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# Trail Construction and Maintenance Notebook

## 2004 Edition

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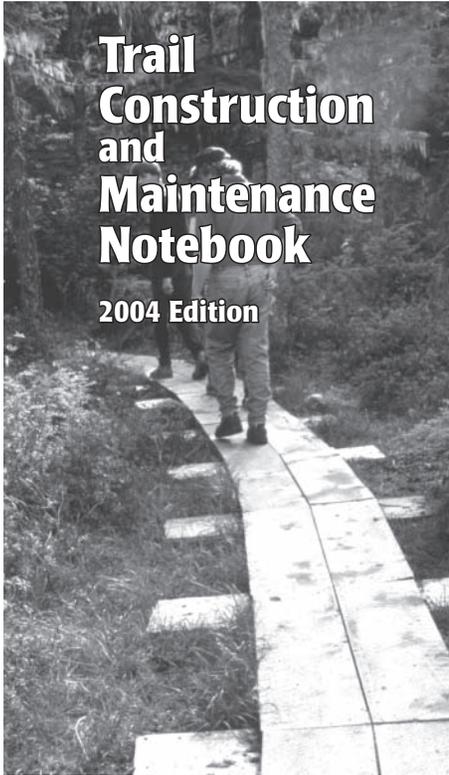


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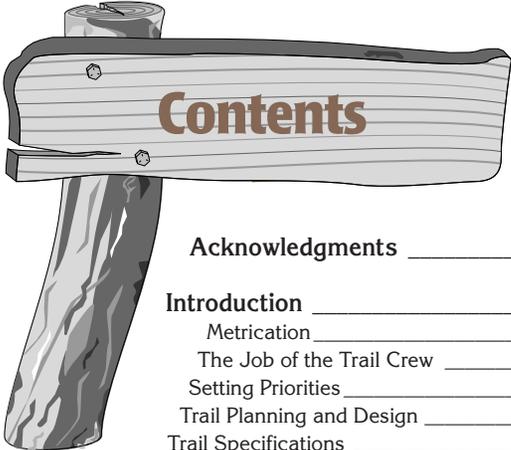
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4E42A25—Trail Notebook

April 2004

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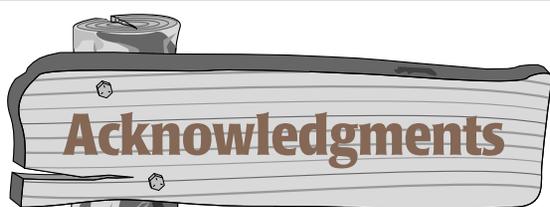
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## Introduction

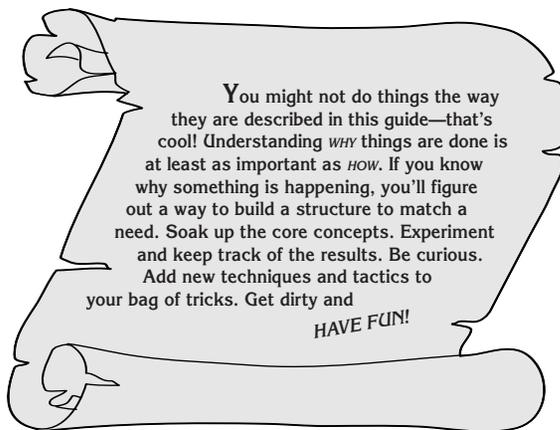
Why write another trail construction and maintenance guide? Good question. Several good trail books and many local manuals already exist. These are being used to train trail crews throughout the country. Only a handful are published or widely available, however. Lots of great information is being circulated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



## 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

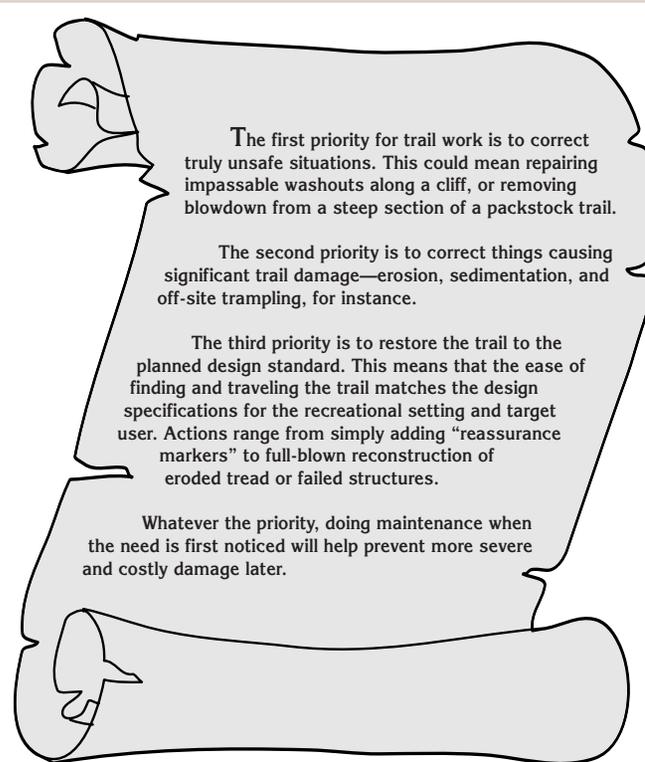
High-quality and timely maintenance will greatly extend the useful life of a trail. The trail crew's task is to direct water and debris off the tread, and keep the users on it. The best trail maintainers are those with "trail eye," the ability to anticipate physical and social threats to trail integrity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



The first priority for trail work is to correct truly unsafe situations. This could mean repairing impassable washouts along a cliff, or removing blowdown from a steep section of a packstock trail.

The second priority is to correct things causing significant trail damage—erosion, sedimentation, and off-site trampling, for instance.

The third priority is to restore the trail to the planned design standard. This means that the ease of finding and traveling the trail matches the design specifications for the recreational setting and target user. Actions range from simply adding "reassurance markers" to full-blown reconstruction of eroded tread or failed structures.

Whatever the priority, doing maintenance when the need is first noticed will help prevent more severe and costly damage later.

## 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.

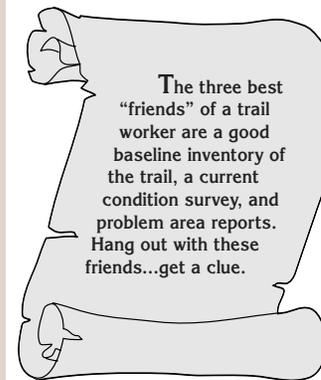
A good trail may appear to have "just happened," but that appearance belies an incredible amount of work in scouting, design, layout, construction, and maintenance. Although this guide is focused on actual dirt work, we want you to clearly understand that solid planning is absolutely essential.

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.



The three best "friends" of a trail worker are a good baseline inventory of the trail, a current condition survey, and problem area reports. Hang out with these friends...get a clue.

## 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 maintenance 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."

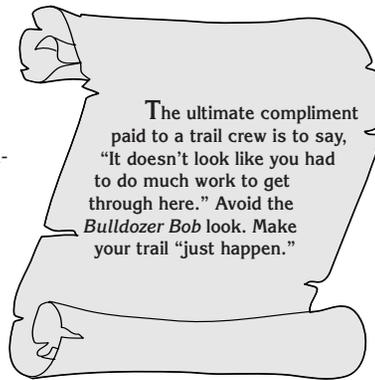
This does not mean that land isn't disturbed during construction. Often terrain dictates that substantial construction is necessary. The final results can still be blended to fit the ground. Over time it will look like it lays gently.

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.

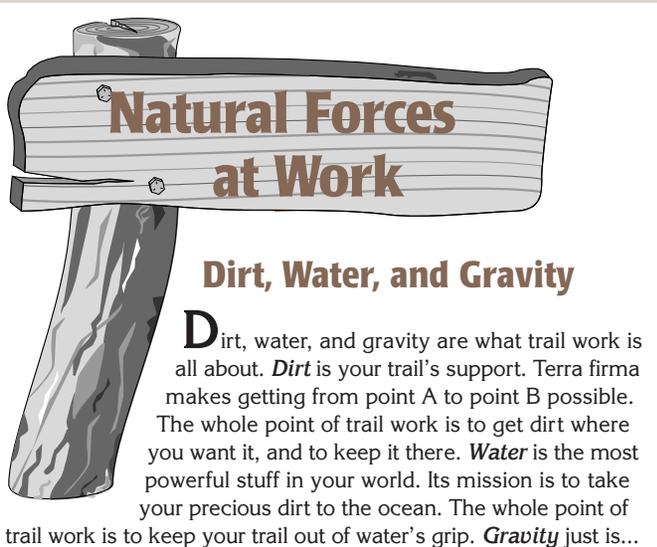
#### HINTS FOR LOCATORS

- 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

**D**irt, 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 punchon. 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

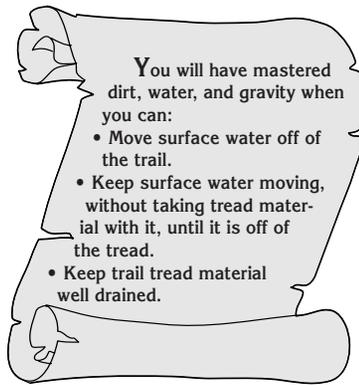
and get it off the trail. When and where you can do that determines what sort of water control or drainage structure you use.

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.



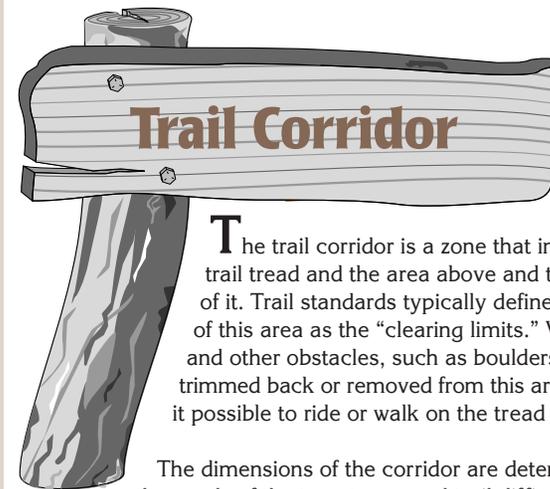
## Critter Effects

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

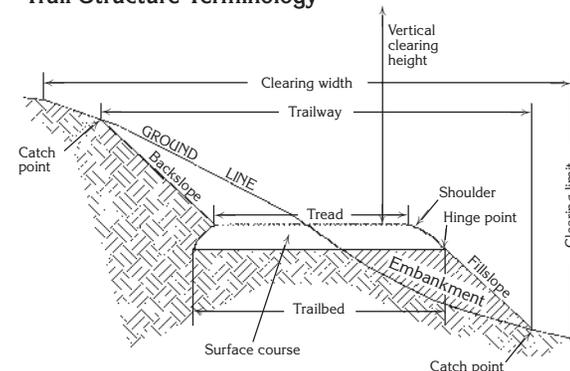


Figure 5—Terms describing the trail corridor. Often there will be detailed dimensions you need to know.

## 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 down 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).

"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.

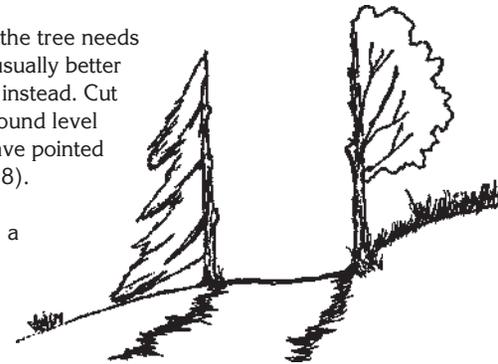


Figure 8—These trees should have been removed rather than pruned.

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.

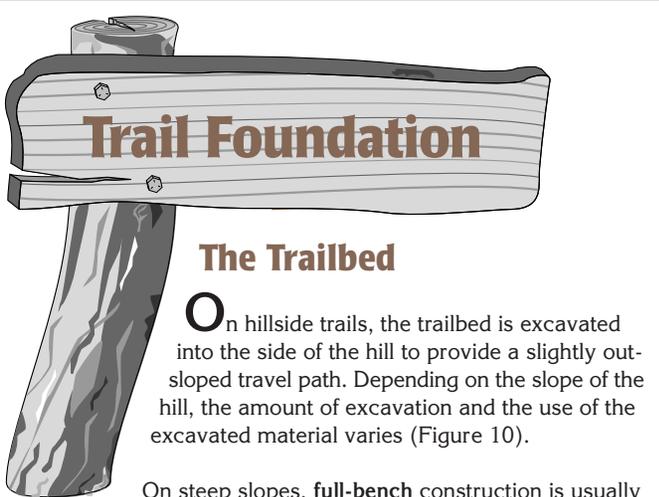
It is hard to decide whether or not to remove "leaners," trees that have not fallen but are leaning across the trail. If the leaner is within the trail clearing zone, it should be removed. Beyond that, it is a matter of discretion whether a leaner needs to be cut. The amount of use on the trail, the 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.





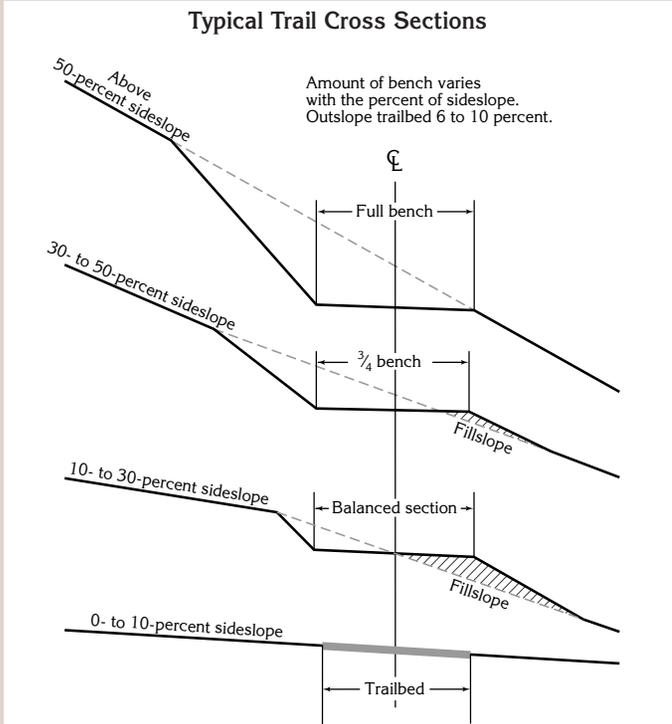
## Trail Foundation

### The Trailbed

On hillside trails, the trailbed is excavated into the side of the hill to provide a slightly out-sloped 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



Amount of bench varies with the percent of sideslope. Outslope trailbed 6 to 10 percent.

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.

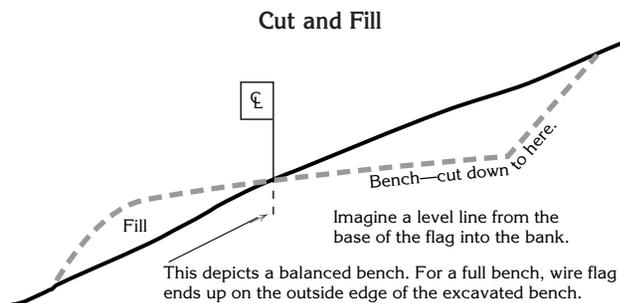


Figure 11—Basic sidehill trail building.

- 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

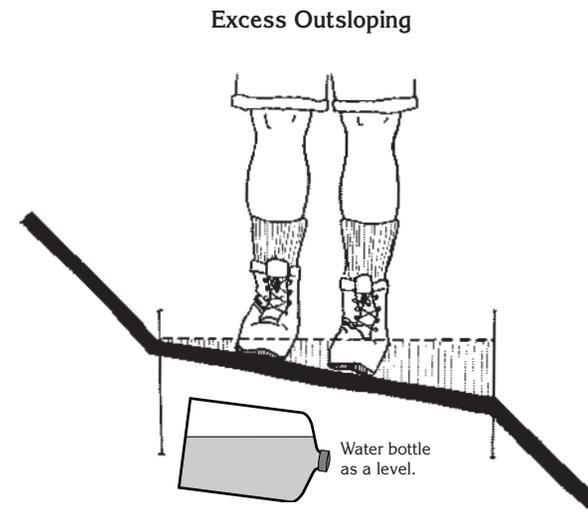


Figure 12—If your ankles start to roll, there is too much outslope.

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.**

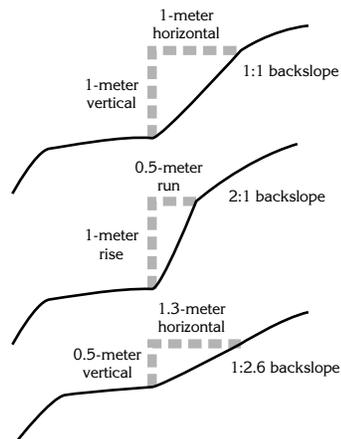


Figure 13—Slopes are noted in metric as a ratio of vertical to horizontal, or “rise” to “run.”

## 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.

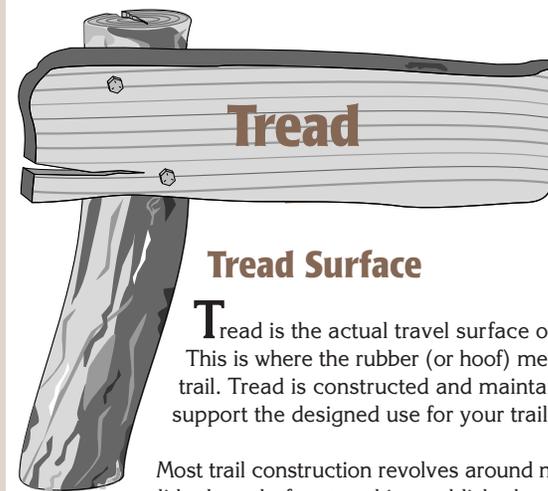
Compare existing trail tread materials with borrow sources. Consider the proportions of gravel, sand, and fines. Individual “fine” particles are not visible to the naked eye and are classified as silt or clay. If the proportions of gravel, sand, and fines are similar, you can expect the borrow materials 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.

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## Tread Surface

**T**read 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

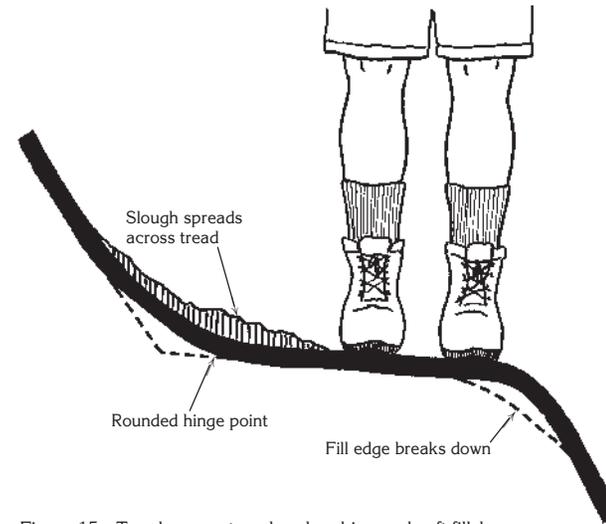


Figure 15—Tread creep at work—sloughing and soft fillslopes.

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

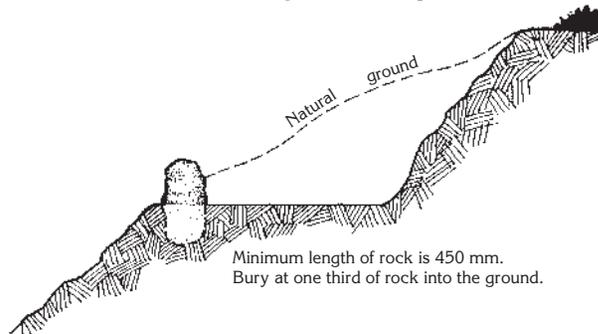


Figure 16—Guide rock properly installed to help prevent tread creep.

