisp design output.

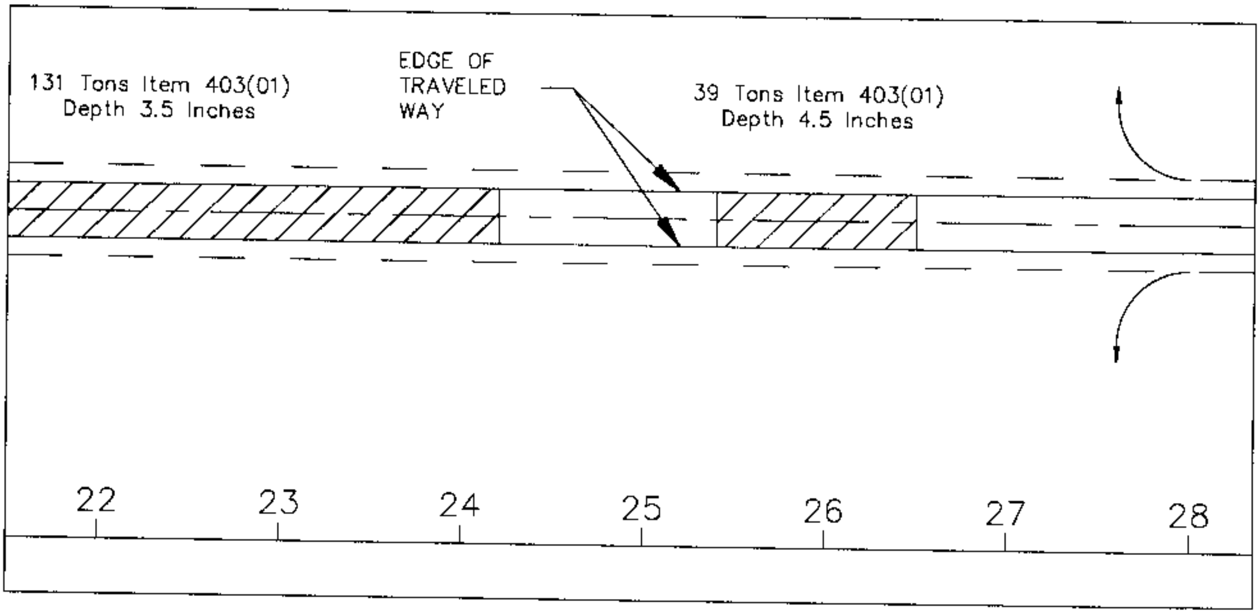

Figure 6.—Sample of Autolisp design output.

(2) *Pavement inlay.* This routine will be similar to the example for road plans, except that the labels will not be placed at each patch.

(3) *Subgrade treatment.* This routine will also be similar to the example for road plans.

Culverts

Similar to the road plans, this routine will prompt the operator to input station, diameter, length, and a reference angle that will indicate the direction of discharge. The program will then insert the culvert at the correct station, scale it for diameter and length, rotate it to the correct angle, place the culvert information text in the drawing below the culvert, and then prompt for the next culvert to install. The program will accumulate culvert lengths by diameter; then when the program has ended, it will place totals in the "Sheet Quantities" table as separate pay items.

Drainage Dips

This will work about the same way as the routine for culverts. There will likely be only one pay item, and the unit will be each.

Drainage Ditches

This will be for furrow ditches, leadoffs, and so forth. The unit is each. These ditches are used extensively in the southeastern coastal plain, with as many as 25 to 30 or more specified per sheet. They are difficult to count. A short Autolisp routine will set a counter and then total these as they are inserted, allowing for 6 or more different types.

Roadside Ditch Protection

Also in the Southeast, there is a need for specifying roadside ditch protection in special treatment, such as sod or paving. Routines will be written for this that are similar to those already discussed, but with variables added to account for foreslope, backslope, depth, and widths.

Quantities Table Contents

A routine will be developed to export the contents of the quantities table to a cost-estimating spreadsheet, such as the one developed by Steve Bingham in Mississippi. The entities in the table will be gathered into a selection set and counted; then they will be repeatedly loaded into a three-attribute insert before exporting with a template file.

Summary

With the increasing workload in road reconstruction, it is hoped that these routines will be useful. They should also work well within Lumberjack plan and profile drawings, with some modification, and for recreation and administrative site development.

These routines could be expanded to be used in the review process. They could operate in a different color and layer, with the outputs displayed off register on the screen. The plans checker would duplicate the process as a check, then make the check layer invisible.

The routines that require "picks" could be designed so that application areas are defined by entering the station numbers from the keyboard. This approach would streamline the variable width applications.

Records could be generated listing the detailed information on individual application areas, individual culvert installations, and so forth. This might be useful as documentation and to help with processing changes during construction.

SHEET QUANTITIES		
ITEM NO	UNIT	
203(01)	SY	138
304(01)	CY	250
403(01)	Ton	169
403(05)	Ton	117

Figure 7.—"Sheet Quantities" table.

Prompt	*Action/remarks*
	User enters Quantities submenu, then elects SpotRock
"Hit <enter> when done:"	
"Pay Item Number:"	<Enter> 304(01)
"Pick lower left corner:"	Pick the lower-left corner of the area to be treated (Station 1+00 in figure 3)
"Pick upper right corner:"	Pick upper right (Station 2+00)
"Width (ft) <12.0>:"	<Enter> (could change default by entering a new value such as 13.5)
"Slope <3.0>:"	<Enter> to accept default (a slope of 0.001 approximates the vertical)
"Depth <4.0>:"	<Enter> to accept default
	Autolisp then draws a Pline around the area, draws two vertical side lines, hatches the area (ANSI 31), erases the Pline to prevent over-plotting (leaving the two side lines), computes quantity of material (CY) and stores this value, creates a text label (21 Cu. Yd. Item 304(01), Depth 4 Inches), and places it centered and above the treatment area
"Pick lower left corner:"	Pick the lower-left corner at Station 3+00 and repeat the process as for the first area, except that a depth of 6.0 inches is selected (Autolisp responds, as before, computing 50 CY)
"Pick lower left corner:"	Repeat for the third area (figure 4), with the depth set to 10 inches (Autolisp calculates 179 CY)
"Pick lower left corner:"	<Enter> because this is the last section.
	Autolisp then reads and stores the current layer name, changes to the layer Quantities, sets the color magenta, places the Item No., 304(01), total quantity, 250, and Unit, CY, in the table as shown in figure 7, and then restores the former layer and redraws the screen

Figure 8.—PAVE_1.LSP for Spot Surfacing.

```
;This routine is used to indicate spot surfacing areas, by hatching,
;in line diagram drawings, compute the volume and place a description
;block at each area, and end by placing the accumulated total in a table.
;Warning: the text styles, x,y coordinates, distances, and volume factor
;are dependent on the UCS and x y scales and other settings peculiar to
;the prototype in the example. These values should be changed for other
;drawing environments.

(prompt "\nLoading PAVE_1 by T. Strassmaier")
(defun c:pave_1) ( / w s d sumv item ll ur ul lr
         tempw tempd temps v lay)
(setvar "cmdecho" 0)
(prompt "\n ")
(prompt "\nHit <Enter> when done: ")
(setq w 12.0                                            ;Set initial defaults
      s 3.0
      d 4.0
      sumv 0.0                                          ;volume accumulator, set at 0
      item (getstring "\nPay Item Number: "))           ;enter item No. once per run
  (while                                                ;loops for defining multiple areas
(setq ll (getpoint "\nPick lower left corner: "))       ;an <Enter> ends the run
(setq ur (getcorner "\nPick upper right corner: " ll)
      ul (list (car ll) (cadr ur))                      ;sets the other corners
      lr list (car ur) (cadr ll))
)
(prompt "\nWidth (ft) <")       ;these display defaults then prompt to accept
(princ w)                       ;or enter a new value which becomes the default
(setq tempw (getreal ">: "))
(if tempw (setq w tempw))
(prompt "\nSlope <")
(princ s)
(setq temps (getreal ">: "))
(if temps (setq s temps))
(prompt "\nDepth (in) <")
(princ d)
(setq tempd (getreal ">: "))
(if tempd (setq d tempd))
(setq l (- (car ur) (car ll))                           ;sets l to length of spread
      v (* d 0.00034208 l (+ (/ (* d s) 12.0) w))       ;volume of spot surfacing
)
(command   "pline" ll ul ur lr "close"                  ;draws rectangle around area
           "hatch" "ansi31" 1200 0 "last" ""            ;hatches it
           "erase" "p" ""                               ;erases it
           "line" ll ul "" "line" lr ur ""              ;draws side lines
;next quantity, item No. and depth are placed centered and above the area
           "text" "s" "s" "c" (list (+ (car ll) (/ l 2)) (+ (cadr ur) 600.0))
           0 (strcat (rtos v 2 0) " Cu. Yd. Item " item) "text" "" (strcat
           "Depth " (rtos d 2 0) " Inches")
)
(setq sumv (+ sumv v))                                  ;accumulates volumes
   )(princ)                                             ;end "while"
(setq lay (getvar "clayer"))                            ;store the current layer
(command   "layer" "m" "quantities" "c" "3" "" ""       ;make layer, set color magenta
           "text" (list -1740.0 6840.0) 0 item          ;print data in Sheet Quantities  table
           "text" (list -1020.0 6840.0) 0 "CY"
           "text" (list -720.0 6840.0) 0 (rtos sumv 2 0)
           "layer" "s" lay ""                           ;resets layer to previous
           "redraw"                                     ;refreshes the screen
)
)(princ)
```

Figure 9.—PAVE_1.LSP Autolisp file.

Possible Problems With Chip Sealing Over an Aggregate Surface

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Introduction

Too often, when a problem with a chip seal over aggregate occurs, a specific cause is difficult to determine. This article discusses possible problem areas with the aggregate base and the prime that may adversely affect the chip seal, along with the chip seal itself.

Assumptions

There are two main assumptions that are built into a chip seal design. First, the chips are "one-sized." A one-sized aggregate, as defined by McLeod (1960), is an aggregate that has a gradation of 60 to 70 percent passing the specified sieve and retained on a sieve having an opening that is 0.7 of the specified size. Second, the surface receiving the chip seal is hard enough so the aggregate particles are not embedded in the existing surface.

