The Joy of Trail Work

A Field Guide for Trails in Arid Lands

Second Edition

Michael Baker
Volunteers for Outdoor Arizona

Second Edition, June 2009

Purpose of this Guide

The soils and rainfall patterns characteristic of arid landscapes present trail builders with unique challenges. This guide focuses on that which appears to be special about trail work in perennially dry landscapes and covers many of the tasks associated with building non-motorized trails using hand tools.

This guide is designed to be used in the field by volunteer leaders and their crew members. Trail design is not included, as this should be addressed well before workers are in the field. However, aspects of trail design are covered where that is appropriate to assessing alignment just before clearing vegetation and building tread. Reassessment in the field may yield noticeable improvements and alterations may be unavoidable once subsurface conditions are revealed.

Warning and Disclaimer

Acknowledgements

This draft is based on the technical section of the Volunteers for Outdoor Arizona (VOAz) crew leader manual produced in 2000 and revised in 2003. It draws upon materials contained in all of the trail work documents included in the bibliography and VOAz field experience, as interpreted by the author. Reviewers include Ed Blanchard, Thom Hulen, Charlie Scully, Mike Snodgrass, and Bruce Weidenhamer. Book design, editing and production assistance provided by Carla Olson.

Volunteers for Outdoor Arizona

The mission of the Volunteers for Outdoor Arizona (VOAz) is to involve Arizona residents and visitors in environmental stewardship through participation in and support of volunteer work that preserves, protects and enhances the public and protected lands of Arizona.

2140 East 5th Street, Suite 8 | Tempe, AZ 85281
(480) 966-2689 | www.voaz.org

OutdoorVoulunteer.org

OutdoorVolunteer.org, a service of Volunteers for Outdoor Arizona, is a searchable, on-line database of volunteer opportunities presented by VOAz and other Arizona conservation organizations. Public and private organizations may list their outdoor volunteering opportunities and use web site for on-line registration and volunteer communications. Contact VOAz for more information.

Recreational Equipment Incorporated (REI) has provided financial support for the preparation of this publication. www.REI.com

Arizona State Parks has provided financial support to cover printing costs. www.AZStateParks.com

CONTENTS

FIGURES

A Note from the Author

> "I went for a walk in the desert with no particular destination in mind. There seemed an obvious and natural route to follow, though it was not initially clear to me why. Then I realized that I was, in fact, walking on a man-made trail. It appeared to have been built some time ago even though there was little of the on-tread or off-tread erosion I am generally accustomed to experiencing. A while later I met someone on a mountain bike coming from the opposite direction. We stopped to chat and I commented on the beautiful trail. She broke into a broad smile as she told me that she had helped to complete this section just last weekend. I congratulated her and we continued on our separate ways."

This little story reflects the vision of some who love to build trails. While pursuing this "ideal" seems to enhance the satisfaction of many volunteer trail builders, it does mean a bit more work than a "less caring" approach. Though this guide may be useful to those who favor quantity over quality, it is written from the vantage point of the latter.

Trail work how-to publications, including this one, are loaded with prescriptions. Those unfamiliar with trail literature should know that many of these prescriptions are without empirical validation. This does not mean that these prescriptions for trail building are of no value, but should be qualified by a "usually", "about", "often", or "nearly always". The natural environment is far too complex to be mastered by rote application of over-simplified rules of thumb. It is my view that understanding a few basic concepts, learning how to handle trail tools, being able to read a landscape, and using your critical imagination is more useful than rigid adherence to formulas and rules. This guide is intended to pass along techniques that I and others have found usually make it a little easier to build good trail in arid landscapes.[1]

If state-of-the-art trail work does not support iron clad certainty about what will or will not work in a specific setting, it is critical that those who care about building good trail attempt to return to past work over a period of years in order to reassess and rebuild as necessary. Many VOAz trail project sites have been revisited many times - often because the work could not be completed in a single weekend.

Having said that, it must also be noted that the essence of really good trails - low maintenance, user friendly, and easy on the environment - is good trail planning. (This is one prescription that always holds.) While sound construction is also required for a good result, poorly planned trails may defeat the best efforts of even experienced trail builders.

Michael Baker

1 The more technical a trail task, the more trustworthy published prescriptions are likely to be. Building wooden bridges, rigging for transporting boulders and the like are done by few trail builders, require a great deal of training, and can yield catastrophic outcomes if not done well. It is likely that no expert in some of these fine arts would support the idea that a novice undertake complex trail building tasks, relying only on a manual, rather than extended experience in the field.

What distinguishes a well-planned recreational trail?

Trails were first created by people needing to get themselves, livestock, lumber or other materials somewhere with the least possible delay and effort. Many “trails of use” have been incorporated into recreational trail networks. Unstable “social”, “bootleg”, or “wildcat” recreational trails are created daily; and there are also recreational trails that are poorly designed.

The question for a volunteer confronted with a poorly laid out trail (existing or planned) is “Do I want to donate my time and energy to this trail if my efforts are likely to be undone by nature and normal use?” Here are a few factors that distinguish well planned trails from those that are not so well planned:

- A trail is well laid out if it roughly follows the contours of the land, gradually gaining or giving up the elevation required in order to reach its destination.[2]

- Well designed trails have regular uphill and downhill sections (grade reversals) even over short runs. This helps drain water off the tread and adds interest.

- Well designed trails require a minimum of built structures in order to reduce the labor required to build them and minimize human intrusion into the natural environment.

- Well designed trails avoid the need to remove many slow growing plants and trees, while still passing close enough for an intimate look and perhaps to capture some shade.

- Environmentally sensitive trails minimize conflicts with wildlife. Wildlife tends to gather along the margins of open space and, of course, around reliable water sources. Humans are drawn to these same places. But we know enough to minimize human intrusions for the benefit of other animals. For the same reason, repeated stream crossings exacerbate wildlife and human conflicts and are another mark of poor trail planning.

- Trails may cross active flood plains but they do not follow them. Flood plain trails disrupt soil that is harmful to aquatic life if washed into streams.

What is “arid land” and why does it require special trail work techniques?

The phrase “arid land” is used here because “desert” seems too narrow to cover the range of locations to which this guide is intended to apply. Places such as the Sonoran and the Mojave Deserts are obviously deserts but chaparral, Juniper/Pinon woodlands and Ponderosa pine forests are also considered arid lands.

A popular definition of desert is any area that receives less than ten inches of rain per year. This definition overlooks the most important characteristic of deserts - their “aridity”, which is a comparison of precipitation to the *potential for water loss* through evaporation and transpiration (what plant leaves give up to the atmosphere).[3] In any dry or arid place, potential evaporation plus transpiration *exceeds* precipitation. A scale based on the ratio of evaporation to precipitation is used by scientists to measure aridity. Areas with a ratio of greater than 3.0 (roughly meaning evaporation divided by precipitation) are considered arid. The ratio for Tucson is 4.3; for Yuma it is 30, and for the interior Sahara it is 600.

While knowing the correct definition of desert is of little practical value to a trail builder, it drives home the critical point is that arid lands lose water like crazy. Most trail building prescriptions are based on

---

2 Stable tread can be built straight up and down the side of a hill. It will have heavy rock steps and be lined on both sides with tightly fitting rock shoulders and periodic outlets for water that will flow down the tread. For very short reaches this may be appropriate. As a general practice it is impractical and is, thus, not discussed here.

3 Arizona Sonoran Desert Museum *A Natural History of the Sonoran Desert* Tucson. 2000. p 9.

soils typical of wetter climates. Moisture is a key factor in binding soil constituents. Dry soil cannot be shaped and is prone to erosion when disturbed.

Distinctive properties of arid land soils that determine how trails weather and respond to user impacts include the following:

1. Desert or arid land soils have formed slowly from the weathering of bed rock or what are referred to as “parent materials”. In wetter regions, however, chemical processes play the dominate role in building the soils. One result of this difference is that dry land soils are more likely to be composed of a dominant soil element (sand, clay, silt) than a blend (loamy[4]).

2. Clays are widespread in arid environments. Wetted clay may become very hard when dried. Near the surface, its ultra fine particle size causes dry clay to turn to powder upon impact. Dry clay soil is readily displaced by wind, user impacts, and rain water runoff. Additionally, high clay content tread becomes very slick when wet and making it poor tread material.

3. Perennially dry soils contain relatively little organic materials resulting from plant decay, which makes them more erodible.

4. Perennially dry soils retain little moisture. The resulting dryness facilitates displacement by wind, user impacts, and runoff.

5. Perennially dry soils are relatively impermeable; thus they shed water rather than absorb it. Runoff contributes to soil erosion.

6. Impermeable soils do not leach precipitated chemicals. Calcium carbonate, in particular, remains near the surface in arid landscapes where it may actually function as a binding agent. Calcium carbonate eventually collects at subsoil beds to form a hard, impermeable layer (caliche). White beds of caliche are found in back cuts, and dry washes.

7. Perennially dry lands left undisturbed for thousands of years can form a varnished hard crust (desert pavement) and develop an overlay of protective “living soil” (cryptobiotic) that does not look like it is living. Once disturbed by human traffic and trail tools, the underlying dry soils have little resistance to erosion caused by wind, human and animal traffic, and especially water falling and flowing across the surface. Stability returns when erosion reaches bedrock or, perhaps, caliche.

8. Soil conditions can vary significantly from one location to another. Thus, there can be no single prescription for trail layout or construction that applies to every arid land location and, in some locations, to a particular reach of trail.

Another relevant and distinctive characteristic of arid lands is the pattern of summer monsoonal rains, which can release several inches of rain within a very short period of time. In addition, one hundred years of abusive grazing by the cattle and sheep industry stripped much of the landscape of native grasses that help retain moisture and resist impact erosion.

Taken together, these soil and weather characteristics and human impact on the land make trails on arid regions especially prone to loss of tread material, or a “hollowing out”, as I refer to it here. In many locations, normal use will loosen native tread material, which then may be transported down tread by runoff during rain events. Water entering a tread from the uphill side cannot be assumed to continue across it and over the outside edge simply as the result of how the tread was shaped when it was built.

---

4 Loamy soil is great for agriculture and generally makes better trail tread in any climate.

This conclusion conflicts with trail work guides in which trail builders are instructed to carefully shape tread to send water from its inside edge to its outside edge where a rounded “critical edge” will allow water to leave the tread. This is viewed as the first line of defense against water-induced breakdowns of tread, and might be called the “Straight Downhill” model, or SDH. SDH assumes that hillside sheet flow can usually be induced to quickly cross and leave a well designed and constructed tread. The SDH model is usually acknowledged to be an “ideal” that will often need to be bolstered with dips and waterbars. This author suggests that the SDH model is less an ideal than an exception to the rule. Fortunately other methods for handling water on trails are readily available. These are a main focus of this guide.[5]

Before you head out to work

Volunteers for VOAz trail events are provided information before and during events to enhance the prospects of an enjoyable experience. There are tips about handling tools and rock at appropriate points in this guide. Here are some general guidelines based on VOAz experience:

1. What to wear and bring, and what to leave at home
   - Work boots, preferably those with hard toes. In practice, many volunteers wear ordinary hiking shoes or running shoes. Sandals and street shoes are unacceptable.
   - Work gloves.
   - Sun screen, hat, long sleeves and long pants. “Long” is to protect from the sun and the many thorn laden plants and trees of arid regions.
   - Clothing appropriate to weather conditions you may encounter (rain, cold).
   - Plenty of water and salty snacks. When it is hot you may need to drink close to a quart of water per hour.
   - Appropriate means for disposing of or bagging and removing personal waste.
   - Your Leave No Trace trash bag to carry out any trash you find, irrespective of who may have left it there.
   - Leave pets and very small children at home or under supervision and at a good distance from the work area.

