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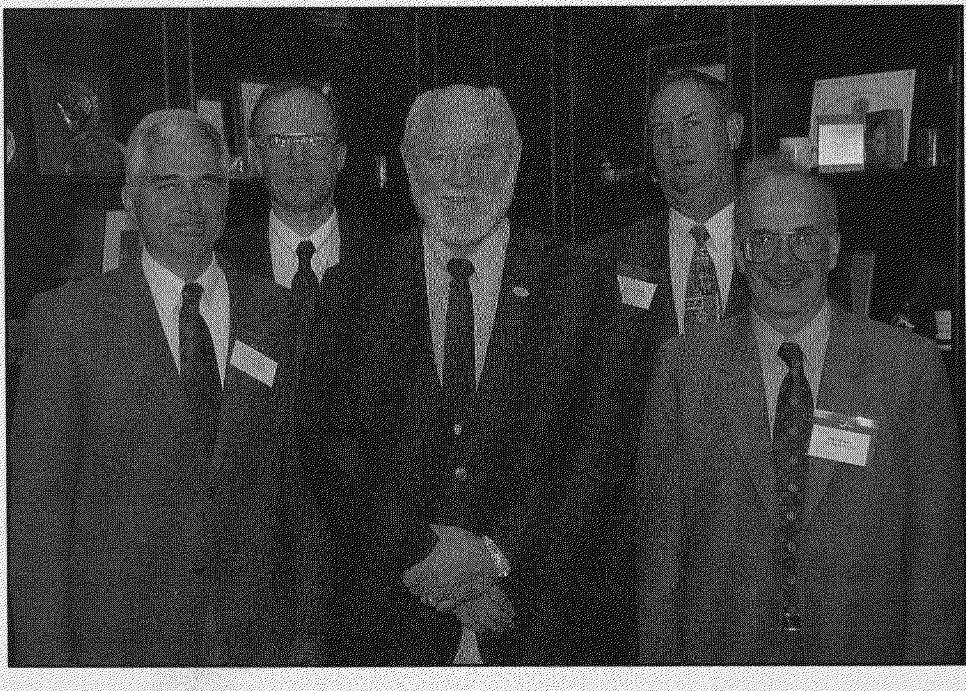
1996 Forest Service Engineers of the Year

Congratulations to all those selected to represent their Region or Station as a candidate for the 1996 Forest Service Engineers of the Year. The finalists in all of the categories included:

Management	Technical	Technician
Gordon Cates	Ken Elmore	Alan Anderson
Richard Christensen	Anne Fischer	Larry Barksdale
Robert Deane	Gary Hubbard	Willis Boyer
Richard Kehr	Rick Kell	James Calcaterra
Robert Littlejohn	John Mohney	Dick Dufourd
Robert Sutton	John Neirinckx	Kim Earney
	Harry Sampson	Tommy Grimes
	Willis Self	Milven Hass

From this list of excellent candidates, the four winners of the 1996 Engineer of the Year awards were selected. The winner of the Managerial Engineer of the Year is Richard Kehr, from the Black Hills National Forest in Region 2. John W. Mohney, Region 6 Regional Office, is the winner of the Technical Engineer of the Year. Two winners were selected for the Technician of the Year: Dick Dufourd from the

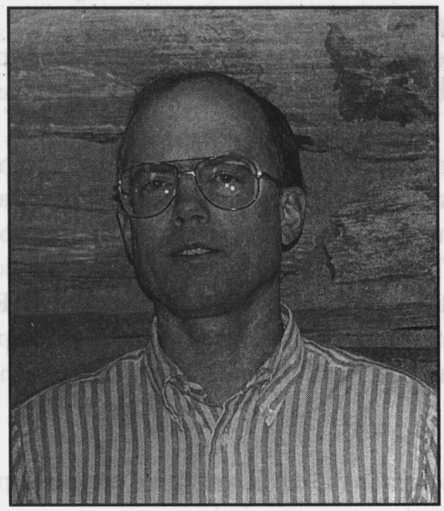


From left, Dick Dufourd; Richard Kehr; Jack W. Thomas, Chief; Alan Anderson; and John Mohney.

Deschutes National Forest in Region 6 and Alan Anderson from the Coconino National Forest in Region 3.

In recognition of their achievements, the Acting Director of Engineering presented each with a special plaque and cash award at a ceremony in Washington, DC, on April 2, 1996. Chief Jack Ward Thomas, Deputy Chief Gray Reynolds, Associated Deputy Chief Janice McDougle, and members of the winners' families were among those who attended the ceremony. A summary of their individual accomplishments and a photo of each winner are included in this article.

Richard Kehr
Managerial Engineer of the Year



Richard Kehr was identified as the top ranger or staff officer candidate on the Black Hills National Forest. This recognition, in combination with his past performance ratings and selection for a variety of acting assignments, demonstrates his exceptional performance and leadership skills as the Recreation and Engineering Group Leader on the Black Hills National Forest. Rich has also received several awards for his performance, including the Regional Forester's Special Achievement Award for his work in developing partnerships to rehabilitate recreational facilities on the Forest.

Rich provides Forest program leadership for trails, road management, travel management, geometronics, capital investment, engineering budget, information management, bridge inspection, scenic byways, capital investment partnerships, and signing. In each of these program areas, he has promoted the team concept with the Districts and Supervisor's Office resource staff areas to develop and meet program goals, develop programs of work, and provide or receive feedback on program status. Three key areas where Rich has taken the initiative to use his group to assist the Forest and provide superior engineering support for ecosystem management are forest planning, range permit renewal, and restoring the timber sale pipeline.

Under Rich's leadership, the Forest's trail, travel management, and signing programs have greatly improved. The Forest trail system has grown from about 160 miles in 1989 to 310 miles today. He campaigned for and received increased funding for trail maintenance, trail reconstruction, and trail construction. Because of his leadership, a Forest-wide trail guide is now available for the public, and trails are correctly displayed on the Forest visitor map. Forest routes are signed, travel management posters are installed, and public information is available concerning travel opportunities.

Rich also serves as a member of the Forest plan revision interdisciplinary team. He provides ecosystem input for infrastructure, travel management, lands, and other human uses of the Forest. His work on the Forest plan has been used as an example for other Forests that are beginning the Forest plan revision process.

Rich is a leader in the development and implementation of new technology to improve forest resource management. Areas in which he demonstrated his technological leadership are described below.

- Initiated and promoted the idea of an information management team for the Forest for the purpose of integrating information development and coordinating installation of the 615 system. He led the Forest information needs assessment, which involved coordination with all disciplines on the Forest.

- Initiated the idea of automated correction guides for the primary base series quad maps. He encouraged one of his employees to develop this idea, with the Geometronics Service Center and the author of Tontocad, Rob Toy, into a nationally adopted tool for updating primary base series maps.

Rich has also demonstrated his leadership skills and commitment to the management of Forest resources by seeking partnerships and grants to augment Forest programs to meet Forest plan objectives. He serves as the chairperson for several large interagency programs. These include: the Peter Norbeck Scenic Byway Interagency Committee (includes State and Federal agencies and two Ranger Districts), the Centennial Trail Interagency Committee (includes five separate State and Federal Parks or Forests), and the Rails-to-Trails committee (partnership with the State of South Dakota).

Examples of his success in the development of partnerships for the interagency management of Forest resources include:

- the Peter Norbeck Scenic Byway Interagency Committee, which successfully won $1,500,000 for the rehabilitation of recreational facilities along the 70-mile byway;

- the challenge cost-share agreement with the Disabled American Veterans for the development of a $750,000 trail and recreational site for persons with disabilities; 50 percent of which is funded by private capital or grants; and

- the 104-mile Rails-to-Trails conversion effort with the State of South Dakota that involves more than $5,000,000 worth of grants and appropriated dollars.

Rich motivates his workforce by providing career development opportunities for his employees. With his support, one employee has qualified for and served as a Logistics Chief on a Regional incident overhead team; another has become a bridge inspector whose services are requested by other Forests; and another has passed the professional engineer exam. Rich also networks and does outreach for job vacancies to reach the full spectrum of potential applicants. An example of his commitment to supporting a diverse workforce is displayed in his efforts to retain a Native American civil engineering cooperative education student he hired. Because he assisted her in settling into the community and provided a challenging and interesting work experience, she has continued with the program for 3 years. He has also developed comprehensive training plans for coop students and civil engineering trainees.

Rich also provides leadership to his community through his involvement in community activities.

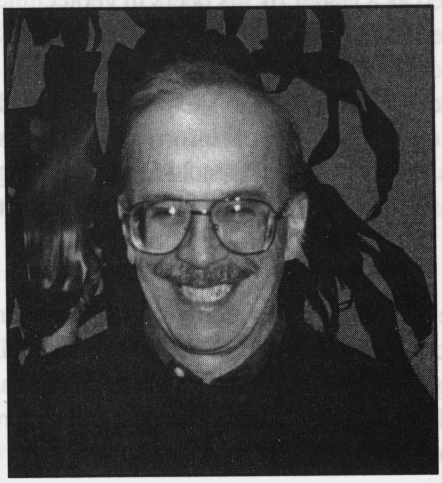
- He voluntarily serves as secretary of the East Custer Sewer District Board of Directors.

- He coaches, as a volunteer, junior high boys' basketball.

- He has served as an Odyssey of the Mind coach for the past 6 years. Odyssey of the Mind is an international problem-solving competition for school children that encourages creativity in problem solving. He and his wife's teams have won three State championships, and one placed seventh at the world competition.

As a professional engineer registered in the State of Washington, Rich continues to expand his engineering and management skills through books, technical journals, and interaction with other professionals both inside and outside the Forest Service.

John W. Mohney
Technical Engineer of the Year



John Mohney is a nationally recognized leader in the areas of geosynthetic materials, slope stability, and retaining walls and has made significant contributions to watershed analysis and ecosystem restoration. As a member of the Region 6 Geotechnical Engineering Group, he has received many letters of thanks and awards in recognition of his efforts in these areas. John has also been recognized by universities, other Federal Agencies, State Highway Departments, and the National Research Council for his technological contributions.

Three areas in which John has made significant contributions to the development and application of new technology include:

- **Bioengineering**—John has made presentations, organized workshops, and provided consultation on many projects in this area. In addition to presentations given to Forest Service employees, John has made presentations in this area to State Highway Departments, the Federal Highway Administration, and the National Park Service.

- **Geosynthetics**—John has conducted Regional training sessions on how to utilize geosynthetics for saving dollars on correcting environmental damage and is providing assistance to the National Research Council on the development of appropriate design and construction standards. He was also selected to be a team member of an FHWA sponsored project that trained engineers in Chile on the use of Geosynthetics.

- **Retaining Walls**—John was the team leader in developing a *National Retaining Wall Design Guide*. He also co-authored the "Trail Design Guide" and an article for *Engineering Fields Notes* on the use of a low-cost wall that can be built at remote locations with hand tools.

John's work has made significant contribution to ecosystem and resource management. The innovative use of bioengineering and geosynthetics has resulted in more effective methods to reduce stream sediment, at lower cost. This technology also allows use at remote locations using hand equipment, making it unnecessary to gain access with heavy equipment.

John is coordinating slope stability workshops, not only for the Forest Service, but also for the Bureau of Land Management, State Departments of Natural Resources, colleges, and the private sector. These workshops teach personnel involved in watershed analysis and restoration to analyze and repair slides more effectively.

John is recognized as a leader by his peers in geotechnical areas. He has also initiated and promoted technology transfer in Geotechnical Services-related programs. His efforts have contributed to the established Regional and national Technology Transfer networks. Because of John's expertise and leadership in these areas, he is often requested to provide technical information and assistance. Those that have requested his assistance on projects include the Washington Office, the Federal Highway Administration, and the State Highway Departments of Oregon and Washington.

As an ordained elder, John is also recognized as a leader in his church and is active in church-related activities in support of the community. He has also provided land development engineering services for "Habitat for Humanity," a volunteer group that provides affordable housing for low-income families, and is a volunteer for "Christmas in April," an annual project that does home repairs for elderly, disabled, and low-income people.

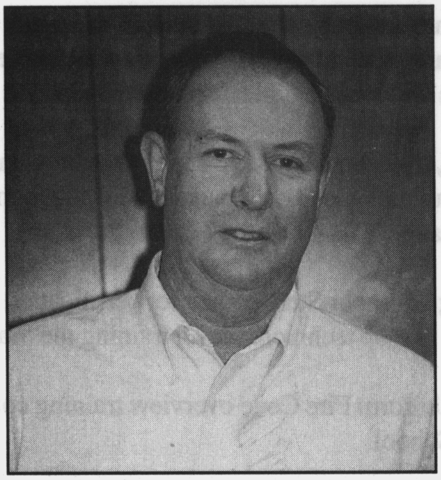
Other demonstrations of John's technical leadership skills include his education and his work to educate others. John has a master's degree in Geotechnical Engineering from the University of California–Berkeley and has kept up his technical training by attending and instructing many technical training sessions and workshops. He is an associate member in the American Society of Civil Engineers (ASCE) and has been active in the Portland Geotechnical ASCE Group. John is a registered Professional Civil Engineer in Oregon and is a registered Professional Civil Engineer and a registered Professional Geotechnical Engineer in California. John has written and presented a number of papers, including a recent one on using geosynthetic materials to reduce the cost of building retaining structures, which was published by the National Research Council.

John has also taught undergraduate and graduate courses on asphalt and pavement design at the University of Portland. He has also reviewed the Washington County Engineering and Permit Requirements for slope and foundation stability and provided input for the Land Use and Transportation Departments' Permit Procedures.

John is a prime example of a technical expert: a person who works within an organization to ensure that the best and the latest technologies are made available. He is sought after within the agency and other organizations for his consultation and training expertise.

Alan Anderson

Engineering Technician of the Year



Alan A. Anderson has provided exceptional engineering support for forest ecosystem and resource management efforts through his outstanding technical expertise in the design, development, construction, and research of many projects and program. In addition to his contributions in the field of hazardous materials management, Alan has shown leadership in civil rights, management, and health and safety.

In addition to his performance ratings, Alan has received many recognitions for his contributions. These include awards for developing an innovative "reward system" for information leading to prosecution of HAZMAT offenders on National Forest System lands and for developing a notebook with HAZMAT and safety information that was distributed to all Forest employees. Alan has also received national recognition as a technical resource for completion of the On-Scene Coordinator course.