Aggregate Base

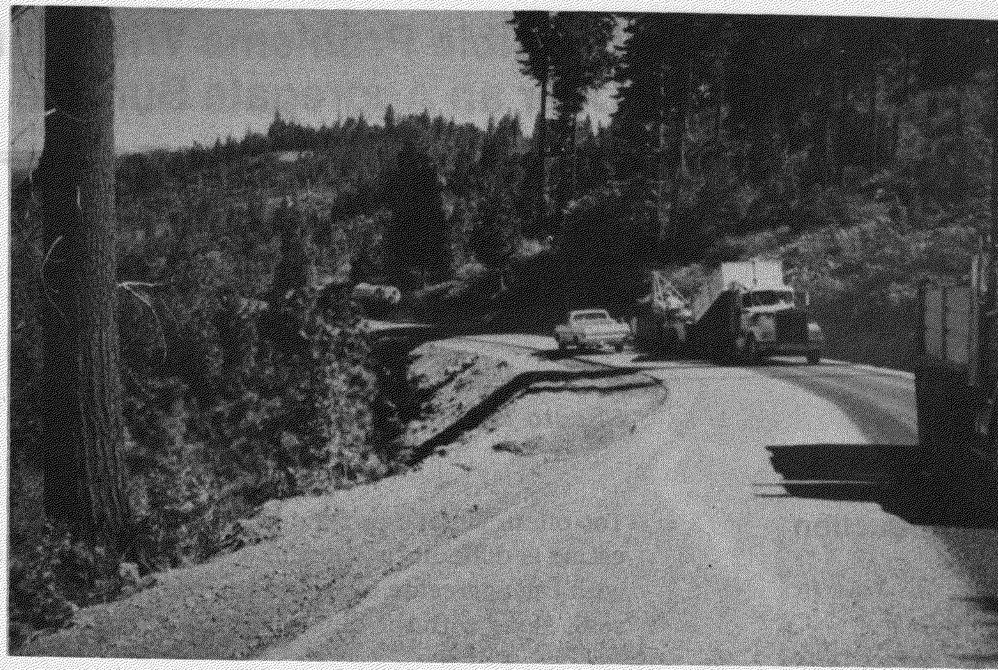
This layer, together with the subbase (if any) and the subgrade, provides the entire structural strength in a typical project that includes a chip seal over aggregate base. Do not consider any structural strength derived from the chip seal.

The following are possible problems:

(1) *Chips become embedded in the aggregate base.* The biggest problem is when the aggregate base allows the chip to be partially embedded in the surface of the base and, therefore, the amount of asphalt material needed to hold the chip in place is reduced. The most obvious cause is that the aggregate base is not compact.

(2) *The aggregate base is out of specifications.* The problem is the gradation is not within specifications and allows the chip to be either embedded in the surface or the base is of insufficient strength and shears from torque or centrifugal forces.

(3) *There is degradation of the aggregate base.* The quality of the aggregate is such that it degrades rapidly.



(4) *There is inclement weather.* If the chip-sealed surface is used during inclement weather and there is insufficient strength in the aggregate base, the surface will deform, resulting in breakup of the chip seal.

Prime

There are several reasons for using prime. It preserves the aggregate base in a compact state by maintaining the moisture content. By preserving the aggregate base in a compact state, construction and limited public traffic can be allowed without appreciable damage. The prime penetrates the surface of the aggregate base and adds to the total thickness of the asphalt-treated material. Also, the prime provides a surface to which the chip seal will readily adhere. The traditional prime is an MC–70 cutback asphalt. The asphalt spread rate depends on the porosity or amount of fines at the surface of the aggregate base. The moisture content of the aggregate base should be at optimum, and the surface of the aggregate base should be damp just before the application of the prime coat.

The following are possible problems:

(1) *There is too much prime.* If too much prime is applied and the entire amount does not penetrate, a puddle of residual asphalt remains on the surface of the aggregate base. The end result of the puddled areas is that when the chip seal is applied, those areas will be flush with asphalt cement and will probably bleed. The flush areas must be blotted before applying a chip seal.

(2) *The prime is picked up.* If traffic is allowed to use a primed road too soon, the prime may adhere to the tires and cause extensive damage to the treated surface. If there is any anticipated or possible use of the

surface by traffic before the completion of the curing period, the prime should be blotted to prevent damage.

(3) *Air pollution regulations prevent using MC-type prime.* In some areas, local air pollution control regulations prevent the use of MC-type cutback asphalts. Substitutes that have been used are diluted emulsified asphalts and SC-type cutback asphalts. Undiluted emulsified asphalts will not penetrate the aggregate surface. Emulsions of the slow-setting type, diluted with four or five parts of water, have served reasonably well as an alternative type of prime. Multiple applications should be made so that the residual asphalt is approximately the same as a normal prime. Because slow-setting emulsified asphalts contain no solvents, they allow for the quicker placement of subsequent courses.

(4) *Chip sealing is placed over fresh prime too soon.* Another major concern is when not enough time is allowed before placing the subsequent chip seal. If the MC-type diluent (kerosene) is not allowed to evaporate before placing the chip seal, the entire chip seal is softened by the remaining diluent. This is especially true when a SC-type cutback asphalt is used; the diluent is usually diesel fuel. Environmental conditions greatly influence the time necessary for the prime to cure. Subsequent courses should not be placed if there is any "asphalt-type" smell present.

(5) *The chip sealing is not done soon enough.* Allowing too much time between the prime and the subsequent chip seals may allow existing traffic to cause extensive damage to the prime and, therefore, the surface of the compacted aggregate base.

(6) *Repair of the primed surface is done after chip seal placement.* Any damage to the primed surface should be repaired before placing a chip seal. If patching is necessary, these patches should be sealed with a heavy application of fog seal before placing the chip seal. Otherwise, a portion of the chip seal emulsion will be absorbed and the chips will not adhere.

Asphalt Emulsion/ Aggregate (Chip) Seals

It is important that the spread rates for the chips and the emulsion be properly designed. Normally, a double chip seal is applied over an aggregate base. Each subsequent layer uses aggregate one-half the nominal dimension of the preceding layer. It also is normal procedure to design each chip seal layer for both aggregate and emulsion spread rates and then add the two emulsion requirements together. Forty percent of this total is applied with the first application of chips and the remaining 60 percent with the second application of chips. The amount of residual asphalt required for a chip seal or seals is based on the average least dimension of the aggregate. The average least dimension is calculated from void space, gradation, and shape of the aggregate. Other factors affecting the required amount of residual asphalt include the kind and amount of traffic and condition of the surface on which the chip seal is being placed.

The following are possible problems:

(1) *The factors change.* If any of the factors change from what was used in the chip seal design the resultant chip seal surface will be adversely affected.

(2) *The chips are not clean.* The cleanness of the chips is important because fines have a tremendous amount of surface area and will prevent the asphalt from properly coating the chips.

(3) *The timing of the chip seal placement is poor.* Chip seals placed late in the season, after mid-September, are likely to have problems, with the emulsions adhering to the chips and curing before the winter season.

(4) *The moisture condition of the chips is not good.* The surface moisture condition of the chips when they are placed affects the adhesion of the emulsion to the chips. The chips should be damp, but not wet, when applied to the fresh emulsion.

(5) *An improper roller is used.* A rubber-tired roller is the roller of choice for all types of chip seals. There may be limited occasions when a smooth-drum roller may be used, but its use is not encouraged and should only be allowed with careful preparation. A vibratory roller should never be used.

(6) *The type of emulsion is poor.* The selection of the type of emulsion and any additives, such as latex, has an effect on the longevity of the chip seal. The emulsions with latex additives are generally considered more forgiving because they retain the chips better and bleed less than emulsions without latex additive.

(7) *There is too much time between chip applications.* The amount of time between the first and second chip seal of a double chip seal application should not be excessive. This is because the amount of emulsion applied with the first course of aggregate is only 40 percent of the total, which makes the aggregate more susceptible to displacement during this period.

Summary

When constructing a chip seal over an aggregate base, one must consider several factors involving the aggregate base, the prime, and the emulsion/chip application. A properly constructed chip seal over an aggregate base road surface can be an economical solution for some low-volume roads.

Proper design cannot be overemphasized. The one factor that will probably change the application rate of the emulsion and the chips is the shape of the aggregate. The Flakiness Index measures the relative flatness of the individual aggregate (figure 1).

As described here, a double chip seal is normally applied to an aggregate surface to provide a durable light-duty road. A single chip seal should not be

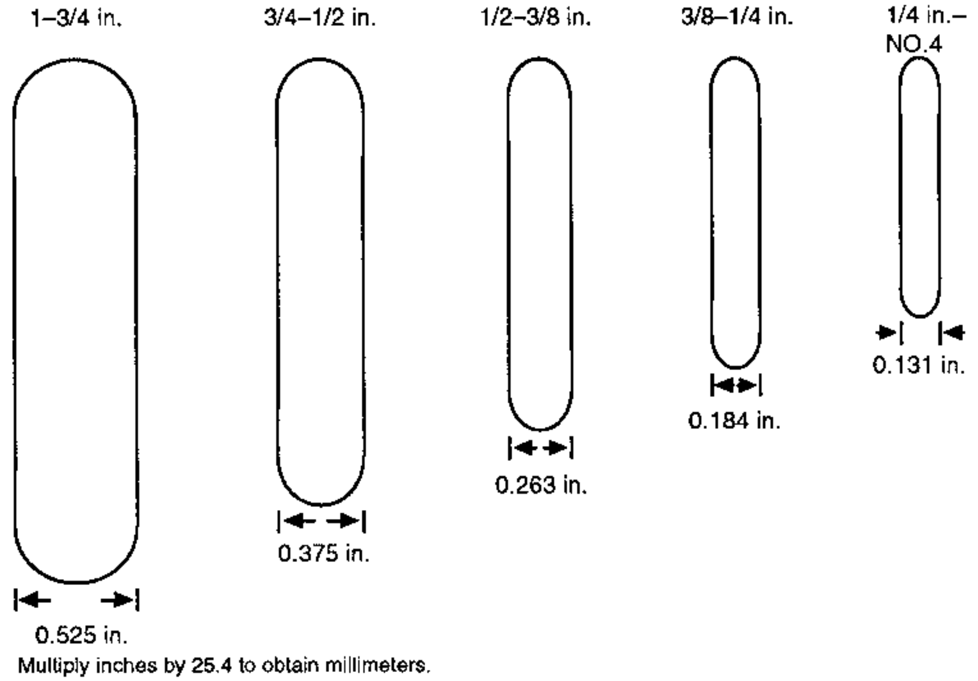


Figure 1.—Slotted sieve openings for testing aggregates for elongated flat particles.

placed on an aggregate surface. The life of a single chip seal on this type of surface is not much more than can be obtained by applying slightly heavier amounts of prime and sanding thoroughly. Single chip seals should only be used on existing chip-sealed or asphalt-mix surfaces.

