Hospitals & Asylums

Sustainable Trails HA-6-4-22

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Trail Names: Rainbow, Rainbow-walker, Rabbit, Cracker

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1. Safety

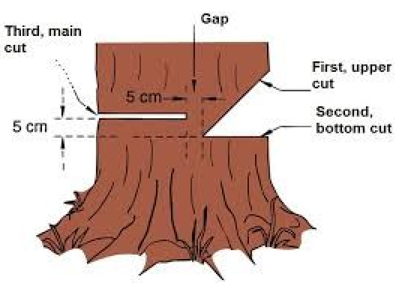
This is the first publication of this work on trails that is not expected to completed until hiking the Triple Crown, the Appalachian, Continental Divide and Pacific Crest Trails, two years from now, mostly for the purpose of thoroughly prohibiting prescribed burns and park narcs nation-wide. Trails minimize the dangers of the wilderness to the point where the forest is theoretically safer than the trials of civilization Trails make walking in the forest less dangerous and injurious; trails get a hiker to their destination, where they can resupply, in a timely fashion, unless they get lost or severely injured. Modern GPS is a dramatic improvement over the uncertainty of the map and compass. Long distance trails have become a safer alternative to rent than urban homelessness, even where forest-urban interface camping is legal and dignified. A high level of physical fitness is needed to hike enough miles everyday to get back to civilization before the food runs out. Traditionally, the Ranger physical fitness test is hike 14 miles with a 65 pound pack in seven hours. At two miles an hour, plus one hour for every thousand feet of elevation gain, not to mention rocky, brushy or otherwise treacherous terrain, it is not always possible for a soldier to hike 14 miles in seven hours. The hiking day, however, begins at dawn and ends at dusk, and modern headlamps work quite well for walking on moderately tricky trails at night. Steep uphill climbs and other unusually strenuous hikes often take some conditioning to walk all day and one may never achieve 20 miles a day, in more difficult terrain, especially during the short days of winter. Most long distance hikers aim to walk 20 miles a day or more. It helps, that backpacking outfits keep getting lighter, most weighing between 25 and 35 pounds, with food, although they weigh at least 50 pounds without extensive market research. Hiker ethics are mostly guided by the Seven Leave No Trace Principles. Although the details are open to elaboration, as the trail goes on, the seven principles have been well established. 1. Plan ahead and prepare. 2. Travel and camp on durable surfaces. 3. Dispose of waste properly. 4. Leave what you find. 5. Minimize campfire impacts. 6. Respect wildlife and 7. Be considerate of others.

The most common injuries faced by hikers are blisters, stubbed toes, shin splints, knee aches, hip and back pain, diarrhea from untreated water, insect, spider and snake bites, especially the chance of Lyme disease and Rocky Mountain Spotted Fever from tick bites, both treated with doxycycline. The chances of injury can be greatly reduced by buying appropriate, quality, outdoor gear and gradually condition oneself to the number of miles, weight of backpack and level of difficulty of the walking. Running with a hiking backpack is certain to cause shin splints, unless done in proper form with a straight back and bent knees, don't fully extend the leg, for short distances, without over-doing it. Blisters can be avoided with sock that are indicated for blister resistance. Shoes should not be tight, to prevent the foot from being crushed. Most hikers wear trail running shoes, with micro-spikes in high-elevation snow. Boots are reserved for forestry workers, bush-wackers and winter campers. Most long-distance hikers use trekking poles, although the fastest hikers don't use them; poles help with balance, treacherous terrain and the prevention and treatment of injury. Good water filters are necessary to prevent infectious, toxic, and particulate caused diarrheal diseases. Boiling does not remove particulate matter that causes non-infectious diarrhea. Sawyer and Be Free water filters are both excellent ways to prevent the 'morning mush', non-life threatening, but chronic, anxiety producing, daily morning diarrhea, in lieu of a healthy stool. A properly rated sleeping bag, a sleeping mat and waterproof and insect proof tent are essential. A small backpacking stove, fuel and cooking kit are essential. Jetboil boils water in about a minute, and is highly fuel efficient, but cannot be used for other purposes. An alternative to the fossil fuel alternative to messy and difficult to light campfires, is sought. An odor proof bag is minimally needed to prevent food loss from a bear encounter. Bear canisters have the advantage of being rat-proof, but can be broken into by a bear in about three minutes, according to a scientific study with a captive bear. Hanging food from a rope is just about the worst thing to do, bears climb trees much better than humans, they can see the low hanging fruit from miles away, it is like waving a flag that says we have food, they can sever ropes with their claws and use their teeth to get through the new PCT dangling rope method. Securely fastened metal cables and bear boxes are effective, however bear boxes can be infested with mice and rats. The most reliable method, approved by a mother bear who had previously scored several shipments of food, is to keep the food in an oder proof bag and watch your "cub or die" (source of the word cupboard). When she came upon me cooking dinner she could not stop advancing although the thought of robbery obviously disturbed the thief, until I took the pot of food off the fire and zipped it up in my food bag, whereupon she went to play with her cub, who climbed a tree in search of their main, natural source of winter calories, whole pine cones. I have not lost anything to bears since, except my liberty from bear phobic regulations in the national parks.

Bears and human campers are united against the common enemy of habitat loss due to the senseless terrorist crimes of arson and prescribed burning. There has been a dramatic increase in wildfires attributed to climate change, but when scientists are tempted with the topic of prescribed burning as a method of wildfire suppression, they invariably initially think it's a good idea, before it is necessary to prove prescribed burns are one of two unscientific crimes of terrorism, burning wilderness, and then they probably do it all over agains, because it is a job they could do while out of work due to meth exposure by the American legal system. The fire problem has two components described as negligent management of debris and ignition under 36CFR§261.5. In the eastern United States both of these components are combined in same day prescribed burning programs. They come in with flamethrowers, burn undesirable flammable vegetation and usually have it extinguished by the end of the day, when they don't get out of control. In areas, like Florida, where the prescribed burners are the descendants of clear-cutters, who once did replant southern long-leaf pine forests, the controlled burns are quite popular. However, in North Carolina, where there is a high level of eco-tourism, only about a quarter acre of a 10,000 acre prescription were fulfilled and the arson had to burn the trail and forst across from the town hall. On the west coast, there is a major wildfire problem, and the season is getting longer, beginning in June, instead of August, and running into the wind fire in October and November when certain select cities are burned to the ground. The different prescribed burning practice in the West is that they slash and pile and leave the piles to dry for two years, by which time the forest and nearby cities have been burned by wildfire. The National Forests in the West must be fined for the destruction of standing slash piles by fire, chipping or scattering. Prescribed burns must be prohibited and the rural public land workforce redirected to trail construction and maintenance and revegetation with native species. The secret ingredient to the wildfires seems to be fairly uniform throughout the United States- identity theft by National Park law enforcement is accidentally or intentionally aggravated to arson by the interception of the FBI, who either light the fires themselves or intoxicate their specially selected criminals or prescribed burners under investigation. On the West Coast, wherever a Ranger had issued one of those easily contested and much hated camping tickets, the court responded by constructing a pretend "stick hut" filled with flammable debris, litter and then urinated and defecated on the litter, that the public had to remove. There are two necessary solutions to this police interference by the legal system and mostly the FBI. One the FBI must be removed from National Park and National Forest cases and the integrity of their communication must be reassured. Two the National Park and National Forest law enforcement are especially enjoined to require a Bachelor degree to prevent recidivism regarding partnership in crime 100 percent of the time, to save their forests from this arson conspiracy under 18USC§81 and Art. 81 of the Uniform Code of Military Justice 10USC§881.

For working on trails, cut- resistant or leather nonskid boots, at least 200 millimeters (8 inches) high, offer the best support and ankle protection. They are required by the Forest Service if you are using cutting, chopping, or digging tools. Steel-toed boots are a good choice when working with rock. Ankle-high hiking boots are okay for some trail work. Sneakers or tennis shoes do not give enough support and protection. Be aware of regional differences. In southeastern Alaska, for example, rubber boots are the norm for most trail work. Hardhats are an agency requirement for many types of trail work, especially when swinging tools, working under the canopy of trees, or when there is any chance of being hit on the head 29CFR§135 and §132. Other safety gear includes eye protection for any type of cutting or rock work, hearing protection near power equipment (85 dB or louder), and dust masks for some types of rock work and in extremely dusty conditions. The Forest Service requires workers required to use a respirator have a medical exam. Don't start the job unless properly equipped. Forest Service Health and Safety Code Handbook (FSH 6709.11) provides some good information that could save your life. The adoption of special safety clothing, hardhats, and other paraphernalia has only slightly reduced the hazards. Hidden internal defect including invisible root and butt rots that allow a tree to break without warning at any time during felling, dead or damaged branches or "widow makers" that can fall at any time, the effects of wind gusts in partially opened stands hitting and snapping off trees that previously have been shielded from the force of the wind by surrounding trees, just felled, create hazards that no amount of personal safety equipment will ever eliminate. Heavy equipment is now available where the operator sits in an enclosed armored cab while the tree is grasped by the machine, severed at the base, and tipped back to be hauled away. Such heavy equipment also renders block clearcutting the only feasible harvesting method, with all of the attendant disease problems in the subsequent stand (Merrill '96: 147). Heavy equipment is often not a feasible method of felling trees in mountainous and boggy terrain, where most trail work is done. Felling dangerous trees and snags on trails and camping areas is an important responsibility of trail construction and restoration.

The Game of Logging mantra is “safety, safety, safety”. Since most logging and outdoor deaths, including wildfire fighting, hiking and camping, are the result of blunt traumas from above, loggers should always check for overhead hazards. Falling overhead object is the leading cause of death in the outdoors. The “death zone” is within 12 feet of the stump and statistics show that 85 percent of all logging injuries occur within this zone. The top side of the tip is a danger zone where a chain at working speed will cause the saw to kick back if something comes in contact with this area. When a kickback occurs with the saw-bar outside of the kerf, the reaction is so explosive, it is impossible to control. The chainbrake feature on modern saws is intended to stop a moving chain before it hits the operator, usually in the face or upper body. On the bottom quarter of the bar tip, just after the moving chain leaves the kickback zone, the operator can use chain pull to gradually pivot the saw, plunging it tip first into the stem. Perfecting the plunge cut is the key to safer felling techniques. Harvesters must pay attention to tree lean and any unsafe limbs that might jar loos during the felling process. In an open-face notch, both the top cut and the bottom cut angle into one another. The top and bottom cuts are exactly perpendicular to the expected line of fall. The hinge controls the fall of the tree until it hits the ground. The length of the hinge should be about 80 percent of the tree’s dbh, and the thickness of the hinge is about 10 percent of dbh. Hinge size and shape is crucial to accurate felling. Once a tree begins to fall, control resides in the hinge. Once a tree begins to fall, the logger should be exiting the area via a preplanned escape route, not following the stem by shaping the hinge as the tree falls (McEvoy ’04: 156, 157).



Anywhere within 12 feet of the stump is the death zone. The logger exits the zone as soon as the tree begins to fall. This feat is accomplished. Once the face cut is complete, the logger uses a plunge cut that is even with, and the correct distance behind, the throat of the open-face notch (using the 80/10 rule). If the tree is 30 inches dbh, the plunge cut is 3 inches behind the throat of the notch, leaving a 3-inch hinge. The feller carefully pivots the bottom tip of the working chain into the stem until the entire tip is safely past the kickback zone. The bar is then plunged parallel to the throat of the notch completely through the tree or to the extent of the bar. If stump diameter exceeds bar length, the feller initiates a plunge cut on the other side so that the cuts match. When the plunge cut is complete, the logger cuts horizontally – in the opposite direction of the face cut – toward the back side of the tree, using felling wedges if necessary to prevent the stem from settling on the bar. The plunge cut is completed a few inches from the back side of the tree, leaving two points of connection between the trunk and stump: the hinge, and the release wood. On larger stems, and in situations where the intended falling direction is opposing lean, some of the tree weight is taken up by plastic felling-wedges. The final felling cut is initiated in traditional fashion. The feller severs the last few inches of fiber, the release wood. The tree then falls in the direction the hinge allows while the feller is safely back from the falling tree, well outside the death zone. In species like ash and spruce sapwood that will experience fiber pull in the hinge area it is wise to use wing cuts on either side of the hinge, going no further than the depth of the sapwood. The wing cuts conserve log value in the butt log, the most valuable part of the tree. Kinetic energy, such as springpoles, limbing and bucking, must be dealt with in a controlled fashion. (McEvoy ’04: 155-160).

Logging has always been an extremely hazardous occupation, historically, second only to underground mining, but since the Mining Safety and Health Act of 1977 reduced mining and underground mining deaths, and since 1997 saw a reduction in fishing deaths to rates competitive with agriculture and airline pilots, logging has been the second most dangerous industrial occupation in the United States after commercial fishing. In 2010, the logging industry employed 95,000 workers, and accounted for 70 deaths. This results in a fatality rate of 73.7 deaths per 100,000 workers that year. This rate is over 21 times higher than the overall fatality rate in the US in 2010 (3.4 deaths per 100,000). Loggers comprise one half of one percent of the total workforce in America, yet they account for nearly 2 percent of all fatalities. During 1992-97, loggers suffered, on average, 128 fatalities per 100,000 workers compared to 5 per 100,000 for all occupations. Over the 6-year period, 1 out of every 780 loggers lost his life to a work injury, which translates into 57 fatal injuries per 1,000 workers over a 45-year lifetime of timber cutting, a 5.7% risk of dying on the job. The average rate of on the job injury for this same time period was 128.3 per 100,000. In the competitive logging industry, the median weekly earnings for full-time wage and salary earners in the forestry and logging occupations was $443, compared to $490 for all occupations (Signatur '98).

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, (tribe), age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. It is sad there are so few blacks in the white, wilderness, discrimination is not presumed.. Since the Great Migration, during the Great Depression, African-American people sold their farms and moved to the city, and subsequently they are distinctly under-represented on federal lands. Rural America in general is white. Hiking and the outdoors are "simply not very appealing to African-Americans" according to a church affiliated, married black couple, administering trail magic (food). They acknowledge that African tribal people identify with the wilderness and by all accounts Buffalo soldiers made much better Rangers than the armed, white, undereducated (Bachelor degree required), veterans, stalking pedestrians in the National Parks today. There are more Asians than blacks on the trails. Latin Americans tend to be working on agricultural lands and only rarely venture into the wilderness except to harvest wild products. Native American tribes are ironically often the most repressive government towards hikers and campers, and they often ticket campers, forcing members to live two families to a trailer. Although Natives wax fondly of hunting and gathering, tribal governments need to invest in trails, not trials, so tribal members and their guests could camp for free and hike a trail to the city to resupply or walk to the often nearby National Recreational Trails in peace.

2. Sustainable design

Recreation trails are for all people. They allow us to go back to our roots. Trails help humans make sense of a world increasingly dominated by automobiles and pavement. They put us in touch with our natural surroundings, soothe our psyches, challenge our bodies, and allow us to practice traditional skills. Building sustainable trails has described as a priority since at least 2007 (Hesselbarth et al '07: 9-10). Sustainable trails have a much larger and central role to play in achieving the Sustainable Development Goals for 2030 than they were given credit for in 2015 when the agenda was released, perpetuating the omission of social security in the United Nations system. Sustainable trails are the best solution for improving life on land to achieve Goal 15 to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss, while achieving Goal 13 to take urgent action to combat climate change and its impacts, Goal 11 to make cities and human settlements inclusive, safe, resilient and sustainable, Goal 8 to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, Goal 6 to ensure availability and sustainable management of water and sanitation for all, Goal 3 to ensure healthy lives and promote well-being for all at all ages, and Goal 1 to end poverty in all its forms everywhere, to provide free housing and transportation in conjunction with a functional international poverty line social security benefit to pay the extremely poor cash benefits. Putting sustainable trails, camping and "trail angels" at the core of the SDGs helps to minimize and reverse the damage to the ecosystem and society, specifically caused by industrial human "development", the automobile and road infrastructure and the destruction of land for use as private residential and industrial property pursuant to the Roman rule of usufruct. Trails and free legal camping, in and near urban communities, and farther out, but connected to the marketplace by trails and public transportation, helps to eliminate the expensive, polluting, dangerous and monopolistic usufruct costs of housing and automobile ownership and misguided urban and rural development. Making trails and free legal camping central to the SDGs helps to ensure that urban and rural development and markets are culturally and physically connected to the wilderness, or make an effort, through the expansion of greenways, parks, and trails passing through private property, to reconnect to the wilderness, to enjoy all the natural beauty, oxygen, exercise and freedom from the crippling costs of housing and the automobile, while remaining connected to the urban market for sold and free food, to protect biodiversity against hunter-gathering, as well as acquire gear, shelter, electricity, wifi, hot bathing water, education and employment, before going to sleep on a billion dollar pillow in the fo-rest.