2. Be mindful of your environment and yourself
   - Start work as early in the day as possible and stop when it gets hot. Heat exhaustion and stroke are very serious threats for any who are simply outside during the hot part of the day, not to mention doing manual labor.
   - Pace yourself. If you do not regularly engage in manual labor, trail work can tire you out fast.
   - If you travel to a site that is several thousand feet higher than where you live, allow for the slowing effects this will have and drink extra water.
   - When lifting, bend your knees and lift using the power of your legs.
   - Strong monsoon storms can come up quickly and are associated with lightning and flash floods. Never cross a flooded wash on foot or in a vehicle. Wait until the surge passes.
   - Thorn laden plants are always prepared to strike when you least expect it (when you become very focused on your work).
   - Dead trees may fall at any time; and there are large numbers of beetle infested, unstable pine trees in the West.
   - Watch out for poisonous desert creatures. Digging and moving rock or dead fall frequently uncovers scorpions. Wear gloves, and tip rock and look underneath before lifting. Tarantulas might be scary looking, but are not generally dangerous. Rattlesnakes are encountered but generally not a problem. Be cautious around undercut rocks, fallen timber and deep shady bushes.

---

5 Troy Scott Parker explains in detail why treads won’t retain a stable cross-slope and his ideas on what to do in *Natural Surface Trails by Design*. Parker is not specifically concerned with arid land treads, which suggests that in this instance the requirements for good trail in arid regions may not be that different from those that apply in some non-arid places.

- Steep slopes sometimes do not offer secure footing. Rocks can be easily dislodged. Avoid working below others on a steep slope.

3. Handling tools
   - Carry only one tool in each hand at your side, not over your shoulder. Sharp and heavier tools should be carried on your downhill side.
   - Stay about six feet behind anyone in front of you when carrying tools to a work site.
   - Store tools not being used off the trail on the uphill side. Make sure that rock bars and buckets are placed in a stable location.

4. Working around others
   - Keep a generous distance between yourself and your co-workers.
   - Call out “coming through” as you approach others who are engaged in work so they may stop and allow you to safely pass.
   - See *Safely Moving Large Rock*

Corridor, Trailway, and Tread Clearing

A trail - in trail builder's lingo - is made up of a *corridor*, *trailway* and *tread*. Plant material and other obstacles are removed from all three areas to afford trail users unobstructed passage and clear viewing lines. Clearing work enhances the natural aesthetic of the landscape in which a trail is placed. It precedes tread construction.

Figure 1 illustrates the trail *corridor* with the *trailway* and the *tread* lying at the midpoint. The tread is the actual travel surface. The trailway straddles and extends six to twelve inches to either side of the tread. The corridor is the full width and height, starting about eighteen inches above grade, needed to accommodate all intended trail users.

Briefly, clearing entails the following:

- Vegetation within the corridor is trimmed to eliminate obstructions to movement and a clear view of the trail ahead (in both directions).
- Shrubs are removed from the trailway, if they are likely to cause annoyance, if not an obstruction, before the next maintenance event.
- All vegetation is removed from the tread area.

Before removing or trimming shrubs and trees make sure there are not active bird nests. If eggs are present, it may be necessary to postpone tasks until the birds have fledged or have been consumed by a predator. Land managers may restrict the scheduling of trail work with such factors in mind.

Corridor dimensions and tread width vary depending on the intended users (hikers, bikers, equestrians) and location (urban, rural, wilderness). The responsible land management agency will normally have established standards. The table below shows some common dimensions for the corridor, trailway, and tread width for multi-use non-motorized trails.[6]

Location	Tread	Trailway	Corridor
Urban	24", 30" and greater	Tread width plus 6" to 12" on either side	Multi-Use: Width: 6' - 8' Height: 8' - 10' Pedestrian Only: 4' W x 7' H
Backcountry	24"		
Wilderness	18"		

Corridor clearing activities relevant for both new trail construction and trail maintenance are described next, followed by a section on disposal of cuttings which applies to all clearing work. Because trail maintenance resources are so limited, it is prudent to error on the side of over-clearing in densely vegetated areas.

6 Trails on most public lands cannot be built until a formal assessment is made of various impacts, including "cultural heritage." Any object uncovered or found should be brought to the attention of the land manager for appropriate handling.

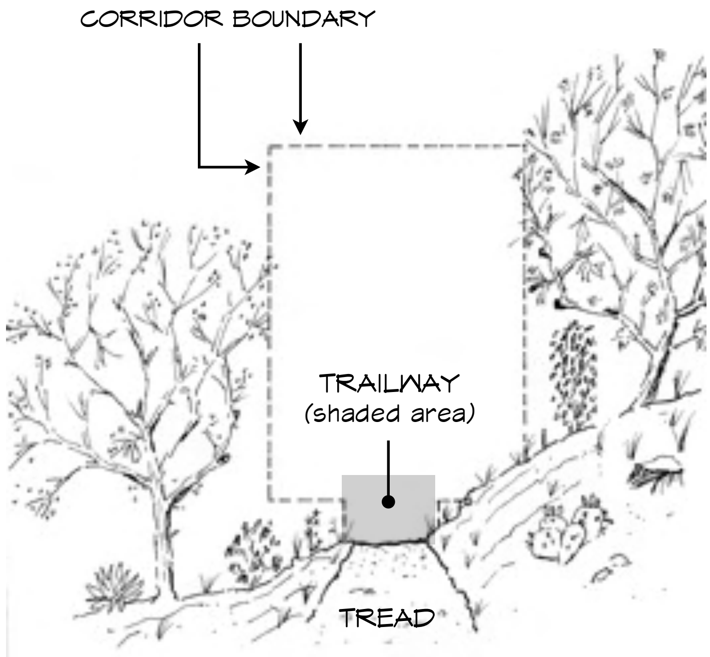


FIGURE 1. Trail Corridor, with trailway and tread

Before starting to clear the corridor for a new trail, assess the alignment, especially where vegetation is sparse. Look for opportunities to adjust the alignment that may make it easier to get a satisfying result from the clearing work, without undermining tread drainage. For example, if the proposed alignment will require heavy trimming of two plants, perhaps an adjustment that results in completely removing just one plant makes more sense. Would a slight adjustment of the alignment eliminate a large amount of tree trimming or the need to transplant a barrel cactus?

Removing Plants

Remove (dig or grub out) plants (both dead and living) from the tread unless their presence helps to stabilize the tread. Grass need not be removed if it is likely to be well trampled by users, or if sunlight and moisture are not sufficient to stimulate rapid growth (as may occur in low lying areas). Exposed tree roots that are not likely to be an annoyance to users may be left in place if. A bare tree root may hold soil in place.

While removing plants from treadway and corridor, it may be necessary to cut the roots of a nearby plant that is to remain, such as a large Saguaro. Minimize chopping and shredding of the roots of those plants that will not be removed. Hand pruning shears may be the best tool for this task.

Quick growing, low value plants should be aggressively trimmed back or grubbed out. Cat claw is always grubbed out from tread and treadway, unless left as a barrier to off-tread movement. High value plants like Barrel and small Saguaro cactus are removed from the tread area, but may be left in the trailway for visual interest and soil stability.

Barrel and small Saguaro cactus can be successfully transplanted. Be mindful to retain most of their shallow roots, maintain the same orientation to the sun (to prevent sun burn), and give them a drink with plenty of verbal reassurance (hugging not advised). Ask the land manager about which plants are of high value. Some plant species are legally protected.

Tools and Technique

The adz (hoe) side of a pick-mattock or Pulaski can be used to dig out plants. Even a rock bar can be used for this task. A come-along can be used to extract tree stumps. Pulling small shrubs by hand is least disruptive of the land. Get a firm grip with one or both hands around the shrub where it emerges from the ground. If it does not respond to a gentle tug, move it from side to side and pull (using leg power). If that does not work, get a tool.

Before digging out larger shrubs, prune them back to facilitate access. Dig deep enough to get the ball of root material below the surface, or at least three inches down. Anything less and the shrub may regenerate. Fill and tamp holes created during this work.

Use the adz or hoe end of a mattock or Pulaski to dig out plants. Let the tool land at a slight angle, as illustrated, for maximum efficiency. Involve the entire body when swinging a digging tool - slightly crouched stance and feet shoulder width apart. The first tool strokes into soil where roots are present should be light to avoid the potentially injurious bounce that can occur should an unexpectedly hard surface is struck. Let the weight of the tool head do most of the work. Accurate aim is more important than powering the swing. Pace yourself because this work can be very tiring

Avoid using the Pulaski axe blade to chop roots. Chopping roots through dirt and small rock rapidly dulls the blade. Traditional Pulaski blades are tempered steel and can send steel chips flying when they are slammed into rock.[7]

Shrubs near the edge of the tread area may be reduced in size rather than fully removed. Reduce the diameter of a shrub by using the hoe (adz) side of a digging tool to chop off unwanted base stem branches[8] around the perimeter to preserve a balanced natural looking plant of the appropriate size.

Trimming Shrubs

Trim/prune shrubs outside the tread but within the trail corridor. Smaller shrubs within the trailway can be trimmed to a height of about 24 inches. In areas where the vegetation is dense with fast growing plants, make sure that there is good visibility on the inside corner of trail bends. Excessive trimming may be appropriate in these locations. Don’t be shy - pruning stimulates growth as does the additional sunlight that may be allowed in as a result of clearing the corridor.

Tools and Technique

Use loppers and small saws[9] to trim shrubs. Trimming techniques that preserve a natural balanced look to plants are described below. Avoid the “haircut” look that results if branches are trimmed straight across one side of a plant.

Two types of loppers are used for trimming shrubs. Those with “anvil” style heads (one sharp blade strikes a flat metal surface) are used for dead branches. “By-pass” or “shear” style heads (two blades

7 Forged Pulaski’s are available at most national lumber yard/home improvement chain stores.

8 Base stem branches are those that emerge directly from the root ball.

9 Most pruning saws cut as you draw the blade toward you.

that pass one another) are best for live branches. Select the latter if you can only carry one. Larger loppers are more versatile than smaller ones. Use only sharpened loppers to avoid shredded cuts.

Hold loppers at the handle ends for maximum leverage and make straight (right-angle) branch cuts. Most loppers are rated for between one-half and two inch diameter branches. Do not use a lopper on a branch that is larger than its rating. Switch to a small saw, rather than attempting to force a cut that may damage the tool.

On taller shrubs, cut branches to the base stem that are more or less perpendicular to the tread. Likewise, cut branches angled to the tread at branch points (where the cut branch grows out of another branch). See Figure 2.

If trimming yields an unnatural-looking plant, remove the plant. *Never prune to grade*. Pruning shrubs to grade can be very provocative - they tend to return with a vengeance. If pruning to grade appears necessary in order to meet clearance standards, remove the entire plant.