## 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

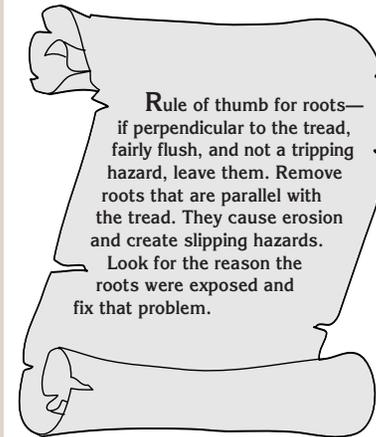
Maintain tread at the designed width. This means filling ruts, holes, and low spots. It includes removing obstacles such as protruding roots and rocks. It also means repairing any sections that have been damaged by landslides, uprooted trees, washouts, or boggy conditions.

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.

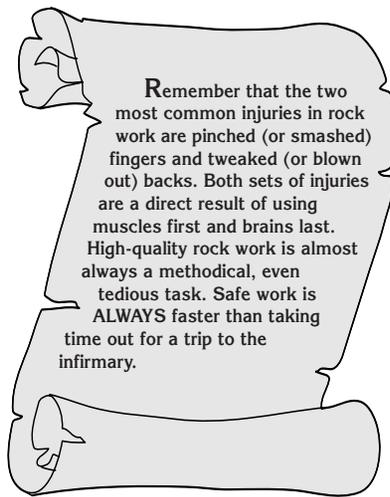
Not all roots and stumps are problems. You should not have to remove many large stumps from an existing trail. Before you do so, consider whether a stump was left the last time around to help keep the trail from creeping downhill.



## 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.



**Remember that the two most common injuries in rock work are pinched (or smashed) fingers and tweaked (or blown out) backs. Both sets of injuries are a direct result of using muscles first and brains last. High-quality rock work is almost always a methodical, even tedious task. Safe work is ALWAYS faster than taking time out for a trip to the infirmary.**

Tools of the trade include:

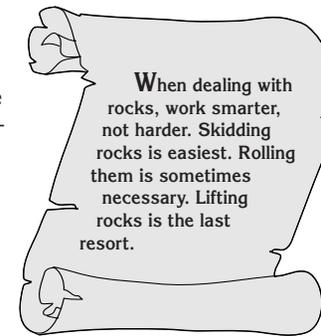
- Lots of high-quality rockbars; don't settle for the cheap digging bars, you need something with high tensile strength.
- Pick mattock.
- Sledge hammer.
- Eye protection, gloves, and hardhat; don't even think of swinging a tool at a rock without wearing these.
- Gravel box, rock bag, rucksack, rock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



**When dealing with rocks, work smarter, not harder. Skidding rocks is easiest. Rolling them is sometimes necessary. Lifting rocks is the last resort.**

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.

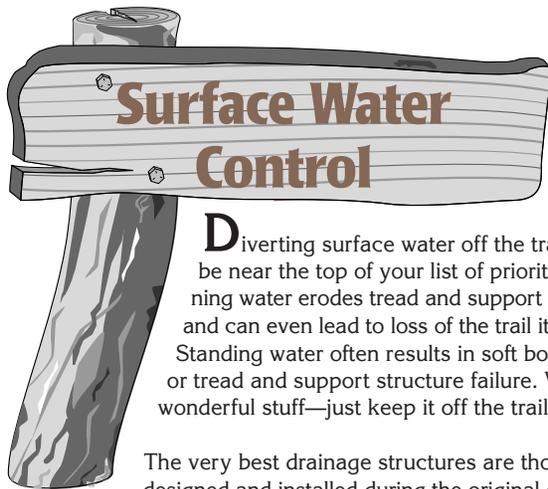
Even worse is the possibility an out-of-control rock might cross a trail or road below you, hitting someone. If there is any possibility of people below, close the trail or road, or post sentries in safe locations to warn travelers of the danger.

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.



## Surface Water Control

**D**iverting 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 tread and support structure failure. Water is wonderful stuff—just keep it off the trail.

The very best drainage structures are those designed and installed during the original construction. These include outsloping the tread and grade dips. We've already discussed outsloping. Let's move on to the next best drainage choice, grade or drain dips. The classic mark of good drainage is that it is self maintaining, requiring minimal care.

### Grade Dips

The best grade dips are designed and built during the original construction. These are also called terrain dips, Coweeta dips, and swales. Other versions, often called rolling grade dips, or drain dips, can be built on most sidehill trails or constructed to replace waterbars. The basic idea is to use a reversal in grade to force water off the trail without the need for any other structure.

**Terrain dips** use grade reversal to take advantage of natural dips in the trail. These need to be planned into the trail when it is first laid out. The grade of the trail is reversed for about 3 to 5 m (10 to 15 ft), then "rolled" back over to resume the descent. A trail

that lies lightly on the land will take advantage of each local drainage to remove water from the tread (Figure 18) as the trail winds around trees and rocks. The terrain dip, which uses existing terrain as the control point for the grade reversal, is a natural part of the landscape.

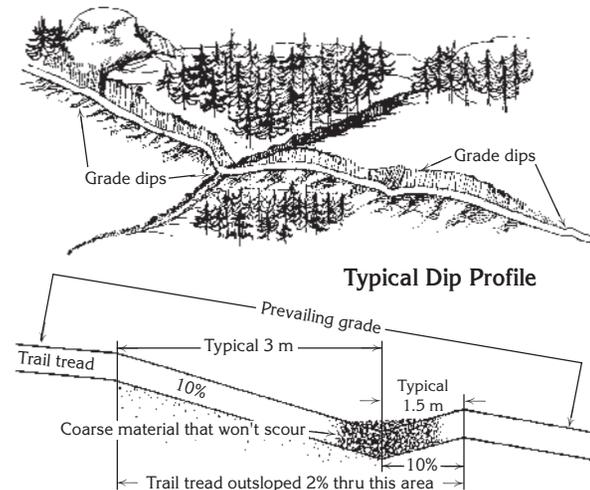


Figure 18—Grade dips are much more effective than waterbars and require less maintenance. Along with outsloping, they are the drainage structure of choice.

The beauty of terrain dips is that water collected from the hillside is not intercepted and carried by the tread. These grade dips are the most unobtrusive of all drainage structures if constructed with smooth grade transitions, and they require very little maintenance. Be sure to protect the drain outlet by placing guide structures along the lower edge of the tread above or below the outlet.

Another kind of grade dip is the **rolling grade dip**, which consists of a short reversal of grade in the tread. These can be designed into most sidehill trails. If a trail is descending at 7-percent grade, a short climb of, say, 3 to 5 m (10 to 20 ft) at 3 percent, followed

by a return to the descent, constitutes a rolling grade dip (Figure 19). Water running down the trail cannot climb over the short rise and will run off the outsloped tread at the bottom of the dip. The beauty of this structure is that there is nothing to rot or be dislodged. Maintenance is simple.



Figure 19—Rolling grade dip designed into the construction of the trail.

If the grade is steep, the tread carries a lot of water, traffic is high, or the soils are erosive, a drain dip may need some additional strengthening. Sometimes a shallow water channel can be constructed in the last several meters of tread leading into the dip. Water follows the channel off the tread without slowing down and depositing soil and debris. A spillway may be needed if there is a potential for headcut erosion in the fillslope. The secret is to keep the water moving at a constant velocity until it is all the way off the tread.

Grade dips should be placed frequently enough to prevent water from building enough volume and velocity to carry off your tread surface. Grade dips are pointless at the very top of grades unless they intercept significant amounts of slope drainage. Usually mid-slope is the best location. Grade dips also should not introduce sediment-laden water into live streams.

Yet another grade dip is the **reinforced or armored grade dip**. In this dip, a curved water channel is constructed and an angled (like a waterbar) reinforcing bar of rock or wood is placed at the top of the grade reversal. The bar is placed in an excavated trench, with its top edge flush with the existing tread surface so it's not an obstacle to traffic. Essentially, this is a buried waterbar.

This short reinforced grade dip can be built to replace waterbars on existing trails, especially trails used by wheeled vehicles. Well-located waterbars can be converted by constructing a curved water channel and recontouring the outslope from the top of the bar. For longevity it is best if the bar is resealed so that the top edge is flush with the existing tread surface and the channel is constructed with the correctly angled bar as the reference point.

The outlet is critical. It should be at least 500 mm (1.5 ft) wide, and outsloped. In shallow dips the task is to prevent berms, soil buildup, and puddling. Reinforced spillways may also be needed.

## Waterbars

The **waterbar** is the second most common drainage structure, after out-sloping. Water moving down the trail is turned by contact with the waterbar and, in theory, is directed off the lower edge of the trail. Waterbars are usually the most dysfunctional tread structures in all of the trail world. Yet trail crews annually install or reinstall them by the thousands.

We encourage the use of reinforced grade dips instead of waterbars at most locations where waterbars have been traditionally used. Here's why—

By design, water hits the waterbar and is turned. The water slows down and sediment drops in the drain. The number one cause of waterbar failure is sediment filling the drain until the water tops the bar and continues down the tread. The bar becomes useless. You can build a good grade dip quicker than a waterbar, and it works better.

On grades less than 5 percent, waterbars are less susceptible to clogging (unless they serve a long reach of tread or are in very erodible tread material). On steeper grades (15 to 20 percent), waterbars are very prone to clogging if the bar is at less than a 45° angle to the trail. Waterbars are mostly useless at grades steeper than 20 percent. At these grades a very fine line exists between clogging the drain and eroding it (and the bar) away.

Most waterbars are dysfunctional because they are not installed at the right angle and are too short. The waterbar needs to be anchored 300 mm (12 in) into the cutslope **and** still extend 300 mm (12 in) into the fillslope. If your tread is 600 mm (24 in) wide, the bar must be 1.7 m (5 ft 6 in) long to be correctly installed at a 45° angle. A bar fitted at an angle of 60° must be 2.4 m (7 ft, 7 in) long. Wider tread requires a longer bar. When the bar is cut too short, the usual response is to install it at a lesser angle. Then it clogs.

Poorly constructed and maintained waterbars also become obstacles. Most waterbars are installed with one-third to one-half of the bar material above the existing tread surface. Some crews even install bars with exposed faces taller than 150 to 200 mm (6 to 8 in). On grades steeper than 7 percent (particularly in erodible soils), the soil placed on the tread below the waterbar is rapidly lost to traffic and water erosion. The structure becomes a “low hurdle” for travelers.

Wimpy little wooden bars less than 150 mm (6 in) in diameter wear or clog quickly into uselessness. Often they rot away in just a few years. Another problem with wooden waterbars is that horses kick them out.

Cyclists of all sorts hate wooden waterbars because of the hazard they present to wheeled traffic. The exposed angled surface can be very slippery, leading to crashes when the wheel slides sideways down the face of the bar. The rider continues down the trail without the cycle. As the grade increases, the angle of the bar (and often the face height) is increased to prevent sedimentation. This raises the crash-and-burn factor.

Are waterbars ever useful? Sure. Wood or rock waterbars are useful on foot and stock trails where a tripping hazard is acceptable, especially at grades less than 5 percent. Also consider reinforced waterbars where you don't have much soil to work with and in areas that experience occasional torrential downpours (Figure 20).

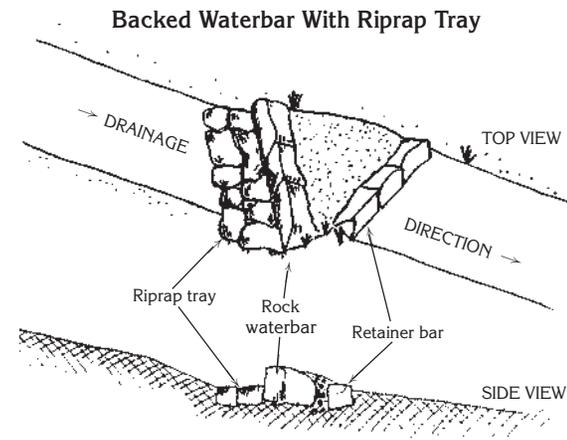


Figure 20—Reinforced or armored waterbars.

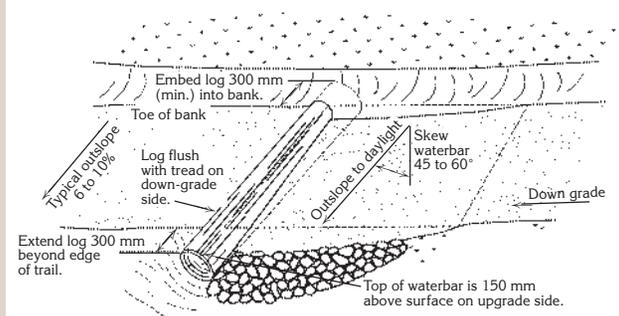
The bar helps keep traffic from wearing a water carrying groove through the drain. Install the bar at an angle of at least 45° and increase the angle as the grade approaches 5 percent or if the soils are very erodible (Figures 21 and 22).

Remember that high-faced bars are barriers to wheeled traffic. On trails that serve wheeled traffic, use either reinforced grade dips or rubber waterbars instead of traditional waterbars. Bikers do not like waterbars because of the “crash factor.” It is important to place rubber waterbars such that wheeled vehicles cannot go around them (creating a water channel around the waterbar). Be sure to cut the rubber belting so that it bends easily under the wheel. A stiff rubber bar at a 45° to 60° angle can cause wrecks (Figure 23).



Figure 21—Waterbars need to be constructed at a 45 to 60° angle to the trail. Water should run off the trail before hitting the waterbar.

### Log or Treated Timber Waterbar and Anchors



#### ANCHORING METHODS

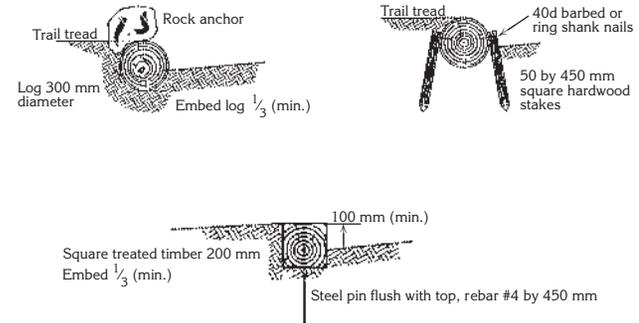
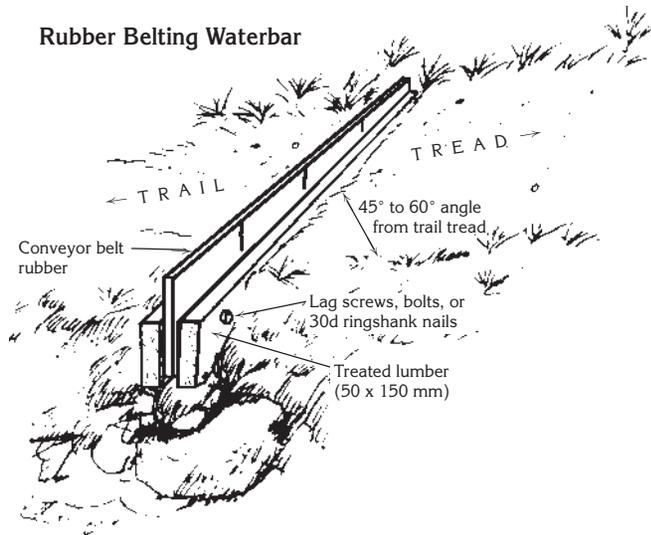
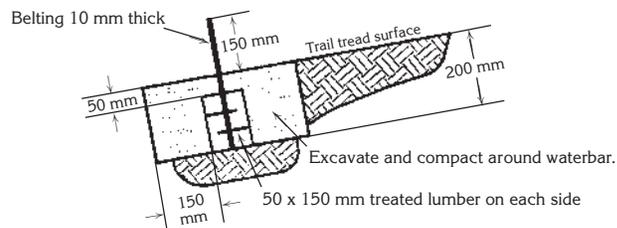


Figure 22—Logs used for waterbars need to be peeled (or treated with preservative), extended at least 300 mm (12 in) into the bank, staked or anchored, and mostly buried.

## Rubber Belting Waterbar



### Nailing and Cutting Detail



Make cuts in belting 300 mm apart for better spring-back.

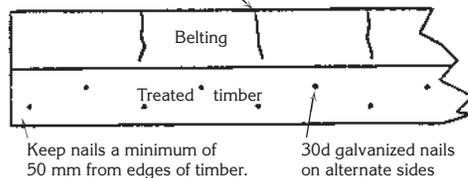
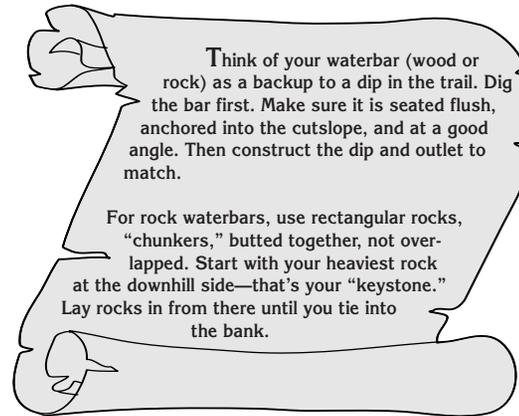


Figure 23—Rubber belt waterbars are good choices on trails used by wheeled vehicles. They are not as good as reinforced grade dips.



Think of your waterbar (wood or rock) as a backup to a dip in the trail. Dig the bar first. Make sure it is seated flush, anchored into the cutslope, and at a good angle. Then construct the dip and outlet to match.

For rock waterbars, 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.

## Maintaining the Drain

The number one enemy of simple drains is sediment. If the drain clogs, the water you are trying to get rid of either continues eroding its way down the tread, or just sits there in a puddle. Your job is to keep that water off, Off, OFF the tread!

The best drains are “self cleaning.” But in the real world most drains collect debris and sediment; this must be removed before the drain stops working. Since a long time may pass between maintenance visits, the drain needs to handle annual high volume runoff without failing.

Most problem drains are waterbars. If the water is slowed by hitting the waterbar, sediment builds up. This can be compounded by inadequate outslloping or an outlet that is too narrow. The extra time it takes to rebuild the offending bar into a functional drain will pay off almost immediately (Figure 24).

The best cure for a waterbar that forces the water to turn too abruptly is to rebuild the structure into a reinforced grade dip. The reset bar and curved water channel keep the sediment-laden

water moving through the outlet. If this is not an option, the next best move is to reset the waterbar at a steeper angle. Usually a longer bar will be needed.

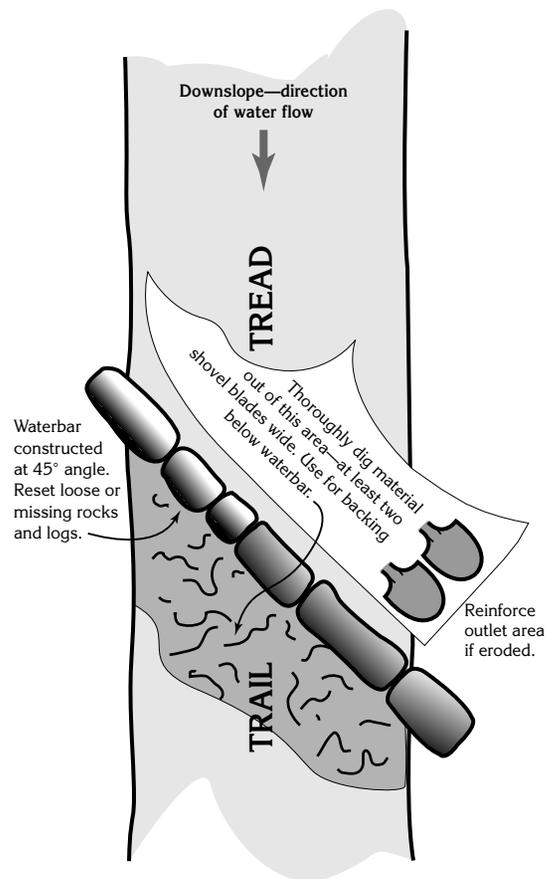


Figure 24—The key to waterbar maintenance is to ensure that sediment will not clog the drain before the next scheduled maintenance. Embed the rocks or logs a little deeper, cover them with soil, and you have a reinforced grade dip.

