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TREES THAT BEAR WITNESS

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Trees ranging from towering Douglas-firs to gnarled white oaks, individual trees with no characteristics in common other than scars on their trunks, are providing yeoman service to the country. These are the "bearing trees" which stand guard over the "corners," or markers, of the great United States Public Land Survey.

The corners mark the boundary lines of public and privately owned lands over a vast portion of the country. Unfortunately, a great number of the original corner monuments—usually wooden posts or marked stones—have been burned up by wildfire, plowed under, bulldozed into oblivion, buried by erosion, or otherwise lost. Those remaining are thus all the more valuable.

But wait, what was all this about bearing trees standing guard over the unobtrusive monuments erected by the old-time government surveyors? Let us look at the beginning. The founding fathers of our country established the Public Land Survey System, the most orderly and well-thought-out large-scale survey scheme devised by man at that time or for generations afterward. Realizing the fragility of corner monuments constructed of native materials along the frontier, they specified that trees, because of their relative permanence compared with man's life span, be utilized in marking the survey upon the ground.

In the Act of May 18, 1796, Congress stated that trees near each land corner were to be marked to identify the corner. Later instructions gave specific details of marking the bearing trees, sometimes called "witness trees". Their size, species, compass direction and distance from the corner were to be entered into the official record. Identifying letters and numbers were to be carved into the trees. These trees not only make the corner more readily identifiable, they also "bear witness" to the corner monument itself. If the corner monument is removed or destroyed, it can be correctly relocated using the recorded measurements to the nearby bearing trees.

The scribing of bearing trees is still required in the survey of the public lands and is also practiced by many private surveyors. The bearing trees are normally blazed with an axe to expose a narrow vertical strip of live wood tissue, and the various symbols required to identify the corner are carved into the wood with a special scribing tool. The marks will remain as long as the tree is sound, although the blaze may heal over and become covered with a thick layer of overgrowth wood.

Many corners had to be established where no trees were available within any reasonable distance. When this occurred, reference marks were chiseled into nearby boulders or rock outcrops, or failing that, mounds of stone or earth were erected and a pattern of pits dug around the corner. Except in the grasslands, where the sod holds the earth, pits and earth mounds were short-lived.

A mark chiseled into a stone outcrop or boulder may seem more permanent, and therefore, superior to marks cut into a tree. Actually, an old veteran of the forest with scribing over 100 years old, is often found standing in silent witness to a corner post which crumbled to dust two generations ago. But, more important, a tree has life. As it lives, it grows each year, producing a more or less distinct concentric growth ring. By counting the number of rings between the axe-smooth face with its carved markings and the current growth, the age of the scribing can be determined, often to the exact year. This is one of the greatest advantages of the tree as an object to bear witness. Like a great ponderous clock, the bearing tree starts counting time from the moment the government surveyor blazes and scribes it.

What purpose is served by this inherent feature of a bearing tree? Occasionally, there arises a situation where the validity of a corner is challenged because another monument or other bearing trees are found in a different location. The imposter is usually exposed by referring to the descriptions in the official record. However, if a study of the official record does not resolve the issue, the "time clock" must be consulted. The tree is carefully notched to reveal the growth rings. If the date indicated by ring count corresponds to the time of the original survey, there can be little doubt as to the authenticity of the corner.

In this manner, a bearing tree can actually bear witness. It can, in effect, testify to the validity and location of the original corner, although the corner monument itself may be long gone. In so doing, these land corner guardians perform a most meritorious and necessary service. The high value of land today, the tremendous expense of developments, and man's dependence on the natural resources of the land—all these make the corners, which determine the limits of land ownership, of inestimable value. Because of this service, and because of the historical significance of those trees marked in the early surveys, the bearing trees of the Public Land Survey are perhaps the most important individual trees in this country.

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“Watts” Happening in Energy Conservation: Compressed Natural Gas (CNG) Vehicular Fuel

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Introduction

With the passage of the Alternative Motor Fuels Act (AMFA) of 1988, the Clean Air Act Amendments (CAAA) of 1990, the National Energy Policy Act of 1992, and the issuance of Executive Order 12759, Federal fleets are both encouraged and mandated to phase in the use of alternative-fueled vehicles over a 6-year period. By fiscal year 1998, 50 percent of all new vehicle acquisitions are to be alternative-fuel-capable vehicles. As a means of reducing the use of gasoline and diesel by 10 percent by fiscal year 1995, complying with Executive Order 12759, and helping to protect our air quality, the Southwestern Region has begun purchasing and using compressed natural gas (CNG) fleet vehicles. Four dedicated CNG vehicles were added to the fleet in fiscal year 1992, and plans are underway to add six dual-fueled vehicles in fiscal year 1993. In addition to these vehicles, we are installing two small refueling systems on the Kaibab and Prescott National Forests. Our intent is to utilize alternative fuels wherever possible to meet future energy reduction goals. Natural gas is an abundant domestic resource and burns significantly cleaner than gasoline or diesel. There are several pipelines located throughout northern Arizona and northern New Mexico servicing the Southwestern States. M85,* another alternative fuel for which original equipment manufacturer (OEM) vehicles are currently being produced, is not currently available in New Mexico or Arizona.

Vehicles

Pickups and vans are currently available from OEM’s as dedicated CNG vehicles. Limited types of bi-fuel vehicles (gasoline and CNG) will be available from OEM’s in fiscal year 1994 and are available now as after-market conversions. Dedicated CNG vehicles have a limited driving range, which makes it necessary to assign them to local use near refueling sites. It is desirable to add storage tanks to these vehicles at this

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*M85 is 85 percent methanol, 15 percent gasoline.

time to increase their range. Tanks are available from either General Motors (GM), the manufacturer, or other sources in the market place. As additional CNG stations open, the use of dedicated vehicles will become less restrictive.

Bi-fueled vehicles currently offer more versatility. Existing gasoline-fueled vehicles can be converted with an additional CNG tank equivalent to 5–15 gallons, depending on vehicle type and size. This will result in an overall increase in range. With the bi-fuel system, vehicles can operate on CNG while near fuel sites and use gasoline when out of range of CNG sources. Several companies offer conversion packages for existing vehicles to fill the gap left by automakers. Conversions to bi-fuel are currently running $4,000 to $5,000, depending on the number or size of tanks installed. This is for a California Air Resources Board (CARB)-approved system. Newer types of systems using two computer chips to monitor and run the engine (one for gasoline and one for CNG) are being developed. This, coupled with an increase in production of CNG storage tanks, should bring about a cost reduction in conversion and OEM systems in the near future.

The GSA Automotive Commodity Center will have vans and pickups available as dedicated and bi-fueled standard items in fiscal year 1994. Cost of the CNG fuel systems is approximately 35 percent higher than standard gasoline-powered vehicles. Funding from the Department of Energy (DOE) for purchase and conversions for alternative fuel has not yet been released. As funds are made available, we hope to offset some of the additional costs associated with the purchase of alternative-fueled vehicles. The DOE, through the National Renewable Energy Lab (NREL), has disseminated a request-for-proposals for a national contract that will provide vendors for vehicle conversions and fueling for alternative-fueled vehicles.

The inherent driving characteristics of CNG vehicles are no different than similar gasoline-powered vehicles. Although there is about a 12 percent power reduction due to the gaseous state of the fuel versus the more liquid gasoline, no real driving differences are generally noticed. CNG is rated at 130 octane, which requires a timing change for the engine to run properly. This is an automatic adjustment done by the CNG operating system.

Refueling Infrastructure

While natural gas is abundant throughout much of the Region, fueling stations are not. The Gas Company of New Mexico is in the process of installing several stations around the State at this time. Fuel is or will be available in Albuquerque, Santa Fe, Farmington, Gallup, and Socorro by mid-summer. In Arizona, CNG is available at Arizona State University; City of Scottsdale; Southwest Gas in the Phoenix, Tucson, and Tempe areas; Pima Community College; and the City of Tucson. However, none of these stations offer public access. A commercial station is expected to be in operation in Phoenix by the end of summer. For CNG to be a good option, fueling stations need to become more abundant and convenient. In New Mexico, our plan is to rely on the commercial stations being developed. In Arizona, we have chosen to install two small stations, one in Williams, another in Prescott. Construction of commercial stations in rural areas is expected to take place more slowly than in the urban areas. With our own fueling stations in the rural areas, we will be able to fuel at home, travel to the urban areas, fill up again, return, and also serve the local driving needs.

Fueling stations come in two types, fast fill and slow fill, or a combination of both. Slow fill installations require smaller compressors and fewer storage tanks and are therefore less expensive. The number of vehicles to be served is also a factor, along with the operating pressures of the system. One therm of natural gas equals 100 standard cubic feet and 100,000 Btu's; 100 to 125 cubic feet of natural gas equals 1.0 gallon of gasoline. The smallest and least expensive compressors on the market are the Fuel Makers (made in Canada) that produce 1.90 cubic feet per minute (CFM), equivalent to 1.04 gallons per hour (gal/hr) of gasoline at 3000 psi. Fuel Makers sell for about $4,000 and can be installed in groups to fuel several vehicles in a slow fill operation. We are installing a compressor produced by Tri Fuels in Oklahoma that produces 8 CFM, equivalent to approximately 4.3 gal/hr at 3600 psi. The expected cost of this system installed is $35,000. This includes 4 or 5 slow fill posts and one fast fill post. Compressor systems go up in size and price from there, ranging in size from 25 to 500 CFM. The more convenient the fill station is to the vehicles being served, the more the drivers will accept using the system.

Natural gas is relatively inexpensive compared to gasoline, equivalent to approximately 35 to 60 cents per gallon. This leaves some room to pay for the additional vehicle cost and the fueling station costs. The fueling stations will need to be paid for directly by buying them outright or by paying a fuel surcharge to a commercial station. Mesa Environmental offers to convert fleets of vehicles and provide fueling facilities all included within the price of the CNG over about 5 or 6 years. The price offered is approximately equal to the local price of unleaded gasoline. With the Forest Service Working Capital Fund (WCF), it may actually be cheaper to buy the stations and depreciate them through the WCF. On the other hand, supporting commercial stations removes the operation and maintenance problems and helps to improve the availability of the fuel to the public and other fleets. In-house slow fill or fast fill stations will not require metering devices and card lock systems that add considerably to the cost.

The operation of CNG vehicles leads us to other considerations. Commercial stations will for the most part be operated by card lock systems. We need to procure credit cards that work with these systems and, for a period of time, may have to procure a variety of cards until some national system is in place. Forest Service offices are often in cool or cold locations around the country. Water in the gas may present a problem to compressors and may be a consideration for storage tanks and vehicle systems. There are systems available to remove the water from the natural gas before it is compressed, and this adds to the cost of the system. Fill hose connections are not completely standardized at this time, and operating pressures once 2,400 psi have grown to 3,000 psi and 3,600 psi. It is likely 3,600 psi will be the standard for a while, but tanks are still being manufactured that are rated at 3,000 psi. The development of an infrastructure will also need to include people who can diagnose and repair CNG systems, both OEM and after-market conversions. This is just beginning to happen in Arizona and New Mexico. Vehicle fuel and fueling systems are required to meet the National Fire Protection Association standard number 52. CNG vehicles will also meet the requirements of AGA 1-85 and AGA standard NGV2.

Safety

CNG vehicles have achieved an excellent safety record. In one study of over 400 million miles of CNG operation, the overall injury rate was 85 percent lower than that of all vehicles on U.S. roads. This lower injury rate was primarily due to reduced fire hazard. There has never been a rupture of a Department of Transportation (DOT)-approved or equivalent CNG storage cylinder. There has never been a known death attributed to the use of CNG. Reportable injuries are negligible and generally associated with refueling or repair incidents. CNG has a higher ignition temperature than gasoline, rapidly dissipates into the atmosphere when spilled, and burns only within a narrow range of mixtures with air.

Most experts agree that vehicles refueled with natural gas are safer than vehicles using gasoline or other alternative fuels. Insurance underwriters have judged compressed-gas-fueled systems to be as safe or safer than any conventional fuel system. Safe operation of CNG and other alternative fuel vehicles will require information and training of the users.

Conclusion

We have just started with alternative motor fuels. CNG and liquefied petroleum gas (LPG) seem to be the best choices to implement. Methanol and ethanol-fueled vehicles will be considered as they become available and the fueling infrastructure develops. Our goal is to utilize existing technology by using off-the-shelf systems and commercial sources for refueling when available. Where a lack of commercial refueling sites exist, we can operate our own sites, generally in remote locations less likely to be developed commercially, to service a portion of our fleet using CNG. CNG is an abundant, viable fuel whose time has come.

Ecosystem Roads Management Project

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This article is dedicated to the memory of Walt Brooks, the Washington Office Sponsor for the Ecosystem Roads Management Project. Walt considered environmental enhancements in road work to be of the greatest importance. Let us carry on the work in which Walt placed so much of his life's effort.

What is the Ecosystem Roads Management Project?

Formerly referred to as the Environmental Roads Initiative, the intention of the Ecosystem Roads Management (ERM) project is to gather information and provide it to the field as an aid in conducting environmentally sound and ecosystem enhancing transportation system activities. Line officers, specialists, and engineers will be provided with the products of ingenuity, innovation, and materials and techniques development—basically the latest and best information available. This is intricately related to the Forest Service commitment to ecosystem management. Road work must be executed in a manner that contributes to multiple-use management of national forests and grasslands by blending the needs of people with environmental values and should be founded on information from all related resources. Road work must be compatible with ecosystem sustainability.

The purpose of this article is not only to support ERM goals, but to increase awareness of the project and the benefits of sharing and building on ideas. All Regions of the Forest Service are exhibiting ingenuity in conducting transportation system activities with environmental considerations as a top priority, and, thus far, several Regions have taken the opportunity to showcase a significant number of ideas. An open invitation is extended to anyone who would like to participate by submitting a roads-related project that did something special for the environment. To submit a project, contact your Regional ERM coordinator or the Roads Program Leader at the San Dimas Technology and Development Center (SDTDC).

Ideas and innovations need not be elegant or complex to be of value to ERM. Simple projects also have the potential to significantly enhance ecosystems or the environment, while being beneficial from an economic, aesthetic, historical, or functional standpoint.

Projects discussed in this article are grouped by project intent, including fish passage, wetlands and watershed, soil retention, low water crossings, visuals and historical, road maintenance, road closures, and use of recycled materials. Some contain specifications and drawings, while others are simple descriptions of what has been done. All are meant to spread good ideas.