Since the advent of agriculture and cities and especially since the Industrial Revolution, before the 1960's, relatively few people ventured into remote forest lands seeking wilderness or backcountry recreation experiences, and management needs were few. However, during the 1960's and early 1970's, visitation increases of 15 percent per year at overnight sites were common. The National Trails System Act of 1968, as amended, calls for establishing trails in both urban and rural settings for people of all ages, interests, skills, and physical abilities. A threefold increase in hiking and backpacking was noted between 1965 and 1977, but felt that the rate of increase had declined between 1977 and 1980. From 1981 to 1984, total dispersed recreation in the National Forest System actually dropped from 151 to 145 million visitor-days. Current estimates are that there are 150 million annual visitors to the National Forest. There are another 300 million visits to the National Parks. Heavy use has had an impact. Many trailheads have been expanded and in some cases paved to accommodate increased use. Trails have been reconstructed to reduce soil erosion and to provide easier and safer access to remote destinations. Overnight sites have been developed to reduce the physical impacts of camping as well as provide shelter and other amenities for overnight visitors. These improvements cost money, and there is annual maintenance. Someone must bear these costs, usually the public land management agency or a trail-maintaining club (Echelberger et al '86: 1-2).

Costs were computed by adding the initial construction costs to 19 years of average annual maintenance and replacement costs and dividing by twenty years. On low-elevation trails with low use and grades less than 15 percent, we observed no maintenance structures or trail problems. On similar trails receiving high use, a moderate amount of erosion control work had been done and some tread (rock paving or wood puncheon) had been used on flat, poorly drained areas; the calculated average annual maintenance costs for a 20-year period ranged from $493.50 (current 2022 dollars/ $210 per mile 1977 dollars) on low-use trails to $1,348.90 per mile (current 2022 dollars/$574 per mile 1977 dollars) on high-use trails. The most expensive trail in the study was a very high use with extensive rock tread and wood puncheon; the calculated annual cost was $6,345 per mile (current 2022 dollars/ $2,700 per mile 1977 dollars). The average annual costs for steep-grade trails in the upper elevation, softwood forest ranged from $683.85 per mile (current 2022 dollars/$291 per mile 1977 dollars) to $3,543.80 per mile (current 2022 dollars/$1,508 per mile 1977 dollars). The low-use trail sections had little work, while the high-use trail sections had extensive erosion control work and were much more expensive to maintain (Echelberger et al '86: 4-7).

By comparison clearing, excavating and seeding a temporary forest road costs between $5,000 and $16,000 per mile. Constructing a new 2-lane undivided road – about $2 million to $3 million per mile in rural areas, about $3 million to $5 million in urban areas. Construct a new 4-lane highway — $4 million to $6 million per mile in rural and suburban areas, $8 million to $10 million per mile in urban areas. This comes to about $100,000-$500,000 average annual cost on a twenty years maintenance cycle. Milling and resurfacing costs between $300,000 a mile in rural areas to $2 million dollars for highways. Rails to trails paved bike-paths cost about $324,000 per mile, $16,200 annually over twenty years. Sidewalks cost $180,000 per mile, $9,000 annually over twenty years. Unpaved trails are significantly cheaper than paved roads and sidewalks, less damaging to the environment than temporary forest service logging roads or other roads, and with camping, provide people with a place to live at little or no cost, yet there are an estimated 4.18 million miles of roads and only 88,600 miles of National Scenic Trails in the United States. An effort is needed to charge transportation departments up to 1.5 percent of total costs to compensate for loss of safe pedestrian passageways, due to the paving over trails and privatizing land on passes, to create recreational trails pursuant to 23USC§206, to be matched by local, state and federal land management agencies. Cross-connecting and side trails are needed to connect cities with each other, the wilderness and the National Recreational Scenic Trails, without any expensive and dangerous roads 16USC§1245.

Trail construction and maintenance costs, adjusted for inflation

Item	1977 Cost	2022 Cost
A. Trail Construction		
1. Clearing	1,742/mile (0.33/linear foot)	4,093.70 (0.78/linear foot)
2. Waterbars	16.50/waterbar	38.78/waterbar
3. Ditching	1.65/linear foot	3.88/linear foot
4. Steps - rock	15.10/step	35.49/step
- log	16.15/step	37.95/step
5. Cribbing - rock	9.45/linear foot	22.21/linear foot
-log	5.85/linear foot	13.75/linear foot
6. Puncheon (bridging)	4.85/linear foot	11.40/linear foot
7. Rock tread		
Stepstones (1 step/2 feet)	2.10/linear foot	4.94/linear foot
Paving (all rock)	4.90/linear foot	11.52/linear foot

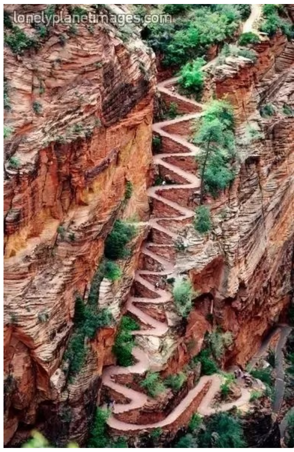
8. Scree walls	2.00/linear foot	4.70/linear foot
9. Special provision		
Pin step	28.00/step	65.80/step
Cut step or ladder used on steep rock faces	45.00/step or ladder	105.75/step or ladder
B. Trail location markers		
1. Paint blazing	31.50/mile	74.03/mile
2. Cairn building		
Large, every 50 feet	10.40/cairn	24.44/cairn
Small, every 100 feet	2.60/cairn	6.11/cairn
C. Trail Maintenance		
1. Patrolling – every year, clear blowdowns, clean ditches	10.40/mile	24.44/mile
2. Brushing – every 3 years		
Low elevation	52.00/mile, inc. patrolling	122.20/mile, inc. patrolling
Mid-elevation	104.000/mile, inc. patrolling	244.40/mile, inc. patrolling
D. Overnight site facilities		
1. Tent platforms (10 ft x 12 ft)	656.00/platform 10 years	1,541.60/platform, 10 years
2. Shelter, 3-sided precut, for 8	6,555.75/twenty years	15,406.01/twenty years
3. Shelter, 3 sided, precut, for 12	8,741.00/every twenty years	20,541.35/twenty years
4. Special water supply	56.00/10 years	131.60/twenty years
5. Signs	15.00/sign every 5 years	35.25/sign
6. Human-waste disposal		
Outhouse and pit	610.00/10 years	1,433.50/10 years
Move outhouse to new pit	160.00/as needed	376.00/as needed
7. Outhouse modified for compost	840.00/20 years	1,974/20 years
E. Management Programs		
1. Caretaker programs		
Full-time, long season with law enforcement (164 days)	10,899.00/annually	25,621.65/annually
Full-time, long season with no law enforcement	8,833/annually	20,757.55/annually
Full-time, no law enforcement (98 days)	5,506.00/annually	12,939.10/annually

Peak-use, no law enforcement (30 days)	1,764/annually	4,145.40/annually
2. Annual site maintenance		
Patrolling only (3 trips year)	42.50/annually	99.88/annually
Low use sites with privy	138.60/annually	325.71/annually
Moderate use with privy	337.00/annually	791.95/annually
Moderate use with caretaker	200.00/annually	470.00/annually
High use with privy	674.00/annually	1,583.90/annually
High use with caretaker	400.00/annually	940.00/annually

Source: Tables 1 & 2. 1977 Forest Service costs; 3 percent average annual inflation estimate. Echelberger, Herbert E.; Plumley, Harriet J. Anatomy of Backcountry Management Costs. United States Department of Agriculture. Forest Service Northeastern Forest Experiment Station. Research Paper NE-575. 1986. pgs. 3 & 4

Because of the variation in terrain characteristics and trail locations within the eastern mountain regions, trail and overnight facility requirements might be expected to vary significantly with use levels. Trail sections were considered problems if they had: 1) severely eroded sections (sections with gullies greater than 6 inches deep or with very loose, unstable soil on a steep grade) for more than 10 feet; 2) side-hill erosion from drainage crossing the trail; 3) poorly drained sections on flat areas that were greater than 10 feet long or that were causing trail widening problems. The use levels represented the capacities for which the sites had i been designed and built. Low-use sites can accommodate 2 to 4 persons per night (200/year); moderate-use sites can accommodate 4 to 8 persons per night (600/year); high-use sites consist of shelters andlor tent platforms and can accommodate about 20 people per night (1,500/year); and very high-use sites have several shelters and tent platforms that can accommodate 50 to 60 people per night (3,000/year). Soil conditions dictated some form of human-waste disposal other than a pit privy, bin composting was chosen over a haul-out system (Echelberger et al '86: 2-3).

The management practices that have been used for resource protection at designated overnight sites receiving clustered use include: 1) shelters or tent platforms to concentrate camping parties and reduce the surface area that becomes trampled and compacted; 2) a human-waste disposal system that does not rely on soil leaching; 3) delineated paths within the overnight site to discourage indiscriminate trampling of ground vegetation; 4) a drinking-water outlet pipe at a "hardened" collection point (this has been used to protect the ground surrounding a spring outlet, especially where frequent trampling could cause soil to wash into the water supply); and 5) resident caretakers to provide visitor information, maintain site facilities, operate compost systems, and where necessary, police the site. Routine maintenance is also required, including litter removal, shelter and privy cleaning and repairs, and sign replacement. At sites with caretakers most of the routine maintenance jobs are handled without additional labor costs. The calculated average annual costs (AC) of designated overnight camping areas ranged from $173.90 (current 2022 dollars/$74 1977 dollars) to $29,555.95 (current 2022 dollars/$12,577 1977 dollars, for large shelters with privy. The sites with the highest average annual costs are the large sites designed for very high use. These sites tend to attract many inexperienced or inconsiderate visitors. They require full-time caretakers with law enforcement responsibilities plus most or all of the structural facilities needed at other locations (Echelberger et al '86: 6-8).



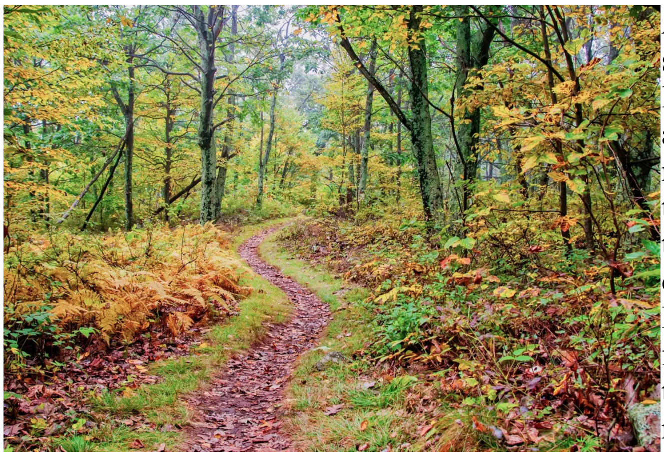
If designing a new trail, make sure it will be sustainable. What does that mean? Sustainability means creating and maintaining trails that are going to be here for long time. Trails with tread that won't be eroded away by water and use. Trails that won't affect water quality or the natural ecosystem. Trails that meet the needs of the intended users and provide a positive user experience. Trails that do no harm to the natural environment. The rolling contour trail is described as the sustainable solution - Outsloped tread, sustainable grades, frequent grade reversals, erosion resistance, path that traverses along the sideslope, provision for sheet flow of runoff, positive user experiences and low maintenance. You need teachers and experience to learn how to lay out and design sustainable trails. If your official trail isn't the path of least resistance, users will create their own trail. Your trail must be more obvious, easier to travel, and more convenient than the alternatives or you're wasting your time and money. To maintain trails it is important to monitor trail conditions closely in order to decide what can be accomplished as basic maintenance, determine what can be deferred and identity areas that need major work. Priorities are to correct truly unsafe situations, correct erosion and restore the trail to planned design. Actions can range from adding reassurance markers or rerouting poorly designed sections of trail. Maintain the trail when the need is first noticed to prevent more severe and costly damage later (Hesselbarth et al '07: 9-10).

Use topographic maps and aerial photos to map the potential route. On the map, identify control points—places where the trail has to go, because of: destination, trailheads, water crossings and rock outcrops. Include positive control points—features such as a scenic overlook, a waterfall, or lakes. Avoid negative control points—areas that have noxious weeds, threatened and endangered species, critical wildlife habitat, or poor soils. When plotting the trail on a map, connect the control points, following contour lines. Keep the grade of each uphill and downhill section less than 10 percent. Plotting your trail with 10-percent grades on a topographic map will help keep the route at a sustainable grade. When you get into the field to start scouting the route, you'll have better flexibility to tweak the grades. Grade can be expressed as a percent or an angle. Percent is easier to understand. Percent grade equals the rise (elevation change) divided by the run (horizontal distance) multiplied by 100. Example: rise of 10 feet x 100 = 10 percent run of 100 feet. Elevation change, up or down, is always a positive number (Hesselbarth et al '07: 12-13).

Tools to scout the route include: clinometer, compass, altimeter, GPS receiver, flagging of different colors, wire pin flags, roll-up pocket surveyor's pole, permanent marker to write notes on the flagging, field book, probe to check soil depth to bedrock, and maps. The objectives of scouting or reconnaissance are to: Verify control points and identify additional control points that you did not spot when you were studying the maps and aerial photos. Verify that the mapped route is feasible. Find the best alignment that fits all objectives. Don't trust an eyeball guess for grade; use your clinometer (clino). Large trees often have natural benches on their uphill side. It's better to locate your trail there than on the downhill side where you'll sever root systems and generally undermine the tree. Your specifications will tell you how close the trail can be to the tree. Look for natural platforms for climbing turns or switchbacks. They save construction costs and better fit the trail to the land. Cross ravines at an angle rather than going straight up and down the ravine banks. Flag locations for grade reversals. Look for indications of shallow bedrock, such as patches of sparse vegetation. Flag the centerline location, particularly in difficult terrain. Look for small draws to locate grade reversals. The trail should climb gently for a few feet on each side of the draw. Avoid laying a trail out on flat terrain because water has no place to drain. Begin with the theoretical route, then try different routes until you find the best continuous route between control points. Reconnaissance is easiest with two people. You and your partner need to use a clinometer to determine sustainable grades. The half rule says that the trail grade should be no more than half the side-slope grade. For example, if you're working on a hill with a 6-percent sideslope, your trail grade should be no more than 3 percent. If the trail is any steeper, it will be a fall-line trail. Fall-line trails let water funnel down, causing erosion and ruts. As side-slopes get steeper, trails designed using the half rule can be too steep (Hesselbarth et al '07: 15-18).