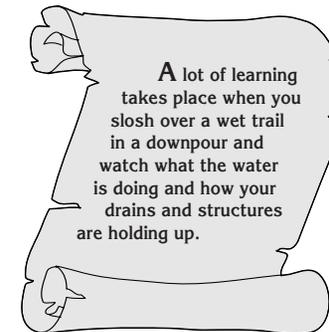
If a lot of tread has eroded below the bar, reset the bar so it is flush with the existing tread height. Regrade the water channel and outlet drain. On gentle trails, tamp the excavated mineral soil sediment into the tread on the downhill side of the bar. Scatter any organic debris well off the trail.

At grades steeper than 7 to 10 percent, or in highly erodible soils, borrow material placed below the bar will usually erode away quickly. This is particularly true on waterbars with high faces. Downhill traffic, especially packstock, will step in the same place every time and dislodge any new material you place there. If a significant step-off exists below the bar, reset the bar flush with the existing tread level and deepen the drain above the bar.

Dig drains and leadoff ditches wide enough to prevent clogging by debris, and graded so water does not slow before it is off the trail. Ditches that allow water to return to the tread below the drain need to be reconstructed so this doesn't happen.

You may need to install additional water control structures if erosion is evident. Figure out where the water is coming from and where it is likely to go. Think about soil type, slope gradient, distance of flow, and volume of water before you start moving dirt.

Eroded trails do not always become major problems. Many eventually stabilize if the trail surface is rocky, and use, water, and slopes are moderate. The key question is whether the loss of tread will materially affect the designed challenge and risk levels of the trail. If not, the erosion isn't significant. It is exceedingly rare for an eroding trail to have a significant effect on aquatic or riparian habitat or stream function.



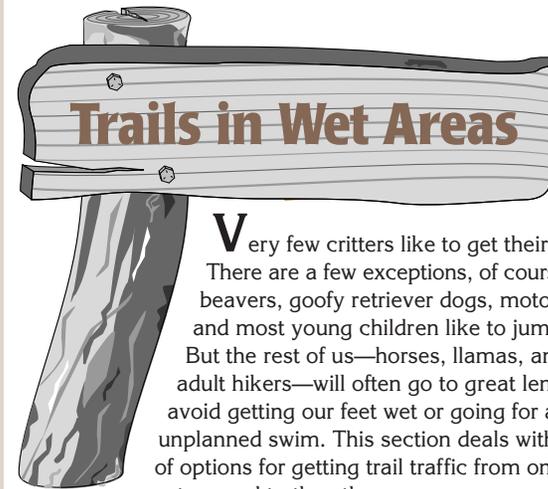
## Ponding

Adequate puddle drains are important. Puddles may produce several kinds of tread damage. Traffic going around puddles may widen the tread (and eventually the puddle). Standing water usually weakens the tread and fillslopes. It can cause a bog to develop if the soils are right. Traffic on the soft lower edge of a puddle can lead to step-throughs and cause tread creep.

When a crew takes a swipe at the berm with a shovel or kicks a hole through it—that's useless puddle control. These small openings are rapidly plugged by floating debris or the mud-mooshing effect of passing traffic. The puddle lives on.

Effective puddle prevention requires constructing a wide drain. The ultimate drain is when the entire section of tread is outsloped. If terrain prevents such outsloping, the next best solution is to cut a puddle drain at least 600 mm (24 in) wide extending across the entire width of the tread. Dig the drain deep enough to ensure that the water can escape the tread. Feather the edges of the drain into the tread so travelers don't trip over them. Plant guide structures along the lower edge of the tread at either side of the drain to keep traffic in the center. In a really long puddle, construct several drains at what appear to be the deepest spots.

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**V**ery few critters like to get their feet wet. There are a few exceptions, of course. Otters, beavers, goofy retriever dogs, motorcyclists, and most young children like to jump right in. But the rest of us—horses, llamas, and stodgy adult hikers—will often go to great lengths to avoid getting our feet wet or going for an unplanned swim. This section deals with a range of options for getting trail traffic from one side of wet ground to the other.

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 will be time well spent. The alternative route should bypass extensive boggy areas, be on a slope for better drainage, and have mineral rather than organic soil for its tread. Don't reroute a problem section of trail to another boggy piece of ground. If you do, the result will be two problem sections instead of one.

Sometimes, *improved drainage* will cure the problem. If so, this is a much less costly solution than other alternatives. Placing *stepping stones* is another technique for crossing bogs and streams. Stepping stones should be large, fairly flat on top, and partially buried in the streambed. Space the stones for the average stride, remembering that trails are for kids, too. It shouldn't be necessary to jump from stone to stone.

Moving up in cost and complexity, two types of structures—*turn-pike and puncheon*—are commonly constructed to provide dry trails through wet or boggy areas. Using *geosynthetics* in combination with these techniques can often result in a better tread

with less fill. Rock and fill *causeways* are popular in some areas where hardened trails are needed to cross fragile alpine meadows.

In situations where long spans are needed high above the ground, or for crossing streams, a *trail bridge* is usually needed instead of puncheon. Bridges require special designs fitted to each application. Engineering approval is needed before constructing either a standard or special design bridge.

*Boardwalks* are common in some parts of the country, particularly parts of Alaska and in the Southeast. These can range from fairly simple structures placed on boggy surfaces, to elevated boardwalks over marshes or lake shores, as are sometimes found at interpretive centers (Figure 25).

Let's look at some of these alternatives in more detail.



Figure 25—This boardwalk relies on pilings for support. Helical earth anchors can also support the structure.

## Improving Drainage

Although an area may appear perfectly flat, often it will have a slight gradient and flow of water. Drainage ditches and culverts can help ensure that water drains off the trail.

Generally, *ditches* are at least 300 mm (12 in) deep, have flat bottoms, and side slopes of 1:1. In many cases, the ditch can be extended beyond the wet area to capture water that might flow onto the trail (Figure 26).

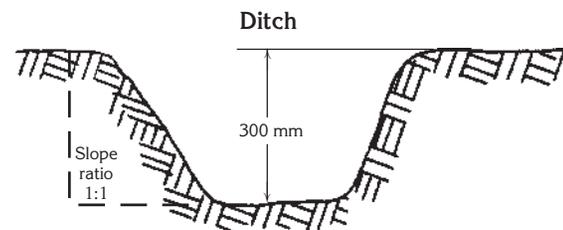


Figure 26—Ditches are a simple and effective way to drain wet areas. Slope angle and depth vary with soil and water conditions.

The simplest way to get water across a trail is to cut a trench across it. These *open-top cross drains* (Figure 27) can be reinforced with rocks or treated timbers to help keep them from caving in. These structures are not usually a good alternative because people and stock stumble on them. One way to reduce this risk is to make the ditch wide enough, at least 600 mm (2 ft), so stock will step in it rather than over it (Figure 28).

An open drain can be filled with gravel. This is called a *French drain*. Start with larger pieces of rock and gravel at the bottom, topping off with smaller aggregate (Figure 29). French drains are often used to drain a spring or seep from under a trail bed.

*Culverts* are probably the best way to move small volumes of water across a trail. They have a big advantage over open top cross ditches because the tread extends over the culvert without

### Open-Top Cross Drain Culvert

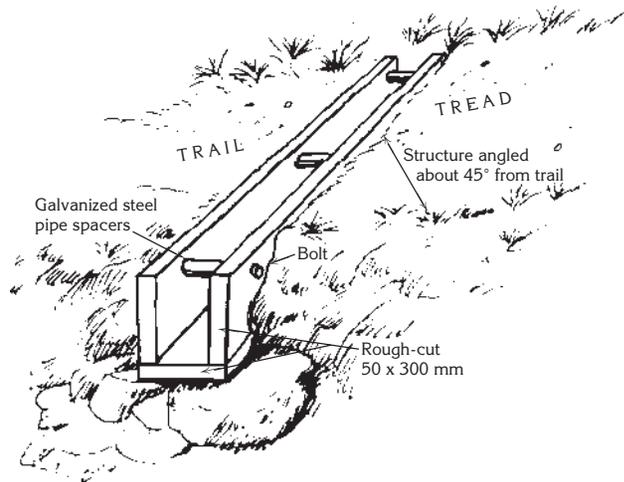


Figure 27—Open-top cross drains or culverts are not often chosen because they are a hazard to livestock, hikers, and bikers.



Figure 28—Wide cross drain and causeway.

### French Drain or Rock Underdrain

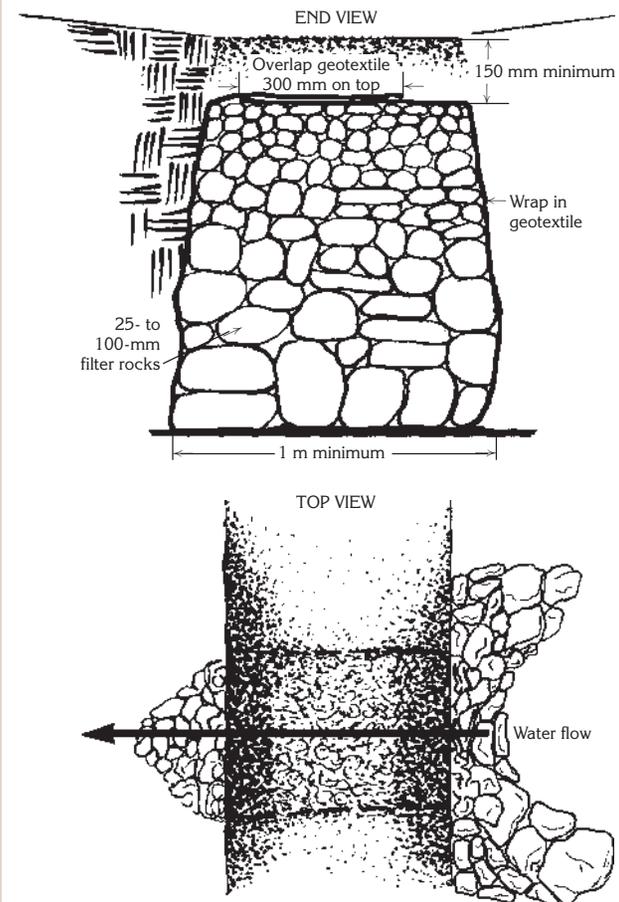


Figure 29—Wrapping French drains with geotextile helps prevent clogging. These are used to drain low-flow springs and seeps.

interruption (Figure 30). Metal or plastic culverts can be installed easily, or the culverts can be constructed out of rock. Dig a ditch across the trail as wide as the culvert and somewhat deeper.



Figure 30—Culverts need to be installed at a sharp enough angle to prevent sediment from being deposited.

Bed the culvert in native soil shaped to fit the culvert. There also needs to be sufficient drop, about 3 percent, from one side to the other so water will flow through the culvert without dropping sediment. The culvert needs to be covered with 150 mm (6 in) or more of fill. Cut the culvert a little longer than the trail width, and build a rock facing around each end to shield it from view and prevent it from washing loose. Often a rock-reinforced spillway will reduce headcutting and washouts.

The local trail manager may have definite preferences for metal, plastic, wood, or rock culverts. Synthetic materials may be taboo in wilderness. Plastic is often preferable to metal because it is lightweight, easy to cut, and less noticeable. Painting the ends of aluminum or steel culverts helps camouflage them. Use a culvert with a diameter large enough to handle maximum storm runoff and to be accessible for cleaning with a shovel or combination tool. Usually this means at least a 260-mm (9-in) diameter culvert.

**Rock culverts** offer a chance to display some real trail skills. Begin by laying large, flat stones in a deep trench to form the bottom of the culvert. In some installations, these bottom rocks

may not be necessary. Then install large, well-matched stones along either side of the trench. Finally, span the side rocks with more large, flat rocks placed tightly together, enough to withstand the expected trail use. Cover the top rocks with tread material to hide and protect the culvert. These culverts, too, need to be large enough to clean out easily. The rocks should not wiggle (Figure 31).

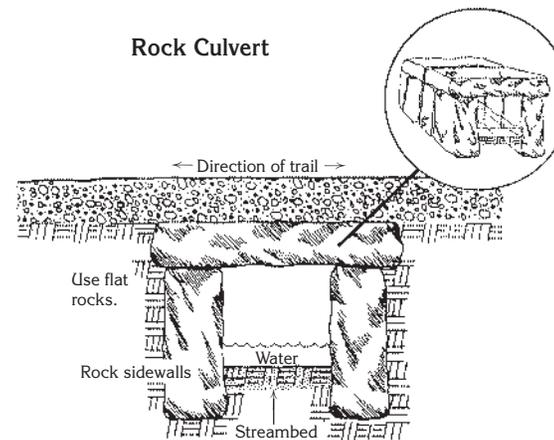


Figure 31—Rock culverts may also have stones laid along the bottom of the culvert. The perfect rocks shown here are seldom found in nature, except reportedly in Southwestern sandstone.

Water flowing toward a culvert often carries a lot of silt. If the water slows as it goes under the trail, the silt may settle out and clog the culvert. A good way to help prevent this from happening is to construct a **settling basin** at the inlet to the culvert (Figure 32). This is a pit at least 300 mm (1 ft) deeper than the base of the culvert. It can be lined with rocks as desired. The idea is that sediment will settle out here, where it is much easier to shovel away, rather than inside the culvert.

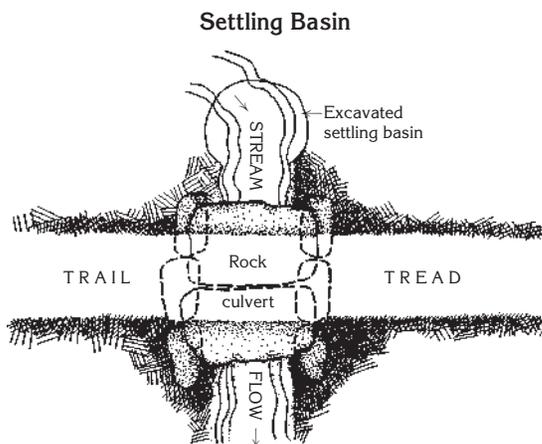


Figure 32—Settling basins help prevent culvert clogging.

## Geosynthetics

Geosynthetics are synthetic materials (usually made from hydrocarbons) that are used with soil or rock in many types of construction. Geosynthetics can increase the effectiveness of construction methods and offer some additional alternatives to traditional trail construction practices.

Geosynthetics perform three major functions: separation, reinforcement, and drainage. Geosynthetic materials include geotextiles (construction fabrics), geonets, sheet drains, geogrids, and geocells. All these materials become a permanent part of the trail, but must be covered with soil or rock to prevent deterioration by ultraviolet light or damage by trail users.

**Geotextiles** (Figure 33) are the most widely used geosynthetic material. Sometimes they are called construction fabrics. They are made from long-lasting synthetic fibers bonded to form a fabric.

They are primarily used for separation and reinforcement over wet, unstable soils. They have the tensile strength needed to support loads and can allow water, but not soil, to seep through. Nonporous geotextiles can be used in drainage applications to intercept and divert ground water.

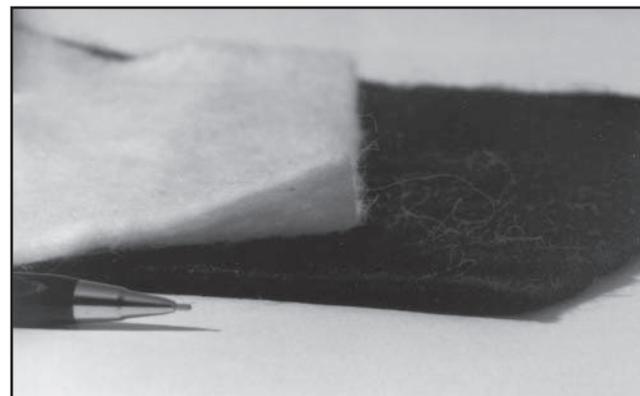


Figure 33—Felt-like geotextiles are easier to work with than heat-bonded, slit-film, or woven products that have a slick texture.

Geotextiles are often used in trail turnpike or causeway construction. They serve as a barrier between the silty, mucky soil beneath the fabric and the mineral, coarse-grained, or granular soil placed as tread material on top of the geotextile. The importance of separation cannot be overemphasized. 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 for trail turnpikes. The fabric should allow water to pass through it, but have openings of 0.3 mm or smaller to prevent silt from passing through.

Geotextile is sensitive to ultraviolet light. It readily decomposes when exposed to sunlight. Unexposed, it lasts indefinitely. Always store unused geotextile in its original wrapper.

**Geonets or geonet composites** (Figure 34) have a thin polyethylene drainage core that is covered on both sides with geotextile. They are used for all three functions—separation, reinforcement, and drainage. Since geonets have a core plus two layers of geotextile, they provide more reinforcement than a single layer of geotextile.

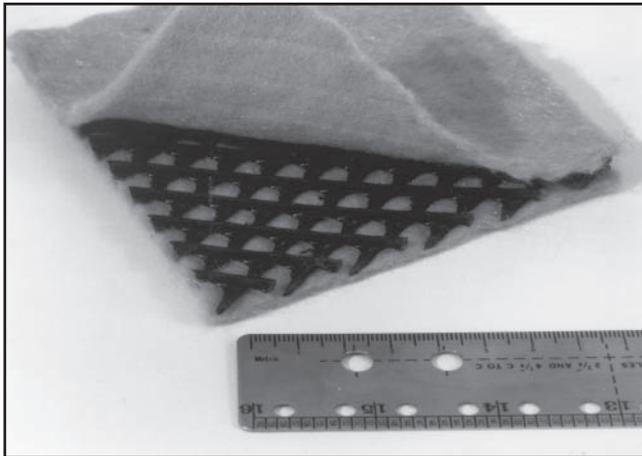


Figure 34—The net-like core of geonet allows drainage.

**Sheet drains** (Figure 35) are another form of composite made with a drainage core and one or two layers of geotextile. The core is usually made of a polyethylene sheet shaped like a thin egg crate. The core provides an impermeable barrier unless it has been perforated by the manufacturer. When used under the trail tread material, sheet drains provide separation, reinforcement, and drainage. Since they have greater bending strength than geotextiles or geonets, less tread fill is often needed.

Sheet drains or geonets can be used as drainage cutoff walls (Figure 36). If the trail section is on a side slope where subsurface water saturates the uphill side of the trail, a cutoff wall can be constructed to intercept surface and subsurface moisture, helping to drain and stabilize the trail section.

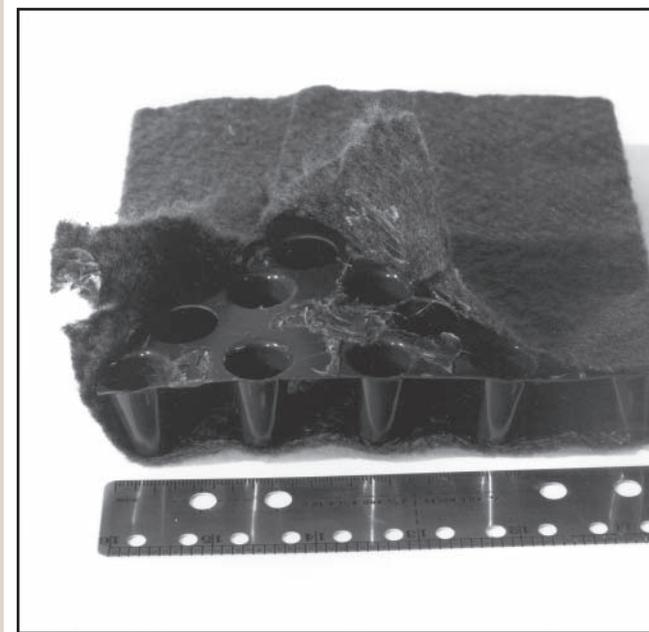


Figure 35—Sheet drains have a large cross section that provides significant drainage capacity. If placed under the trail tread, orient the sheet drain with the geotextile side on the bottom and the plastic core on top.