Fish Passage

Paving of Corrugated Metal Pipe Inverts for Repair and Fish Passage

The Southern Region picked up on an innovation of the Oklahoma Department of Transportation (ODOT) whereby ODOT research engineers developed repair methods for damaged inverts on corrugated metal pipe (CMP). The mountainous areas of eastern Oklahoma subject CMP's to acidic, highly oxygenated running water that—in conjunction with bedloads of sharply fractured gravel and rock—rapidly deteriorate pipe inverts through abrasion, perforation, and corrosion. This deterioration leads to saturation of bedding material, piping, erosion, and, sometimes, settlement of the pipe and road surface. ODOT's objective was to develop simple and economical (yet effective) repair methods—alternatives to removal and replacement of the CMP.

One in-place rehabilitation method successfully implemented involves manually trowelling a cement grout mix onto the CMP invert (figure 1). This maintains the integrity of the structure at minimum expense. A total of 10 pipes, none of which had suffered extreme settlement, were

Figure 1.—Grout repair of 72" CMP with baffles and depressions for fish passage.

treated in this manner by ODOT. Two different design mixes provided "very good, no cracking" performance ratings.

Environmental Benefits

Personnel on the Ouachita National Forest realized that additional benefits from CMP invert paving were possible. In terms of environmental concerns, two main benefits came to light:

(1) Rock baffles can be installed in the grout, in addition to formed depressions, to provide resting pools for fish passage. The Ouachita National Forest has experimented with various rock baffle and depression patterns, as shown in figure 2. Each pattern has proved functional.

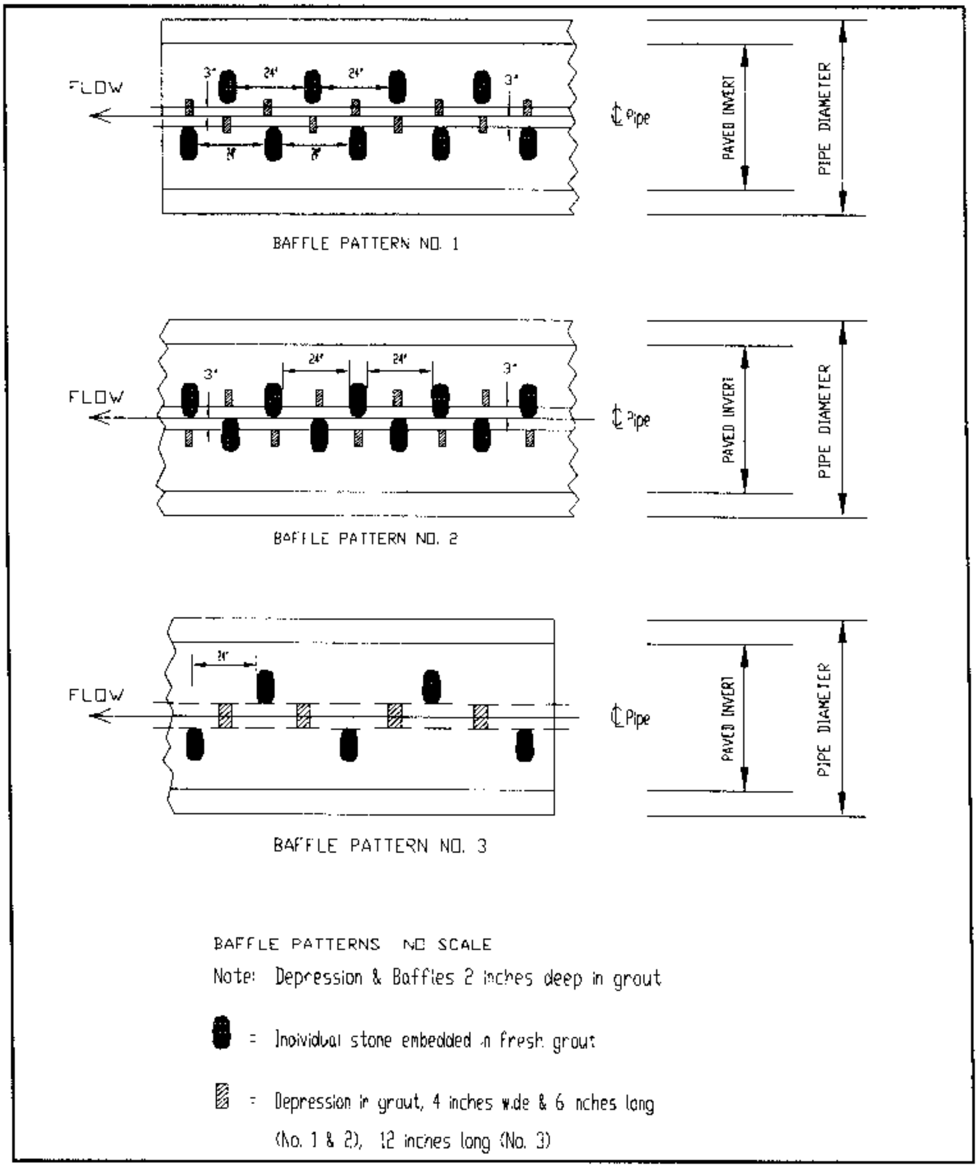

Figure 2.—Functional rock baffle and formed depression patterns.

An initial pipe repair project on the Ouachita proved the value of the method in terms of fish passage. Orangebelly darters, acting as a surrogate for the Forest Service-listed sensitive paleback darter, were found in an electrofishing survey to be successfully passing through the pipe.

(2) Sedimentation and erosion in the streambed is virtually eliminated because the road embankment is not excavated nor the pipe bedding disturbed during repair activities, as is required for pipe removal and replacement. Disruption of normal stream flow is also minimized because the repair method takes less time, thus needing less damming or diversion of water.

Economic Benefits

Initial project work on the Ouachita National Forest indicates substantial economic benefits are possible when employing this repair method. The paving grout, complete with rock baffles and formed depressions, can be installed for less than 12 percent of the cost of removal and replacement of the CMP. This statistic applies to a 72-inch CMP and does not include the costs of providing for fish passage or sedimentation control measures on the replaced pipe.

The Ouachita National Forest has experienced satisfactory service with concrete specified under Forest Service Specifications for Construction of Roads and Bridges, section 602, method B, with increased cement and slump. A cement factor of 7 and a slump of 6 inches was specified. Rock for use as baffles should be hard stone meeting the requirements for rubble of section 622.02 of the specifications. Soft stone or shale should not be used.

Details and specifications concerning grout paving of CMP inverts will be published by SDTDC in an upcoming *Tech Tip*.

Additional Fish Passage Projects

The Ouachita National Forest also experimented with retrofitting concrete box culverts with reinforced concrete curbs as a fish passage modification. Four of five outlets in an installation were fitted with 8- by 8-inch curbs (see figure 3), concentrating low flows in the fifth outlet for fish passage. The curbs retain bedload, providing a natural streambed to enhance passage during high flows. Installation of the curbs is relatively easy; the outlet slabs are drilled for the grouting-in of rebar, then the curbs are formed up and poured. Cost depends on the remoteness of the project and local materials and labor cost.

The Jefferson National Forest in the Southern Region, in addition to other forests around the country, has successfully installed oversize culverts at a lowered invert elevation. Installing the invert below the natural stream level results in sedimentation that provides a natural streambed for fish passage. The oversize provides room for sediment while maintaining required flow area in the pipe.

Figure 3.—Low flow concentrated in the uncurbed outlet.

The Targhee National Forest in the Intermountain Region installed double culverts in a small, fluctuating stream. One pipe was installed lower than the other to concentrate low flows, with alternating baffles welded in to further provide water depth for fish passage.

The Willamette National Forest in the Pacific Northwest Region is planning on installing prefabricated baffles in existing major CMP's to provide for fish passage. Materials under consideration for baffle construction include precast concrete and steel plate. The baffles are to be hydrodynamically designed so water pressure prevents the baffle from rattling around in the pipe. The baffles will be cabled together and fed into the pipe during installation.

These projects highlight some important considerations for fish passage. Most passage problems are associated with excessive water velocity, vertical barriers, or insufficient water depth. All factors must be considered to optimize an installation from biological, hydrological, and engineering standpoints.

Wetlands and Watershed

In the Southwestern Region, an increasing awareness of environmental considerations has resulted in a multidisciplinary approach to healing the scars of the past. Many ecosystems were damaged by overgrazing and excessive timber cutting prior to the turn of the century. In addition, access was gained in the area by the paths of least resistance. All of these are at odds with maintaining diverse, healthy, productive, and sustainable ecosystems. Road engineers have not always foreseen all the ramifications of road work. Past efforts have focused on design considerations, safety, operating within budget constraints, and maintaining access. More recently, increased emphasis has been placed on the environment. Methods to promote healing through road construction, reconstruction, and maintenance are being devised.

Resource specialists were among the first to recognize the contribution of roads to damage inflicted on riparian areas, meadows, drainages, vegetation regimes, and wildlife habitat. Meadow invasion by ponderosa pine, rabbit brush, and other mesic vegetation indicates soil drying, water table lowering, and other ecosystem impacts. Partly responsible are road cross-drain pipes installed with inlet elevations below the natural meadow surface. This practice effectively removes water from the roadway, a prime engineering consideration, but often initiates gully head-cutting and erosion. Relieving the pipe outlet usually requires digging long trenches, also initiating gully erosion and concentrating water. Both result in dryer soil and a lowered water table, with disastrous results to wetland areas, hydric vegetation, fish, and wildlife.

Raising the inlet of a cross-drain pipe by elbow installation (figure 4) or by removal and re-installation of the pipe at a higher elevation circumvents its soil-moisture draining and water table lowering characteristics. The inlet is generally raised to the natural meadow elevation; thus, runoff ponding occurs, encouraging sedimentation and slowing headwall

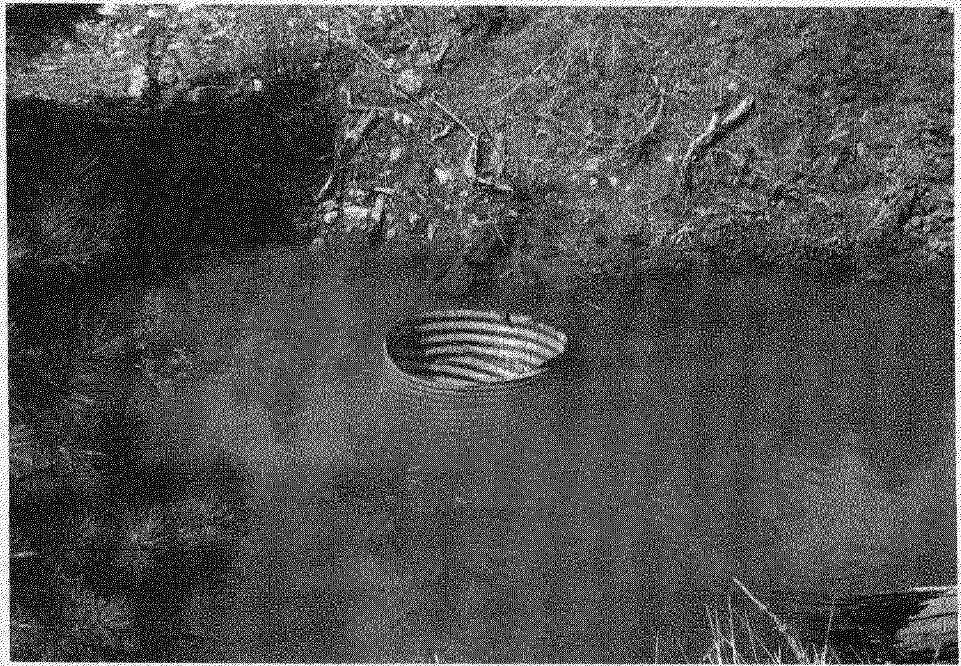

Figure 4.—Elbow installed on cross drain to pond water and preserve sediment.

retreat. Downstream treatments include splash aprons and gully plugs. Aprons are used to reduce the force of falling water on soil and retard gully deepening and downcutting, while plugs encourage ponding and soil preservation.

On a forest in Texas, a wildlife pond was created by construction of a road embankment with a submerged and gated outlet control structure for water level control.

Roadway embankments can be specifically designed to function as gully plugs. Drainage structures are sized to pass the peak flow of the design recurrence interval required for the facility in question. The invert is placed at the elevation desired for water ponding and sediment deposition levels, rather than the standard installation procedure of bedding the pipe in the drainage bottom. Generally, the road surface should be at least 2 feet above water levels to prevent a decrease in bearing capacity. Embankments are specifically designed and constructed to provide an impervious dam to prevent piping and possible loss of fill, although in some cases large, uniformly sized rock is used to provide a pervious layer that allows seepage. Impervious embankments provide wetlands creation and restoration; wildlife drinks; retardation of bank cutting, gully erosion, and incision; and sediment preservation (figure 5).

Roadway embankments across broad, relatively flat meadows can be constructed to break up the concentration of water. The fill is constructed with a pervious layer that allows seepage and sheet flow in a manner imitating natural drainage patterns. Screened aggregate (with a

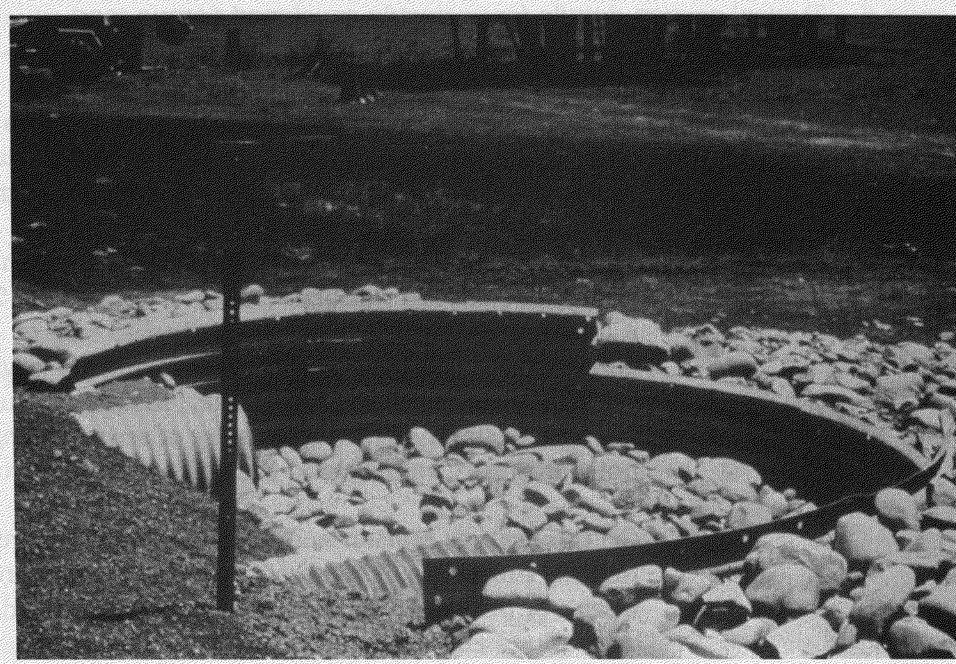

Figure 5.—Splash apron protects soil from the force of falling water.

grading of 3-inch minimum and 6-inch maximum) providing the porous layer, enveloped in geotextile (figure 6), has been successfully used on the Tahoe National Forest in the Pacific Southwest Region, while very coarse, uniformly graded pit-run material has been used effectively in the Southwestern Region. Finer aggregate placed on the porous layer provides a smooth riding surface. Water is not collected for passage through a pipe; it remains spread across a relatively large area, encouraging infiltration and soil moisture recharge. This application works best in broad, flat meadows without defined low spots or canyons that concentrate water.