For example, a narrow winding trail might be the right choice for foot traffic in the backcountry, while a wider trail tread with broad sweeping turns would be appropriate for an ATV (all-terrain vehicle) route. A smooth trail with gentle grades is more appropriate for an interpretive trail or a trail designed for persons with disabilities. Challenging trails that include rocky boulder fields and some jumps might be designed for mountain bikes and motorcycles. The steepness of the hillside determines how difficult a trail is to build. The steeper the hillside, the more excavation will be needed to cut in a stable backslope. Trail grade also has a direct bearing on how much design, construction, and maintenance work will be needed to establish solid tread and keep it solid. Grades range from 1 percent for wheelchair access to 50 percent or greater for scramble routes. Most high-use trails should be constructed with an average trail grade in the 5- to 10-percent range. Trails of greater difficulty can be built at grades approaching 15 percent if solid rock is available. Trails steeper than 20 percent become difficult to maintain in the original location without resorting to steps or hardened surfaces. Use flagging tape to mark the trail opening or corridor. Use colors that stand out from the vegetation. Fluorescent pink should work in most areas (Hesselbarth et al '07: 18-20)

You will need to use the clino to keep the trail's grade within the limits of the half rule. Two or More Persons Flagging—Stand on the centerline point, direct your partner ahead to the desired location, then take a reading with your clino. When the desired location is determined, the front person ties a piece of flagging on vegetation with the knot facing the intended trail, then moves ahead. The person with the clino moves up to the flagging and directs the next shot. A third person can be scouting ahead for obstacles or good locations. One-Person Flagging— Stand at a point that is to be the centerline and tie flagging at eye level. Then move about 3 to 6 meters (10 to 20 feet) to the next centerline point and sight back to the last flag. When you have the desired location, tie another piece of flagging at eye level. While flagging the route, you will discover impassable terrain, additional control points, and obstacles that weren't evident on the map. Use different colors of flagging for the other possible routes as you lay in the trail options. Always use a clino to measure sustainable grades. If you're working in heavy brush and you can't see your partner through the clino, have your partner wiggle a bright flashlight. Start by tying flagging to the branches of trees at eye level and about every 3 meters (10 feet). Don't forget to tie the knot so that it faces the intended trail location. This way, if another crew continues the work, they will know your intentions. Flagging that is close together helps trail designers and builders visualize the flow of the trail. If you are working in an open area without trees or shrubs, use pin flags instead of flagging. Now, run or walk the trail. When your trail alignment feels really good and you're satisfied with the locations of the pin flags, have the land manager check your design. You'll need to have the manager's approval before cutting any vegetation or removing any dirt (Hesselbarth et al '07: 20-23).



An esthetically functional trail is one that fits the setting. It lies lightly on the land and often looks like it just "happened." Well-designed trails take advantage of natural drainage features, reducing maintenance that might be needed, while meeting the needs of the users. The trail might pitch around trees and rocks, follow natural benches, and otherwise take advantage of natural land features. It's much more important to understand how the forces of water and gravity combine to move dirt than it is to actually dig dirt. Water in the erode mode strips tread surface, undercuts support structures, and blasts apart fill on its way downhill. Water has carrying capacity. More water can carry more dirt. Faster water can carry even more dirt. You need to keep water from running down the trail. Water also can affect soil strength. While the general rule of thumb is that drier soils are stronger (more cohesive) than saturated soils, fine, dry soils may blow away. The best trail workers can identify basic soils in their area and know their wet, dry, and wear properties. They also know plant indicators that tell them about the underlying soil and drainage. Keep surface water from running down the trail. Keep tread material on the trail and keep it well drained. Critters include packstock, pocket gophers, humans, bears, elk, deer, cows, and sheep. Critters burrow through the tread, walk around the designated (but inconvenient) tread, tightrope walk the downhill edge of the tread, shortcut the tread, roll rocks on the tread, chew up the tread, or uproot the tread. Don't build switchbacks across a ridge or other major "game route." Don't let tread obstacles like bogs or deeply trenched tread develop. Make it inconvenient for packstock to walk the outer edge of your tread (Hesselbarth et al '07: 26-27).

3. Erosion

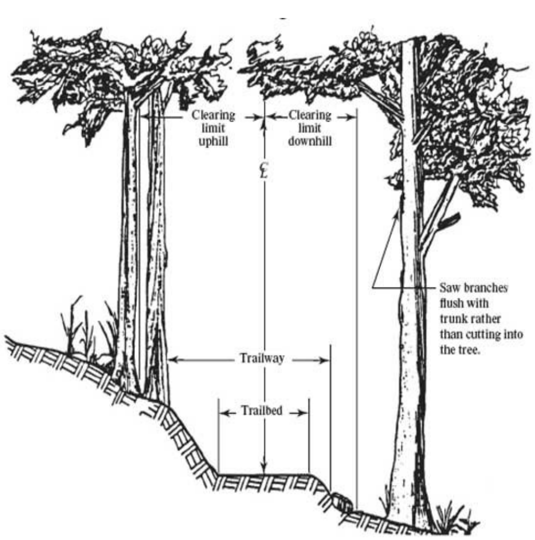
Diverting surface water off the trail should be near the top of your list of priorities. Running water erodes tread and support structures, and can even lead to loss of the trail itself. Standing water often results in soft, boggy tread or failure of the tread and support structures. The very best drainage designs are those built into new construction. These include frequent grade reversals and outsloping the entire tread. When rain falls on hillsides, after the plants have all gotten a drink, the water continues to flow down the hill in dispersed sheets—called sheet flow. All the design elements for a rolling contour trail—building the trail into the sideslope, maintaining sustainable grades, adding frequent grade reversals, and outsloped tread—let water continue to sheet across the trail where it will do little damage. Design elements for a rolling contour trail let water sheet across the trail. Sheet flow prevents water from being channeled down the trail, where it could cause erosion. Sometimes, grade reversals are called grade dips, terrain dips, Coweeta dips, or swales. For less confusion, let's call them grade reversals. The basic idea is to use a reversal in grade to keep water moving across the trail. Grade reversals are designed and built into new trails. Grade reversals take advantage of natural dips in the terrain. The grade of the trail is reversed for about 3 to 5 meters (10 to 15 feet), then "rolled" back over to resume the descent. Grade reversals should be placed frequently, about every 5 to 15 meters (20 to 50 feet). Grade reversals are much more effective than waterbars and require less maintenance. Grade reversals with outsloped tread are the drainage structure of choice. Create a grade reversal by curving the trail around large trees and rocks (Hesselbarth et al '07: 30-31).

Gullies form as water eats away the tread material on steep trails. Puddles sit in low-lying areas that leave the water nowhere to go. When water starts destroying your trail, trail users start skirting around the damage. The trail becomes wider or multiple new trails are formed. Getting water off the trail takes more than digging a drainage ditch. Find out where the water is coming from, then find a way to move it off the trail. Knicks are constructed into existing trails. For a knick to be effective, the trail tread must have lower ground next to it so the water has a place to drain. A knick is a shaved down semicircle about 3 meters (10 feet) long that is outsloped about 15 percent in the center (figure 14). Knicks are smooth and subtle and should be unnoticeable to users. If terrain prevents such outsloping, the next best solution is to cut a puddle drain at least 600 millimeters (24 inches) wide, extending across the entire width of the tread. Dig the drain deep enough to ensure that the water will flow off the tread. Feather the edges of the drain into the tread so trail users don't trip. Plant rocks or other large stationary objects (guide structures) along the lower edge of the tread to keep traffic in the center. In a really long puddle, construct several drains at what appear to be the deepest spots. Another way to force water off existing trails is to use a rolling grade dip. A rolling grade dip is used on steeper sections of trail. It also works well to drain water off the lower edge of contour trails. A rolling grade dip builds on the knick design. A rolling grade dip is a knick with a long ramp about 4 1⁄2 meters (15 feet) built on its downhill side (figure 15). For example, if a trail is descending at a 7-percent grade, a rolling grade dip includes: A short climb of 3 to 5 meters (10 to 20 feet) at 3 percent. A return to the descent. Water running down the trail cannot climb over the short rise and will run off the outsloped tread at the bottom of the knick. Rolling grade dips should be placed frequently enough to prevent water from building up enough volume and velocity to carry your tread's surface away. Rolling grade dips are pointless at the top of a grade. Midslope usually is the best location. The steeper the trail, the more rolling grade dips will be needed. Rolling grade dips should not be constructed where they might send sediment-laden water into live streams (Hesselbarth et al '07: 33-36).

Waterbars are commonly used drainage structures. Make sure that waterbars are installed correctly and are in the right location. Water moving down the trail turns when it contacts the waterbar and, in theory, is directed off the lower edge of the trail. Logs used for waterbars need to be peeled (or treated with preservative), extended at least 300 millimeters (12 inches) into the bank, staked or anchored, and mostly buried. Waterbars commonly fail when sediment fills the drain. Water tops the waterbar and continues down the tread. The waterbar becomes useless. You can build a good rolling grade dip quicker than you can install a waterbar, and a rolling grade dip works better. On grades of less than 5 percent, waterbars are less susceptible to clogging unless they serve a long reach of tread or are constructed in extremely erodible tread material. On steeper grades (15 to 20 percent), waterbars are prone to clogging if they are at less than a 45-degree angle to the trail. Waterbars are mostly useless for grades steeper than 20 percent. At these grades a very fine line exists between clogging the drain and eroding it (and the waterbar) away. Most waterbars are not installed at the correct angle, are too short, and don't include a grade reversal. Poorly constructed and maintained waterbars become obstacles and disrupt the flow of the trail. The structure becomes a low hurdle for travelers, who walk around it, widening the trail. A problem with wooden waterbars is that horses can kick them out. Rock, if available, is always more durable than wood. Cyclists of all sorts hate waterbars because the exposed surface can be very slippery, leading to crashes when a wheel slides down the face of the waterbar. As the grade increases, the angle of the waterbar (and often the height of its face) is increased to prevent sedimentation, raising the crash-and-burn factor.

Waterbars need to be constructed at a 45- to 60-degree angle to the trail. Rock waterbars are more durable than wood. A variation from the traditional waterbar is the waterbar with riprap tray. The riprap tray is built with rock placed in an excavated trench. The tops of the rocks are flush with the existing tread surface, so they're not an obstacle to traffic. Next, construct a rock waterbar. Use rectangular rocks, chunkers, butted together, not overlapped. Start with your heaviest rock at the downhill side—that's your keystone. Lay rocks in from there until you tie into the bank. Bury two-thirds of each rock at a 45- to 60-degree angle to the trail. Add a retainer bar of rock angled in the opposite direction from the waterbar. The downhill edge of the retainer bar is at an angle so it nearly touches the downhill edge of the waterbar. Fill the space between the waterbar and retainer with compacted tread material. The best cure for a waterbar that is clogged with sediment of forces the water to turn too abruptly is to rebuild the structure into a rolling or armored grade dip. If you've tried various drainage methods and water is still tearing up your trail, it's time to think seriously about rerouting the problem sections. Remember: locating the new section of trail on a sideslope, keeping the trail grade less than half of the grade of the hillside, building with a full bench cut to create a solid, durable tread, constructing plenty of grade reversals, outsloping the tread and compacting the entire trail tread. A short section of eroded trail may cause less environmental damage than construction of a longer rerouted section. Weigh your options wisely (Hesselbarth et al '07: 36- 42).

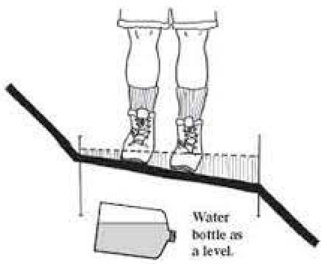
4. Trail construction



The trail corridor includes the trail's tread and the area above and to the sides of the tread. Trail standards typically define the edges of the trail corridor as the clearing limits. Vegetation is trimmed back and obstacles, such as boulders and fallen trees, are removed from the trail corridor to make it possible to ride or walk on the tread. The dimensions of the corridor are determined by the needs of the target users and the challenge of the trail. For example, in the Northern Rockies, trail corridors for traditional packstock are cleared 2.5 meters (8 feet) wide and 3 meters (10 feet) high. Hiking trails are cleared 2 meters (6 feet) wide and 2.5 meters (8 feet) high. Check with your local trail manager to determine the appropriate dimensions for each of your trails. The trailway is cleared farther than the flattened trailbed, up to eight feet high. Saw branches flush with tree. Plants growing into trail corridors or trees falling across them are a significant threat to a trail's integrity. Brush is a major culprit. Other encroaching plants such as thistles or dense ferns may make travel unpleasant or even hide the trail completely. In level terrain, the corridor is cleared an equal distance on either side of the tread's centerline. For a hiking trail, this means that the corridor is cleared for a distance of 1 meter (3 feet) either side of center. Within 300 millimeters (1 foot) of the edge of the tread, plant material and debris should be cleared all the way to the ground. Farther than 500 millimeters (1.5 feet) from the trail edge, plants do not have to be cleared unless they are taller than 500 millimeters (1.5 feet) or so. Fallen logs usually are removed to the clearing limit. Consider brushing only the uphill side of the trail. This approach keeps users off the trail's downhill edge and keeps the trail in place. Cut intruding brush back at the base of the plant rather than in midair at the clearing limit boundary. Cut all plant stems close to the ground. Scatter the resulting debris as far as practical. Toss stems and branches so the cut ends lie away from the trail (they'll sail farther through brush as well). Don't windrow the debris unless you really and truly commit to burn or otherwise remove it (and do this out of sight of the trail). Rubbing the cut ends of trailside logs or stumps with soil reduces the brightness of a fresh saw cut. In especially sensitive areas, cut stumps flush with the ground and cover them with dirt, pine needles, or moss (Hesselbarth et al '07: 43-47).

Some trails may have to be brushed several times a year, some once every few years. Usually, trees growing within the corridor should be removed. Prune limbs close to the tree trunk. For a clean cut, make a shallow undercut first, then follow with the top cut. This prevents the limb from peeling bark off the tree as it falls. Do not use an ax for pruning. If more than half of the tree needs pruning, it is usually better to cut it down. Cut trees off at ground level and do not leave pointed stobs.

Logging out a trail means cutting away trees that have fallen across it. The work can be hazardous. The size of the trees you are dealing with, restrictions on motorized equipment, and your skill and training determine whether chain saws, crosscut saws, bow saws, or axes are used. You need training to operate a chain saw or a crosscut saw. Your training, experience, and level of certification can allow you to buck trees already on the ground or to undertake the more advanced (and hazardous) business of felling standing trees. Be sure you are properly trained and certified before cutting standing or fallen trees. Using an ax to cut standing or fallen trees poses similar hazards. Some trees may be felled more safely by blasting. Check with a certified blaster to learn where blasting is feasible. Cut fallen trees out as wide as your normal clearing limits on the uphill side, but closer to the trail on the downhill side. Roll the log pieces off the trail and outside the clearing limits on the downhill side. Never leave them across ditches or waterbar outflows. If you leave logs on the uphill side of the trail, turn or bury them so they won't roll or slide onto the trail. Sometimes you'll find a fallen tree lying parallel with the trail. If the trunk of the tree is not within the clearing limits and you decide to leave it in place, prune the limbs flush with the trunk. Limbing the tree so it rests on the ground helps the trunk decay faster. It is hard to decide whether or not to remove leaners, trees that have not fallen but are leaning across the trail. If a leaner is within the trail clearing zone, it should be removed. Beyond that, it is a matter of discretion. Felling a leaner, especially one that is hung up in other trees, can be very hazardous. Only highly qualified sawyers should work on leaners. Blasting is another way to remove leaners safely. Based on injury statistics, felling standing trees (including snags) is one of the most dangerous activities for trail workers. Do not even con- sider felling trees unless you have been formally trained and certified (Hesselbarth et al '07: 48-50).



