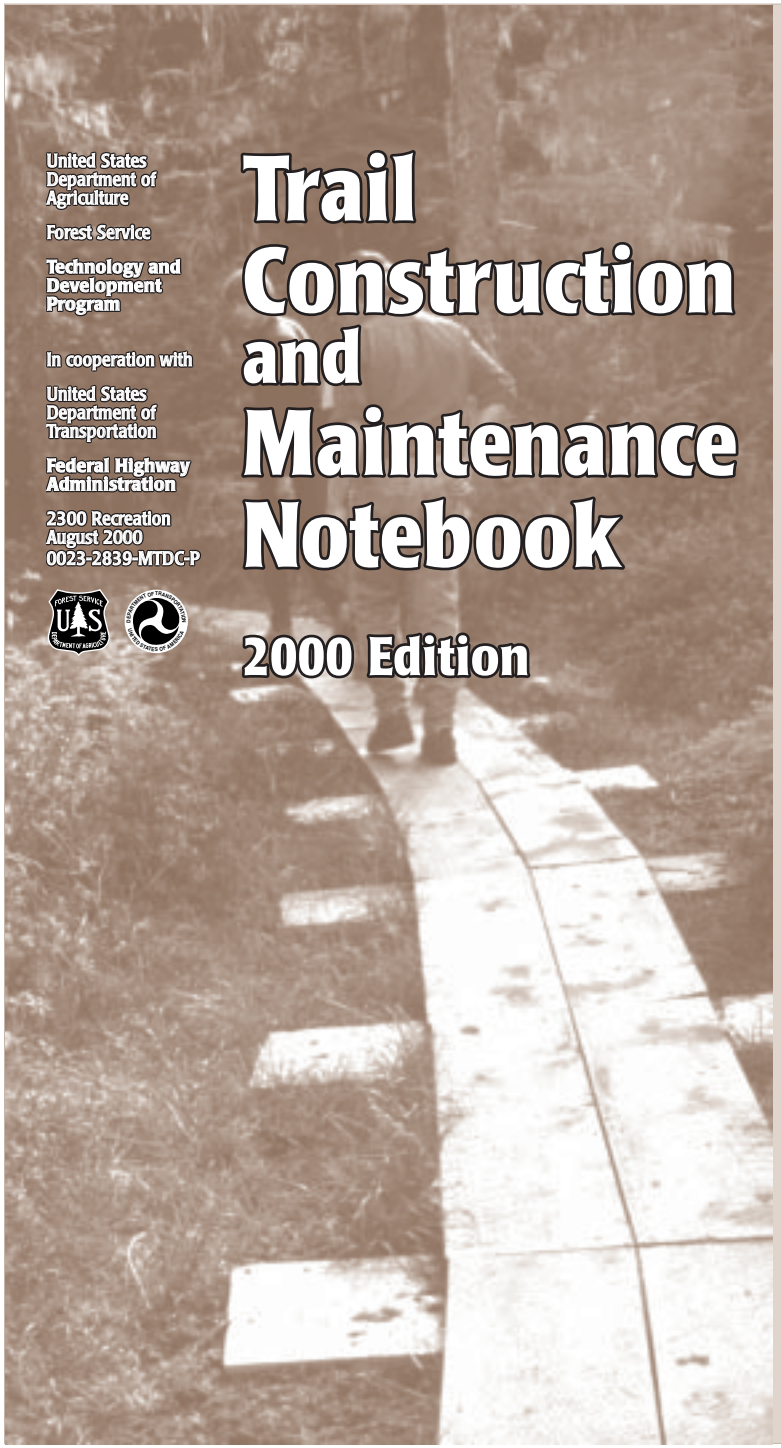

United States Department of Agriculture

Forest Service

Technology and Development Program

In cooperation with

United States Department of Transportation

Federal Highway Administration

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Trail Construction and Maintenance Notebook

2000 Edition

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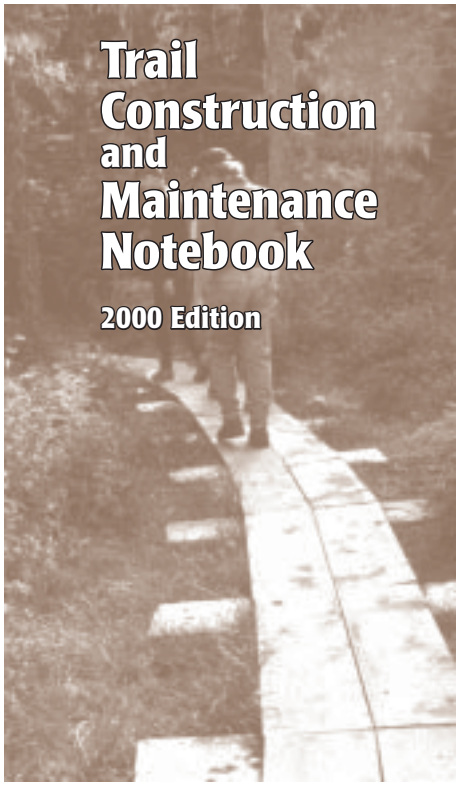


Trail Construction and Maintenance Notebook

2000 Edition

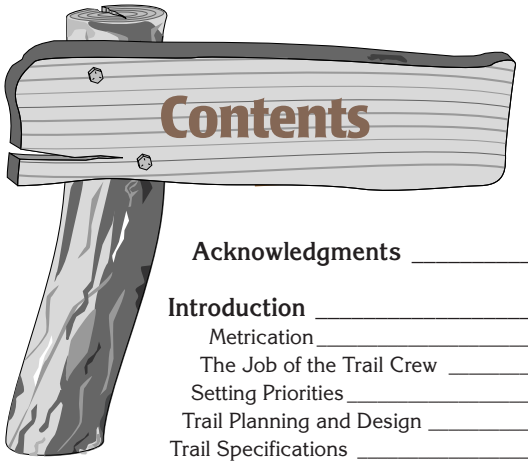
Woody Hesselbarth
Moose Creek Ranger District, Nez Perce National Forest
Northern Region

Brian Vachowski, Project Leader

USDA Forest Service
Technology and Development Program
Missoula, MT

4E42A25–Trail Notebook

August 2000



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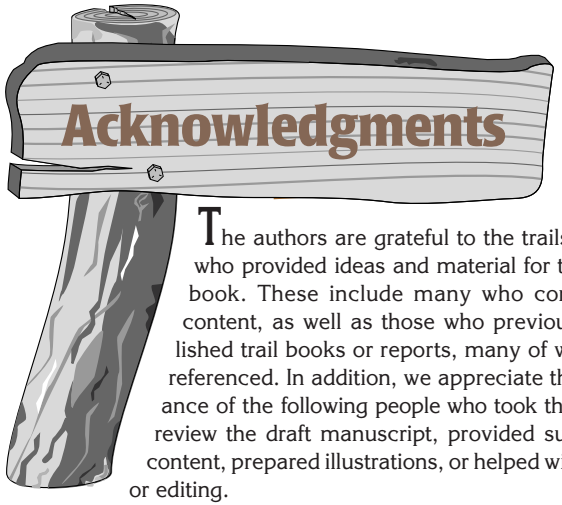

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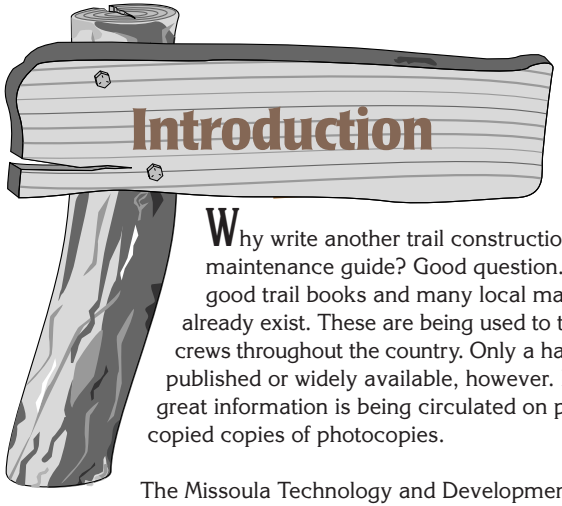


Introduction

Why write another trail construction and maintenance guide? Good question. Several good trail books and many local manuals already exist. These are being used to train trail crews throughout the country. Only a handful are published or widely available, however. Lots of great information is being circulated on photocopied copies of photocopies.