Double chip seals, on structurally adequate base, have been applied on several Forests and have commonly carried 20 to 30 million board feet per year, with lives of 5 to 8 years. Several on the Shasta-Trinity National Forests were placed in the early 1970's and, with a couple of subsequent single chip seal applications, are still functioning.

There are many positive factors for using chip seals. Several alternative methods of construction can be designed to accommodate local conditions. Any negative factors commonly associated with chip seal failures are usually caused by improper design or construction and should not preclude the future use of these types of surfaces.

Reference

McLeod, Norman W. 1960. "Basic Principles for the Design and Construction of Seal Coats and Surface Treatments with Cutback Asphalt and Asphalt Cements." Supplement to *Association of Asphalt Paving Technologists' Proceedings*, Volume 29.

Trail Hardening Test

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Introduction

Trails located through areas of poor soils and steep slopes and in undrained or wet locations are easily damaged and will eventually be of concern to Forest management. As trail users avoid these problem areas, the trails become wider and the problem is compounded; vegetation is lost and soils erode into dusty channels. These problems of drainage, erosion, and braiding are universal to trail managers. The best way to avoid these problems is routing, or rerouting, trails away from problem areas, but this option is not always feasible. Funding, terrain, and management constraints may prohibit the relocation and reconstruction of a trail system. In these cases, the solution lies in stabilizing the trail locations that contribute to resource damage.

In 1987, the State of Washington Interagency Committee for Outdoor Recreation and the Forest Service entered into an agreement to study trail tread hardening techniques. The State provided the funding for this project. The purpose of the study was to "evaluate the effectiveness of existing trail hardening methods and materials" on multipurpose trails—those used by hikers, motorcyclists, and horseback riders.

Treatments

The following trail tread hardening techniques or products were selected for evaluation in this project.

Soil Cement

Soil-cement treatment of a trail (or road) consists of mixing a calculated amount of Portland cement with native soils. It is a technology that has been in use for many years. Different methods of mixing the cement with the soil have been tried. For example, it has been mixed in cement mixers, and it has been mixed in-place (that is, spread on the ground and mixed into the soil materials). Because of the relative inaccessibility of the trail segments chosen and the lack of confidence in being able to control proportions of mix when spread on the ground, the soil, cement, and water were mixed in wheelbarrows and then spread on the trail surface. However, the process of spreading the cement on the ground and mixing it into in-place soils also was tried. Specific details of installation and the cost of soil cement are discussed later in this article.

Concrete Blocks

A precast concrete block, marketed under the name "Grass Grid paving block" and made by Smithwick Block Company and Western Block Company of Portland, Oregon, was installed. The blocks were available at a local concrete materials outlet. These blocks are 17.25 inches wide by 23 inches long by 3.5 inches high, with 4 by 4-inch holes. The blocks weigh approximately 60 pounds each and have a minimum compressive strength of 4,000 pounds per square inch (psi).

Geoweb

Geoweb is a grid confinement system made out of high-density polyethylene. The manufacturer, Presto Products, Inc., of Appleton, Wisconsin, donated materials for the project. Geoweb comes either 4 or 8 inches thick and in sections 8 feet wide by 20 feet long (expanded). When collapsed, the sections are 11.5 feet long by 4 or 8 inches thick. A 4-inch-thick section weighs 57 pounds.

ECO–50 (Asphalt Polymer)

ECO–50 is a polymerized asphalt product sold by Evergreen Chemical Products of Oakland, California. It is used as a soil solidifier on trails and is applied to a trail scarified to the depth of treatment desired. After mixing with the specified proportions of water and soil, it is compacted in-place and allowed to cure and harden. Up to 4 weeks of curing may be required before the ECO–50-treated trail reaches its full strength. However, the trail can be used before reaching full strength.

Installation

Two trail segments in need of maintenance and/or reconstruction on the Naches Ranger District of the Wenatchee National Forest were chosen for evaluation. On the Naches Ranger District, approximately 400 feet each of Bear Creek trail #943 and Quartz Mountain trail #948 were hardened. The

Table 1.—Comparison of treatments used on the Bear Creek trail.

	Concrete blocks	*ECO–50*	*Geoweb*	*Soil cement*
Ease of installation	Easy (1)	Moderate (3)	Moderate (2)	Difficult (4)
Availability	Masonry stores (2)	Manufacturer (4)	Distributor (3)	Hardware stores (1)
Cost	$9.08 per linear foot (4)	$7.75 per linear foot (3)	$6.03 per linear foot (1)	$6.67 per linear foot (2)
Transportability	Hard work (4)	Work (2)	Easy (1)	Hard work (3)
Traction	Good (1)	Good (3)	Good (3)	Good (2)
Tread protection capability	Excellent (1)	Fair (4)	Good (3)	Excellent (2)
Durability	Very good (2)	Poor (4)	Good (3)	Very good (1)
Esthetics	Shape and form do not fit well in the woods (3)	Takes on color of native materials (1)	Shape and material do not fit well in the woods (3)	Color close to native materials (2)

Rankings within each category are shown in parentheses.

Bear Creek trail was relocated before hardening. Both segments are in the Little Naches River drainage, which has high recreational use. These trails are mainly used by motorcyclists. Horseback riders, mountain bikers, and hikers also use them.

Bear Creek Trail #943

The Bear Creek trail test section is located adjacent to Bear Creek and Forest Service Road 1911. Site elevation is approximately 3,200 feet above the mean sea level. The low-strength soils present are prone to severe rutting from motorcycle use and erosion once the duff layer has been removed. The duff layer is approximately 4 inches thick over a substrate of mottled clay that is rich in organic material. The drainage is poor. The site was chosen because of the wet, low-strength soils, the need to relocate the trail away from Bear Creek, and the easy access. The trail grade in its new location averages about 3 percent. The length of each treatment averages around 60 feet. The water required for construction (that is, compaction and mixing with the asphalt and soil cement) was obtained from Bear Creek. A comparison of the four different treatment methods for this trail is shown in table 1.

Segment 1. The first segment constructed was built with the Grass Grid paving blocks. The trail grade was first leveled and brushed. The duff layer, where present, was not disturbed. A 3-foot-wide strip of geofabric was then spread over the prepared surface. The blocks were hauled from the road in wheelbarrows, two or three at a time, down the hill and cross country about 400 feet to the trail. The concrete blocks were then placed directly on the fabric (figure 1). The long dimension of the block was placed perpendicular to the trail centerline. No. 3 rebar anchors, 40 inches long and bent to shape, were placed at each corner of the blocks. Some blocks were left unanchored to see how well they would stay in-place. The holes in the blocks were then backfilled and compacted, with 3 inches of backfill placed over the blocks and then compacted. Backfill was hauled an average of 130 feet. Log rails, 6 to 10 inches in diameter, were added the following year to keep trail users (especially motorcyclists) on the relocated trail. A total of 54 blocks were used on the 75 feet of trail constructed in this segment. The total cost of installation and materials was $8.89 per linear foot.

Results. The concrete block segment on the Bear Creek trail has functioned extremely well (figure 2). Only at the approach to the trail are the blocks exposed. Unanchored blocks have stayed in-place. The trail surface is extremely durable.

Segment 2. The second segment was constructed in much the same manner as a standard Forest Service trail turnpike (FS–7700–70 from FSH 2309.18, *Trails Management Handbook*), except the trail surface was treated with ECO–50. The ground surface was first cleared of all brush and debris. A ditch was constructed, and a culvert was installed. A 3-foot-wide strip of geofabric was then laid down on the ground. Retainer logs were cut and stacked in-place to form a trail tread width of approximately 2 feet. The area between the logs was then backfilled and compacted to within a few inches of the top of the logs. The average length of haul was about 160 feet. Another layer of woven geofabric was placed over the top of the compacted backfill material. This was done to better control the depth of soil material

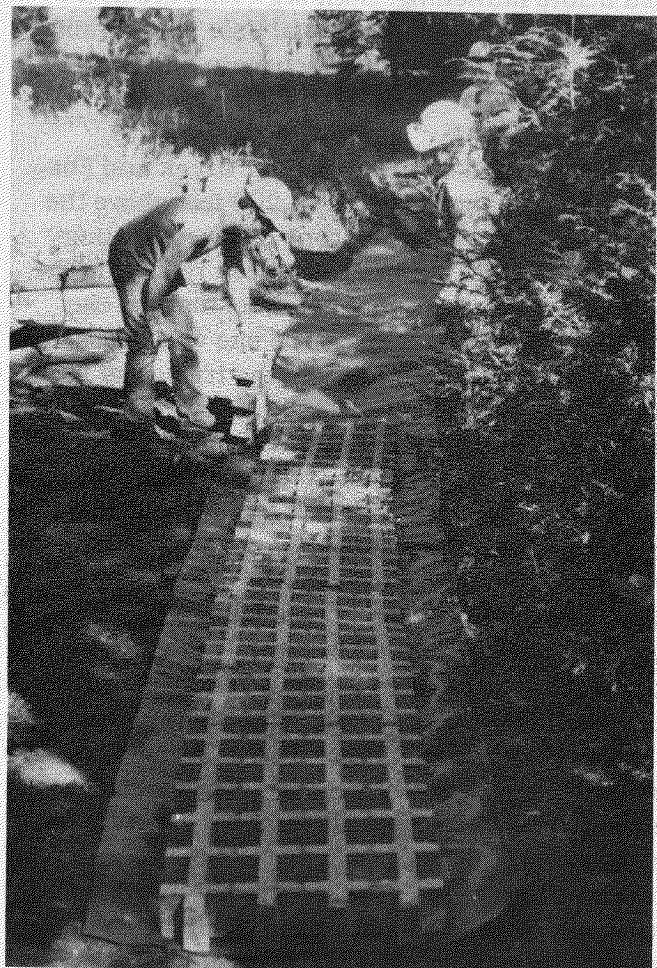

Figure 1.—Placement of the concrete blocks on geofabric on Bear Creek trail segment 1 (October 1987).