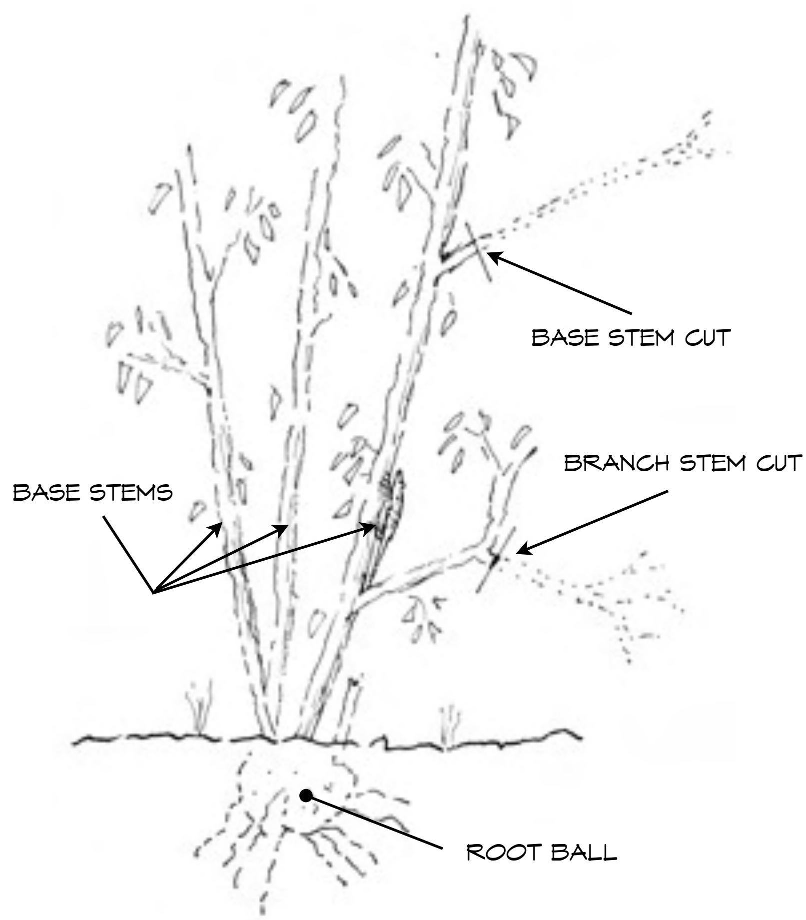


FIGURE 2. Shrub pruning points

Pre-clearing Corridor

Manually clearing dense stands of scrub oak and Manzanita is so hard that land managers should try to have the corridor pre-cleared using chain saws. This is great for the volunteers if it is done right. Shrub cutting should not be at grade. Leave some base stem length left for use in loosening roots balls. The trail planner should spray paint plants to be cut. Otherwise, chain saw operators are apt to clear far more than is desirable.

Trimming Trees

Trim tree limbs that project into the trail corridor and are, or soon will be, an obstacle to trail user visibility or movement.

Avoid heavy trimming of trees such as Palo Verde during the heat of summer. The shade lost can result in sun-burn damage to their photosynthetic bark.

Tools and Technique

Bow saws are for dead limbs and pruning saws are for live limbs. Pole saws are needed for trimming high tree branches on equestrian trails. Two persons equipped with hard hats and eye protection may work together on using a pole saw to trim high branches. One saws while the other manages traffic and moves cut materials outside the corridor.

Use of chain saws may be appropriate but it is beyond the scope of this guide and should be undertaken only by a trained chain saw operator approved by the land manager.

Do not damage the *bark collar* when removing an entire branch from a tree. The bark collar is a bulge on the bottom side of the junction of a branch with the trunk. It protects the tree trunk from invasive microorganisms and insects in a damaged limb. Damaging or removing a bark collar threatens the health of the entire tree.

Trimming should not disrupt the natural balance of a tree. This happens when too many branches are removed from the side of a tree that is close to the tread. Trimming only one side of the tree produces what is called a “flag effect”. Preserve a balanced profile by removing limbs from all sides. If that is not practical, consider removing the entire tree or adjusting the tread alignment until balanced trimming is possible.

Limbs that are cut off more than a couple of inches from the trunk produce unattractive “hat racks”. There is little demand for hat racks in the outback.

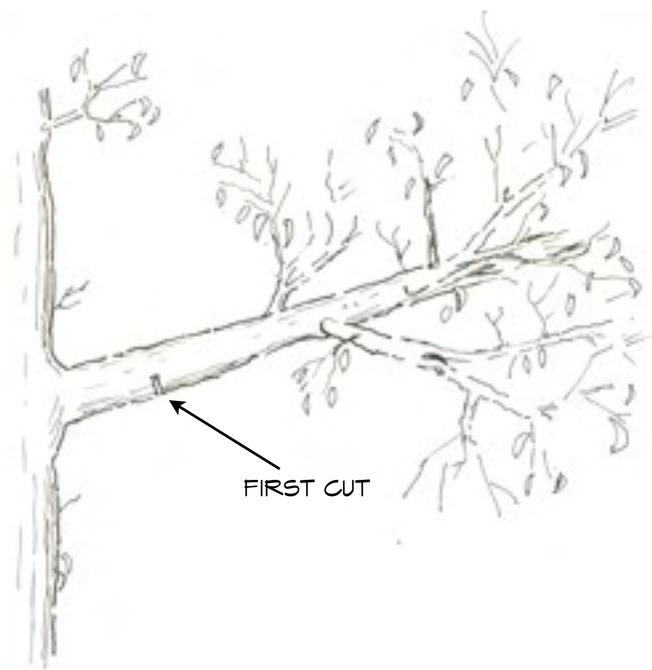
Two persons equipped with hard hats and eye protection may remove large branches. Make sure others are clear of the work area. A third person may be needed if there is heavy trail traffic. Use this three-step process to remove large tree limbs (see Figure 3):

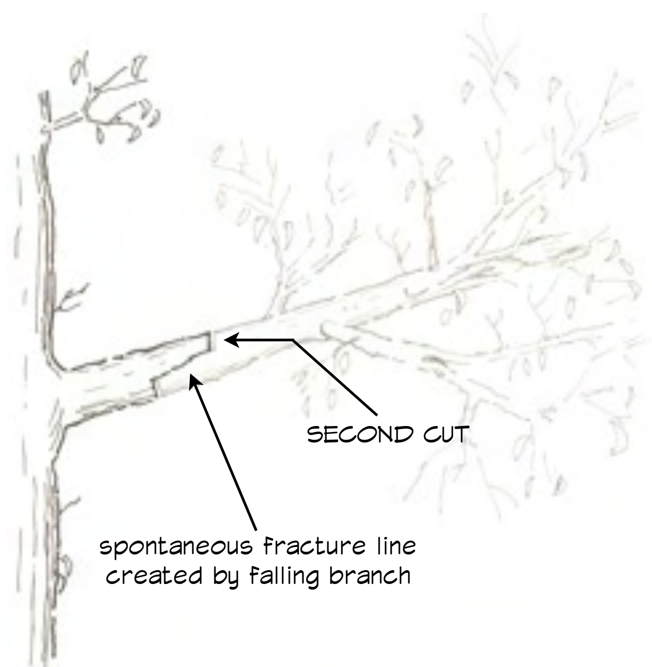
1. Make the first cut about four inches out from the bark collar and straight across on the bottom side of the limb. Don’t cut too deep lest the weight of the branch bind the saw blade. This cut prevents the branch from ripping bark from the trunk when it falls as the second cut is made.

2. A second cut across the top of the branch and a few more inches out on the branch will fell the limb. One person saws while the other is positioned to safety direct (but not catch) the movement of the falling branch. Remove each cut branch from the work area before starting work on another branch.

3. The third cut - the dress cut - safely removes the “hat rack” created at step two. To avoid scaring the trunk or bark collar, make a shallow cut about ½-inch beyond the bark collar and

around the entire circumference of the limb stub. At this point you can complete the final cut. Do not listen to anyone who claims that an exposed stump be dressed with dirt, pitch, iodine, beer or any other substance.





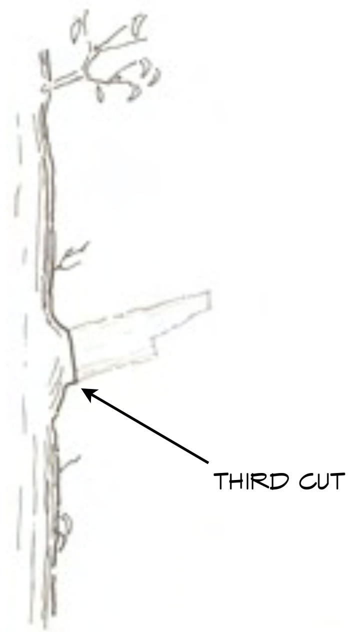


FIGURE 3. Cutting Sequence, Heavy Tree Limbs

Felling Small Trees

Trees that are within or at the edge the tread space, or that are partially downed and likely to land on the trail, need to be removed. Whenever possible, have the land manager take care of all tree felling prior to undertaking other work on a trail - especially partially downed and large trees. *This section applies only to felling small trees* (up to about six inches diameter) using hand tools.

Tools and Techniques

Fell a small tree with a large bow saw or pruning saw. A mattock, pry bar, or come-along may be used to remove tree roots. Unless it is a tiny tree, which one worker can safely fell, two or three people should work together to fell a tree. While one worker cuts, the others provide feedback on movement of the tree, keep others a safe distance away, and halt work when necessary. Remove all unneeded tools from the immediate area before getting underway.

Tree felling sequence:

1. Determine the best direction for a safe fall - where the falling tree will cause the least collateral damage and end on the ground and not in the branches of another tree.

2. Cut a notch on that side of the tree, three to four feet above the ground. This is easier and safer than making the cut near the ground, and provides a lever to help loosen the roots.

3. Start cutting on the side opposite the notch until the tree appears ready to fall.

4. Everyone except the worker making the cut should move away as trees do not always fall in a predictable manner. Shouting “timber” is appropriate and fun.

If the tree is outside of the tread space, cut the remaining trunk off at grade. Roots of trees that rapidly regenerate, such as scrub oak, may need to be removed if they are near or within the tread space. To remove a tree stump dig around the roots and periodically move the remaining trunk side to side to hasten extraction. Chop the roots with the adz side of a mattock. Using saws for cutting roots ruins the blades.[10]

Disposal of Removed Plant Material

Removed plant material may include sod, root clumps, whole plants, and branches of varying sizes. Larger items may be used to block points vulnerable to short-cutting, as may occur at turns and switchbacks, and for trail closures (see *Trail Closure and Landscape Rehabilitation*). Finer materials may be used to dress the edges of the tread and other visible blight that may result from tread construction. In sparsely vegetated areas, check with nearby crews. Debris for blocking off trail movement may be needed on other work sections.

As corridor clearing work starts, assess how much material may be needed for the above tasks and stockpiled close by but not so close as to interfere with the trail work. Plant debris remaining after all of the above have been taken care of may be dispersed as follows:

- **Carry, don't throw**, branches outside of the corridor. Place downhill unless the hillside slope is less than about ten percent.
- Tuck cuttings outside the corridor under live or dead plants of the same species.
- Point cut ends away from corridor or stick them into the ground
- Do not place plant debris in significant drainages. Plant debris in drainages creates two problems: 1) heavy debris may alter the flow pattern and provoke erosion, and 2) plant debris left in a drainage may be swept downstream during flash floods and gathered into debris dams that can create havoc.

10 Modern pruning saws have good, long lasting blades. But, if they are damaged by inappropriate use they usually cannot be sharpened.