The Missoula Technology and Development Center (MTDC) was asked to pull together basic trail construction and maintenance information, present it in an easy-to-understand fashion, and orient it just to activities done in the field. We do not intend to duplicate information already in the Forest Service handbooks or manuals for tasks better completed in the office, although we've tried to make sure this notebook is consistent with current policies and direction. We worked to keep it small and readable so it would end up in trail crew packs instead of propping up table legs.

Since this notebook covers just the basics, you'll want to read the more detailed *Forest Service Trails Handbook* (FSH 2309.18), *Specifications for Construction and Maintenance of Trails* (EM-7720-103), *Standard Drawings for Construction and Maintenance of Trails* (EM-7720-104), *Standards for Forest Service Signs and Posters* (EM-7100-15), *Forest Service Health and Safety Code* (FSH 6709.11), *Transportation Structures Handbook* (FSH 7709.56b), and selected references from the bibliography. Other sources cover winter trails, paved or surfaced trails, and other specialized trails.

We have also found there are many regional differences in techniques, tools, and terminology throughout the country. It is impossible to describe them all, and we hope you aren't offended if your favorite has been left out or called a funny name.

There is very little "new" about trail work. Our culture, though, has forgotten a lot about trails. Most of us know very little about water and dirt when we attempt our first trail job.

You might not do things the way they are described in this guide—that's cool! Understanding *WHY* things are done is at least as important as *HOW*. If you know why something is happening, you'll figure out a way to build a structure to match a need. Soak up the core concepts. Experiment and keep track of the results. Be curious. Add new techniques and tactics to your bag of tricks. Get dirty and HAVE FUN!

Metrication

Metrication lives! Standard International (SI) units of measurement (metric) are used throughout the text followed by roughly equivalent English measurements in parentheses. Bear with us as we join the rest of the world. There is a handy conversion chart on the inside back cover to help the metrically challenged make the transition.

One other word on measurements. Most crews don't haul measuring tapes around to measure things. A really handy way of keeping track of commonly used measures is to mark them on tool handles. For example, if your typical tread is supposed to be 600 mm (24 in), mark that distance on the shovel handle.

The Job of the Trail Crew

The most important thing in trail maintenance is your personal well-being and safety. Are you fit? Do you know your limitations? Do you have the skills you need?

Your personal gear, clothing, and safety equipment are important. Let's start with your feet. Most trail work is in pretty rough country. Leather boots, at least 200 mm (8 in) high, offer the best support and ankle protection and are a Forest Service requirement when using cutting or digging tools. 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 southeast Alaska, for example, rubber boots are the norm for most trail work.

Pants rather than shorts give greater protection from scrapes, insects, and sunburn. Long-sleeve shirts are best for the same reasons. Bring your foul-weather gear. You won't forget a good pair of gloves more than once. Drinking water, lip moisturizer, sunscreen, sunglasses, insect repellent, and personal medications round out the list.

Hardhats are an agency requirement for many types of trail work, especially when working in timber or when there is any chance of being hit on the head. Other safety gear you need includes eye protection for any type of cutting or rock work, ear protection near most motorized equipment, and dust masks for some types of rock work and in extremely dusty conditions. Don't start the job unless you are properly equipped. Take a look at the *FOREST SERVICE HEALTH AND SAFETY CODE* (FSH 6709.11) for some good information that could save your life.

As a crew, you'll need a first aid kit, the training to know how to use it, and a realistic emergency and communication plan. The project leader should prepare a job hazard analysis that identifies the specific hazards of the work you will be doing, and should also hold safety briefings before you start and whenever you do something new.

Setting Priorities

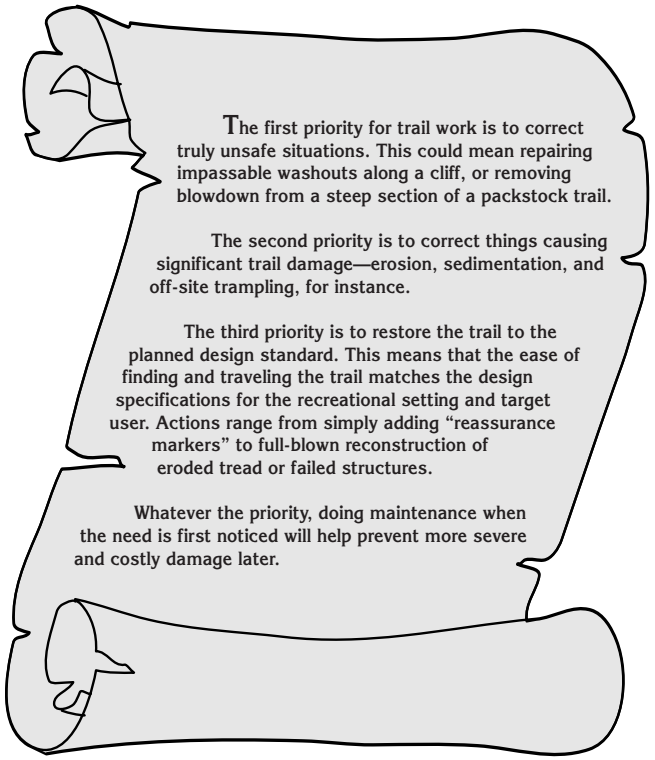
High-quality and timely maintenance will greatly extend the useful life of a trail. The trail crew's task is to direct water and debris off the tread, and keep the users on it. The best trail maintainers are those with "trail eye," the ability to anticipate physical and social threats to trail integrity and to head off problems.

Even though you know the proper maintenance specifications, sometimes there is too much work for the time you have to spend. How do you decide what to do?

Since it's a given that there will always be more work to do than people to do it, it's important to:

- Monitor your trail conditions closely.
- Decide what can be accomplished as basic maintenance.
- Determine what can be deferred.
- Identify what area will need major work.

This 'trail triage' is critically important if your maintenance dollars are going to be spent keeping most of the tread in the best possible condition.



Trail Planning and Design

Recreation trails are for 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 allow us to come more closely in touch with our natural surroundings, to soothe our psyches, to challenge our bodies, and to practice ancient skills.

Keep this in mind when designing, constructing, and maintaining trails. Although many trails have some purely utilitarian value, their esthetic and recreational qualities are important to most people. A well-crafted trail is unobtrusive, environmentally sensitive, and fun.

Human psychology also plays a role. A useful trail must be easy, obvious, and convenient. Trails exist simply because they are an easier way of getting someplace. Of course, many trails, such as wilderness trails, dirt bike routes, or climbing routes, are deliberately challenging with a relatively high degree of risk. Rest assured, however, that if your official trail isn't the "path of least resistance" for users trying to get from point A to point B, they will create their own trail. Your trail must be easier, more obvious, and more convenient than the alternatives (relative to the challenge level sought) or you're wasting your time and money.