Constructing contour trails into the sideslope requires excavating the side of the hill to provide a solid, stable trail tread. Stay away from flat areas because water has nowhere to go. Keep grades sustainable by using the half rule and add plenty of grade reversals. Slightly outsloping the tread (about 5 percent) is a must to help move water across the trail. Trail professionals almost always prefer full-bench construction. A full bench is constructed by cutting the full width of the tread into the hillside and casting the excavated soil as far from the trail as possible. Full-bench construction requires more excavation and leaves a larger backslope than partial-bench construction, but the trailbed will be more durable and require less maintenance. Partial-bench construction is another method to cut in a trail, but it takes a good deal of trail-building experience to get this method right. The trail tread will be part hillside and part fill material. The fillslope needs to be composed from good, solid material like rock or decay-resistant wood. And it has to get compacted evenly. The backslope is the excavated, exposed area above the tread surface. The backslope should match the angle of repose of the parent material (the sideslope). Backslopes are noted as a ratio of vertical rise to horizontal dis- tance, or “rise” to “run.” Most soils are stable with a 1:1 backslope. Solid rock can have a steeper 2:1 backslope, while less cohesive soils may need a 1:2 backslope. Angle the backslope until loose material quits falling down onto the trail tread. Stabilize the entire backslope by compacting it with the back of a McLeod. One option to reduce backslope excavation is to con- struct a retaining wall. The fillslope is that area below the tread sur- face on the downhill side. Fillslopes often need to be reinforced with retaining or crib walls to keep them from failing. Fillslope failures are common and will wipe out the trail. That’s why most trailbuilders prefer full-bench trails (Hesselbarth et al '07: 51-54).

The procedure for the actual dirt moving once vegetation has been cleared. Place pin flags to keep the diggers on course. Straddle a centerline flag and face uphill. Swing your Pulaski or other tool to mark the area to be cleared. Where the tool strikes the hillside will be approximately the top of the backslope. The steeper the slope, the higher the backslope. Define the area to be dug to mineral soil. Clear about the same distance above and below the flag. Keep the duff handy by placing it uphill. It will be used later. Stand on the trail and work the tread parallel to the direction of travel. Level out the tread and get the right outslope. Don’t continue facing uphill when you’re shaping the tread, despite the tendency to do so. Make sure that the width of the rough tread is about the length of a Pulaski handle. Make sure grade reversals and other drainage structures are flagged and constructed as you go. Look at the natural slope and try to match it. Round off the top of the backslope, where the backslope meets the trail tread, and the downhill edge of the trail. Keeping these areas smooth and rounded will help water sheet across the trail. Walk the trail to check the tread’s outslope. If you can feel your ankles rolling downhill, there is too much outslope. A partially filled water bottle makes a good level or you can stand a McLeod on the trail tread—the handle should lean slightly downhill. Compact the entire tread, including the backslope, with the back of a McLeod. Don’t leave compaction up to trail users. They will only compact the center, creating a rut. Place the duff saved earlier onto the scattered dirt that was tossed downhill. The duff helps naturalize the outside edge and makes the new trail look like it has been there for years. Be careful not to create a berm with the duff (Hesselbarth et al '07: 55).

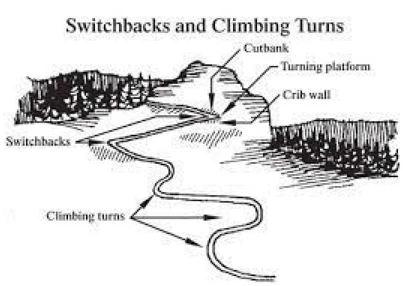
Tread is the actual travel surface. Soil type and texture have a major influence on soil drainage and durability. Texture refers to the size of individual soil particles. Clay and silt are the soil components with the smallest particles. Small particles tend to be muddy when wet and dusty when dry. Clay and silt don't provide good drainage. Sand is made of large particles that don't bind together at all and are very unstable. The best soil type is a mixture of clay, silt, and sand. If your soil is lacking any one of these, you can attempt to add what's missing. Easier trails should have a smooth tread surface. Backcountry trails can be rougher and more challenging. Leaving some obstacles in the trail helps slow down users and reduce conflict. An outsloped tread is one that is lower on the outside or downhill side of the trail than it is on the inside or bankside. Outsloping lets water sheet across the trail naturally. The tread should be outsloped at least 5 percent. Loss of outslope is the first maintenance problem that develops on all trails. If you can do nothing else when budgets are tight, reestablish the outslope. Removing roots and stumps is hard work. Explosives and stump grinders are good alternatives for removing stumps, but chances are you'll have to do the work by hand. Often, a sharpened pick mattock or Pulaski is used to chop away at the roots. You should not have to remove many large stumps from an existing trail. Before you remove a stump, consider whether other crews might have left it to keep the trail from creeping downhill (Hesselbarth et al '07: 58-59).

Rock work for trails ranges from building rock walls to blasting solid rock. When rock needs to be removed, a good blaster can save a crew an astounding amount of work. When rock needs to be used, someone building a rock retaining wall may be a true artisan, creating a structure that lasts for centuries. The secret to moving large rocks is to think first. Plan where the rock should go and anticipate how it might roll. Lots of high-quality rockbars are needed. Pick-mattock. Sledge hammer. Eye protection, gloves, and hardhat. Don't even think of swinging a tool at a rock without wearing the required personal protective equipment. Gravel box, rock bag, rucksack, rock litter—all useful for carrying rocks of various sizes. Winch and cable systems. Some rocks can be dragged or lifted into place. All sorts of motorized equipment, including rock drills and rock breakers. Chemical expansion agents can be poured into holes drilled into large rocks, breaking them without explosives. Devices like the Boulder Buster, Magnum Buster, and BMS Micro-Blaster crack rocks without explosives and can be used by persons who are not certified blasters. Often, large rocks are best removed by blasting. Other solutions include ramping the trail over them, or rerouting the trail around them. Rocks should be removed to a depth of at least 100 millimeters (4 inches) below the tread surface, or in accordance with your specific trail standards. Simply knocking off the top of a rock flush with the existing tread may leave an obstacle after soil has eroded around the rock (Hesselbarth et al '07: 60).

Rockbars work great for moving medium and large rocks. Use the bars to pry rocks out of the ground and guide them off the trail. When crewmembers have two or three bars under various sides of a large rock, they can apply leverage to the stone and virtually float it to a new location with a rowing motion. Use a small rock or log as a fulcrum for better leverage. It may seem like fun at the time, but avoid the temptation to kick a large stone loose. When rocks careen

down the mountainside they may knock down small trees, gouge bark, wipe out trail structures, start rockslides or hit someone. When you need to lift rocks, be sure to keep your back straight and lift with the strong muscles of your legs. Sharing the burden with another person can be a good idea. To load a large rock into a wheelbarrow, lean the wheelbarrow back on its handles, roll the rock in gently over the handles (or rocks placed there) and tip the wheelbarrow forward. Often small rocks are needed for fill mate- rial behind crib walls, in turnpikes and cribbed staircases, and in voids in sections of trail built in talus (rock debris). Buck- ets and wheelbarrows are handy here. So are canvas carrying bags (Hesselbarth et al '07: 60-62).
5. Switchbacks

Switchbacks, climbing turns, retaining walls, and similar trail elements are common in trail construction. They are often relatively difficult to design and construct correctly. Inadequate maintenance greatly shortens their useful lives. However, a well-designed trail with elements that are built properly can last for decades and be quite unobtrusive. Switchbacks and climbing turns are used to reverse the direction of travel on hillsides and to gain elevation quickly. What is the difference between the two? A climbing turn is a reversal in direction that maintains the existing grade going through the turn without a constructed landing. Climbing turns have a wider turn radius and are used on gentle slopes, typically 15 percent or less. Ideally, 7-percent sideslopes are best. A switchback is also a reversal in direction, but it has a relatively level constructed landing. Switchbacks are used on steeper terrain, usually steeper than 15 percent. Switchback turns have pretty tight corners because of the steeper grades. Usually, special treatments such as approaches, barriers, and drainages need to be considered. Both of these turns take skill to locate. Understanding user psychology (human or animal) is more important to the success of climbing turns and switchbacks than to the success of any other trail element. The turns must be easier, more obvious, and more convenient than the alternatives. Climbing turns work best when terrain or vegetation screens the view of travelers coming down the upper approach toward the turn. Avoid building sets of these turns on open hillsides unless the terrain is very steep. It’s usually best not to build turns, or the connecting legs of a series of turns, on or across a ridge. The local critters have traveled directly up and down these ridges since the last ice age and will not be forced onto your trail and turns (Hesselbarth et al '07: 101-102).



Climbing turns are the trail element most often constructed inappropriately. The usual problem is that a climbing turn is built (or attempted) on steep terrain where a switchback is needed. A climbing turn is built on the slope surface, and where it turns, it climbs at the same rate as the slope itself. Climbing turns work best when built on slopes of 15 percent or less. The advantages of climbing turns in appropriate terrain is that a wider radius turn of 4 to 6 meters (13 to 20 feet) is relatively easy to construct. Climbing turns continue the climb through the turn. They can be insloped or outsloped. Add grade reversals at both approaches to keep water off the turn. Trails that serve off-highway-vehicle traffic often use insloped, or banked turns so that riders can keep up enough speed for control. Climbing turns are also easier than switchbacks for packstock and bikes to negotiate. Climbing turns are usually less expensive than switchbacks because much less excavation is required and fill is not used. The tread at each end of the turn should be full-bench construction, matching that of the approaches. As the turn reaches the fall line, less material will be excavated. In the turn, the tread should not require excavation other than that needed to reach mineral soil. To prevent shortcutting, wrap the turn around natural obstacles or place guide structures along the inside edge of the turn. The psychologically perfect place to build climbing turns is through dense brush or dog-hair thickets of trees. Always design grade reversals into both of the approaches to keep water off the turn (Hesselbarth et al '07: 102-104).

Switchbacks are used in steep terrain. Suitable terrain for a switchback becomes harder to locate and maintenance costs increase as the sideslope becomes steeper. Sideslopes from 15 to 45 percent are preferred locations for switchbacks. Although switchbacks can be constructed on sideslopes of up to 55 percent, retaining structures are needed on such steep slopes. Switchback turns are harder to build correctly than climbing turns, but they keep tread stable on steeper terrain. Most switchbacks are constructed to a much lower standard than is needed. The key to successful switchback construction is adequate excavation, using appropriate structures to hold the fill in place, and building psychologically sound approaches. Look for natural platforms when you are scouting for possible switch- back locations. Use these platforms as control points when locating the connecting tread. Suitable platforms will save you a lot of time later by reducing the amount of excavation and fill needed. A switchback consists of two approaches, a landing or turning plat- form, a drain for the upper approach and platform, and guide structures. The upper approach and the upper half of the turning platform are excavated from the slope. Part of the lower approach and the lower half of the turn are constructed on fill. The approaches are the place where most of the trouble starts with switchback turns.

The approaches should be designed for the primary user group. In general, the last 20 meters (65 feet) to the turn should be as steep as the desired level of difficulty will allow. This grade should be smoothly eased to match that of the turn in the last 2 to 3 meters (6 1⁄2 to 10 feet). Do not flatten the grade for 20 meters (65 feet) before the turn. If anything, steepen the approach grades to foster the sense that the switch- back is the most convenient way of gaining or losing altitude. There is absolutely nothing as infuriating as walking a nearly flat grade to a distant switchback turn while looking several meters over the edge at the nearly flat grade headed the other direction. You can build a Maginot Line of barricades and still not prevent people, pack- stock, and wildlife from cutting your switchback. The only exception is a trail designed primarily for wheeled vehicles where a flatter approach makes it easier for riders to control their vehicles. As the upper approach nears the turn, a grade reversal should be constructed. The tread below this point should be insloped until the halfway point in the turn. Both sides of this drain ditch should be back- sloped to an angle appropriate for the local soil. As the turn is reached, the tread should be 0.5 to 1 meter (19 to 39 inches) wider than the approach tread. This is particularly important on small radius turns and for wheeled vehicles. It’s less necessary for hikers and packstock. The turn can be a smooth radius ranging from 1.5 to 3 meters (5 to 10 feet) or a simple Y-shaped platform. A smooth radius turn is important if the trail’s use includes wheeled traffic or packstrings. The Y platform works for hikers (Hesselbarth et al '07: 105-110).

The turn platform is nearly flat, reaching no more than a 5-percent grade. The upper side is excavated from the sideslope and borrow is used to construct the fill on the lower side. Switchbacks on steep sideslopes can require very large excavations to reach a stable backslope angle and provide clearance for packstock loads. The greater the turn's radius, the wider the platform, or the flatter the turn, the more excavation that will be required. A point may be reached where a retaining wall is needed to stabilize the backslope. The amount of tamped fill required on the lower side of the turn will usually be at least as much as was excavated from the upper side unless a retaining wall is used to support the fill. A retaining wall is absolutely necessary where the terrain is steeper than the angle of repose for the fill material. The tread in the upper portion should be insloped, leading to a drain along the toe of the backslope. This drain should extend along the entire backslope and be daylighted (have an outlet) where the excavation ends. Construct a spillway for the drain to protect the adjacent fill from erosion. You may need guide structures—rock walls or logs are common—on the inside of the turn to keep traffic on the trail. Construct the approach on the lower side of the turn on tamped fill. The retaining wall should extend for most of this length (Hesselbarth et al '07: 105-110).

The tread on the lower portion of the turn should be outsloped. The fill section transitions into the full-bench part of the approach; the approach changes grade to match the general tread grade. Try to avoid "stacking" a set of switchback turns on a hillside. Long legs between turns help reduce the temptation to shortcut. Staggering the turns so that legs are not the same length reduces the sense of artificiality. Keep the grade between turns as steep as the challenge allows. Remember, travelers will cut switchbacks when they feel it's more convenient to do so than to stay on the tread. The designer's goal is to make travel on the trail more attractive than the shortcut. Maintaining climbing turns and switchbacks requires working on the tread, improving drainage, and doing any necessary work on retaining walls, guide structures, and barricades. The tread should be insloped or outsloped as necessary, slough should be removed to return the tread to design width, and tread obstacles should be removed. Long sections of trails between switchbacks are usually better than short sections. Fewer switchbacks will be needed, with fewer turns to shortcut (Hesselbarth et al '07: 105-110).

Retaining structures keep dirt and rock in place. The retaining wall keeps fill from following the call of gravity and taking the tread with it. Retaining walls are useful for keeping scree slopes from sliding down and obliterating the tread, for keeping streams from eroding abutments, and for holding trail tread in place on steep sideslopes. Two common retaining structures are the rock retaining wall and the log crib wall. Of course, rock is more durable and lasts longer than wood. Ideally, the bigger the rock, the better. Big rocks are less likely to shift or become dislodged. At least half of the rocks should weigh more than 60 kilograms (130 pounds). The best rock is rectangular with flat surfaces on all sides. Round river rock is the worst. To build a rock retaining wall, excavate a footing to firm, stable dirt or to solid rock. Tilt the footing slightly into the hillside (batter) so the rock wall will lean into the hill and dig it deep enough to support the foundation tier of rocks (these are usually the largest rocks in the wall). Ideally, the footing is dug so that the foundation tier is embedded for the full thickness of the rocks. The batter should range from 2:1 to 4:1. Factors determining this angle include the size and regularity of the rock, the depth of header rocks, and the steepness and stability of the slope. At batter angles steeper than 4:1 or so, cement, internal anchors, or both, may be needed for stability (Hesselbarth et al '07: 112-113).