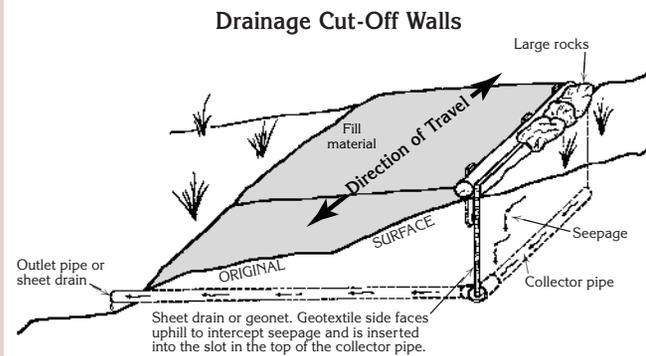


Figure 36—Sheet drain or geonet used to intercept seepage.

**Geogrids** (Figure 37) are made from polyethylene sheeting that is formed into very open grid-like configurations. Geogrids are good for reinforcement because they have high tensile strengths, and coarse aggregate can interlock into the grid structure. Geogrids are normally placed on top of a layer of geotextile to obtain separation from saturated soils in wet areas.

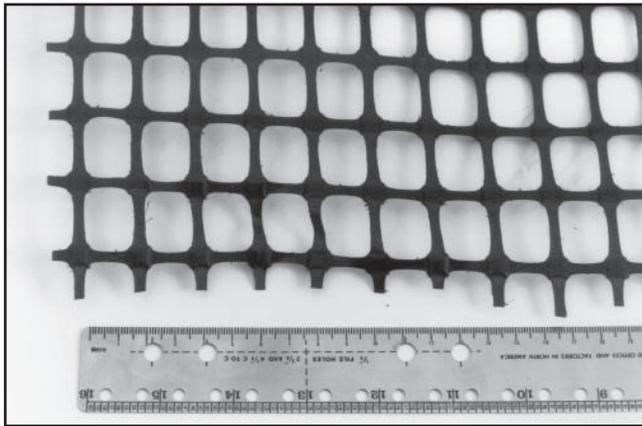


Figure 37—Geogrids are normally placed on top of a layer of geotextile to obtain separation from saturated soils.

Concrete grid blocks are another technique for armoring switch-back turns or steeper slopes, especially on trails designed for motorized traffic.

**Geocells** (Figure 38) are usually made from polyethylene strips bonded to form a honeycomb structure. Each of the cells is filled with backfill and compacted. Geocells are good for reinforcement, reduce the amount of fill material required, and help hold the fill in place. Geocell usually has geotextile under it to provide separation from saturated soils. The grids need to be covered with soil so they will never be exposed. Exposed geocells present a substantial hazard to vehicles due to loss of traction.



Figure 38—Geocell usually has geotextile under it to provide separation from saturated soils.

Multiple layers of filled geocells, each level offset to provide sufficient batter, are used as retaining walls. Vegetation grows in the “flower pot” cells along the face of the wall, providing attractive camouflage (Figure 39).

## Turnpikes

Turnpikes are used to elevate the trail above wet ground. The technique uses fill material from parallel side ditches and from offsite to build up the trail base higher than the surrounding water table. Turnpike construction is used to provide a stable trail base



Figure 39—"Flower pot" retaining wall of geocells.

in areas of high water table and fair to well drained soils. Turnpikes are practical up to 10 percent trail grade (Figure 40).

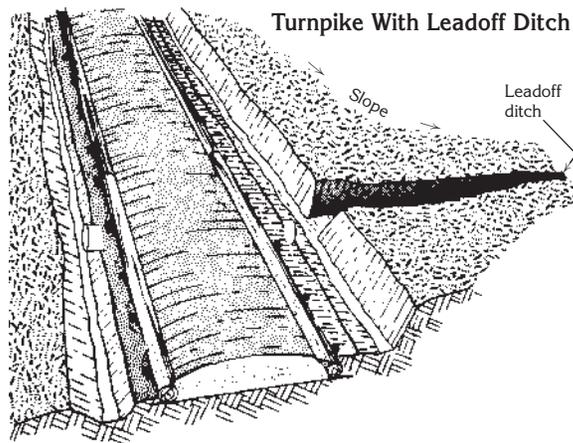


Figure 40—Trail turnpike.

A turnpike should be used primarily in flat areas with 0 to 20 percent sideslope where there is wet or boggy ground. The most important consideration is to lower the water level below the trail base and carry the water under and away from the trail at frequent intervals. Turnpikes requires some degree of drainage. When the ground is so wet that grading work cannot be accomplished and drainage is not possible, use puncheon surfacing instead. However, a turnpike is easier and cheaper to build and may last longer than puncheon. A causeway is another alternative where ground water saturation is not a problem but a hardened tread is needed.

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 would protrude above the turnpike tread or cause large rips in geotextiles should be removed or at least cut flush below the final base grade.

Ditch both sides of the trail to lower the water table. Install geotextile or other geosynthetic materials and retainer rocks or logs. Geotextile and geogrid should go under any retainer rocks or logs (Figure 41). Lay the geotextile over the top with no excavation, then fill over with high quality fill. An alternative method, one that not only provides for separation between good fill and clay but also keeps a layer of soil drier than the muck beneath, is called encapsulation, or the sausage technique. Excavate 250 to 300 mm (10 to 12 in) of muck from the middle of the turnpike. Lay down a roll of geotextile the length of the turnpike, wide enough

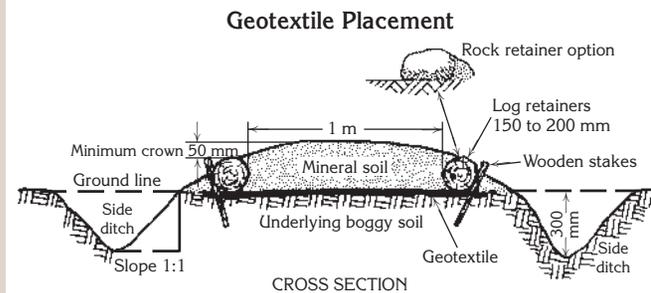


Figure 41—Place geotextile under the retainer logs or rocks before staking.

to fold back over the top with a 300-mm (1-ft) overlap (Figure 42). Place 150 mm (6 in) of good fill, or even rocks, on top of the single layer of geotextile, then fold the geotextile back over the top and continue to fill with tread material.

### Sausage or Encapsulation Technique

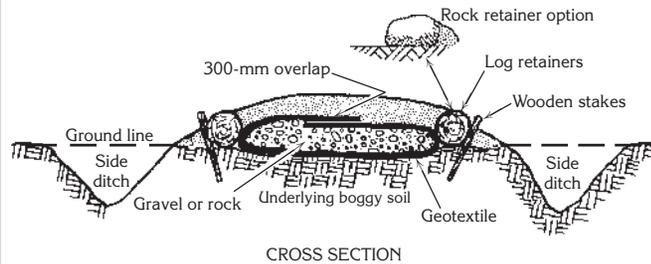


Figure 42—Sausage or encapsulation method.

Rocks or logs can be used for retainers. Rocks last longer. If you use logs, they should be at least 150 mm (6 in) in diameter and peeled. Lay retainer logs in one continuous row along each edge of the trail tread. The logs can be notched to join them, if desired. However, in some species notching may cause the logs to rot faster (Figure 43).

### Notched Retainer Log

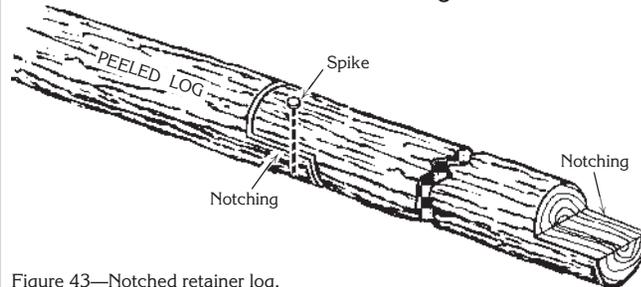


Figure 43—Notched retainer log.

Anchor the logs with stakes or, better yet, large rocks along the outside. Inside, the fill and surfacing hold the retainer logs (Figure 44).

Firm mineral soil; coarse-grained soils or granular material; or small, well-graded angular rock are needed for fill. Often it is necessary to haul in gravel or other well-drained material 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 tread is 50 mm (2 in) or a minimum of 2-percent grade above the retainers. It doesn't hurt to overfill to begin with, as the fill will settle.

### Sapling Stake

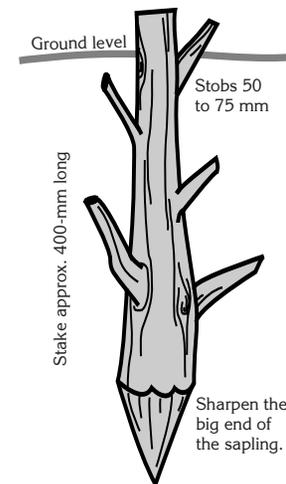


Figure 44—Try this old Alaska trick if your stakes tend to work up out of boggy ground.

Construct a dip, waterbar, or a drainage structure at each end of the turnpike where necessary to keep water from flowing onto the structure. Keep the approaches as straight as possible coming onto a turnpike, to minimize the chance that stock or motorbike users will cut the corners and end up in the ditches.

Turnpike maintenance, especially recrowning, is particularly important the year after construction; most of the soil settling occurs during the first year.

## Causeways

A more environmentally friendly relative of the turnpike is the causeway, essentially a turnpike without side ditches (Figure 45). Causeways filled with crushed rock have been successfully used throughout the Sierra Nevada and elsewhere to create an elevated, hardened tread across seasonally wet alpine meadows. Often multiple parallel paths are restored and replaced with a single causeway. Causeways create less environmental impact than turnpikes because ditches are not used and the water table is not lowered. The risk is that in highly saturated soils the causeway could sink into the ground, a problem that geotextile can help prevent.

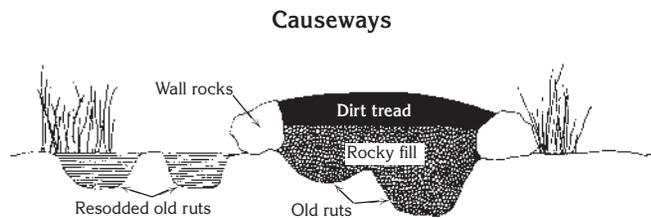


Figure 45—Causeways create an elevated, hardened tread across seasonably wet areas.

## Puncheon

Puncheon is a wooden walkway used to cross bogs or deep muskeg, to bridge boulder fields, or to cross small streams. It can be used where uneven terrain or lack of tread material makes turnpike construction impractical (Figure 46). Puncheon is also preferred over turnpike where firm, mineral soil cannot be easily reached; puncheon can be supported on muddy surfaces better than turnpike, which requires effective drainage.

Puncheon resembles a short version of the familiar log stringer trail bridge. It consists of a deck or flooring made of sawn, 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 surface puncheon. Puncheon placed flush with the wetland surface is known as subsurface puncheon.

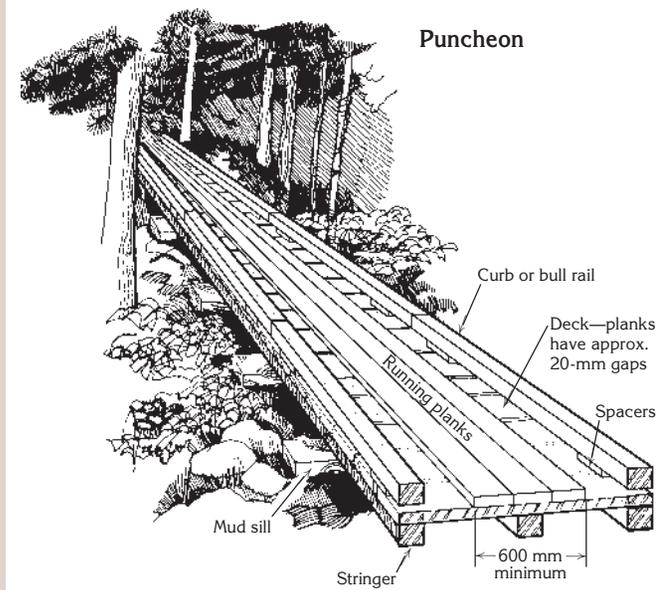


Figure 46—Puncheon.

Sooner or later, you'll probably hear the term, corduroy. Corduroy is basically a primitive type of puncheon. It consists of laying three or more native logs on the ground as stringers with cross logs laid side by side across the stringers and bound together with wire or nails (Figure 47). Corduroy should always be buried, with only the tread exposed. Corduroy is notorious for not lasting very long and consuming large amounts of material. It should only be used as a temporary measure.

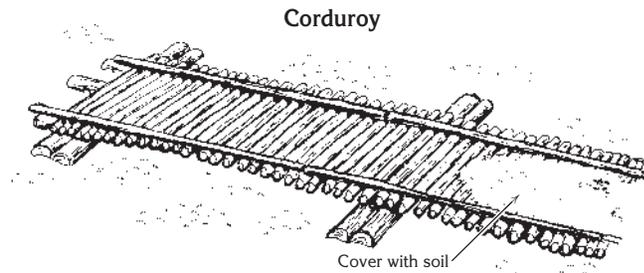


Figure 47—Corduroy should be considered a temporary fix until a more permanent structure can be installed.

Here's how to build puncheon. First of all, 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 m (10 ft) coming up to a puncheon. Any curves either approaching or while on the puncheon add to the risk of slipping, especially to stock and to mountain bike and motorcycle users.

To begin construction, install mud sills. These support the stringers. Mud sills can be made of native logs, treated posts, short treated planks, or precast concrete parking lot curb blocks. The mud sills are laid in trenches at both ends of the area to be bridged at intervals of 1.8 to 3 m (6 to 10 ft) (Figure 48). They are approximately 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 the needed flotation. Enclosing rock and fill in geotextile minimizes

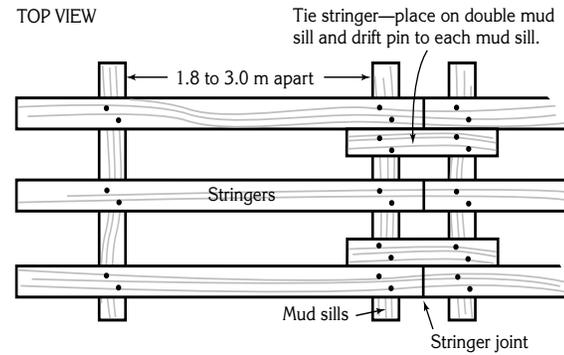


Figure 48—Mud sill and stringer layout.

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 m (8 ft).

Stringers made from 200-mm (8-in) peeled logs or treated timbers are set on top of the mud sills. They should be at least 3 m (10 ft) long and matched by 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 sufficient for hiking trails, but for heavier uses, such as stock use, three are recommended.

Notch the mud sills, if necessary, to stabilize the stringers and to even out the top surfaces (Figure 49). To hold the stringers in place, toenail spikes through the stringers to the mud sills or drive Number 4 rebar ( $\frac{1}{2}$  in) through holes in the stringers.

Next comes the decking. The thickness needs to be strong enough for the loads the structure will need to support. Lengths can be as narrow as 460 mm (18 in) for a limited-duty puncheon for hikers. The decking should be 1.2 to 1.5 m (4 to 5 ft) long for puncheon suitable for stock use.

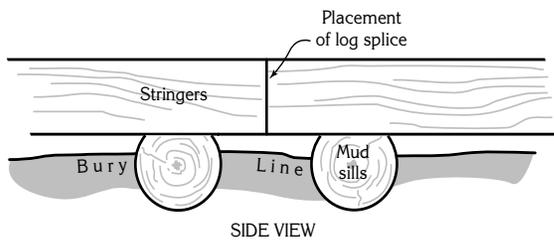


Figure 49—When using logs, notch the mudsill—not the stringer. Do not notch them more than one third of their diameter.

Do not spike decking to the center stringer, if you have one, because center spikes may work themselves up with time and become obstacles. Leave at least a 20-mm ( $\frac{3}{4}$ -in) gap between decking pieces to allow water to run off (Figure 50). 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.

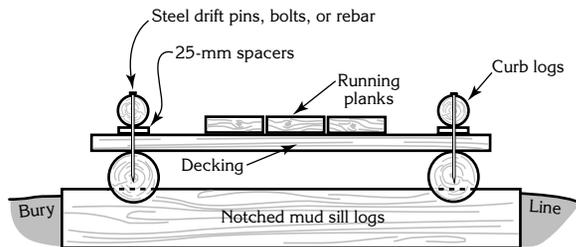


Figure 50—Place decking planks on stringers to provide bearing for the full width of the plank.

Running planks are often added down the center for stock to walk on. Often the running planks are untreated because horseshoes cut out 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.

Curb logs, 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 or backing plate needs to be put at each end of the structure to keep the stringers from contacting the soil (Figure 51). If the plate stays in place, do not spike it to the ends of the stringers. Spiking causes the stringers to rot faster.

In the rare case where puncheon is constructed on grades steeper than 5 percent, treat the surface to reduce slipping. Use cleats, commercial fish netting, mineral roofing, or other surfacing.

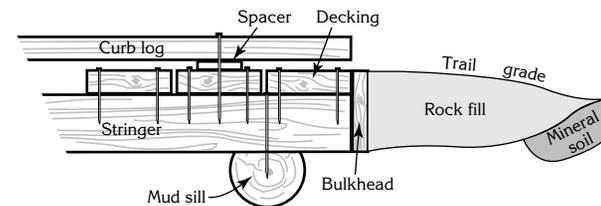


Figure 51—Place a bulkhead or backing plate at each end of the puncheon. Approaches should have a rising grade so water will not run onto the structure.

## Subsurface Puncheon

Subsurface puncheon involves construction with the mud sill, stringers, and decking under the surface. This design depends on continual water saturation for preservation (Figure 52). Moisture, air, and wood are needed before wood can rot. Remove any one of these and rot won't occur. 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.

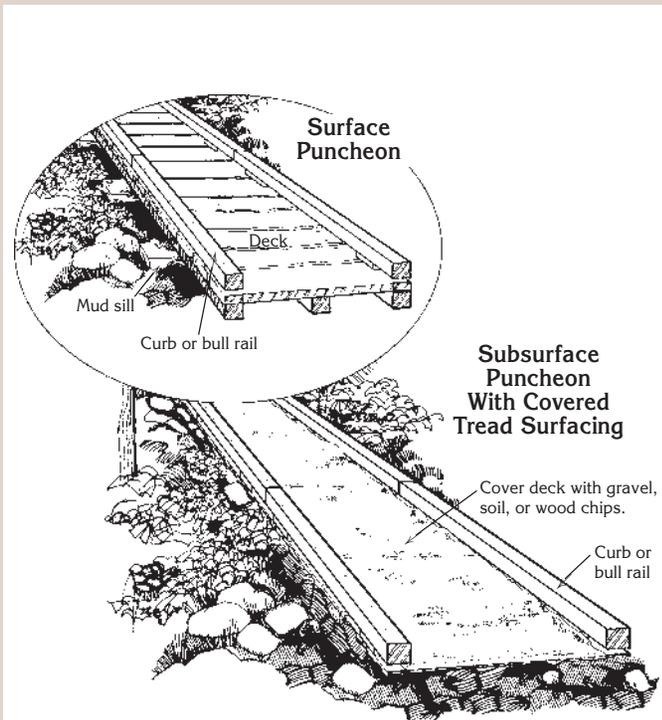
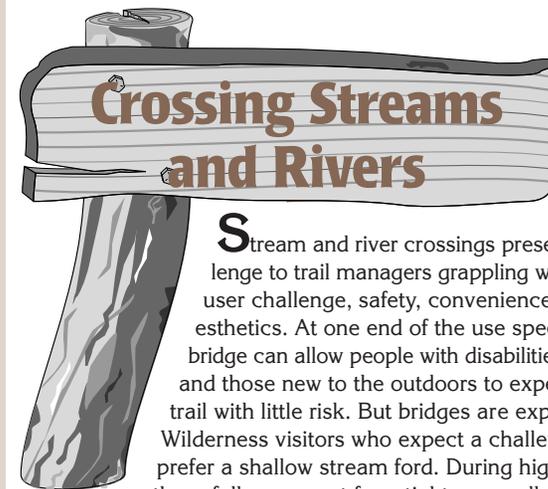


Figure 52—Subsurface puncheon with covered tread surfacing.