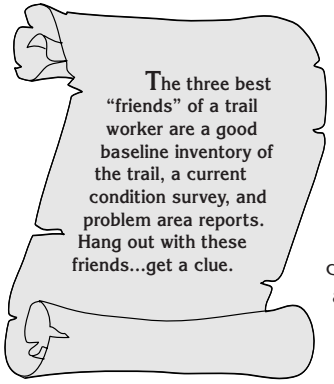
A good trail may appear to have "just happened," but that appearance belies an incredible amount of work in scouting, design, layout, construction, and maintenance. Although this guide is focused on actual dirt work, we want you to clearly understand that solid planning is absolutely essential.

If you've ever encountered a trail "disaster," chances are that it resulted from short-circuited planning. Acts of God aside, some of the worst trail problems result from not doing the hard work of thinking before putting on the gloves and hardhat. Some glaring examples of "fixes":

- Building out-of-rhythm short reroutes instead of rebuilding the old trail in place.
- Feeble rock crib walls.
- Stacked switchbacks with long, nearly level approaches.

Planning is not a hoop to be jumped through. Planning is stupidity avoidance. Do good planning for all levels of trail work.

Good planning also includes monitoring trail condition. It's hard to do good planning unless you have some idea of the current situation and trend.



Trail Specifications

All trails are not created equal. Each is ideally designed, constructed, and maintained to meet specific requirements. These specifications relate to the recreational activities the trail is intended to provide, the planned level of difficulty, the amount of use expected, and physical characteristics of the land. Ecological and esthetic considerations are also important.

For example, a narrow winding trail might be the right choice for foot traffic in wilderness, while one with broad, sweeping turns would be appropriate for an ATV (all-terrain vehicle) route. A smooth trail with a gentle grade is more appropriate for an interpretive trail or a trail designed for disabled persons (Figures 1 and 2).

Steepness or grade helps determine how difficult a trail is to use. The grade also has a direct bearing on how much design, construction, and mainte-nance work will be needed to establish solid tread and keep it that way. Grades range from 1 percent for wheelchair access to 50 percent or greater for scramble routes. Most high-use trails should probably be constructed in the 5- to 12-percent range. Trails of greater challenge or in more durable soils can be built at

Figure 1—A narrow, winding trail might be the right choice for wilderness.

Figure 2—A smooth trail with a gentle grade is appropriate for an interpretive trail or a trail designed for easy access.

grades approaching 20 percent. Trails at grades over 20 percent become difficult to maintain in the original location without resorting to steps or hardened surfaces.

Specifications are important. You'll want to refer to the *Forest Service Trails Management Handbook* (FSH 2309.18) for guidelines for most any type of trail you'll have the opportunity to build.

Light on the Land

No discussion of trails is complete without talking straight to the topic of esthetics. We're talking scenic beauty here. Pleasing to the eye. The task is simple. An esthetically functional trail is one that fits the setting. It lays light on the land. It often looks like it just "happened."

This does not mean that land isn't disturbed during construction. Often terrain dictates that substantial construction is necessary. The final results can still be blended to fit the ground. Over time it will look like it lays gently.

Well-designed trails take advantage of natural drainage features, and are low-maintenance trails that meet the needs of the user. The trail might pitch around trees and rocks, follow natural benches, and otherwise take advantage of natural land features (Figure 3).

Figure 3—Design and construct your trail to fit the land.

The best trails show little evidence of the work that goes into them. A little extra effort spent widely scattering cut vegetation, blending backslopes, avoiding drill hole scars, raking leaves back over fillslopes, or restoring borrow sites pays off in a more natural-looking trail. Be a Master. Do artful trail work.

Trail Layout

There is a real art to trail layout. Some basics can be taught, but the locator must develop an "eye" for fitting the flagline to the ground. This skill can only be developed with experience. Hiking or walking cross-country does not qualify someone as a trail locator. Also there is a general assumption that a person who lays out logging roads can lay out trails. This is often not true. The road locator looks at the terrain through the eyes of a bulldozer. The trail locator must look through the eyes of a hand builder. There are many nuances to the trail flagline that don't exist with a road flagline.

Here are some steps to help you do a good job of trail layout. You will also want to look over the *Forest Service Trails Management Handbook* (FSH 2309.18) for lots more good information.

Planning the Route on the Map. Be certain you know the objectives of the trail—things like the intended user, desired difficulty level, and desired experience. Then go to the maps to determine a potential route.

Use topographic maps and aerial photos to map the potential route. On the map, identify potential **Control Points**, places where the trail has to go, where there is no choice because of:

- Termini
- Gaps or passes
- Stream crossings
- Rock outcrops
- Known areas to avoid (threatened and endangered species, poor soils)
- Known features to include (scenic overlook, waterfall).

Connect the control points and determine approximate grades along the route. Doing this helps to determine if the route is feasible, or if special structures like switchbacks or bridges are needed.

Scouting the Mapped Route. Tools to scout the route include clinometer, compass, altimeter, flagging of different colors, wire or wood stakes, roll-up pocket surveyor's pole, permanent marker to make notes on the flagging, field book, probe to check soil depth to bedrock, maps, and perhaps a GPS (global positioning system) unit. The objectives of scouting or reconnaissance are to:

- Verify control points and identify additional control points not picked up on aerial photos.
- Determine if the preliminary mapped route is feasible.
- Find the best alignment that fits all objectives.
- Identify natural features to enhance the user's experience.
- Validate that the route is reasonable to construct and maintain.

Field scouting requires a sound knowledge of map and compass reading and of finding your way on the ground. Begin with the theoretical route, then try different routes until the best continuous route between the targets is found. Keep field notes of potential routes. It may be useful to hang reference flags at potential control points or features to help relocate them later. Reconnaissance is easiest with two people. One person can serve as a control point along the general route being scouted while the other searches ahead for obstacles or good locations.

Flagging the Final Route. Final flagging should wait until the best route has been determined by scouting.

Hang flags at about 3-m (10-ft) intervals. Don't scrimp. Flagging is cheap compared with the time spent locating the route.

Animals carry off flags, wind blows them down. You also obtain the best alignment with close flagging.

Flag the centerline. The steeper the sidehill, the more grade is affected by moving the line up or down the slope. Grade can be seriously compromised by leaving the construction crew too much latitude for deciding the final location.

Sometimes you have no choice but to go through a spot that ideally should have been avoided. Make sure the trail can be reasonably constructed through such spots.

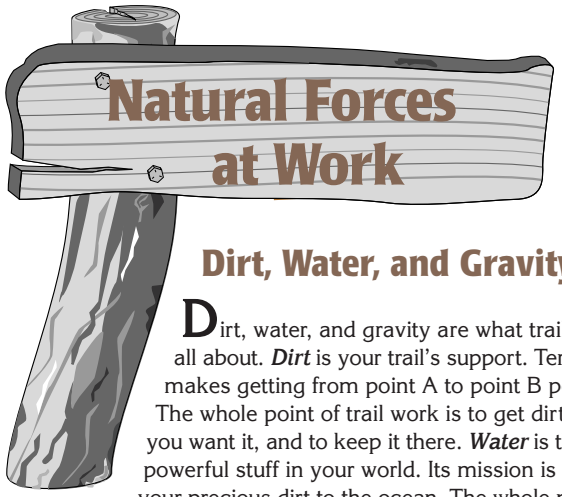
One Person Flagging. Stand at a point that is to be the centerline and tie flagging at eye level. Then move about 3 to 6 m (10 to 20 ft) to the next centerline point and sight back to the last flag. When you have the desired location, tie another flag at eye level.