Figure 2.—Bear Creek trail segment 1 after two seasons of use (June 1990).

treated with ECO–50. Then, 2 to 3 inches of well-graded sandy backfill was placed over the second geofabric layer. The ECO–50 was applied to the backfill and thoroughly mixed with a rake; it is generally mixed with 7 parts water to 1 part ECO–50. A 2-gallon garden-type sprinkler can was used to apply the ECO–50 to the trail; 2 gallons of ECO–50 mix treat approximately 4 feet of trail to a 3-inch depth. Compaction was done by tamping with a rake on end and trampling the mix with feet (figure 3). The trail was then left to cure. The cost of materials and installation was $7.75 per linear foot.

Results. The ECO–50 segment locally showed signs of beginning to break up before the end of the first year. By the end of the third season, the geofabric was locally exposed (figure 4). Where it did not break up, the surface seemed to function adequately; the segment maintained a natural-appearing surface. The areas that broke up were repaired during the 1989 field season with a more concentrated solution of the ECO–50. The stresses of motorcycle traffic may be too great for the ECO–50. The backfill may have been too clean (that is, not enough fines to bind the mix), and the presence of the second layer of geofabric (acting as a plane of weakness) may have contributed to the poor functioning of ECO–50 on the Bear Creek trail.

Segment 3. Test segment 3 of the Bear Creek trail was constructed using Geoweb. In preparation, the ground was brushed and large stubs removed. A 3-foot-wide strip of geofabric was then laid over the ground. The duff layer was not removed. The Geoweb sections were expanded to their full dimension (8 by 20 feet) and cut into sections that, when expanded, were approximately 2.5 by 8 feet. The Geoweb was laid on the geofabric, staked open with rebar, and then backfilled with clean granular sand and gravel (3-inch minus) (figure 5). The haul distance to the midpoint of the segment was approximately 220 feet. Log rails were added the following year. An additional depth of approximately 2 to 3 inches of compacted fill was placed over the top of the Geoweb. The cost for the installation of Geoweb was approximately $6.03 per linear foot.

Figure 3.—Compacting the ECO–50/soil mix on Bear Creek trail segment 2.

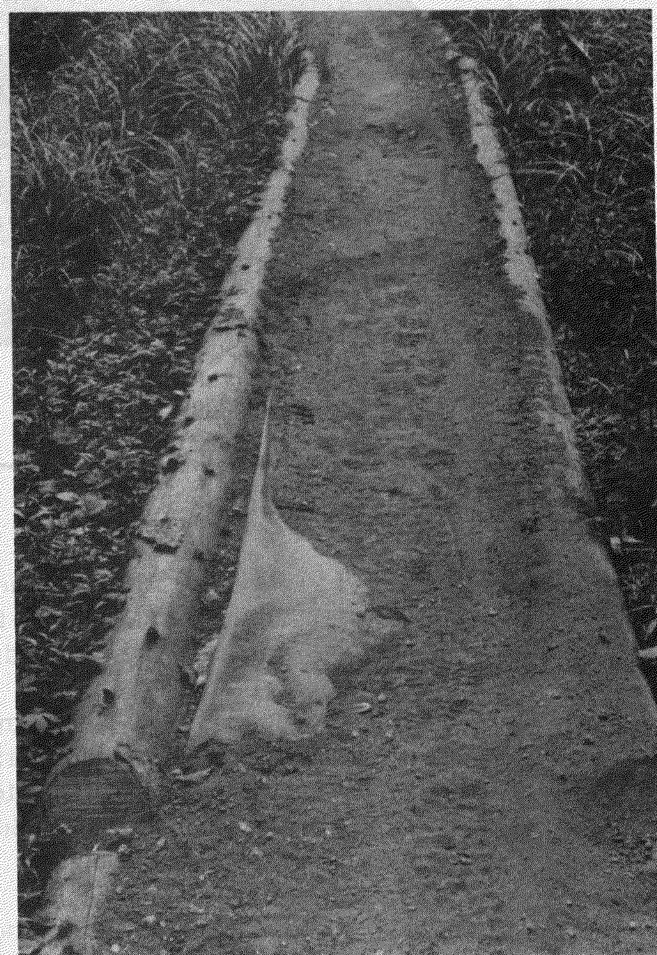

Figure 4.—The ECO–50 segment after two seasons of use on Bear Creek trail segment 2. Geofabric is exposed at the lower-left corner of the photograph (August 1990).

Figure 5.—Backfilling the Geoweb on Bear Creek trail segment 3 (October 1987). Log rails were added later.

Figure 6.—Geoweb is locally exposed after three seasons of use on Bear Creek trail segment 3 (August 1990).

Results. Although the Geoweb became exposed from traffic, it still functioned fairly well over the study period (figure 6). The surface, although not hardened or stabilized, was acceptable for walking and riding.

Segment 4. This segment was reconstructed by adding a culvert, bringing in additional fill material, and placing a layer of geofabric. A ditch was constructed to concentrate the water. It was drained via a culvert to the opposite side of the trail. Segment 4 at the beginning of the 1988 season of use is shown in figure 7.

Results. The trail functioned fairly well even with the minimal treatment, mainly because drainage was established and the trail prism constructed above water level. However, with use, this surface is still subject to rutting when wet (figure 8).

Segment 5. Soil cement was used for tread hardening of test segment 5. Little surface preparation was required because the trail location was grassy and flat. A ditch was dug to intercept water, and a culvert was installed to pass the water under the trail. Geofabric was laid down directly over the grass. Side rails were cut and staked in-place about 24 inches apart. The area between the side rails was then backfilled to within a few inches of the top of the rails. Guidelines for the use of soil cement as a road construction material are available through the Portland Cement Association, whose handbooks recommend soil laboratory testing to determine the optimum soil-cement-water ratios. Because laboratory testing equipment was generally unavailable, the cement content needed to stabilize the soils (12 percent) was determined by an educated estimate (based on association literature). The haul distance was approximately 430 feet. Seven heaping shovelfuls of soil were well mixed with one heaping shovelful of cement and the proper amount of water to give a stiff mix. The mixing was done in wheelbarrows and dumped onto the trail. The mix was spread and compacted to a 2- to

Figure 7.—Bear Creek trail segment 4 was constructed using a layer of geofabric (June 1988).

Figure 8.—Bear Creek trail segment 4 after two seasons of use (June 1990).

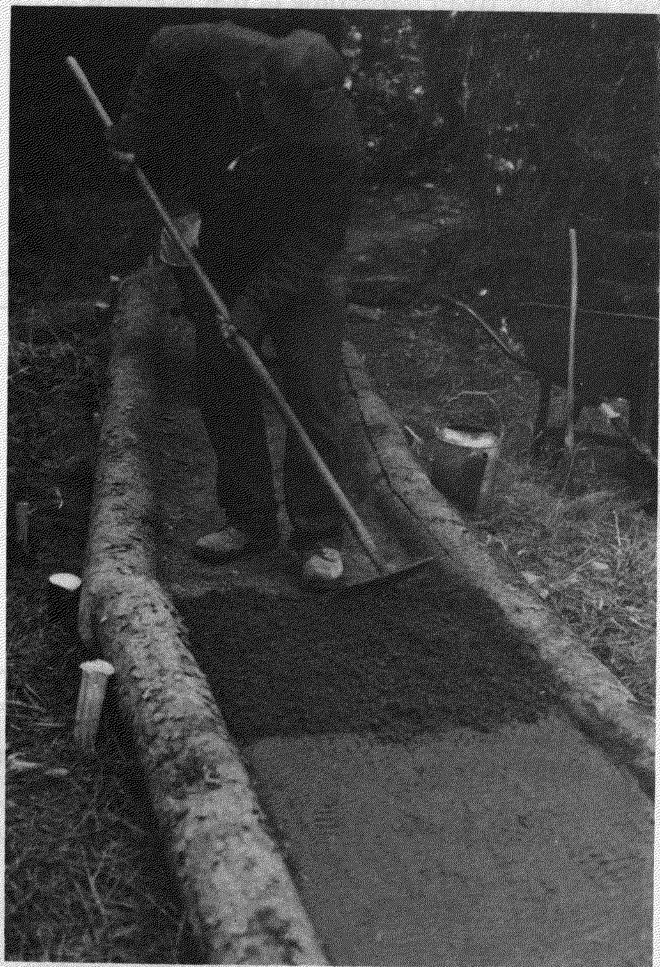

Figure 9.—Compacting the soil-cement mixture on Bear Creek trail segment 5 (October 1987).

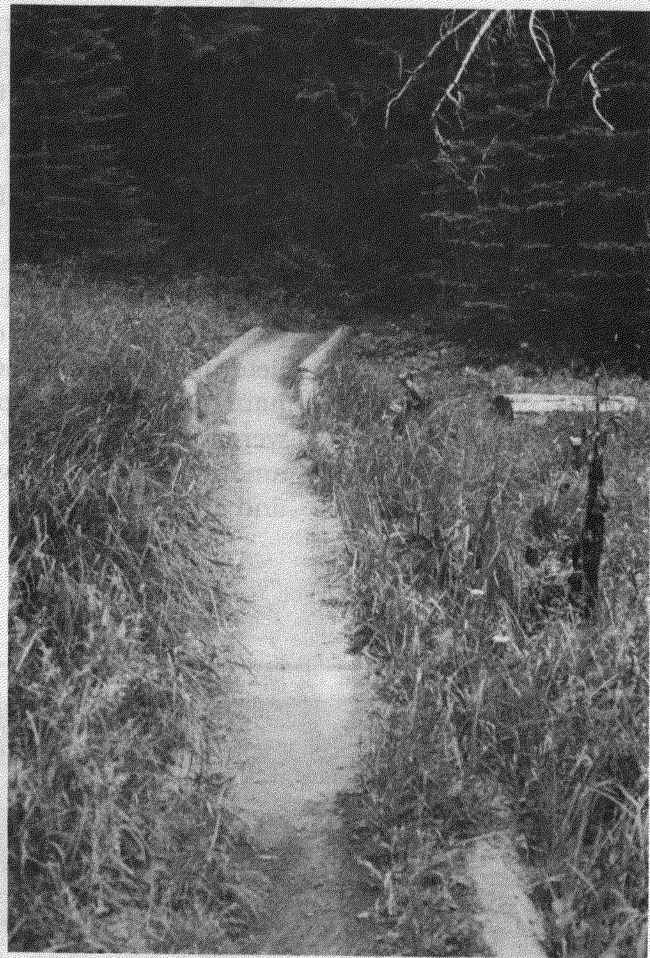

Figure 10.—The soil-cement segment after three seasons of use on Bear Creek trail segment 5 (August 1990).