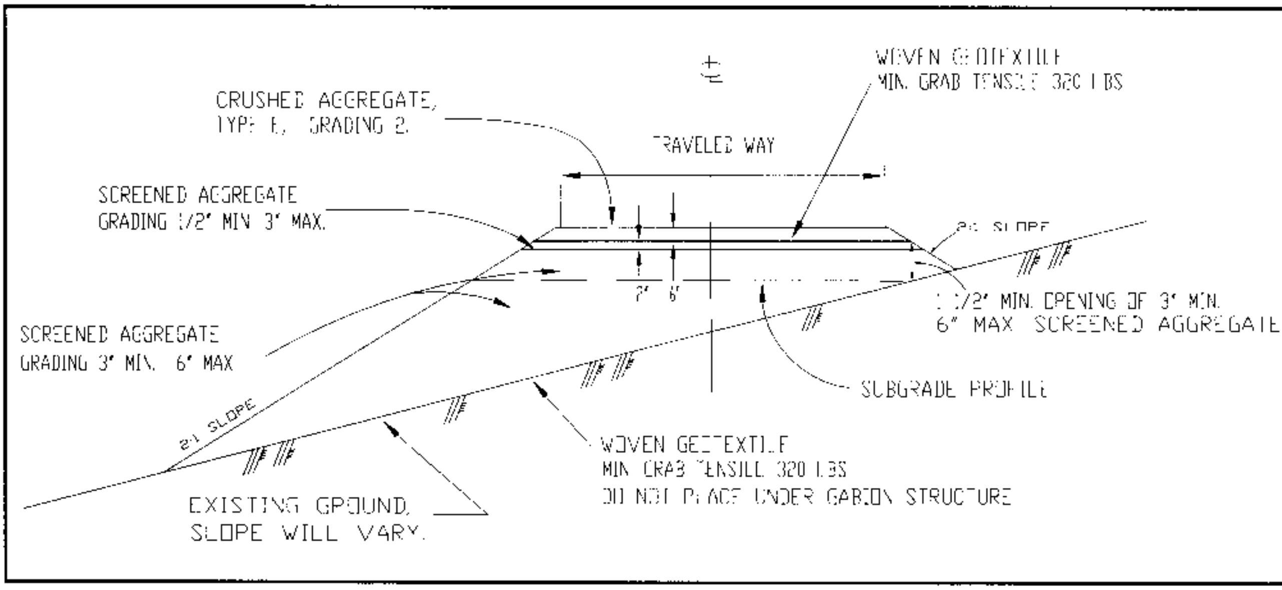

Figure 6.—Typical section details for geotextile enveloped porous road embankment.

Gully plugs can be constructed of jersey barriers (figure 7), concrete, or treated timber or from recycled or on-site materials. Placing the plugs at carefully arranged intervals optimizes their sediment preserving capabilities and economic benefits. A grade of about +2 percent from the top of one plug to the toe of the next one upstream has successfully been used. The Lassen National Forest in the Pacific Southwest Region built a concrete spillway 1-foot high just upstream of a large culvert. In conjunction with the road fill, this seemingly negligible spillway height created a wetland 60 acres in size. Installing plugs in conjunction with increasing the infiltration capacity of surrounding upland soils increases both plug survivability and the soil's biomass production potential.

On the Francis Marion and Sumter National Forests in the Southern Region, hundreds of years of intensive agricultural use has damaged the health of the land. Roads have been constructed and reconstructed as gully plugs and gully fillers as an aid in restoring watersheds and healing gully erosion.

Figure 7.—Jersey barrier gully plug.

On the Targhee National Forest in the Intermountain Region, bridge spans have been increased as bridges are replaced to avoid working in stream bottoms and to decrease the risk of substructure erosion.

Retaining Soil

Discussions of recent experimentation and innovations in retaining walls and soil reinforcement abound in the literature (*Engineering Field Notes* articles, etc.). Two additional wall types have come to the attention of ERM, a polymer cell confinement wall, and the TEXSOL, or three-dimensional geotextile technique. A polymer cell wall installation is discussed here.

Polymer Cell Confinement Gravity Wall

Polymer cell confinement, or "geoweb," was used to retain a through-cut at the junction of FR 20S19 and State Highway 190 on the Sequoia National Forest in the Pacific Southwest Region. This design solution was developed to address a need to maintain visual quality in a visually sensitive zone along a well-traveled State highway. Additional concerns included construction of a Forest Route intersection with the highway that would not be a maintenance problem for either the Forest Service or the State department of transportation, CalTrans, and finding an economical solution.

This wall was designed and constructed as part of the Osa timber sale in October 1989. The geoweb system minimizes the volume of material removed to provide a through-cut by shoring cohesionless native material at a ratio of 0.375:1. Native material is backfilled in the cells, creating a "gravity retaining wall" (figure 8). Carbon black additives in the plastic material provide protection against ultraviolet degradation and allow the wall to blend into a shadowed hillside. For an aesthetically pleasing view, the 8-foot plastic panels are installed to result in an undulating "top-of-cut" line, producing a naturally appearing blend of wall with hillside rather than a rigid, straight cutslope line (figure 9).

The construction procedure involved excavating the through-cut, placement of a French drain system, installation of geotextile on the cutslope and geoweb base, placement and backfill with native material of the geoweb confinement cells themselves, and seeding and vegetative plantings. The geoweb material is shipped and handled in collapsed form and is propped open for infilling by pegged 2 by 4's (figure 10). The small terraces created by a 3-inch setback of successively installed panels (figure 11) were swept of excess infill material, and the entire wall and upper slope hydroseeded. The slope above the wall was laid back on a 1.25:1, covered with coconut fiber matting, and planted with native trees (5-gallon size).

Drainage in the structure consists of relatively heavy (8 oz/yd^2 or 1.3 kg/m^2) nonwoven needle-punched geotextile behind the wall, and a French drain containing 6 inches of perforated corrugated metal pipe (PCMP) along the full 150-foot length of the wall. A French drain was also installed parallel to the highway; both drains joined in a State-approved concrete catch basin 6 feet below grade. Surface water is also directed to the catch basin, and all water is taken underneath the highway in a 24-inch CMP.

Figure 8.—Backfilling of polymer cell confinement gravity wall.

Figure 9.—Completed gravity wall. Note the undulating "top of cut" line.

Figure 10.—Expanding confinement cell units.

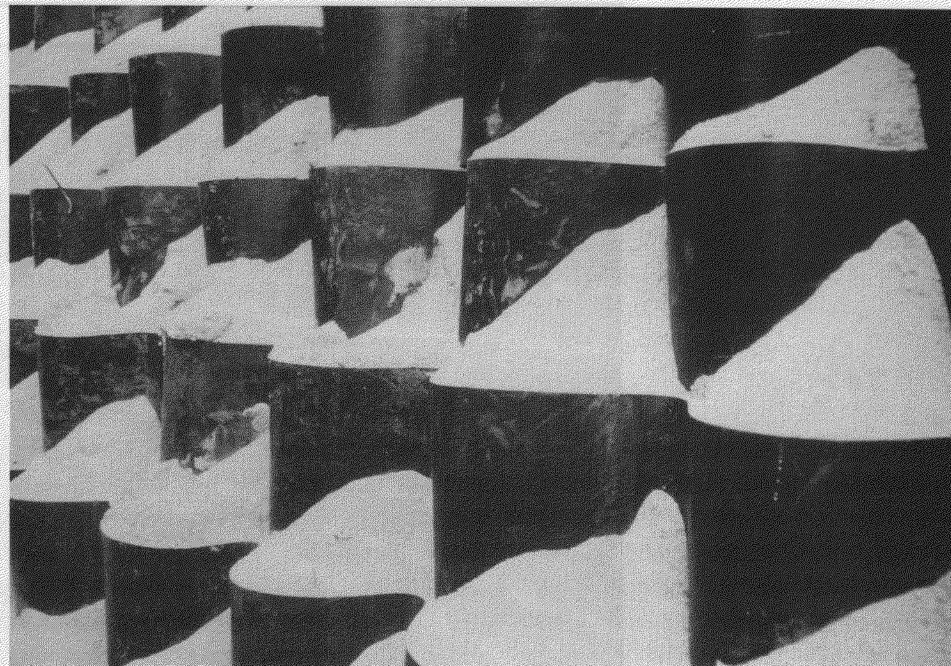

Figure 11.—Three inch terraces created by setback of successive confinement cell layers.

Low Water Crossings

Fords

The Daniel Boone National Forest in the Southern Region has made wide use of concrete plank fords. A series of precast concrete planks—approximately 4 inches thick, 18 inches wide, and 14 feet long, with 1/4-inch-thick steel brackets connected with 5/8 by 2-1/4 inch steel hexhead bolts—form a reasonably flexible mat structure. The mats provide a stable surface that will not deform under load, minimizing channel disturbances and sedimentation and, in the process, protecting fish habitat. The mats are potentially reusable in the event of road closure. The planks are made by the Job Corps.

In a similar application, the National Forests in Florida have made use of rock dips in stream crossings rather than installing culverts. Large rock is used to provide sufficient strength to support log truck traffic in terrain and soils not normally suited to fords. Generally, the fords are used on lower standard roads and offer the advantages of low cost and the elimination of borrow pit development for embankment construction over culverts and the channel modifications associated with drainage structures.

Geowebs have been successfully used in low water crossings. The geoweb is placed on a prepared surface over geotextile fabric, which provides separation and filtration functions, filled with surfacing material, and topped with an additional layer of the same material to allow for compaction and provide a protective coating. Installed properly, the geosynthetic material is shielded from damaging ultraviolet light and the crushing action of wheel loads. Geowebs are an economical alternative, quickly and easily installed, usually without stream diversion, and can be laced into immediate use.

Road No. 314 on the Angelina Ranger District of the National Forests in Texas crosses a wide lowland that is part of a large drainage area. The forest weighed the costs and impacts of all-weather access against needs and determined that, rather than building an embankment with sufficient drainage structures, a road with grade close to that of the surrounding ground elevation would be adequate. This results in the road being flooded periodically, with road surface and subgrade suffering a subsequent loss in strength. Some success at expanding the operating season of the road by use of soil modifiers has been reported.

Vented Fords and Low Water Bridges

The Lassen National Forest in the Pacific Southwest Region built a vented low water crossing by installing a cattleguard at the center of the crossing. The space between cattleguard bases provides a channel for normal flows. During spring runoff or high flows, water passes over the cattleguard and the normal concrete-surfaced low water crossing.

The Eldorado National Forest, also in the Pacific Southwest Region, built a low water bridge over a drainage with flows fluctuating from 15 feet wide and 1 foot deep to 180 feet wide and 5 feet deep. Many structures were considered, including gabion and concrete low water crossings, box culverts, and various types of bridges, yet the low water bridge concept was found to represent the optimum blend of function and treatment of environmental concerns. These concerns included:

- Minimizing disturbance to the stream during construction;
- Providing for fish passage during low flows; and
- Avoiding damming and subsequent channeling during peak flows.

The low water bridge consists of a modified cattleguard-grid running surface supported by concrete piers, complete with concrete approach slabs and rip-rapped cutoff walls. The pier footings were placed 5 feet below streambed elevation to prevent scouring and are sized such that soil bearing pressure is less than 1 ton per square foot. The grid understructure distributes load to three W-shapes and two channels, and two extra rails per grid were added to provide a smoother riding surface.

The low bid of $53,000 for construction of the structure was approximately 50 percent of the estimated cost of the least expensive acceptable alternative.

Extremely heavy spring runoff overtopped the structure after its completion with no damage or apparent effects, and no undue maintenance has been required after many years of service. No settling of piers or cracking in the concrete has been noted, although the structure does collect excess debris during high flows. The forest has been pleased with the aesthetic form of the structure and its low initial cost, low maintenance, and minimal environmental effects.

Visuals and Historical

A large landslide on a recently relocated section of U.S. 76 prompted the Georgia Department of Transportation (DOT) to request a waste area on forest land on the Tallulah Ranger District of the Chattahoochee and Oconee National Forests. Rather than wasting the material in the general forest area, forest personnel worked with the DOT in locating and constructing a vista on forest land adjacent to the highway.

Landscaping and Revegetation for Visual Effect

A project has been proposed to improve alignment and sight distance along Idaho Forest Highway 30, part of U.S. Highway 93, located between the town of Salmon and the summit of Lost Trail Pass at the Montana State line on the Salmon National Forest. The project is complicated by the very steep topography and existence of potential chinook salmon and steelhead habitat adjacent to the lower segments of the road. The preferred alternative will generally follow the existing alignment, with some $28 million budgeted for the 8.3-mile project. The route is designated as a Scenic Byway.

The contract for the first 3 miles of road, funded by the Federal Highway Administration and administered by the Forest Service, was awarded in October 1992. A landscape and revegetation plan (LRP) was prepared for the project by contract to explain the erosion control concepts that will be utilized on the project, species selection and plant spacing, construction and planting techniques, and the need for monitoring. It will include a set of line diagrams for use during construction.