HINTS FOR LOCATORS

- 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 you can build to the tree.
- Look for "natural platforms" for switchbacks. This saves on construction and better fits the land.
- Cross ravines at an angle rather than going straight down and up the ravine banks.
- Be sure to flag locations for grade dips or Coweeta dips.
- Where vegetation is generally dense, patches of sparse vegetation are a good indication of shallow bedrock.
- The more difficult the terrain, the more critical it is to flag the centerline location.
- Don't trust your eyeball guess for grade; use your clinometer.

Two or More Persons Flagging. A person with a clinometer stands on the centerline point, directs a person ahead to the desired location, then takes an eye-level shot on that person if they are the same height. It is better to take a shot on a rod with bright flagging tied at the height of the clinometer reader's eye.

When the desired location is determined, the front person hangs a flag and moves ahead. The person with the clinometer moves up to the flag and directs the next shot. A third person can be scouting ahead for obstacles or good locations.



Natural Forces at Work

Dirt, Water, and Gravity

Dirt, water, and gravity are what trail work is all about. ***Dirt*** is your trail's support. Terra firma makes getting from point A to point B possible. The whole point of trail work is to get dirt where you want it, and to keep it there. ***Water*** is the most powerful stuff in your world. Its mission is to take your precious dirt to the ocean. The whole point of trail work is to keep your trail out of water's grip. ***Gravity*** just is...

It is much more important to understand how the forces of water and gravity combine to move dirt than it is to actually dig dirt, install waterbars, or build puncheon. If you work trails long enough, you will see hundreds of examples of trail structures built with little understanding of the forces at hand. Such structures don't work and the dirt goes downhill. You will save time, money, and your sanity if you get grounded in the basic physics first.

Water erodes soil surfaces by picking up soil particles and carrying them off. It builds soil surfaces by getting tired and dropping soil particles. And it alters soil structure by hanging out with soil particles.

Water in the 'erode mode' strips tread surface, undercuts support structures, and blasts apart fill on its way downhill. How much damage is done depends on the amount of water involved and how fast it is moving.

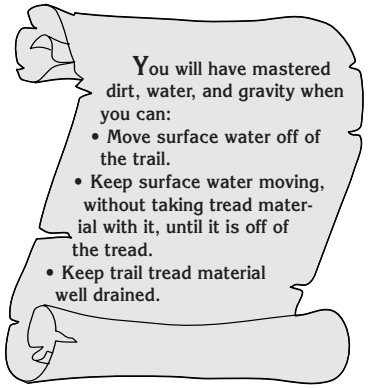
Water has "carrying capacity." More water can carry more dirt. Faster water can carry more dirt. You need to slow water down

and get it off the trail. When and where you can do that determines what sort of water control or drainage structure you use.

Water has "deposit" ability. If you slow water down, it loses its ability to carry soil. If you abruptly turn or block water, it slows down. This has some advantages if you are restoring eroded tread and use check dams to capture waterborne soil. It works to your disadvantage if your waterbar happens to be the abrupt turn and the soil drops, clogging the waterbar (Figure 4).

Figure 4—Too much water and sediment washed this waterbar out. Keep the water moving until you get the suspended soil where you want it. This sounds simple, but most failed water diversion structures are ones clogged with deposited soil.

Water can also affect soil strength. The general rule of thumb is that drier soils are stronger (more cohesive) than saturated soils, but it is also true that fine, dry soils blow away. The best trail workers can identify basic soils in their areas and know their wet, dry, and wear properties. They will also know about plant indicators that will tell them about the underlying soil and drainage.



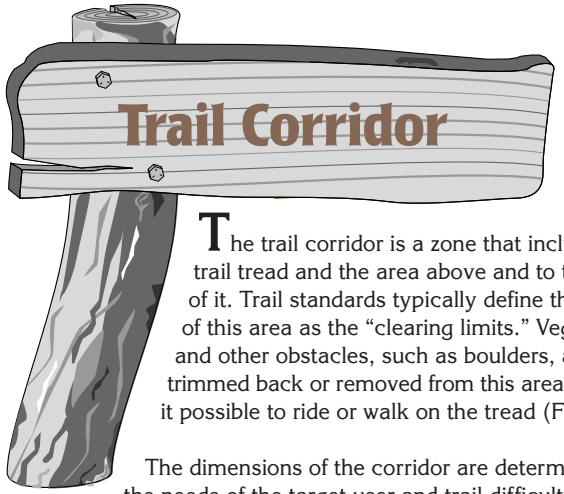
Critter Effects

Gravity has a partner—the Critter. Critters include packstock, pocket gophers, humans, bears, elk, deer, cows, and sheep. Critters will burrow through your 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.

Gravity waits in glee for critters to loosen up more soil. If you recognize potential critter effects (especially from humans, deer, elk, domestic livestock, and packstock), you can beat the system for a while and hang onto that dirt. How?

- 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.

Your trail strategies are only as good as your understanding of the critter's mind.



The trail corridor is a zone that includes the trail tread and the area above and to the sides of it. Trail standards typically define the edges of this area as the "clearing limits." Vegetation and other obstacles, such as boulders, are trimmed back or removed from this area to make it possible to ride or walk on the tread (Figure 5).

The dimensions of the corridor are determined by the needs of the target user and trail difficulty level. For example, in the Northern Rockies, trail corridors for traditional packstock are cleared 2.5 m (8 ft) wide and 3 m (10 ft) high. Hiker trails are cleared 2 m (6 ft) wide and 2.5 m (8 ft) high. Check with your local trail manager to determine the appropriate dimensions for each of your trails.

Trail Structure Terminology

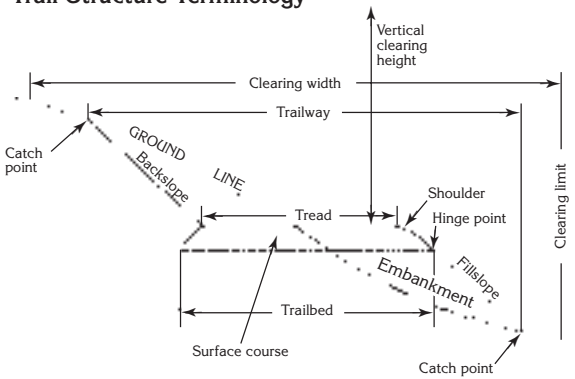


Figure 5—Terms describing the trail corridor. Often there will be detailed dimensions you need to know.

Clearing and Brushing

Working to wipe out your trail is no less than that great nuclear furnace in the sky—Old Sol, the sun. Working in cahoots with the mad scientist, Dr. Photosynthesis, the sun works an alchemy that converts dirt and water into a gravity-defying artifice called a plant. Seasoned trail workers will attest to the singular will and incredible power of plants. No sooner is a trail corridor cleared of plants than they begin a rush toward this new avenue of sunlight.

A significant threat to trail integrity comes from plants growing into trail corridors, or from trees falling across them. Brush is a major culprit. Other encroaching plants such as thistles or dense ferns may make travel unpleasant or even completely hide the trail. If people have trouble traveling your tread, they'll move over, usually along the lower edge, or make their own "volunteer" trail. Cut this veggie stuff out! (Figure 6).

Figure 6—Vegetation before trail clearing. Each type of trail has its own requirements for clearing.

In level terrain the corridor is cleared an equal distance on either side of the tread centerline. Using the hiking trail example, this means that the corridor is cleared for a distance of 1 m (3 ft) either side of center. Within 300 mm (1 ft) of the edge of the tread, plant material and debris should be cleared all the way to the ground. Farther than 500 mm (1.5 ft) from the trail edge, plants do not have to be cleared unless they are taller than 500 mm or so. Fallen logs usually are removed to the clearing limit.