3-inch depth with rakes and footpower (figure 9). After curing, the trail surface was sealed with ECO–50; sand was used to blot the excess ECO–50. The approximate cost of constructing segment 5 was $6.67 per linear foot.

Results. The trail surface was well hardened, durable, and smooth and has a reasonably natural-looking surface (figure 10). Some cracking has occurred in the first few feet of the soil-cement segment; it has thus far performed extremely well.

Segment 6. The standard Forest Service turnpike with geofabric and side rails was constructed for segment 6. No subgrade preparation was required before laying down the geofabric. A ditch was constructed to the culvert placed in segment 5. The geofabric was laid down, side rails were cut and stacked in-place, and backfilling was done with material found less than 100 feet from the trail. Segment 6 at the beginning of the first season of use

(1988) is shown in figure 11. The approximate cost of constructing segment 6 was $5.18 per linear foot.

Results. This segment functioned well, although the surface became slightly rutted and thus subject to water ponding. Use when wet would likely lead to further rutting. It is natural looking, especially with grasses growing inside the log rails, but outside the wheel track (figure 12).

Quartz Mountain Trail #948

The Quartz Mountain trail test section is located on a very draughty southwest aspect slope. Project elevation is approximately 3,000 feet. The site is extremely dry, dusty, rocky, and steep. The trail grade averages about 30 percent through test segment 3. Traffic on the existing trail has rutted the tread. In places, the trail was as wide as 10 feet, where motorcyclists accelerate and spin out as they climb the hill. The soils are dry, loose, and nonplastic and generally lack vegetation for stabilization. The work was done during October 1987 and June 1988. A comparison of the treatment methods for the Quartz Mountain trail is shown in table 2.

Figure 11.—The completed standard Forest Service turnpike on Bear Creek trail segment 6 (June 1988).

Figure 12.—The standard Forest Service turnpike on Bear Creek trail segment 6 after three seasons of use (August 1990).

Segment 1. Trail tread segment 1 of the Quartz Mountain trail was hardened using the Grass Grid paving block. The subgrade on the existing alignment was smoothed and graded so that the blocks would lay flat. The blocks were hauled, two or three at a time, in wheelbarrows uphill 200 feet to the project. The blocks were laid directly on the subgrade without geofabric. Driving rebar anchors into the subgrade was attempted but proved difficult because bedrock was encountered within 18 inches of the surface. The holes in the blocks were backfilled (figure 13). Approximately 2 inches of soil was placed over the top of the blocks. The cost of construction, including materials, was about $2.80 per linear foot.

Results. The concrete blocks installed on the Quartz Mountain trail have functioned well. They are durable and provide a surface with good traction for motorcycles climbing the hill (figure 14). Bikers seem to have some difficulty staying on the tread because tire tracks were observed on both sides of the trail; however, the majority of the problem is on the inside of the corner. The blocks seem to be staying in place even though only a few anchors were placed. A few of the blocks have had outside edges break off.

Segment 2. A soil-aggregate-cement mix was used to harden segment 2. The trail was first smoothed and cleared of large rocks. A slip form made of 2-by-4 lumber spaced 2 feet apart was constructed (figure 15). Portland cement and a soil-aggregate mixture was mixed in wheelbarrows at a ratio of

Table 2.—Comparison of treatments used on the Quartz Mountain trail.

	Concrete blocks	*Soil cement*	*Geoweb*	*ECO–50*
Ease of installation	Easy (1)	Hard work (4)	Fairly easy (2)	Moderately easy (3)
Availability	Masonry suppliers (2)	Hardware stores (1)	Distributors (3)	Manufacturer (4)
Cost (including installation)	$2.80 per linear foot (2)	$4.23 per linear foot (3)	$4.38 per linear foot (4)	$2.01 per linear foot (1)
Transportability	Very difficult (4)	Difficult (3)	Easy (1)	Moderate (2)
Traction	Good (1)	Good (2)	Marginal (3)	? (4)
Tread protection capability	Excellent (2)	Excellent (1)	Marginal (3)	Poor (4)
Durability	Very good (2)	Excellent (1)	Fair (3)	Poor (4)
Esthetics	Does not blend well with the environment (3)	Good (2)	Does not blend well with the environment (4)	Good (1)

Rankings within each category are shown in parentheses.

Figure 13.—Backfilling the concrete blocks on Quartz Mountain trail segment 1 (October 1987).

Figure 14.—Quartz Mountain trail segment 1 after three seasons of use (August 1990).

1 to 7 with enough water to make a stiff mix. Aggregate from an old stockpile was used in the mixture to provide a rough surface for better traction on the steep trail. The mix was then dumped into the slip form and compacted with rakes and footpower. Rake marks in the surface of the soil cement provide surface roughness for improved traction. The slip form proved to be an easy and effective way of controlling the depth of the mix and the width of the trail tread. The compacted depth of the soil-aggregate-cement mixture was at least 3.5 inches. The mix was then allowed to cure, sealed with ECO-50, and blotted with soil material from the site. The approximate cost for segment 2 was $4.23 per linear foot.

Results. The soil-cement segment on the Quartz Mountain trail has performed well. It is durable and has shown no signs of cracking or other distress. The trail tread is well defined, although the straight nature of the segment makes it look more like a steep, narrow, and dirty sidewalk in the woods (figure 16). Some erosion has occurred along the edges of the trail. If the trail had been subexcavated, with the top of the soil cement placed at

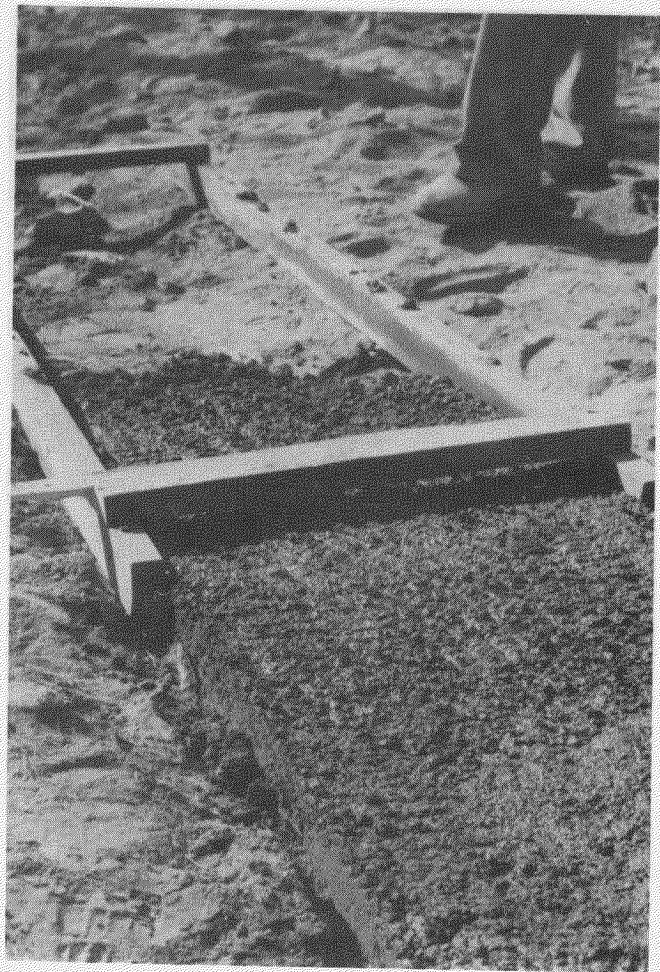

Figure 15.—Quartz Mountain trail segment 2 tread surface after two seasons of use (June 1990).

Figure 16.—The slip form with backfilled soil cement on Quartz Mountain trail segment 2 (October 1987).

surface level, some of the erosion may have been prevented. Traction is good going uphill. Loose debris, in the form of soil and fine rock fragments, make walking downhill on the trail somewhat treacherous.

Segment 3. Segment 3 was hardened using ECO–50, which was mixed with the native materials in-place with a rake and compacted by tamping with a rake and footpower. Within a few months after placement, the hardened surface began to break up. See the discussion for segment 5 below for the approximate cost of treatment with the ECO–50.

Results. After it was determined that the ECO–50 was not going to work in hardening segment 3, Portland cement was tried (October 1989). The cement, approximately 10 percent by weight, was mixed in-place with soil and water using a rake. It was then compacted by tamping with the rake and stomping with feet. By the end of the study period, the soil cement also was back to pretreatment conditions. Of all the segments on the Quartz

Mountain trail chosen for study, this segment apparently has the severest conditions.

Segment 4. Geoweb was used on segment 4. The trail tread was sub-excavated 4 inches by 24 inches wide to allow for the placement of the Geoweb. Smoothing of the bed for the Geoweb seemed to be critical because it would not lie flat otherwise. The Geoweb was expanded and held in-place with stakes until it was backfilled enough for it to remain expanded (figure 17). Individual cells were compacted before placing a 2-inch cover of soil over the Geoweb. The approximate cost for segment 4 was $4.38 per linear foot.

Results. Early in the following season of use (1988), the Geoweb became exposed; the cover material had been worn off by the forces of motorcycle traffic. The Geoweb was particularly exposed on the corners and at the approach to the segment. As the Geoweb became more exposed, it seemed that trail users were avoiding this area (figure 18). The exposed Geoweb

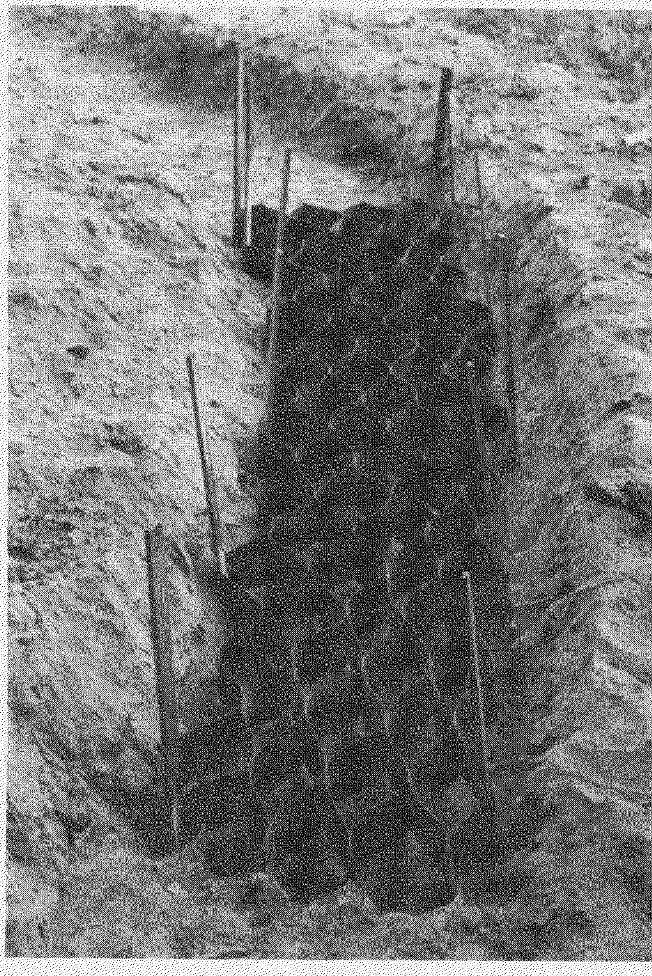

Figure 17.—The Geoweb ready for backfilling on Quartz Mountain trail segment 4 (October 1987).

