

## **UC Davis**

### **Recent Work**

#### **Title**

Reconditioning and stabilization of unpaved roads for reducing road maintenance and impacts on fisheries habitat

#### **Permalink**

<https://escholarship.org/uc/item/5m85727j>

#### **Author**

Sheehy, Donna McConnaha

#### **Publication Date**

2001-09-24

## RECONDITIONING AND STABILIZATION OF UNPAVED ROADS FOR REDUCING ROAD MAINTENANCE AND IMPACTS ON FISHERIES HABITAT

Donna McConnaha Sheehy, Transportation Management Engineer, USDA Forest Service -  
Regional Office, 200 E. Broadway, P.O. Box 7669, Missoula, MT 59807. Phone: 406-329-3312.  
Fax: 406-329-3198. Email: dsheehy@fs.fed.us

Abstract: Forest Managers are facing a series of problems that are making it difficult to effectively manage the vast national system of over 644,000km (400,000 miles) of forest roads and protect the environment. Current national funding levels are inadequate to maintain these roads to environmental and safety standards. With years of low maintenance budgets, many of these roads are worn out and not maintainable. Current methods of reconditioning and stabilizing worn-out native and aggregate surface roads have had limited success and can be quite costly. Pit development for aggregate surfacing can also be an expensive and lengthy process. In addition, there may be environmental impacts associated with pit development. Road maintenance is necessary to prevent damage to the road, to maintain safety, and to preclude adverse impacts to resources resulting from lack of road maintenance. When maintenance is not performed, roads can be major sources of sediment deposited into streams. This is especially critical when roads are adjacent to streams with sensitive species and any sediment deposited into the streams could have adverse effects. However, road maintenance activities can also result in direct sediment delivery to streams. Ground disturbance from road blading constitutes the greatest risk to adjacent streams from increased sediment production. Oftentimes, road managers are left with the options of either not maintaining the road at all or with a very short window of operation that may not allow for the best level of maintenance on the road. Obviously, there is a need to develop a tough, stable, long-lasting, maintainable road surface that will weather well, require less maintenance (particularly blading), and cost substantially less than importing or replacing crushed aggregate surfacing. In 1990, the Northern Region of the U.S. Department of Agriculture Forest Service began utilizing and evaluating a machine called the Mobile In Place Processor to recondition native surfaced roads. In 1998, the Forest Service began adding binders to the in place processing to stabilize both aggregate and native surfaced roads. Preliminary studies indicate that roads treated in this manner require less maintenance. The running surface does not washboard, ravel or generate dust, and surface erosion is significantly reduced which equates to less sediment in adjacent drainages. The end product is a much more serviceable road with little to no impact on watersheds and fisheries habitat.

### Background

#### *Road System*

Nationally, the USDA Forest Service has jurisdiction on over 644,000km (400,000 miles) of roads. The Northern Region of the Forest Service, which includes Montana, portions of North and South Dakota, and Northern Idaho, contains over 88,100km (54,700 miles) of forest roads. Of these roads, approximately 82 percent are native-surfaced, 16 percent are aggregate-surfaced, and only 2 percent are paved.

In general, roads can affect fish habitat and water quality in three different ways. Roads that run parallel to stream channels can reduce shade and increase water temperatures. Secondly, roads create an impermeable surface, which changes an infiltration-dominant surface to a runoff-dominant surface. This leads towards alterations in runoff and affect peak flows. This increased flow can also trigger in-stream channel erosion resulting in degraded fish habitat. The third mechanism is through erosion and sedimentation. As road surfaces are runoff dominant, they allow for transport of sediment from road surfaces, cut-slopes, and ditches to be transported to nearby streams.

#### *Lack of Funding*

Proper road maintenance and implementation of best management practices (BMPs) can minimize the amount of sediment being delivered to streams. Often budget shortfalls prohibit any road maintenance or only allow partial maintenance to occur. Many road surfaces are only graded when they should be watered, graded and shaped, and then rolled to re-compact the surface.

Historically, maintenance budgets have been low for many years. Current national funding levels are inadequate to maintain the roads to environmental and safety standards. National annual road maintenance needs have been estimated at \$568 million per year, of which \$197 million represents an immediate and serious threat to the environment, safety, and Forest Service mission. The 1999 annual maintenance funding

was \$99 million. That funding is only 20% of the funding necessary to maintain the roads to standards. The backlog of maintenance and capital improvement needs is \$8.4 billion and growing.