On moderate to steep side slopes, a different strategy is often useful. Travel along the lower (outer) edge of the tread is a significant cause of tread failure. You can use trailside material to help hold traffic to the center of the tread. A downed log cut nearly flush with the downhill edge of the trail will encourage travelers to move up to avoid it. Rocks, limbed trees, and the like can all be left near the lower edge of the tread to guide traffic back to the center (Figure 7).

Figure 7—Rocks and logs help to keep the trail in place. And remember that this is a path through nature, not a monument to Attila the Hun.

The key is to make sure that the guide material will not interfere with travel on the center of the tread. For example, bikers need enough room for pedals or foot pegs to clear both the backslope and the guide structures.

On the uphill side of the trail, cut and remove material for a greater distance from centerline. For instance, on slopes steeper than 50 percent you may want to cut downed logs or protruding branches 2 m (6.5 ft) horizontal distance or more from the centerline. This is particularly true if you're dealing with packstock as they tend to shy away from objects at the level of their heads.

Using this "movable corridor" takes some thought. Recognize that this may be a difficult decision for inexperienced crews. Continue to revisit the basic reasons for clearing a corridor and the consequences of taking or leaving material.

Finally, remember that the "scorched earth" look created by a corridor with straight edges is not very pleasing to the eye. Work with natural vegetation patterns to "feather" or meander the edges of your clearing work so they don't have such a severe appearance. 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 end lies 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 logs or stumps with soil will reduce the brightness of a fresh saw cut. In especially sensitive areas, cut stumps flush with the ground and cover with dirt, pine needles, or moss. Rub dirt on stobs or bury them. Remember...this is America the Beautiful!

Some trails may have to be brushed several times a year. Some once every few years. Doing a little corridor maintenance when it is needed is a lot easier than waiting until plants cause expensive problems. Jump on potential problem areas before they become real problems.

Removing Trees

Trees growing within the corridor should usually be removed. Remember that those cute little seedlings will eventually grow into pack-snagging adolescent trees. They are a lot easier to pull up by the roots when they are small than they are to lop when they grow up.

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 over half of the tree needs pruning, it is usually better to cut it down instead. Cut trees off at ground level and do not leave pointed stobs (Figure 8).

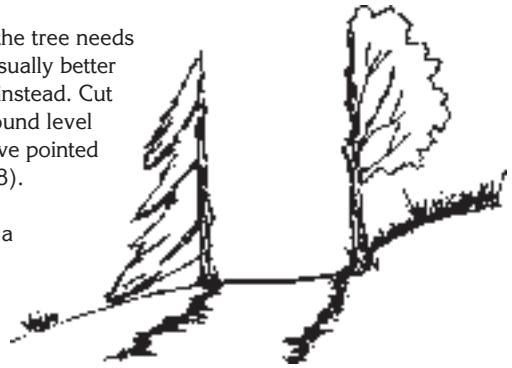


Figure 8—These trees should have been removed rather than pruned.

"Logging out" a trail means cutting away trees that have fallen across it. It can be quite hazardous. The size of the trees you are dealing with, restrictions on motorized equipment, and your skill and training will determine whether chain saws, crosscut saws, bow saws, or axes are used. Safety first!

You need training to operate power saws and crosscut saws. Your training, experience, and, in some cases, 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 either standing or fallen trees. Remember that using an ax exposes you to similar hazards.

Some trees may be more safely felled by blasting. Check with a certified blaster to learn where blasting is a feasible alternative.

Removing fallen trees is a thinking person's game. The required training will help you think through problems, so we won't relate the details here.

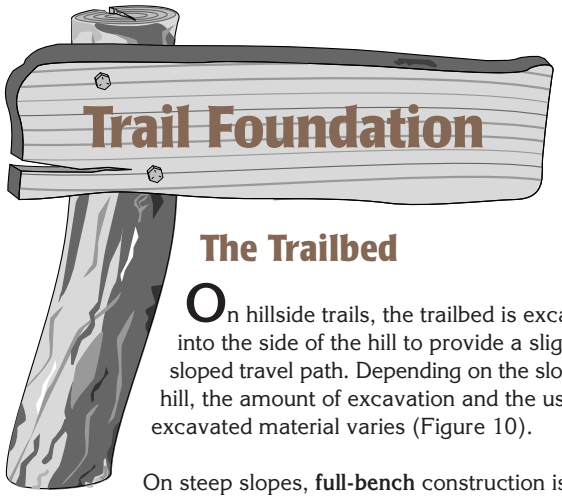
Cut the log out as wide as your normal clearing limits on the uphill side, and out of the "clearing zone" but closer to the trail on the downhill side. Roll the log pieces off the trail and outside the clearing limits on the downhill side. Never leave them across ditches or waterbar outflows. If you leave logs on the uphill side of the trail, turn or bed 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.

It is hard to decide whether or not to remove "leaners," trees that have not fallen but are leaning across the trail. If the leaner is within the trail clearing zone, it should be removed. Beyond that, it is a matter of discretion whether a leaner needs to be cut. The amount of use on the trail, the time until the trail is maintained again, the soundness of the tree, and the potential hazard the leaner is creating all need to be considered in your decision. Felling a leaner, especially one that is hung up in other trees, can be very hazardous. Only highly qualified sawyers should do it (Figure 9). Blasting is another way to safely remove leaners.

Figure 9—If you are uncomfortable with your ability to safely cut a tree due to the hazards or your lack of experience, walk away from it!

Felling standing trees (including snags) is statistically one of the most dangerous activities a trail worker can engage in. Simply put, do not even consider felling trees unless you have been formally trained and certified. Bringing in a trained sawyer is cheaper than bringing in a coroner.



Trail Foundation

The Trailbed

On hillside trails, the trailbed is excavated into the side of the hill to provide a slightly outsloped travel path. Depending on the slope of the hill, the amount of excavation and the use of the excavated material varies (Figure 10).

On steep slopes, **full-bench** construction is usually needed. Soil excavated from the hill is cast aside as far as possible from the trail and not used at all in the fillslope. Especially on steep slopes, relying on fill for part of the trailbed is a bad idea. This soft material is likely to erode away quickly, creating dangerous soft spots on the downhill edge of the trail. If fill is used, it often needs to be reinforced with expensive crib or retaining walls. As the slope of the hillside decreases, it becomes more feasible to use fill material as part of the trailbed. However, even though it requires more hillside excavation, full-bench trailbeds will generally be more durable and require less maintenance than partial bench construction. There is a tradeoff, though. Full-bench construction is often more costly because more excavation is needed, and it also results in a larger backslope. Most trail professionals will usually prefer full-bench construction.

Typical Trail Cross Sections

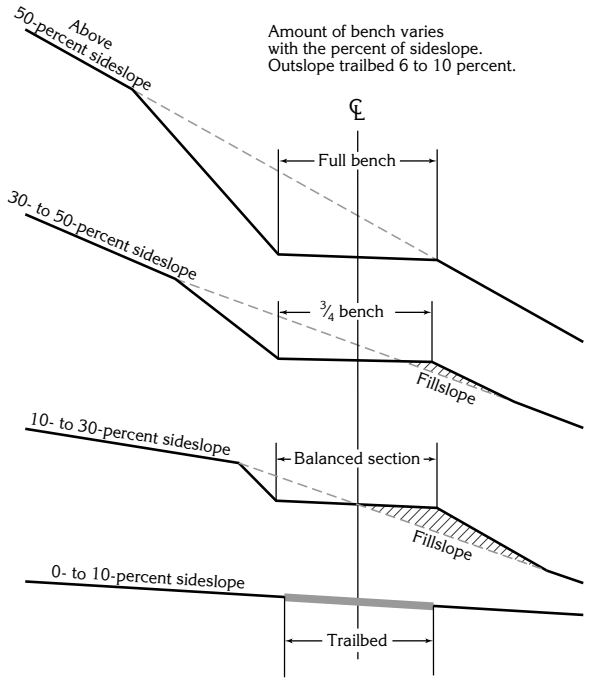


Figure 10—Typical trailway cross sections. Full-bench construction will give you the fewest problems—especially on steep slopes.