**S**tream and river crossings present a challenge to trail managers grappling with a mix of user challenge, safety, convenience, cost, and esthetics. At one end of the use spectrum, a bridge can allow people with disabilities, toddlers, and those new to the outdoors to experience the trail with little risk. But 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. Each kind of water crossing has consequences for the recreation experience and the lands being accessed. Choose wisely from the spectrum of options before committing present and future resources to any given crossing.

The Minimum Tool philosophy suggests that we get the job done with the least long-term impact while still meeting management objectives for an area. A few Minimum Tool questions for crossings are:

- Do we really need a bridge here? Do we really need to be through here a month earlier each spring?
- Will someone be killed or injured if we don't provide an easier crossing?
- Is this really the best place to cross this stream?
- What alternatives do we have to cross this stream, including not crossing it at all?
  - Can we afford to do this?
  - What are the environmental and social consequences of a given type of crossing here?
- Who will really care if we don't build (or replace) a bridge?
  - It's a wonderful thing to keep one's feet dry. But it is expensive to keep feet dry in the backcountry.

## Shallow Stream Fords

A shallow stream ford is a consciously constructed crossing that will last for decades with a minimum of maintenance (barring major flood or debris torrent) 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 not designed to be used during high runoff, but are intended to be used when flows are moderate to low. A ford for hikers and “nontraditional” packstock (like llamas and pack goats) should not be more than 400 to 600 mm (16 to 24 in) deep (about knee high) during most of the use season. A horse ford (Figure 53) shouldn’t be deeper than 1 m (39 in).

### Shallow Stream Ford or Gully Crossing Log Structure

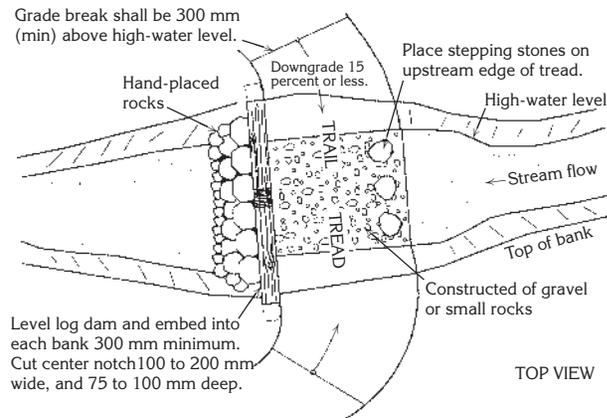


Figure 53—Build fords when the water is low. Place stepping stones for hikers (continued on next page).

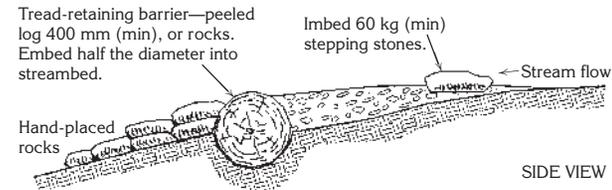


Figure 53—(continued).

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. Avoid locations where the stream turns, because the water will undercut approaches on the outside of a turn.

The tread in the ford is level, ideally made of medium-sized gravel. This provides solid footing. The plan is to even out the flow through the ford so the gravel-sized material isn’t washed away, leaving only cobble or boulders.

You can do this by arranging a level riprap of big rocks (like a miniature dam) or anchoring a log about 1 to 2 m (3 to 7 ft) downstream from the trail centerline. The idea is to evenly slow the water as it goes across the ford. This slowing effect can be enhanced by placing several rows of stepping stones or rocks upstream from the tread. These slow the water entering the ford and begin to even out the flow. Be sure these upper rocks are not too close to the trail to avoid a scouring effect.

On trails receiving motorized use, concrete planks or blocks placed in soft stream bottoms can strengthen the trail tread for a solid crossing.

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 or parts of the dam. Debris can catch in the dam or stepping stone line and alter flow characteristics. Approaches can erode into jumpoffs or turn into boggy traps. Maintenance consists of retaining or restoring the design criteria of an even shallow flow with solid footing.

## Bridges

Bridges range from a simple foot log with handrails to multiple span, suspended, and truss structures (Figure 54).



Figure 54—Typical log stringer trail bridge.

On national forests, all bridges require design approval from engineering before being constructed. A national standard trail bridge drawing is available, and some regions have standardized, approved designs for simple bridges.

On hiking trails, foot logs can be used to cross streams where safe fords cannot be located or to provide access during periods of high runoff. Constructed foot logs consist of a log, sills, and bulkheads. The foot log should be level and well anchored. Notch the sill, not the log. The top surface should be hewn to provide a walking surface at least 250 mm (10 in) wide. Don't let the log or rails touch the ground. Remove all bark from logs and poles (Figure 55).



Figure 55—Log footbridge. The sill can be notched to accommodate the logs, not vice-versa.

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. If you have handrails, construct them according to plan. Improperly constructed handrails are a big liability, because they are not strong enough.

Choosing the materials for a bridge is not a simple process. Even the use of native material for a simple foot log has consequences. For example, most untreated logs of a durable wood (like coastal Douglas-fir) have a useful life of less than 20 years. Yet a log that

is big enough to support visitor traffic and winter snow loads may be 100 years old. Plus, the typical bridge has three to four stringers. Multiply this replacement-to-growth ratio by several replacement cycles and you see how it's possible to create a slow motion clearcut around the bridge site.

Imported materials are often used to extend a bridge's life. Pressure-treated wood, metal, concrete, wood laminates, and even "space-age" composites are being used in bridges. Many of these materials must be trucked or flown to a bridge site and the old materials hauled out. All this is really expensive. Yet, these costs may be less than the more frequent and more dangerous replacement of structures made from 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 to avoid trashing the site by allowing winch guylines and dragged logs to scar trees and disturb the ground. The damage done in a moment can last for decades.

Other types of bridges include multiple span, suspended, and truss structures (Figure 56). A two-plank-wide suspended foot bridge with cable handrails is more complex than it looks. Mid-stream piers for multiple spans need to be professionally designed to support the design loads and withstand expected flood events. It does no one any good to win the National Primitive Skills Award for building a gigantic bridge by hand—only to have it fail a year later due to a design or construction oversight.

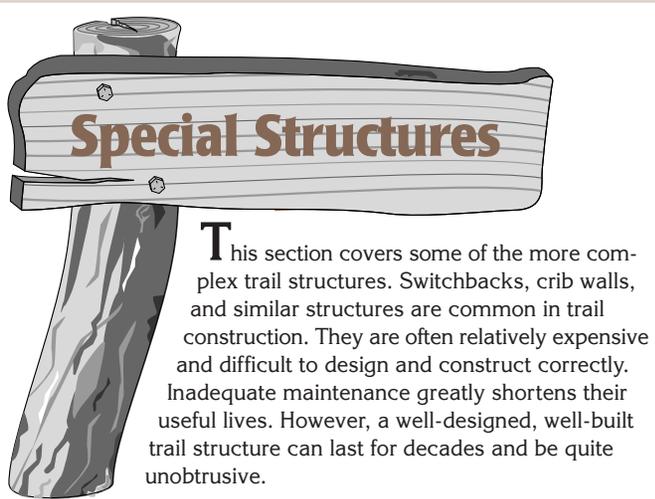


Figure 56—Suspension trail bridge typical of the Northern Rockies.

Bridges are expensive, so it makes sense to take good care of them. Check foot logs and bridges annually for problems. 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.

Report any of the following problems to a qualified bridge inspector who can determine whether the bridge should remain open to traffic: rot; bent, broken, or disconnected steel members; large checks, splits, crushed areas, or insect damage in wood members; permanent sag or excessive deflection; erosion around abutments; broken concrete; concrete with cracks larger than 3 mm ( $\frac{1}{8}$  in); or exposed rebar.

All bridge structures need to be inspected by a qualified bridge inspector at least every 4 years.



This section covers some of the more complex trail structures. Switchbacks, crib walls, and similar structures are common in trail construction. They are often relatively expensive and difficult to design and construct correctly. Inadequate maintenance greatly shortens their useful lives. However, a well-designed, well-built trail structure can last for decades and be quite unobtrusive.

Special structures are more frequently used on low-challenge trails where easy, wide, and smooth grades are the management goal. The cost of building relatively easy trail into progressively more difficult terrain quickly becomes prohibitive (remember how many fortunes and lives were poured into constructing railroads). Keep in mind the Minimum Tool philosophy and build only as many structures as you absolutely need to reach your goal.

Switchbacks and climbing turns are used to reverse the direction of travel on hillsides and to gain elevation in a limited distance. 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. A *switchback* is also a reversal in direction, but has a relatively level constructed landing (Figure 57). Switchbacks usually involve special treatment of the approaches, barriers, and drainages. They are used on steeper terrain, usually steeper than 15 to 20 percent. Both of these turns take skill to locate and are relatively expensive to construct and maintain. Choosing when to use each one is not always easy.

### Switchbacks and Climbing Turns

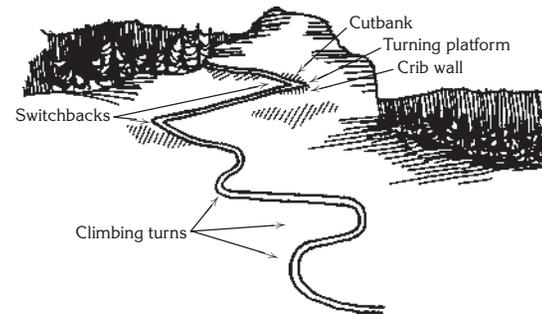


Figure 57—Climbing turns can be built on gentler slopes, usually not more than 15 to 20 percent. Switchbacks are needed on steeper sites.

Trail designers should make every effort to minimize the use of these turns. Planning carefully to avoid impassable or very difficult terrain reduces the need for switchbacks and climbing turns.

User psychology (human or animal) is more important to the success of these structures than any other trail structure. The turns must be easier, more obvious, and more convenient than the alternatives. They 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. They are not going to understand why you are building low hurdles in their path...and they will not be forced onto your trail and turns.

Try to avoid "stacking" a set of switchback turns on a patch of hillside. Long legs between turns help reduce the temptation to shortcut. Staggering the turns so that all legs are not the same length reduces the sense of artificiality. Keep the grade between turns as steep as the design challenge level allows. Remember, travelers will cut switchbacks when they feel it's more convenient

to cut the turn rather than stay on the tread. The designer's goal is to make travel on the trail more attractive than the shortcut (Figure 58).

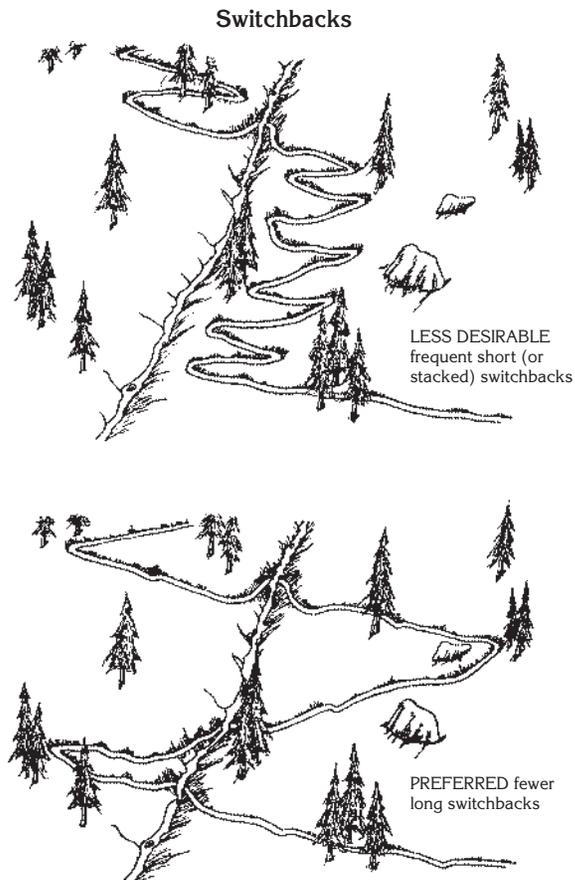


Figure 58—Long sections of trail between switchbacks are usually better than short—fewer switchbacks will be needed, with fewer turns to shortcut.

## Climbing Turns

Next to waterbars, climbing turns are the trail structure 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. If the slope is 40 percent, the turn forces travelers to climb at 40 percent. It is almost impossible to keep a climbing turn from eroding and becoming increasingly difficult to travel if the slope is steeper than 20 percent.

The advantages of climbing turns in appropriate terrain is that a larger radius turn (4 to 6 m, 13 to 20 ft) is relatively easy to construct. Trails that serve off-highway-vehicle traffic often use insloped, or banked, climbing turns so that riders can keep up enough speed for control (Figure 59). Climbing turns are also easier than switchbacks for packstock to negotiate. Climbing turns are usually less expensive than switchbacks because much less excavation is required, and fill is not used.

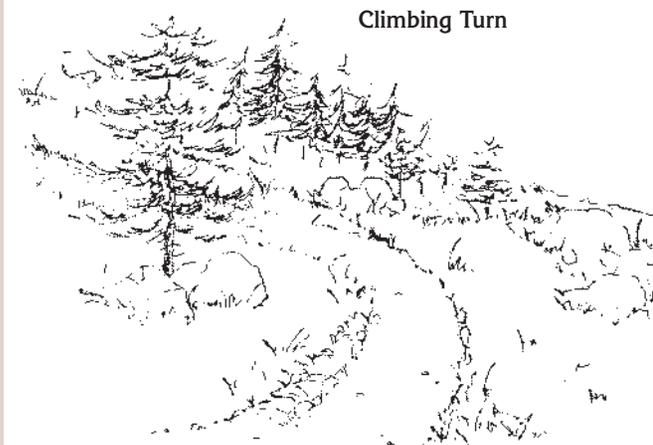


Figure 59—Climbing turns continue the climb through the turn. They can be insloped or outsloped.

The tread at each end of the turn will be full bench construction, matching that of the approaches. As the turn reaches the fall line, the amount of material excavated will decrease. In the turn, the tread will not require excavation other than that needed to reach mineral soil.

Guide structures should be placed along the inside edge of the turn. Temptation-reducing barricades can be added if necessary. The psychologically perfect place to build climbing turns is through dense brush or dog-hair thickets of trees. Be sure to design grade dips into the approaches.

## Switchbacks

Switchback turns are harder to build correctly, but retain stable tread on steeper terrain. Most switchbacks are constructed to a much lower standard than is needed. The key to successful switchback construction is making an 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 switchback locations. Use these for control points when locating the connecting tread. These 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 turn platform, a drain for the upper approach and platform, and guide structures. The upper approach and the upper half of the turn platform are excavated from the slope. Part of the lower approach and the lower half of the turn are constructed on fill (Figure 60).

The approaches are the place where most of the trouble with switchback turns start. The approaches should be designed for the primary user group. In general, the last 20 m (65 ft) to the

turn should be as steep as the desired challenge level will allow. This grade should be smoothly eased to match that of the turn in the last 2 to 3 m (6.5 to 10 ft).

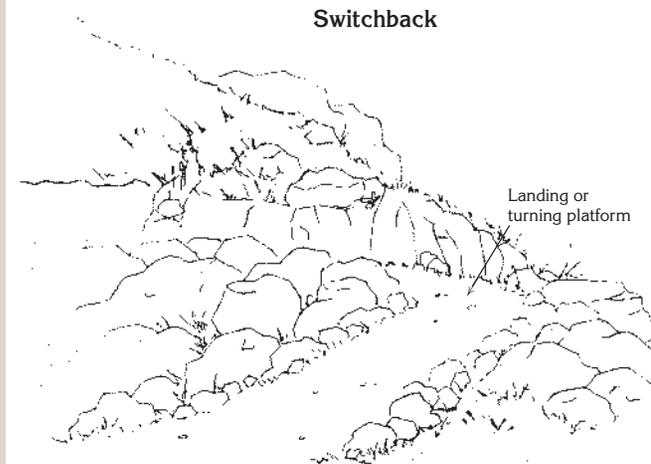


Figure 60—Switchback with a radial turning platform.

Do not “flatten” the grade 20 m (65 ft) before the turn. If anything, steepen the approach grades to foster the sense that the switchback 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, packstock, and wildlife from cutting your switchback. The only exception is a trail designed primarily for wheeled vehicles. The flatter approach makes control easier.

As the upper approach nears the turn, a grade dip should be installed. The tread below this point should be insloped until the halfway point in the turn. Both sides of this trench should be back-sloped to an angle appropriate for the local soil. As the turn is

reached, the tread should be widened 0.5 m to 1 m (1.6 to 3.2 ft) 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 m (5 to 10 ft) 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 (Figure 61). The turn platform is

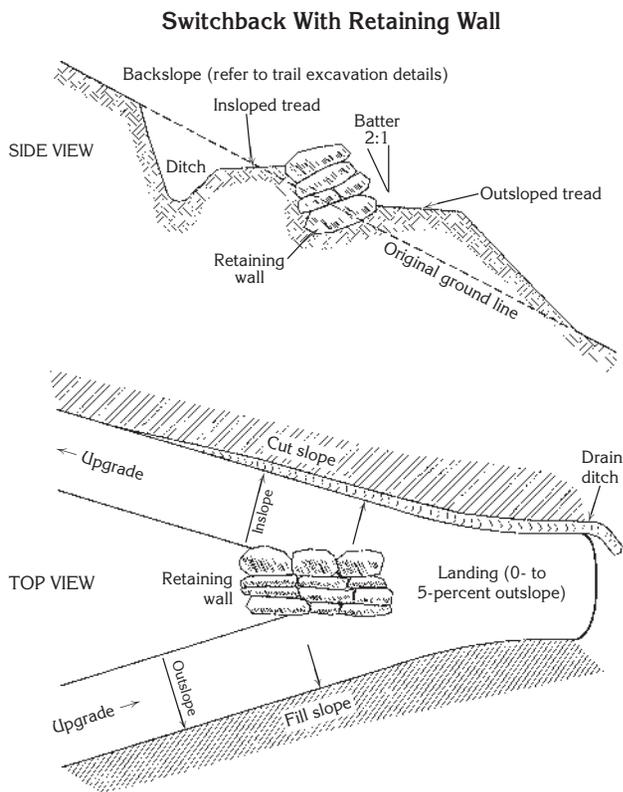


Figure 61—Switchback with a “Y” turning platform.

nearly flat, reaching no more than a 5-percent grade. The upper side is excavated from the side slope and the borrow 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 radius, the wider the platform, or the flatter the turn, the greater the excavation required. A point may be reached where a crib wall is needed to keep the backslope to a reasonable size.

The amount of tamped fill required on the lower side of the turn will usually be at least as much as excavated from the upper side unless a crib wall is used to support the fill. A crib 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 in the trench and be daylighted (have an outlet) where the excavation ends. Construct a spillway 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 crib wall should extend for most of this length. 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.