Cutslopes will be varied throughout the project, ranging from rock sculpture and slope serrations to planting benches and planting pockets. Topsoil will be conserved for placement on most cutslopes (over 100,000 square yards total area).

Extensive use of gabion walls and geotextile-reinforced embankment is proposed. Gabion-faced wall will be up to 25 feet high with a total length of 800 feet. Some 400 feet of regular gabion wall is proposed. Almost 1,200 feet of stepped gabion-faced wall is proposed with heights of up to 50 feet. Additionally, a geotextile-reinforced retaining wall, 600 feet long with heights of up to 60 feet, is proposed.

A third contract, scheduled to be awarded in about 1996, will include 2 miles of split grade design. The existing roadway will be widened slightly into a two-lane standard road for northbound traffic. A vertical wall up to 20 feet high will separate this from a single lane of southbound traffic. The split grade design is required to minimize the amount of waste generated by the project and to protect the water quality of the North Fork of the Salmon River, immediately adjacent to the existing highway in scattered sections.

Historical Structures

The Ozark and St. Francis National Forests in the Southern Region took special measures under a recent reconstruction contract to retain culverts constructed by the Civilian Conservation Corps (CCC) during the 1930's. Rock inlet basins with metal pipe and stone box culverts were used extensively, and on older forest roads many of these structures exist in operable condition.

Water velocity and a washing whirlpool in the basins create a self-cleaning action; local experience indicates that a clogged basin is a rare event (figure 12). The few documented failures usually resulted from slides or severe flooding. The rock sill represents a hardened weir that reduces ditch erosion, and the basin reduces the added backslope excavation needed for the normal "duck's nest" type of inlet. The operable condition and self-cleaning properties of the basins, as well as reduced erosion potential, are reasons to retain the structures from an engineering point of view; aesthetic and historical values also merit retention. Engineers on the Ozark and St. Francis National Forests believe the structures are useful, and they replicate the functional design on new construction (figure 13).

Figure 12.—Self-cleaning catch basin constructed by the CCC.

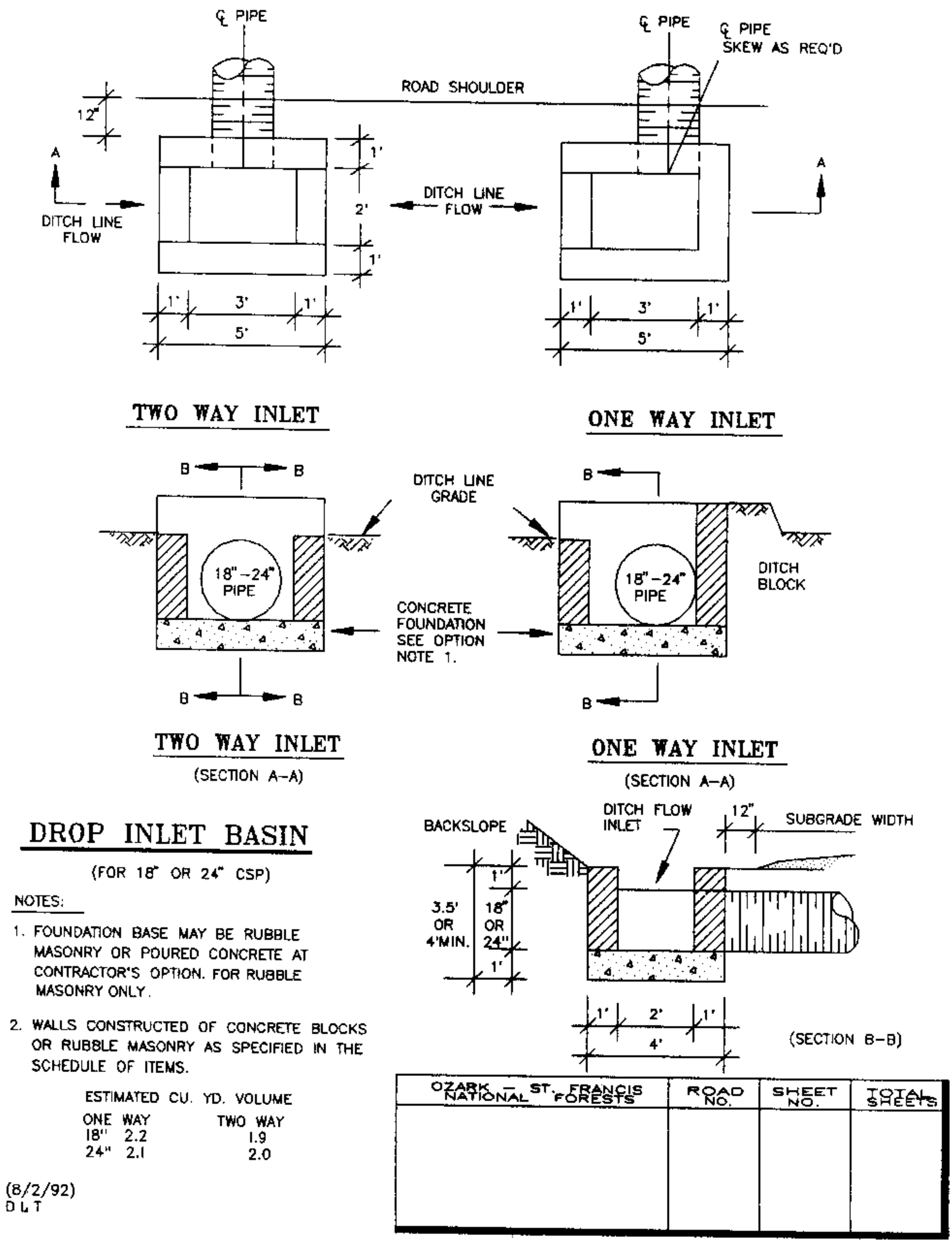

Figure 13.—Details for new construction of basins replicating CCC work.

Two types of structures exist, one including a CMP and the other a box culvert constructed exclusively from rock slabs (figure 14). Salvage and repair of the CMP structures is not difficult. Should a CMP require replacement, either the old pipe slips out and the new is remortared in, or the lintel rock removed, the pipe replaced, and the lintel rock remortared into place. The box culverts vary in type and size of stone used and were built with and without mortar. These structures are utilized and maintained where feasible, but replaced with a CMP if unserviceable.

Figure 14.—CCC constructed rock slab box culvert.

In a related project, a reinforced concrete slab deck with steel stringer bridge originally built in 1940 was replaced with a reinforced concrete and structural steel bridge in 1987. The decision to retain some of the original stone masonry abutments was made not only for their historical value, but because it meant the new abutments could be installed at a higher elevation, reducing substructure needs (figure 15).

In a cooperative effort with the county, the Targhee National Forest in the Intermountain Region designed a bridge replacement that left the existing CCC-constructed rock masonry abutments in place as an example of the work done by the corps. The bridge was accepted for a grant by the Timber Bridge Initiative program, and the Forest helped the county build it.

Figure 15.—Preserved CCC stone masonry abutments.

Road Maintenance

Reducing Sediment Through Road Maintenance

During ditch pulling activities, a "less is better" approach can sometimes be the best policy for sediment reduction. Selectively pulling ditches where required, rather than routinely pulling all ditches, has economic and environmental benefits. Lessening the amount of disturbance to the soil and vegetation in the ditch, while still providing for adequate drainage, will minimize sedimentation. During maintenance, stable cut slopes can be undermined, possibly causing slopes steeper than the material's natural angle of repose, with resulting slides and slope failure contributing to blockages and sedimentation. Tailoring ditch geometries to actual drainage needs can also alleviate slope undercutting in oversize ditches or in ditches with small flows.

Ditch heeling, or storing accumulated ditch waste against the cut slope toe during successive operations until the amount of material bermed requires removal, is an alternative to ditch pulling. Heeling is effective when dealing with smaller material volumes and can save maintenance time and money while providing for adequate drainage and resource protection. Heeled material aids in cut slope stabilization and helps prevent material moving down the cut slope from reaching the ditch bottom, where it is available for transport downstream.

Areas in which large volumes of material move from the cut slope into the ditch may require special treatments rather than simple removal and disposal. When realignment of the ditch away from the slope is not feasible, drainage can be provided through the slough material by placing two logs side-by-side but with a gap, then bridging the gap with a third log. Sloughing material covers the logs, while a limited amount of drainage can occur between the logs.

Ditch soil can be compacted, with resulting reduced erosion potential, by tilting the mold board forward during ditch pulling and heeling operations and by running the grader tires in the ditch and on the foreslope. Accumulated rock can be spread out in the ditch bottom as armoring material to combat scour. Gully plugs constructed in steep ditches slow the flow, reduce its erosive potential, and encourage the deposition of sediment. Grass and scattered rocks left in the ditch also slow flowing water.

The decision to leave or place obstructions in a ditch must be carefully weighed, so they remain assets and not become liabilities. Impeded drainage may cause flow over the road or water standing in the ditch, both of which represent ditch malfunction and possible safety and operations problems.

Culvert inlet basins often appear to be "manmade slide areas" due to the toe of the cut being made farther into the hill to provide room for the catch basin. As the pipe inlet and catch basin are cleaned, the slope above may be undermined, causing more material to slide downslope. Culvert extensions have been successfully used to raise the inlet elevation, allowing material stabilizing the toe-of-slope to remain while providing for flow into the pipe. The new flowline is maintained at an elevation low enough to prevent subgrade saturation and drainage bypassing the culvert. A ditch dam can be placed downstream of the inlet to retard flow-by.

Settlement basins provide a pool for deposition of sediment prior to entry of ditch water into a live stream. Not intended for large volumes of water, they are relatively small and lined with rock to prevent erosion.

One primary objective in road surface maintenance is drainage of surface water. Poor drainage leads to saturation of road surfacing and base, erosion, and sedimentation. Maintenance of the surface section (outsloped, insloped, or crowned) and of surface smoothness is imperative to proper surface drainage. Surface cross-drains are useful in removing water from steeper sections of road and those prone to surface rutting. Breaking up the concentration of water is especially important in these situations. Surface cross-drains include open-top culverts, intercepting dips, cross ditches, and flavel bars. Flavel bars are a cross between interceptors and water bars, consisting of a shallow V-shaped ditch that runs at approximately a 20° angle to the road centerline for a length of 50 to 75 feet. The berm is placed on the downhill side, and the water can be directed to either side of the road, depending on surface section. Flavel bars are used mainly on roads with limited traffic volume and low vehicle speeds.

Preventive measures are sometimes required to limit erosion on fill slopes. Rip-rap at culvert outlets armors the ground, retards the formation of gullies, and allows water to disperse. Filter windrows composed of logging slash and vegetative material, when placed on fill slopes, are effective at passing water but trapping sediment. Perhaps the most effective erosion preventive measure is seeding. Straw, mulch, or erosion control blankets can aid in protecting highly erodible areas until the seed germinates and takes root.

Road Closures

Temporary Roads, Closures, and Obliteration

The Targhee National Forest in the Intermountain Region has done much beneficial work in road closures, obliteration, and reducing impacts from temporary roads. In the past 2 years, 120 miles of road have been obliterated. Roads in riparian areas are specifically targeted for road obliteration. Parking areas and turnarounds are built at closure gates to help gain public acceptance of the gates and road closures. Roads are seeded, even for short-term closures, so that the grass will act as a silt trap and help prevent erosion. Obliterated roads are seeded with grasses palatable to wildlife. Roads that are both permanently and temporarily closed are waterbarred to facilitate drainage and to trap and store water for wildlife. Timber sales are one means to improve location, for example, moving roads out of riparian areas. Cooperative agreements with county agencies to move roads causing resource damage have successfully been completed.

The Southern Region has made wide use of "linear wildlife openings" as an added benefit from closed roads. Low volume roads, for the most part, are closed at the end of use and seeded for establishment as wildlife openings (figure 16).

The Lake Tahoe Basin Management Unit's maintenance level 1 road system has increased as some level 2 roads have been placed in the level 1 status. A new process is being used whereby the existing road surface is ripped to a depth of 12 to 18 inches with a soil cultivator pulled behind a D4H dozer, the ripped surface seeded, and a pine needle mulch spread on top. The road prism and drainage features are left in place. This process reduces soil erosion by increasing soil permeability and percolation rates; the grass helps by binding the soil together and encouraging infiltration. The road is then closed with a gate and kept available if needed for emergency access or future timber harvest. Two major problems are remedied: soil erosion potential is lowered and road maintenance expenditures are reduced.

Recycled Materials

Paper Mulch Hydroseeding

The Tiller Ranger District of the Umpqua National Forest in the Pacific Northwest Region initially used paper mulch in 1991 on a roadside stabilization contract. The contractor had some paper mulch left over

Figure 16.—Linear wildlife opening.

from a stabilization project just finished for a small city in California, so the contract was modified to include CalTrans specifications. The project consisted of raw slopes along a two-lane paved forest highway adjacent to the South Umpqua River. Some of these slopes had been eroding for years, and previous attempts to establish ground cover had been unsuccessful. The eroded material reaching the river was of significant concern in terms of fisheries habitat degradation. Figure 17 shows an area considered "hardest to revegetate" 3 to 4 months after application. This is the most grass on the site in more than 20 years.

The material is placed as a slurry mixture using standard hydroseeding equipment and methods. The distance that the material can be sprayed while maintaining its composition is very impressive. The material has the consistency of paper mâché, forms a very cohesive mass that clings to whatever it lands on, and stands up to wind, snow, and rain. Seed and fertilizer stay in the mulch until germination takes place. Figure 18 shows grass growing out of paper mulch. Outstanding success has been experienced at establishing grass on all kinds of slopes and stabilizing soil until natural vegetation has the opportunity to get started.

Stabilization hydroseeding is usually performed in the fall or early spring, preferably before heavy rains start or after they have finished. However, the Federal Highway Administration reconstructed a portion of Douglas County Highway 1, located 2 miles below the Tiller Ranger Station, and, at the recommendation of district personnel, used paper mulch. They sprayed it during a hot day in August. It was not until

Figure 17.—Successful stabilization of a slope considered "hardest to revegetate."

Figure 18.—Grass growing out of paper mulch.

several hot, dry months later that precipitation came, demonstrating two things: it did not dry up and blow away, and it did not wash off the slopes during several very heavy storms early in the season.