Constructing Sidehill Trails

Looking at construction plans is one thing, but going out and building a sidehill trail is quite another. Here is a proven method that works even for the complete novice. This is for the actual digging part once vegetation has been cleared.

- Mark the centerline of the trail with wire flags no more than 3 m (10 ft) apart. These wire flags are the key to explaining how

to dig the tread, and they keep the diggers on course.

- Remove leaf litter, duff, and humus down to mineral soil. To mark the area to be cleared, straddle the flag facing the uphill slope. Swing your Pulaski or other tool. Where the tool strikes the ground is approximately the upper edge of the cut bank. The steeper the slope, the higher the cut bank. Do this at each centerline flag, then scratch a line between them. This defines the area to be raked to mineral soil. Clear about the same distance below the flag. Keep the duff handy, as it will be used later. Don't clear more trail than can be dug in a day unless you know it isn't going to rain before you can complete the segment.
- For a balanced bench trail, the point where the wire flag enters the ground is the finished grade. Scratch a line between flags to keep yourself on course. Facing the uphill slope, begin digging about 150 mm (6 in) from the flag cutting back into the slope. Imagine a level line drawn from the base of the flag into the bank. Dig into the bank down to this line, but not below (Figure 11). Pull the excavated material to the outer edge. Tamp this fill material as you go. On a full-bench trail, the wire flag essentially ends up at the outside edge of the trail. For less than a full-bench trail, the flag ends up somewhere between the centerline and outside edge. Keep this in mind when you place the wire flags.
- There is a tendency to want to stay facing uphill. To properly shape the tread, you need to stand on the trail and work the tread parallel to the trail direction to level out the toe of the cutslope and to get the right outslope.

Cut and Fill

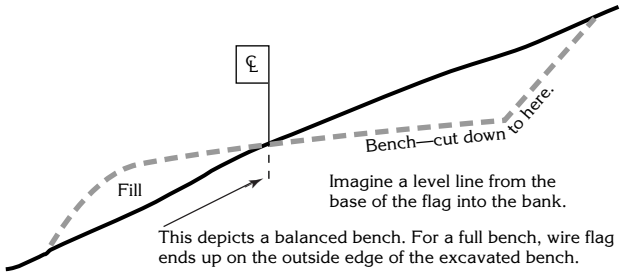


Figure 11—Basic sidehill trail building.

- There is a tendency to make the trail too narrow. If the width of rough tread equals the length of a Pulaski handle, the narrower finished tread will be about right for a good hiking trail.
- Make sure grade dips and other drainage structures are flagged and constructed as you go.
- If you try to slope the cut bank close to the original surface, you will usually get somewhere close to what is needed. Slope ratios are hard to understand. Instead, look at the natural slope and try to match it.
- Round off the top of the cutslope. The easiest way to do this is to rake parallel to the cut edge with a fire rake.
- The best way to check the outslope is to walk the tread. If you can feel your ankles rolling downhill, there is too much outslope (Figure 12). The outslope should be barely detectable to the eye. If you can see a lot of outslope, it's probably too much. A partially filled water bottle makes a good level.
- Once the bench construction is finished, stand on the tread and pull the reserved duff up onto the fillslope with a fire rake. This helps stabilize the fill (especially important in high rainfall areas), and makes the new trail look like it has been there for

Excess Outsloping

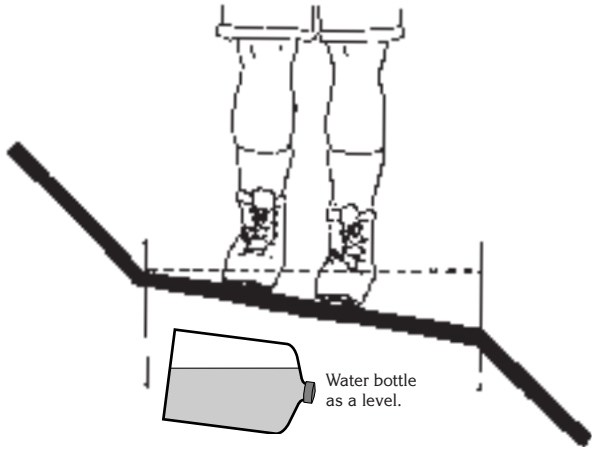


Figure 12—If your ankles start to roll, there is too much outslope.

years. Be careful not to create a berm with the duff. On full-bench trails there will be no need for the duff, as the outside edge of the trail has not been disturbed. Sometimes contract specifications call for scattering rather than reserving the duff.

While often described as a percent, slopes are also described as a ratio of vertical to horizontal, or "rise" to "run." The protocol for metric (SI) notation continues this tradition, with the additional change of eliminating fractions from the notation. For slopes flatter than 1:1, express the slope as a ratio of one unit vertical to the number of horizontal units. For slopes steeper than 1:1, express the slope as the ratio of the number of vertical units to one unit horizontal. Figure 13 shows examples.

TRANSPORTATION ENGINEERS HAVE USED A DIFFERENT SYSTEM—AND STILL DO—FOR NONMETRIC SLOPE MEASUREMENTS. MAKE SURE YOU UNDERSTAND WHICH SYSTEM IS BEING USED.

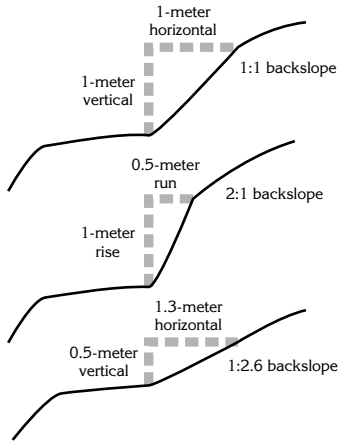


Figure 13—Slopes are noted in metric as a ratio of vertical to horizontal, or "rise" to "run."

Backslope

The backslope is the excavated, exposed area of the trailway above the tread surface. Backslopes range from near vertical (in rock) to 1:2 in soils having little cohesion. Backslopes cannot be steeper than the exposed material's ability to stay put during typical climatic conditions. Most inexperienced crews construct backslopes that exceed the parent material's angle of repose. Translation? The slope usually fails within a year, blocking the tread.

A second option is to construct a crib wall and use fill to support the entire tread surface. This can be less obtrusive than huge backslope excavations and more stable, if the wall is well constructed. Much less backslope, if any, may be needed.

Look at the surrounding landscape and soil to see what is stable. A handy rule of thumb is to create a somewhat gentler slope than you think necessary. Although you will initially expose more raw soil, the chances of it remaining stable and revegetating are greater than if you leave a backslope so steep that it keeps sloughing.

Fillslope

The fillslope is that area of the trail below (downslope from) the tread surface. A full-bench tread, of course, will not have any fill associated with this side of the trail. Fillslopes are critical. If you take care of the downhill side of the trailway, you'll avoid the vast majority of problems associated with trail maintenance.