Alan was selected by the Regional Office to participate on a Forest Service/Bureau of Land Management committee to select a contractor for HAZMAT services. Other projects that he is involved in include: preparing and administering road packages for timber sales; maintaining the Forest facility management system; conducting building condition surveys with District representatives; monitoring accomplishments by the Districts; providing Districts with technical information to accomplish minor construction/heavy maintenance projects; performing sanitary surveys of nonpublic water systems; providing technical assistance to lands, recreation and Districts for special use permits; performing survey and documentation for HAZMAT on proposed land exchange parcels; investigating HAZMAT releases/incidents on Forest lands; preparing cleanup and disposal work orders and inspecting work; conducting Forest inventory of HAZMAT; completing the action plan to bring all facilities up to date; preparing and implementing Hazard Communication Plan and Emergency Response Plan for the Forest; and serving as COR on recreation capital investment contracts.

Alan develops and implements new technology for engineering applications. Examples of Alan's efforts to seek out, implement, and share new technology include:

- researching new methods for removal of lead paint from a water tank that were included in a lead paint removal contract and sharing the technology with contacts at the Corps of Engineers;

- using in-situ bioremediations (bacteria/enzymes used to digest hazardous materials) for fuel/hydrocarbon compound spill cleanups; reducing costs and exposure to hazardous materials;

- designing and administering installation of single-ply membrane polyethylene roofing material for several Forest Service buildings (although the initial cost is higher, the benefits of reduced maintenance and a 20- to 30-year industry guarantee justify the installation of this innovative system);

- using chemical retarders and polypropylene fibers (for strength) in concrete structures and sidewalks when these products were initially introduced; though this was not the typical solution, it was the one that best fit the need;

- on his own, attending courses on fire inspection and code enforcement, the Uniform Building Code and management, and confined space training, then sharing what he learns with co-workers;

- completing 160-hour State course for certification as a State HAZMAT technician, the top technician-level training the State offers; and

- attending Uniform Fire Code overview training conducted by the Arizona State Fire School.

Alan's leadership ability is demonstrated in his involvement in Forest Service committees, his role in organizing training sessions, his work with students, and his participation in community activities. He has displayed his technological expertise and provided leadership through his coordination with District employees, other staff groups, other agencies, and the public. His contributions in these areas include:

- coordinating HAZMAT spill cleanups with State agencies (Arizona Department of Environmental Quality, Arizona Department of Transportation, Division of Public Safety) to minimize impact on resources and facilitate a team approach;

- coordinating closely with District and Supervisor's Office specialists to use timber sale designs that incorporate forest ecosystem management philosophies;

- as a certified Emergency Medical Technician, coordinating/conducting Basic First Aid/CPR training for the Forest in which Neighboring Forests, the Rocky Mountain Research Station, and local governments often participate;

- coordinating and conducting HAZMAT training for the Coconino and working with neighboring Forests, the Rocky Mountain Research Station, the City of Flagstaff, and local fire departments to provide or participate in training;

- through his work in expanded dispatch, is becoming an integral part of the Coconino National Forest fire suppression effort;

- being an active member of the Forest Civil Rights Action Group for 3 years, and being a member of the Forest Safety Committee;

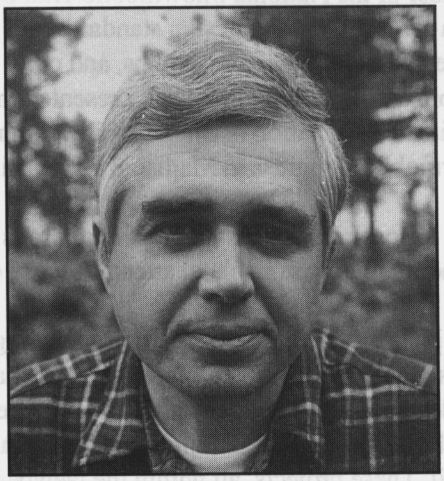
- mentoring coop students and organizing/using/helping Northern Arizona University environmental science and engineering students in HAZMAT studies and projects on the Forest; and

- by being proactive, securing funding for HAZMAT projects from the Regional and Washington Offices.

Alan's participation in the community also demonstrates ways in which he uses his technical and leadership skills. Alan is an active member of the Doney Park Volunteer Fire Department and a member of the National Fire Protection Association. As a church deacon, Sunday school teacher, and Site Committee member, Alan was instrumental in securing the land for the new church, and is participating in construction planning. He is a member of the organizing committee and a volunteer worker for annual City of Flagstaff household hazwaste Cleanup Day and a member of the Flagstaff Chamber of Commerce Environmental Task Force. The task force provides information sharing and training to businesses within the Flagstaff metropolitan area.

Dick Dufourd

Engineering Technician of the Year



Dick Dufourd is the Off-Highway Vehicle (OHV) program manager for the 318-mile East Fort Rock OHV project on the Bend/ Fort Rock Ranger District. This complex project, covering 110,000 acres, is one of the largest OHV trail systems in the Nation that is located on a single Ranger District. He is also on detail as the OHV Specialist providing user contacts, information and education, and law enforcement. In addition, Dick is the Project Engineer responsible for the planning, location, survey, design, and construction of the project.

Dick has received numerous recognitions for his contributions to this trail system and past projects. These contributions have been recognized not only by the Forest Service but by other organizations. In addition to his performance ratings, recognitions that Dick has received include:

- an Employee Suggestion Award for the design of a low-maintenance, lightweight, easily transported trail cattle guard (this design is now incorporated in the American Motorcyclist Association Off-Highway Vehicle Design Guide, which is distributed and used nationally;

- the 1995 Public Service Award from the Blue Ribbon Coalition; and

- the 1994 Achievement Award from the Central Oregon Motorcycle and ATV Club for his planning, design, and construction of the East Fort Rock OHV Trail.

Dick is recognized nationally for his technical knowledge of sno-parks, snowmobiles, and OHV trails and facilities. He has been involved in technology transfer in these areas as described below.

- Wrote a sno-park design guide for the Region that is used by the Forest Service, user groups, and other State and Federal agencies.

- Served on a team to review the draft Regional Sign Handbook; wrote guidelines for winter trail signing, and incorporated them in a Handbook Supplement that was used as a field guide. Much of this supplement was later incorporated in EM-7100-15, *Standards for Forest Service Signs and Posters*.

- Presented the results of a project to test and develop snowmobile stopping and sign recognition distances to the International Association of Snowmobile Administrators at the International Snowmobile Congress. He assisted the Missoula Technology and Development Center by helping develop testing methods, standards, criteria, and performing the testing.

- Was a member of the National Snowmobile Trail Signing Task Force, which developed a series of consistent sign standards and guidelines. This group met with the Forest Service, user groups, and other State and Federal agencies from across the country. Dick presented the task force findings to the International Association of Snowmobile Administrators at the International Snowmobile Congress in Madison, Wisconsin.

- Was invited to speak last year at the National Trails Symposium in Anchorage, a true honor, but was unable to attend because of schedule conflicts.

Dick is skilled in all phases of project engineering, including road, trail, and facility planning, survey, design, contract preparation, and contract administration. Dick personally located, designed, prepared, and administered the contracts for the 10-Mile Sno-park, Newberry Group Site Campground, Obsidian Flow Interpretive Trail, and Little Crater Trail. These projects, all within the Newberry Crater, helped to set the stage for this area to become recognized as a national monument.

Other activities in which Dick has demonstrated his leadership and technical skills include:

- serving as consultant for the Oregon State Winter Recreation Advisory Committee to provide input on sno-park management and design;

- serving as member of the Forest's Recreation Strategy Group, which formulated a proactive mission, vision, and strategy for recreation in Central Oregon;

- participating as a team member to review and revise the Special Project Specifications for the Road and Bridge specification book;

Federal agencies and user group organizations, including Washington State Parks, The Blue Ribbon Coalition conferences, the Northeast and Western Chapters of International Association of Snowmobile Administrators (IASA), and the National Snowmobile Workshop.

Dick's involvement in the East Fort Rock OHV trail system also demonstrates his leadership and technical skills. Dick has led this project through planning, engineering, construction, and implementation phases.

As the project planner, Dick was responsible for the field location of all the trails and facilities for the project. He coordinated the activities of all other resource specialists to perform the field surveys needed to complete the plan. He also spent considerable time educating Forest Service staff and resource specialist in the methods and benefits of OHV management. He took the lead in conducting a field trip to Region 5 with the project IDT, Bureau of Land Management, and Oregon Department of Fish and Wildlife officials. He gained valuable information on management methods and effects of OHV use.

As the project engineer, Dick has been solely responsible for the survey, design, and construction of the Force Account project. He developed construction techniques for OHV trails in pumiceous soils by researching several equipment options, then purchasing a SWECO trail tractor.

As OHV specialist, Dick led teams of resource specialists to develop a comprehensive sign plan and monitoring plan and is developing an interpretive plan for the East Fort Rock Trail project. He used the student intern program to obtain help in preparing a high-quality interim trail map.

As the first managed, designated OHV trail system in Central Oregon, the East Fort Rock OHV project is serving as a model for other OHV programs in the Northwest. The Bureau of Land Management, other forests, and other agencies are already using the results of this project and are seeking Dick's aid for the planning and development of their OHV programs.

In order to gain financial and other support for the project, Dick developed a strong partnership with the Oregon ATV Allocation Committee and was able to persuade the committee to invest in the project. He has recruited and coordinated volunteers from many groups, including Girl Scouts, to aid in the implementation of this project. Volunteers are now asking to "adopt a trail" to further their involvement in maintaining the system. With Dick's guidance, other volunteers are developing and building prototype grooming equipment that can be towed behind all-terrain vehicles (ATVs) to maintain the trails. More than 1,000 volunteer hours have been donated annually on this project.

Dick's creativity has been recognized in the design of the project. Thirty trail cattle guards of Dick's design have been installed and have proven to be highly effective. Cedar bales, which are weed free, have been used to control and direct use in sensitive plant habitat. More than a mile of split-rail cedar fencing that is visually pleasing and effective has been placed to control use. Split-rail is also being used in kiosk and facility design for consistency and a natural appearance. Dick also fostered the use of transplanting native grass and shrubs as a rehab technique. Road and trail closure methods effectively disguise the old facilities and deter use.

Dick provides the same leadership and technical skill contributions to the community. Examples of his community support appear below.

- Played an active role on the citizen's committee that formulated the Newberry National Volcanic Monument by serving as chairman of its Winter Recreation Committee and Transportation Committee and as member of the Legislative Committee that drafted the bill for Congress.

- Served as cochairperson of an Eagle Scout project that installed Wood Duck nesting boxes around Davis Lake. Served as Forest Service liaison and arranged snowmobile transportation and a cookout for the scouts.

- Encouraged user groups to work together and support each other. Spearheaded the snowmobile club to host sled dog races and to work road guards and checkpoints for motorcycle events.

- Worked with the sled dog group, and developed race trail marking and management guidelines that were incorporated by the International Sled Dog Racing Association.

- Served as director and is a current member of the Oregon State Snowmobile Association and a member of its Legal Action Committee.

- Is a member of the Central Oregon Motorcycle and ATV Club.

Improved Autonomous Accuracy for Forest Service GPS Receivers

Bill Kilroy
Mechanical Engineering Technician
Missoula Technology and Development Center

Forest Service field employees can now use global positioning system (GPS) receivers with the same autonomous accuracy afforded the United States military. Normally, the signal from global positioning satellites is degraded, limiting accuracy to within 100 meters 95 percent of the time. Certain GPS receivers can be "keyed" so they are not affected by the signal degradation. These receivers are accurate to within 16 meters 95 percent of the time. Differential correction can provide even better accuracy, but is not always available during real time, particularly in mountainous terrain.

The Missoula Technology and Development Center (MTDC) has worked with the National Security Agency to establish a Communications Security Account that allows the Center to key GPS receivers for all Forest Service units. The Center also keys some receivers for the Bureau of Land Management. Each receiver must be rekeyed annually or whenever the Department of Defense changes the code.

Now about 60 of these receivers are used throughout the Forest Service. We anticipate that another 100 will be purchased during 1996.

Two types of GPS receivers can be purchased by the Forest Service and keyed by the Missoula Technology and Development Center: the Trimble Centurion and the military Precision Lightweight GPS Receiver (PLGR) manufactured by Rockwell Collins. The Center has tested both receivers.

Trimble Centurion

The Trimble Centurion GPS receiver (Figure 1) was evaluated at the Lubrecht GPS test facility in western Montana during the summer of 1994. When "keyed" these receivers will remove the effects of selective availability (SA) and antispoof (AS) as imposed by the Department of Defense. Results of this evaluation indicate that the Centurion, operating autonomously, will be an excellent tool for relocating points under forest canopy conditions.

The Trimble Centurion is a dual-frequency P(Y) code, six-channel GPS receiver. It is also known as the Trimble III and resembles both the Trimpack and Pathfinder Basic series of hand-held receivers. It has a built-in antenna, provision for a remote antenna, and a data I/O port. The Centurion is compatible with the MC-V Data Logger. Data from the MC-V are compatible with Pathfinder version 2.53 or later software. During the tests conducted at Lubrecht, both SA and AS were on, the Centurion was "keyed," and all tests were conducted under a forest canopy (Figure 2). The dome antenna from a Pathfinder Professional was used as a remote. It is a single-frequency (L-1) antenna, and was mounted on a 2-meter-high range pole for convenience (Figure 3). When data logging was required, the receiver was connected to the MC-V Data Logger.