## Crib Walls and Other Retaining Structures

Retaining structures are designed to keep dirt and rock in place. The crib wall keeps fill from following the call of gravity and taking the tread with it. Retaining structures are useful for keeping scree slopes from sliding down and obliterating the tread, for keeping streams from eroding abutments, and for blocking traffic from going places it shouldn't.

The most common retaining structure is the crib wall. “Crib” is used primarily to keep compacted fill in place. Well-built crib is the most stable kind of uncemented retaining structure (except perhaps wire gabion).

Construct wood crib by interlocking logs or beams, pinned or notched (if logs) at the joints. Lay sill logs at right angles to the direction of travel and alternate tiers of face logs and header logs (Figure 62). 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, and are held in place by the fill. Outside the tread to keep water from saturating the fill and excavation. Use guide structures to keep traffic off the edge.

Wood crib is also used to construct piers for bridges and to hold rock fill for abutments. Wood crib is easier to build than rock cribbing, but is less durable, especially in environments visited by rot or fire. Be sure to select rot-resistant logs if using native materials.

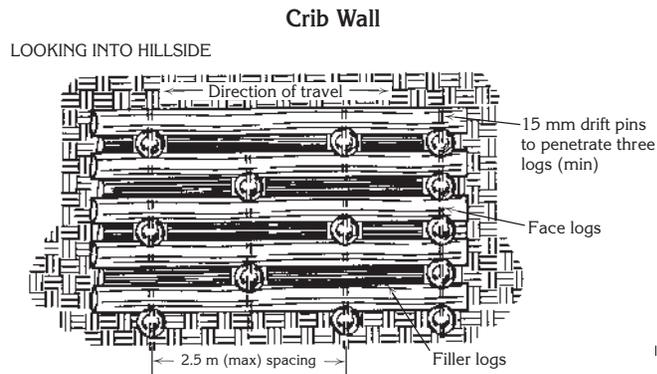


Figure 62—The characteristics of a crib wall. Treated logs are recommended (continued on next page).

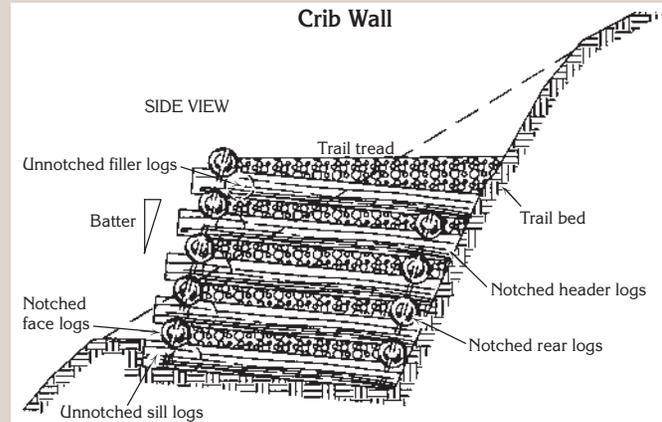


Figure 62—(continued).

Rock or crib retaining walls are used when a sturdy wall is needed to contain compacted fill or to hold an excavation wall in place. Rock retaining walls are also called “dry masonry” because no mortar is used between stones. Rock, when available on site, is preferred over logs.

To build a rock wall, excavate a footing in soil or to solid rock. The footing should be insloped to match the designed batter angle and deep enough to support the foundation tier of stones (these are usually the largest stones in the wall) for the full width of the tread. Ideally, the footing is dug so that the foundation tier is embedded for the full thickness of the stones (Figure 63).

Ideally, the stones should weigh at least 20 kg (45 lb). At least half of the stones should weigh more than 60 kg (130 lb). The ideal stone is rectangular with flat surfaces on all sides. The worst stone to use is rounded like river rock.

### Crib Wall Construction

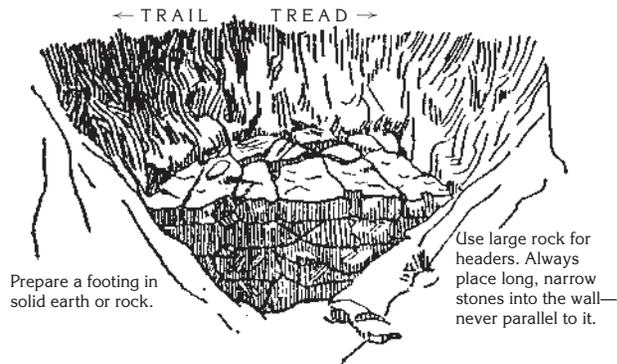
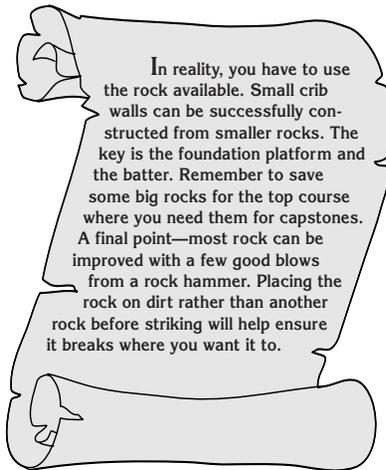


Figure 63—Rock placement and batter is critical on the first courses.



In reality, you have to use the rock available. Small crib walls can be successfully constructed from smaller rocks. The key is the foundation platform and the batter. Remember to save some big rocks for the top course where you need them for capstones. A final point—most rock can be improved with a few good blows from a rock hammer. Placing the rock on dirt rather than another rock before striking will help ensure it breaks where you want it to.

The batter should range from 2:1 to 4:1 (Figure 64). Factors determining this angle include the size and regularity of the rock, the depth of header stones, and the steepness and stability of the slope. At batter angles steeper than 4:1 or so, cement, or internal anchors (or both) may be needed for stability.

On short walls, it may be possible to construct

the entire structure starting upon a single keystone. The keystone is laid into the footing and successive tiers are laid. Each tier's face stones overlap the gaps between stones in the next lower tier. Each face tier includes tie or header stones that overlap the gaps between face stones and those deeper in the wall. The foundation

### Crib Wall Terminology

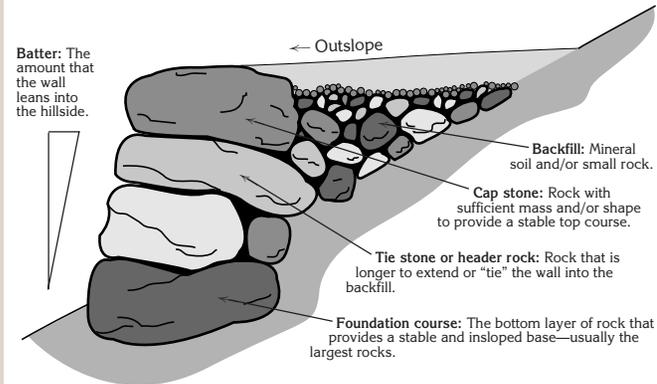


Figure 64—Terms used to describe crib walls.

tier (or the keystone) should be insloped slightly and rest on the excavated surface, not on fill. Each successive face tier should be staggered slightly into the hill to create the desired amount of batter. Header stones should also be used to tie deeper stones to those closer to the face. This is particularly important if the wall widens in cross section as it gains height.

Stones in each successive tier should be set so they have at least three points of good contact with the stones 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.* Backfill and tamp as you build.

Other forms of retaining walls include gabion and variations of wet masonry. Gabion is a series of wire baskets filled with rock. The baskets are wired together in tiers and can be effective where no suitable source of crib stone is available. Gabion is more artificial looking than crib (in the eyes of traditionalists at any rate), and may have a shorter 'lifespan,' depending on the type of wire used and the climate.

## Steps

Steps and stairways are used to gain a lot of elevation in a short distance. Steps are common on steep hiking trails in New England and elsewhere, less common (but not unheard of) on western trails used by horses and mules. Wooden steps of all configurations are common in coastal Alaska (Figure 65).



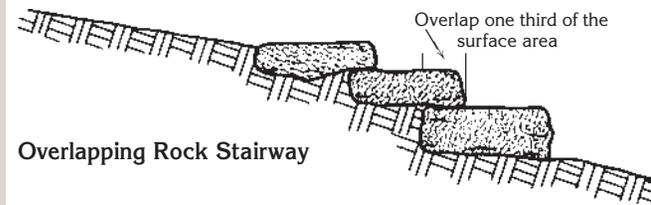
Figure 65—Step and run stairs in Alaska (plank boardwalk in foreground).

Sometimes steps are used in an existing trail to fix a problem caused by poor trail location or design. The result often 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.

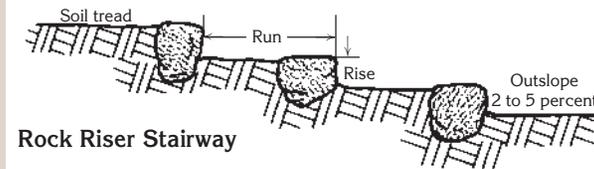
Your goal is to design the height (rise) and depth (run) of the steps to match the level of challenge desired. Steps are harder to negotiate as the rise increases. The difficulty also increases as the steps are closer together. Yet, as the trail becomes steeper, the step must either be higher or the 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.

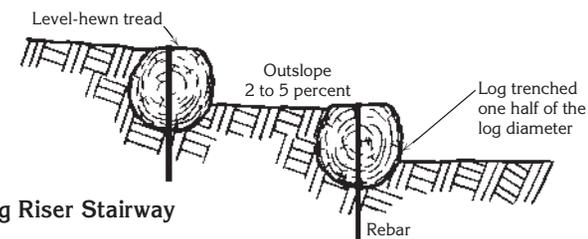
The components of a step are: the rise, the run, a landing on easier grades, and often retainer logs (Figure 66). The rise is the vertical distance gained at the face of each step. The run is the distance from the edge of one step to the base of the next step's face. The landing is the extension of the run above the step. In structures where the landing is composed of tamped fill material, retainer logs are used to retain the fill.



Overlapping Rock Stairway

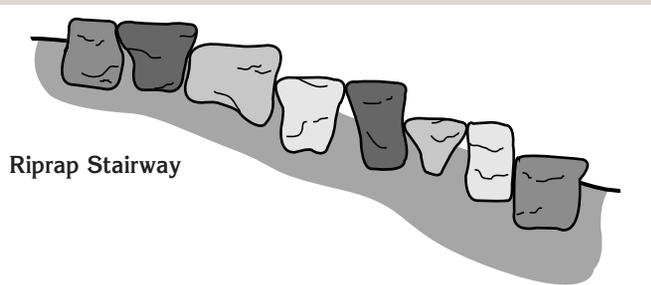


Rock Riser Stairway



Log Riser Stairway

Figure 66—Common types of steps (continued on next page).



Riprap Stairway

Figure 66—(continued).

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 mm (6 to 8 in) and the run long enough to hold a hiker's entire foot rather than just their toe (Figure 67). It's helpful to armor the sides of steps with rocks to encourage users to stay on the steps.

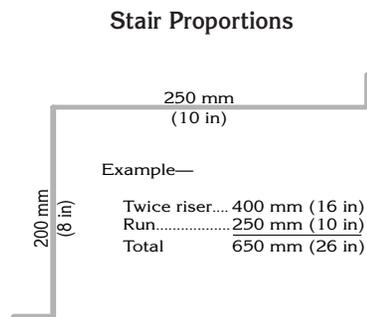


Figure 67—A general rule of thumb for stairs: Twice the riser plus the tread should equal 635 to 686 mm (25 to 27 in).

In more primitive settings, you don't need a uniform flight of steps as long as the route is obvious and there is solid tread at each stepping point. In the Sierra, a cross between cobblestones and stairs, locally called riprap, is commonly used for this purpose. Elsewhere, riprap refers to rock forming a loose retaining wall.

The most important area of the step is usually in the run. This is where most traffic steps as it climbs. If the step is composed of something like a board on edge with fill behind it, then the traffic will step onto the landing. Almost all foot traffic descending the step will walk off the edge of the step. 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 of each step should not contain a batter that creates a "face run" of over 50 mm (2 in) from top to bottom. 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 slightly sloped to one side. When the trail traverses a slope, each step and landing should be slightly outsloped. Water should not be allowed to descend long lengths of a set of steps or to collect on or behind a step on the landing. A drain dip where the trail approaches the top of the steps is a good idea.

Build stairways from the bottom up, at a break in the grade. The most common mistake is to start part way up a grade. If you do so, the trail will wash out below the stairs (Figure 68). The

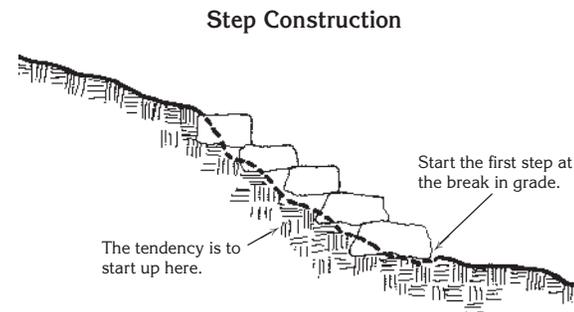


Figure 68—Begin laying steps at the bottom of a grade rather than midway.

bottom stair 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 stair is placed atop the previous stair. Wood stairs are usually pinned to each other and into the footing. Dry masonry rock stairs usually rely on the contact with the stair below and with the footing to provide stability.

Steps with landings are a bit harder to secure in place because the stairs do not overlap. Each step can either be placed in an excavated footing and the material below the rise removed to form the landing of the next lower step. This is usually the most stable arrangement. Or the step can be secured on the surface and fill used to form a landing behind it. The material used to provide the rise does double duty as a retaining structure when the landing consists of tamped fill. These steps must be seated well to prevent them from being dislodged by traffic. For stock use, landings should be long enough to hold all four of the animal's feet.

Individual steps can be placed at any point in a trail. They are useful for retaining tread material in rocky pitches or to protect tree roots. Single steps installed midslope usually become high-step obstacles on stock trails or where there is heavy traffic or erosion.

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 material in footings excavated into the slope.

## Maintaining Special Structures

Maintaining climbing turns and switchbacks requires working on the tread, maintaining 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.

Retaining walls should be carefully checked for shifting, bulges, or loose structural material. Make sure that all the footings are protected from erosion. Guide structures should be secure. Check turn barricades for effectiveness and rebuild as necessary.

Remember, these special structures are relatively expensive and deserve careful attention to protect the investment.

Some special tactics include the use of:

- Internal anchors for increasing the stability of retaining walls.
- Precision blasting to obtain sufficient sized footings in rock.
- Power tamping equipment to strengthen fill.
- Cable systems for moving large rock or timbers to retaining wall locations.

The best way to learn how to build these structures is to seek someone who designs and builds well thought-out switchbacks, climbing turns, or walls. Have that expert conduct a seminar for your crew or actually participate in the construction.

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**T**rail signing 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.

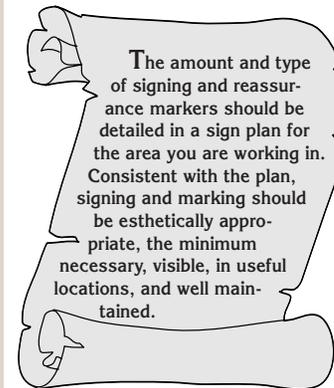
*Signing* is typically used at trailheads to identify the trailhead and the trails there. At some locations, destinations accessed by these trails and the distances to the destinations will be displayed. (See

*STANDARDS FOR FOREST SERVICE SIGNS & POSTERS*, (EM 7100-15), especially parts 2.7, 5.1.1, and 5.4-5.11). Signs are also used at system trail junctions (and road crossings) to identify each trail by name and indicate its direction. Signs are also used to identify features, destinations, and occasionally, regulations, warnings, or closures.

**Reassurance Markers** include cut or painted blazes on trees; wood, plastic, or metal marker tags; marker posts; and cairns. These markers are used to help travelers identify the trail corridor when the tread is indistinct, the ground is covered with snow, or when the path is confused by multiple trails or obscured by weather such as dense fog. National Trails are usually marked periodically with specially designed marker tags. Signs or reassurance markers can be used to identify a system trail at confusing junctions.

The amount of signing or reassurance marking depends primarily on the planned level of challenge for the user. Low challenge trails will typically be signed with destinations and distances. The trail will usually be so obvious that reassurance marking is necessary only at points of confusion. As the desired opportunity for challenge rises, the amount of information given by signs usually

drops to trail identification and direction. You may find special guidelines for wilderness. Reassurance markers are more useful as the tread becomes more difficult to identify and follow.



The amount and type of signing and reassurance markers should be detailed in a sign plan for the area you are working in. Consistent with the plan, signing and marking should be esthetically appropriate, the minimum necessary, visible, in useful locations, and well maintained.

## Installing Signs

Trail signs are made of a variety of materials; the most typical is a routed wood sign. Signs are usually 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 usually looks less artificial; it is usually chosen in primitive settings. Purchased posts should usually be pressure treated. Their longer lifespan will offset the initial purchasing and transportation costs. Round posts appear less artificial than square posts and provide more options for custom alignment of signs at trail junctions. Posts should be at least 150 mm (6 inches) in diameter.

Well-placed signs are easily readable, yet far enough from the tread to provide clearance for normal traffic. In deep snow country, try to locate the post in relatively flat surroundings to reduce the effects of snow creep.

Spikes or lag screws can be used at the base of the post to improve anchoring (Figure 69). Seat the post in the hole and hold it vertical while you drop a few rocks into the hole to secure it. Tamp these rocks with a rockbar or tool handle to jam them into

## Signpost Installation

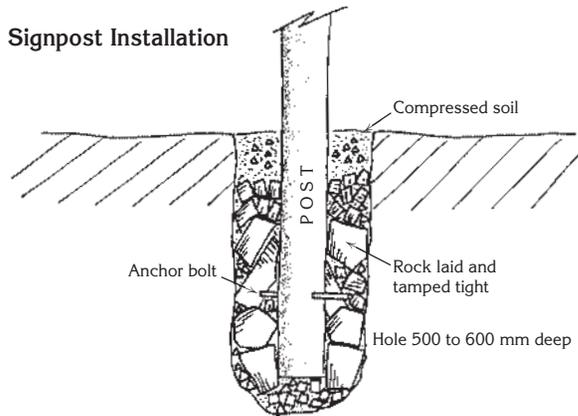


Figure 69—The key to placing solid posts is to tamp the rock and soil with a rockbar as you fill the hole.

place. Continue to place rocks and dirt in the hole, tamping as you go. Top off the hole with mounded soil to accommodate settling and prevent puddling around the post.

In rocky areas or very soft soils (such as adjacent to a turnpike structure), sign posts can be supported by a cairn. Horizontally placed spikes or lag screws should be used at the base for anchors. Chinking with smaller rocks help tighten the post against the cairn stones.

Signs should have holes predrilled so they can be attached to the post. Level each sign and secure it to the post using plated lag screws. Plated hardware reduces rust stains on the sign. Plated 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 specialty theft-prevention hardware. The bottom edge of signs should be set about 1.5 m (60 in) above tread level. The sign's top edge should be 50 mm (2 in) below the top of the post. Where snow loads are a problem, the post can be notched and the signs seated full depth. Treated posts will be susceptible to rotting where they are notched, so they should be spot treated with preservative.

Use caution when mounting signs to trees. The sign should be obvious to travelers and legible from the tread. If mounting on trees doesn't meet these conditions, use a post instead. Mount signs to trees with plated lag screws and plated washers, rather than spikes. This way, the sign can be periodically loosened to accommodate tree growth. Leave a gap between the sign and the tree to allow for the growth.

## Installing Reassurance Markers

Reassurance markers are used only where the trail is not obvious. If the tread is obvious during the regular use season, these markers aren't needed. Reassurance markers may be useful if a trail is hard to follow because the tread is indistinct, regularly covered with snow during part of the normal use season, or if weather conditions (such as fog), make the trail hard to distinguish at times. Reassurance markers are also useful at junctions with nonsystem (informal) trails, or where multiple trails cause confusion.