The Forest Service has spent the last three years trying to determine what the deferred maintenance needs are on a national level and are continuing to update and refine the existing data. Based on the information that is currently in the Forest Service databases from the deferred maintenance surveys, the Northern Region has a \$200 million annual maintenance need (\$4,000/mile) to maintain these roads to standards identified in the road management objectives. In addition, deferred maintenance surveys identified a backlog need of over \$429 million to bring these roads to their identified standard. Capital Improvement needs are estimated at over \$228 million. These estimates only partially address the need for all of the roads in the Region. The complete need for roads has yet to be determined.

### *Un-maintainable Roads*

With years of historically low maintenance budgets, many of these native and aggregate surfaced roads are worn-out and not maintainable in their current condition. The existing roadbeds are extremely rough and composed of cobbles, ledge rock, and boulders, with little or no fines. Roads in this condition can be major sources of sediment deposit, in the form of runoff, to nearby streams (See Figure 1).



Fig 1. Typical example of a worn-out, un-maintainable road.

Traditionally, native surfaced roads of this type were maintained by methods which did not always result in a satisfactory end product (either ripping, grading and grid rolling). Surfacing these roads with aggregate surfacing provides a good end product, but is usually cost prohibitive, especially considering the number of road miles on the system.

Resurfacing requires hauling material either from existing pits or developing new pits. Development of new material sources requires the proper permits, royalty fees, environmental assessments or impact statements and can become quite expensive and involve possible delays. In addition, pit sites can have substantial impacts on the environment.

### *Road Maintenance Activities*

Road maintenance activities can also result in direct sediment delivery to streams. Ground disturbance from road blading, particularly where the road is immediately adjacent to streams, constitutes the greatest risk from increased sediment production. Other activities such as culvert and ditch maintenance may also increase sediment delivery to streams. Road maintenance activities may also result in reduction or removal of streamside vegetation through brushing activities, possibly resulting in temperature increases. The risk of temperature increases is highest in very small streams. Brushing may also reduce stabilizing vegetation on cut and fill slopes.

The potential adverse effects of road maintenance must be considered in the context of performing maintenance versus possible consequences of not maintaining roads. Road maintenance is necessary to prevent damage to the road, to maintain safety by reducing dust, washboards and raveling, and to preclude adverse impacts to resources resulting from lack of road maintenance. Proper and timely road maintenance is proven to minimize sediment delivery to streams from open roads. Lack of road maintenance could result in more serious impacts to streams, ranging from washouts to increased risk of vehicle accidents resulting in potential toxic fuels introduced into the stream. Lack of maintenance can result in severe rutting and gullying during wet periods, and consequently, contributes large amounts of sediment into the watershed (see Figure 2).



Fig. 2. Road damage resulting from lack of maintenance.

Obviously maintenance is needed. There is a great need to make unmaintainable, sediment-producing roads into maintainable roads with a tough, stable, long-lasting surface that requires less maintenance (particularly blading), weathers well, and significantly reduces sediment production both from lack of maintenance and from maintenance activities, and costs substantially less than traditional methods of resurfacing.

### *Mobile In Place Processing*

In 1990, the Northern Region began experimenting with an alternate method of reconditioning worn-out, native surfaced roads. The Mobile In Place Processor was first used to recondition 37km (23 miles) of road on the Lolo National Forest. Since then, over 300 kilometers (200 miles) of worn-out native-surfaced roads have been reconditioned in Montana, Idaho, Wyoming and Alaska. The Canadian government and several state and local U.S. governments have also expressed an interest in the machine and the process.

In 1998, the Forest Service expanded the process of road reconditioning by adding binders in order to lengthen the life of the road and reduce required maintenance. The first project used calcium chloride flake to stabilize the top 2.5 inches of an aggregate surfaced road. In year 2000, a native surfaced road was stabilized with the use of calcium chloride flake. Several other projects have since been completed.

Preliminary studies indicate that roads treated in this manner require less maintenance. The running surface does not washboard, rut, pothole, ravel or generate dust, and surface erosion is significantly reduced which results in less sediment into adjacent drainages. The end product is a much more serviceable road with little-to-no impact on watersheds and fisheries habitat.

Initial tests show that using the Mobile In Place Processor and adding a binder such as calcium chloride can be a useful tool to mitigate sediment delivery from road surfaces. Traditional applications of binders sprayed on the road surface form a thin layer of stabilized soil which acts like a crust and quickly breaks down under traffic. However, calcium chloride combined with reprocessing and compaction of the road surface bind a deep layer of the road surface material together, which prevents the finer material from eroding from the road surface. This not only minimizes sedimentation to adjacent streams, but also creates a stable surface that is more durable and does not break down or lose its integrity as fast. Roads treated in this manner require less maintenance including less grading. The end product is a native or aggregate surface road with little to no impact on watersheds and fisheries habitat.