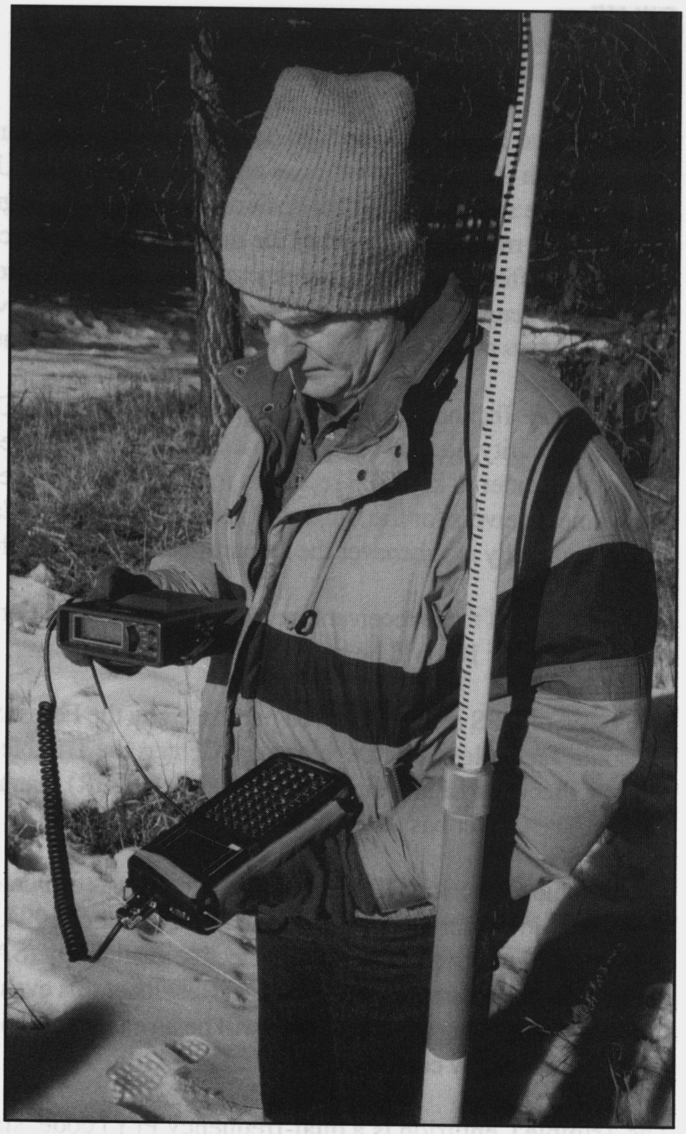


Figure 1. —The Trimble Centurion hand-held receiver.

Figure 2.—The Trimble Centurion was tested under a forest canopy.

Figure 3.—The dome antenna from a Pathfinder Professional served as a remote antenna.

Navigational Error

The navigational accuracy of the Centurion receiver was tested by having one operator relocate objects previously located and entered as waypoints by someone else. The operator was not told exactly what these objects were: a stump, a mouse hole, a small seedling, or some other feature. When the operator was as close as possible to a specific waypoint, the distance from the antenna to the physical feature was measured. This distance was recorded as the navigational error. These values are recorded in Table 1. During this test the observed position dilution of precision (PDOP) values were generally less than 3. Throughout most of the test the receiver was tracking six to eight satellites.

Table 1—Navigation error (selective availability and antispoof on).

A	7.0/2.1
B	18.0/5.5
C	26.0/7.9
D	15.5/4.7
E	13.5/4.1
F	26.0/7.9
G	33.0/10.1
H	7.0/2.1
I	15.0/4.6
Average	17.9/5.5

Horizontal and Vertical Accuracy

The autonomous operational accuracy of the Centurion was determined by collecting 180 or more position records at each of 7 stations. This was under the forest canopy with both selective availability and antispoof on. A walk file was also recorded for area determination. The MC-V Data Logger recorded data that were analyzed with the Pathfinder software.

The horizontal and elevation errors are recorded in Table 2. These were calculated using a mean value from the statistics and the known position for each station. The area error calculation is also included. It was derived from the walk and combined point file.

Table 2—Horizontal and vertical error (selective availability and antispoof on).

Station	Position records	Horizontal error (ft/m)	Vertical error (m)
1	189	16.35/4.98	7
2	189	19.50/5.94	6
3	196	15.04/4.58	6
4	189	9.46/2.88	10
5	188	8.50/2.59	7
6	190	23.46/7.15	7
7	188	19.59/5.97	9
		Average 15.99/4.87	
	Error in area:	Walk file 0.4%	
		Point file 2.7%	

The vertical errors are all positive, with the 2-meter height of the antenna accounted for in these data. This indicates a vertical bias of approximately 8 meters. The reason for this bias is unknown, but will be investigated in further tests.

Operating Efficiency

The operating efficiency rating is an effort to quantify the effect a tree canopy has on a receiver. This rating is determined by the update rate of the receiver and the number of positions it would be expected to record when in a clear position. When under a canopy, this same receiver can be expected to record fewer positions during the same time period because of signal attenuation. In both situations the receiver is considered to be under the same constraints of PDOP mask and satellite availability. The operating efficiency will then be determined by dividing the actual number of positions recorded by the receiver by the number that would be expected during the same time interval, were the receiver in an "open" environment. The rating is expressed as a percentage. Table 3 rates the Centurion receiver operating under a forest canopy.

Table 3—Operating efficiency under a forest canopy.

Station	Positions recorded under canopy	Positions in time interval open	Efficinecy %
1	189	189	100
2	189	189	100
3	196	196	100
4	189	189	98
5	188	188	100
6	190	190	100
7	188	188	100
			Average 99.7

The results presented in Table 3 show that the tree canopy had very little effect on the Centurion receiver's performance. The unit seldom lost its lock on satellites regardless of the canopy conditions. Further testing will be done under a hardwood and dense conifer canopy.

Range and Azimuth

At each station on the test course, the range and azimuth to the next station were obtained from the Centurion. These values were then compared with the range and azimuth readings obtained with a compass and chain. Table 4 presents this comparison.

Table 4—Range and azimuth comparison.

Station	Azimuth: (Degrees) Cent.	Compass	Diff.	Range: (Meters) Cent.	Chain	Diff.
1 to 2	270	273	3	73	69	4
2 to 3	209	209	0	109	105	4
3 to 4	122	119	3	76	78	2
4 to 5	128	127	1	47	51	4
5 to 6	62	62	0	58	60	2
6 to 7	28	7	21	62	65	3
7 to 8	318	323	5	82	80	2
			Average 5			Average 3

Results

These results indicate the Centurion is a highly effective tool for real-time autonomous operation under a canopy, given the constraints of both selective availability and antispoof. The Centurion produced an average real-time navigational accuracy of 5.5 meters, an operating efficiency of almost 100 percent under the forest canopy, and a horizontal accuracy of 4.9 meters. These values were obtained using about 180 positions at each station.

Figure 4.—The military Precision Lightweight GPS Receiver (PLGR).

The Military Precision Lightweight GPS Receiver

The Precision Lightweight GPS Receiver (PLGR) (Figure 4) is a five-channel, single-frequency L1 P/Y code receiver manufactured for the United States military. This receiver is capable of a position accuracy better than 16 meters spherical error probability (SEP) in autonomous operation.

Two of these receivers were provided to the Forest Service by the Electronics Test Company, U.S. Army Electronic Proving Ground, Ft. Huachuca, Arizona. During fiscal year 1994, these units were evaluated at the Forest Service's GPS Hardwood Test Site, Bedford, Indiana.

This site is located under a heavy canopy of mixed oak, hickory, and beech trees. It is typical of the central hardwood timberlands. The test course was a closed traverse containing seven positions on two finger ridges and another station in the bottom of the draw between the ridges. The exact latitude and longitude of these positions had been determined previously.

In the test, the receiver was placed over each of these points (Figure 5), and the average of 180 position recordings was taken. This was repeated for 120, 60, 30, and 10 position records at each station. The averages were compared to the known latitude and longitude at each station, and the horizontal error was calculated.

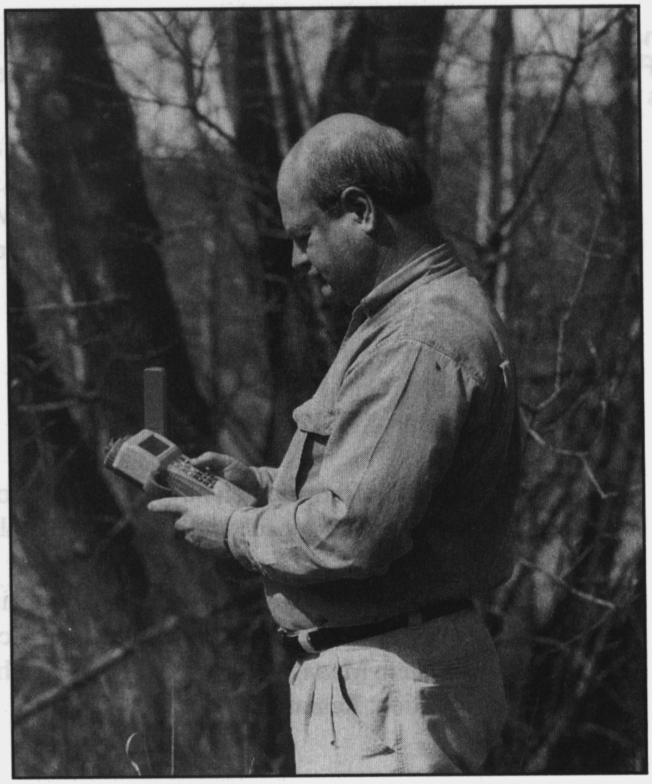


Figure 5.—Position readings taken with the military PLGR receiver were compared to known positions.

The preliminary results (Table 5) show the average horizontal error in meters for each station using both receivers tested.

Table 5—The average horizontal error in meters.

Records averaged:	180	120	60	30	10	1
Receiver A:	5.9	6.5	14.1	18.4	15.4	16.2
Receiver B:	9.3	5.0	13.5	11.1	8.6	13.1
Max error:	25	15	24	29	30	51

These data show that the horizontal error can be significantly reduced by averaging a minimum of 120 to 180 position records. For receiver A, the error was reduced from 16.2 meters to 6.5 meters by averaging 120 position records. The maximum error was also reduced from 51 meters to 15 meters. The error, however, is more variable. When using the PLGR for horizontal positioning, occasional errors as large as 25 to 30 meters can be expected, even with averaging. The receivers should be used only in applications where this amount of error is acceptable.

Waypoint navigation tests were also conducted. The position coordinates in these tests were determined by averaging 30 position records. The PLGR produced an average navigational error of 8.0 meters, and a maximum navigational error of 14.9 meters. The PLGR should be an effective tool for navigating to or relocating positions or features.

Purchasing and Keying GPS Receivers

Contact your Regional GPS Coordinator to purchase either GPS receiver. After the receivers have been purchased, they must be keyed at MTDC.

The receivers must be sent to the Center by accountable mail, such as Federal Express or United Parcel Service. Include a return shipping label or a shipping account number with the receiver. All receivers must have a Forest Service property tag attached. Ship receivers (with new batteries) to:

Bill Kilroy
USDA Forest Service—MTDC
Building One, Fort Missoula
Missoula, MT 59801.

For more information on buying a receiver or having one keyed, call Bill Kilroy at (406) 329-3925, or send him a Data General message at B. Kilroy:R01a.

The Forest Service staffs cooperating to maintain the Missoula Technology and Development Center's Communications Security Account include: Engineering, Ecosystem Management, Fire, Forest Health Protection, Lands, Law Enforcement, Recreation, Research, and Timber Sales.

The Wood River Project

Christina Lilienthal
Forest Landscape Architect
Winema National Forest, Region 6

Special thanks to Roger Bergmann of San Dimas for his technical contributions to this article.

The design of the Wood River Accessible Fishing and Day-Use Area offers access to a high-quality fishing river in a natural wetland environment where people can universally access places to picnic, fish, and learn about the wildlife and wetland environment through interpretation. The facility has accessible "sweet-smelling" toilets and parking. In addition, there is a bus turn-out designed into the loop to accommodate school tours or tour buses for groups traveling through the area or en route to Crater Lake National Park.

The site design was created to provide a fully accessible recreational experience at "the hub" or main part of the facility. The farther one moves from the hub, the more private and "natural" the experience becomes. Boardwalks are designed low to maintain a low profile in the landscape and allow passage for beaver hauling logs. The farther one goes, the more "wild" the environmental experience. Shade and benching are planned frequently along the trail for rest and contemplation, with particular consideration to the elderly and parents with young children.

The site was planned to lead people easily through the wetland environment while protecting the natural resources and providing learning opportunities. Edging the trail, boardwalks, and bridges with 4 x 4's, and using protective barriers on fishing platforms, helps people to navigate and to feel secure in a possibly unfamiliar environment. This is particularly important for the safety of persons with visual and mobility disabilities and for young children.

The design included visual cues, such as entry posts, to signify the beginning of a trail, and benches and shade at natural intervals. The changes in trail surfacing from stabilized aggregate to boardwalk provide cues for possible elevation to a visually impaired person walking with a cane. Communicating information without placing a sign was a priority. Signs are intended primarily for orientation or interpretive use.

Hazards were minimized to allow safe use of the hub area and the picnic areas. Venturing farther from the hub offers greater challenge to the visitors as they enter an increasingly "free" environment. The trail was designed to be fully accessible, with some increased grade toward the more distant finishing platforms.

Efficient to use, the trail system provides for rest and relaxation. The picnic sites enable a person with a disability to become one with a family group. The toilet facilities have excellent access, are easy to open, and have roomy interiors for maneuverability. All facilities were designed for universal access.

Design Objectives

To provide a universally accessible trail, the design and construction had to provide for a trail tread surface that was "firm, stable, and slip-resistant." Use of soil stabilizers on trails has been increasing in the past several years, but many questions remain as to which products are easiest to use; which last the longest with the least amount of maintenance; and which work best under certain environmental conditions. When the Wood River Project was about to enter its construction phase, the San Dimas Technology and Development Center (SDTDC) began a study to find answers to some of the questions regarding soil stabilizers. The Winema National Forest and SDTDC entered into an agreement that may help all trail designers in the future.

Roger Bergmann, a Mechanical Engineering Technician from SDTDC, was sent to the Wood River Project where he directed the mixing and placement of several types of soil-stabilizing products. These products, including pine tar emulsion, ground seed hulls, latex polymer, flyash, bentonite clay, and enzymes, were mixed with coarse and fine aggregates in a total of 28 test sections. There were also four control sections and one section of macadam (geotextile, pea gravel, asphalt emulsion, and blotter sand).

Figure 1.—Macadam (black) and road oil trail surface applications on trail prior to covering with "fines" to blend with the environment.

As a result of this project, Roger wrote a report, *Soil Stabilizer for Use on Universally Accessible Trails*, 9523 1804. He cites several recent *Engineering Field Notes* articles that address trail-hardening testing, barrier-free accessible trail surface materials, and surfacing with nonstandard stabilizers.

To obtain a copy of Roger's report, send a DG message to Mailroom: W07A or a written request to USDA Forest Service, San Dimas Technology and Development Center, 444 East Bonita Avenue, San Dimas, California 91773, Attn: Recreation Program Leader.