Tread Construction & Maintenance

Trail users enjoy traveling on a firm, relatively flat, clean, and dry tread that does not require their undivided attention. On the other hand, some hikers and mountain bikers appreciate surface texture and negotiable rock outcroppings that provide a challenge. Expectations vary widely between urban high traffic trails and remote wilderness trails. Land managers want a tread that stands up well under the impacts of use and weathering.

The section of this guide covering Tread Drainage is about managing water that flows along the tread and removing it from the tread. While it is convenient to address tread building and tread drainage as separate topics, this separation is somewhat artificial. Most reaches of a well-planned trail tread are part of the drainage plan for that tread. On any project, trail drainage is understood and taken into account before starting to build tread.

Rainfall and the resulting runoff may be expected to collect on the tread and travel down tread for some distance. Only in certain soil conditions will an appreciable amount quickly cross and leave the tread. Trail tread should regularly “reverse grade”[11] allowing water to leave the tread at the bottom of each grade reversal.

Tread Soil Assessment

The first step in both new tread construction and maintenance is to assess soil properties. Soil properties will, by and large, determine how use and weathering will affect the tread and what can be done to minimize tread destruction on non-motorized natural surface trails. It may be necessary to start a small area of tread excavation to complete an assessment.

While an over-simplification of the topic of arid land soils, three profiles appear to capture the most important properties that trail builders working in the Southwest need to understand:

Compactable Soil
When the hard native surface is broken, this soil yields a mixture of fine soil, sand, gravel and rock of varying size. Loosened material can be removed to leave an even tread surface that compacts well. Soils containing a wide variety of separates (different sized materials) form the most durable trail tread surface in most arid and non-arid regions. Under these conditions, a tread of moderate grade may shed some water off its outside edge if shaped to slope from its inside (uphill) edge down to its outside edge (this is called "tread out-slope"). Hollowing out progresses slowly.[12]

Rocky Non-compactable Soil
This may be the most commonly encountered desert soil condition. When the surface is broken, soil (predominantly clay) turns powdery but is hard to excavate due to a large amount of rock. Larger rocks or cobble are removed leaving divots as material is removed. The “finished” tread surface is made up of fine soils that do not compact well and the tops of the next layer of rock. Hollowing out will initiate immediately with use but is restrained by high rock content. Trail planning should provide for numerous grade reversals.

---

11 The expression “grade reversal” is used in reference to trail tread. A grade reversal of interest here is any instance when a tread that is headed downhill changes its grade and starts to climb uphill creating a low point where water may be drained from the tread.

12 Hollowing out is a process of trail breakdown. Trail traffic knocks loose material from the tread surface, which is then transported during rain events down the trail to a low point where it deposits or exits the trail.

Shaping tread to move water to the outside edge is of limited value because hollowing out will soon override the capacity of tread to shed water. The unevenness of the land may provide opportunities for dumping small amount of water off the tread where a depression along the outside edge permits a few feet of exaggerated out-slope (think of these as micro-dips).

Non-compactable Soil
This soil is typically composed primarily of clay and loosens easily, unless it is hardened clay.[13] Soils consisting primarily of sand or gravel behave in a similar manner, but are less common. Tread built on such soils cannot be given any lasting form and hollowing out proceeds immediately. The rate of erosion relates directly to the trail grade. Only trails with minimal grade are stable. Trail planning should provide for numerous dips and fully hardened (armored) outflow points. Water that lands on or enters the tread from the uphill side will stay on the tread until it reaches a grade reversal (see *Tread Drainage*).

Construction on a Hillside with >10% Slope

This section describes a general process for building full-bench tread. There is a consensus among trail builders that full-bench construction - the entire width of the tread is on native, largely undisturbed soil - affords the most stable tread. The alternative to full bench construction is "cut and fill" construction where some portion of the tread rests on fill. Trail tread resting on fill material too readily falls away under use and weathering. In addition to basic tread construction, this section includes several special tread structures including steps, climbing turns, and switchbacks.[14]

Tools and Technique
The pick mattock, Mcleod, and shovel are the bare essentials for tread construction. The Pulaski, mini-mattock (short-handled digging tool), rock bar, bucket, landscape blanket, and rock cradle/sling are sometimes useful. As the slope of the hillside increases the amount of work involved in excavating a tread bench increases dramatically. Do not expect this work to go quickly.

When building new hillside tread:

1. *Work at a moderate pace* to preserve energy and maintain focus on quality. Working fast can result in tread that drifts away from the flagged alignment (workers lose sight of the tread flagging alignment), that is too deep, and that slopes into the hillside rather than away from it.

2. *Work from a position within the tread space* facing up trail. This is easier than working while facing down trail, because it minimizes the distance between the end a tool and the surface being worked with the tool. Do the same when bending to pick up rock or other debris - squat on the downhill side of the object to be lifted.

3. *Stand in the tread space while working*, not downhill to the side of the tread. While this does not feel natural, it helps to minimize damage to the trailway and corridor areas and preserve a clean edge to the tread.[15] Loosened soil left along the outside edge is easily mistaken to be a part of

13 Soils with a high proportion of clay are slippery when wet (dangerous tread surface), become very hard as they dry out (good tread surface), and turn to powder upon impact when completely dried out (poor tread surface).

14 The difference between building tread on a hillside slope of greater than about 10% and one that is less is not as arbitrary as it might seem. Tread on a slope of less than 11% should require little, if any, bench excavation.

15 Workers who start tread shaping while on the tread often drift downhill without even realizing it. Gravity reigns! That being said, this author has seen an experienced trail worker stand at the low edge of a tread and efficiently build perfectly fine tread. His toes were at the edge and he used his digging tool only to loosen the soil. Then he moved up onto the tread area to gather and disperse the loosened soil. No berm was created and the tread was on native soil.

the tread.

4. Avoid absolute uniformity of tread width - that will look unnatural.

Pre-construction Assessment:[16]

1. Look for any low slope areas where full bench construction is not appropriate. It is easy to miss such opportunities unless noted before work gets underway.

2. Use the results of a "Tread Soil Assessment" to determine how trail users and water will affect the tread. What should the finished tread should look like? How will it respond to use and weathering?

3. Assess the designer's plan for draining the trail. Are natural features fully taken advantage of to facilitate getting water off the tread? Are there long runs of tread that might need to be drained more frequently than provided for in the current layout? (See *Trail Drainage* for additional guidelines.)

4. Are special structures to drain water from the tread or navigate a sharp turn a part of the section of tread to be built? Should these be built before, during, or after basic tread construction?

Construction Sequence

1. Preparation for tread excavation

    a. Gather and store duff, small twigs, and clean gravel from the trailway by hand or by light scraping with a Mcleod.

    b. Dislodge any large visible rock within the tread space by hand or with the pick end of a mattock or a rock bar. Stockpile rock that may be needed for blocking, closure work, rip rap, guide stones, cairns, etc. Excess rock may be placed weathered side up in a stable location. Scatter other small rock downhill and outside the corridor.

    c. Determine if tread fill material will be needed and where to obtain it. Soil excavated from elsewhere on the trail is the first choice - a barrow pit the second.

    d. Alternative methods for disposing of excess excavated soil are:

        i. First choice: Place in buckets (only half-filled) or wheel barrows and take to other work areas that need it.

        ii. Second choice: Use a shovel to pitch it downhill into shrubs and thinly across the landscape unless it is windy. When everything and everyone becomes covered with soil, switch to the third choice.

        iii. Third choice: Place in buckets or bags or onto landscape blankets and scatter, outside the corridor. Do not leave soil in piles.

2. Add flags to make sure there is no ambiguity about tread alignment. VOAz marks a tread alignment with flags or whiskers placed at the outside edge of the final tread, with occasional flagging on the uphill side to convey the appropriate tread width. Land managers determine the

16 VOAz relies on trained, volunteer Technical Advisors to plan trail work and prepare written work notes for each crew so that little on-site, day of reassessment is needed. This speeds up the work and may assure a greater consistency across all work areas. However, Technical Advisors can miss things, the tread area may be buried under vegetation prior to corridor clearing, and not every organization can provide a similar level of advance planning.

standard tread width and how much deviation from this standard is acceptable.

As an additional guide, a line may be scored along the inside (uphill) edge of the tread. Do this by first creating a "dotted line". Working uphill, look at the outside edge flags and use a mattock to make a nick opposite each flag to mark the desired tread width. Join the dots with a shallow, mattock wide trench. The trench need not be very deep, because this additional mark is just to help people get started. This line will be lost as soon as excavation gets underway. Outside edge flagging should not be removed before the tread is completed.

3. Rough in the tread and some of the uphill slope (back-slope) using the three tool sequence described below. "Rough" means to dig to within a few inches of where the final tread and back-slope will be - perhaps eighty percent of the required excavation.

   Tread excavation may be easiest with a team of at least two workers using the three basic tread construction tools: pick mattock, Mcleod, and shovel. This allows some to rest while others work. The sequence described below is repeated several times - many times on a steep slope - in order to excavate down close to the final tread location. Peeling off thin layers of soil and rock is easier work and affords better control. Otherwise, it is easy to dig too deep.

   a. *Use a mattock to loosen soil*. In rocky soil a full-sized mattock is required. A light mattock, Pulaski, or Mcleod may work with looser soils. Grip a mattock - hands spaced about one foot apart with one hand near the end of the handle. Assume a stable stance, and allow the weight of the tool to do most of the work (while standing on the tread area, facing up trail). Shallow strokes save energy and improve accuracy. Avoid knocking loosened soil off the downhill side of the tread.

      To avoid walking over and compacting material already loosened, loosen some soil from the tread area, *back down* the tread a bit, and loosen some more.

      On steep slopes, soil and rock will start to fall onto the trail from the uphill side as excavation proceeds. Start pulling unstable soil and rock from the area uphill of the tread down onto the tread at the same time the tread is being cut. This begins the process of giving a stable shape to the uphill side of the tread.[17]

   b. *Use a Mcleod to gather loosened soil into piles* pulled toward the inside (uphill) edge of the tread area. Keep all loosened soil within the tread space.

   c. *Use a shovel to remove piles of soil* (flat shovels work well in less rocky soils), unless needed for fill in the immediate area. Disperse excess soil according to plan.

      Each pass should result in a surface that looks rather like a tread, with a slight downward slope from the inside edge to a clean, berm-free outside edge of the tread.

   d. Reassess and repeat as necessary until about eighty percent of the excavation is completed. With each pass, pull any material that has ended up outside the tread space back onto the tread. Fine tuning or finishing the tread is part of the last step after all special structures are in place.

4. Shape a stable slope uphill from the tread (back-slope). Blend the top of the cut area to meet the slope of the hillside to achieve a natural appearance. Leave plants with a good foothold and stable rocks in place. Leave pockets in the slope to trap seeds and moisture and facilitate new plant growth.

   On very steep hillsides, blending into the natural hillside can be impractical. One trick is to

17 Leaving excavation of the entire uphill slope to a subsequent step can be discouraging when a handsome, nearly formed tread is suddenly loaded with soil and rock from the uphill side of the tread.

excavate a narrow bench just above and outside of the tread bench that can catch some of the material that will fall from a steep bank cut. Facing a steep cut with rock armor is another stabilizing measure.