The Northern Region of the Forest Service is continuing to utilize this process to produce a maintainable road, as the process has become a viable, cost effective tool for road maintenance.

### Equipment and Operation

The process of recycling and stabilizing existing road surfaces revolves around use of the Mobile In Place Processor, which is usually followed by a motor grader of 135 horsepower or greater, Elliot Grid Roller, traditional vibratory roller, calibrated spreader, and water truck.

#### *The Mobile In Place Processor*

The original model for the Mobile In Place Processor was a rock crusher developed by Crude Tool Works of Kenai, Alaska. The 1991 purchase price was \$196,500. This machine was designed to break up permafrost and had not been utilized as a road maintenance device.

Triple Tree Inc., of Missoula, Montana, purchased the rock crusher and made over \$45,000 in modifications to the machine (patent pending) in order to process road surfaces more effectively.

The machine resembles a giant roto-tiller and consists of a two-component kit: a front rotary drum attachment and a rear power pack. This kit mounts on any suitable carrier such as loaders, graders, or scrapers (see Figure 3). The machine is essentially balanced as the drum and the power pack each weigh approximately 5,450kg (12,000 lbs). The kit components can be mounted or removed from a loader in approximately 12 person-hours.



Fig. 3. Mobile In Place Processor mounted on a "Cat" loader - rotary drum on front lift arms and power pack at rear.

#### *Rotary Drum Attachment*

The rotary drum attachment consists of the drum and a 76mm (3in.), removable solid steel rear impact plate. The rotary drum is 0.9m (3ft.) in diameter by 3m (9.5ft.) wide and can turn in forward and reverse motion at 84rpm. It can also be raised for slope work. Three types of drum shave have been constructed: those that produce a level surface, windrow to middle, and windrow to sides.

The drum has 272 carbide tipped teeth in knuckle holders mounted in a spiraled inward pattern. The teeth rotate after every strike to produce even wear. Teeth have an average life of 8 hours and are the only routine replacement item. Teeth are quickly removed with either a forked tool and hammer or an air drill and are easily installed with a tap of the hammer. Teeth cost approximately \$3.20 each in 1993. A tooth hits every 3.175mm (0.125in.) of soil. The teeth crush the rock and rip the material as the drum rotates. The loose rock revolves counterclockwise to the impact plate where it is further fractured, crushed and blended (see Figure 4).



Fig. 4. Rotary drum processing a road surface.

### *Power Pack Attachment*

The power pack attachment includes a Caterpillar Model 3406 (D-9) diesel engine, rated at 400hp, a hydraulic pump with reservoir and related hardware, and work lights and taillights. The power pack allows the machine to operate in temperatures ranging from -45 to 26 degrees C (-50 to 80 degrees F).

### *Machine Modifications*

The Mobile In Place Processor has been modified and updated by the road contractor, Triple Tree Inc., in order to increase its efficiency and to produce a better end product that met gradation specifications (Hegman and Kreyens 1991). These modifications resulted in better rock fragmentation and decreased the outcast of larger rocks. They also added additional protection and stability, simplified the machine operation and increased maneuverability.

### *Machine Capabilities*

The machine processes most existing road surface materials to a specified depth of 0 to 150mm (0 to 6in.) and a gradation of minus 100mm (4in.). It cuts a path 3m (10ft.) wide and leaves the road material in a well-mixed state. The materials show a general reduction to approximately the 100mm (4-inch) class with approximately 95% of the material passing through the 50mm (2-inch) size. The underlying fine materials are brought to the surface to bond the newly broken aggregates together. The content of road fines or dirt are not increased significantly, so future erosion potential is low.

### *Technical Specifications*

A Special Project Specification for mobile rock processing was developed for use in the Northern Region and generally controls the work. This specification does not specify the type of equipment to be used, but describes the desired end product. It is modified as needed to meet site-specific conditions.

Measurement for contract payment has usually been by slope distance along the centerline of the road. Payment is either by km (mile), by Station, or by Lump Sum. Some small projects were simply equipment rental by the hour.

### *Operation*

The key to obtaining a maintainable road does not depend solely on the Mobile In Place Processor. It is a combination of several steps.