Challenges

The challenges were many. Designing to minimize intrusion into the wildlife habitat while providing visitors the opportunity to see how animals live involved consultation with many different people and agencies. Building boardwalks and bridges through wetland areas while preserving the delicate site amenities required creative construction methods and minimal use of machinery. Aggregate and other construction materials were shuttled with all-terrain, four-wheeled vehicles with small trailers attached. Hand tools were used to remove native soil from trail locations and place it in areas that needed to be filled and revegetated. Geotextile was placed in the excavated trail area before backfilling with crushed aggregate base material that was compacted with a vibratory plate. Then, the fine or coarse aggregate for the surface material was placed in appropriate locations and the various stabilizers were mixed in place and compacted.

Equipment had to be rented to achieve certain steps of trail construction such as rototilling and compaction. No electricity was available, so generators were needed to operate power hand tools and equipment and some liquid stabilizers were applied with hand pumps. It was challenging to construct facilities with unskilled youth while achieving technical adequacy; however, once they understood the techniques, the work went well.

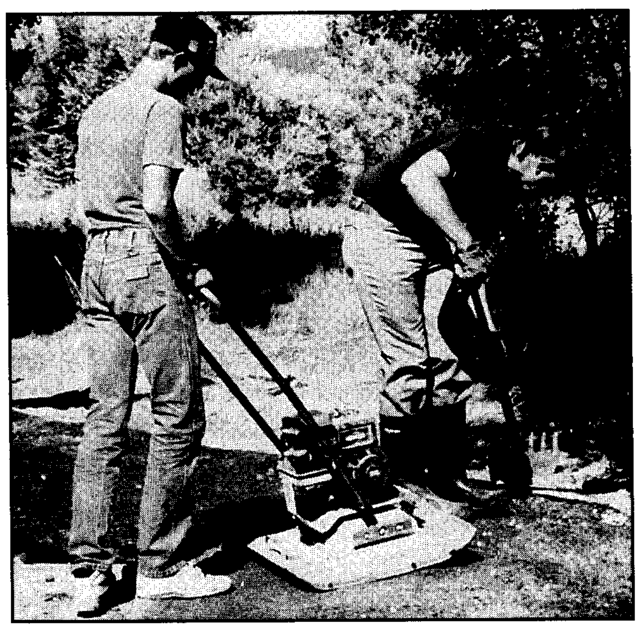
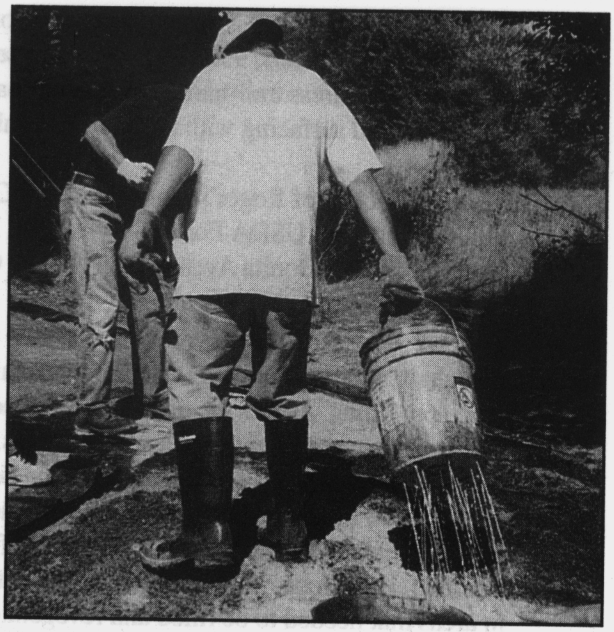


Figure 2.—Youth operating the compactor on trail surface.



Current/Anticipated Users

Expected visitors range in age from babies to the elderly. Single people, families, and groups can all enjoy this facility. Local people continued to recreate at the site even when it was under construction. They seemed to find the act of construction interesting as well. Visitors will primarily be local, at least at first, because the project is located near the southern access to Crater Lake National Park. As word about the facility spreads, nonlocal visitors are expected.

The Klamath Tribes published an article about the facility in *Tribal News* because they felt it would have special appeal to their elders who wanted to get out and be in a natural setting. Spokes Unlimited, a local resource center for people with disabilities, published an article about the Wood River Project in its newsletter. Articles appeared in the local newspaper about constructing the facility with local youth. Other Federal employees have already used some of the construction drawings to build facilities at other locations and have inquired about the accessible trail surface-testing project. SDTDC published the technical document, *Soil Stabilizer for Use on Universally Accessible Trails*, which explains the use of trail additives and uses photographs from the Wood River Project to demonstrate technique.

The facility was designed to be a low-maintenance area. Construction materials were selected to endure for a long time with minimal maintenance. The Wood River Project is a national site for SDTDC to test trail additives for accessible trail surfacing. Monitoring of these trail surfaces over the next several years will provide useful information on effective materials and long-lasting surfaces. SDTDC is currently contacting other forests in an effort to establish test sites in other geographic areas with different climatic and soil conditions.

Benefits

The benefits of building this project through a partnership between the Winema National Forest and Integral Youth Services expanded to involve SDTDC and many local businesses and individuals that donated materials or resources to construct the project. The project became reality and gained tremendous meaning through the years by community involvement and effort in the project. A sign recognizing all the youth who participated in construction will be placed at the site. This has given people an opportunity to share in a team effort for the benefit of many.

Cost/Savings

The cost estimate for the project was originally figured to be about $300,000. Because it became a Challenge Cost-Share Project, partners became involved and, through the efforts

Figure 4.—Trail Prism created using rototiller and hand-removal methods by "at risk" youth.

of Integral Youth Services, local donations of materials and contributions provided meaningful work opportunities for "at-risk" youth from the community. At the same time, grant funding provided support in addition to resources made available by the Forest Service. Federal budget cuts required that the partnership and multiple creative funding courses involve local, State, and Federal levels.

Quotes from the Forest Service Technical Staff

"We picked this project because it is large enough, and has a variety of trails. The area has the freeze and thaw of winter and hot summers. There's a little of everything." (Roger Bergmann, SDTDC Mechanical Engineering Technician)

"This year the youth completed 3,200 feet of trail. They put down gravel, timbered the edges, and finished the surfaces. [Test] results will be used throughout the Northwest and United States. This project will go on and benefit all kinds of people." (Sydney Vidricksen, Designer and Construction Technical Advisor)

"We had a good mix this year: seven men and five women. They did a fine job." (Sydney Vidricksen)

Quotes from Youth in the Field

Alisha Bauman, a senior at Klamath Union High School, is typical of the project workers. At the Wood River Project, Bauman's job involved timbering and pumping to apply the stabilizer. "I love it. I think it's great," Bauman said. "I'm going to try to get this job again. I like trail surfacing the best."

(John Potter) "I think it's pretty great. A lot of people enjoy the work and need the money and experience, and we're doing something to benefit the community." Potter, a junior at Klamath Union High School, said he worked hard to assure himself a spot on next year's crew. The budding builder and architect liked watching the behind-the-scenes work. "It's nice to hear how things were calculated," he said.

(Lana Groves) "It's better than working in an office." She hopes to become a surgeon and said the YCC job has helped because she's "learned to deal with people, socialize, give orders, and be patient."

"There's nature all around. You're learning a lot and gaining skills. You get out there and find out what you're made out of! Wow! I DID do that! It's like a membership. . .like you belong. I learned about the importance of conserving the land. . .I learned about leadership. I've known people who were in trouble, got in this program and worked it out. It was a life-changing experience." (Heather Hitchcock)

Lessons Learned/ Suggestions

It is possible to construct a project like this with a partnership. A critical requirement is having technical support available on-site, preferably the same individual if it is a multi-year project. The commitment of the partners is also key, as is the willingness to work out problems and follow through. The Executive Director of Integral Youth Services was vital to the continuity of this multi-year project and contributed significantly to the acquisition of needed materials, supplies, and grants. Technical support of Forest Service personnel at the staff level was important during critical periods. Access to additional training such as firefighting, safety and tool use, and operation of all-terrain vehicles was a benefit to the youth.

Summary

The Wood River Project on the Winema National Forest in Region 6 brought together people of varied backgrounds to work toward a common vision. It connected the community and its youth to the USDA Forest Service, and initiated partnerships between them. It joined Forest Service personnel from Ranger Districts, the Supervisor's Office, the Regional Office, and the technology and development group. It brought engineers together to achieve an excellent example of the reinvention of the government while at the same time meeting the needs of visitors to our national forests.

Bioremediation Using Land Treatment for Hydrocarbon-Contaminated Soils

Allan K. Porter, P.E., AVID Engineering INC.
former HAZMAT Engineer for USDA Forest Service
Region 3

For more than 25 years land farming has been used as a remediation method for the treatment of hydrocarbon-contaminated soils in the United States. This technology has proven to be cost-competitive with other soil remediation methods. (Kostecki and Calabrese, 1989)

Land treatment uses naturally occurring soil bacteria to biologically oxidize and immobilize the hydrocarbon contaminants in the soil. The majority of the biological process occurs in the top 6 to 12 inches of soil. This reach of soil is usually referred to as the "Zone of Incorporation" (ZOI). These aerobic biological processes convert the hydrocarbon compounds from the organic state to the inorganic state, namely, carbon dioxide (CO^2). As soil depth increases there is additional oxidation and immobilization occurring, but not at the same rate as in the ZOI. Generally, most biologic oxidation processes stop past soil depths of more than 5 feet. Land treatment (land farming) uses these natural processes to treat petroleum-contaminated soils that have been excavated from around leaking underground storage tanks.

Several environmental factors control this oxidation process through the active ZOI. These include:

- the oxygen content of the soils,
- soil pH,
- soil temperature
- availability of mineral nutrients within the soils,
- soil moisture, and
- the nutritional quality of the organic carbon present in the soil as a result of the hydrocarbon spill.

Generally, native soil bacteria are capable of oxidizing and utilizing the benzene, toluene, and xylene (BTX) compounds in spilled hydrocarbons as a nutrient source. These populations of metabolically capable organisms increase until they are limited by some other metabolic requirement such as mineral nutrients. The mineral nutrients can generally be augmented by the addition of commercially available fertilizers that contain primarily nitrogen and phosphorous. Unless soil conditions warrant the addition of fertilizers that contain a lime ingredient, no attempt to adjust soil pH should be made, as native soil micro-organisms are best able to carry out metabolic functions at the existing soil pH.

A general rule of thumb to use in determining how much additional nitrogen–phosphorous fertilizer should be added to a bioremediation waste pit is based on a carbon:nitrogen: phosphorous ratio range of between 100:2:0.2 to 100:4:0.4. (Kostecki, et al., 1989; Torpy, et al., 1989). The amount of carbon nutrient compound available in soils resulting from a hydrocarbon spill is based on the reported total petroleum hydrocarbon (TPH) concentration (expressed in terms of mg TPH present/kg of soil). The TPH concentration of contaminated soils is obtained by field checks (usually with a portable gas chromatograph or a volatile organic compound [VOC] "sniffer") or by sending a soil sample in a sealed container to a lab that is equipped for this type of analysis. This TPH concentration can be used as the concentration of organic carbon nutrients available for biological oxidation processes within the contaminated soil.

Using the above ratios of nutrient application loading, the following example shows how a fertilizer application can be calculated.

Example

The loading rate of the fertilizer onto the remediation area is usually limited to small, frequent doses. In general, the application of the fertilizers should be performed by rototilling the fertilizer into the first 6 to 8 inches of the treatment area. The rototilling of the treatment area serves two purposes. The first is the obvious mixing of nutrients past the surface of the treatment area; the second involves an aeration process that introduces oxygen to deeper soil levels. The rototilling also serves to increase the volatilization of the hydrocarbons in the contaminated soil.

The fertilizer loading rate is further influenced by the amount of water that can be added to the treatment area. The transport of nutrients from the fertilizer within the treatment volume is almost wholly dependent on the movement of water through the soil column. Because of the limiting nature of this type of transport, the availability of the mineral nutrient to the active micro-organisms is directly related to how much and how often water is applied to the treatment area. If irrigation water is available at the treatment site, care should be taken not to saturate the contaminated soils within the treatment pit, as excess moisture within the containment area could require an unnecessary drain tile system to be built in the bottom of the waste pit. In addition to the increased costs associated with the construction of a leachate collection system within the treatment containment volume, the presence of excess water at the bottom of the soil pit could cause local conditions to become either anoxic or anaerobic. Either of these two occurrences would hinder the hydrocarbon oxidation processes in the soils, and would also increase the chances of further contamination of the soils underneath the containment pit should there be any break in the containment liner. The contaminated soils should be maintained in a "moist" condition; that is, the lower layer of soils should show some indication of moisture by either visual or tactile inspection.

If there is a depth of at least 100 feet between the contaminated soils and any groundwater, linings for the containment pits are not required for remediation processes in New Mexico. The requirement for a liner, however, is also dependent on the extent to which the soils are saturated with petroleum product. If a soil seems to be wholly saturated with a petroleum product, a containment liner in the treatment pit would be necessary. The costs of using a liner in this case must be weighed against the option of adding uncontaminated soils to the saturated soils in order to "dilute" the petroleum product below a saturated state. In all instances of petroleum contamination of soils, the primary concern is to isolate the contamination within the treatment volume. Isolation of the petroleum-contaminated soils will prevent the further contamination of the surrounding soils or, in the worst case, having the contamination reach underlying groundwater.

In Arizona liners are required for any remediation procedure. There is no consideration given for degree of saturation of petroleum contaminants in the soils, and no regulations dealing with placement of liners if groundwater is below a critical depth. All petroleum-contaminated soil to be treated within the State of Arizona must have impermeable liners placed between the soils to be treated and the underlying earth.

Arizona also requires that the Arizona Department of Environmental Quality be notified of any remediation process that involves volatilization of aromatic petroleum hydrocarbons. The Arizona Department of Environmental Quality will be involved in permitting the remediation site in order to maintain some control on the amount of regulated (BTX and Ethylbenzene) emissions into the atmosphere. This regulation is probably not going to affect remediation efforts that occur on most Forest Service properties, but may apply to remediation efforts around the cities of Phoenix and Tucson because of the impact on those cities' airshed quality.

Minimum levels of acceptable TPH concentrations remaining in the remediated soil vary between the two states in Region 3. The New Mexico Environmental Improvement Division considers soils with a maximum TPH of 50 parts per million (ppm or mg/kg) as being acceptably clean. Arizona has an acceptance level of TPH concentration at 100 ppm or mg/kg.