5. Finish or polish the tread. This should be done after special structures (dips, turns, etc.) are completed. If the trail is in an area with extremely loose soil (high clay, sand, or gravel content), the outside edge may need to be reinforced with a one-rock wall (described in *Rock Wall and Armor*). The finishing phase includes "taking a fresh look." This may reveal overlooked and incomplete work. Here are some finishing tasks:

    a. Finish the tread and dispose of excess material. Fill any holes created by the removal of rock(s) with a mixture of gravel and soil, and tamp.

       If the soil assessment suggests that the tread will likely hold its shape and only gradually hollow out (that is, the soil compacts well), make sure that the tread slopes slightly from the inside to the outside edge. A cross-slope or "out-slope" of five to ten percent is comfortable to walk on. Gradually shave material off of the tread surface to achieve the desired shape. Compact with a tamper or the flat side of a McLeod blade. *Do not build out-slope using fill material.*

       In rocky soils that do not compact well (powdery dry soil) but resist hollowing out, it is still a good idea to build in some out-slope, even though the inevitable gradual hollowing that will follow will cause most water to be carried some distance along the trail. Where tread is on soil with high clay content, carefully shaping out-slope and a rounded "critical" edge is useless (see *Tread Drainage*).

    b. Look for soil that has slipped off the edge on the downhill side. Stand on the tread, gather loose material back onto the tread and disperse it.

    c. Remove unsightly debris left near the tread, or lodged in a tree or bush from an unsuccessful toss.

    d. Meandering trails that are introduced to support tread drainage create opportunities for those who tend to follow straight lines (equestrians and mountain bikers) to cut the inside corners of tread lying on low sloping hillsides. Set a few boulders and other long-lasting barrier materials in stable locations on the inside of gentle curves to discourage this.

    e. Dress disturbed areas adjacent to the tread with a thin layer of duff, twigs and grasses, and fine gravel.

    f. Close borrow pits by filling with debris and masking scars on the landscape.

Construction on a Hillside with 5-10% Slope

Building tread on very low slopes calls for a lighter touch. Sometimes the first work is done without using any tools. The distinction with tread construction on steeper slopes is made because a different approach to forming tread is called for in these circumstances.[18]

Such reaches of tread are found at the base of a hill as a trail ascends onto or descends from steeper slopes. Trail users can laterally traverse slopes of up to about ten percent for sustained periods. Thus, there may be no need to excavate a full tread bench. In practice, there will rarely be significant reaches of tread where absolutely no surface work is needed. Low slope areas contain plants, rocks, or small

18 Trail planners avoid low slopes because they are harder to drain. A swale (described under *Tread Drainage*) may be used to drain tread on low slopes.

bulges that need to be removed. The sequence of work may simply be to remove obstacle rocks (often by hand), smooth out bumps, and fill divots. If the alignment seems ambiguous, add guide stones (see *Way Markers*). Trail users will clarify the tread's location.

There seems to be an irresistible tendency to grab a McLeod and start working the surface wherever new trail markers are in place. This tendency should be resisted lest you end up with a dysfunctional trench.

Construction on Nearly Flat Land (<5% Slope)

Trail designers try to avoid placing trail on flat land because it is difficult to drain. If flat tread on native soil hollows out and water accumulates, trail users find another route. Trail braiding or widening is the long term result. While this may be less of an issue in arid regions than wet meadows, trail users love to get out on the trail right after a rain as this is a time when the desert is very enjoyable.

Simple Crowned Treads

If compactable mineral soil can be imported, build a crowned tread. Small amounts of water that flow to and become trapped on the higher side should seep through or quickly evaporate in arid landscapes and where the area draining toward the trail is not very large.

Crowned Tread with Trenches

If no fill can be imported but the resident soil is compactable[19], scoop soil from each side of the tread area to form a crown with trenches on both sides. Compact the crown well. Trenches may be extended to an available drainage line to take water away from the tread. When it is necessary to bring water from a high side trench to the lower side of the tread, introduce a swale (shallow depression) crossing to the tread.

Rock Steps and Stair Cases

Isolated or single steps provide an immediate, stable small vertical change of elevation. When an alternative more gradual alignment is not available, stair cases are built to avoid excessively steep tread.

Trail users don't like steps; they will try to go around them. Stair cases are especially unacceptable to bikers and equestrians. This, plus the amount of work involved in building steps, limits their use. On the other hand, a well-built rock stair case can be an attractive feature.[20]

Step terminology and specifications (see Figure 4):

- Riser - the exposed vertical face of a step. Keep to less than 8 inches of exposed height for hikers and 6 inches for horses.[21]
- Tread - the exposed horizontal face of a step. The front to back depth should be at least a full boot (twelve inches).
- Run - the horizontal distance from one riser to the next. The run is equal to or greater than the tread depth. A length of run behind the tread stone may be built with compacted native soil or gravel, which may drain better. The grade on a run should be less than five percent. Steeper grades lead to erosion of soil from underneath the next tread above and may destabilize it. Horses require larger runs, ranging from a minimum of four feet to over nine feet.

---

19 The most compactable soils are a mixture of clay, silt, sand, gravel, and small rock

20 Less enduring and decidedly less attractive steps may be built of logs (Cedar or Juniper) anchored with reinforcing bars driven through holes at the ends of each tread.

21 See Hancock, et. al under web resources.

Figure 4 illustrates the stair/step components defined above, and several ways in which a string of steps may be built.

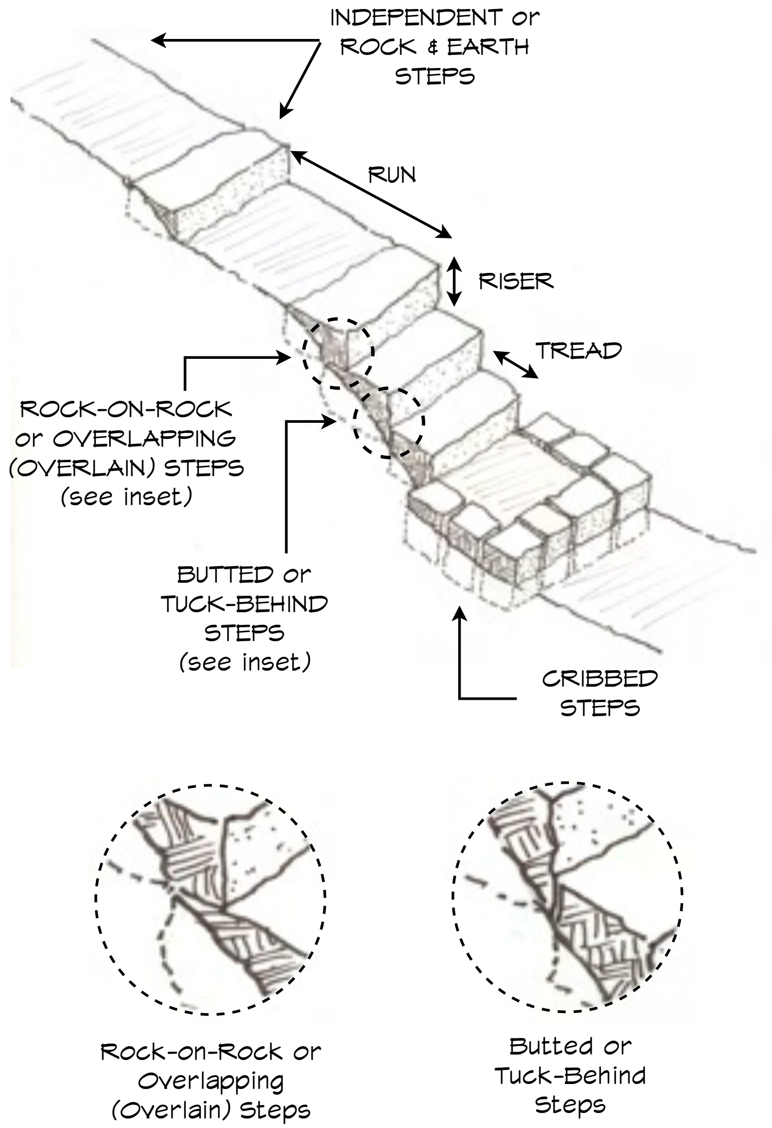


FIGURE 4. Step Components and Configurations

Build sequence for a rock staircase:

1. Flag the top and bottom of the complete run, determine the average grade and determine the number of stair treads based on the maximum allowable riser height.

2. Measure the width and collect more than enough rock needed to build the complete structure. Steps made of rectangular rocks weighing 100-200 pounds (too heavy for one person to lift), and long enough to form an entire step width are best.

3. If possible, lay out the rocks in a nearby location. Place them in the potential step sequence that appears to make the best use of available rock in order to achieve a fit with the terrain. Reserve one of the largest rocks for the first step at the bottom of the stair case.

4. If soil conditions permit, partially bury the first tread stone. This and all subsequent steps must not move when jumped upon.

   Tread immediately beyond the bottom of a staircase needs a few feet of <5% grade to prevent erosion. If this is not possible, and water may be expected to flow down the steps, make certain the tread is partially buried. Set a heavy flat rock flush with the tread grade at the bottom of the riser to absorb the force of water coming off the tread.

5. Working uphill from the first tread, build according to the rise, tread, and run specifications listed above. Hikers do not like down-sloping tread; therefore, tread rocks should be level or have a slight back-pitch.

   Do not use shims to stabilize tread rocks. It may be necessary to shape some rocks with a mallet and chisel to achieve a solid fit between steps.

   If backfill is needed on runs, layer in a mixture of soil and gravel. Compact each layer well.

6. Anticipate how water may enter and leave the staircase. If significant amounts of water are likely to pool on a run, open a drain.

7. Dress the sides and block potential bypass routes. Rock side-aprons are sometimes used for this purpose and to control erosion.

Turns to Reverse Trail Direction

Well designed trails wind and meander as they make their way through the landscape toward their destination. If it is necessary for a trail to quickly reverse direction in order to gain/lose elevation, special tread construction requirements come into play. Reversal of trail direction is inherently problematic so trail planners try to avoid it.

Any direction-reversing turn is best placed just beyond a rounded, sloping ridge. Such placement helps to mask the presence of a turn to trail users and thereby reduce the temptation to take a short-cut across the inside of the turn. Wrapping a turn around a large rock outcropping or a large tree with low branches is another good practice. Trail planners avoid stacking a series of direction-reversing turns because this creates a powerful incentive for cross-cutting especially in sparsely vegetated landscapes.

Climbing turns and switchbacks create a sharp reversal of trail direction. A climbing turn (or descending turn, if you are headed down trail) is the preferred of these two devices. It is the easiest to build and maintain. However, climbing turns are generally limited to hillsides with less than ten percent slope, although soil conditions and the amount of water coming onto the tread from the uphill side may be more determinative than by slope alone. There is a tendency to over-use climbing turns because building a switchback so much more labor intensive. Therefore, if you are in doubt about whether a slope is too steep for a climbing turn, it probably is.

Climbing Turn

A climbing turn must be laid out so that the tread ascends/descends at a uniform grade throughout the turn. The wide sweep that is required of a climbing turn must be anticipated in the initial layout of the tread. Improper layout (that is, making the turn too tight) may force construction of a switchback instead.

Building a climbing turn involves the same tools and techniques as building side-hill tread. The tread is built to shed water to the downhill side on both legs of the turn. The middle of the turn does not pitch to either side, so that water will flow down to the lower leg and then, it is hoped, off the tread.