The cost of paper mulch is basically the same as the other wood fiber mulches the district has used in the past: approximately $650 to $700 an acre. Two suppliers are available, Hamilton Manufacturing in Twin Falls, Idaho, distributing Nature's Own, and Thermoguard in Billings, Montana. Both products are composed of recycled paper products. A local contractor in the Tiller area is attempting to duplicate the mulch, but it needs some improvement to meet specifications.

Some important advantages of paper mulch have become apparent: first, it stays put on all kinds of slopes and through all kinds of weather; second, recycled materials are used; thus, something is returned to the environment from whence it came.

CalTrans specifications for the slurry mixture and the paper mulch were modified into a special project specification for successful use on a particular project on the district.

Crusher Screen Walkway for Cattleguards

On the Lassen National Forest in the Pacific Southwest Region, used crusher screen was welded onto one side of a cattleguard grid to provide a safe surface for passage of pedestrians and cyclists while still keeping cattle out. The cattleguard is located at the entrance to a major campground.

Salvaged Bridges

Targhee National Forest engineers built a temporary bridge out of salvaged 8- by 18-inch stringers and used it twice to cross small streams within cutting areas, instead of placing temporary culverts causing impacts to the streams both during installation and removal. A flood-damaged bridge was salvaged and temporarily placed into service in another location to avoid fording the stream, using a culvert, or canceling a timber sale.

Recycled Asphalt and Road Surfacing

Milled asphalt provided by the State highway department was very successfully reused by the Targhee as dust abatement and surfacing on a campground access road.

The Idaho Panhandle National Forest had a Roto Trimmer under contract to re-establish cushion material to a specified depth on 24.2 miles of native surface roads and 2.0 miles of old chipseal roads.

The machine worked up to a 6-inch depth on native surface roads and 4 to 6 inches on old chipseal road. The maximum size rock allowed in the cushion material was 4 inches. The fine and coarse particles were required to be evenly processed across the entire width of the road. Any rock that could not be processed was side cast. River rock or round rock tended to roll around in the drum and was difficult to process.

The original rough roadbed, with large rock protruding above the surface or bedrock surfaces, was processed (chewed) and mixed with the fines that were generated while working on the rock. This left a pit-run type of surfacing. The road was then bladed, shaped, and compacted.

The recycling process worked very well. A borrow source did not need to be developed, nor did rock have to be hauled. Everything was generated on the roadway, resulting in cost savings.

This machine did not throw rock or generate excessive dust. Dust and rock were kept at the immediate drum working area. Oversized rock just rolled out each side of the drum and was side cast by the grader. Most of the roads that we worked were next to streams or rivers, on which there was no noticeable impact.

Use of Conveyor Belting for Road Drainage

The Wallowa–Whitman National Forest in the Pacific Northwest Region is experimenting with water diverters made of 5 ply, 12-inch by 20-foot used conveyor belting attached to a 4-inch by 8-inch by 20-foot rough sawn, no. 2 or better treated timber. The diverter is installed at a skew angle determined by road outslope to aid in shedding surface water (figure 19). The grade on the belt is 4 percent greater than outslope to ensure drainage and cleansing action. Outfall protection is provided where necessary, to prevent erosion. The belting protrudes approximately 3 inches above the road surface and bends easily under tire loads, yet is stiff enough to channel water off the road. Six of seven experimental installations are functioning properly; the seventh suffered washing damage. Compared to the standard grade dips, the diverters are expected to need less maintenance, appear to function better on steeper road grades, and do not require isolated steepening of grade as the standard does.

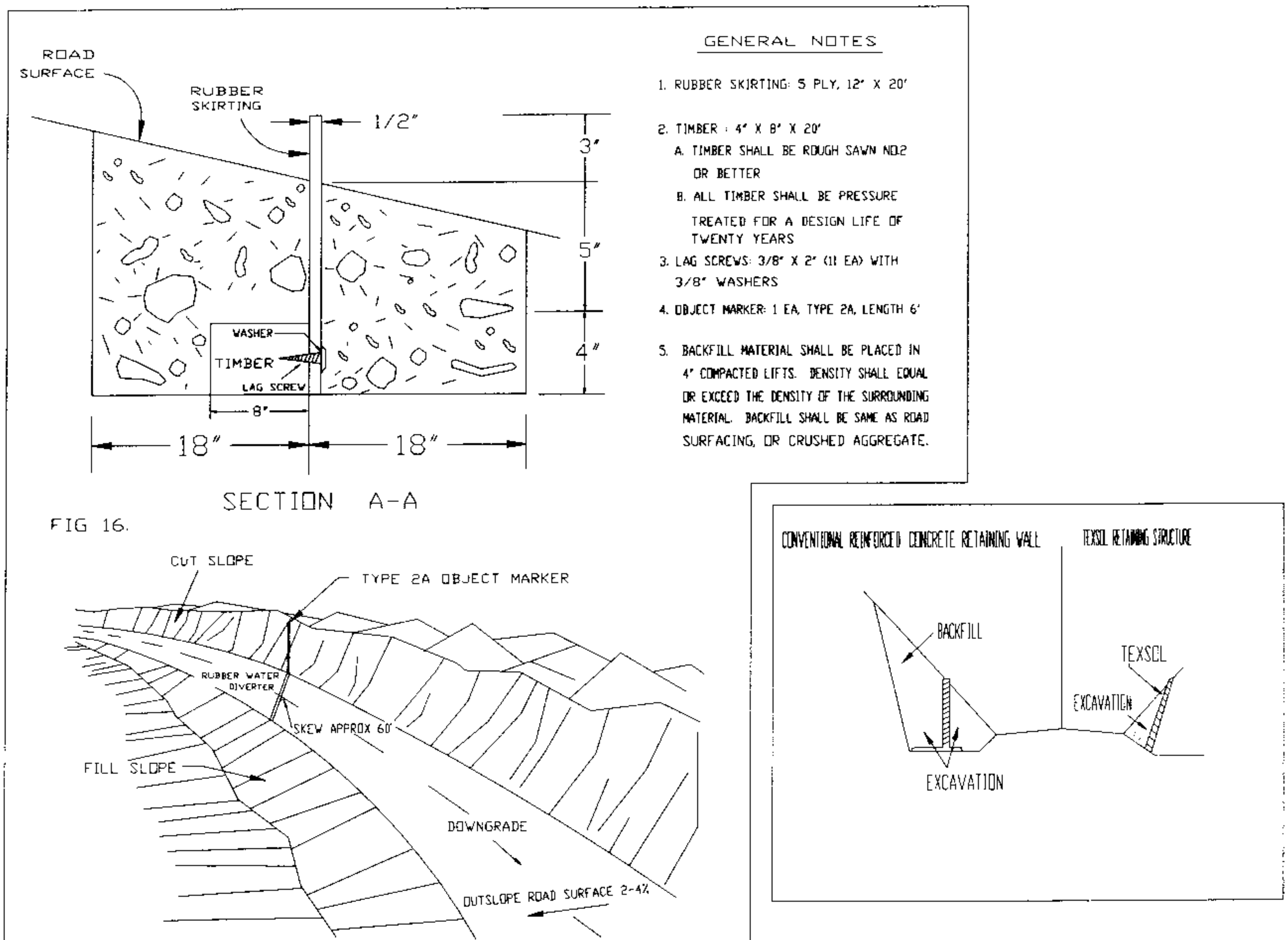

Figure 19.—Rubber water diverter details.

Construction of a Portable Bridge West Engineering Zone, Three Rivers District, Kootenai National Forest

Tom Grabinski, Zone Engineer, Kootenai National Forest

A stream crossing on an existing road required a bridge structure in order to facilitate a road necessary for the Waper Ridge Timber Sale. The existing road had been constructed several years earlier but had the major drainage structures removed, primarily native log bridges. The West Engineering Zone designed the replacement structure, with the Regional Office reviewing and approving the design. In August 1992, the combined efforts of the timber purchaser road contractor, Davidson Kelson Construction of Bonners Ferry, Idaho, and the Youth Conservation Corps (YCC) crew (eight students and a leader) resulted in a 30-foot treated timber portable bridge. The contractor agreed to allow the YCC crew to work with his crew to help construct this portable bridge. A total of 5 days was needed to fabricate, move, and erect the bridge.

The engineering zone had excess timber stringers and treated, glue-laminated deck panels from several bridges salvaged in years past. We were lacking two stringers, which the local county road department donated. The contractor purchased all the hardware, nails, bolts, and nuts.

The contractor started the assembly by laying out the stringers on the sills and getting the spacer blocks and tie rods in place. Upon completion of the stringer layout, the deck panels were placed on the stringers. Then the YCC crew came on-site, nailed all the deck panels (72 total) to the stringers, and nailed the running planks to the deck using 3/8- by 10-inch ring shank nails. The contractor finished the project by installing the curb blocks and rail to the deck panels, then cutting the bridge lengthwise for transport to the bridge site. All treated timber that was field cut was treated with a copper napthenate solution. The bridge stringers were fastened to the 12-inch by 12-inch by 16-foot timber sill with eight angle plates and lag bolts.

The contractor spent 3 days constructing and loading the portable bridge, with help from the YCC crew during 2 of the days. It took the better part of 2 days to install the bridge and get the approaches built. The purchaser is required to remove the bridge and move it to the Forest Service storage yard upon completion of the sale.

The cost estimate for the purchaser to fabricate this 30-foot portable bridge, move it to the site, install it, and later remove and place it in the storage area is $6,521. All the timber members were furnished by the Forest Service. The estimated value of this portable bridge is over $15,000.

The YCC crew gained some great experience and work satisfaction in helping the contractor construct the bridge. The crew also got to see the installation done by the contractor. The contractor appreciated the help from this young YCC crew.

The bridge is still in place and will be for the remainder of 1993. Upon removal, it will be stored at one of our work centers for future use on the zone. The bridge design provided an inventory rating of 59 tons for an HS vehicle and an inventory rating of 96 tons for a 3S2 vehicle.

Drawings and load rating are available; if more information is desired, contact Lou Kurtz or Jesse James at the Kootenai National Forest, West Zone Engineering, 1437 N. Highway 2, Troy, MT 59935; DG: R01F14D04A or phone 406-295-4693.

Figure 1.—Contractor's crew finishing bridge construction.

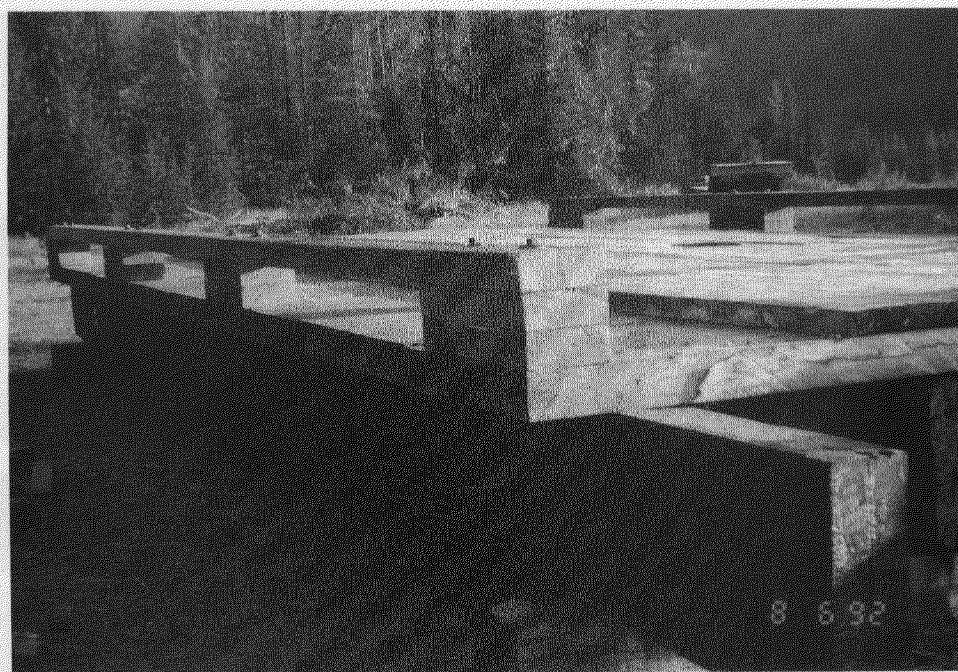

Figure 2.—Finished bridge prior to sawing it in half.

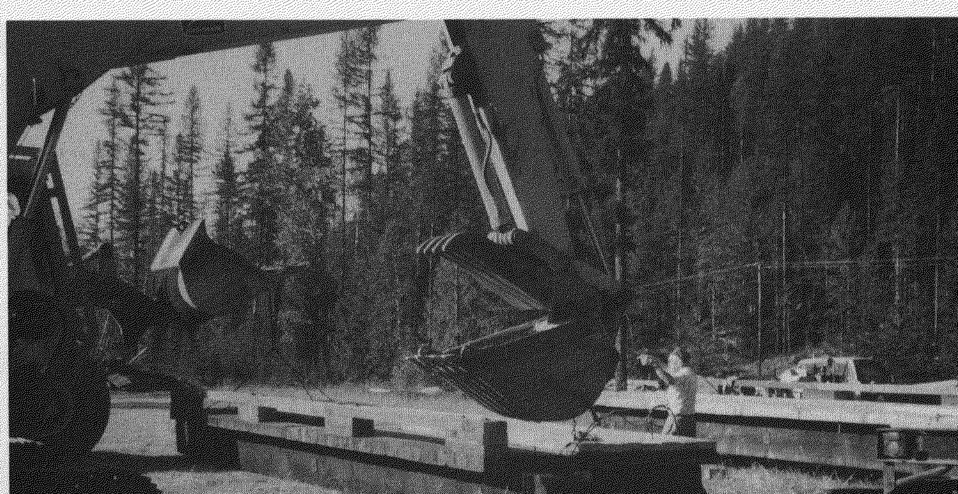

Figure 3.—Getting ready to load the first half.

Figure 4.—Loading second half on flat bed trailer.

Figure 5.—Bridge site on existing road, native log bridge was originally placed and removed.

Figure 6.—Placement of sill timber prior to bridge placement.

Figure 7.—Unloading (Oops!) the bridge at the site.

Figure 8.—Successful placement of the first half.

Develop Computer-Based Instrumentation Systems for Measuring and Recording Timber Harvesting Machine Functions—Phase 1

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Abstract

We conducted a review of sensors with potential for machine instrumentation systems. The specifications of the sensors selected for use in the development of the data acquisition system are summarized. The sensors are commercially available and, although sensor outputs vary in type (frequency, voltage, current) and magnitude, signal conditioning networks make them compatible with a wide variety of data collection platforms.