The keystone is laid into the footing and successive tiers are laid. For each tier, overlap the gaps between rocks in the next lower tier, called breaking the joints. Each tier should be staggered slightly into the hill to create the desired amount of batter. Header rocks are long rocks turned and placed so that they extend deep into the hillside. Using header rocks is particularly important if the wall's cross section widens as the wall gets higher. Rocks in each successive tier should be set so they have at least three points of good contact with the rocks below. Good contact is defined as no wobble or shifting under a load without relying on shims (or chinking) to eliminate rocking. Shims are prone to shifting and should not be used to establish contact, especially on the face of the wall, where they can fall out. Add backfill and tamp crushed rocks into the cracks as you build. Construct wood walls by interlocking logs or beams, pinned or notched (for logs) at the joints. Lay sill logs at right angles to the direction of travel and alternate tiers of face logs and header log. Each successive tier is set to provide enough batter to resist creep pressure from the slope and to reduce pressure on the face logs from the fill. The ends of the header logs are seated against the backslope of the excavation for stability. As fill is tamped in place, filler logs are placed inside the structure to plug the spaces between the face logs. Filler logs are held in place by the fill. Outslope the tread to keep water from saturating the fill and excavation. Use guide structures to keep traffic off the edge of the tread. All retaining structures should be checked carefully for shifting, bulging, or loose structural material. Make sure that all the footings are protected from erosion. Anchor guides should be secure. Wire baskets (often called gabions) are another retaining structure. Gabions are wire baskets filled with rock). The baskets are wired together in tiers and can be effective where no suitable source of well-shaped rock is available. Gabions look more artificial (in the eyes of traditionalists at any rate) and may not last as long as a rock wall, depending on the type of wire used and the climate (Hesselbarth et al '07: 114-116).

Steps are used to gain a lot of elevation in a short distance. Steps are common on steep hiking trails in New England and elsewhere and less common (but not unheard of) on western trails used by horses and mules. Wooden steps of all configurations are common in coastal Alaska. Sometimes steps are used on an existing trail to fix a problem caused by poor trail location or design. Often, the result is out of character with the desired experience and esthetics of the trail. Before you construct steps, make sure they are consistent with the expectations of those the trail is designed to serve. Your goal is to design the height (rise) and depth (run) of the steps to match the challenge desired. Steps are harder to negotiate as the rise increases. The difficulty also increases as the steps are closer together. Yet as the trail becomes steeper, the step must either be higher or the distance between steps must be shorter. Steps can be built into a trail that traverses the slope. This allows the traveler to gain elevation rapidly, without the scary steepness of a stairway. The components of a step are: the rise, the run, a landing on easier grades, and often retainer logs. The rise is the height of the face of each step. The run is the distance from the edge of one step to the base of the next step’s face. The landing is the extension of the run above the step. In structures where the landing is composed of tamped fill material, logs are used to retain the fill. Hikers, especially backpackers, generally don’t like steps and will walk alongside them if there is any opportunity. The steps need to be comfortable to climb or they won’t be used. This means keeping the rise a reasonable 150 to 200 millimeters (6 to 8 inches) and the run long enough to hold a hiker’s entire foot, 254 to 305 millimeters (10 to 12 inches, figure 81). It’s helpful to corral the sides of steps with rocks to encourage users to stay on the steps. A general rule of thumb for stairs: twice the riser plus the tread should equal 635 to 686 millimeters (25 to 27 inches) (Hesselbarth et al '07: 116-118).

The most important area of the step is usually the tread. This is where most users step as they climb. The top of the step (and landing) should be stable and provide secure footing. The edge of the step should be solid and durable. The face or riser of each step should not slope back too far. This is particularly important as the rise of the step increases. If the stairway climbs straight up the hill, each step should be slightly crowned to drain water to the edges or be sloped slightly to one side. When the trail traverses a slope, each step and landing should be out- sloped slightly. Water should not be allowed to descend very far down a set of steps or to collect on the landing. A grade reversal or drain dip is a good idea where the trail approaches the top of the steps. Build stairways from the bottom up, at a break in the grade. Bury the first rock; it will act as an anchor. The most common mistake is to start part way up a grade. If you do so, the trail will wash out below the stairs. The bottom step should be constructed on a solid, excavated footing. If it is constructed on top of exposed rock, it should be well pinned to the footing. Each successive step is placed atop the previous step. Wood steps are usually pinned to each other and to the footing. Dry masonry rock steps usually rely on the contact with the step below and with the footing to provide stability. Steps with landings are a bit harder to secure because the steps do not overlap. Each step can be placed in an excavated footing and the material below the rise removed to form the landing of the next lower step. Usually, this is the most stable arrangement. Or the step can be secured on the surface and fill can be used to form a landing behind it. When the landing consists of tamped fill, the material used to provide the rise does double duty as a retaining structure. These steps must be seated well to prevent them from being dislodged by traffic. For stock use, landings should be long enough, about 2 meters (6 1⁄2 feet), to hold all four of the animal's feet. In all steps, the key is to use the largest material possible and to seat it as deeply as possible. Rocks should be massive and rectangular. On steps that traverse a slope, it helps to seat the upper end of the step in footings excavated into the slope. Pavers can be used to armor switchback turns and steeper slopes, especially on trails designed for motorized traffic. Some styles of pavers allow vegetation to penetrate them; others have voids that can be filled with soil, gravel, or other suitable material (Hesselbarth et al '07: 118-122).

6. Trail maintenance

A solid, outsloped surface is the objective of trail maintenance. Remove and scatter berm material that collects at the outside edge of the trail. Reshape the tread and restore the outslope. Maintain the tread at the designed width. Remove all the debris that has fallen on the tread—the sticks and stones and candy wrappers. Compact all tread and sections of backslope that were reworked. On hillside trails, slough (pronounced sluff) is soil, rock, and debris that has moved downhill to the inside of the tread, narrowing the tread. Slough needs to be removed Slough that doesn't get removed is the main reason trails "creep" downhill. Loosen compacted slough with a mattock or Pulaski, then remove the soil with a shovel or McLeod. Reshape the tread to restore its outslope. Avoid disturbing the entire backslope unless it is absolutely necessary to do so. Chop off the toe of the slough and blend the slope back into the hillside. Remember to compact the tread thoroughly. Berms are made of soil that has built up on the outside of the tread, forming a barrier that prevents water from sheeting off. Berms form when water erodes trail tread that wasn't compacted during construction, depositing it on the edge of the trail. Water runs down the tread, gathering volume and soil as it goes. Berm formation is the single largest contributor to erosion of the tread. Removing berms is always the best practice. Berms may form a false edge, especially when berms are associated with tread creep. False edge is unconsolidated material, often including significant amounts of organic material, that can't bear weight. This is probably the least stable trail feature on most trails and a major contributor to step-throughs and wrecks. If berms persist, an insloped turn may be an option. Essentially this is a turn with a built-up berm. Insloped turns will improve trail flow and add an element of fun on off-highway vehicle and mountain bike trails. Special attention needs to be placed on creating proper drainage. To fix tread creep, cut the backslope properly, remove slough, and reestablish the 5-percent outslope. Where soil is in short supply, you may have to install a short retaining wall and haul in tread material (Hesselbarth et al '07: 63-68).

Simple restoration may consist of blocking shortcuts and allowing the vegetation to recover. Complex restoration projects include obliterating the tread, recontouring, and planting native species. Careful monitoring and followup are needed to ensure that almost all evidence of the old trail is gone. Restoration projects range from simple and relatively inexpensive to complex and costly. Reclamation strategies include: closure, stabilization, recontouring, revegetation, and monitoring. If the abandoned trail is not blocked to prevent further use, it may persist indefinitely. Closure is particularly important if stabilization and revegetation are to succeed. Stabilizing abandoned tread to prevent further erosion will promote natural revegetation in some instances. Trails break natural drainage patterns and collect and concentrate surface waterflows. Restoring the natural contour of the slope reestablishes the local drainage patterns and reduces the likelihood of erosion. Abandoned trails need to be blocked off effectively, and with sensitivity. Plant native grasses and plants. Use shrubs or deadfall to fill the opening left by the abandoned trail. Recontouring usually eliminates any temptation to use the old trail and assists revegetation. Pull fillslope material back into the cut and use additional material to rebuild the slope, if necessary. Completely break up or scarify the compacted tread at least 4 inches deep. Doing so will allow native grasses, plants, and seed to take hold and grow. Fill in the visual or vertical opening of the corridor by planting shrubs, trees, and even deadfall. Finally, sprinkle leaves and needles to complete the disguise. Remove culverts and replace them with ditches (Hesselbarth et al '07: 134-138).

Check dams are used to stop erosion and hold material in place during site restoration. Check dams are intended to slow and hold surface water long enough for the water to deposit sediment it is carrying. Check dams should be used with drainage structures to reduce overall erosion from the abandoned tread. Spacing between dams depends on the steepness of the old grade and the degree of restoration desired. If the check dams are intended only to slow down erosion on a 25-percent grade, relatively wide spacing is sufficient, every 20 meters (65 feet). If the intent is to fill in half of the old trench, the bottom of each dam should be level with the top of the next lower dam. On steeper grades, the dams need to be closer together. If the intent is to approach complete recontouring of the trench, the dams should be closer still, especially on grades steeper than 25 percent. A point of diminishing returns is reached on grades steeper than 40 percent. Check dams would have to be built right on top of each other to retain soil at the full depth of the trench (Hesselbarth et al '07: 139-140). Check dams are the best method to control erosion, however hikers prefer a smooth trail, with less than 5 percent grade, to steps; don't construct check dams until mud, washout or gullies warrant them.

7. Revegetation

Healthy forest tend to regenerate naturally after disturbances such as fire, windstorms, ice storms, avalanches, insect attacks, disease and grazing or browsing. The restorationist may need to reintroduce selectively missing, threatened, or under-represented species, particularly animals that have been

regionally exterminated or plant species whose seed tends to disperse slowly. The restorationist's overarching goal is the recreation of a fully functioning ecosystem that contains a species composition and diversity comparable to similar local ecosystems. If forest damage has been severe and sources of seed are depleted (both on living plants and in the soil seed bank) and no adjacent intact forest exists, then restoration may require some reseeding or replanting of trees as well as other ecosystem components, such as shrubs and other understory plants. The reintroduction of absent wildlife and the control of exotic species may also be necessary (Berger '08: 156-159). Revegetation can be accomplished passively or actively. Passive revegetation allows surrounding vegetation to colonize the abandoned trail. This process works when erosion has been stopped, precipitation is adequate, the tread has been scarified, and adjacent vegetation spreads and grows rapidly. Disturbed soil provides an opportunity for invasive plants to take hold. Active revegetation ranges from transplanting propagated native plants to importing genetically appropriate seed. Successful revegetation almost never happens in a single season. Plan carefully for best results (Harris et al '96).

Natural regeneration, if occurring, is generally preferable to artificial planting of either seeds of seedlings. Naturally regenerated trees tend to be more disease-resistant than artificially planted seeds. When natural regeneration for some reason is unreliable, then seeding with locally adapted native seed is preferable to nonlocal seed, and it is especially preferable to the seeds of genetically engineered "supertrees". These supertrees may grow quickly but they are likely to be genetically homogenous and, therefore, probably lack sufficient genetic variability to respond to future climatic and other stresses. Seeding versus planting seedlings or other container-grown plants allows for more natural microsite selection and natural root development. Nursery stock may suffer root deformity or damage if improperly grown or handled, and, even under the best of circumstances container-grown specimens will experience transplantation shock, which retards development. A tree that has been transplanted needs eight to ten years to be completely clear of shock (Berger '08: 143, 144, 146). Forest landscape restoration aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes. Forest landscape restoration is carried out under the assumption that improving the flow of forest goods and services requires a balance between livelihoods and nature protection, and that this is best achieved within dynamic, multifunctional landscapes. A restored landscape might consist of areas that are protected for watershed management and nature conservation, linked by regenerated native forests along rivers and streams. The landscape may also include well-managed natural or planted forests for production of wood, fruit and non-wood forest products for industrial purposes. Hardwoods can be grown from rooted cuttings, as is done with willows (*Salix* sp.) and poplars (*Populus* sp.), or they can be grown from seed, as is done for black walnut (*Juglans nigra*). The fastest growing sprouts usually develop high on the larger stump or buttress roots (Merrill ’96: 140).

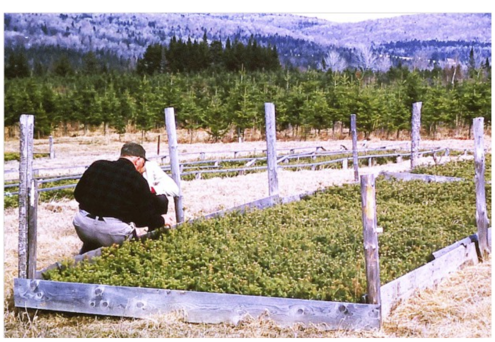
When natural methods fail, or when the complement of species desired in the new stand is not already present, clearcutting is usually followed by planting. The result is an even-aged stand managed to optimize stocking and growth rates. Artificial reproduction is the most common method of reproducing coniferous stands, especially when the new stand will feature early – and mid-successional species. This method can involve the application of seed, but most often two- to four year old seedlings are planted, usually by hand or – if the terrain is not too steep- by machine. Although hardwood stands almost never require replanting if natural methods are employed correctly (timing of treatments is always crucial), a growing number of woodland owners in the eastern United States have been experimenting with the establishment of small plantations of valuable hardwoods. The most serious risk to these plantings is browse damage from deer, but a seedlings can be grow in protective, opaque plastic tubes to protect buds from browsing and prolong the growing season. Planting ensures a new crop as soon after cutting as feasible and also allows the opportunity to improve growth rates and timber values by using genetically improved seedlings. In the years following World War II, the forest industry and the U.S. Forest Service invested heavily in tree-breeding programs that relied mostly on artificial methods in the coniferous forests of the West. Planting is also the predominant regeneration method on the pine lands of the Southeast. Although the artificial methods work well to quickly replace forest cover, the stands that result from these methods are dangerously uniform – in structure, species composition and DNA (McEvoy '04: 87, 88).

Eroding areas, such as stream banks and active landslides, or fires need to be stabilized mechanically or protected before other treatment. Stream and stream bank stabilization may be done with logs, root wads, wattling, erosion-control fabric, boulders and other types of bank armor. Local species found on stream banks before disturbance may need to be planted to ensure quicker regeneration under the threat of erosion or because successful natural regeneration by desired species is unlikely. Whereas fast-growing, short-lived species, such as alder, may provide a quick response to eroding stream banks (and will provide streams with needed inputs of leaf litter), in coniferous forests long-lived species that grow along waterways may also need to be interplanted along the bank is so that, over the long term, the waterways will benefit ecologically from large fallen trees that create pools for fish habitat. Unneeded roads should be closed, ripped with heavy machinery if necessary, and then planted. Other hardened and impermeable compacted soils may also need to be broken up. Trees and other species may need to be reseeded, and, where soils are lacking in natural microorganisms, the inoculation of some seed species or seedlings with nitrogen-fixing bacteria and mycorhizzal fungi may be advisable to improve rates of plant establishment. Shrub and tree seedlings may need to be planted there is an urgent need for erosion-prevention. Although, in general, plantations are vastly inferior to natural forests in their biodiversity and in their resistance to disease and pests (because of their uniformity) plantations are typically quite productive and efficient at producing desired tree species (Berger '08: 161-163).