Place markers carefully. They should be clearly visible from any point where the trail could be lost. This is a judgment call, and often controversial, based on the challenge level served by the trail and the conditions along it. Higher challenge trails need fewer markers; lower challenge trails may need more. If part of a trail has reassurance markers, all of it should be marked.

Each marker location should be flagged before installation and checked for visibility in the desired direction of travel. Each location should be marked in both directions (on both sides of the same tree) so there is no question whether or not the marker is official. This second marker might not be as usefully sited for those traveling the opposite direction. The marking decisions should be based on traffic traveling in both directions. Be conservative with markers. It's better to improve tread visibility than to rely on markers except on high challenge trails where tread may frequently not be visible at all.

The classic reassurance marker is a blaze cut on a tree. The **standard Forest Service blaze** should always be used to differentiate it from the freeform blazes and antler rubbings that appear on nonsystem trails (Figure 70). Different types of blazes may be used on some specially designated trails, such as the Appalachian Trail. Cut blazes carefully as a mistake can't be repaired. If a blaze is consistently buried by snow during part of the use season, the blaze can be cut higher on the tree, but not so high that it becomes difficult to locate from the tread. Blazes are no longer cut on trees in many parts of the country.

### Blazes and Marker Tags

Top blaze:  
100 mm wide  
and 50 mm tall.

Vertical space  
between blazes:  
50 to 100 mm.

Lower blaze:  
100 mm wide  
and 200 mm tall.

Distance from the  
ground: 1.5 m  
for foot trails.

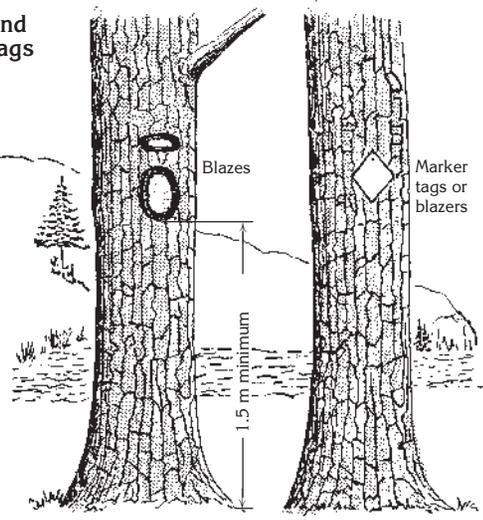


Figure 70—Blaze trees on both sides. Cut no deeper than necessary for clear visibility.

Next up the scale of reassurance markers is a routed or branded **wooden trail marker**, which is routed or branded onto wood and mounted on the tree. Routing and scorching is much more durable than branding. A variation of these markers are routed or branded national trail markers. Check with your local trail manager and review your forest plan to learn what's appropriate in designated wilderness—there is much variability nationwide.

**Painted blazes** are sometimes used for visibility. Be absolutely sure to use a template of a size specified in your trail management plan. Always use the specified color. Don't let just anyone start painting blazes. They should not be painted on rocks.

**Marker tags** or "blazers" are used when higher visibility is desired and esthetic considerations are not as high. Most common are colored diamonds of either plastic or metal. Various colors are used. For trails used by mountain bikes or off-highway vehicles, the tags should be reflective. These tags should be mounted on trees with aluminum nails. Allow 12 mm (½ inch) or so behind the tag for additional tree growth. Directional arrows, where appropriate, should be placed in a similar fashion. Blazers can also be mounted on wooden or fiberglass posts.

**Cairns** are used in open areas where low visibility or snow cover makes following the tread difficult or where the tread is rocky and indistinct. Two or three stones piled one on top of the other, "rock ducks," are no substitute for cairns and should be scattered at every opportunity. Cairns are similar in construction to rock crib and consist of circular tiers of stones (Figure 71).

Make the base wide enough to provide enough batter for stability. In really deep snow country, it might be necessary to add a long guide pole in the center as the cairn is built. An anchored pipe can be built into the center of the cairn so a pole can be replaced or removed each summer.

Cairns should be spaced closely enough that during typical episodes of poor visibility (such as dense fog) the next cairn is visible in either direction from any given cairn. Cairns should be placed on small rises (not in swales). If cairns are used in areas of large talus, use a 2-m (6.5-ft) guide pole in the center to differentiate the cairn from adjacent piles of rock. The best time to decide where to place cairns is during a day with poor visibility.

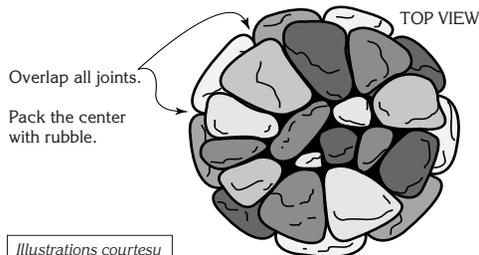
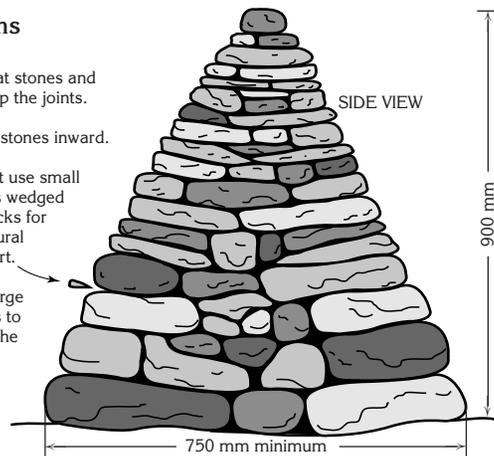
## Cairns

Use flat stones and overlap the joints.

Slope stones inward.

Do not use small stones wedged in cracks for structural support.

Use large stones to build the base.



Illustrations courtesy of the Appalachian Mountain Club's Trail Adopter Handbook.

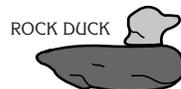


Figure 71—Two- or three-stone “rock ducks” are not a substitute for cairns and should not be built.

**Guide poles** are used in settings similar to cairns. They are most useful in snowfield crossings to keep traffic in the vicinity of the buried tread. Guide poles should be long enough to extend about 2 m (6.5 ft) above the top of the snowpack during the typical use season. 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.

## Sign and Marker Maintenance

Sign maintenance consists of remounting loose or fallen signs, repairing or replacing signs, and resetting or replacing leaning, damaged, rotting, or missing posts.

If the sign is missing, a replacement sign should be ordered and installed. Check out the probable cause of the loss. If it was theft, consider using theft-resistant hardware to mount the replacement. If the sign was eaten by wildlife, look at less palatable materials. If the weather or natural events munched the sign, consider stronger materials, a different location, or an alternate strategy for mounting.

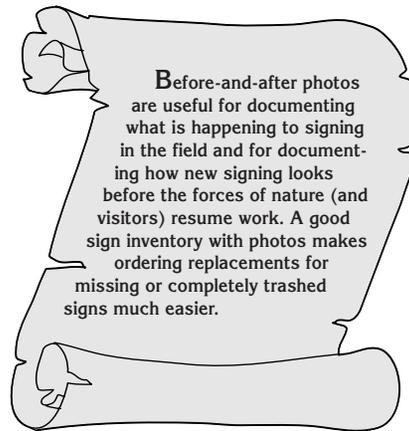
For signs mounted on trees, you may need to loosen the lag screws slightly to give the tree growing room. If the sign is on a post, check to make sure that it is snugly attached. Replace rotting posts. Don't just try to get through “one more season.”

Check with your manager for guidelines when signs should be replaced due to bullet holes, chipped paint, missing or illegible letters, incorrect information, cracked boards, splintered mounting holes, or missing pieces. At each candidate sign, consider the consequences of not repairing or replacing deficient signing. Take some photos to help portray the situation.

Cut blazes may, on rare occasions, need to be “freshened.” If a blaze has “healed” to the point where it doesn't resemble an official blaze, it may be carefully recut.

Blazers and marker tags should be checked for continued usefulness. If the tread is more obvious than when these markers were originally installed, consider removing some. If folks are getting lost, restore more visible tread, move existing reassurance markers to more visible locations, or add a few markers where they will be most effective.

Remove all signing and reassurance marking that doesn't fit the plan for the area.



**N**aturalizing abandoned trails requires as much attention and planning as constructing new trail.

The goal is to reduce the impact human trails have on the landscape. Simple restoration may consist of blocking new shortcuts and allowing the vegetation to recover. Complex restoration projects include obliterating the trail, recontouring, and planting genetically appropriate species. Careful monitoring and followup are necessary to ensure that almost all evidence of the trail is gone. Thus, restoration ranges from simple and relatively inexpensive to complex and costly (Figure 72).

Past practices of trail abandonment have left permanent scars on the land. If you've worked in trails awhile, you probably know of abandoned trails that had a few logs and rocks dragged into the



Figure 72—Candidate trail for a causeway or rerouting, combined with naturalization.

tread and trenches. Decades later, those same trails are still visible, still eroding, still ugly, and sometimes, still carrying visitor traffic!

Naturalization strategies include: closure, stabilization, recontouring, revegetation, and monitoring. Restoration needs to be carefully planned. The consequences of each strategy should be examined. Consult with a hydrologist and soil and plant specialists when planning a naturalization project.

Each abandoned trail should be closed (Figure 73). This is true whether an entire trail is abandoned or a segment with multiple trails is being narrowed back to one tread. If the trail is not blocked to prevent further use, the trail may persist indefinitely. Closure is particularly important if stabilization and revegetation are being attempted. The abandoned tread should be blocked to all traffic, recontoured, and disguised to prevent users from being tempted to take it. This work should be accomplished for all segments visible from trails that remain open.



Figure 73—Abandoned trails need to be blocked off effectively, and with sensitivity.

Stabilize abandoned tread to prevent further erosion. This will promote natural revegetation in some instances. Trails break natural drainage patterns and collect and concentrate surface water flows. Restoring the natural contour of the slope reestablishes the local drainage patterns and reduces the likelihood of erosion. Recontouring usually eliminates any temptation to use the old trail and facilitates revegetation efforts. Pull any fillslope material back into the cut and use additional material to rebuild the slope, if necessary.

Remove culverts and replace them with ditches. Loosen the soil with hand tools, stock and harrow, or heavy equipment to speed revegetation.

## Check Dams

Check dams are used on pieces of abandoned, trenched tread to arrest further erosion and to hold material placed during site restoration. Sometimes check dams are appropriate for trails in active use. Check dams are intended to slow and hold surface water long enough to deposit transported sediment. They should be used with drainage structures to reduce overall erosion from the abandoned tread (Figure 74).

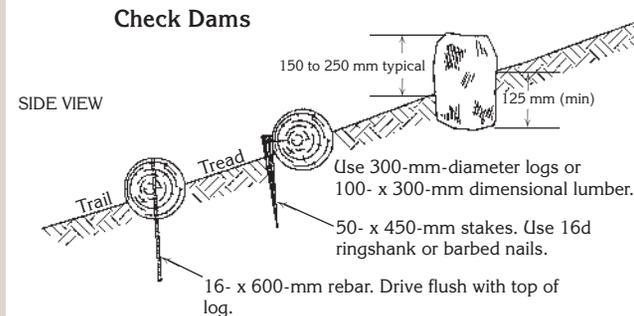


Figure 74—Check dams or retainer bars allow soil to rebuild on eroded trails (continued on next page).

## Check Dams

TOP VIEW

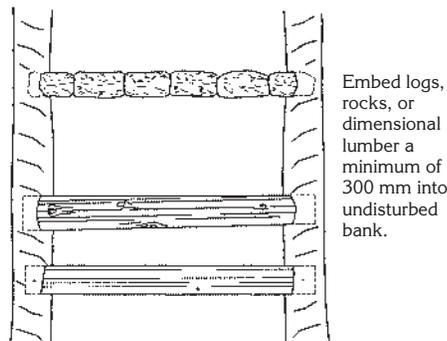


Figure 74—(continued).

Check dams are best used as holding structures for fill used to recontour the old tread. The material used in the dam should be seated in an excavated footing that extends into the sides of the trench. As material behind the dam naturally builds up, successive levels can be added to the dam with enough batter to offer stability against the pressure of the fill. The top of the dam should be level or slightly higher than the trench walls. For watertightness, chinking and tamped fill should be used to complete the uphill face of the dam. Fill is then added behind the dam to finish the process. It generally takes a long time for these trenches to fill up. Most never do. If they do, add fill below the dam to finish the process.

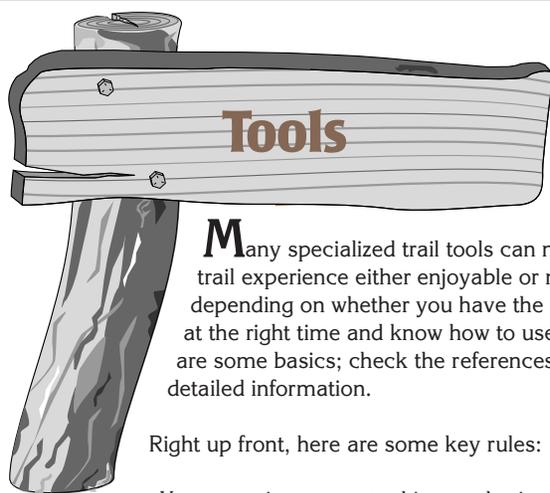
Spacing between dams depends on the steepness of the old grade and the degree of restoration desired. If the check dam is intended only to slow down erosion, then relatively wide spacing is sufficient (every 20 m (65 ft) on a 25-percent grade). If the intent is for half of the old trench to be filled back in, 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 above 25 percent. A point of diminishing returns is reached on grades above 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.

## Revegetation

Revegetation can be accomplished passively or actively. Passive revegetation allows surrounding vegetation to colonize the abandoned trail. This works when erosion has been stopped, adequate precipitation occurs, and adjacent vegetation spreads and grows rapidly. Active revegetation ranges from transplanting onsite vegetation to importing genetically appropriate seed or propagated plants. Successful revegetation almost never happens in a single season. Plan carefully for best results.

There are no cookbook answers for returning abandoned trails to their natural condition. Each site should be evaluated for its potential to regrow and heal. On sites that are moist and relatively flat, it may be possible to block off the trail and allow rehabilitation to proceed naturally. Dry, steep sites will take a lot of work.



**M**any specialized trail tools can make your trail experience either enjoyable or miserable, depending on whether you have the right tool at the right time and know how to use it. Here are some basics; check the references for more detailed information.

Right up front, here are some key rules:

- Your most important tool is your brain—use it.
- Always use proper personal protective equipment like hardhats, gloves, and safety glasses. Make sure a job hazard analysis has been approved and a safety plan is being followed. Select the right tools for the job. Carefully inspect them before you use them. Make sure handles are sound, smooth, and straight, and heads are tight.
- Pace yourself. Take rest breaks, and keep your mind on your work. Trade off on tools occasionally for relief from repetitive stresses.
- Keep cutting tools sharp. A dull tool makes your work harder and more dangerous.
- Before you start, clear away any brush or limbs that might catch a swinging tool unexpectedly.
- Posture is important. Stand comfortably in balance. Adjust your stance and tool grip continually to prevent slipping and to avoid glancing blows. Be especially careful when working in wet, slippery conditions.
- Be thinking about the consequences of every move. If you are working with a rock or log, think ahead so you are not standing in the wrong place when it moves. Be ready to toss your tool aside and jump free. Avoid cutting toward any part of your body, and watch out for your coworkers. Use skill, not brute force.

- When carrying, loading, or storing a cutting tool, cover the blade with a sheath to protect both the sharp edge and yourself. In vehicles, make sure tools are fastened down.
- Maintain at least 3 m (10 ft) between workers as a safe operating distance when using individual chopping and cutting tools.
- Carry sharp tools at your downhill side. Grasp the handle at about the balance point with the sharpened blade forward and down. If you fall, throw the tool clear.
- At the job site, lay tools temporarily against a stump or downed log with blades directed away from passing workers. Never sink double bit axes, Pulaskis, mattocks, or similar double-edged tools into the ground or in stumps where they become dangerous obstacles.

## Tools for Measuring

**Clinometers.** A clinometer is a simple, yet very useful, instrument for measuring grades. Most clinometers have two scales, one indicating percent of slope, the other showing degrees. Percent slope, the relationship between the amount of elevational rise or drop over a horizontal distance, is the most commonly used measure. Don't confuse percent and degree readings. It is easy to do! Expressed as an equation:

$$\text{Percent of Grade} = \frac{\text{Rise}}{\text{Run}} \times 100 \text{ percent}$$

A section of trail 30 m (100 ft) long with 3 m (10 ft) of elevational difference would be a 10-percent grade.

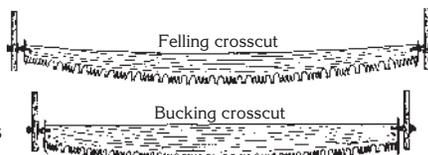
**Tape Measures.** Get a tape measure that has metric units. Another good idea is to mark off commonly used measurements on your tools. Know the length of your feet, arms, fingers, and other handy rulers as a ready reference on the trail. Calibrate the length of your pace over a known course so you can easily estimate longer distances.

**Global Positioning Systems.** Quite a few trail surveyors are finding GPS to be the hot ticket 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 a lot of trail location work.

## Tools for Sawing

### Crosscut Saws.

Crosscut saws may be asymmetric or symmetric. Asymmetric crosscut saws require only one sawyer. They are heavier so they can be pushed and pulled without buckling. Most asymmetric saws are bucking saws. Symmetric crosscut saws, those designed 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 helps sawyers wedge the cut quickly. Bucking crosscuts have straight backs and are heavier and stiffer than felling saws.



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. You can also tie the saw into a narrow V (not a sharp C, for carrying. Don't store it this way.

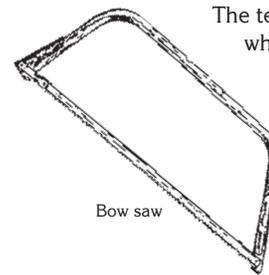
Use blade guards made of sections of rubber-lined firehose slit lengthwise. Velcro fasteners facilitate removal. Don't leave a wet guard on a saw.

A sharp crosscut is a pleasure to operate, but a dull or incorrectly filed saw is a source of endless frustration, hence its reputation as a misery whip. Never sharpen without a saw vise and knowledge. Field sharpening ruins crosscut saws.

To prevent tree sap from binding the crosscut blade in the cut, lightly lubricate the blade with citrus-based solvent. Kerosene is no longer recommended because it is highly flammable and is a health hazard if it is absorbed through the skin, or inhaled. Lightly coat the blade with the light machine oil to prevent rust.

For more information, Warren Miller's classic, *THE CROSSCUT SAW MANUAL* (revised 1988) is available from the Missoula Technology and Development Center.

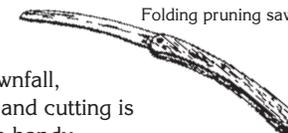
**Bow Saws.** Bow saws are useful for clearing small downfall and for limbing. They consist of a tubular steel frame designed to accept replaceable blades. The blades detach by loosening a wing nut or releasing a throw clamp.



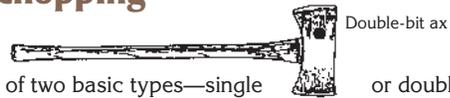
The teeth are needle sharp, so wear gloves when sawing and keep your hands clear of the cut and the blade. Carry bow saws by your side with the blade pointed down. Cover the blade with plastic blade guards or small diameter fire hose secured with Velcro fasteners. Always carry spare parts and plenty of replacement blades.

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

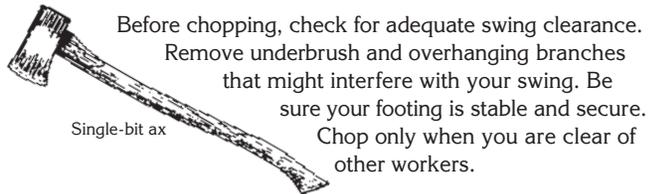
**Pruning Saws.** Pruning saws are useful for limbing, some brushing, and removing small downfall, especially where space is limited and cutting is difficult. Folding pruning saws are handy.