In order to standardize any bioremediation design that might be used within Region 3, the following guidelines are suggested.

1. Excavate the contaminated soil from the hydrocarbon spill-site until the point of zero contamination in the surrounding soil is reached as determined by laboratory tests for TPH. This zero-point will be determined and certified by the authorized State authority in which the forest operations are located. Alternatively, if an outside contractor is being used to help determine the extend of hydrocarbon contamination, the contractor will be able to find the zero-point of contamination in the surrounding soils. The Forest Service or its contractor(s) should follow all necessary chain of custody documentation when dealing with contaminated soil samples.

Sample collection and preservation procedures must include:

- identification and qualifications of the persons conducting the sampling;
- a description of the sampling procedures and equipment used;
- decontamination procedures used on the sampling and drilling equipment;
- a description of the sample containers;
- methods used to prevent volatile losses from the samples during and after collection; and
- methods used to preserve the samples at 4 degrees celsius (40 degrees F) until delivery to a qualified laboratory.

2. A containment area should be built and lined with an impermeable material. This containment area can be shaped by simply using dirt berms to enclose a given area.

The size of the containment area is based on the quantity of soils to be treated and the physical dimensions of the impermeable liners available for use. The only required dimension in the containment area is the depth of soil. In order to make full use of the ZOI, the treated soil needs to be maintained between 12 and 18 inches in depth. This depth requirement will control the overall treatment area needed. All Forest Service-related remediation enclosures within Region 3 will include a liner between the contaminated soil and the underlying earth.

3. The physical location of the bioremediation treatment enclosure needs to be chosen so as to be out of a floodplain or water saturated area. Care should also be taken to place the treatment area at some distance from existing surface waters.

4. Once the contaminated soil is placed in the treatment enclosure, an initial TPH concentration should be done on the soil. An average value of contamination levels can be found by taking TPH samples from several areas within the treatment area. Once these initial samples are taken, the contaminated soil can be sprinkled with water. Fertilizer should be added to the contaminated soils based on the following rations:

- [TPH conc.] = Conc. of Carbon Nutrients Present
- Carbon Nutrient (from a):Nitrogen:Phosphorous = Between 100:2:0.2 and 100:4:0.4

Fertilizer doses should only be added once a month.

5. TPH concentrations should be determined once a month during the remediation process. The soil samples should be taken from several areas within the treatment area in order to obtain a representative contamination profile. Soil samples may be submitted to analytical laboratories in clean canning/jelly jars. The inner portion of the jar lids can be turned upside down so the plastic gasket on the lid is not touching the soil sample. Teflon tape should be used on the threaded portion of the jar to ensure an airtight seal. The sample jar should be completely filled with soil in order to minimize the head space available in the jar for accumulation of volatile hydrocarbon compounds.

6. Records should be kept for all TPH concentrations, TPH sampling dates, amounts of fertilizer applied to the treatment area and dates of treatment, and climatological conditions (maximum daily temperatures, minimum daily temperatures, cloudy skies, clear skies, etc.).

7. The treatment period will probably last for a minimum of 6 months. The process can be considered complete once the TPH concentrations in the treatment areas fall below the maximum acceptable contamination levels (MCLs) as regulated by the responsible State environmental regulatory agency. (For Region 3, Arizona Department of Environmental Quality [ADEQ] TPH_{max} = 100 ppm; New Mexico Environmental Improvement Division (NMEID) TPH_{max} = 50 ppm.)

8. All sampling data should be retained for submission to the responsible State environmental regulatory agency. When the TPH concentrations fall below the

prescribed MCLs, all sampling records should be submitted to the responsible State environmental agency for verification that remediation has been completed. Notification that the State has determined that the soils are acceptably remediated should be obtained in writing.

The remediated soils can then be removed from the treatment area. These soils should not be used as fill in the original contaminated excavation. Also, these soils should not be used as fill in an area that will be saturated through runoff conditions or by groundwater.

Once the remediated soils are removed from the containment/treatment area, the liner under the treatment area should be checked for any rips or tears. Rips or tears in the liner may have allowed the migration of petroleum contaminants into the underlying soil. If the liner has been torn, random sampling of the underlying soils should be made to determine if the petroleum products have indeed migrated into this soil. Generally, a portable sniffer or GC similar to the equipment used to determine the original extent of contamination will be adequate for this testing.

Depending on the local climate, total time for adequate soil remediation will be approximately 6 months. The total time will vary according to local weather conditions, most notably the average daily temperatures. If the remediation effort goes on into the late fall or begins in the early spring when freezing temperatures are still encountered, then the remediation period will be correspondingly longer.

If the time frame associated with bioremediation becomes prohibitively long, specialized soil bacteria cultures that may shorten the overall treatment time are available from commercial sources. These specialized soil bacteria strains have already been acclimated to using hydrocarbon compounds as their major source of nutrients. Private environmental remediation contractors will have more information on these specialized microbes. The costs associated with buying these specialized microbes should be weighed against the total treatment time that might be saved.

References

Borquin, A.W., "Bioremediation of Hazardous Waste," *Hazardous Materials Control*, Vol. 2, No. 6; September–October 1989, pp. 16–23.

Kostecki, P.T. and Calabrese, E.J., "Petroleum Contaminated Soils," Chelsea, Mich., Lewis Publishers, 1989.

Torpy, M.F., Stroo, H.F., and Brubaker, G., "Biological Treatment of Hazardous Waste," *Pollution Engineering*, May 1989, pp. 80–86.

Wilson, J.T., Leach, L.E., Henson, M., and Jones, J.N., "In Situ Biorestoration as a Groundwater Remediation Technique," *Ground Water Monitoring Review*, Fall 1986, pp. 56–64.

"Workshop on Bioremediation of Hazardous Wastes," EP 7.2:B52.

"Evaluation of Volatilization of Hazardous Constituents at Hazardous Wasteland Treatment Sites," EP 1.89/2:600/S–86/071.

"Field and Laboratory Evaluation of Petroleum Land Treatment System Closure," EP 1.89/2:600/S2–85/134.

"Land treatment of an oily waste—degradation, immobilization, and bio-accumulation," EP 1.89/2:600/S–85–009.

Bridges: Some Old, Some New; Some Needed, Some Not

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Kathleen Tillman
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Some bridges are not needed? Certainly an unusual statement for an agency managing a road system. Road networks typically expand to satisfy an increasing demand, thus adding or replacing bridges. However, for many national forests within Regions 5 and 6 that have implemented the Northwest Forest Plan (formerly the President's Plan) and that have been affected by a host of other environmental concerns, the unusual is happening.

This article explains the process being used to develop a long-range plan for bridges on one these forests. Why a plan? Why not just establish a simple replacement schedule based on the anticipated life of the bridges? The following background information should help the reader understand the complexity of the situation.

Background

Imagine a road system of approximately 3,000 miles that supports the recreational activities of a large urban population (Seattle) and an annual timber harvest of 319 MMBF. Also, consider that the roads on this system lie on the west face of the Cascade Range between Mt. Rainier and the Canadian border, have side slopes typically ranging from 30 to 100 percent, and receive an annual rainfall of 70 to 150 inches. This road system also includes 260 bridges and more culverts than one might guess. Now, imagine the impact on the system if the annual timber harvest suddenly decreases to 12 MMBF (yes, 12, not a misprint).

This situation actually has occurred on the Mt. Baker–Snoqualmie National Forest (MBS) during the last several years. A road system, currently valued at $430 million, constructed principally by and for the timber program, was left without a primary user; but more important, it was left without a primary maintainer. In addition, through purchaser credit and capital investment funding, the roads were receiving various degrees of reconstruction on a cycle of once every 30 years; thus, their economic life was being restored on schedule.

Much of the need for traffic-generated maintenance disappeared with the reduction in timber haul. Unfortunately, the severe environmental conditions under which this system must survive requires extensive and continual maintenance, even without traffic. Available funding from appropriations is well below the amount needed to maintain the current mileage.

Furthermore, maintenance is defined as the work necessary to keep a facility operating through its service life. Bridges, culverts, and other structures will eventually require replacement or rehabilitation. Anticipated future funding for reconstruction will be minor in comparison to need.

Because this situation is prevalent, to varying degrees, throughout the Northwest, all national forests in Region 6 are evaluating their current access needs against available funding pursuant to a program titled "Resizing the Road System."

Resizing and ATM Planning

During the past couple of years, and with considerable public input, the MBS has completed a revised Access and Travel Management (ATM) Plan. Through various means (road decommissioning, land exchange, abandoning easements, etc.), the system has been reduced to about 2,700 miles, with 230 bridges. The ATM Plan identified an additional 580 miles of unneeded road. A risk analysis is under way to compare the potential for failure on these roads with a limited amount of watershed restoration funding. Various treatments will be considered, ranging from full decommissioning to natural closure (allowing the roads to revegetate naturally, with no work done).

It is, however, a race with time. Roadside brush grows rapidly, limiting access for maintenance equipment and disrupting road drainage. Typically, after 4 to 7 years of unattended growth, access is difficult or impossible. The contract cost for brush removal has increased steadily, last year reaching $500 per mile. It is now apparent that considerably more miles will close than originally planned.

Bridge Plan: An Extension of ATM

The ATM process incorporated the usual factors to define the objectives for each road: recreational opportunities, timber, fire, administration, wildlife concerns, history of failures, cost of maintenance, and the presence of major culverts and bridges (expensive links in the system). The length of bridges on the MBS ranges from 20 to 300 feet, with average replacement costs of $1,500 per lineal foot per lane. Some have considerable life remaining; others have none. The following questions were posed: Which of the 230 bridges should be maintained for future access?; Which can be justified for relocation, replacement, rehabilitation, or converted for trail use?; Which should be removed or abandoned?

National forests have used different strategies for bridge construction during the past 30 years. Preferences, or perhaps interpretation of the policy on purchaser credit, varied regarding the type of materials used in construction. The MBS used all types, but constructed more temporary bridges (out of untreated wood) than other forests in the Region (at one time there were more than 90). The majority of the remaining 65 temporary bridges are expected to fall below the legal load limit within 10 years and become unsafe for all traffic within 15 years.

The MBS also made extensive use of the modular bridge (Big R and Hamilton EZ) for temporary access; 19 are currently in use. These moveable bridges are a valuable asset and will provide flexibility in resizing the system.

Strategy for 20 Years

Selected data from the bridge and major culvert (BMC) inventory were copied directly into a PC spreadsheet. Headings were modified, and additional columns were added to display a strategy for the next 20 years. An example of the plan is shown in Figure 1.

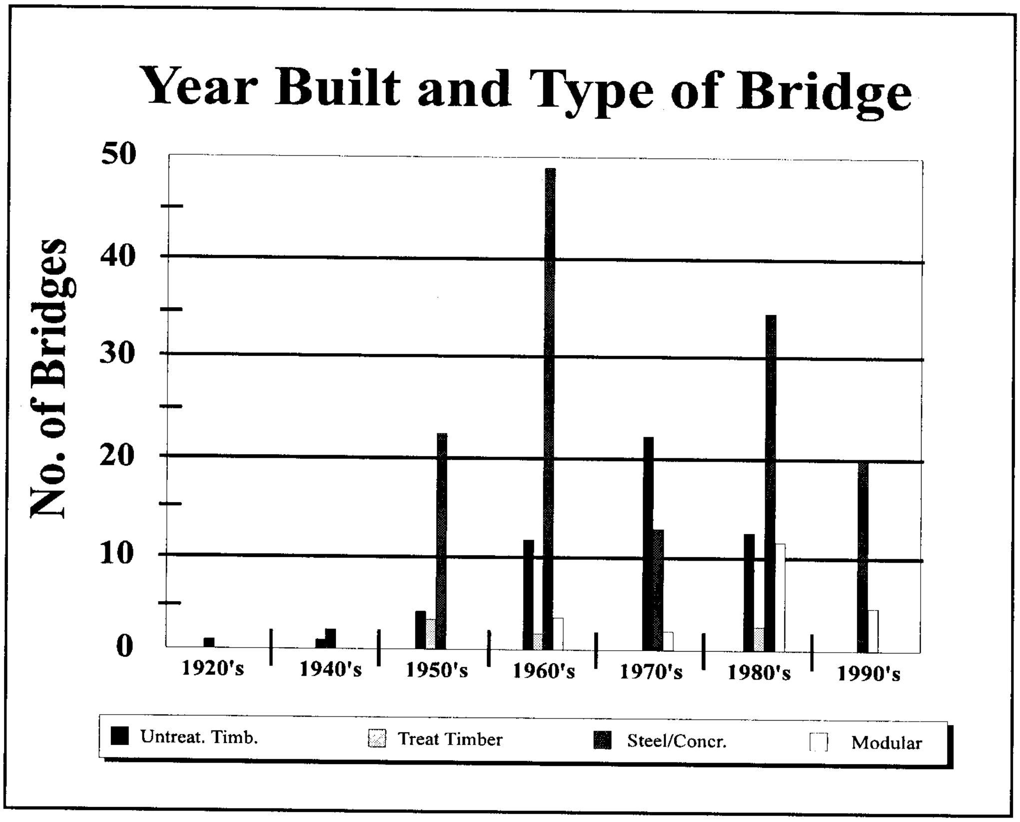
MT. BAKER-SNOQUALMIE NF BRIDGE PROGRAM—1996