Figure 18.—Quartz Mountain trail segment 4 after two seasons of use (June 1990). Note the exposed geoweb. It was removed shortly after this photo was taken.

became a hazard because it was slippery. It was removed from the trail tread early during the 1990 field season. Without the Geoweb, the trail quickly returned to its prestudy condition. By the end of the season, the trail was rutted to a depth of approximately 12 inches.

Segment 5. Because segment 3 was treated with ECO–50, segment 5 was initially left untreated. However, when it became apparent that the ECO–50 was not going to work on segment 3, segment 5, mainly because of its flatter grade, was treated with the product. Depths of treatment varied from 1.5 to 4 inches. Nothing worked; the trail is back to its prestudy condition. Site conditions and use were too severe on the Quartz Mountain trail for the ECO–50. The approximate cost per linear foot of segment 5 was $2.01.

Traffic Counters

The trail segments were monitored as to the type and amount of use they receive. This monitoring was done using a trail traffic counter and camera system developed at the Missoula Equipment Development Center of the Forest Service and manufactured by Diamond Traffic Products of Oakridge, Oregon. Motorcycles are the dominant use on both trails. Numerous deer and elk and one coyote also were recorded by the system.

Discussion

Problem areas cannot always be avoided. Those areas where the subgrade is wet and soft require that drainage be achieved and the trail prism constructed above water. Trail hardening techniques can function as durable surfaces. The use of concrete blocks and soil cement proved to work well in wet areas such as on the Bear Creek trail and on steep grades of the Quartz Mountain trail. Geoweb functioned adequately on the Bear Creek trail (wet area). Further testing of ECO–50 and Geoweb, in addition to some other potential tread hardeners, is recommended. The stabilization of surface layers over Geoweb by the use of soil cement or some other hardener should be further investigated, especially on steep trails.

One problem encountered during the study, primarily on the Quartz Mountain trail, was keeping users on the trail. Where the trail was not well defined, users tended to wander off the trail. However, even where the trail was well defined by hardening, such as through the concrete block and soil-cement segments, there was some offtrail use. The steepness of the Quartz Mountain trail undoubtedly contributed to the problem. The offtrail travel may have been inadvertent because users accelerated up the hill and tried to stay on the narrow trail. Rocks and logs were placed alongside the trail in an effort to force users onto it. These were fairly effective in that objective. A method of better defining the trail is the use of vegetation. Wildflowers lining the trail tread may help prevent trail widening.

Mixing materials such as soil, cement, and water in-place should apparently be avoided. The results were poor for those test segments where mixing in-place was tried. Mixing with controlled amounts of materials in a wheelbarrow proved to be the best way to achieve the desired hardening. For best results, one should follow manufacturers' recommendations as closely as the site conditions will allow. For example, the ECO–50 application guide recommended adding fines (1 to 3 percent) in the form of Portland cement or lime to those materials, such as beach sands, that lack adequate fines. The lack of fines may have contributed to the poor performance of the ECO–50. Also, the second layer of geofabric installed, in an effort to better control the mixture, may have contributed to failure; it may have functioned as a plane of weakness.

The rebar anchors used to hold the concrete blocks in-place are not needed if curb rails are installed. On the steep Quartz Mountain trail, where no curb rails were installed, the blocks stayed in-place; there, only the first few blocks were anchored. The weight of the blocks and the backfill material apparently adequately anchors the blocks.

The products in this test all seemed to have some limitations, even the ones that functioned well. For example, the concrete blocks and the Geoweb are not natural looking and thus may not meet trail visual objectives. The concrete blocks and bags of Portland cement are extremely heavy (60 pounds and 95 pounds, respectively). Portland cement and ECO–50 both require water in their mixes, preferably from a source near the project. These limitations need to be considered before a hardening method is chosen. However, in those areas where drainage of the site can be easily achieved, the standard Forest Service turnpike is the recommended treatment.

One aspect of trail use not addressed by the study is user acceptance of the various treatments. As mentioned previously, motorcyclists mostly used the two trails selected for the study. Although some of the treatments tried are very visible, especially the concrete blocks and the Geoweb, no comments or complaints were received by the District. However, in response to proposed projects—for example, timber sales—organized motorcycle user groups have made it clear that trails through the forest environment with little or no evidence of human presence are highly valued.

Not much has been written about trail hardening techniques for multipurpose trails. The best source of information found was through the Forest Service technology transfer network. Manufacturers provided brochures for the use of the products tried in this test. The Portland Cement Association also provided information on the use of soil cement.

For information on the products discussed in this report, contact the following manufacturers and distributors:

(1) Geoweb (and Geoblock)—Presto Products, Inc., GEOSYSTEMS Division, P.O. Box 2399, Appleton, Wisconsin 54913-2399, 1-800-548-3424.

(2) Soil cement—Portland Cement Association, 5420 Old Orchard Road, Skokie, Illinois 60077-4321, 708-966-6200.

(3) Grass Grid paving block—Smithwick Block Co., 1750 Lombard Place, P.O. Box 11207, Portland, Oregon 97211, 503-285-4557.

(4) Traffic counters—Diamond Traffic Products, 76433 Alder Street, Oakridge, Oregon 97463, 503-782-3903.

For additional information, please contact Daryl Gusey at Naches Ranger District, Wenatchee National Forest, 509-653-2205 or DG at R06F17D08A.

Is Optical Storage in Our Future?

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Washington Office Engineering

Introduction

To some degree, optical storage is already here. We are likely to see more optical storage in the future—and perhaps in a big way. This article provides some reasons.

It is important to begin by defining optical storage. Those who record music on a compact disc (CD) use optical storage. A laser picks up information from the pattern of pits placed in the plastic disc. There are about a dozen different types of optical storage devices. Rather than be too technical about the various kinds, this discussion is limited to likely uses. There are a variety of types vying for the market. A lack of widely accepted standards slows rapid growth for most of the optical media. Yet some areas, such as compact disc read only memory (CD–ROM) is very hot. CD–ROM is growing faster than color television did for its first years of existence.

Types of Opticals

CD–ROM is similar to the 4¾-inch CD disc. Plants manufacture both discs to a popular standard, for low-cost distribution of information. CD–ROM is a form of publishing. It stores digital computer information, including text, pictures, drawings, maps, scanned images, and sound. It is nothing more than another drive for a computer, such as a hard or floppy diskette. It can store over 600 megabytes of information, or the equivalent of a year's worth of *The Washington Post*—except you can fit it all in your coat pocket. It also allows one to find anything on the disc quickly.

Corporations and Government can store and distribute data on CD–ROM for as low as 5 to 10 percent of the cost of paper distribution. It is the current least-cost media for distributing information. It should be in many offices and homes before long. It has multimedia capability. For example, an encyclopedia on the market makes use of animations, text, photographs, and sound to produce a "living book."

Erasables are basically under development. They provide the future option of supplementing data processing by giving the user 600 megabytes or more storage close at hand. Unlike CD–ROM, erasables allow reading and writing. They are an extension of the floppy and hard disks, Bernoulli, or magneto-optical (which is a combination laser and magnetic technology). All of these devices including the optical card (which is about the size of a credit card) are in search of more reusable storage in less space.

Write once read many (WORM) are devices for recording text or video. One can add more data to them later but cannot erase the data. Disks vary between 5¼ to 14 inches, depending on the system.

Laser disc is a term associated with a 12-inch analog recording of video or still frame photography. With it, one can store a full motion video, such as a movie.

There are other variations. Some optical systems are interactive. These technologies are not considered here because, for the most part, they are not on the market, but they can be seen or read about.

Discussion

WORM devices are not likely at this time for most Forest Service offices. They are quite expensive and require considerable skill in using them. In the future, they may have a place archiving paper or electronic documents. They are used for interim storage before the production of laser discs from WORM data.

Laser discs have limited use. They are expensive and complicated. Some Forest Service offices have found them useful in showing recreation information to the public, especially when incorporated with a touch screen micro. One product is the *Special Collections: Forest Service Photographs* disc produced by the USDA National Agricultural Library for the Forest Service. Readers may have seen the disc, which should be in each Regional Office; it contains 20,000 photographs dating back to Gifford Pinchot. With the right equipment, it provides an excellent photograph index and data base. Some Forest Service visionaries saw this medium as a way to keep tabs on our historical collection. Original work at selected, secured sites could provide prints or copies. The Washington Office Engineering evaluation of WORM and laser discs in 1988 and 1989 determined that this is a good idea in principle. Practice is more difficult.

One Region is investigating erasables with the Washington Office. It is an area worth watching. Price will be a deterrent for most.

CD–ROM

The one area that repeatedly shows the most potential is CD–ROM. Washington Office Engineering has monitored this technology since 1986, shortly after it began in 1985. Engineering Systems' *Communique* periodically reported on CD–ROM progress, in and out of Government. In 1987, Microsoft Corporation began supporting and promoting the technology. From the beginning, the U.S. Geological Survey saw the value of the technology and formed the Special Interest Group on CD–ROM Applications and Technology (SIGCAT). This group, with more than 4,100 members around the globe, has influenced the standards and interest in CD–ROM. Forest Service employees are participating in SIGCAT to keep current. SIGCAT has several working groups, including a new one on GIS to promote and channel the use of CD–ROM and GIS applications. The Washington Office Engineering laser disc evaluation pointed to CD–ROM as the most promising optical storage for Forest Service Engineering in the near future.