## Tools for Chopping

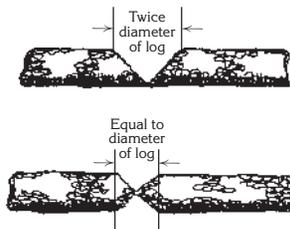


**Axes.** Axes are of two basic types—single bit or double bit. Single-bit axes have one cutting edge opposite a flat face. Double-bit axes have two symmetrically opposed cutting edges. One edge is maintained at razor sharpness and the other is usually somewhat duller as a result of chopping around rocks or dirt. Mark the duller edge with a spot of paint.



Stand comfortably with your weight evenly distributed and both feet planted shoulder-width apart. Measure the correct distance to stand from the cut 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 mm (6 in) of the head. 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.

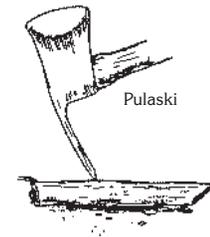


Proficiency with axes requires practice. Inexperienced users with dull axes may cause serious accidents. In general, the force of the swing is not as important as accurate placement. Always chop away from your body. Stand so a glancing blow will not strike you. If you must cut toward

yourself, “choke up” on the handle with both hands and use short swings for more control.

## Tools for Grubbing

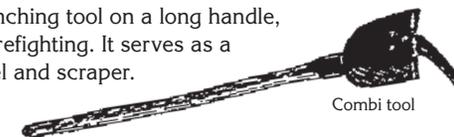
**Pulaskis.** The Pulaski combines an ax and a grub hoe into one multipurpose firefighting tool. It isn't as good as a hoe or mattock for grubbing, nor as good as an ax for chopping. It is a popular trail tool because it is widely available and easier to carry than single-purpose tools.



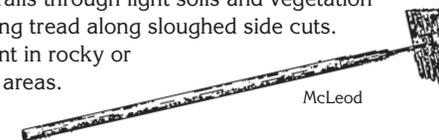
When using the hoe end, stand bent at the waist with your back straight and parallel to the ground, knees flexed, and one foot slightly forward. Hold the handle with both hands so the head is at an angle to your body, and use short, smooth, shallow swings. Let the hoe hit the ground on its corner. Use the ax end to chop large roots after the dirt has been cleared by the hoe. Always wear safety goggles while grubbing to guard against 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 like an ax. When sharpening the hoe, maintain the existing inside edge bevel. Never sharpen the top of the hoe.

**Combination Tools.** 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.

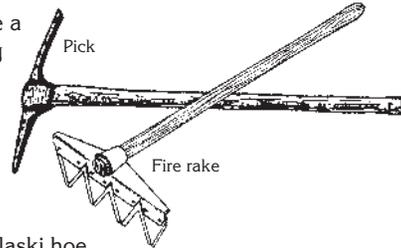


**McLeods.** The McLeod combines a heavy-duty rake with a large, sturdy hoe. McLeods work well for constructing trails through light soils and vegetation or for reestablishing tread along sloughed side cuts. They are inefficient in rocky or unusually brushy areas.



**Fire Rake (Council Tool).** The fire rake is another fire tool used widely for tread work, especially in the East.

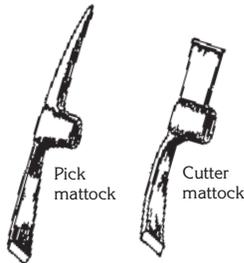
**Picks.** Pick heads have a pointed tip for breaking hard rock by forcing a natural seam. They also have a chisel tip for breaking softer materials.



Work the pick like a Pulaski hoe with short, deliberate, downward strokes. Avoid raising the pick overhead while swinging. Always wear safety goggles while using a pick to guard against flying rock chips.

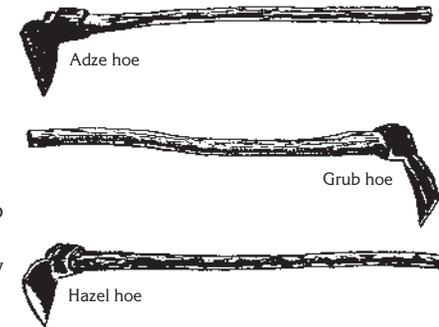
Use a grinder or mill bastard file to sharpen pointed tips to 3-mm ( $\frac{1}{8}$ -inch) squares. When sharpening chisel tips, maintain the factory bevel.

**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 pointed tip for breaking rocks and a grubbing blade for working softer materials. The grubbing blade may also be used to cut roots or remove small stumps. Moreover, with the edge of the tool, you can tamp dirt and loose rocks or smooth a new tread.



Maintain good cutting edges on mattocks. Sharpen grubbing blades to maintain a 35° edge bevel on the underside. Sharpen pick ends like you would a pick, and maintain factory bevels on cutter blades.

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

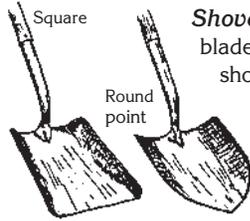


**Stump Grinders.** If you have lots of stumps to remove, consider buying or renting a gasoline-powered stump grinder. These portable grinders are powered by a chain saw motor and have carbide teeth that can be resharpened or replaced. They grind through a stump in much less time and with a whole lot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



Stump grinder

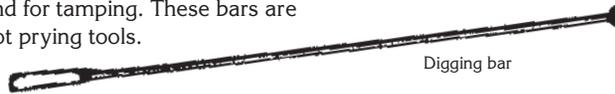
## Tools for Digging and Tamping



**Shovels.** Shovels are available in various blade shapes and handle lengths. A No. 2 shovel is standard. A smaller No. 1 shovel can be used. Fire shovels are good for scraping soil well off the trail.

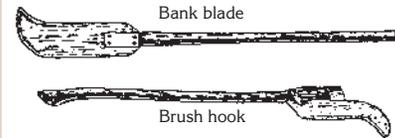
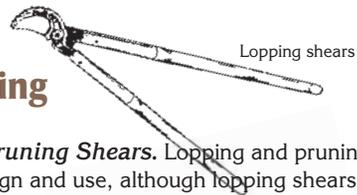
When shifting or scooping materials, bend your knees and lift with your legs, not your back. Use your thigh as a fulcrum to push the shovel against. This makes the handle an efficient lever and saves your energy and your back. A shovel used with a pick or bar is most effective; picks or bars make prying with the shovel unnecessary.

**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.



## Tools for Brushing

**Lopping Shears and Pruning Shears.** Lopping and pruning shears are similar in design and use, although lopping shears have longer handles to improve reach and may have gear drives to increase leverage for thicker stems. 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. The compound style cuts saplings better than hand saws or axes.



**Bank Blades and Brush Hooks.** Bank blades and brush hooks are designed specifically for cutting through thickets of heavy brush

or saplings. Use them for clearing work that is too heavy for a scythe and not suited for an ax.

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



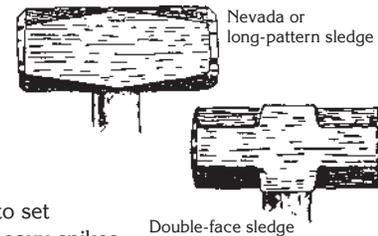
**Weed Cutters (Grass Whips).**

Weed cutters are used for cutting light growth like grasses and annual plants that grow along trails. They are lightweight and durable and usually swung like a golf club.

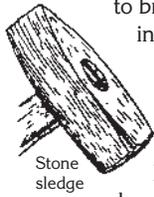
**Power Weed Cutters.** Several manufacturers make "weed whackers," motorized weed cutters that use plastic line to cut weeds. Some have blades that substitute for the line. These can be a good option for mowing grass and weeds on trails. Follow the manufacturer's instructions for safe use and operation.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

## Tools for Pounding and Hammering

**Sledge Hammers.** Sledge hammers have heads forged from heat-treated high carbon steel; they weigh from 3.6 to 9 kg (8 to 20 lb).



Driving sledges are used to set heavy timbers and drive heavy spikes or hardened nails. Stone sledges are used

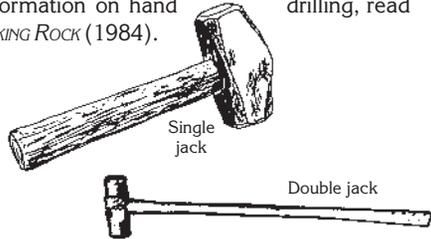


Stone sledge

to break boulders or concrete. Because of differences in tempering, these tools are not interchangeable.

**Hand-Drilling Hammers.** Hand-drilling 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.

For more information on hand drilling, read *HAND DRILLING AND BREAKING ROCK* (1984).



Single jack

Double jack

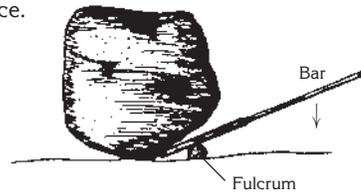
## Tools for Lifting and Hauling

**Rockbars.** Use a rockbar (also called pry bar) for prying large, heavy objects. These bars are heavy duty. They have a chisel tip on one end and a rounded handle on the other.



Rockbar

Place the tip of the chisel under an 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 body weight over your palms. Never straddle the bar when prying. When the object raises as much as the bite will allow, block it and use a larger fulcrum or shorter bite on the same fulcrum to raise it further. You will gain proficiency with practice.

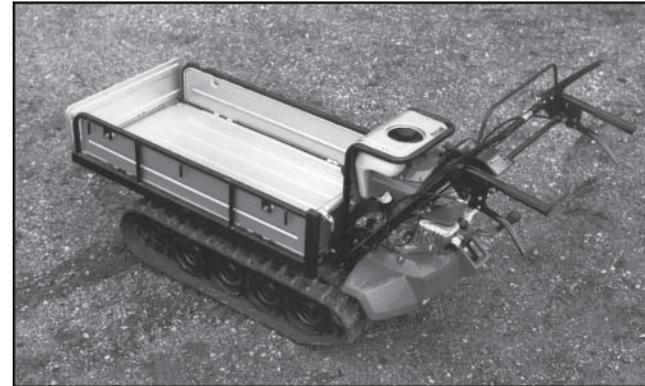


**Block and Tackles.** A block and tackle is a set of pulley blocks and ropes used for hoisting or hauling. They come in different styles, sizes, and capacities.

**Ratchet Winches.** Ratchet winches (also called come-alongs) are useful for pulling stumps and for moving large rocks and logs. These winches offer mechanical advantage—the Grip Hoist is a specialized winching system that provides a mechanical advantage of 30:1 or more. You really need to know what you are doing with these tools to use them safely and effectively.

**Wheelbarrows.** Wheelbarrows with pneumatic tires are best as these tires can be inflated or deflated to roll easily on different surfaces.

**Motorized Carriers.** If your budget and regulations allow, consider a motorized carrier. These come in various configurations and typically feature a dump body. A trailer pulled behind an all-terrain vehicle is another possibility. MTDC has construction plans for a gravel trailer.



A motorized carrier.



ATV trailer (plans available from MTDC).

**Packstock Bags and Panniers.**

Fabric bags or hard-sided panniers with drop bottoms work well for carrying trail construction materials on packstock. MTDC has a design available for fabric bags. Off-the-shelf fruit picking bags also work well as a low-cost alternative for occasional or light duty use. Commercial aluminum drop panniers are a more expensive option.



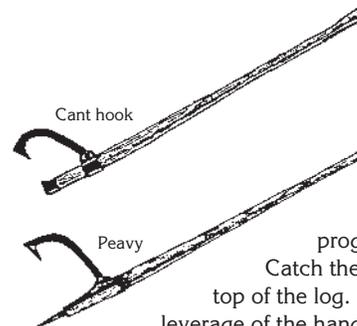
Packstock bag.

**Canvas Bags.**

Heavy-duty canvas bags sold to carry coal are great for dirt, small rocks, and mulch.



Canvas coal bag.



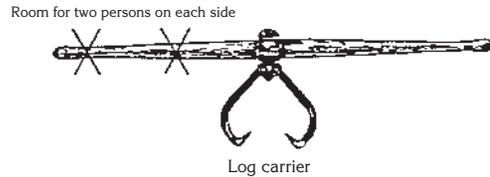
**Cant Hooks and Peavys.**

Cant hooks and peavys afford leverage for moving or rotating logs.

To roll a heavy log, use a series of short bites with the hook and maintain your progress by quickly resetting it.

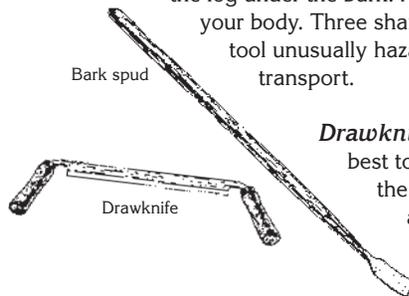
Catch the log with the hook hanging on top of the log. Rotate the log using the leverage of the handle, working the tool like a ratchet. Moving large logs may require several hooks working together. Avoid taking large bites; a heavy log will roll back and pin the handle before the hook can be reset.

**Log Carriers.** Log carriers enable teams of workers to move logs. The tool hooks the log, allowing persons on either side of the handle to drag it. Several carriers could allow four or more persons to carry a large log.



## Tools for Peeling and Shaping

**Bark Spuds (Peeling Spuds).** Use a bark spud to peel green logs. Position 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 pry away from your body. Three sharpened edges make this tool unusually hazardous to use and transport.

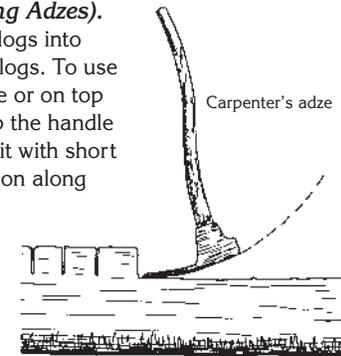


stroke with arms extended and pull the tool toward you while keeping even pressure on the blade. Keep fingers clear of blade corners.

**Drawknives.** A drawknife 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

## Carpenter's Adzes (Cutting Adzes).

This tool trims and shapes logs into hewed timbers or flattened logs. To use a cutting adze, stand astride or on top of the log to be hewed. Grip the handle with both hands and swing it with short strokes in a pendulum motion along the log. Use your thigh as a stop for your arm and to control the depth of the cut. When standing on a log and swinging, stand on the heel of your forward foot, toe pointed up.

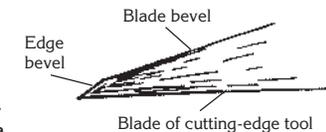


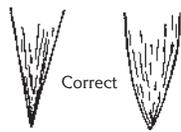
A square-tapered eye and handle end allows the head to tighten when swung, but also allows its removal for carrying and sharpening. Some adzes may have a small set screw to further secure handles to heads. An adze needs to be razor sharp to work. Never use this tool for grubbing.

## Tools for Sharpening

**About 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 the 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.

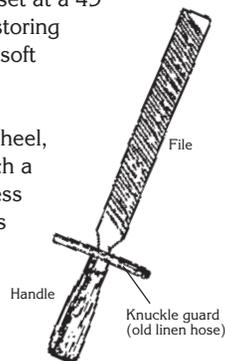


Restoring the blade bevel requires coarser grinding tools to reshape worn cutting blades. Reshape blades with hand files, sandstone wheels, or electric grinders. Remove visible nicks by grinding the metal back on the blade. Remember that the correct blade bevel must be maintained. If the shape can't be maintained, have a blacksmith recondition the tool head or discard it.

If a cutting edge is nicked from a rock, it often is work hardened. A file will skip over these spots and create an uneven edge. Use a whetstone to reduce the work-hardened area, then resume filing. Alternate the two 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° from the edge; they are used for finishing work. Double cut files have two series of parallel teeth set at a 45° 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.

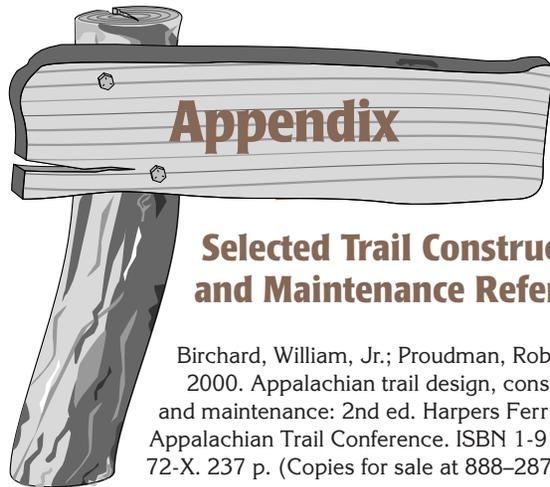
Files are measured from the point to the heel, excluding the tange (the tip used to attach a handle). Length determines the coarseness of files. There are generally three degrees of file coarseness: bastard, second cut, and smooth. The bastard will be the coarsest file available for different cuts of files of the same length. A 254-mm (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 to prevent cuts from the sharpened edge. Secure the tool so both hands are free for filing. Use the largest file you can, depending on the size, nature, and workable stroke length of the job. 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. An old piece of fire hose sewn shut on one end makes a great file holder for several files, a guard, and handle. A hand-tool sharpening gauge that gives you all the correct angles can be ordered from the General Services Administration (GSA).





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### Library Card

Hesselbarth, Woody; Vachowski, Brian. 2004. Trail construction and maintenance notebook: 2004 edition. Tech. Rep. 0423-2825-MTDC-P. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 139 p.

This notebook describes techniques used to construct and maintain trails. It is written for trail crew workers and is intended to be taken along on work projects. Numerous illustrations help explain the main points. The notebook was printed in 1996 and has been revised slightly during three reprintings. Revisions in this edition update references and reflect minor editorial changes.

Keywords: drainage, fords, puncheon, restoration, signs, trail construction, trail crews, trail maintenance, trail planning, turnpikes.

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## METRIC CONVERSIONS

To Convert From This Unit	To This Unit	Multiply by
inch	millimeter	25.4*
inch	centimeter	2.54*
foot	meter	0.3048*
yard	meter	0.9144*
mile	kilometer	1.6
millimeter	inch	0.039
centimeter	inch	0.394
centimeter	foot	0.0328
meter	foot	3.28
meter	yard	1.09
kilometer	mile	0.62
acre	hectare (sq. hectometer)	0.405
square kilometer	square mile	0.386*
hectare (square hectometer)	acre	2.47
ounce (avoirdupois)	gram	28.35
pound (avoirdupois)	kilogram	0.45
ton (2000 pound)	kilogram	907.18
ton (2000 pound)	megagram (metric ton)	0.9
gram	ounce (avoirdupois)	0.035
kilogram	pound (avoirdupois)	2.2
megagram	ton (2000 pound)	1.102
ounce (U.S. liquid)	milliliter	30
cup (inch-pound sys)	milliliter	247
cup (inch-pound sys)	liter	0.24
gallon (inch-pound sys)	liter	3.8
quart (inch-pound sys)	liter	0.95
pint (inch-pound sys)	liter	0.47
milliliter	ounce (U.S. liquid)	0.034
liter	gallon	0.264
liter	quart	1.057
degrees Fahrenheit	degrees Celsius	(° F - 32) ÷ 1.8
degrees Celsius	degrees Fahrenheit	(° C x 1.8) + 32

\*These items are exact conversion factors for the units [the others give approximate conversions]

## Metric Comparisons

- A millimeter, which is one-thousandth of a meter, is about the thickness of a dime.
- One inch is just a fraction ( $\frac{1}{64}$  inch) longer than 25 mm (1 inch = 25.4 mm).
- 150 mm is the length of a dollar bill.
- One foot is about  $\frac{3}{16}$  inch longer than 300 mm (12 inches = 304.8 mm).
- A meter is a little longer than a yard, about a yard plus the length of a piece of chalk.

1 km (about  $\frac{5}{8}$  of a mile)

|<----->|

1 mile

|<----->|