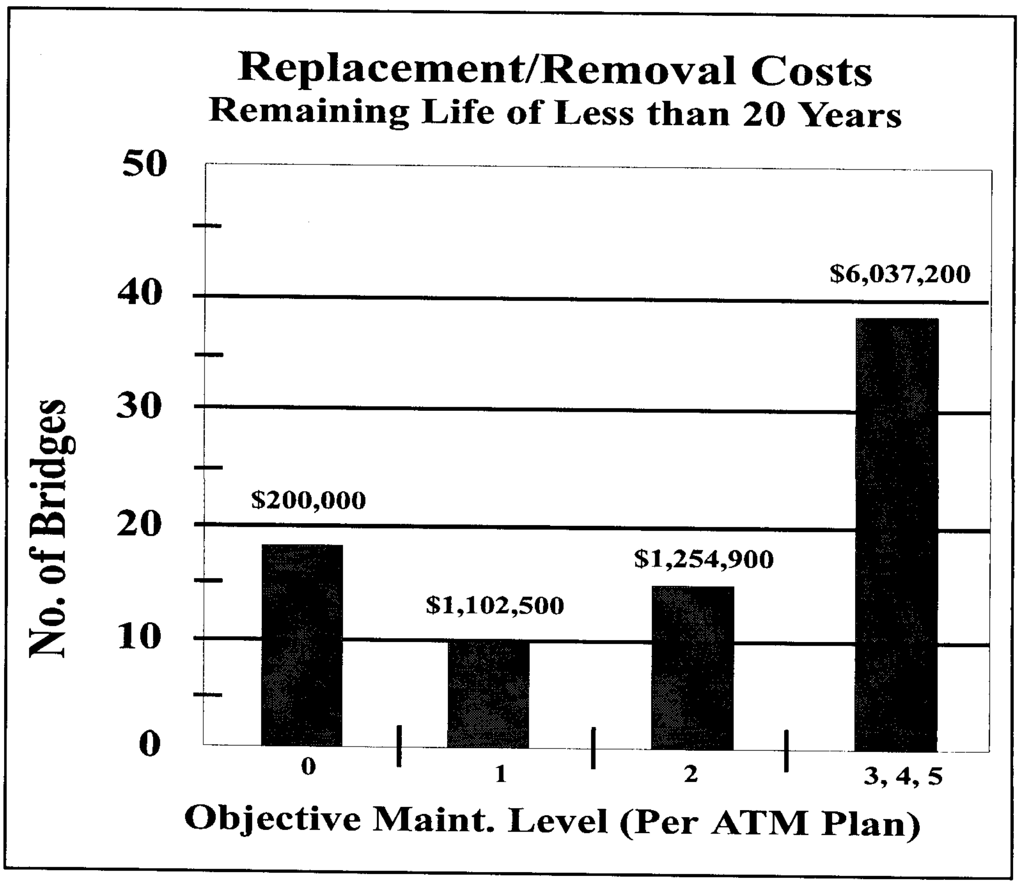
RD	Route Number	MP	Bridge Name	Feature Intersected	Year Built	Rem Life	Mat Typ	Op ML	Obj ML	Len (ft)	Md No.	****DRAFT (3-19-96)**** ← 20 year Strategy → 1996-2000 2001-2005 2006-2010 2011-2015	Reconst M$	Reconst @Yr
01	1064000	0.10	W. Bacon Ck	Bacon Creek	1989	45	14	1	1	160		Legal →	0	
01	1100000	16.80	Little Sandy	Little Sandy Creek	1964	20	21	5	5	82		Legal →	0	
01	1100000	17.80	Boulder Creek	Boulder Creek	1993	48	22	5	5	297		Legal →	0	
01	1100000	20.30	Swift Creek	Swift Creek	1981	35	22	4	5	270		Legal →	0	
01	1100000	20.10	Park Creek	Park Creek	1981	40	22	5	5	103		Legal →	0	
01	1107000	5.30	Anderson Ck	Anderson Ck	1980	5	4	3	3	61		Legal/Post 10T/Replace	92	2000
01	1130000	2.20	Park Creek	Park Creek	1955	10	20	3	3	65		Legal → }Replace	98	2005
01	1130015	0.60	Morovitz Ck	Morovitz Ck	1985	0	4	1	0	70		Remove xxx →	5	1998
01	1200000	2.10	Sulphur #1	Sulphur Cr	1954	9	21	4	4	52		Legal — }Replace	78	2004
01	1200000	3.70	Sulphur #2	Sulphur Cr	1954	9	21	3	3	67		Legal — }Replace	101	2004
01	1200000	4.60	Rocky Cr	Rocky Cr	1959	13	20	3	3	68		Legal — }Replace	102	2009
01	1200000	4.70	Part Time Ck	Part Time Ck	1959	13	20	3	3	21		Legal — }Replace	32	2009
01	1200011	0.10	Scout	Sulphur Ck	1954	3	4	2	0	40		Post 5T-} Remove xxx →	5	1999
01	1260000	0.80	Sisters Bridge	S. Fk Nooksack	1971	25	20	2	1	140		Legal →		
01	1400000	6.80	Jackman Creek	Jackman Creek	1985	40	23	3	2	71		Legal →		
01	1550000	0.80	Irene	Cascade River	1965	20	20	3	3	180		Legal — }Replace	270	2015
01	1570000	1.70	Found Creek	Cascade River	1978	25	22	3	3	163		Legal →		
01	1570000	2.80	Vee Creek	Vee Creek	1986	10	4	1	0	73		Legal/Post 5T/Remove xxx →	5	2005
01	1571000	1.00	Sonny Boy Ck	Sonny Boy Ck	1966	NA	NA	1	0	0		Bridge washed out–don't replace		
01	1571000	0.50	Kindy Creek	Kindey Creek	1960	0	4	1	0	66		Remove xxx →	5	1996
01	1600000	19.20	Illabot Creek	Illabot Creek	1968	20	20	3	3	105		Legal →		
01	1600000	20.50	Otter Creek	Otter Creek	1993	40	14	2	0	80	M3	Close/Move Modular #3 to Rd 1700000	15	1999
01	1700000	8.10	Gee Creek	Gee Creek	1956	10	20	4	4	115		Legal/Post 10T/Replace	173	2005
01	1700000	11.40	Finney II	Finney Creek	1957	10	20	4	4	52		Legal/Post 10T/Replace	78	2005
01	1715000	0.30	Finney Creek	Finney Creek	1987	10	4	2	2	47		Legal/Post 5T/Replace ?(AMA–timber only)	71	2005
01	1715000	0.80	Clendenen Ck	Clendenen Ck	1983	10	4	2	2	60		Legal/Post 5T/Replace ?(AMA–timber only)	90	2005
01	1890000	1.80	Swede Ck	Swede Ck	1990	40	14	2	2	60	M10	Move Mod #10 to ?? /Replace ? (AMA–timber only)	90	2000

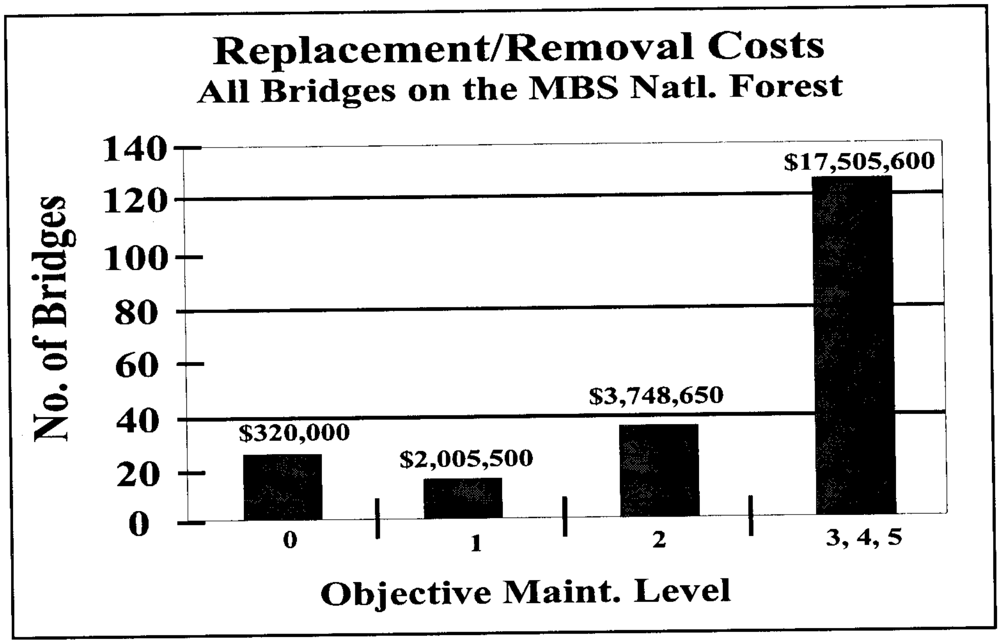
Note: Ml. = Maintenance levels. Op. = Operational Obj. = Objective (per ATM Plan) Unneeded = 0; Closed/storage = 1; High Clearance = 2; Passenger Car = 3, 4, 5

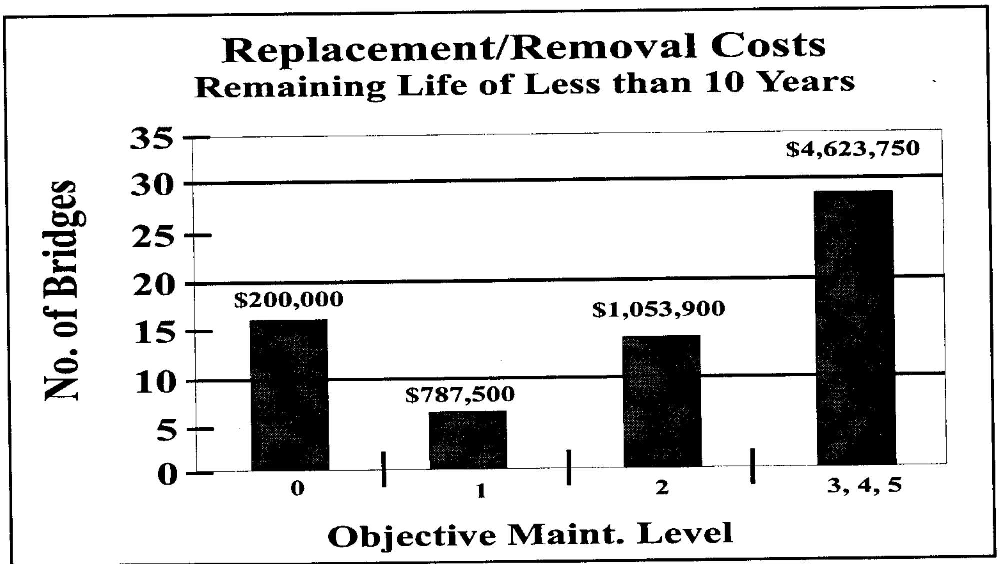
Figure 1-Sample Page from the Bridge Management Plan (Page 1 of 9)

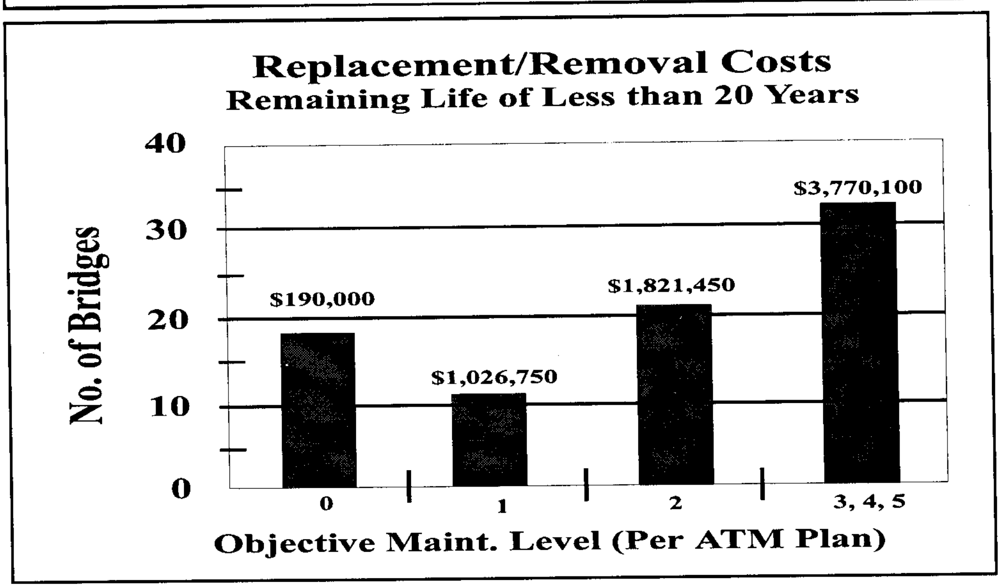
Figure 1


Year Built and Type of Bridge
No. of Bridges
50
40
30
20
10
0
1920's
1940's
1950's
1960's
1970's
1980's
1990's
Untreat. Timb.
Treat Timber
Steel/Concr.
Modular


Replacement/Removal Costs
Remaining Life of Less than 20 Years
No. of Bridges
50
40
30
20
10
0
$200,000
$1,102,500
$1,254,900
$6,037,200
0
1
2
3, 4, 5
Objective Maint. Level (Per ATM Plan)


Replacement/Removal Costs
All Bridges on the MBS Natl. Forest
No. of Bridges
140
120
100
80
60
40
20
0
$320,000
$2,005,500
$3,748,650
$17,505,600
0
1
2
3, 4, 5
Objective Maint. Level


Replacement/Removal Costs
Remaining Life of Less than 10 Years
No. of Bridges
35
30
25
20
15
10
5
0
$200,000
$787,500
$1,053,900
$4,623,750
0
1
2
3, 4, 5
Objective Maint. Level


Replacement/Removal Costs
Remaining Life of Less than 20 Years
No. of Bridges
40
30
20
10
0
$190,000
$1,026,750
$1,821,450
$3,770,100
0
1
2
3, 4, 5
Objective Maint. Level (Per ATM Plan)