While there are many off-the-shelf CD-ROM titles available, the value of the technology is having needed data ready to access. With this in mind, Washington Office Engineering put together a data-conversion effort in a sampler pilot disc to show proof of the concept. Two hundred copies of the disc, delivered February 1991, offer user evaluation and trial.

The Sampler

Samples of data on a CD-ROM disc give users an opportunity to access a variety of information that might interest them (figure 1). The more users there are who try the disc, the more likely there will be feedback for product evaluation. This will be helpful in creating future discs or deciding whether this technology is worthwhile. The samples on the disc and their selection reasons include the following:

(1) *The FSH 7109.31 portion of the Manual of Uniform Traffic Control Devices (MUTCD)*—This shows CD-ROM use for FSH with graphics. It may allow CD-ROM use with the Signs Advisory Expert System under development.

(2) *FSH 7109.13b, Cartographic Specs and Symbols*—This is another sample use of CD-ROM for complex graphics in FSH.

(3) *January to June 1990, Engineering Field Notes*—These articles provide a contrasting way to look at a printed publication, including the original art and photography.

(4) *Road and Bridge Specs*—Nearly 400 pages of specifications are now on CD-ROM. This gives instant lookup, retrieval, or printing of any portion from a workstation. This form of publishing, printing, and handling can reduce costs 80 percent or more.

(5) *Guide to the Identification of Bearing Tree Remains, EM 7150-5*—This is an example of how a document and 48 slides (35 mm) are used together to capture the original document. It shows that CD-ROM is suitable to store photography in VGA, 320 by 200, 256 colors, PCX format. These images could add to a data base or be mailed via the Data General for viewing, printing, or incorporating into a document.

(6) *Off-Highway Haul, EM 7730-1*—This is another sample of a printed document on CD-ROM.

(7) *Fire Resistant Clothing Special Report, ED&T Pub. 829.2*—About 3,000 Technology & Development publications dating to 1940 exist on microfiche. There is a desire to store them in a more compact, easy-to-use form. This conversion was to be electronic; however, it proved difficult. Microfiche conversion is still a desirable goal.

(8) *AutoCAD drawings*—Storing drawings is a challenge. Many drawings from Regions 3 and 6 and TontoCAD and AutoCAD demos and animations prove the suitability of CD-ROM for storage. A utility allows quick viewing of drawings. The demos and animations suggest new ways of presenting information.

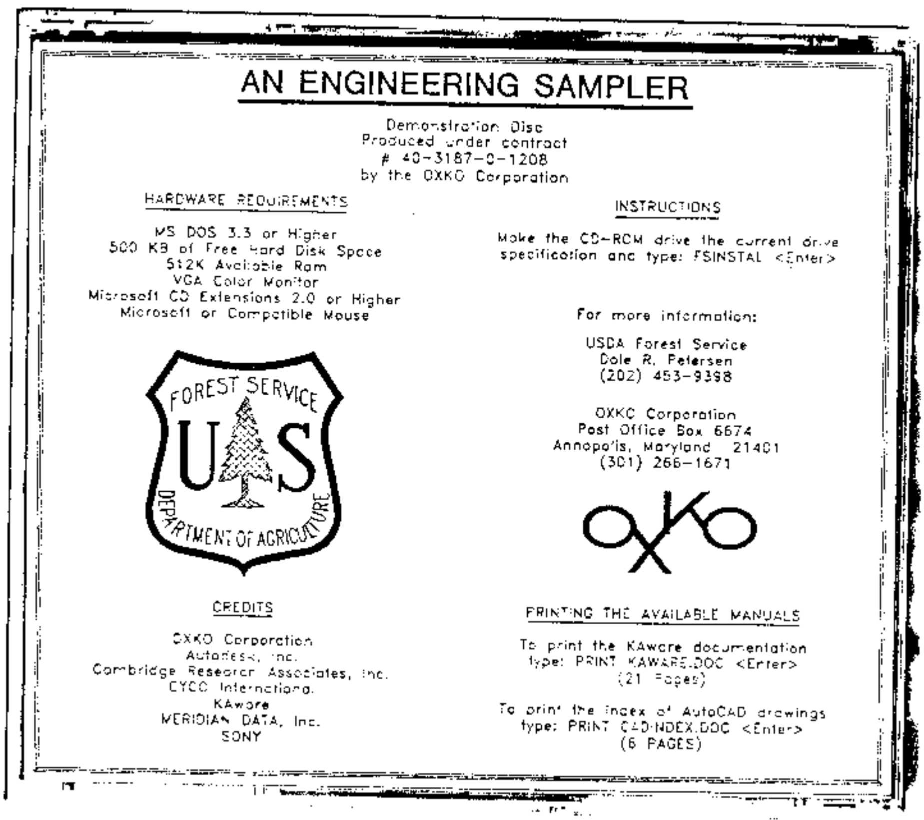

Figure 1.—Front and back covers of Engineering's sampler CD.

(9) *Map demo*—This shows how a digitized map looks on CD-ROM. It suggests that GIS applications can use map data of this quality. Shown is the Wildwoods Quadrangle near Chattanooga, Tennessee.

These products came from paper and electronic documents. Although this project was part of the Washington Office Engineering approved Integrated Resource Management Plan, it is a pilot effort. The sampler disc has created much enthusiasm Service-wide and outside the Forest Service in both public and private sectors. Everyone should take the opportunity to see this CD-ROM if possible. Reactions to the disc will be, in effect, another evaluation of the CD-ROM concept for Engineering use. Washington Office Engineering has, in the fiscal year 1991 approved Integrated Resource Management Plan, the planned development of a CD-ROM disc with real data. User reaction will influence the contents of the next disc. More effort will ensure the accuracy of the data. The approval process for release of information should apply to CD-ROM.

Steven Oxman, President of OXKO Corporation and contractor for the Engineering CD-ROM pilot disc, has written the article in this issue, titled "The Making of a CD-ROM." It provides details and lessons learned, on making a CD-ROM. The most important lesson is to get the data readied for CD-ROM if that is the selected storage form. If one begins by organizing the data with CD-ROM in mind, there will be fewer problems. ASCII files are the easiest to use. AutoCAD drawings, color graphics, pictures, and 35 mm slides will convert—some with difficulty. Microfiche conversion is technically possible, but it still needs to be proven that it can be done.

For the Doubters

It is not fair to judge CD-ROM until it has been seen and used. Retailers, such as CompuAdd, are promoting the technology for home use, and prices are falling. The recent IBM advertisements are pushing multimedia using CD-ROM. A July 1990 report by the Office of Technology Assessment, titled "Helping America Compete—The Role of Federal Scientific & Technical Information," refers to the use of CD-ROM throughout. For example, it states, "The U.S. Geological Survey expects that many of these digitized maps will be . . . in CD-ROM format at a fraction of the cost of the equivalent magnetic tapes or printed paper documents." This suggests that GIS workstations will use CD-ROM. The report suggests that Forest Service monitoring data could be on CD-ROM. A compendium published by the U.S. Geological Survey lists U.S. Government CD-ROM titles already published. The list grows every day. Many Forest Service offices have CD-ROM drives or are planning to buy them. Some offices plan to publish their own data on CD-ROM.

Back to the Future

How soon optical storage comes to each office depends on the employees. As shown here, there are claims for CD-ROM. Uses apply to any field; in the Forest Service, Engineering, Personnel, Watershed, and Research all have discovered some of those uses. For the most part, anyone should be able to get approval authority for opticals, if the need is demonstrated. We, as professionals in our field, need to look around and see what is there; if it makes sense, try it. If it works, carry it out more broadly. The future is here, and it is up to everyone to prove it.

The Making of a CD–ROM

Steven W. Oxman
President
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Washington Office Note

In 1987, the OXKO Corporation of Annapolis, Maryland, developed a proof-of-concept expert system for Washington Office Engineering. The March-April 1988 issue of Engineering Field Notes *documented this effort in an article by Steven Oxman, "A Ski Area Monitoring Expert System Prototype." Although this expert system is not in current use, its development led to an expert system tutorial sponsored by Washington Office Engineering in November 1987. At that session, Margaret Bro and Jack Lowe, both from Region 2, developed the beginning of what is now the CTIP Signs Advisory System. Fong Ou, Washington Office Engineering, is leading that development. In June 1990, OXKO was awarded a proof-of-concept contract to produce an Engineering sampler CD-ROM. One of the documents converted to CD-ROM on that disc is the Manual of Uniform Traffic Control Devices (MUTCD). This offers the opportunity to bring the MUTCD and the Signs Advisory together because this is one reference the system uses. More engineering data are expected to be converted to CD-ROM that the Signs Advisory can use. The article below should help those interested understand how to convert today's data into tomorrow's medium that computers can use. The previous article in this issue, "Is Optical Storage in Our Future?," highlights some of the items on the disc produced by OXKO.*

—Dale Petersen

Introduction

CD–ROM or, otherwise known as compact disc read only memory, is a physical disc that can permanently store up to 660 million characters of computer-based data, whether it be text or graphics. The disc is similar to a record. When it is mounted into a CD–ROM reader, it spins and the reader's read head is semi-permanent—it will move in a preprogrammed manner from the outside to the inside of the disc to find information in which the computer is interested. The CD–ROM disc also is similar to a record in that once the information is placed on it, it cannot be accidentally or intentionally deleted or changed.

Many people ask: "Why do we want to have read only memories, and what value would they be?" The answer is: they produce a permanent record of important information. In the case of CD–ROM, one can produce a small medium that is 5¼ inches in diameter and approximately ⅛ inch in thickness and has the equivalent of 660 million characters of information on it.

Many feel it is important to be able to write over information and that they will always want to do it. One example of a device that can be written over is a home stereo cassette player. However, when individuals go to the store and spend money for cassettes that have music, how often do they write over the music on the cassettes? They find the songs to be so important that although the medium allows them to write over them, the individuals do not want to. In many cases, they will label the cassette to ensure that no one will accidentally write over that music.

Instead of cassettes, many people are now buying compact discs (often referred to as laser discs) for their music. The CD-ROM is very much the same kind of device. It is a good medium when one needs to professionally develop a collection of data, information, and knowledge and have it professionally assembled and delivered in a concise, compact, but extensive package.

What Makes up a CD-ROM?

CD-ROM discs consist of glass or plastic material with pits burned into them in such a manner (changes and lengths between pits and nonpits—that is, lands) as to represent ones and zeros. This technique is used in lieu of the magnetic fields and iron particles to represent the ones and zeros in magnetic tape and disk units.