Generally no preparatory work is required other than blasting or pre-breaking of large oversize rock or outcroppings to save on tooth breakage and machine wear. A hand-held Pionjar Rock Hammer or excavator mounted hydrohammer is used where blasting is not an option.

The optimal procedure has been to operate the machine downhill at idling speed against the grain of the rock. A 3m (10ft.) wide by 100 to 150mm (4 to 6in.) deep pass is made, followed with another pass alongside for most roads over 3m (10ft.) wide. When attempting to grind down to 150mm (6in.) of depth, the machine will usually make two passes to obtain full breakage of the rock material. Small side cast windrows are produced which are rerepped to produce a smaller particle size.

A grader smoothes the windrows, a water truck applies compaction water and controls dust (minimal), and a traditional vibratory roller used in conjunction with an Elliot Grid Vibratory Compactor brings up fines and compacts the layer. The surface is then ready for the application of the calcium chloride solid (flakes or pellets).

When a project calls for calcium chloride stabilization, it is applied with a calibrated spreader (see Figure 5). The road is then reprocessed to a depth of 2.5 inches with the Mobile In Place Processor to thoroughly mix the CaCl into the top layer. The surface is smoothed with a blade and roller compacted. After the road surface has been shaped with a motor patrol, a top treatment of chloride is applied to a damp road surface; this helps bond the finished surface together as water will chemically release the calcium chloride.



Fig. 5. Calibrated spreader applying Calcium Chloride to a previously processed road. The result is a finished road with a hard, smooth, maintainable driving surface. Grinding with the In Place Processor also works well in frozen soil, as the rocks stay in place for crushing. Some dampness in the soil is preferred for decreased machinewear, dust control, and compaction.

#### *Material Quality*

The material quality cannot be regulated to a precise gradation that crushed or screened material can. However, tests have shown that there is a substantial improvement to most materials processed by this recycling method and costs are substantially less. The materials show a reduction to approximately the 100mm (4in.) maximum size with good blending of all materials within the processing depth. This, combined with adjustable depth control and good compaction, provides an excellent, long lasting, and maintainable road cushion material. It appears that roads would not need to be recrushed for 6 to 10 years, depending on traffic volumes, and if dust control materials are utilized (see Figures 6 and 7).



Fig. 6. A typical road section before in-place processing.





Fig. 7. A typical road section after in-place processing.

### Project Summary

One of the first road reconditioning projects to include the use of calcium chloride was for Copper Creek Road located on the Helena National Forest in Lincoln, Montana (Monlux 2000). A summary of the 1998 project follows:

#### *Project Description*

The Copper Creek Road is located next to a critical drainage with sensitive fish species. The road is a 20-foot wide double lane that has good quality, well graded  $\frac{3}{4}$  inch crushed aggregate. The surfacing aggregate had a history of severe wash boarding even though it was maintained by blading, watering and rolling three times a year. Magnesium chloride dust abatement has been applied once every 3 to 4 years. Snow keeps the road closed during winter months. Rain accounts for about 8 of the 19 inches of annual precipitation. Vehicle speeds are greater than 35 miles per hour and grades are 2 percent in the test sections. Traffic volumes are from 20 to 50 light vehicles per day from mid-May through November with intermittent log truck traffic.

Seventeen different test sections were constructed utilizing different maintenance techniques. Calcium chloride flake and Bentonite clay were used on eight of the test sections. In-place processing and mixing was done by the Mobile In Place Processor.

#### *Project Results*

The best performing treatment was calcium chloride flake at 4.2 pounds per square yard mixed into a 2.5-inch depth of aggregate. The 4.2#/SY application rate of flake at 77 percent concentration equals about 1.3 percent pure calcium chloride by weight aggregate. This treatment section lasted more than two seasons without blading. Washboards started to appear in the 4.2#/SY section in late June 2000.

The following five benefits were observed:

1. Improved ride comfort and safety
2. Reduced airborne dust
3. Reduced aggregate surfacing loss
4. Reduced blading (no need to surface blade for more than two years)
5. Less erosion from the road surface, and less sediment in nearby streams

These benefits are possible on many other roads that require annual blading maintenance.

### Project Cost

Although actual costs per mile are somewhat greater for this treatment, serviceability is significantly improved over other treatments. The serviceability assessment shown on Table 1 is related to the five benefits described above. Detailed cost and performance data is shown in Tables 1 and 2.

### Recommendations

Stabilization of aggregate surfacing with Calcium Chloride flake should be considered for roads requiring annual blading maintenance. Due to differences in road aggregate, aspect, and geometrics, specialists suggest including one or more 500 foot long untreated control sections on future projects to verify the effectiveness of the treatment and application rates.