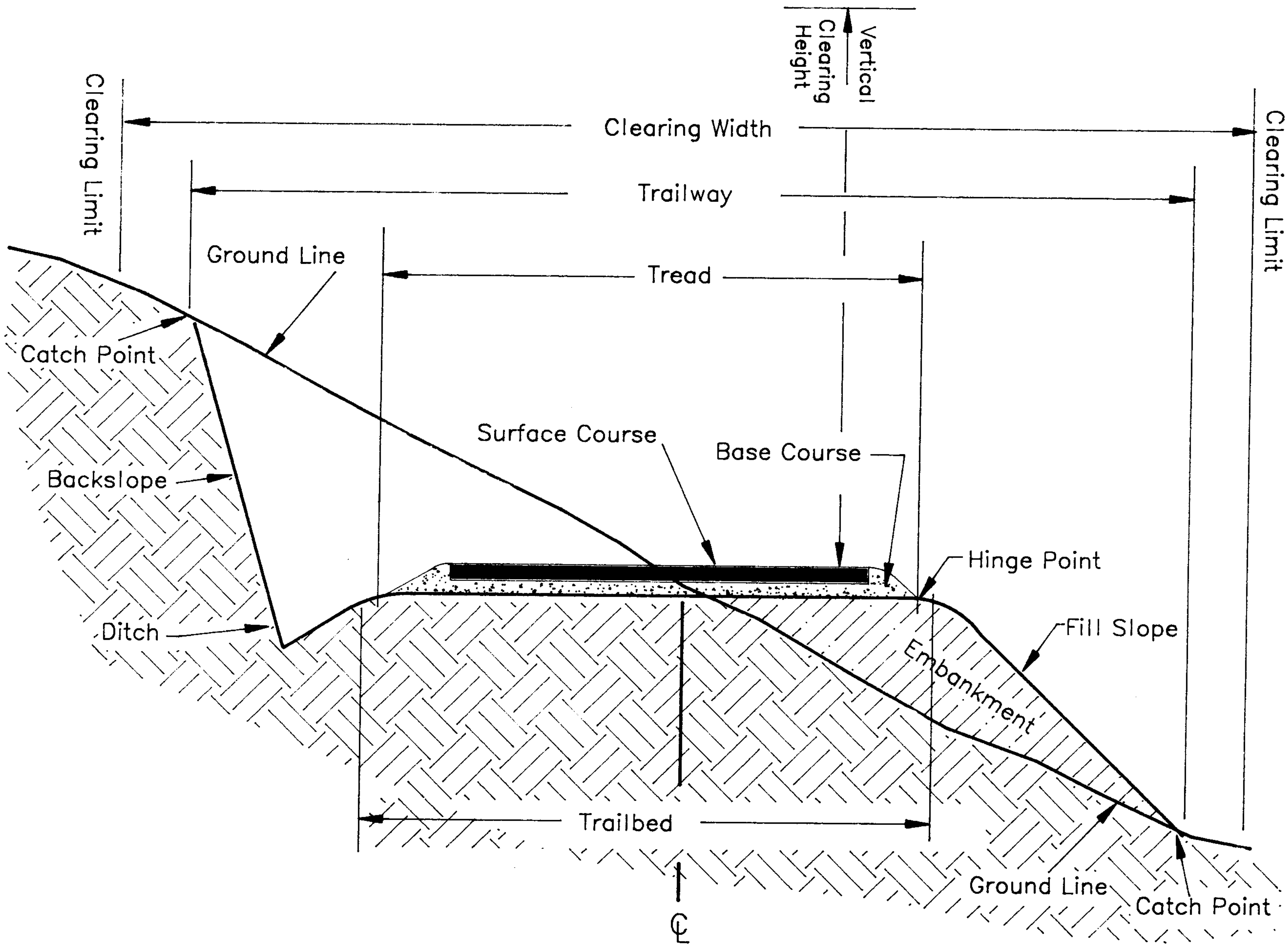
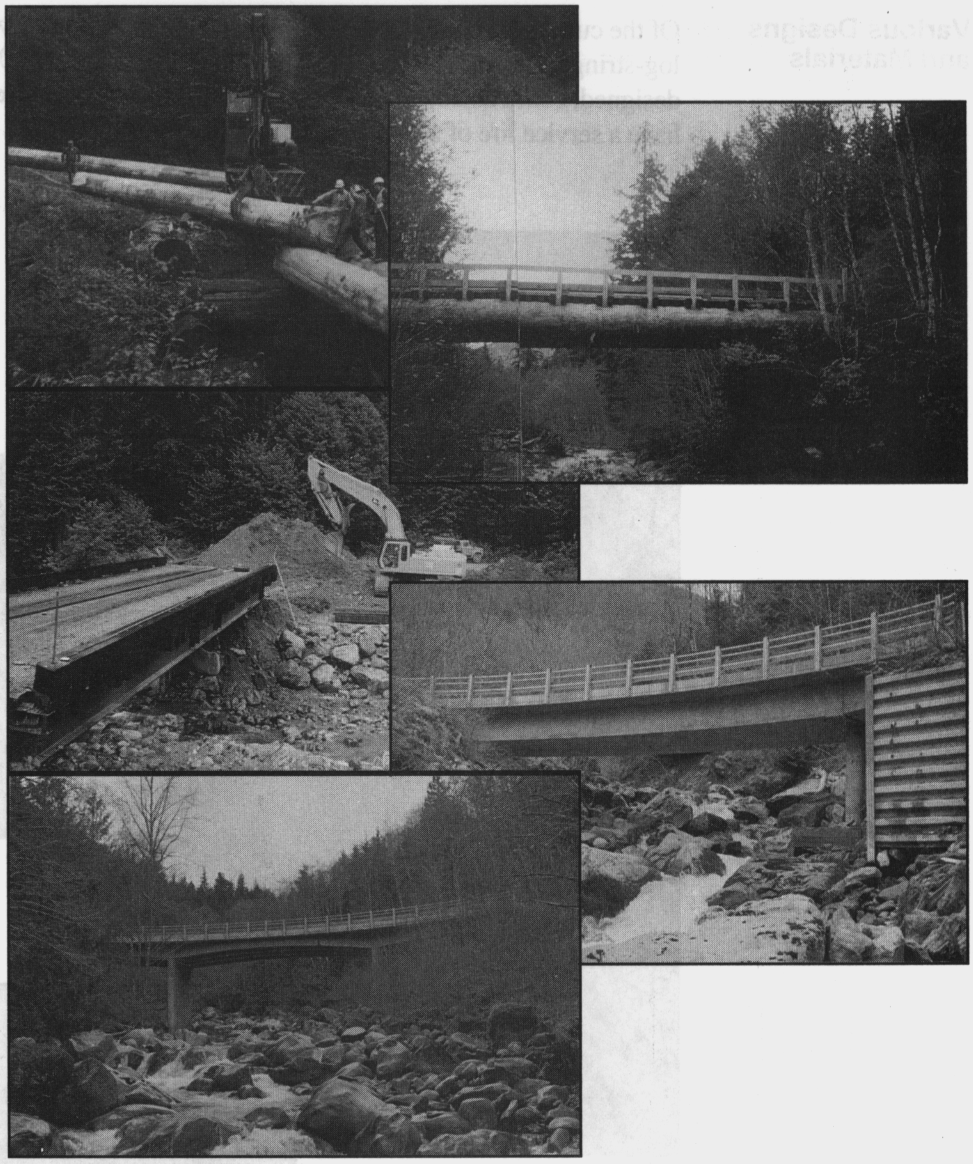


Figure I — Illustration of Trail Structure Terms (4–96)

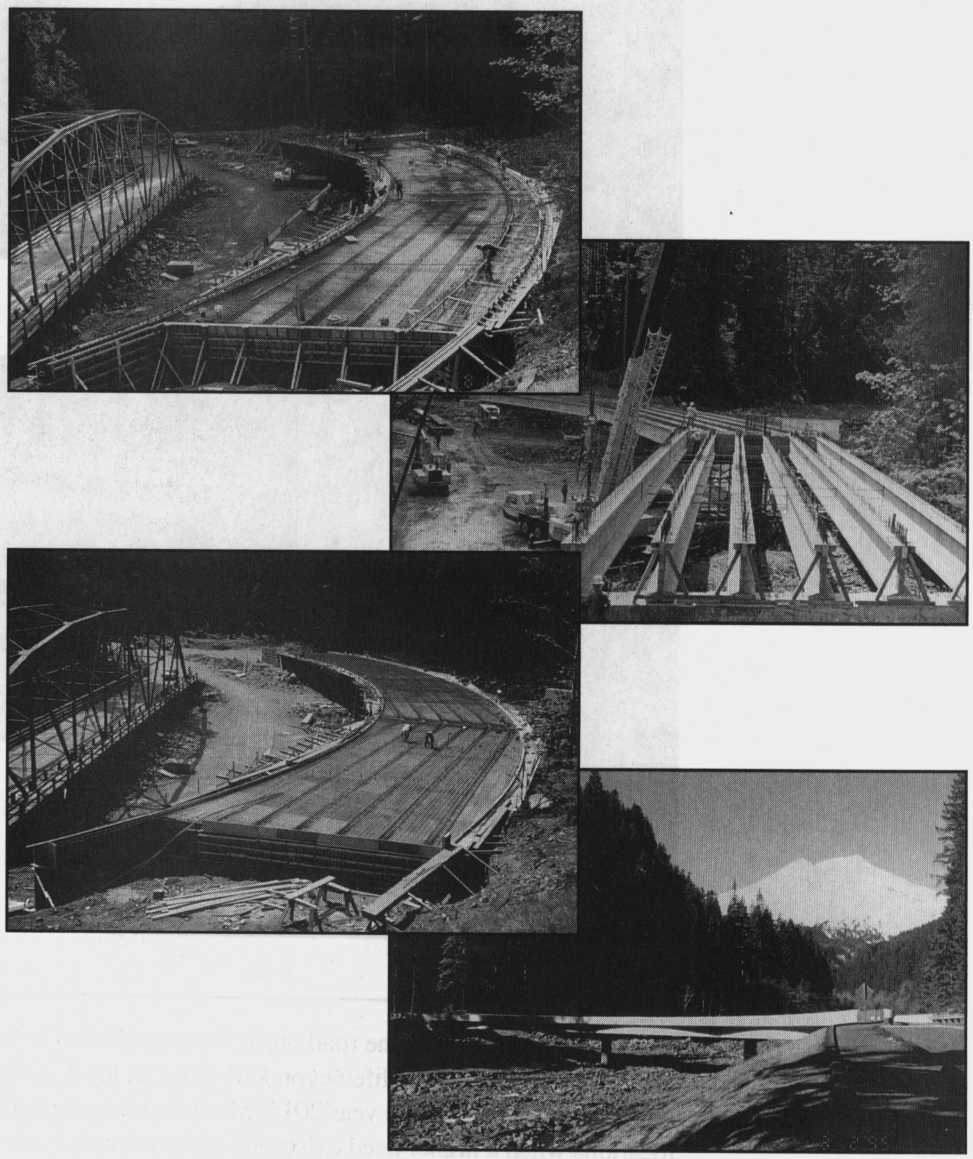


The strategy is based on the road objectives established in the ATM Plan. Note that bridges with an expected life beyond 20 years (at legal load or higher) are shown with an arrow through the year 2015. Modular bridges are moved to different locations when a higher need exists and when relocation cost can be justified. Some bridges will be removed or converted for trail use, and some will be posted at lower load limits for periods of time (limited use for recreational and administrative access).

It is probable that the funding for bridge replacements or rehabilitation will be less than the amount identified in this plan. Also, as watershed analyses are completed, changes may occur in road objectives. The plan will remain dynamic. This is the beginning. It took more than 60 years to create the road system, and it will take several more to reach the right size for the future.

Various Designs and Materials

Of the current inventory of 230 bridges, 65 are of untreated wood constructed in a log-stringer design, and near the end of their useful life of 10 to 20 years. Well-designed, constructed, and maintained concrete and steel bridges are expected to have a service life of 50 years or longer.

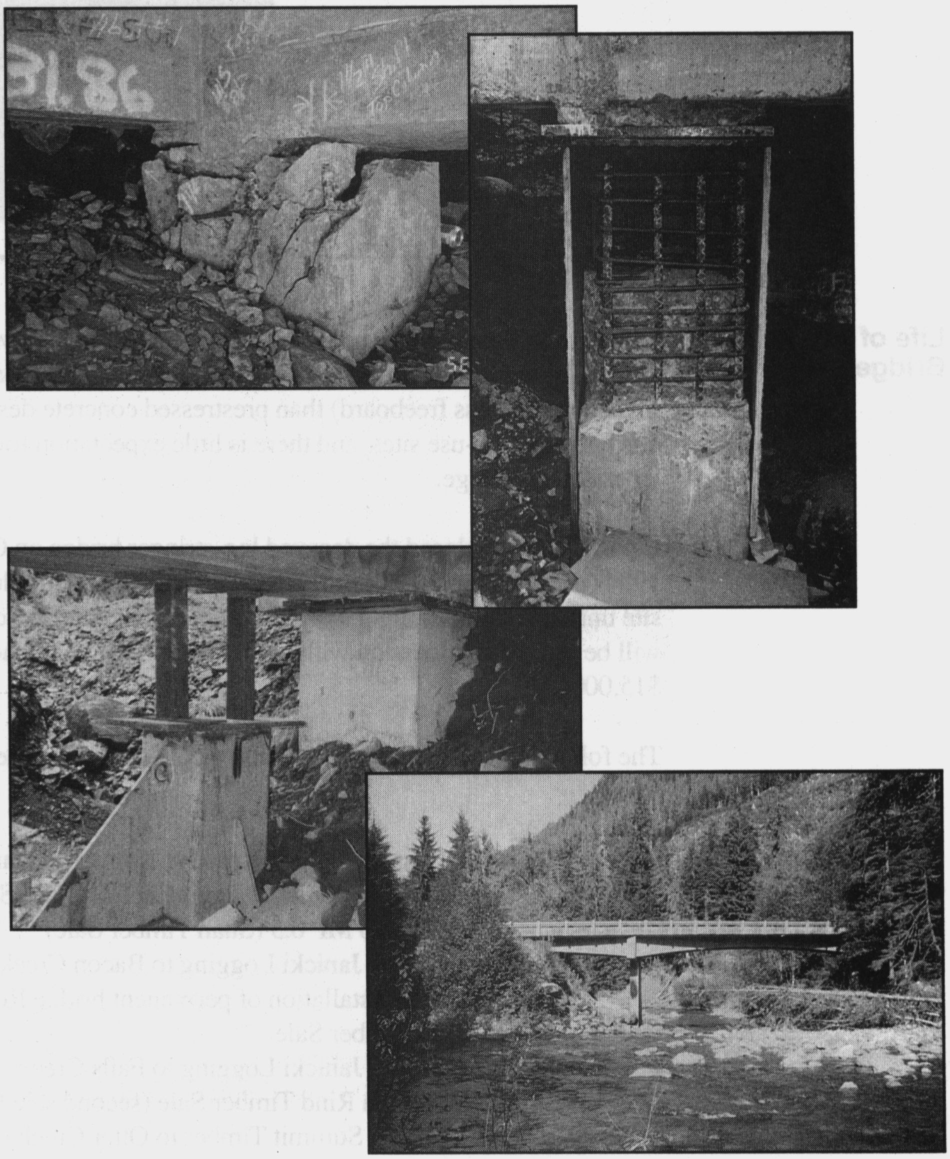


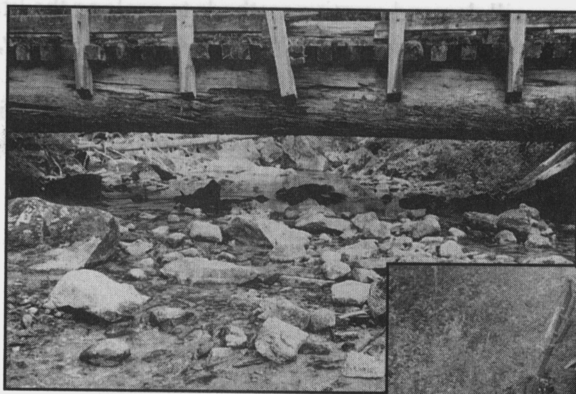
Replacements

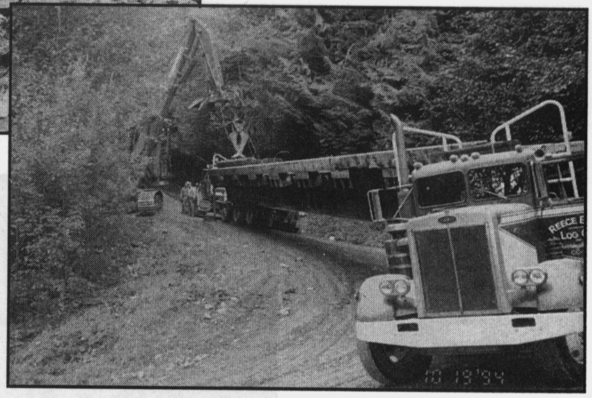
The Baker Lake Highway (Forest Road 11) crossing at Boulder Creek. The one-lane, steel-truss bridge, built in 1933, was replaced with a two-lane concrete bridge in 1993. (RO CIP $1.13 million).