CD-ROM is another medium for storing digital information. As far as an end-user is concerned, the CD-ROM unit and disc together make up another data source that is not much different than a floppy disk, a hard disk drive, or a magnetic tape unit. The technology, as it exists today, is random, as with hard and floppy disks, but the time it takes to seek information is usually slower than both the hard and floppy disks.

The amount of information a CD-ROM disc can store is similar to high-capacity tape units. However, CD-ROM discs can be searched randomly rather than sequentially, as with a tape unit.

The time to transfer sequential information and data from a CD-ROM, once the beginning of that material has been located, is usually not too long. Many of the CD-ROM drives available on the market today have acceptable data transfer rates. The biggest pitfall in the units today is the seek-access time required.

The average floppy disk contains approximately 1 megabyte of information, or 1 million characters of information; the CD-ROM unit can store 660 times this capacity. Therefore, even though CD-ROM is slower than its floppy cousin, the fact that such a large amount of information is available without changing diskettes makes CD-ROM an efficient and reasonably fast data storage and retrieval medium.

For information that is either being updated often or needs to be acquired rapidly, CD-ROM might not be the correct medium. However, when an extensive amount of information needs to be available for retrieval in a reasonable time and needs to be as compact as possible, the CD-ROM drive and disc medium will often be the right choice.

CD–ROM Development

A CD–ROM disc project will include the following tasks that are done serially, with each step being a task or milestone in the CD–ROM development. To be able to manage the CD–ROM development properly, it is necessary to put together a chart of tasks with the estimated and completed dates for the project. Although there are a few tasks that can be done in parallel, doing most of the work in a serial manner is beneficial from the standpoint of quality assurance. However, if time becomes a constraint in developing a CD–ROM, certain tasks can be put in parallel with each other to complete a project on time.

Acquisition of Requisite Information

The first step in developing a CD–ROM is to acquire the requisite information to be put on a disc. All the source information provided should be checked and inspected, with documentation generated that tells exactly what has been received and the result of the physical audit of the incoming information. This information should be used to ensure that the client agrees with the CD–ROM developer in what has been received; there then will be a document that will serve as an auditable trail later if any questions arise as to the information received. If any additional information is provided to the developer after the initial delivery, it also will be documented in a similar manner.

Conversion of Source Text Material to Personal Computer ASCII Format

Much of the material the developer is to receive will be coming in a text format from some source. The sources might include computer input, paper text input, and fiche input. It will be up to the developer to convert the material to a personal computer (PC) ASCII format that can be used by a CD-ROM engine. It should be assumed that the text data conversion work will experience some problems and difficulty and that, by planning for this up front, the project plan will be developed in a realistic fashion. The conversion of the textual information into PC ASCII format should be with tools that are specially designed for this kind of work. The outcome of this task will be PC-readable ASCII standard textual information that can be used by a PC-based CD–ROM engine.

Scanning of Graphics

The next task is to scan graphics source material that is provided to the developer. Each graphic is scanned using PC-based scanning equipment that allows for good quality at a cost-effective price. The material will be input into a graphical data base that will later be used by the CD–ROM engine; these graphics can then be presented to the end-user. When using standard IBM PC VGA monitors, the actual dot resolution shown on the screen will be 75 dots to the inch, typically converted from 300 dots to the inch on scanners. What will occur is a decrease in resolution, or the material will have to be resized to fit on a computer monitor at the same resolution. Quite frequently when using the 75-dots-to-the-inch presentation screen, panning and zooming or a simulation of these capabilities will provide for both the ability to show the full material on the screen in a lesser format and smaller amounts of the material at a time on the screen in a greater resolution. Often, it will be necessary to show the client multiple capabilities.

Graphics Cleanup

When scanning graphics material, the end result often needs some manual cleanup using graphic cleanup software. Approximately 50 percent of the graphics that are scanned need some cleanup. One should allow for cleanup on a time-and-expense basis to ensure that the graphics material has a reasonable presentation quality.

Quality Assurance of the Text & Graphics

In developing a CD–ROM and the text and graphics material on personal computers with hard disks, the movement of text from one machine to another and the scanning of graphics material through optical scanning devices require a large amount of quality assurance effort. This ensures that all the work is accomplished properly and that any problems will be identified for fixing. Such an effort should ensure a high-quality product. Anyone who does not consider this quality assurance work probably has not had enough experience and has not encountered these problems in performing such work.

Text & Graphics Modifications

After the quality assurance step is completed, there will most likely be text and graphics cleanup work that is required, as well as some fixing of materials. At this point all the cleanup and fixing of textual and graphics material should be done to ensure a high-quality product. Again, this is an area that some might not consider important, but it is.

Installation of Text & Graphics Material Into the CD–ROM Engine

This task includes the installation of the ASCII-based textual material and the scanned graphics material into the CD–ROM engine that is being used. This includes the development of the indices, connections to different engine capabilities, and the relationship of text to graphics material via table of contents, indexing, cross-referencing, and hot key functions.

Quality Assurance of the CD–ROM Engine Integration

Once the text and graphics material is integrated with the CD–ROM engine, the next step is to run quality assurance testing on the development PC workstation in such a way that exactly what will be shown in the CD–ROM environment is simulated once the CD–ROM is cut. The only difference in running this simulation versus running the CD–ROM is that the system will tend to run faster; the hard disk has a faster seek time than the CDROM's. However, from the standpoint of serial searching a presentation, those times will not be affected, because the spin time on the CD–ROM is similar to that of the hard disk. In addition, the quality of presentation, the format, the use of function keys, and the other user-system interface functions will be able to be tested exactly the way they will be on the CD–ROM. This step is important to ensure that the CD–ROM production is done on time with as few errors as possible.

Required Fixes

After performing the quality assurance step, there most likely will be some items that need to be changed, such as the lack of a table of contents item, the incorrect indexing of an item, the incorrect connection of a textual reference to a graphics presentation, or the missing of a necessary index or reference. Anything found to be missing or in error will be fixed in this step.

Development of Ancillary Files

Certain ancillary files are necessary on the CD–ROM to ensure that it is as user friendly and informative as possible. These files include, but are not limited to, a credits file and a "notes to you" file. The credits file provides all references to credits necessary from the standpoint of contracts, copyrights, and parties that have assisted with the work. The notes to you file presents notes to the ultimate user that will make the use of the CD–ROM easier, particularly when the paper user manual or the paper inserted in the jewel box is missing. This is helpful to users who have their CD-ROM's permanently stored in the CD-ROM reader and have lost or misfiled the jewel box with the jewel box insert or the user manual.

Installation File Development

No matter how automatic and easy it is to install a CD-ROM application onto a PC, certain non-PC-trained people still have a difficult time. Because of this, installation files developed on the CD-ROM can be initiated automatically to perform the necessary configuration work to make the application run as smoothly and as easily as possible for the end-user. Providing this capability is important.

Documentation

There are three documents often considered for CD-ROM projects: a user manual, a procedure manual, and the jewel box insert. The user manual assists users with getting the CD-ROM online and in use. If the jewel box insert and the instructions on the CD-ROM itself are informative enough as they should be, then a user manual is superfluous. If the client would like to know how this CD-ROM was developed, then a procedure manual on how to develop the CD-ROM and redevelop other versions of the CD-ROM would be important. However, if the client does not have the indigenous capabilities to do this work, a procedure manual also is superfluous. Information on how to load and run the CD-ROM on the CD-ROM itself and as a jewel box insert is important documentation for these kinds of projects.

Development of Ancillary Menus

Experience in working with large text management systems and CD-ROM systems has shown that to facilitate the navigation of the material, ancillary menus that look and function like a hierarchy of tables of contents support the top-level searching of materials and graphics. These ancillary menus will assist users in getting to needed material faster and easier. OXKO not only provides techniques often requested by clients, but also ancillary menus to make the CD-ROM information acquisition by end users as easy as possible.

CD-ROM Disc Graphic

The CD-ROM disc should have a label that includes a reference to what the disc is, the disc title, contractual requirements as to who made the disc and for whom it was made, copyright information, and standards information proving that the CD-ROM conforms with the ISO-9660 standard. Also, basic information as to how to load and get the CD-ROM software running is provided on the label. This graphic is developed using computer graphics development tools, shot into a graphics quality format as needed to be placed on the CD-ROM disc. This graphic is provided to CD-ROM production.

Quality Assurance of the Ancillary Files

The next step is quality assurance work on the ancillary files, including the credits and notes to you files, the installation procedure and file, the documentation, the ancillary menus, and the CD-ROM disc graphic. Each item is checked manually and checked on the PC to be sure that each is correct and operates properly.

Required Fixes

Anything found during the quality assurance step above that is in error is then fixed, and new testing and checkout are performed. In this way, all the problems prior to producing a disc are caught.

Alpha Disc

The next step is to master the alpha version of the CD–ROM. The material will go out for mastering and will include all requisite information that includes the downloaded material on digital magnetic media. The alpha disc will be a polycarbon disc that is used for test purposes; it will not include the CD–ROM graphic on the disc surface.

Quality Assurance of the Alpha Disc

Quality assurance testing of the alpha disc is then performed, with a search for any and all possible problems. Any problems that are found are documented.

Alpha Fixing

Any and all problems that are found during the quality assurance step are fixed at this time. The development outcome of this work is a beta disc.

Beta Disc

The beta disc is then subcontracted out for development. This beta disc is also a polycarbon form for more testing.

Quality Assurance of the Beta Disc

The quality assurance of the beta disc ensures that any and all problems that might still be on the disc are found and addressed. Although this seems like too many quality assurance steps, remember that there is always room for finding problems prior to going to production discs. Even though many people consider this unimportant, from the standpoint of actually producing CD–ROM's, this is a useful and usually necessary step.

Production of the CD–ROM Discs

The last step is to ship out the jewel box insert, the CD–ROM disc graphic, and the final magnetic media of the materials for production of the CD–ROM discs. These discs will then be produced in the quantity requested by the client and inserted into the jewel boxes with the proper insert added and packaged, as decided by the developer and the client.

Conclusions

This article discusses the steps that one must perform to develop a CD–ROM disc. These steps are the actual steps taken by OXKO in developing a CD–ROM. It should be noted that this is the technique used for all CD–ROM production. If, in the future, periodic updates of the CD–ROM are required, very similar steps would be taken to perform each update. When material is already in its proper format and has been checked, testing in that area is minimal. Testing when additions, modifications, or deletions have been made should be more rigorous.

Through careful, painstaking work and multiple quality assurance steps, a high-quality CD–ROM disc can be produced.

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