Where realistic, a 20-year cost comparison should be calculated that includes:

1. Calcium chloride flake at 4.2#/SY
2. Magnesium chloride brine at 1.08 gallons/SY
3. Asphalt paving

Magnesium Chloride brine was not used on this project and may require two applications and two mixing passes to keep the liquid product on the road. Review detailed information in Tables 1 and 2.

Table 1  
Test Section Blading Requirements, Serviceability and Costs

Treatment Description (Note: All sections were bladed, watered & compacted when treated and when maintained during summer months)	Additional Blade Mtc required in 58 week period 98, 99, 00 Seasons	Serviceability Assessment By # of Weeks		Cost of Mtc/ Mile from 6-15-1998 to 6-30-2000	
		Good	Bad	Actual Costs (a)	Costs for Same Serviceability (b)
Traditional Blading, Watering & Compaction	6 (2 in 98, 3 in 99, 1 in 00)	10	48	\$3,600 (a)	\$19,800
Mixing 2.5 inches deep with In Place Processor	6 (2 in 98, 3 in 99, 1 in 00)	12	46	\$4,420 (a)	\$19,840
Bentonite Clay mixed 2.5 inches deep with In Place Processor	5 (1 in 98, 3 in 99, 1 in 00)	16	42	\$4,940 (a)	\$19,240
1.6#/SY CaCl Flake on surface as dust abatement	4 (1 in 98, 2 in 99, 1 in 00)	19	39	\$3,900	\$17,400
Bentonite Clay mixed 2.5 inches deep with In Place Processor. 1.6#/SY CaCl Flake on surface	4 (1 in 98, 2 in 99, 1 in 00)	20	38	\$5,840	\$19,040
2.2#/SY CaCl Flake mixed 2.5 inches deep with In Place Processor	3 (0 in 98, 2 in 99, 1 in 00)	40	18	\$4,540	\$11,740
4.2#/SY CaCl Flake mixed 2.5 inches deep with In Place Processor	0 (0 in 98, 0 in 99, 0 in 00)	58	0	\$5,140	\$5,140

(a) Cost for these treatment sections should be increased at least \$400 per mile for aggregate surfacing replacement since aggregate loss is controlled by calcium chloride flake on other treatment sections.

(b) Costs per mile for the "same serviceability" assume one blading is needed for every two weeks of bad serviceability.

Table 2  
 Cost Per Mile Calculations for Each Treatment Type  
 (Based on a 6.2 mile long road segment near Lincoln Montana)

Treatment Description (Note: All sections were bladed, watered & compacted when treated and when maintained during summer months)	Blading Cost per mile (# of blading, watering & rolling) times \$600/mile	In Place Processor Mixing Cost/mile	Bentonite Cost/mile @ \$100/Ton	Chloride Flake Cost/mile @ \$160/Ton	Total of Actual Cost/mile 6-15-98 to 6-30-00	Costs/mile for Same Serviceability (b)  (# Bladings) x (Cost/Blading) + Actual costs
Traditional Blading, Watering & Compaction	7 x \$600 = \$4200	\$0	\$0	\$0	\$4200 (a)	24x\$600+\$4200 = \$18,600
Mixing 2.5 inches deep with In Place Processor	7 x \$600 = \$4200	\$640	\$0	\$0	\$4840 (a)	23x\$600+\$4840 = \$18,640
Bentonite Clay mixed 2.5 inches deep with In Place Processor	6 x \$600 = \$3600	\$640	\$1300	\$0	\$5540 (a)	21x\$600+\$5440 = \$17,440
1.6#/SY CaCl Flake on surface as dust abatement	5 x \$600 = \$3000	\$0	\$0	\$1500	\$4500	19.5x\$600+\$4500 = \$16,200
Bentonite Clay mixed 2.5 inches deep with In Place Processor. 1.6#/SY CaCl Flake on surface	5 x \$600 = \$3000	\$640	\$1300	\$1500	\$6440	19x\$600+\$6440 = \$17,840
2.2#/SY CaCl Flake mixed 2.5 inches deep with In Place Processor	4 x \$600 = \$2400	\$640	\$0	\$2100	\$5140	9x\$600+\$5140 = \$10,540
4.2#/SY CaCl Flake mixed 2.5 inches deep with In Place Processor	1 x \$500 - \$600	\$640	\$0	\$3900	\$5140	\$5,140

(a) Cost for these treatment sections should be increased at least \$400 per mile for aggregate surfacing replacement since aggregate loss is controlled by calcium chloride flake on other treatment sections.