Introduction

The development of a comprehensive instrumentation system is needed to optimize the performance of forestry/agricultural equipment and its implements and/or component functions. Such instrumentation systems can reduce operational and maintenance costs by automatically controlling critical machine parameters for optimal efficiency. These systems can also provide a highly accurate, real-time database for detailed analyses of machine performance to make improvements in machine management and implement design. The design of this type of data acquisition system is governed by the machine or implement it will monitor and the environment in which it operates.

Forest machines have undergone tremendous evolution in the past 25 years, from chainsaw felling and skidding to the feller bunchers, forwarders, and cut to length processors of today. Data collection concerning current machine functions would provide needed information on day-to-day operations of modern forest equipment. Such a database could form the foundation for a rational redesign of current equipment to meet today's challenges. Acquiring such information can be accelerated with data acquisition systems that can operate unattended on a continual basis.

The primary components of these real-time data collection systems are electronic transducers and sensors that perform in environments that are dirty, wet, cold, hot, dry, and oily. Transducers are devices or substances that convert input energy of one form into output energy of another form. They are composed of some type of sensor and energy conversion package.

Sensors are devices that detect and respond to signals or stimuli. They are not always used as transducer parts but can function as stand-alone detection devices, e.g., thermometers. For this discussion, sensor output is to be converted to an electrical signal, effectively a transducer, for composite data collection.

To accomplish the task of developing a computer-based data acquisition system, a cooperative study between the Engineering Unit of the Southern Forest Experimentation Station and the Tuskegee University School of Electrical Engineering was initiated in 1991. In the initial phase, sensor selections, in accordance with known system design criteria, were made.

The investigators intend to develop a system from which the operating state of any given machine subsystem can be determined from basic information gathered from its component parts. Engine speed, engine temperature, fuel flow, hydraulic pressure, forward and backward movement duration, operation mode (idle, service, etc.), cab temperature, component activation, and wheel torque are the parameters to be continuously monitored.

In the second phase, the sensors will be installed on a test vehicle for field validation. The last phase will be the selection and test of the appropriate data acquisition platform. This paper is a report on the first phase of the development of this data acquisition system.

Selection Criteria/ Machine Functions

Determining the efficiency of any forest operations equipment requires the understanding of three variables. They are the environment, the energy transferred by the machine or implement, and the work done.

The determination of the environment in which the machinery works is normally quantified by the temperature, humidity, visibility, wind, and precipitation. The environmental conditions extend beyond climatic conditions into the realm of ground cover, ground slope, and soil moisture content. The effect of some combination of these parameters means the difference between operation and shutdown.

Work done by the machine is commonly measured in time and motion, simply put, production.

The energy released at combustion is subject to losses during transfer from one machine component or implement to another. To predict the performance of the equipment, those losses have to be quantified. The energy transferred from the power train is usually measured by determining the state of energy of its components. Commonly measured parameters are temperature, load, speed of rotation, torque, and flow.

Sensor selection was based on cost, reliability, physical size, and adaptability for use on forest machines. An extensive search was conducted for sources of transducers and sensors. The sensors selected were subsequently laboratory tested in order to further understand their specific characteristics, in addition to verifying manufacturers' specifications.

Sensor Selection

Transducers and sensors for this project were to be selected for initial test with a Polycorder Model PC-706 as the data collection platform. The configuration of the Polycorder is limited to ±5 V or 50 mV and 5 V excitation with no frequency or current-to-voltage signal conditioning. This could be a hindrance, but most sensors have signal conditioning networks for compatibility with a variety of data collection platforms.

Sensor validation will be done with a Franklin Logger Skidder with a Detroit Diesel engine and an articulated/oscillation frame. The operational characteristics of the machine were used to define the working range of some of the sensors. Most selections were made for typical forest operations machinery.

Temperature Sensors

Practical temperature measurements are usually made with one of four devices: thermocouples, resistance temperature detectors (RTD's), thermistors, or integrated circuit transducers (I.C. sensors).

Thermocouples are the most commonly used temperature measuring devices, in part because they are self-powered, simple, rugged, inexpensive, and offer a variety of temperature ranges from which to select. Because of their widespread use, the operational limitations of thermocouples have been rigorously defined (Hibbs and Greene 1990), including:

(1) Stability of the reference temperature;

(2) Secondary effects due to temperature gradients across junction boxes or multiplexers;

(3) Variation in thermocouple output relative to National Bureau of Standards (NBS) standards (low voltage);

(4) Accuracy of voltage measurement of thermocouple output (output is non-linear);

(5) Processing required to convert the reference temperature and measured voltage to a temperature; and

(6) Difference in temperature between the sensor and the object being measured (sensitivity).

Thermocouples are commonly used to monitor ambient temperatures for determination of the environmental/climatic conditions in which the machine is operating. Oil and coolant temperatures are primary indicators of proper engine function and are often monitored using thermocouples. This type of diagnostic information is required in the performance analysis of internal combustion engines (Luckman and Engle 1990). The temperature relationships that exist between the exhaust gas and the intake air are proportional to fuel consumption (Gautz, Chancellor, and Rumsey 1989).

A type K cement-on Omega thermocouple with millisecond response and very small reference junction thickness was selected. This thermocouple—equipped with a 3-foot, 30-gauge thermocouple wire—is ideal for measuring temperatures on metals, plastics, and ceramics with flat or curved surfaces. The frequency and sensitivity of this thermocouple, along with the ease of installation and a working range of 260 to 360°C, should prove appropriate for engine manifold measurements.

RTD sensors were also investigated for their potential use in the data acquisition system. Those selected for investigation utilize nickel or nickel/manganese grids, constructed much like wide-temperature-range strain gauges, having great response time and providing absolute temperature measurements without the use of reference junctions. The measurement circuits are relatively simple, and the sensors are very stable over years of use when properly installed. They are bonded to structures using standard strain gauge installation techniques.

The temperature coefficient of nickel sensors is very high and nonlinear; thus, for real-time data collection they are commonly used with linear passive (LST) networks. LST's are small passive devices, encapsulated in molded epoxy cases, whose primary function is to linearize the gauge resistance versus temperature. The resistance can also be measured directly and converted to temperature with the charts supplied by the manufacturer. The sensor being mounted on the forestry test machine is the WTG-50B with the matching network LST-100F-350D. The sensor temperature range is -200 to 500°F with a resistance of 50 ohms ±0.3 percent at 0°C.

The selected Micro-Measurement (MM) resistance temperature sensor is being used to monitor engine manifold temperature. Although these are generally more costly than thermocouples, technical considerations exceeded the cost factor because of the sensor's compatibility with other devices being used for this data acquisition system. Temperature compensation (McLaughlin, et al. 1989) due to thermoexpansion across the manifold can be related to actual combustion temperature for fuel consumption correlation.

Pressure Transducers

The mechanical advantage of hydraulic systems makes them ideally suited for application throughout the forest machinery industry. By monitoring fluid pressure, parameters—such as engine speed, torque output, hydraulic cylinder stroke, etc.—can be determined and related to system performance.

Paine's pressure transducer is made of bonded strain gauges on four arms of a Wheatstone bridge. The transducer is versatile and, when properly configured, can be used to monitor hydraulic (Self, Summer, McLaughlin 1987) or medium interface pressures (Burcham and Mathes 1987). Pressure is registered from a change in resistance due to strain, and this change in resistance is converted to an electrical signal proportional to the pressure. The transducer is in an all-welded, all-stainless-steel enclosure, making it suitable for use in industrial applications, including environments containing extremely corrosive materials. The pressure range is 0 to 5,000 psi with a proof of pressure of 150 percent and burst pressure of 200 percent of the rated range. The excitation is 10 Vdc with an input resistance of 350 ±35 ohms and an operating temperature range of -25 to 250°F.

The BHL-type DFH pressure cell translates changes in fluid pressure into corresponding changes in output signal voltage. This is made possible by use of strain gauges designed for diaphragm strain measurements in a Wheatstone bridge circuit. Any change of fluid pressure displaces the diaphragm, causing the strain gauges to change resistance slightly. This change in resistance upsets the bridge balance, which corresponds exactly to variation in pressure on the diaphragm. The DHF pressure cell may be operated without adverse effect at pressure overloads up to 200 percent rated capacity, and it is protected from damage caused by high velocity solid particles in the fluid. The measurable pressure range is 0 to 3,500 psi, and it will withstand a transient pressure change of 500 percent of rated capacity in systems where the temperature is -65 to 250°F. The recommended input voltage (excitation for the bridge) is 12 Vac (rms) or Vdc with a maximum permissible level of 20 Vac (rms) or Vdc.

Other Sensors

The Longfellow linear motion position (displacement) transducer, used to produce an electrical analog signal proportional to movement of some part of a machine or implement, is being installed on the test vehicle to monitor articulation. The analog output may be used to produce a visual readout or to instruct a computer to perform some function in an event-driven control system. The transducer provides a dc voltage output at high level; consequently it does not require a complicated electronic circuit to produce a useful signal voltage. For applications where it is subjected to water, oils, etc., the unit may be ordered with water-resistant seals. Essentially potentiometers, they are always used in a three-terminal voltage divider configuration. The effective travel (stroke) is 6 inches (150 mm) to 48 inches (1200 mm) with a 0.236-inch (6-mm) shaft diameter and 10**8 useful life operations. The total resistance is 5 kilohms ±20 percent with two accuracy options: option A, ±1.0 percent, or B, ±0.1 percent, and a working temperature range of -65 to 105°C.

In the literature reviewed, the use of flowmeters was limited to determining fuel consumption. The data collected from the meters were used as one of the parameters for determining engine performance (Summers and Batchelder 1984). Infrared or near-infrared optical sensors (transmitters and receivers) are used when hard-wired configurations are not possible (Wiedemann, Bowman, and McCollum 1987) or for improved speed and accuracy for real-time data collection (Christensen and Hummel 1986).

The IR-Opflow flowmeter has an infrared optical/electric signal pickup. In operation, fluid flows through the meter by first passing through a helical nozzle, which causes flow to spiral, rotating in a helical pattern. The spiralling fluid causes the rotor to spin. The rotor is designed to immediately develop a rotation-induced, friction-free fluid bearing, eliminating any potential bearing wear. An infrared electro-optical transmitter and receiver is molded into the body of the meter with a pair of miniature circuit boards, which produces a square wave electronic signal output proportional to the flow. The design eliminates the need for flow straighteners or special lengths of inlet piping to stabilize turbulent flow. The detectable flow rates range from 0.1 to 125 L/min (0.03 to 37.5 gpm) for fluids with viscosities within 1 to 15 cSt, and it has a working pressure of 150 psig at 175°F. The specified ambient temperature range is -40 to 185°F with wetted materials made of PVDF (polyvinylidenefluoride). The power required is 5 to 18 Vdc (6 to 33 mA), and the output signal is a square wave directly proportional to flow.

The compact meter is suitable for measurement of very low flow rates. It can be installed in any orientation, immediately adjacent to 90° elbows or other fixtures. It can be installed upstream or downstream for greater system design flexibility. The sensor is compatible with most solvents, with all wetted parts made of high quality PVDF for durability.

Comus vibration and motion sensing switches provide an excellent alternative for unattended studies of machine operating time. They are an improvement over the Servis recorder because the electrical signal allows them to be integrated into the data acquisition system.

These are mercury switches, which have many significant advantages over comparable switching devices. In addition to being compact, they offer consistent operation and dependability for an exceptionally long life. These glass- or metal-type switches are hermetically sealed and backfilled with a pure hydrogen atmosphere. The construction of the basic mercury switch consists of two or more electrodes hermetically sealed in a metal case, with a quantity of free-flowing mercury. The switch is operated by tilting it to allow the mercury pool to make or break contact. In glass switches, contact is made when the mercury pool touches the center electrode, which is insulated from the metal but bonded to it. The amount of travel required to move the switch from the "just open" to the "just closed" position is measured in degrees and referred to as the "differential angle." The vibration and motion sensing switches selected are the COMUS M series, which are omni-directional switches. Their "operating angle" indicates the position at which the switch "must be on" or "must be off." Because M series switches are omni-directional, axial orientation when mounting is critical. The CM14-4 switch has its contacts always open when the switch is at rest. When subject to vibration or motion, the contact will continually close and open. They return to the open state when the switch returns to the "at rest" condition.

In contrast, the CM18-1 type switch may be either open or closed when at rest, depending on the position of the electrode. Contact is normally open when the center electrode is vertical and normally closed when the center electrode is inverted. A slight amount of motion or vibration causes the contacts to change state while the disturbance continues. The operating temperature ranges from -35 to 210°F, and the differential angles range between 25° (min) to 35° (max) for the CM14-0 switch. The sensors have an ampere rating for ac resistive loads of 2 A at 30 Vac for CM14-0 and 0.2 A at 30 Vac for the CM18-0, with mercury to dry metal (MDM) contact for both switches.

The switches are compact, offering dependability and exceptionally long life, while providing consistency in operation. The sensors are suitable for high switching current (ac and dc), long non-operating life, and have low contact resistance. Note that mercury freezes at -39°C (-22°F) and boils at 327°C (647°F), giving the switches a considerable temperature range.

A Wiegand effect sensor is capable of producing an induced voltage pulse of 0.5 to 2 V in the presence of longitudinal magnetic field cycling, depending on the excitation field strength and orientation. The sensor does not require an external source of power. It may be applicable for direction-of-motion sensing with a suitable signal conditioning circuit. The objective of extensive laboratory testing was to determine the relationship between the output voltage pulses and the strength, shape, speed of rotation, as well as the proximity of the permanent magnet to the sensor. It was found that a single narrow rectangular permanent magnet produced pulses with sharper peaks in comparison with a stack of flat wider magnets. The Weigand effect sensors have high level output pulses between 0.5 to 2 volts. Pulse width is nominally 20 u-sec at all pulse rates for temperatures ranging from -65 to 200°C.

Proximity sensors are commonly used to determine the speed of rotation of a moving part, such as an engine or power takeoff (PTO) drive shaft or wheel (Palmer 1984). When the sensors were used on engine drive shafts or wheels, most often the speed of rotation was used to calculate theoretical vehicle ground speed. The PTO, as well as the engine rotation, are usually two of the parameters used to determine engine performance (Zhang, Perumpral, and Byler 1985).