Borrow Pits

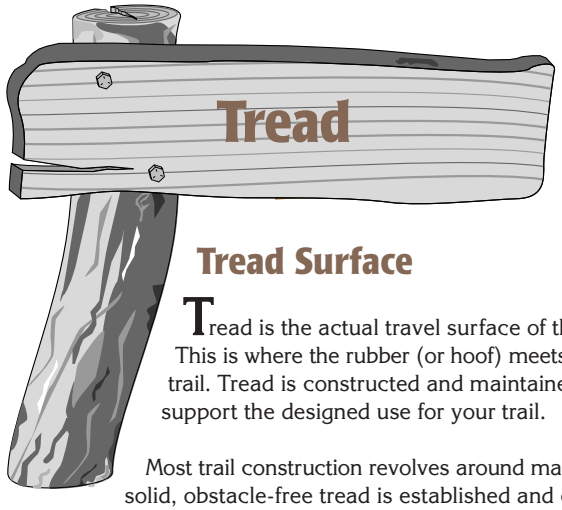
Often you will need fill material. The hole you dig is called a borrow pit. It should be as close to the work site as possible, but screened from view. The material in the pit also needs to be suitable for the desired use. Good choices are soils with a balanced mixture of different size particles. Sand and gravel work well. So do small, well-graded angular rocks.

Compare existing trail tread materials with borrow sources. Consider the proportions of gravel, sand, and fines. Individual "fine" particles are not visible to the naked eye and are classified as silt or clay. If the proportions of gravel, sand, and fines are similar, you can expect the borrow materials to perform as well as the existing trail tread materials. If the borrow source has a smaller proportion of fines, you can expect better performance under wet conditions.

Soils from bogs are normally not suitable for tread fill because they lose strength when they become wet. These dark organic soils are identified by musty odor when damp. In temperate parts of the country you'll want to avoid organic soils. In the arid Southwest, however, organic material can be added to dry clay to keep it from blowing away.

Creek bottoms that are replenished by storms and seasonal water flow, and the base of slopes or cliffs where heavy runoff or gravity deposit sand and gravel, are good places to look. Don't destroy aquatic or riparian habitat with your pit.

Save all squares of vegetation removed from the top of the pit. You'll need them for restoration. Place them in the shade and keep them moist by covering them with wet burlap. To rehabilitate, grade the pit out to natural contours with topsoil and debris, then revegetate. Camouflage the area and access trails with boulders and dead wood.



Tread

Tread Surface

Tread is the actual travel surface of the trail. This is where the rubber (or hoof) meets the trail. Tread is constructed and maintained to support the designed use for your trail.

Most trail construction revolves around making sure solid, obstacle-free tread is established and enough protection is provided to keep it in place. If you don't do a good job of locating, constructing, and maintaining tread, the users will find their own pathways instead.

Outsloping is the first line of defense against tread erosion. An outsloped tread is one that is lower on the outside or downhill side of the trail than it is on the inside or bank side. Outsloping lets water run naturally off the trail. A 500-mm (2-ft) wide trail would have an outside edge 30 to 60 mm (1.2 to 2.4 in) lower than the inside edge. Tread is also the travel surface on structures like turnpike and puncheon. Tread, whenever elevated, should be slightly crowned to drain better.

Tread Creep

Does your sidehill trail display:

- Exposed bedrock or roots along the upper side of the tread?
- Daisy-chained tread alignment (Figure 14)?
- Pack bumpers, jump-offs, and prominent tread anchors?

Figure 14—Some classic signs of tread creep. This trail needs help now.

All three are indications that the tread surface has been eroded and compacted by travel along the lower edge. Insidious tread creep at work. Tread creep should be arrested or the trail will eventually become very difficult or dangerous to travel.

What causes tread creep? The answer is simple. Most livestock, two-wheeled traffic, and some people have a natural tendency to walk the outside edges of sidehill trails. Sloughing makes the edge the flattest place to walk. As the tread moves downhill, it also narrows, with the result that more traffic travels closer to the outer edge. Other causes of tread creep are constructing a trail that is too narrow or with cutslopes that are too steep. Your job is to bring the trail back uphill to its original location and keep it there (Figure 15).

One of the best ways to do this is to take advantage of large stationary objects (guide structures) to prevent animals and people from walking the edge. Trees, log ends, rocks, and stumps left close to the downhill edge of the trail will keep animals walking closer to the middle. Guide structures should be no more than 500 mm (1 ft) high so they will not catch animals' packs.

Causes of Trail Creep

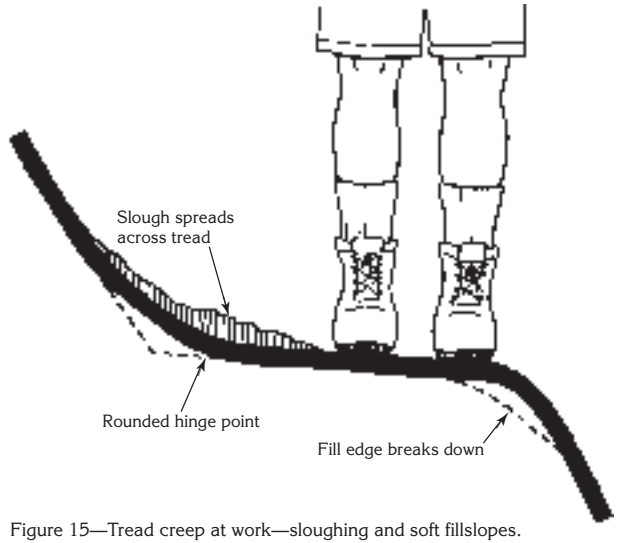


Figure 15—Tread creep at work—sloughing and soft fillslopes.

Curb rocks need to be well anchored, and they should be placed at random distances so they don't look like a wall or trap water on the tread.

Tread between these anchors will creep downhill creating a situation where the trail climbs over every tread anchor and descends again. At the bottom of these "dips," water and sediment collect. This is the weakest portion of the tread and the most prone to catastrophic failure. The tread can be so soft that packstock may punch completely through the tread (called a step-through) or bicycles or dirt bikes may collapse the edge. The result can be a bad wreck.

Where soil is in short supply, you may have to install a short crib wall and haul in tread material. Thin tread on bedrock will not usually stay put without some support. If normal slough removal does not work on more substantial soils, the tread should be

benched back into the slope in the original alignment. Guide structures should be installed on the outside edge of the tread to keep traffic toward the center.

A note on guide structures: If you use a rock, be sure it is big enough that at least one-third of it may be buried (so people and bears won't roll it away) and it will still be obtrusive enough that hikers and horses won't walk over it (Figure 16). Log ends should be sawed back at an angle if the top edge of the log is more than 500 mm (20 in) above the tread. If you have really substantial berm to remove, leave 1-m (3-ft) long portions at 3- to 5-m (10- to 15-ft) intervals with the ends feathered into the fillslope to serve as guide structures.

Stabilizing Tread Creep

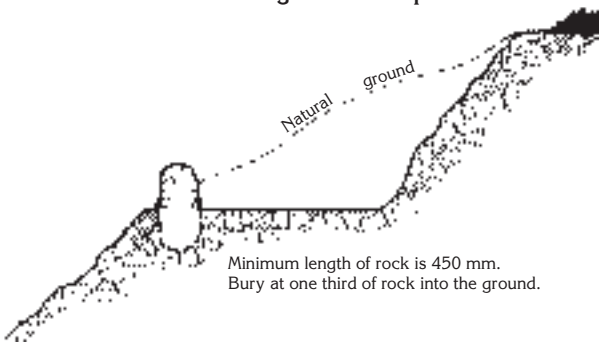


Figure 16—Guide rock properly installed to help prevent tread creep.

Slough and Berm

On hillside trails, slough (pronounced "sluff") is soil, rock, and debris that has moved downhill to the inside of the tread, narrowing it. Slough needs to be removed (Figure 17). Removing slough is hard work, and is often not done adequately. Leaving slough is another reason trails "creep" downhill.