Regeneration foresters stress minimizing cost per established seedling to provide an incentive for stand establishment rather than merely for a cheap reforestation effort. Natural regeneration has one primary advantage over artificial regeneration – little or no initial dollar outlay is required. One hundred percent survival is an attainable goal. It is common to compensate for mortality by planting more than the desired number of trees. Higher planting densities reduce the likelihood for replanting and replanting may be extremely costly. High planting densities, however, can result in overstocked plantations, reducing merchantable yields and values. Under the Oregon Forest Practices Act reforestation of clearcuts is mandatory unless land use is changed from forestry to some other enterprise. Successful artificial reforestation is influenced by the origin and condition of seed. Seed from similar, local sites has the best general adaptation to a site. Non-local seed may result in reduced yields and partial or complete failure of the plantation anytime during the rotation. Damaged seed or seed from cones collected at the wrong time have reduced vigor and viability. Cone storage conditions that are too warm and moist favor harmful molds. Seeds of some species have stratification requirements that must be met for rapid and vigorous germination. Seed viability can be prolonged under careful seed storage conditions. Seeds size is not a reliable indicator of resultant seedling size or vigor. Reforestation in the Pacific Northwest depends primarily on seeds –either for direct seeding or for planting nursery-grown seedlings. Insects, other animals, and certain chemicals may affect the quantity of viable seed. Proper identification of mature seed and cones is important because ones often open and shed seed just a few days after seeds are mature. Cone maturity may vary by more than a month between low and high elevations, and as much as 3 weeks between adjacent trees. Cone collection period in any one location should not be more than 2 to 3 weeks, but there are reports of top-quality seed collected more than a month after maturity. The intensity of cone harvest by squirrels indicates seed maturity. The cone collection period can be lengthened by collecting cones one to two weeks before anticipated seed maturity. Cones should be stored in a cool, moist environment until seed maturity. There is a reduction in seed germination with up to 3 months of storage in cones if storage conditions are carefully monitored and fungal growth prevented. Carefully handled mature seed is bright, compared to the dull and often dusty appearance of seed damaged by mechanical processing (Cleary '78: 41,43, 48, 225).

If planting is necessary, try to use locally grown and, therefore, locally adapted seed or plant stock. Even trees of the same species grown elsewhere in another region may not do as well as trees whose ancestors have been adapted to local conditions for hundreds, if not thousands, of years. While seeds are less expensive than seedlings, their survival is less certain. The smaller and younger the sprout, the more vulnerable it is to drought, shading and physical damage. Seeds are also susceptible to wildlife predation. Extra seed is normally planted in expectation of inevitable losses. To improve plant survival on inhospitable sites or where livestock or wildlife predation is expected, seedlings may benefit from extra help, including bud capping and caging (to protect against browsing), screening and shading to protect against full sun, mulching to help deter competing weedy vegetation, fertilization to compensate for soil deficiencies and watering or irrigation to aid plant establishment. Successful planting beings with the selection of healthy, undamaged, and pest-free stock. If using container stock, make sure the roots are neither circling nor kinked. When planting make sure the trees won't interfere with each other over time. Most trees should be six or eight feet apart. Allow for average seedling mortality, which is usually twenty-five percent or more (some experts put it as high as forty percent). Trees that have spreading foliage need to be planted farther apart than those that are more upright in form. Try to include some of the native understory plants, if these are missing from the ecosystem, particularly species with edible seedpods, fruits and nuts to support wildlife. If planting on a hill, insider whether the slope has a southern or northern exposure. Some trees are more shade-tolerant, but do poorly in full sun. Some trees will flourish in poorly drained soils while other drought-tolerant trees require the substrate to be well-drained (sandy). To maximize the chances of seedling or seed survival, competing brush, grasses and weeds need to be removed around the new plantings. Generally, planting should be done in late fall or early spring. Planting a small seedling from a tube with its plug of earth generally requires only a few deft strokes of a short hoe, planting bar, or shovel. A hole is dug and the seedling is inserted perpendicular to the horizontal plane of the soil, regardless of the grounds' slope. For proper tree growth, roots must have enough to hand straight down in the hole and must not be either jammed together, bent into a "J" or forced to circle the hole. The roots of a bare root seedling should be pruned to remove dead or damaged roots and then soaked overnight in water before planting. Avoid exposing roots to air, because tiny roots will dry out immediately and the tree will be harmed (Berger '08: 234, 235).

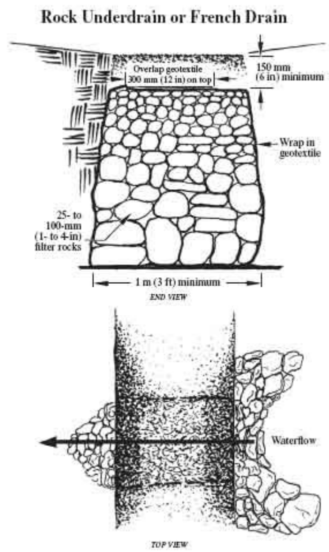
If planting a conifer, the tree should be buried just below the starts of the needles. Deciduous trees should be planted so that, when the soil settles, the top of the root crown will be flush with the soil level. Planting lower leads to root crown rot, and planting higher causes drying. A timed release fertilizer tab may be inserted in the bottom of the hole to aid the re in getting established. If the terrain is rocky, trees can be planted amongst rocks, provided that the hole is filled with soil and that water can drain through the rocks. If soil is very compacted, it may be necessary to auger or dig it out and then backfill soil into the hole, so that the tree's roots can penetrate the soil more easily. Once the tree is planted, soil is scraped back in to fill the hole, and the soil is tamped down around the seedling with the heel of one' boot to eliminate air pockets. If planting a well developed tree with soil from a pot or in a rootball, the hole needs to be correctly sized, and care must be taken to insure adequate contact between the rootball with its soil and the surrounding ground, so that the roots do not dry out. Container grown trees should have a temporary watering basin - a circular rim of earth built around the tree well beyond the circle formed by its outermost branches - to increase water percolation to the roots. Exposing the roots to air can dry and damage them, whereas piling soil against the trunk can lead to rot. In a hot, arid area, however, with sandy soil and occasional wet winters, it may be preferable to plant the tree slightly lower in the ground to collect moisture and avoid drying of the root collar. In some climates, natural rainfall may be sufficient to establish new trees with a high probability of success. Otherwise, the trees may require irrigation or individual watering deeply in the dry season, until their roots reach the damp soil of the water table or become hardy enough to depend on the vagaries of natural rainfall. After planting, stands of trees will benefit from weeding, brush control, thinning, improvement cutting (to remove defective trees, and pruning. Protection from uncontrolled and unwanted fire, insects, damage and disease may also be necessary (Berger '08: 235, 236).



If planting is a regular activity, owners may want to plant locally purchased seedlings in a transplant bed on the property, allowing them to grow for a season or two before outplanting. If the stock is infected or infested with invasive organisms, it is far easier to control in a transplant bed than in the field. To establish a transplant bed on a nonforest soil, cultivate the area in the same fashion as a garden (using a 6-by-6 inch spacing for seedlings) and apply at least one shovelful of soil from the forest area that is to be outplanted per 100 square feet of bed. The soil inoculates the transplant bed with favorable fungi and bacteria that the seedlings will encounter when outplanted. Nonnative species should never be introduced to natural forests. Homeowners should be educated about the dangers of planting nonnative species. When reseeding skid trails and landings, use only native grasses and forbs, preferably from local sources to reduce the chances of introducing exotics that are mixed in with seed. Mulch seeded areas with mulch hay should be from local sources that are known to be free of exotic species. If manure is used it must be from clean pastures. Horse manure is more likely to have noxious seeds

(McEvoy ’04: 188-189).

8. Turnpikes and puncheons

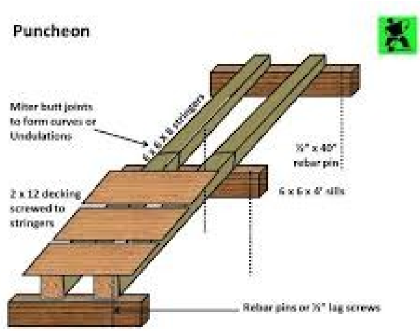


Because nearly every technique for fixing trails in boggy areas is expensive and needs to be repeated periodically, relocating the problem section of trail should be considered first. Scouting for suitable places to relocate trails and reviewing soil maps is time well spent. The alternative route should traverse the sideslope for better drainage. Moving up in cost and complexity, two types of structures—turnpikes and puncheon—are commonly constructed to keep trails dry through wet or boggy areas. A trail bridge may be needed in situations where long spans will be high above the ground or for crossing streams. Bridges require special designs fitted to each type of use. Engineering approval is needed before constructing either a standard or specially designed bridge. Boardwalks are common in some parts of the country, particularly in parts of Alaska and in the Southeast. They can range from fairly simple structures placed on boggy surfaces to elevated boardwalks over marshes or lake shores, such as those found at some interpretive centers. Rock underdrains (often called French drains) are ditches filled with gravel. They can be used to drain a spring or seep running across the trail. Wrap the gravel with geotextile to help prevent silt from clogging the rock voids. Start with larger pieces of rock and gravel at the bottom, topping off with smaller aggregate. Finish the drain with 150 millimeters (6 inches) of tread material so that the surface matches the rest of the trail. Wrapping rock underdrains with geotextile helps prevent them from clogging. Rock underdrains are used to drain low-flow springs and seeps (Hesselbarth et al '07: 70-74).

Geosynthetics are synthetic materials (usually made from hydrocar- bons) that are used with soil or rock in many types of road and trail construction. They have the tensile strength needed to support loads and can allow water, but not soil, to seep through. Geotextiles are often used when constructing turnpikes or causeways. The geotextiles separate the silty, mucky soil beneath the fabric from the mineral, coarse-grained, or granular soil placed as tread material on top of the geotextile. The importance of separation cannot be over- emphasized. It takes only about 20 percent silt or clay before mineral soil takes on the characteristics of mud—and mud is certainly not what you want for your tread surface. Most geotextiles commonly used in road construction work are suitable for trail turnpikes. The fabric should allow water to pass through, but have openings of 0.3 millimeter (0.01 inch) or smaller that silt can’t pass through. Geotextiles need to be carefully sized, trimmed, and sometimes fastened down before they are covered with fill. The fabric needs to be overlapped at joints and trimmed to fit over bedrock. The fabric must be covered with tread material (Hesselbarth et al '07: 72).

Turnpikes elevate a trail above wet ground. The technique uses fill material from parallel side ditches and from areas offsite to build up the trail base so it is higher than the water table. Turnpike construction can provide a stable trail base in areas with a high water table and fairly well- to well-drained soils. Turnpikes are practical for trail grades up to 10 percent. A turnpike should be used primarily in flat areas with wet or boggy ground that have up to 20-percent sideslope. Turnpikes are easier and cheaper to build than puncheon and may last longer. Begin your turnpike by clearing the site wide enough for the trail tread plus a ditch and retainer log or rocks on either side of the trail tread. Rocks, stumps, and stobs that protrude above the turnpike tread should be removed or at least cut below the final base grade. itch both sides of the trail to lower the water table. Install retainer rocks or logs. Use high-quality fill material. Firm mineral soil, coarse grained soils or granular material, or small, well-graded angular rocks are needed for fill. Often gravel or other well-drained material must be hauled in to surface the trail tread,. If good soil is excavated from the ditch, it can be used as fill. Fill the trail until the crown of the trail treat is 50 millimeters (2 inches) or has a minimum 2-percent grade above the retainers. It doesn't hurt for the fill to be a little too high to being with, because it will settle. Turnpike maintenance includes recrowning the tread, cleaning out the ditches, and making sure the ditches are deep enough. A turnpike without ditches is sometimes called a causeway. These structures are viable alternatives where a hardened tread is needed and groundwater saturation is not a problem. Turnpikes without ditches have been used successfully throughout the Sierra Nevada and elsewhere to create an elevated, hardened tread across seasonally wet alpine meadows. The surface can also be reinforced with large stones, called armoring, paving, or flagstone. Often multiple parallel paths are restored and replaced with a single causeway. These structures can create less environmental impact than turnpikes with ditches because they do not lower the water table. The risk is that in highly saturated soils the turnpike without ditches could sink into the ground, a problem that geotextile can help prevent (Hesselbarth et al '07: 75-81).

When the ground is so wet the trail cannot be graded and there's no way to drain the trail, use puncheon. Puncheon is a wooden walkway used to cross bogs or deep muskeg, to bridge boulder fields, or to cross small streams. Puncheon resembles a short version of the familiar log stringer trail bridge. It consists of a deck or flooring made of sawed, treated timber or native logs placed on stringers to elevate the trail across wet areas that are not easy to drain. Puncheon that is slightly elevated is termed standard puncheon. The entire structure must extend to solid mineral soil so soft spots do not develop at either end. Approaches should be straight for at least 3 meters (10 feet) coming up to the puncheon. Any curves either approaching or on the puncheon add to the risk of slipping, especially for stock, mountain bike riders, and motorcycle riders. To begin construction, install mud sills to support the stringers. Mud sills can be made of native logs, treated posts, short treated planks, or precast concrete parking lot wheel blocks. The mud sills are laid in trenches at both ends of the area to be bridged at intervals of 1.8 to 3 meters (6 to 10 feet). They are about two-thirds buried in firm ground. If firm footing is not available, use rock and fill to solidify the bottom of the trench, increase the length of the sill log to give it better flotation, or use more sills for enough floatation. Enclosing rock and fill in geotextile minimizes the amount of rock and fill required. For stability, especially in boggy terrain, the mud sills should be as long as practical, up to 2.5 meters (8 feet) long (Hesselbarth et al '07: 81-86).



Stringers made from 200-millimeter- (8-inch-) diameter peeled logs or treated timbers are set on top of the mud sills. They should be at least 3 meters (10 feet) long and about the same length and diameter. Stringers also need to be level with each other so the surface of the puncheon will be level when the decking is added. Two stringers are adequate for hiking trails, but for heavier traffic, such as packstock, three stringers are recommended. Notch the mud sills, if necessary, to stabilize the stringers and to even out the top surfaces. To hold the stringers in place, toe- nail spikes through the stringers to the mud sills or drive No. 4 rebar through holes in the stringers (Hesselbarth et al '07: 81-86). Decking pieces are fastened perpendicular to the stringers. The decking thickness will vary, depending on the loads the structure will need to support. Decking can be as short as 460 millimeters (18 inches) for a limited-duty puncheon for hikers. For stock or ATV use, decking should be 1.2 to 1.5 meters (4 to 5 feet) wide. Do not spike decking to the center stringer, if you have one, because center spikes may work themselves up and become obstacles. Leave at least a 20-millimeter (3⁄4-inch) gap between decking pieces to allow water to run off. Decking should be placed with tree growth rings curving down. This encourages water to run off rather than soak in and helps to prevent cupping. Running planks are often added down the center for stock to walk on. Often the running planks are untreated because horseshoes wear down the plank before wood has a chance to rot. Do not leave gaps between running planks because they can trap mountain bike or motorcycle wheels. Curbs, also called bull rails, should be placed along each side of the puncheon for the full length of the structure to keep traffic in the center. To provide for drainage, nail spacers between the curb logs and the decking. Finally, a bulkhead (sometimes called a backing plate) needs to be put at each end of the structure to keep the stringers from contacting the soil. If the plate stays in place, do not spike it to the ends of the stringers. Spiking causes the stringers to rot faster (Hesselbarth et al '07: 81-86).

Subsurface puncheon is used in standing water or bogs. It is constructed with mud sills, stringers, and decking flush with or under the wetland's surface. This design depends on continual water saturation for preservation. Moisture, air, and favorable temperatures are needed for wood to rot. Remove any one of these and wood won't rot. A good rule for reducing rot is to keep the structure continually dry or continually wet. Totally saturated wood will not rot because no air is present. Cover the surface between the curb logs with a layer of gravel, wood chips, or soil to help keep everything wet. Corduroy is basically a primitive type of puncheon. It consists of three or more native logs laid on the ground as stringers with logs laid side- by-side across them and nailed in place. Corduroy should always be buried, with only the side rails exposed. Corduroy is notorious for decaying quickly and consuming large amounts of material. It should be used only as a temporary measure and is not recommended for new construction. The use of corduroy may indicate that your trail has been poorly sited (Hesselbarth et al '07: 87 – 88).