Rehabilitation

The future will demand creative methods to prolong the life of bridges. The South Fork Canyon Creek Bridge (Rd. 16 MP 8.4), shown below, was constructed in 1959. During the past 10 years, a large-scale earth movement on one side of the creek had sheared the abutment columns on one end and was beginning to damage the two piers and the other abutment. With the assistance of the Regional Office Bridge Section, the forest constructed a repair in 1994 that allows movement and can be adjusted to support legal load.







Life of a Modular Bridge

Modular Bridges are designed to facilitate movement between different locations. Normally, they are not used as permanent installations because of the higher cost and greater depth (less freeboard) than prestressed concrete designs. Some, however, are currently at high-use sites, and there is little expectation for acquiring the funding for a permanent bridge.

EZ Bridge #3 replaced the decayed log-stringer bridge on Otter Creek (Rd. 16) in 1994 (photos above). According to the ATM Plan, the modular will remain at this site until decommissioning work is completed beyond the crossing, at which time it will be moved to a location with higher need. Typical reloaction costs average about $15,000.

The following is the history of Hamilton EZ Bridge #3, one of 19 modulars on the forest:

- 1982—Purchased new and stored at Koma Kulshan Guard Station
- 1983—Installed by Janicki Logging at East Fork Shannon Creek on Rd. 1152–100 MP 0.5 (Shan Timber Sale)
- 1988—Moved by Janicki Logging to Bacon Creek for temporary crossing during installation of permanent bridge Rd. 1064 MP 0.1 for Bacon Rind Timber Sale
- 1988—Moved by Janicki Logging to Falls Creek on Rd. 1065–020 MP 0.1 for Bacon Rind Timber Sale (second sale location)
- 1994—Moved by Summit Timber to Otter Creek on Illabot Rd. 16 MP 20.7 to replace decayed log-stringer bridge (temporary access)

Integration of Remote Sensing Into Resource Data Collection: Working With Imagery in ARC/INFO

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Abstract

Forest Service users can work with digital imagery using the existing IBM hardware and software. The ARC/INFO provides the means of importing and exporting, georeferencing, displaying, classifying, and analyzing digital imagery. The ARC/INFO commands and functions, and where to find more information about them, are organized under each task as a general reference for ease of use.

Introduction

The Remote Sensing Applications Center, a detached unit of the Washington Office (WO) Engineering Staff, supplies technical support for remote sensing, image processing, and integration of resource data into a Geographic Information System (GIS). This paper is intended to provide support to users of digital imagery on the new IBM platform. There is a rich source of digital imagery from remote sensing available to Forest Service users in the forms of satellite imagery (Landsat Thematic Mapper [TM] and Multispectral Scanner [MSS], and SPOT Panchromatic [Pan] and Multispectral [XS]), digital orthophotoquads (DOQ's), digital camera imagery, and scanned air photos. Many of you may think that the newly purchased IBM hardware/software (from the 615 procurement) is just for GIS and office automation. While these are the primary intended uses, you may be pleased to discover that through ARC/INFO's GRID module, a variety of image-processing functions can also be used, ranging from image display and enhancement to image classification procedures. What follows is a guide to some of the commands and functions in GRID and other ARC/INFO modules that will allow you to work with digital imagery.

Though ARC/INFO's GRID module is not intended to be an image-processing package, it does have enough functionality to perform basic image manipulation. The major areas of functionality that will be addressed are Importing/Exporting image formats, Georeferencing, Image Display, Image Classification, Filtering, and 3-D perspectives. More information about all of the topics and specific syntax for a command can be found in the on-line ARC/INFO documentation by typing 'help' from any ARC/INFO prompt or 'arcdoc' at the UNIX prompt. Either command will bring up a list of topics such as *Cell-based Modeling with GRID* and *Image Integration.*

When a command is referenced for the first time, it will be highlighted, followed in parentheses by the ARC/INFO module it is run from (i.e., **projectdefine** [ARC]). Some commands may exist as both an ARC command and a GRID command. In many cases, the command functions the same in both modules.

If you don't have a digital image, you may want to work with the sample data set already on your IBM system. If installed by your system administrator, this data set can be found in the following directory:

$SAMPLESHOME/tutorial/data (contains various image types including: TIFF, ERDAS .lan, .bil, and SunRasterfiles)

Please make a copy of the data you are interested in experimenting with in your own directory and leave the original intact.

Importing and Exporting from Various Image Formats

When using imagery in ARC/INFO for anything other than display purposes, it is necessary first to convert the image to a "grid" format. Several types of digital imagery can be imported as grids using **imagegrid** (ARC). These images can be in raw transfer formats such as band interleaved by line (.bil), band interleaved by pixel (.bip), or band sequential (.bsq). These types of files require that a header file be created before they are imported. Refer to the on-line topic *Image Integration* for more information on how to create the header file. Other image formats that can be imported include ERDAS (.lan and .gis), Imagine (.img files), GRASS, run length compressed (.rlc), SunRasterfiles, ARC Digitized Raster Graphics (ADRG), and TIFF. These formats typically have the header information included in the image file itself and are imported into a grid format without any special preparations. When importing images, any extensions mentioned above in parentheses should be part of the import file's name. If not, rename the file with the appropriate extension. GRASS and ADRG files are expected to follow their respective naming conventions. A single-band image such as a DOQ, DEM, or SPOT Pan will import as a single grid. A multiband image such as Landsat TM, MSS, or SPOT XS will import as a grid stack, with each band corresponding to a layer in the stack.

Each of the formats above (except ADRG) can also be exported from ARC/INFO using the command **gridimage** (ARC). The ERDAS option will export either a Revision 7.4 .gis file if the input grid was a single-band image or .lan file if the input grid was a multiband image. The GRASS option exports a 4.0 cell map. Refer to the on-line topic *Image Integration* for more details on importing and exporting image data.

Georeferencing

Both georeferenced and nongeoreferenced images can be converted to grids. A georeferenced image will have established the relationship between the image (row, column) coordinate system and some map coordinate system such as UTM or State Plane. A nongeoreferenced image will need to have that relationship established before other coverages will overlay on it and other images will interact with it properly. The ARC/INFO provides many tools such as **controlpoints** (ARC), **griddeskew** (ARC), **rectify** (ARC), **register** (ARC), **adjust** (GRID), **llsfit** (GRID), **project** (GRID), **resample** (GRID), and **warp** (GRID) to assist in this task. Using these commands, complete georeferencing of an image can be accomplished.

If the imported image is georeferenced, this information will be extracted from the header file. **Projectdefine** (ARC) may need to be run after importing an image to finish the georeferencing process. This can be checked by using **describe** (ARC or GRID) to see if all the georeferencing information is present. If the message "NO COORDINATE SYSTEM DEFINED" is seen in the describe output, then projectdefine does need to be run. The typical inputs needed are projection, zone, datum, and units.

Other related things you can do with a grid or multiple grids include flipping, mirroring, rotating, shifting, edgematching, mosaicing, clipping, and boundary simplification. The commands to perform these actions are: **flip** (GRID), **mirror** (GRID), **rotate** (GRID), **shift** (GRID); edgematching uses **controlpoints** and **adjust**, **merge** (GRID) and **mosaic** (GRID); clipping uses **setwindow** (GRID) and **boundaryclean** (GRID). Refer to the on-line topics *Image Integration* and *Cell-based Modeling with GRID* for more details on georeferencing images.

Image Display

An image can be displayed in GRID, ARCEDIT, or ARCPLOT, and the commands listed in this section work in all three modules unless otherwise indicated. After starting one of the modules above, set the display device using **display 9999** and the map extent using **mapextent** <gridname>. The grid can be displayed using **image**, **gridcomposite**, **gridpaint**, and **gridshades**. When given the option, apply the linear stretch for initial viewing (this is the default stretch). In GRID, custom stretches can be applied to the image display using a remap table. **Buildsta** (GRID) is used to calculate statistics on an individual grid. **Histogram** (GRID) can be used to view the distribution of values in a grid, and **scattergram** (GRID) can be used to view the distribution of value between two grids. The **remapgrid** (GRID) command opens a menu-based tool for creating and testing alternative contrast stretches on a grid. The command acts on only one grid or grid stack layer at a time. The remap table does not affect the existing data in the grid. **Slice** (GRID) and **reclass** (GRID) can also be used with a remap table to create a new grid whose values are actually changed to reflect the remap table.

Statistics for each of the grid stack layers are built using **stackstats** (GRID). This command will generate an ASCII output file if a filename is provided. The statistics file contains a minimum, maximum, mean, and standard deviation for each layer. If the detail option is specified, a covariance and correlation matrix between all layers is also calculated. The distribution of values within each layer can be graphically viewed with either of the following commands: **stackhistogram** (GRID) or **stackscattergram** (GRID). Refer to the on-line topics *Image Integration* and *Cell-based Modeling with GRID* for more details on displaying images.

Image Classification

Image-processing capabilities are available through the use of GRID multivariate analysis routines. Cluster analysis, classification, and principal components analysis (PCA) all work on grid stacks. All grids in the stack must be in the same projection. They should overlap but do not need to overlay precisely. Cell (pixel) sizes do not need to be the same, but any output will default to the cell size of the coarsest layer in the stack.

The procedure for conducting supervised and unsupervised classification on imagery is outlined in the on-line *Cell-based Modeling with GRID* (pp. 42-44). The GRID commands used in these processes include: **classsample**, **classprob**, **classsig**,

drawsig, editsig, isocluster, mlclassify, samplesig, setmask, and **shadegrid**. For example, a typical supervised classification would begin with delineating and evaluating training sites using classsample, an interactive menu-based tool. Classsig creates a signature file from the training sites. Isocluster is the routine that develops a signature file of spectral classes for an unsupervised classification. Signatures developed for a classification, whether supervised or unsupervised, can be viewed and analyzed using **drawsig** (GRID), and **dendrogram** (GRID) as well as stackscattergram and stackhistogram. Editsig creates a modified signature file that can be used to reduce or eliminate classes from the original signature file. The signature file can be used with either mlclassify or classprob. Mlclassify produces a maximum likelihood classification. Classprob produces a stack of probability layers, one for each class represented in the signature file, showing the probability that a single pixel belongs to a certain class. Shadegrid is an interactive tool that can be used to assign a color to a particular class. Refer to the on-line topic *Cell-based Modeling with GRID* for more details on classifying images.

Neighborhood Analysis

Post-processing of a classified image often involves the use of neighborhood analysis routines such as filtering. Filtering techniques are often used to smooth the salt-and-pepper appearance of a classified image and create a more map-like product. In GRID, neighborhood analysis routines are divided into four types of functions: focal, local, zonal, and block. The focal functions act most like the "moving window" neighborhood (filtering) functions commonly found in image-processing packages. The local, zonal, and block functions are used more in GIS analysis after the image processing tasks are completed. Refer to the on-line topic *Cell-based Modeling with GRID* for more details on local, zonal, and block functions. Many of these neighborhood analysis functions can be used to perform image to image change detection.

Focal functions act on a neighborhood of cells surrounding a single pixel on the input grid. The output grid reflects the action of the neighborhood function on the pixel. These functions all begin with the word 'focal.' For example, the **focalmax** (GRID) function examines the neighborhood of cells around a single pixel on an input grid and outputs the maximum value found in the neighborhood as that pixel's value on the output grid. The function then moves on to the next pixel in the grid until all pixels and their neighborhoods have been processed. The shape and size of the neighborhood are specified on the command line. Refer to the on-line topic *Cell-based Modeling with GRID* for more details on neighborhood analysis.

3-D Surface Views

One additional way of using imagery in ARC/INFO is to create a three-dimensional view of an area by "draping" an image over a digital elevation model (DEM). Three-dimensional views can be developed using a variety of triangulated irregular network (TIN) commands that begin with the word 'surface' in ARCPLOT. For example, by default the **surfacedrape** (ARCPLOT) generates a fishnet (wire-frame) model of the DEM. If an image or GIS coverage is specified on the command line, the contents of that file are draped over the fishnet model of the DEM, creating a 3-D perspective. Refer to the on-line topic *Surface Modeling with TIN* for more details on terrain and surface analysis.

Conclusions

Many types of analyses can be performed on images using ARC/INFO. The GRID module offers a set of basic tools to use in image processing. Basic functions such as image display are straightforward and can be used for countless tasks such as overlaying and updating existing GIS coverages. Other image-processing functions such as supervised and unsupervised classification allow users familiar with such functions to create land cover maps and perform change detection. With these basic tools and the abundant imagery available to the Forest Service, you can begin using digital imagery for a variety of purposes, ranging from forest planning and monitoring to forest health protection and fire mapping.

List of On-line Topics and Commands Modules Referenced

ARC Commands
Cell-based Modeling with GRID
GRID Commands
Image Integration
Surface Modeling with TIN

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