Reestablishing Outslope

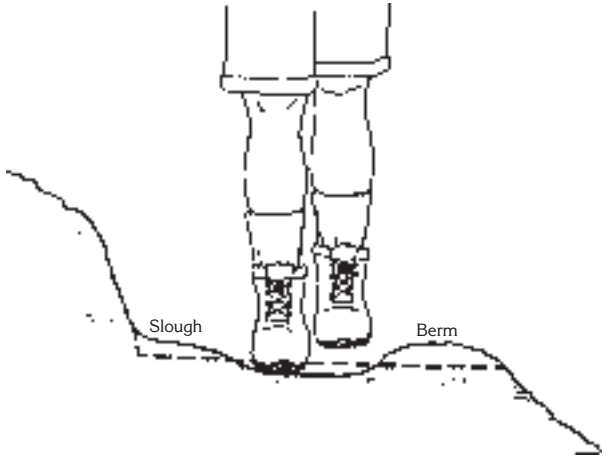


Figure 17—Remove the slough and berm, leaving the trail outsloped so water will run off. One fist's worth of drop for the length of a Pulaski is a good rule of thumb.

Loosen compacted slough with a mattock or Pulaski, then remove the soil with a shovel or McLeod. Use excess soil to fill holes in the tread, or on the downhill side of waterbars. Reshape the tread to restore its outslope. Avoid disturbing the entire cutbank unless absolutely necessary. Chop off the toe of the slough, and blend the slope back into the cutbank.

Berm is soil that has built up on the outside of the tread, forming a barrier that prevents water from running off the trail. Berms are a natural consequence of tread surface erosion and redeposition, and of inadequate compaction during construction. Berms prevent water from flowing off the trail. Water runs down the tread itself, gathering volume and soil as it goes. Berm formation is the single largest contributor to erosion of the tread surface. Removing berms is almost always the best practice. Observe erosion on trails with and without berms, see what works best in your area, and ask the project leader for a recommendation if you are in doubt.

Berms also trap water in puddles on level portions of tread and at the bottom of dips. Trapped water contributes to soil saturation, greatly reducing tread cohesion. Saturated tread material is prone to mass wasting and step-throughs.

Berms, especially when associated with tread creep, may form a false edge. False edge is unconsolidated material, often including significant amounts of organic material, that has almost no ability to bear weight. This is probably the least stable trail feature on most trails and the major contributor to step-throughs and wrecks.

Berms should not be constructed intentionally. Guide structures or even guard rails, if appropriate, should be combined with tread outsloping to keep users on the center of the trail and water off of it.

Tread Maintenance

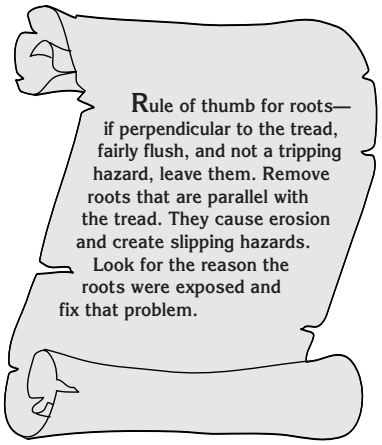
Maintain tread at the designed width. This means filling ruts, holes, and low spots. It includes removing obstacles such as protruding roots and rocks. It also means repairing any sections that have been damaged by landslides, uprooted trees, washouts, or boggy conditions.

Tread maintenance aims for a solid, outsloped surface. Remove all the debris that has fallen on the tread, the sticks and stones and candy wrappers. Pull the lower edge berm back onto the tread surface and use it to restore the outslope. Use any slough material in the same fashion. Remove and widely scatter organic debris well beyond the clearing limits, preferably out of sight.

Removing Roots and Stumps

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. A sharpened pick mattock or Pulaski is most often used to chop away at the roots. If you are relying on some type of winch system to help you pull out the stump, be sure to leave the stumps high enough to give you something to latch on to for leverage.

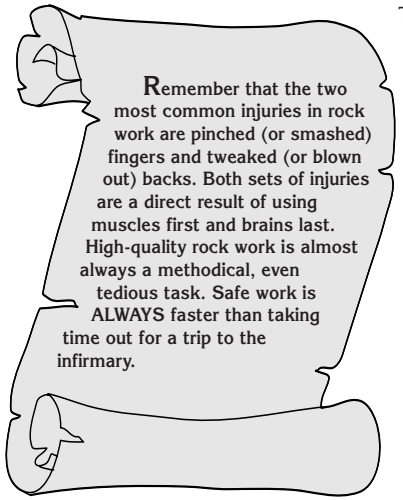
Not all roots and stumps are problems. You should not have to remove many large stumps from an existing trail. Before you do so, consider whether a stump was left the last time around to help keep the trail from creeping downhill.



Rock Removal

Rock work ranges from shoveling cobble to blasting solid rock. Both ends of the spectrum are often specialty work. The good blaster can save a crew an astounding amount of work. Someone building a rock retaining wall may be a true artisan, creating a structure that lasts for centuries. The key to any decent rock work is good planning and finely honed skills.

The secret to moving large rocks is to think first. Plan out where the rock should go, and anticipate how it might roll. Be patient—moving rock in a hurry almost always results in the rock ending up in the wrong location. Communicate with all the crew about how the task is progressing and what move should occur next.



Tools of the trade include:

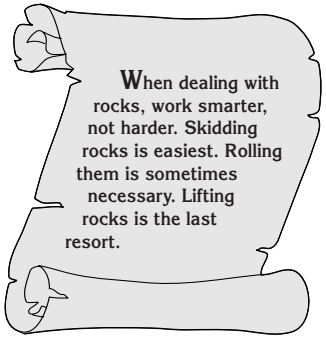
- Lots of high-quality rockbars; don't settle for the cheap digging bars, you need something with high tensile strength.
- Pick mattock.
- Sledge hammer.
- Eye protection, gloves, and hardhat; don't even think of swinging a tool at a rock without wearing these.
- Gravel box, rock bag, rucksack, rock litter; items useful for carrying rock 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 breakers.

Blasting is useful for removing rocks or greatly reducing their size. Careful blasting techniques can produce gravel-sized material. Motorized equipment can be used to split boulders or to grind down projecting tread obstacles. Chemical expansion agents poured into drilled holes will break large rocks without explosives. Drills and wedges can be used to quarry stone for retaining walls or guide structures.

Your specific trail maintenance specifications may call for removing embedded rocks. Use good judgment here. Often very large rocks are better 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 mm (4 in) below the tread surface, or in accordance with your specific trail standards. Simply knocking off the top flush with the existing tread may mean a future obstacle as erosion removes soil from around the rock.

Rockbars work great for moving medium and large rocks. Use the bars to pry rocks out of the ground and then to guide them around. When crew members 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 small rocks or logs 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, and start rockslides.

Even worse is the possibility an out-of-control rock might cross a trail or road below you, hitting someone. If there is any possibility of people below, close the trail or road, or post sentries in safe locations to warn travelers of the danger.

You might construct a barrier by laying logs against two trees to stop a rolling rock before it gains much momentum. Once a rock is loose, do not try to stop it.

When you need to lift rocks, be sure to keep your back straight and to lift with the strong muscles of your legs. Sharing the burden with another person is sometimes 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 onto its wheels. Keep your fingers clear any time you deal with rocks.

Small stones are often needed for fill material behind crib walls, in turnpikes and cribbed staircases, and in voids in talus sections of trail. Buckets and wheelbarrows are handy here. So are canvas carrying bags. If you are part of a large crew, handing rocks person-to-person often works well. Remember, twisting your upper body while holding a heavy rock usually isn't a good idea.