9. Fords and Bridges

Bridges are expensive. Wilderness visitors who expect a challenge may prefer a shallow stream ford. During high water, these folks may opt for a tightrope walk across a fallen log. A shallow stream ford is a consciously constructed crossing that will last for decades with a minimum of maintenance (barring major floods) and will provide a relatively low challenge to users. The idea behind a shallow stream ford is to provide solid footing at a consistent depth from one bank to the other. Most fords are designed to be used just during low to moderate flows. A ford for hikers and packstock, such as llamas and pack goats, should be no deeper than 400 to 600 millimeters (16 to 24 inches, about knee high) during most of the use season. A horse ford shouldn't be deeper than 1 meter (39 inches). Fords should be located in wider, shallower portions of the stream. The approaches should climb a short distance above the typical high water line so that water isn't channeled down the tread (figure 57). Avoid locations where the stream turns, because the water will undercut approaches on the outside of a turn. The tread in the ford should be level, ideally made of rock or medium- sized gravel that provides solid footing. The plan is to even out the waterflow through the ford so the gravel-sized material isn't washed away, leaving only cobble or boulders. Make sure you don't block passage for fish and other aquatic organisms. Well-constructed shallow stream fords are almost maintenance free. Watch for deep spots developing in the crossing. Floods or seasonal runoff can wash away the approaches. Debris can be trapped in the line of stepping stones, altering flow characteristics. Approaches can erode or turn into boggy traps. Maintenance consists of retaining or restoring an even, shallow flow and solid footing. When working in streams, consult the land manager and a fishery biologist to find out what you can and cannot do (Hesselbarth et al '07: 90-92).

Culverts are probably the best way to move small volumes of water under a trail (figure 59). The tread extends over the culvert without interruption. Metal or plastic culverts can be installed easily, or culverts can be constructed out of rock. To install metal or plastic culverts, dig a ditch across the trail as wide as the culvert and somewhat deeper. Bed the culvert in native soil shaped to fit it. There needs to be enough drop (about 3 percent) from one side of the trail to the other to keep water flowing through the culvert without dropping sediment. The culvert needs to be covered with 150 millimeters (6 inches) or more of fill. Cut the culvert a little longer than the trail's width, and build a rock facing around each end to shield the culvert from view and prevent it from washing loose. Often a rock-reinforced spillway will reduce headcutting and washouts on the downhill side of the culvert. The local trail manager may have definite preferences for metal, plastic, wood, or rock culverts. Synthetic materials may be taboo in wilderness. Plastic is lighter than metal, easy to cut, and less notice- able. Aluminum or plastic are preferred over steel in acidic soils. Painting the ends of aluminum or steel culverts helps camouflage them. A culvert should be big enough to handle maximum storm runoff and allow it to be cleaned easily. Usually this means the culvert should be at least 260 millimeters (9 inches) in diameter. Rock culverts offer workers a chance to display some real trail building skills (figure 60). Begin by laying large, flat stones in a deep trench to form the bottom of the culvert. In some installations, these rocks may not be necessary. Then install large, well-matched stones along either side of the trench. Finally, span the side rocks with large, flat rocks placed tightly together so they can withstand the expected trail use. Cover the top rocks with tread material to hide and protect the culvert. These culverts need to be large enough to clean out easily. The rocks should not wiggle. Water flowing toward a culvert often carries a lot of silt and debris. If the water slows as it goes into the culvert, the silt and debris may settle out, clogging the culvert. A good way to help prevent this problem is by constructing a settling basin at the inlet to the culvert. This basin should be at least 300 millimeters (1 foot) deeper than the base of the culvert. Sediment will settle out in the basin, where it is much easier to shovel away, rather than inside the culvert (Hesselbarth et al '07: 93-95).

Trail bridges range from a simple foot bridge with a handrail to multiple span, suspended, and truss structures. In the Forest Service, handrails are required on all bridges unless an analysis (design warrant) shows that the risk of falling off the bridge is minimal or

the trail itself presents a higher risk. All bridges require a curb. On hiking trails, log footbridges can be used to cross streams or to provide access during periods of high runoff. Log foot- bridges consist of a log, sills, and bulkheads. The log needs drainage and airspace to keep it from rotting. The foot log should be level and well anchored. Notch the sill—not the log—when leveling the foot log. The foot log should be no less than 457 millimeters (18 inches) in diameter. The top surface should be hewed to provide a walking surface that is at least 250 millimeters (10 inches) wide. Don't let the log or rails sit on the bare ground. Remove all bark from logs and poles. If the foot log is associated with a shallow stream ford, be sure to position the log upstream or well downstream of the ford. Logs immediately below the crossing can trap travelers who lose their footing in the ford. Most untreated logs of a durable wood (like coastal Douglas- fir) have a useful life of less than 20 years. Yet it may take 100 years for a log to grow big enough to support foot traffic and winter snow. The typical bridge has three to four stringers. Multiply this replacement-to-growth ratio by several replacement cycles and you can see how it's possible to create a slow-motion clearcut around a bridge site. Often, materials are imported to avoid the problem of "clearcuts" near the bridge. Pressure-treated wood, metal, concrete, wood laminates, and even fiber-reinforced polymers are being used in bridges. The cost of transporting durable materials may be less than the cost of frequently rebuilding structures made with native materials. It's possible to mix-and-match steel or other "unnatural but hidden" components with wood facing and decking to achieve a natural appearance. Unless your bridge is preassembled and flown right onto a prepared set of abutments, you'll end up moving heavy materials around the bridge site. Be careful not to allow winch guylines and logs to scar trees and disturb the ground. Damage done in a moment can last for decades.
Other types of trail bridges include multiple-span, suspended, and truss structures. A two-plank-wide suspended footbridge with cable handrails is more complex than it looks. Midstream piers for multiple span structures need to be designed by qualified engineers to support the design loads and to withstand the expected flood events. Loose decking, planking, curbs, or handrails should be repaired as soon as possible. Clean debris and organic material from all exposed wood surfaces on the bridge or supporting structures. Structural members should be checked for shifting, loose, or missing spikes or bolts. Approaches need to be well drained so water does not run onto the bridge. The Forest Service requires all bridge structures to be inspected by a certified bridge inspector at least every 5 years (Hesselbarth et al '07: 98-100).

10. Trail signs

Trail signs comes in two forms. Trailhead and junction signs are used to identify trail names, directions, destinations, and distances. Reassurance markers are used to mark the trail corridor when the tread may be difficult to follow. road crossings) to identify each trail by name and indicate its direction. Signs may identify features, destinations, and occasionally, regulations, warnings, or closures. Reassurance markers include cut blazes on trees; wood, plastic, or metal tags; posts; and cairns. Reassurance markers are more useful as the tread becomes more difficult to identify and follow. These markers help travelers identify the trail corridor when the tread is indistinct, the ground is covered with snow, or when the route is confused by multiple trails or obscured by weather, such as dense fog. National trails usually are marked periodically with specially designed tags. Trail signs are made of a variety of materials; the most typical is Carsonite or wood. Usually, signs are mounted on posts or trees. Signs in rocky areas should be mounted on a post seated in an excavated hole or supported by a well-constructed cairn. Wooden posts may be obtained onsite or hauled in. Onsite (native) material is usually less expensive, but may have a shorter useful life. Native material looks less artificial; it may be preferred in primitive settings. Purchased posts should be pressure treated. Their longer lifespan will offset the higher initial purchase and transportation costs. Round posts appear less artificial than square posts and provide more options for custom alignment of signs at trail junctions (Hesselbarth et al '07: 134).

Posts should be at least 150 millimeters (6 inches) in diameter. Signs should be placed where they are easy to read, but far enough from the tread to leave clearance for normal traffic. The key to placing solid posts is to tamp the rock and soil with a rockbar as you fill the hole. Signs should have holes already drilled so they can be attached to the post. Level each sign and secure it with galvanized lag screws or, better yet, through-bolts that have a bolt head and washer on one side and a washer and nut on the other. Galvanized hardware reduces rust stains on the sign. New wood preservatives like ACQ (alkaline copper qua- ternary compound) are highly corrosive to aluminum and carbon steel. Use triple-dipped galvanized fasteners. Galvanized washers should be used between the head of the screw and the sign face to reduce the potential for the sign to pull over the screw. In areas where sign theft is a problem, use special theft-prevention hardware. The bottom edge of signs should be set about 1.5 meters (60 inches) above the tread. The sign's top edge should be 50 millimeters (2 inches) below the top of the post. 123-128 Sign maintenance consists of remounting loose or fallen signs, repairing or replacing signs, and resetting or replacing leaning, damaged, rotting, or missing posts (Hesselbarth et al '07: 134).

Blazers (sometimes called marker tags) are used when higher visibility is desired and esthetic considerations are not critical. The most common tags are colored diamonds of plastic or metal, reflective for night use or nonreflective when called for in the trail management plan. Various colors are used. These tags should be mounted on trees using aluminum nails. Allow 12 millimmeters (1⁄2 inch) or so behind the tag for additional tree growth. Directional arrows, where appropriate, should be placed in a similar fashion. Markers also can be mounted on wooden or fiberglass posts. Painted blazes are sometimes used. Be absolutely sure to use a template of a size and color specified in your trail management plan. Don't let just anyone start painting blazes. Cairns are used in open areas where low visibility or snow cover makes it difficult to follow the tread or where the tread is rocky and in- distinct. Two or three stones piled one on top of the other—sometimes called rock ducks—are no substitute for cairns and should be scattered at every opportunity. Cairns are similar in construction to rock cribs and consist of circular tiers of stones. Make the base of the cairn wide enough to provide enough batter for stability. Cairns should be spaced closely enough that the next cairn is visible in either direction from any given cairn during periods of poor visibility (such as dense fog). In some settings, guide poles are more effective than cairns. They are most useful in snowfield crossings to keep traffic in the vicinity of the buried trail. Guide poles should be long enough to extend about 2 m (6.5 ft) above the top of the snowpack during the typical season of use. Guide poles should be at least 100 mm (4 in) in diameter. They should be sturdy enough to withstand early season storms before the snow can support them and to withstand pressures from snow creep later in the season. Avoid placing guide poles in avalanche paths. Don't mark trails for winter travel if they cross known avalanche paths. Guide poles are also used in large meadows where tall grasses make cairns hard to spot, or where there is too little stone for cairns (Hesselbarth et al '07: 128-133).

11. International Dark Sky Places

Light pollution is increasing around the globe. More than 80 per cent of the world's population is currently estimated to live under a “lit sky”, a figure closer to 99 per cent in Europe and North America. The amount of artificial light on the Earth’s surface is increasing by at least 2 per cent each year and could be much greater. Light pollution is a significant and growing threat to wildlife including many species of migratory birds. Every year, light pollution contributes to the death of millions of birds. It alters the natural patterns of light and dark in ecosystems. It can change birds' migration patterns, foraging behaviours, and vocal communication. Attracted by artificial light at night, particularly when there is low cloud, fog, rain or when flying at lower altitudes, migrating birds become disorientated and may end up circling in illuminated areas. Depleted energy reserves put them at risk of exhaustion, predation, and fatal collision with buildings.

The United Nations Environment Program Convention on Migratory Species Resolution 13.5 Light Pollution Guidelines for Wildlife, was adopted on February 2020 in Gandhinagar, set forth six principles of best lighting practices and call for Environmental Impact Assessments for relevant projects that could result in light pollution. These should consider the main sources of light pollution at a certain site, the likely wild species that could be impacted, and facts about proximity to important habitats and migratory pathways. New guidelines focusing on migratory landbirds and bats are currently being developed (Keil '22). Artificial light can disrupt critical behaviour and cause physiological changes in wildlife . For example, hatchling marine turtles may not be able to find the ocean when beaches are lit , and fledgling seabirds may not take their first flight if their nesting habitat never becomes dark . Tammar wallabies exposed to artificial light have been shown to delay reproduction and clownfish eggs incubated under constant light do not hatch. Consequently, artificial light has the potential to stall the recovery of a threatened species. For migratory species, the impact of artificial light may compromise an animal’s ability to undertake long-distance migrations integral to its life cycle. These Guidelines take an outcomes approach to assessing and mitigating the effect of artificial light on wildlife**.** The Annex to Resolution 13.5 by the Australian Government Department of the Environment and Energy Department of Biodiversity, Conservation and Attractions National Light Pollution Guidelines for Wildlife Including marine turtle, seabirds and migratory shorebirds version 1.0 was published on January 2020. Pursuant to Decision 13.138(a) to 13.139 – Light Pollution Guidelines for Wildlife – have been selected to be the topic of World Migratory Bird Day, celebrated in both May and October each year, in spring 2022.

Natural darkness has a conservation value and should be protected through good quality lighting design and management for the benefit of all living things. To that end, all infrastructure that has outdoor artificial lighting or internal lighting that is externally visible should incorporate best practice lighting design. Best practice lighting design incorporates the following design principles. Start with natural darkness and only add light for specific purposes. Use adaptive light controls to manage light timing, intensity and colour. Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill. Use the lowest intensity lighting appropriate for the task. Use non-reflective, dark-coloured surfaces. Use lights with reduced or filtered blue, violet and ultra-violet wavelengths. Use light information, wildlife biological and ecological information, and proposed mitigation and light management, assess the risk of impact of artificial light to wildlife. Exterior lighting for public, commercial or industrial applications is typically designed to provide a safe working environment. Lighting may also be required to provide for human amenity or commerce. Conversely, areas of darkness, seasonal management of artificial light, or minimized sky glow may be necessary for wildlife protection, astronomy or dark sky tourism.

Less than 100 years ago, everyone could look up and see a spectacular starry night sky. Now, millions of children across the globe will never experience the Milky Way where they live. The inappropriate or excessive use of artificial light – known as light pollution – can have serious environmental consequences for humans, wildlife, and our climate. Components of light pollution include: Glare – excessive brightness that causes visual discomfort. Skyglow – brightening of the night sky over inhabited areas. Light trespass – light falling where it is not intended or needed. Clutter – bright, confusing and excessive groupings of light sources. This light, and the electricity used to create it, is being wasted by spilling it into the sky, rather than focusing it on to the actual objects and areas that people want illuminated. traditional industrial lighting should remain illuminated all night because the High-Pressure Sodium, metal halide, and fluorescent lights have a long warm up and cool down period. This could jeopardise operator safety in the event of an emergency. With the introduction of smart controlled LED lights, plant lighting can be switched on and off instantly and activated only when needed, for example, when an operator is physically present within the site. All light fittings should be located, directed or shielded to avoid lighting anything but the target object or area to precent light spill. Only use lighting when and where it's needed. If safety is concern, install motion detector lights and timers. Properly shield all outdoor lights. Keep your blinds drawn to keep light inside. Become a citizen scientist and help measure light pollution.

The award-winning International Dark Sky Places (IDSP) Program was founded in 2001 to encourage communities, parks and protected areas around the world to preserve and protect dark sites through responsible lighting policies and public education. As of January 2022, there are 195 certified IDSPs in the world. International Dark Sky Communities are legally organized cities and towns that adopt quality outdoor lighting ordinances and undertake efforts to educate residents about the importance of dark skies. International Dark Sky Parks are publicly- or privately-owned spaces protected for natural conservation that implement good outdoor lighting and provide dark sky programs for visitors. International Dark Sky Reserves consist of a dark "core" zone surrounded by a populated periphery where policy controls are enacted to protect the darkness of the core. International Dark Sky Sanctuaries are the most remote (and often darkest) places in the world whose conservation state is most fragile. Urban Night Sky Places (UNSPs) are sites near or surrounded by large urban environs whose planning and design actively promote an authentic nighttime experience in the midst of significant artificial light at night, and that otherwise do not qualify for designation within any other International Dark Sky Places category. After reviewing the guidelines, applicants can start the designation process by submitting an inquiry for their site. From there, IDA staff will provide an initial assessment of the site's eligibility and next steps for the applicant. If deemed eligible based on Program criteria, the applying place will be given a link to pay a non-refundable pre-application fee of USD 250.00. Once the application is complete, the applicant must notify the IDSP Program Manager of their intention to submit a finished draft of their application for review. Following, after the application has been reviewed and deemed to meet all of the relevant Program requirements by the Director of Conservation, it is submitted to the IDA Dark Sky Places Committee (DSPC). The DSPC judges the quality of the application and assesses whether the nomination is awarded the official certification. The entire process takes, on average, 1-3 years from initial inquiry to the formal designation.