The theoretical speed is the speed at which the vehicle would travel if there were no slip between the rolling surface and the tire or track, and the power train was 100 percent efficient. Actual ground speed varies with soil type, topography, load, etc., all of which affect the amount of slip between the tire and the rolling surface. Actual speed has been measured in numerous ways— by manually timing the vehicle over a prescribed path or by radar (Summers and Batchelder 1984), ultrasound, or laser.

Future Work

The selected sensors are being mounted on the Franklin Logger Skidder for validation. This will provide the base line information from which sampling rates will be determined. The sampling rates for the study will be dependent on the machine and the operating environment.

The information will also have to be broken into the information that the operator needs to know versus the information that should be handled by the semi-intelligent acquisition platform. Consideration should be given to the length of operators' shifts and to critical criteria relative to overall operation safety and machine performance.

The sensors will only provide signal output, but the interpretation of the information is critical for the completion of the final phase of the project. The validation phase of the project will determine the type of platform requirements that are necessary for data storage and manipulation. This entails the signal storage, calibration, and reduction to engineering parameters. Cross checks with other variables for computation will determine the operating state of the machine.

Summary

The sensor selection phase of the project is completed, and the validation of the sensors is ongoing. During this phase, we will determine what machine functions or parameters provide the most useful information and the frequency at which they need to be sampled. The rate of sampling is dependent on the sensor's output frequency in conjunction with the machine's or component's rate of change of energy. This will require engineering judgment of the machine design limitation, the operation being undertaken, and the response of the operator. We conclude that there is a very large array of transducers and sensors from which to choose that, when properly configured, will provide all the information needed to determine the state of a machine and its implements.

Contact Tyrone Kelley, Timothy P. McDonald, or Bryce J. Stokes at the Southern Forest Experiment Station for a list of sensor types, manufacturers, model numbers, operating ranges, desired ranges and environments, and costs.

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Specifications for Differential GPS Coordinate Data Submission to the Geometronics Service Center

Troy Warburton, Cadastral Analyst, Geometronics Service Center

Globally Positioned Satellite (GPS) data is a viable source of information for map revision and new mapping. Due to the ease of operation of the GPS units, and the instantaneous coordinates that can be observed, a framework of guidelines to protect the reliability and authenticity of the coordinate data must be developed. These specifications are proposed as a framework for GPS coordinate data submission to the Geometronics Service Center (GSC).

The GSC realizes the significant contribution that GPS will make to the mapping process. These guidelines are intended to help assimilate the GPS data into the mapping process and not to hinder future development or application of the technology. A common set of guidelines is needed to provide for consistency of the data, identify reliability of the data to an intended user, and ensure the use of the data for a variety of applications. An integral part of this framework must be the ability to share and obtain GPS data with agencies outside the Forest Service. This framework should be common to all GPS-obtained data regardless of the application or accuracy level.

A valid concern about GPS data is the current lack of information available about the coordinate data. If a Metadata Statement (data about data) containing information about the collection process would precede the coordinate data, then the data's proper application and reliability could be determined. The coordinate data should include standard feature information, so proper identification of the point, line, or polygon can be determined.

A. The Metadata Statement should include:

Position in Metadata Statement	Description	Abbreviation
1	Format	
	a. Point	PNT
	b. Line	LNE
	c. Polygon	PLY
	d. Special Circumstance	SPC
	e. Non-standard	NON
2	Date of Collection	MMDDYY
	Alternative: Julian Day and Year	
	Example: 12693 (Day 126, 1993)	
3	Submitting Agency and Contact	RO4A
	If Forest Service Include:	
	1. Region	
	2. Forest	
	3. District	
4	Channels Receiver Is Capable of Tracking.	1
	Categories:	
	1. L1 C/A, Code	
	2. L1 C/A, Code–Carrier Smoothing	
	3. L1 C/A, Carrier	
	4. Dual Frequency	
	5. Other (List)	
5	PDOP Mask Setting	00
6	Elevation Mask Angle Setting	00
7	PDOP Switch Setting	00
8	Signal Level Mask Setting	00
9	Position Fix Mode	
	a. 2D	2D
	b. 3D	3D
	c. 2D/3D Mix	MX
10	Order of Base Stations Used	1
11	Base Station Position Logging Interval (in Seconds)	00
12	Distance from Base Station (in Kilometers)	000KM
13	Total Number of Corrected Position Fixes	0000
14	Datum of Data	
	a. NAD 27	NAD27
	b. NAD 83	NAD83
	c. WGS 84	WGS84
15	Coordinate Type	
	a. Latitude, Longitude	GEOGR
	b. UTM 27	UTM27
	c. UTM 83	UTM83
	d. State Plane Coordinate 27	SPC27
	e. State Plane Coordinate 83	SPC83
16	Zone	0000

B. The coordinate data feature information should include:

Position in Coordinate Data Statement	Description	Space in Statement
1	Meridian	000
2	Township Number	000
3	Range Number	000
4	Section Number	00
5	Description of the Feature	000
6	Coordinate Data	X, Y

The present Forest Service cartographic feature file (CFF) code identification number should be used, when possible, to encourage standardization of terms for feature description. These codes are currently in use for the digital collection of the primary base quads at GSC. A listing of the codes may be obtained from the Geometronics Service Center, 2222 West 2300 South, Salt Lake City, UT 84119-2020. Certain features will require additional information due to the fact that the CFF code will not be specific enough for identification. Under these special circumstances, the additional information included with the CFF code will aid in the identification of the feature. This information will include the feature's name or identification number along with specific point information. Mineral surveys, homestead entry surveys, bench marks, mineral monuments, and corners of the rectangular survey system are examples of such a circumstance. A unique numbering system should be used to properly identify the specific corner of the survey. Two numbering systems in use are the alphanumeric system, defined in *Corner Search, Perpetuation, & Recordation, A Training Guide* (USDA November 1986), and the Bureau of Land Management's (BLM's) PCCS point identification scheme, defined in the *GCDB Data Collection Software User Documentation, Users Manual.* Information about the PCCS point identification scheme can be obtained from any State office of the BLM.

An ASCII file with a standard format should be used, with key data elements assigned in specific order. If a variation of the standard format is used, a description of the format should accompany the Metadata Statement. The distinction between standard formats for point, line, polygon, non-standard, and special circumstances will be noted in the standard Metadata Statement. Point data will be defined as a single coordinate that can be identified by a CFF code. Line and polygon data will have a string of coordinates that can be identified by a CFF code. A special circumstance format will incorporate extra information for point identification in addition to the CFF code. A non-standard format is one that is unique to the user. A description statement must accompany a non-standard format for proper identification of the format elements.

Standard Formats

Example of Point Feature Format

METADATA STATEMENT

PNT, 083092, R04A, 1, 08, 10, 6, 6, 3D, 1, 1, 20, 180, NAD27, SPC27, 1101

COORDINATE POINT DATA

BOI, 6S, 44E, 24, 427, 745720.10, 441661.60

Example of Line or Polygon Feature Format

METADATA STATEMENT

LNE, 083092, R04A, 1, 08, 10, 6, 6, 3D, 1, 1, 20, 180, NAD27, SPC27, 1101

COORDINATE DATA

BOI, 6S, 44E, 24, 101
745720.10, 441661.60
745718.66, 441653.30
745715.21, 441644.17

Example of Special Circumstance Feature Format

METADATA STATEMENT

NON, 083092, R04A, 1, 08, 10, 6, 6, 3D, 1, 1, 20, 180, NAD27, SPC27, 1101
Description statement would have to be included.

COORDINATE POINT DATA

Format would be unique to the user.

With a common framework of guidelines, the use and reliability of GPS data will become an integral part of map revision and new mapping. The added information contained in the Metadata Statement will aid the user in determining the appropriate application and reliability of the coordinate data. The framework will encourage standardization of GPS data so its usefulness can be maximized and questionable data can be identified.

Use the following form to submit differential GPS (DGPS) data if the user is unable to combine the Metadata Statement, coordinate information, and coordinate data in the recognized standard format above.

5-13-93

DIFFERENTIAL GPS COORDINATE DATA SUBMISSION TO THE GEOMETRONICS SERVICE CENTER

I. Metadata Statement:

GENERAL INFORMATION

1. Submitting Agency and Contact:
   1. Agency ____________
   2. Region ____________
   3. Forest ____________
   4. District ____________

2. Date of Collection: ____________

3. Contact: ____________

RECEIVER INFORMATION

4. Channels Receiver is Capable of Tracking: # ____________

Categories:
1. L1 C/A, Code
2. L1 C/A, Code–Carrier Smoothing
3. L1 C/A, Carrier
4. Dual Frequency
5. Other (list)

5. PDOP Mask Setting: ____________
6. Elevation Mask Angle Setting: ____________
7. PDOP Switch Setting: ____________
8. Signal Level Mask Setting: ____________

9. Position Fix Mode: # ____________
   1. 2D
   2. 3D
   3. 2D/3D Mix

BASE STATION INFORMATION

10. Order of Base Stations Used: ____________
11. Base Station Position Logging Interval: (In Seconds) ____________
12. Distance From Base Station: (In Kilometers) ____________

DATA INFORMATION

13. Total Number of Corrected Position Fixes: ____________
14. Coordinate type: # ____________
    1. Latitude, Longitude
    2. UTM 27
    3. UTM 83
    4. State Plane Coordinate 27
    5. State Plane Coordinate 83

15. Datum of data: # ____________
    1. NAD 27
    2. NAD 83
    3. WGS 84

16. Zone: ____________

II. Coordinate/Feature Information:

1. Meridian: ____________
2. Township Number: ____________
3. Range Number: ____________
4. Section Number: ____________
5. Description of the feature:
   CFF Code
   Description ____________
   ____

III. Coordinate File Name: ____________

1992 *Engineering Field Notes* Article Award Winners

Congratulations, *Engineering Field Notes* authors! The votes have been tallied, and we are proud to announce our 1992 article award winners.

Article	Author
"Barrier-Free Horse Ramp"	Deborah Dorman and Jill Bard Pacific Northwest Region Willamette National Forest Sweet Home Ranger District
"Functionalism, Professionalism, and the New Middle"	John Lupis, Intermountain Region Regional Office
"Central Tire Inflation: the USDA Forest Service Program"	Paul H. Greenfield, WO San Dimas Technology and Development Center

We appreciate everyone who took the time and effort to write and send in an article. We would also like to thank everyone who took the time to fill out and return a rating sheet. According to the comments received, *Engineering Field Notes* articles are saving the Forest Service time and resources.

In order for *Engineering Field Notes* to continue to be a valuable resource to personnel in the field, it is important that we continue to receive such relevant articles. Can you think of a project on which you worked, a workshop you attended, or other information that may be of value Service-wide? If so, send in an article and maybe next year your article will be selected as one of the top *Engineering Field Notes* articles of the year.

The Use of GPS for Cadastral Surveys in the Rocky Mountain Region

Carl Sumpter, Land Surveyor
Medicine Bow National Forest

Introduction

The Forest Service Landline (cadastral surveys) Program has the responsibility for locating and posting the ownership boundaries for all national forest lands and national grasslands in the United States. Within the Rocky Mountain Region (Colorado, Wyoming, South Dakota, Nebraska, and Kansas) this amounts to 16 national forests and 6 national grasslands covering approximately 22 million acres.

Because all the lands of the Rocky Mountain Region are covered by the U.S. Rectangular Survey System, the subsequent boundary surveys are performed in accordance with the Bureau of Land Management (BLM) and the *Manual of Instructions for the Survey of the Public Lands of the United States.* These surveys are usually retracement surveys of the original Government surveys and resurveys made by the U.S. General Land Office in the late 1800's and early 1900's.

In order for the Forest Service to locate their land boundaries, a resurvey is usually required. These resurveys usually involve section subdivision surveys, retracements of full or partial townships, retracement of mineral surveys, homestead entry surveys, and metes and bounds surveys.

The purpose of these surveys is to locate and monument the property corners and property lines of the National Forest System lands with signs/posts to within 1 foot of the actual property lines. The resulting surveys produce many miles of property line, which must be marked with signs and posts to show forest ownership. The amount of property line located and marked varies between forests; for example, it may range from 10 miles to 500 miles per year depending on the forest.

Given the number of miles required to be located and marked and the increase in potential trespass by commercial/urban development adjacent to Federal lands, the demand for landline location surveys will continue to increase. As the Forest Service moves into the era of geographical information systems (GIS's) in support of ecosystems management objectives, the need for accurate property boundary location, control surveys, and the precise location of spatially related data will be required.

In 1982, a landline location productivity analysis team looked into the Forest Service Landline Location Program and determined that the forests should be looking for ways to make the cadastral surveying program more efficient. One of the recommendations was the implementation of new technology as it became available. The use of Globally Positioned Satellite (GPS) technology is one method used to make cadastral surveys more efficient.

GPS in the Rocky Mountain Region

The use of survey grade GPS receivers in the Rocky Mountain Region began in July 1991 with the acquisition of three Trimble 4000 ST's on the Black Hills National Forest and another three Trimble 4000 ST's by the Region. In July 1992, the Medicine Bow National Forest acquired two Trimble 4000 SE's and one more in April 1993. The Arapaho and Roosevelt National Forests acquired three Trimble 4000 SE's and a Pathfinder Basic Plus in July 1992. In February 1993, the Region acquired two Trimble 4000 SSE's, and two more are scheduled for fiscal years 1994–95. The Region also has 40 to 50 Trimble Pathfinder GPS units and 1 Trimble Community Basestation used mainly for resource applications.

The Medicine Bow National Forest has been established as the GPS Center of Excellence for the Rocky Mountain Region. The GPS center was established to provide training for survey grade GPS, maintain the Regional GPS equipment cache, evaluate new GPS technology, and integrate it into existing survey practices, as wells as to provide GPS survey support for the other forests and to perform the more difficult or special GPS cadastral and geodetic control projects using a "super-crew."

The GPS center has evaluated and is in the precess of implementing the use of real-time kinematic and real-time differential GPS technology for cadastral surveys. The GPS center also has the responsibility for maintaining the Community Basestation and providing training on Pathfinder GPS receivers to the resource users.

The super-crew concept was developed to ensure completion of GPS projects on forests where the need for GPS surveys is not required on a continuous basis at the present time. Another responsibility is to provide training and to increase the experience level of the forest land surveyors while performing the project. The super-crew is composed of the Regional GPS Coordinator, the Regional Land Surveyor, the Medicine Bow Forest Land Surveyor, and the Black Hills GPS Land Surveyor.