The normal hollowing out of the center or the primary line of user traffic will capture and transport water through a climbing turn. It may be appropriate to place a dip at the lower end of the turn in order to remove water coming around the corner. A dip on the upper leg could be added to reduce flow into the turn. Water pulled off the upper leg must not undermine the tread on the section below. All of this potential dipping and draining should not significantly disrupt a smooth continuous climb through the turn. See Figure 5.

FIGURE 5. Perspective View of Climbing Turn with Drain Dips on Upper Leg and at Bottom of Turn

Switchback[22]
A switchback is required when the slope of the land (>10%) or other factors rule out a climbing turn. Good switchback design allows trail users (hikers, mountain bikers, equestrians, and/or pack animals) to move safely and comfortably through a turn. Users should not have to stop, turn and then proceed. Switchback tread is built to drain differently than standard tread. Switchbacks must be laid out and construction supervised by trail builders with training and experience with this structure.

Standards for switchback construction and more elaborate construction guidelines than those that follow are available in several trail work manuals.[23] In desert landscapes, soils conditions may warrant deviation from customary practice.

A few key design principles:

1. On multi-use trails, make sure that there are generous sight-lines for cyclists coming downhill and approaching turns.

2. Build a turning platform that is adequate for all users (four foot turning radius for pedestrians only; six to eight feet for hikers, equestrians, and average bikers; up to eight feet for heavy mountain bike use and higher speed mountain bikers).

3. On trails serving mountain bikers, there should be some way to slow bikers as they enter from the uphill side. The best way is to build in a safe (i.e., very obvious) pinch point or a couple of sharp turns uphill from the turn. Another way is to hold the grade to no more than five percent for the six to ten feet leading into the upper end of the turning platform to provide a braking zone. However, this may complicate the task of draining the switchback.

4. Discourage cross-cutting between the trail segments on either side of the turn. With the exception of the braking zone mentioned above, build the upper and lower approaches to the turn at the maximum allowable grade for the site in order to maximize the separation between upper and lower approaches to the turn.

Construction Sequence:
(*Complete after clearing the corridor. Plan and cross-section views of a switchback are shown in Figures 6 and 7, respectively.*)

1. Determine where excess material will be deposited and clean the work area. If some of the excavated material may be needed for back-fill or rock work, plan for temporary stockpiling.

2. Locate sources of any rock needed for wall building or armoring.

3. Rough-out the turning platform, the braking zone and the approach legs to confirm that the flagged alignment can be built to specification. If there is to be a wall supporting some portion of the outer half of the turning platform (hard to avoid), try to plan for the excavated amount to equal the final compacted fill (hard to do). This will minimize the amount of fill material to be imported and excavated material that must be dispersed.

4. Start any needed platform support wall along the lower edge. Back fill and tamp in layers with material excavated from the uphill side of the platform to reach the appropriate height.

---

22 The term “switchback” is from the early years of railroad construction through mountainous terrain. To allow a train to climb a steep hillside, a rail would be laid out at the maximum permissible grade. Where it was necessary to go back in the opposite direction, a reach of flat rail was built that could accommodate the full length of a train. After a train pulled to the end of the flat section, a switch would be thrown to connect to another uphill reach of rail, and the engine would reverse direction and continue the climb (or descent).

23 See Austin, Birkey, Hasselbarth, and International Mountain Biking Association publications in the bibliography.

5. Decide how water coming into the switchback will be handled. This is where textbook designs may fail in some arid soils.

   For the most part switchback tread is built the same way as regular tread. If tread slopes at all, it slopes from its inside edge to its outside edge, except for the reach of the uphill leg that includes at least the breaking zone and the uphill half of the turning platform, where customary practice is reversed. Within this area, tread and platform slope from the outside to the inside (or, into the hillside). A drain is dug along the inside (back side) of the tread to collect water to be dumped off the end of the turning platform.

Why standard switchback design may fail in arid landscapes.

In clay-laden or otherwise fragile soils, a back side drain is prone to clog. Drains that are self cleaning in these soil conditions must be armored and steep. Adding armor increases the size of the drain and the work involved in building it; which means, among other things, more hillside to cut. The specification for the braking zone (low tread grade) conflicts with that for a self-cleaning drain (steep tread grade). When the back-side drain clogs, water is pushed out onto the tread and may bypass the planned exit and even stay on the tread all the way through the turn.

The standard design may fail if tread hollowing-out is likely. A rut may be worked in and make its way all the way through the turn, bringing water with it. Moreover, if the platform is not excavated to sufficient vertical depth - a common occurrence given the amount of work this involves - the grade on the lower approach to the turn will be steeper than the planned grade. This will hasten hollowing-out.

Design adjustments for switchbacks in areas with unstable soils.

- Harden the spine of the turning platform as a barrier to hollowing out. The spine is an imaginary line bisecting the turning platform into an upper and lower half (see Figure 6). The surface of the platform slopes down on either side of this line. Set large flat rocks into the uphill side of the platform along the spine and pitched to direct water toward the back side of the turn. Gently slope the other half of the platform in the downhill direction. The hardened spine should stop any hollowing out of the tread from passing through the turn.[24] The spine itself should also pitch down from the apex (center point of the turning radius) to the outside edge of the platform to help the back side properly drain.

  It may be wise to harden the entire width of the tread at the junction of the lower end of the turning platform and the lower approach leg. An area of stone pitching hardening is shown in Figure 6.

- Improve the stability of the soil on the uphill side of the platform (behind the hardened spine) by adding sand and gravel to the native soil.

- Assume that water will flow along the back area of the platform. If possible, harden the back edge of the platform next to the hill cut with heavy, flat rock(s). If the slope heading toward the outflow point is shallow, material will deposit and heavy rains may flush this material off of the hardened surface.

- It is very difficulty to predict exactly where water will flow across the uphill side of the turning platform once tread wear commences. Build the outflow area to accept and disperse water at any point from the spine to the back side hill cut. Make sure that the top edge of any rock in the outflow structure is low enough to allow water to leave the platform.

---

24 If hardening the spine is not possible because of resource limitations (and you cannot eliminate the switchback altogether), build for a turn that will erode and carry water down onto the lower tread and drain from that point.

- Armoring the hill cut on the back side of the turn should reduce clogging of the drain line.
- Add drain dips on the upper and lower approach legs to get water off the tread before and after the turn. Make certain that water drawn off the tread above the turn has a non-destructive path across the tread just below the turn.

6. Add barriers to discourage short cutting just before the turn. Place large, unstable-looking rocks, large tree branches, or spiny plant material such as cat claw between the legs of the turn. Place a large, very stable rock at the apex of the turning radius flush with the platform spine rock. Many trail users will naturally try to cut the inside corner of a switchback.

7. Look for additional opportunities to drain the tread of accumulated water along the steep sections of trail approaching both ends of the turn.

Avoid making bets that the switchback will hold up. Plan to return within a year or soon after a significant storm to repair any damage.

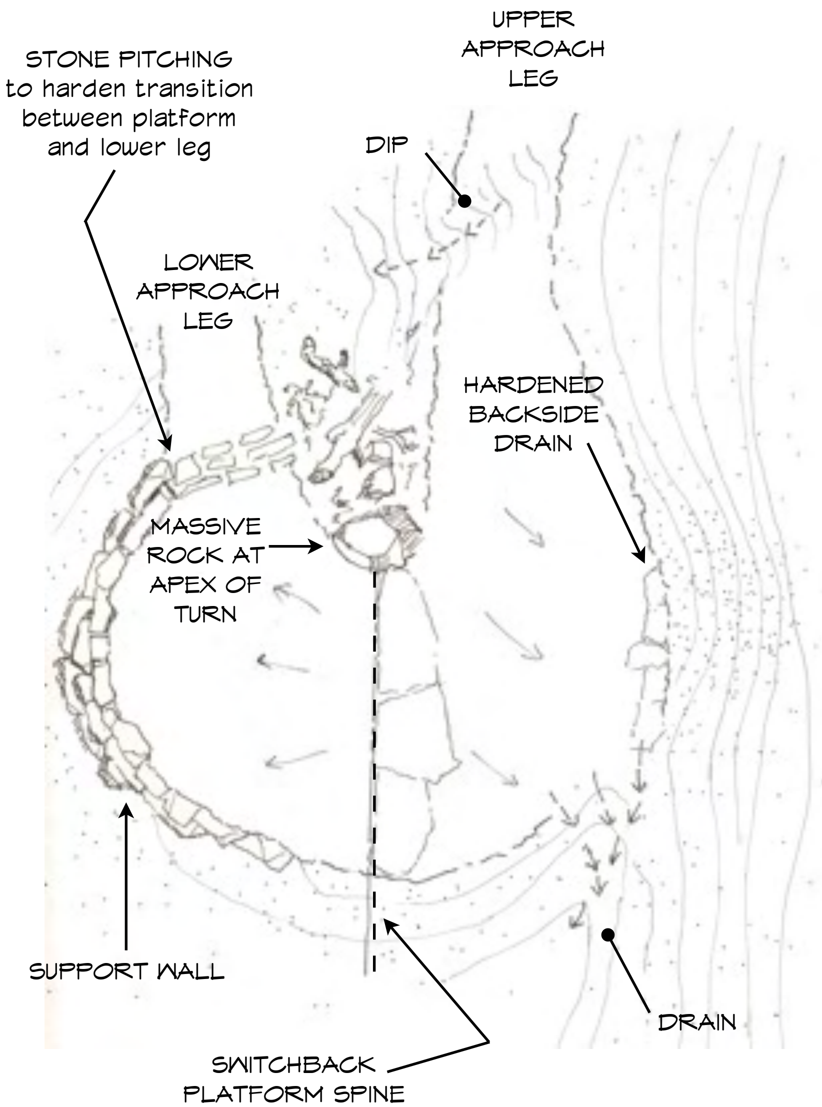


FIGURE 6. Plan View of Switchback

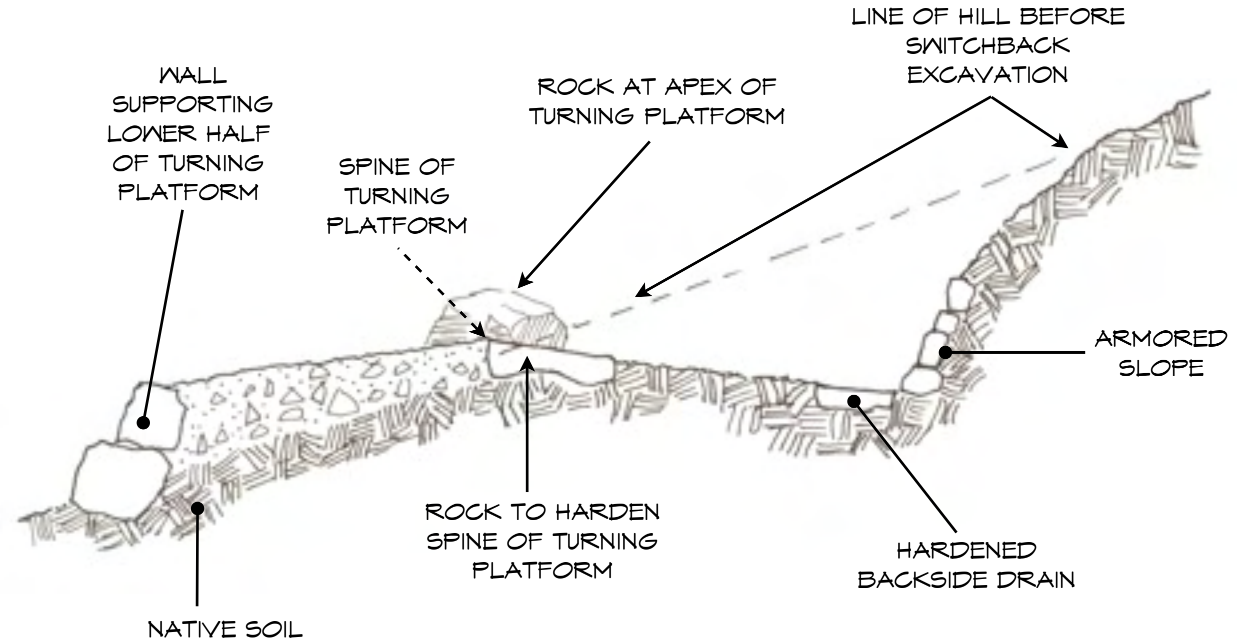


FIGURE 7. Cross-section View of Switchback (slopes away from spine exaggerated)