(b) Costs per mile for the "same serviceability" assume one blading is needed for every two weeks of bad serviceability.

## Summary

### Limitations

There are limitations on materials that can be processed in place. Most large metamorphic or igneous boulders are not easily reduced and may require some pre-processing. Some are just too hard. Generally, if the material can be ripped with a D8 size dozer, then the Mobile In Place Processor can process it. Round rock causes some problems in that they become stuck between the teeth or roll around in the drum until they are side cast, rather than processed.

### Performance Benefits for Calcium Chloride Projects

The following five benefits were observed for chloride stabilization projects:

1. Improved ride comfort and safety
2. Reduced airborne dust
3. Reduced aggregate surfacing loss
4. Reduced blading—no need to surface blade for more than two years
5. Less erosion from the road surface, and less sediment in nearby streams

These benefits are possible on many other roads that require annual blading maintenance.

### *Additional Benefits of In Place Processing*

The following additional benefits were observed on native surfaced roads that were in place processed.

#### Economics

In most cases the cost of in place processing is a fraction of the cost of crushing material or hauling pit run material to the site. Even though in-place processing produces a superior product to conventional methods of ripping, grading and grid rolling, operating costs are quite similar.

This process eliminates the road surface memory, which may contain soft spots, potholes, and washboards. The cushion and sub-surface have been trimmed to a smooth flat plane that will dissipate most moisture laterally and eliminate previous problem areas. The road surfaces produced with this recycling process should require less maintenance and a longer life, resulting in long term cost savings. Critically short maintenance funds could be used on other projects.

#### Environmental Impacts

The recycling of road surfaces eliminates the need for opening new material sources and any associated new road construction. The actual reconstruction process generates less dust and side casting than traditional methods resulting in fewer impacts on adjacent drainages and any associated fisheries. The process utilizes the existing materials in the road surface to build a stable cushion. When the material is compacted with a vibratory roller, a finished product is developed that will last for years with less environmental damage.

### *Further Research Needs*

Further study needs to be applied on different types of geologies to determine if this process is as effective in reducing maintenance needs and sediment in granitic soils. Further study needs to be done to determine how much sediment is being reduced. Presumably because the road requires less blading, we assume there is less sediment being produced. This is probably a viable assumption, but would be beneficial to compare roads with native surface, gravel surface, and surfaces processed with the calcium chloride treatment in different geologies. The long-term effects of calcium chloride to water quality and fisheries habitat also needs to be determined. Initial research indicates that in the short-term it seems to be fairly benign (Vischer 2001).

Acknowledgements: The author would like to acknowledge the cooperation of the following individuals in supplying the relevant data and information: Steve Monlux, Materials Engineer, Northern Region Regional Office, USFS (Retired); Shane Hendrickson, Fisheries Biologist, Lolo National Forest, Missoula, Montana; and Triple Tree Inc., Missoula, Montana 406-258-6213, Bob Greil, Dick Greil, Tom Greil, Jim Greil.

Biographical Sketch: Donna Sheehy is a Transportation Management Engineer for the Northern Region of the USFS. She began her career in the Northern Region in 1972 working as an Engineering aid for the Deerlodge National Forest in Butte. Upon graduation from college, Donna transferred to the Helena National Forest where she was the Transportation Planner and Logging Engineer until 1990 when she transferred to the Regional Office in her current position. Donna did some graduate studies in Logging Engineering at Oregon State University in Corvallis, Oregon. Donna's received her B.S. in Engineering Science and her A.A. in Speech and Art from Montana College of Mineral Science and Technology in 1977 in Butte, Montana. She has been a registered professional engineer in the state of Montana since April of 1982.

### References

- Hegman and Kreyns. Field Testing of Roto Trimmer Mobile Rock Processor. USDA Forest Service Engineering Field Notes. Volume 23. September-October 1991.
- Monlux. Reducing Maintenance on Aggregate Road Surfacing, Copper Creek Road, Helena National Forest, Final Report. USDA Forest Service, July 2000.
- Northrup. Development of Cushion Aggregate on Native Surfaced Roads by Use of the Roto Trimmer. USDA Forest Service, 1994.
- Vischer. Preliminary Report of Chloride Concentration Levels and Movement within the Soil for Region 1 Road Projects Treated with Chloride Dust Abatement/stabilization Materials. USDA Forest Service, July 25, 2001.