GPS Applications

Currently, survey and geodetic GPS receivers are used for a variety of applications, including:

- Horizontal control for cadastral surveys, GIS, and resource management activities
- Horizontal and vertical control for photogrammetric projects covering large areas
- Establishment of forest-wide control networks in conjunction with the High Accuracy Reference Network (HARN)
- Densification of horizontal control networks on National Forest System lands relative to the individual State's HARN's
- Geodetic location of microwave equipment, radio antennas, and GPS basestation antenna for other Federal agencies
- Verification and checking of cadastral contracts performed by private contractors
- Township and section subdivision.

Resource grade receivers (Pathfinders) are used for initial corner and triangulation station search with some rights-of-way (ROW) applications. At the present time, the Pathfinders are not much use for cadastral applications. However, the new carrier phase (sub-meter) receivers and the use of real-time differential will make these receivers valuable for cadastral applications.

Benefits of Using GPS

The Rocky Mountain Region has found the use of GPS to be a very significant time- and cost-saving tool. For example, on contract cadastral check surveys the time savings is approximately 20 percent. GPS can also be used effectively to establish control for section subdivision. For example, a nine-section subdivision in mountainous terrain can be controlled in 5 days using GPS instead of 4 weeks using conventional traversing methods.

Another benefit is the reduction of field personnel required to perform a survey. For example, on the grasslands only one person was required to complete an eight-station perimeter traverse for a section subdivision in 4 hours. Using conventional traverse techniques, this same traverse would have taken 7 days to complete. Another advantage of using GPS is that there is no need for cutting line or having station intervisibility. Also, GPS delivers accuracies in a forested environment at better than 1:100,000 and in a non-forested environment at better than 1:1,000,000.

GPS Survey Methods

The GPS surveys are performed using a variety of GPS surveying techniques, including: static, kinematic, fast static, and real-time kinematic and real-time differential. The use of GPS is integrated into existing cadastral survey techniques—i.e., total stations, theodolite, and electronic distance measuring instruments—to achieve the most efficient and cost-effective surveys.

Static survey methods are used primarily for geodetic and cadastral control and site locations. Station occupation time per point varies with the length of the base line and canopy cover. Observation times for single frequency receivers (4000 SE) are usually 1 to 2 hours in length for a baseline length of 10 to 20 km, resulting in a baseline accuracy of 1 cm horizontal and 2 cm vertical. The use of dual frequency receivers (4000 SSE) requires an occupation time of 1 to 5 hours for a baseline length of 10 to >50 km, resulting in an accuracy of 5 mm horizontal and 1 cm vertical. Static methods deliver the highest accuracy.

Kinematic survey methods are used where the canopy is not a factor and the receivers can maintain continuous lock with the satellite constellations. Typical surveys include section subdivision, ROW, site, point locations, and some control. Station occupation times are as short as 2 minutes or less with accuracies of 2 cm horizontal.

Fast static survey methods are used for cadastral and photogrammetric control and some point location activities. Accuracies are 2 cm horizontal, and this technique is the fastest not requiring continuous satellite lock.

Real-time kinematic survey methods (the most advanced) are used for township and section subdivision, site plans, topographic mapping, and engineering applications. The best use of this method is for initial corner search and monument location. This technique requires the use of radio transmitters to broadcast the correction message to the remote receiver so navigation and point positioning is accomplished in real-time. Accuracy level is 1 cm horizontal and 2 cm vertical with occupation times of 2 seconds. This is the fastest and most advanced method available, but continuous satellite lock must be maintained.

Real-time differential survey methods are used for initial corner search to the sub-meter level, ROW, point portions, and resource applications. The best use of this method is for the posting and marking of Forest Service property boundaries. This technique also requires the use of raid transmitters to broadcast the correction message to the remote receiver so navigation and point positioning is accomplished in real-time. Accuracy level is about 18 cm horizontal.

All of these methods are employed in the Rocky Mountain Region; however, real-time kinematic and real-time differential GPS surveying methods produce the most significant savings (50 to 80 percent) in surveying costs. This dramatic savings is realized by significantly reducing the number of field survey personnel and the amount of field and travel time required to perform cadastral surveys. For example, subdividing a single section (1 by 1 mile) down to 40-acre parcels is normally accomplished in about 1 month using conventional surveying techniques. Using real-time kinematic GPS survey methods, this can be done in 1 week.

Disadvantages of Using GPS

The use of GPS for cadastral and resource activities is not without its negative aspects. For example, the degradation of the GPS signal by the Department of Defense, known as Selective Availability (SA), is the biggest problem for resource users and for initial corner search for cadastral applications. The effect of SA is a degraded positional and navigational accuracy. For all grades of receivers, when operating in the autonomous mode (one receiver), the accuracy level decreases from 12 meters to 100 meters. The use of two receivers, one located over a point of known position, is required to post-process the data or else the use of real-time methods is required to achieve the high accuracy levels and negate the effects of SA.

The skill level of the field surveyors is consistent with conventional surveying methods, so this is not really a problem. However, the GPS survey project supervisor needs considerably more advanced skills. These include effective mission planning, GPS network design, GPS project management, network adjustments, knowledge of geodesy, land surveying, a considerable knowledge of using and managing microcomputers, and a working knowledge of GIS's. Having personnel with all these skills present on each forest was not feasible. This was one of the driving forces behind the Rocky Mountain Region's decision to have a GPS super-crew.

There is a slight increase in office time because of pre-mission planning and post-data processing, but it is not significant. On some projects there may be an increase in personnel required for security of receivers placed near human or livestock activity.

Overall, there are no real drawbacks to using GPS for cadastral surveying. However, the user should be aware that GPS is not the answer for all cadastral survey projects, and neither is only one GPS survey method. The key to using GPS for cadastral survey applications is to be flexible.

Summary

In a time of change throughout the Forest Service, the ability to respond to changing management goals, shrinking budgets, and available personnel requires the adoption of new technologies to meet the increasing workload. The use of GPS surveying technology allows the Rocky Mountain Region to respond in a timely and cost-effective manner to meet the ever-changing resource management objectives and the related property landline location targets.

Evaluation of the American Ranger Clearing Machine

Michael A. Thompson, Research General Engineer
North Central Forest Experiment Station

The American Ranger Model 300T is a large, tracked vehicle with a front-mounted, high-speed cutterhead designed to fell and shred plant material in its path (figure 1). The cutterhead is composed of a heavy 28-inch-diameter, drum-like structure with 81 free swinging tubular cutters mounted in a diagonal pattern along the drum (figure 2). The cutterhead may be raised or lowered by the operator to avoid rocks or to raise or lower stumps; however, it cannot be tilted. The specifications for this machine are presented in table 1.

The American Ranger is designed to clear land for rights-of-way, trails, roads, fire lanes, construction sites, recreation areas, etc. The shredded material (with the texture of coarse garden mulch) is left in the machine's path, creating a woody mat that can be used as surfacing for many applications. The productivity and cost of this machine depend on the characteristics of the site being cleared. The main factors are the terrain, rock content of the soil surface, and the size, hardness, and amount of vegetation that needs to be shredded. The cost and productivity of clearing with this machine were evaluated on several different sites to provide performance information to prospective users.

Methods

Continuous time study was used to evaluate the American Ranger on five different sites during a 4-day period. One person timed the work elements of the machine while a second recorded travel distances and other pertinent information (such as site characteristics). The time constraints did not allow detailed measurement of site variables; therefore, each site was qualified by terrain, species, tree size, and relative density (table 2).

Performance

The machine cleared land at a rate of between 0.14 and 0.54 acres per hour, depending on the conditions (table 3). This equates to between 790 and 2,960 feet per hour of 8-foot-wide cleared strip. The productivity of the machine was most sensitive to the density of material cleared from the site. Very thick areas required more time to reduce the material and sometimes required more than one pass for acceptable reduction. The larger chunks of material would have to be removed from the mulch to satisfy the requirements of certain types of roads and trails.

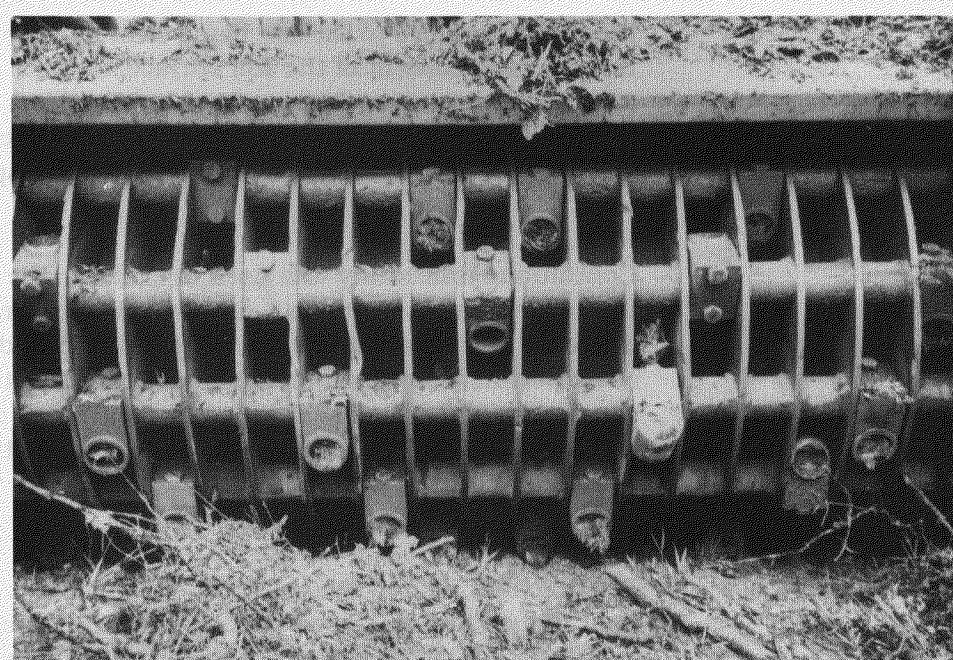

Figure 2.—Front view of the cutterhead on the American Ranger.

Table 1.—Specifications of the American Ranger Model 300T.

Engine:	
Type —	Cummins NTA-855-P400
Output —	400 HP @ 2100 rpm (298 kW @ 35 rps)
Mobility:	
Type —	Tracks, 23.5 in (60 cm) wide
Wheelbase —	108 in (274 cm)
Transmission —	Hydrostatic
Speed —	Infinitely variable from 0 to 1.5 mph (2.4 km/h) Forward or reverse
Chassis:	
Frame Type	Fabricated from channel, structural tubing, and plate
Length x width x height —	265 x 102 x 106 in (673 x 259 x 269 cm)
Weight —	16 tons (14.5 metric tonnes)
Ground pressure —	6.3 psi (43.5 kPa)
Ground clearance —	15 in (38 cm)
Cutterhead:	
Diameter —	28 in (71 cm)
Width —	101 in (257 cm)
Rotational speed —	1800 rpm
Number of cutters —	81

Manufactured by American Ranger Mfg., Inc., Appleton, Wisconsin.

Table 2.—Site characteristics of the areas cleared with the American Ranger.

Site	Terrain	Species	Tree size (dbh)	Density
A	old railroad grade	softwood, aspen	2 to 4 in	sparse
B	old railroad grade	softwood	2 to 10 in	very thick
C	rolling, some lowlands	mixed	2 to 6 in	thick
D	old railroad grade	softwood, aspen	2 to 6 in	sparse
E	rolling	mixed	4 to 12 in	cleared[1]

[1] This area had been previously cleared by a feller/buncher; the objective was to lower the stumps and form a snowmobile trail.

Table 3.—Performance of the American Ranger Model 300T clearing machine.

Site	Distance[1] (feet)	Time[2] (min)	Productivity[3] feet/SH	Productivity[3] acres/SH	Cost[4] $/mile	Cost[4] $/acre
A	5,470	71.7	2,960	0.54	143	148
B	1,160	59.0	790	0.14	533	571
C	580	16.6	1,370	0.25	308	320
D	5,278	91.0	2,270	0.41	186	195
E	10,360	142.5	2,850	0.52	148	154

[1] Observed distance while clearing (clearing width was 8 feet)
[2] Observed time while clearing (does not include delays)
[3] SH = scheduled hours (a utilization of 65 percent is assumed)
[4] Based on an hourly cost of $80 for the machine and operator (1990 dollars)

The cost of clearing with the American Ranger was estimated using standard machine rates calculation procedures.[1] Costs ranged from $143 to $533 per mile of 8-foot-wide cleared strip, depending on the site conditions. Costs per cleared acre were very similar, because 1 mile 8 feet wide is approximately 1 acre. Additional costs associated with enhancing the cleared area to satisfy a particular objective would be minimal for most applications.

The number and size of rocks on the soil surface will affect the operating efficiency of this machine. Its individual tubular cutters and mounting blocks are particularly susceptible to damage from large rocks. Replacing worn or damaged blocks and cutters requires two people and is time consuming. The safety of onlookers is also of concern when operating the machine because rocks and other debris are sometimes projected over significant distances, especially in the line of travel.

A major advantage of clearing with the American Ranger is the aesthetic appearance of the cleared trail (figure 3). The vegetative mat that is formed can be used to protect sensitive soils from damaging traffic. The mat might also discourage vegetative growth for several years, lowering road and trail maintenance requirements. There are no stumps or slash to dispose of or place adjacent to the cleared area, as would be expected with conventional construction methods. Also, the area will revert naturally to it original state if left alone. This is ideal for hiking or nature trails, logging roads on good ground, and recreation areas. Most other types of trails and logging roads will never again be as they were prior to construction.

Figure 3.—Appearance of trail cleared by the American Ranger.

Another advantage of using this machine is that the finished trail is at the same level as the adjacent ground. The cleared road or trail does not trap or channel water as it might if built with traditional grubbing techniques. In addition, leaving the root mass intact provides added support for traffic and may cause less dieback or windthrow of adjacent vegetation than traditional methods.

There is currently only one machine in existence. This machine has been thoroughly rebuilt and is available for contract work. Additional machines are planned in the future. Inquiries should be directed to American Ranger Mfg. Inc., 2701 East Winslow Ave., Appleton, WI 54915; (414) 731-5777.

References

[1]Miyata, Edwin S. 1980. *Determining Fixed and Operating Costs of Logging Equipment.* Gen. Tech. Rep. NC-55. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 16 p.

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