Appendix

Tools

Clinometers—A clinometer, called a clino by trail workers, is a simple, yet useful, instrument for measuring grades. Most clinometers have two scales, one indicating percent of slope, the other showing degrees. Percent slope, the relationship between rise or drop over a horizontal distance, is the most commonly used measure. Percent readings are found on the right hand side of the scale. Don't confuse percent and degree readings. It is easy to do! Expressed as an equation: Percent of Grade = Rise x 100 percent Run A section of trail 30 meters (100 feet) long with 3 meters (10 feet) of difference in elevation would be a 10-percent grade. A 100-percent grade represents 45 degrees. Traditionalists often prefer an Abney level to a clinometer. They are easier to see through and there are no measurements to read.

Global Positioning Systems (GPS)—Most trail surveyors are using GPS receivers for accurate trail location, inventory, and contract preparation. Real-time correction is no longer necessary and prices have fallen. GPS is becoming the norm for locating trails.

Tape Measures—Get a tape measure with metric units. Mark off commonly used measurements on your tool handles. Know the length of your feet, arms, fingers, and other rulers that are always handy on the trail. Calibrate the length of your pace over a known course so you can easily estimate longer distances.

Sawing

Bow Saws—These saws are useful for clearing small downfall and for limbing. They consist of a tubular steel frame that accepts replaceable blades. The blades can be removed by loosening a wing nut or releasing a throw clamp.

Chain Saws—A chain saw can make short work of your cutting tasks—but it is not for wilderness use. Specialized instruction and certification are required, so make sure you are certified before operating a chain saw.

Crosscut Saws— Symmetric crosscut saws, those de- signed for a sawyer at either end, follow two basic patterns. Felling crosscuts are light, flexible, and have concave backs that conform easily to the arc of the cut and the sawyer's arm. The narrowed distance between the teeth and back leaves room for sawyers to get wedges into the cut quickly. Bucking crosscuts have straight backs and are heavier and stiffer than felling saws. Bucking saws are recommended for most trail work because they are more versatile. Bucking saws also are available as asymmetric saws, with a handle at one end that can be used by a single sawyer. Cover the blades with sections of rubber-lined firehose slit lengthwise. Velcro fasteners make these guards easy to put on and take off. When carrying a saw, lay it flat across one shoulder with a guard covering the teeth. The teeth need to face away from the neck. Don't leave a wet guard on a saw. A sharp crosscut saw is a pleasure to operate, but a dull or incorrectly filed saw is a source of endless frustration, leading to its reputation as a misery whip. Never sharpen a saw without a saw vise and the knowledge to use it. Field sharpening ruins crosscut saws.

Pruning Saws—Pruning saws are useful for limbing, some brushing, and removing small downfall, especially where space is limited and cutting is difficult. Folding pruning saws are handy.

Axes—Axes are of two basic types: single or double bit. Double-bit axes have two symmetrically op- posed cutting edges. One edge is maintained at razor sharpness. The other edge usually is somewhat duller, because it is used when chopping around rocks or dirt. Mark the duller edge with a spot of paint. Before chopping with an ax, check for adequate clearance for your swing. Remove any underbrush and overhanging branches that might interfere. Be sure your footing is stable and secure. Chop only when you are clear of other workers. Stand comfortably with your weight evenly distributed and both feet planted shoulder-width apart. Measure where to stand by holding the handle near the end and stretching your arms out toward the cut. You should be able to touch the blade to the cut. Begin chopping by sliding your forward hand within 150 millimeters (6 inches) of the axhead. As you swing, your forward hand slides back down the handle to the other hand. Just after impact, give the handle a slight twist to pop severed wood out of the cut.

The combination or combi tool is basically a military entrenching tool on a long handle, developed for firefighting. It serves as a light-duty shovel and scraper.

Fire Rakes (Council Tools)—The fire rake is another fire tool widely used for trail work, especially in the East.

Hoes—Use an adze hoe, grub hoe, or hazel hoe to break up sod clumps when constructing new trail or when leveling an existing trail tread. These hoes also are useful in heavy duff. They generally work better than a Pulaski.

Mattocks—The pick mattock is often recommended as the standard tool for trail work. For many applications, it is much better than a Pulaski. It has a point- ed tip for breaking rocks and a grubbing blade for working softer materials. The grubbing blade also may be used to cut roots or remove small stumps. With the edge of the tool, you can tamp dirt and loose rocks or smooth a new tread. A pick mattock can be used to pry rocks without fear of breaking a handle. Two people working with pick mattocks may not need to carry rock bars. Maintain good cutting edges on mattocks. Sharpen grubbing blades to maintain a 35-degree edge bevel on the underside. Sharpen pick ends as you would a pick, and maintain factory bevels on cutter blades.

The McLeod combines a heavy-duty rake with a large, sturdy hoe. McLeods work well for constructing trails through light soils and vegetation or for reestablishing tread when ma- terial from the backslope sloughs onto the trail. A McLeod is essential for compacting tread and is helpful for checking outslope. If you hate leaving a bolt impression in your compacted tread, remove the bolt that secures the toolhead and weld the head to the mounting plate. McLeods are inefficient in rocky or unusually brushy areas.

Picks—Pick heads have a pointed tip that can break up hard rock by forcing a natural seam. They also have a chisel tip for breaking softer materials. Work the pick as you would the hoe on a Pulaski with short, deliberate, downward strokes. Avoid raising the pick overhead while swinging. Always wear safety goggles while using a pick to protect yourself from flying rock chips. Use a grinder or mill bastard file to sharpen the pointed tip to a 3-millimeter (1⁄8-inch) square. When sharpening the chisel tip, maintain the factory bevel.

Pulaskis—The Pulaski combines an ax and a grub hoe into a multipurpose firefighting tool. It isn't as good as a hoe or mattock for grubbing, nor is it as good as an ax for chopping. It is a popular trail tool, mostly because it is widely available and easier to carry than several single- purpose tools. When using the hoe end of a Pulaski, stand bent at the waist with your back straight and parallel to the ground, knees flexed, and one foot slightly forward. Hold the handle with both hands so the head is at an angle to your body, and use short, smooth, shallow swings. Let the hoe hit the ground on its corner. Use the ax end to chop large roots after the dirt has been cleared by the hoe. Always wear safety goggles while grubbing to protect yourself from flying chips of rock and dirt. Carry the Pulaski at your side. Grip the handle firmly near the head and point the ax end away from your body and down. Sharpen the cutting edge of the Pulaski's ax as you would any other ax. When sharpening the Pulaski's hoe end, maintain the existing inside edge bevel. Never sharpen the top of the hoe.

Stump Grinders—If you have lots of stumps to remove, consider buying or renting a gasoline-powered stump grinder. These portable grinders are powered by a chain saw motor and have carbide teeth that can be sharpened or replaced. They grind through a stump in much less time and with a whole lot less frustration than would be needed to dig the stump out.

Digging and Tamping Bars—A digging and tamping bar is about the same length as a rockbar, but much lighter. It is designed with a chisel tip for loosening dirt or rocks and a flattened end for tamping. These bars are not prying tools.

Shovels—Shovels are available in various blade shapes and handle lengths. The common, or round-point, shovel weighs between 2.3 and 2.7 kilograms (5 and6 pounds). Its head measures about 200 by 300 millimeters (8 by 12 inches). If a shovel feels too heavy or large, choose a smaller version—remember, you have to lift everything the head holds. The square shovel is a flat-bottomed model intended for shoveling loose materials, not digging. When scooping materials, bend your knees and lift with your legs, not your back. Push the shovel against your thigh, which serves as a fulcrum. This makes the handle an efficient lever and saves your energy and your back. Don't use the shovel to pry objects out of the trail—that's a job for a pick and a pry bar.

Tools for Brushing

Bank Blades and Brush Hooks—Bank blades and brush hooks are designed specifically for cutting through thickets of heavy brush or sap- lings. Use them for clearing work that is too heavy for a scythe and not suited for an ax.

Lopping Shears and Pruning Shears—Lopping and pruning shears are similar in design and use. Lopping shears have long handles and may have gears to increase leverage for thicker stems. Pruning shears are small enough to fit in one hand and are designed to cut small stems and branches. Cutting edges vary, but generally one blade binds and cuts a stem against an anvil or beveled hook. We recommend the hook and blade shear for overhead cuts because the curved blades transfer the weight of the shears to the limb. Lopping and pruning shears do a better job of making a nice clean cut than hand saws or axes.

Power Weed Cutters—Several manufacturers make "weed whackers," motorized weed cutters that use plastic line to cut weeds. Some have metal blades that substitute for the line. These can be a good option for mowing grass and weeds on trails. Follow the manufacturer's instructions for safe use and operation. Eye protection is especially important.

Swedish Brush (Sandvik) Axes—These clearing tools work well in brushy thickets or in rocky or confined areas.

Weed Cutters (Grass Whips)—Weed cutters are used for cutting light growth like grasses and an- nual plants that grow along trails. They are lightweight and durable and usually are swung like a golf club.

Tools for Pounding and Hammering

Hand-Drilling Hammers—Hand-drill- ing hammers are used to drill steel into rock or to drive wedges and feathers into cracks or drilled holes. There are two types of hand-drilling hammers—single jacks and double jacks.

Sledge Hammers—Sledge hammers have heads forged from heat-treated high carbon steel; they weigh from 3.6 to 9 kilograms (8 to 20 pounds). Driving sledges are used to set heavy timbers and drive heavy spikes or hardened nails. Stone sledges are used to break boulders or concrete. Because of differences in tempering, these tools are not interchangeable.

Tools for Lifting and Hauling

Block and Tackle—A block and tackle is a set of pulley blocks and ropes used for hoisting or hauling. They come in different styles, sizes, and capacities.

Canvas Bags—Heavy-duty canvas bags sold to carry coal are great for dirt, small rocks, and mulch. They are more durable than similar-looking shopping bags.

Motorized Carriers—If your budget and regulations allow, consider a motorized carrier. They come in various configurations and typically feature a dump body. A trailer pulled behind an all-terrain vehicle may be an alternative to a motorized carrier.

Packstock Bags and Pan- niers—Fabric bags or hard-sided panniers with drop bottoms work well when packstock are used to carry trail construction materials.

Rockbars—Use a rockbar (also called pry bar) for lifting or skidding large, heavy objects. These bars are heavy duty. They have a chisel tip on one end. The other end can be rounded or pointed. Place the tip of the chisel under the object to be moved. Wedge a log or rock between the bar and the ground to act as a fulcrum. Press the handle down with your weight over your palms. Never straddle the bar when prying. When the object raises as much as the bite allows, block it and use a larger fulcrum or shorter bite on the same fulcrum to raise the object farther. The rounded end of a rockbar is great for compacting material into rock cracks when armoring trail. You can use the pointed end to break large rocks by jabbing the point into a crack and twisting.

Tools for Peeling and Shaping

Bark Spuds (Peeling Spuds)—Use a bark spud to peel green logs. Have the log about hip high. Hold the tool firmly with both hands and push the dished blade lengthwise along the log under the bark. Always peel away from your body. Its three sharpened edges make this tool unusually hazardous to use and transport.

Drawknives—A draw- knife works best to peel dry logs. Position the log about waist high, and grasp both handles so the beveled edge of the blade faces the log. Begin each stroke with arms extended and pull the tool toward you while keeping even pressure on the blade. Keep your fingers clear of the blade's corners.

Tools for Sharpening

Inspect all tools before use. Sharpening makes tools last longer. A small scratch that is ignored could lead to a serious crack or nick in the blade. Use a file or grindstone to remove metal from a dull edge. If there are no visible nicks, a touchup with a whetstone will restore a keen cutting edge. In these instances, you need only restore the edge bevel. Whetting the edge removes very small bits of metal from the blade and causes the remaining metal to burr slightly on the cutting edge. This burr is called a feather, or wire edge. Remove this weak strip by honing the edge on the other side. The correctly honed edge is sharp, does not have a wire edge, and does not reflect light or show a sharpening line. Wear gloves when sharpening cutting edges. Restoring the blade bevel requires coarser grinding tools to reshape worn cutting blades. Reshape blades with hand files, sandstone wheels, or electric grinders. Remove visible nicks by grinding the metal back on the blade. Remember that the correct blade bevel must be maintained. If the shape can't be maintained, have a blacksmith recondition the toolhead or discard it. If a cutting edge is nicked by a rock, it may be work hardened. A file will skip over these spots and create an uneven edge. Use a whetstone or the edge of a bastard file to reduce the work-hardened area, then resume filing. Alternate using a whetstone and the file until the file cuts smoothly over the entire length of the edge.

Files—Files come in single or double, curved or rasp cuts. Single-cut files have one series of parallel teeth angled 60 to 80 degrees from the edge; they are used for finishing work. Double-cut files have two series of parallel teeth set at a 45-degree angle to each other; they are used for restoring shape. Curved files are used for shaping soft metals. Rasp-cut files are used for wood. Files are measured from the point to the heel, exclud- ing the tang (the tip used to attach a handle). File coarseness is termed bastard, second cut, or smooth. The bastard will be the coarsest file available for files of the same length. A 254-millimeter (10-inch) mill bastard file is good for all-around tool sharpening. Before filing, fit the file with a handle and knuckle guard. Always wear gloves on both hands. Secure the tool so both hands are free for filing. Use the largest file you can. Remember that files are designed to cut in one direction only. Apply even pressure on the push stroke, then lift the file up and off the tool while returning for another pass. Store or transport files so they are not thrown together. Protect them from other tools as well. An old piece of fire hose sewn shut on one end makes a great holder for several files, a guard, and a handle.

Mechanized Trail Building Equipment

Grading Equipment—Several types of graders that can be pulled with ATVs work well for maintaining wider trails used by motorized traffic. MTDC has designed a rock rake to fit on an ATV for trail work. An experienced operator can use small mechanized equipment to make wonderful singletrack trails. Such equipment also is great for constructing wider trails for motorized traffic and packstock. A Web site showing a variety of small mechanized equipment and attachments for trail work can be found at: *http://www.fhwa.dot.gov/ environment/equip/.*

Mini Excavators—Mini excavators can excavate tread and move mate- rial and rocks from place to place. They are even more popular with trail contractors than dozers, because dozers can only push material. Excavators can dig and move material. Mini excavators are available from many manufacturers.

Trail Dozers—Trail-sized dozers are becoming more common for cutting singletrack trail. When an experienced operator follows a good design, the trails built by a dozer are impressive.

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Woody Hesselbarth maintained his sense of humor throughout a 5-year battle with cancer. Woody began working for the Forest Service in 1977 as a seasonal recreation technician on the White River National Forest. His first permanent position was as the trails specialist for the Nez Perce National Forest. During the last 12 years of his career he worked as a wildland fire dispatcher for the Cleveland and Arapaho-Roosevelt National Forests. Since publication of the first edition of the "Trail Construction and Maintenance Notebook" in 1996, several excellent books about trail construction and maintenance have been published by the International Mountain Bicycling Association (IMBA), the Student Conservation Association (SCA), and the Appalachian Mountain Club, among others. At the same time, this notebook has remained popular, especially because of its pocket size and its wide availability through a partnership between the Forest Service, U.S. Department of Agriculture, and the Federal Highway Administration's Recreational Trails Program. Official direction for the USDA Forest Service can be found in: Trails Management Handbook (FSH 2309.18). Forest Service Standard Specifications for Construction and Maintenance of Trails (EM-7720-103). Sign and Poster Guidelines for the Forest Service (EM- 7100-15). Forest Service Health and Safety Code Handbook (FSH 6709.11). Bridges and Structures (FSM 7722 and FSM 7736). The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program.

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