Tread Maintenance and Repair

Maintenance and repair entails restoring a tread to whatever standards apply to that trail. In some cases, this may entail simple corridor re-clearing, cleaning drainage structures of debris, and some tread reshaping. A higher level of maintenance can combine these tasks with resolving major tread and structure breakdowns. The latter may involve realignment and take on most of the tasks associated with new trail construction. The tools and methods are essentially the same as those that apply to new tread construction.[25]

If maintenance/repair makes sense (rather than realignment), here are the most common problems and solutions:

1. The tread is overgrown: Clear plant and tree growth from the trail corridor, trailway and tread.

2. New social/wildcat trails have emerged: Assess why this has happened. If the legal route fails to address legitimate user interests, maintenance may not be worth the effort. If trail users are just taking advantage of a very obvious short-cut opportunity, block it.

3. Drainage structures are clogged: Clean and try to rebuild so that they are self cleaning using a steeper and/or hardened outflow surface.

---

25 Many legacy trails need constant maintenance. These trails are un-planned "trails of use" or perhaps poorly planned recreational treads. In some cases, poorly maintained trail may be little used, so the real question is: Should such trails be closed rather than maintained? In other cases, at least some realignment is the only answer if you are to achieve a tread that is satisfactory from a user's perspective and that entails reasonable long-term maintenance costs.

4. Excessive tread erosion: Before working on the tread look for signs of erosion and ways that trapped water can be taken off the tread. Getting out to a trail during or shortly after a heavy storm is the easiest way to diagnose trail drainage problems.

5. Soil has built up along the inside edge of the tread (slough) and/or there is a mound at the outside edge (berm) and the tread is hollowing out. The usual advice is to bring dislocated material into the center of the tread and tamp it down to make sure the tread slopes outward. This will only help if the soil will hold its shape once compacted.

   If tread hollowing is evident, it is likely that tread is on soil that does not compact well. It hardly seems worth the effort to bring easily dislodged soil to a place where normal tread use will loosen it and water will transport it down trail. It is better to gather the loose material from both sides on the tread and disperse it. Consider inserting an additional grade reversal to help drain the tread.

6. The tread is widening (downhill creep) because the soils at the outside edge are weak: Add a one-rock wall at the outside edge, or add a more robust rock support if this is not likely to hold (see *Rock Wall and Armor for Tread Support*).

7. A deep rut is developing down the middle of the tread: This is a sure sign of bad design. The trail is probably too steep for the type of soil. Steps and/or tread hardening may be required if realignment is not practical.

8. Walls and other rock structures have broken down: Determine the cause and correct accordingly. If horses or other users have knocked loose rocks, rebuild with heavier rock. Blown-out creek crossings may or may not be due to poor initial design or construction; heavy desert storms create runoff forces and flow dynamics that are very hard to predict.

Rock Wall and Armor for Tread Support

Rock is used in many different ways to support and protect trail tread. Rock walls are used to support tread where there is a weak edge or no base for tread on a steep slope. Because of the effort and time involved in building good walls, they should be used only when absolutely necessary. Armor - rock facing - can stabilize slopes above or below a trail tread.

Safely Moving Large Rock

Most trail work injuries result from handling rock. For this reason, this section start with guidelines to help reduce the risk of injury while handling large rock.[26]

A few do's and don'ts:

- Volunteers handling rock should wear hard-toed shoes and gloves.
- Lift with the legs not the back. Look to the sky when ready to lift and your butt will be where it should be - down.
- Avoid damaging the landscape by sliding rocks or allowing them to roll downhill. The latter could also damage workers and already completed trail work.
- Roll rocks only on very low slopes.
- Warn anyone who is downhill; if the situation becomes the least bit precarious, shout "Heads up, please - moving rock!" If a rock begins to roll uncontrolled, shout "Rock!" When a loose rock has completely stopped moving, shout "Clear!"
- Due to the forces involved, even a minor pinch between rocks can cause serious injury. Keeps hands and feet well clear of the spaces between rocks when they are being moved together or when rock bars are being used.

The safest way to move a rock is for one person to do it. For larger rocks, teams of two or more workers will be needed. Close communication based on pre-established verbal commands are required to manage this added source of risk.

Rock bars (not round tamping bars) can be used to move larger rocks. *When a fulcrum is needed, the person using the bar should place it*. Having another worker place the fulcrum increases the chances of injury.

Lifting a large rock out of a hole requires three persons with rock bars. Two bars must always be supporting the rock while the third is repositioned to achieve added leverage. Fill the hole under a large rock being lifted with small rocks as it is moved up. Use a stick or tool handle to position the small rocks. Never place hands under a rock being supported by rock bars.

Using a rock cradle, sling or stretcher to move very large rock

A rock cradle is a device that two or more workers can use to safely transport large rock.[27] When using a rock cradle, everyone involved must first understand how to use it. Appoint a team leader, develop a strategy for moving the load (where will you walk), and review your verbal commands.

---

26 Using leverage gained with rock bars and fulcrums, bribes, sweet talk, or bluster and specialty tools (come along, gripe hoist, rigging, catapult) to move very large rock is best learned in the field working with an expert.

27 These devices include the Austin, Z sling, fireman's crib, and brewery or landscape blankets. A piece of plywood propped atop two lengths of 2x4 is not a rock cradle.

A command vocabulary:

- "Ready to lift" (everyone repeats)
- "All lift on the count one, two, lift" (leader only)
- "Down" (used by anyone who needs to set the load back on the ground)

Set the team and move:

1. Position taller and stronger volunteers on the downhill side and, taking relative strength into consideration, and make sure the load is shared equitably.

2. The first lift is to test the stability of the rock in the cradle. The rock may shift when lifted - even drop out of the cradle.

3. The leader monitors the team and guides movement. If the leader sees a problem that requires clarification, s/he gives the "down" command. Restart at step two once the problem is resolved.

4. Any worker who feels her/his grip is failing, stumbles, or needs a rest commands "down". Whenever a rock is lowered to the ground, keep some tension in the cradle rigging to prevent the rock from rolling out of the device and, possibly, out of control.

A special problem: Filling a large hole created by removing a large rock
Removing a very large rock from the tread will occasionally create a very large hole to fill. One way to fill such a hole is to tamp in a mixture of smaller rocks, crushed rock or gravel and soil. If enough fill material is not readily available, enlarge the same hole until it is big enough to accommodate the rock at or below grade. Tamp soil and crushed rock over and around it.

One-Rock Wall[28]

The impact of boots, hooves and wheels landing near the outside edge of a tread can push a portion of the tread downhill. On slopes of loose soils (high proportions of gravel, or sand, or clay), it may take very little pressure to break down the outside edge of the tread. A single course of rock completely buried along the outside edge can help to disperse the impact of users.

Construction sequence:

1. Assess if a one-rock wall will do the job. Plant a test rock if necessary to see if it will remain in place (there is "good purchase"). If not, a buttressed one-rock wall may work (see below).

2. Find rock needed to build the entire length of wall and lay it out in the middle of the tread with each rock opposite its place in the wall. Rocks with a decidedly long axis are best. Rocks that fit closely together will result in a more stable structure. Rocks that are not that big - one person can easily lift them - may be stood on end to provide greater effective mass.

3. Dig a trench, rather than a bench, if the soil is firm enough to permit this, just outside the tread area. The top of the wall should be a little below the outside edge of the tread. By the time the tread is finished, the wall should be nearly, if not completely, invisible. Sloughing excess soil off the tread onto the downhill side of the wall may look ugly at first, but should add stability.

4. While a one-rock wall is not intended for users to step or ride on, give it a stomp. If it moves, a buttressed wall may be needed (see *Buttressed One-Rock Wall*).

---

28 Previously, the VOAz Crew Leader Manual labeled these "crib walls." However, that term has a very different meaning in the long history of tread building. Out of deference to those who have gone before, the more descriptive "one-rock wall" is used here.

5. If there is concern about trail users drifting onto a one-rock wall, insert an occasional oblong rock within a one-rock the wall, with the long dimension vertical and projecting above the wall. This will create a guide stone (also referred to as a “tombstone”) that pushes tread users away from the one-rock wall you are placing along the outside edge of the tread.

If soils are unstable enough to warrant a one-rock wall, then tread hollowing-out is bound to occur. Dips will be needed to allow water flowing down the tread to escape at grade reversal points (See *Trail Drainage*). Leaving small gaps between wall rocks will not likely drain water from the tread and may reduce the structural integrity of the wall.

Buttressed One-Rock Wall

If the single-rock wall proves to be unstable, gather more rock of proper size, remove the one-rock structure and start at a lower point where solid support is possible. Build a rock structure to buttress or support the single-rock wall needed for tread support (see *Multi-Course Rock Wall*).

Multi-Course Rock Wall

Among trail work enthusiasts, large rock walls built without mortar are the *grand dames* of trails. Although they are quite visible and not especially virtuous to those seeking a wilderness experience, when properly built, rock walls are handsome testaments to the trail builder’s skill.

Rock walls require a lot of hard work to build. They are among the most dangerous trail structures to build because they require handling large rock, often on steep hill sides. Multi-course rock wall construction must be led by trained and experienced trail workers.

Wall Design Principles

Rock walls built without mortar must slope (batter) into the hillside to allow gravity to assure stability. The steeper the cross slope the greater the batter. Volunteers for Outdoor Colorado recommends from 1:5 (horizontal run over vertical rise) for walls less than 24 inches high to as much as 1:3 for walls over four feet high. The largest rocks are used at the bottom to provide a solid footing and at the top (capstones) to help hold the entire structure in place and resist dislocation.

Though large rocks are hard to move and more dangerous to handle, they are preferred for stability. Using larger rocks means there are fewer rock interfaces to resolve. Smaller rocks may be used in between the bottom and capstone courses.[29]

Construction sequence:
(Figure 8 shows a cross-section view of a completed wall.)

1. Survey the terrain for resources, especially uphill. If resources are limited, determine the minimum size rock to be collected that will allow completion of the wall without an undo amount of time and energy spent gathering rock. The wall design may need to be adapted based on the available resources. For example, with only poor quality, modest-sized rock the batter may need to be increased.

   Fractured or blocky basalt, granite, and limestone are best. Irregularly shaped rocks may work as capstones or “tombstones” to help keep users off the wall.

2. The trench for the base course should be dug to accommodate specific rocks. Thus, base course trench excavation cannot proceed very far until the base course rocks are secured and lined out in

29 Many miles of trail tread in the Grand Canyon are supported by walls built with small rock. However, some of these have been in place for less than 70 years, so it is difficult to draw firm conclusions with respect to long-term stability.

the expected order.[30] The base course must slope in toward the hill, as illustrated in Figure 8. The base course is the most critical part of the wall. Get this right and the rest of the job will be much easier.

Water flowing down the face of the wall, whatever its source, may erode the base of the wall unless special measures are taken. Consider: a base course that projects beyond the face of the wall to absorb the impact of falling water; flat rock paving along the base; or, a rip rap apron set at the base course and into the ground so that it will not slide downhill.

3. Gather enough additional rock at any one time to complete at least the next wall course.

4. *The vertical joints of one course should not line up with those of the course above or below* but be offset a few inches.

5. Each rock must have *three points of contact* as it is added to the wall. A worker standing on a wall rock should not be able to move it by shifting her weight from side to side.

6. Both the *batter and an in-sloping top face must be preserved* as each course is added.

7. Small wedged shaped rocks (shims) may be placed on the inside, but not the exposed face, to close gaps and help retain backfill. *Shims cannot be used to support the weight of the wall because they will become loose*.

8. Back-fill as needed with small fitted angular rock first and then fine gravel. Add back-fill in thin layers and gently pack each layer with a mallet or tamping bar.

9. In a wall with more than three courses, long rocks (called headers or tie stones) laid perpendicular to the face of the wall are included for added stability. A large portion of these rocks are buried in the back-filled area behind the wall.

10. The top course of rock (capstone) is not part of tread. Nonetheless, it must be stable enough to carry the weight of a hiker and absorb occasional boot or hoof strikes without being dislodged.

11. Determine how water on the tread behind the wall will likely get off the tread. Make certain that it will not undermine the wall.

12. Pull out the whisk broom, dust off the loose dirt, and photograph yourself with your master piece!

30 Some trail builders fashion a template of each base course rock to guide trench excavation by wrapping the bottom and sides with chicken wire.

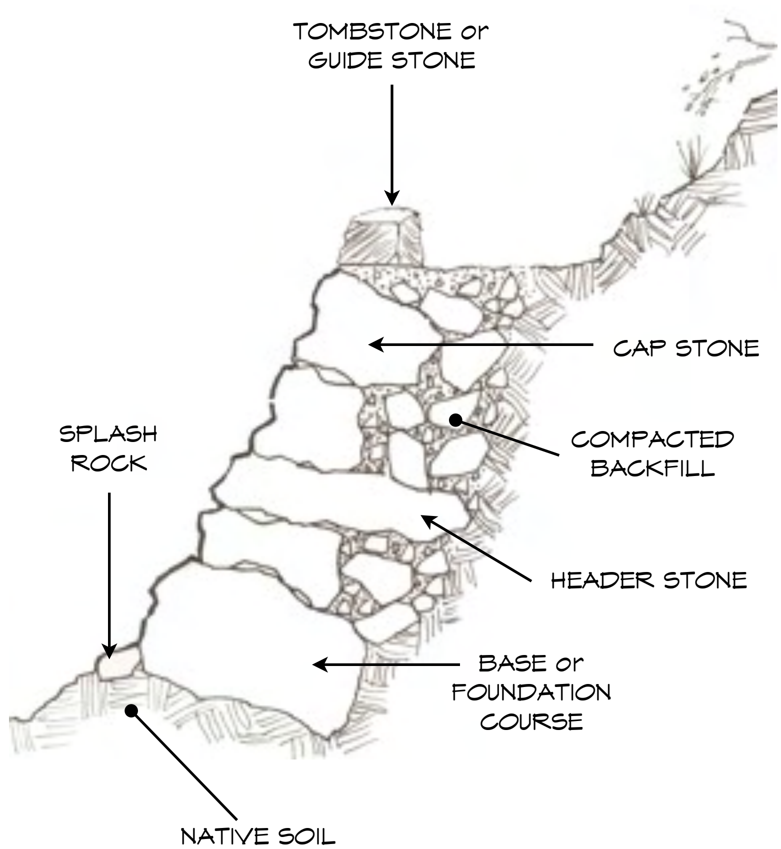


FIGURE 8. Cross-section View of Rock Wall

Rubble Wall

Walls that are built to support tread may take many different forms. Any configuration that will be stable in the particular place it is needed will do. Heavy rock placed in a contiguous, highly battered "assemblage" will tend to hold together as a unit and support a tread and even resist flood events in dry washes. The rock can be quite irregular but should be fit together rather than just tossed into place.

Armor

Armor is a rock facing *carefully* placed to stabilize a slope or a reach of tread surface.

Unstable Slope

Armor may be placed uphill of a tread where it is not possible or desirable to excavate the hillside to achieve a stable slope. Armor may used to help stabilize an area below a tread, where full wall treatment to support the tread is not needed. Armored faces need a stable footing to support the rock with which they are built.

Tread Surface

Tread at a shallow/low flow ephemeral crossing and tread that lies on sandy soil can be severely eroded by weather and use. One technique for hardening a reach of erodible tread is to pave it with large, stable flat rock that is closely fitted together (flagstone). This is usually the easiest method, provided the required paving material is available

Rip rap paving is built using smaller rock set in a way that it is not easily dislodged by trail users or runoff. Small reaches (about four feet of tread length) are bound with large, stable rock and the interior space is packed with smaller flat rock placed on edge as shown in Figure 9a. Soil is brushed across the finished surface to fill the crevasses.

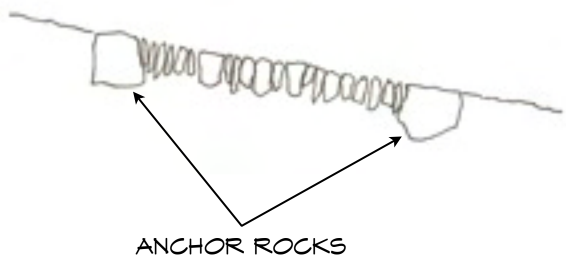


FIGURE 9a. Longitudinal Cross-section of the "Rip Rap" method of Tread Paving

“Stone pitching” is a heavier duty version of the same technique, as illustrated in Figure 9b, and has its roots in ancient road building. It is more commonly used in wet climates to deal with eroding, soggy trail conditions. It can be used in arid landscapes to pave a steep reach of tread that would otherwise trap water and erode. Heavy, stable bounding rocks are set along the down-tread edge of an area to be paved, and on the sides of the tread, if needed. Medium sized flat rock is “pitched” (set on edge) and fit closely together. The section is capped with heavy rock on the up-tread end of the section to hold everything in place. This can also provide the base for another section of stone pitching. Sections are usually four to five feet in length. An aggregate mixture is tamped in to fill the interstices.

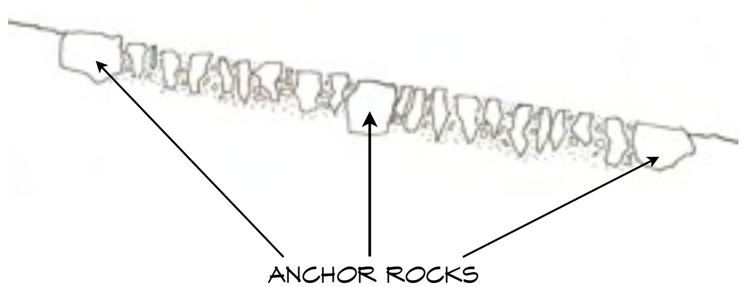


FIGURE 9b. Longitudinal Cross-section of the "Stone Pitching" method of Tread Paving

The slope on any of the larger flat rock faces to be walked on should be no more than five percent. There should be no normal steps - only very small rises between rocks. A guide line set along the entire run can help maintain the proper height and maintain a smooth slope to the final surface.

Tread Drainage[31]

Rain that lands on a side-hill tread and sheet flow entering a trail tread from the hillside above the trail tends to flow down the tread.[32]

A well planned reach of trail tread regularly reverses grade creating low points toward which water will flow. Water leaves the tread at these low points unless it has somehow managed to escape before that point. Water neither pools nor initiates a head-cut (erosion that works it way uphill) on well planned and constructed trails.

Tread that does not rapidly break down is the product of both sensitive layout and sound construction. Both involve consideration of soil characteristics[33] as well as other factors, such as the slope of the terrain on which a tread lies. Locating appropriate "grade reversal" points is a trail design task, although on-site adjustments may be appropriate.

In this guide, designs for introducing grade reversal are called "grade reversals" (surprise!). Designs for getting water off the tread at low points are simply referred to as the "outflow". This distinction is made because each grade reversal device may be combined with one or more different outflow configurations to achieve a good overall result.

Grade Reversals

Four grade reversal devices for limiting the distance water may travel along a tread (grade dip, drain dip, micro-dip, and swale) are described here. All are variations on the same simple idea: as you move downhill on a reach of trail with normal trail grade[34], allow the grade to increase - become steeper - for a distance, and then reverse the grade and climb until the tread returns to the trend line downhill.

Grade Dip

Shallow depressions or undulations form *naturally* on the land as a result of sheet erosion. Building a tread across a natural undulation in the terrain - though not necessarily straight across - inserts a grade reversal (*grade dip* or *rolling grade dip*) that will bring any water captured on the tread down the tread to the low point. As these are part of the design of a tread, there should be nothing to build other than standard tread. Getting the water off the tread at the bottom of a grade dip is addressed under the section *Outflow*.

Drain Dip

Undulations or grade reversals may be built into a tread where they do not naturally occur. The trail builder's label for these is *drain dip*. Trail planners look for any natural depression along a planned or existing tread that could facilitate outflow. This will be the bottom of the dip. Absent natural features to guide placement, drain dips may be inserted into any long run of trail that is likely to trap water.[35]

Figure 10 illustrates the introduction of grade reversals into a planned or existing tread. Looking at the top line in the Figure between points A and B, imagine you are standing on the other side of a valley looking across at a trail has either been laid out or built. The line between A and B is either a line of flags

---

31 Separating tread construction from tread drainage is convenient for this guide, but tread and drainage work is of one piece. Large sections of tread are also part of the tread drainage system and are built accordingly.

32 Water flowing within a drainage or wash, as opposed to hillside sheet flow, must never be diverted by a trail onto the tread.

33 See "What is 'arid land' and why does it require special trail work techniques?" at the beginning of this guide.

34 Usually this is less than eight percent over longer runs and less in highly erodible soils.

35 *Grade dips* and *drain dips* are terms introduced in the past that really have little relevance. You need dips (grade reversals) to drain water off tread. You can create them by artful trail placement on a naturally undulating landscape (grade dip) or you can introduce them just about anywhere (drain dip).

for a new trail or the edge of a tread that has been built. It is a perfectly straight line at constant grade. The planner must have used a transit to lay it out and took some rule about allowable grade too literally. Unless the soils in the area are highly compactable and the tread is sloped to send water to a berm-free outside edge, most of the water that accumulates on this tread is apt to make its way down to B as the normal hollowing out process gets under way. The dash-dot-dot line represents a fold in the land where water accumulates during rain events. Because the designer maintained constant grade even through this fold, water coming down that fold will be encouraged to turn an head down the trail.

On the lower part of the diagram, the alignment between A and B has been adjusted with thought of how to shed accumulating water. Four grade reversals have been introduced (marked by their outflow points), including one at the fold (grade dip). Under most arid land conditions this will greatly enhance the long term stability of the tread.

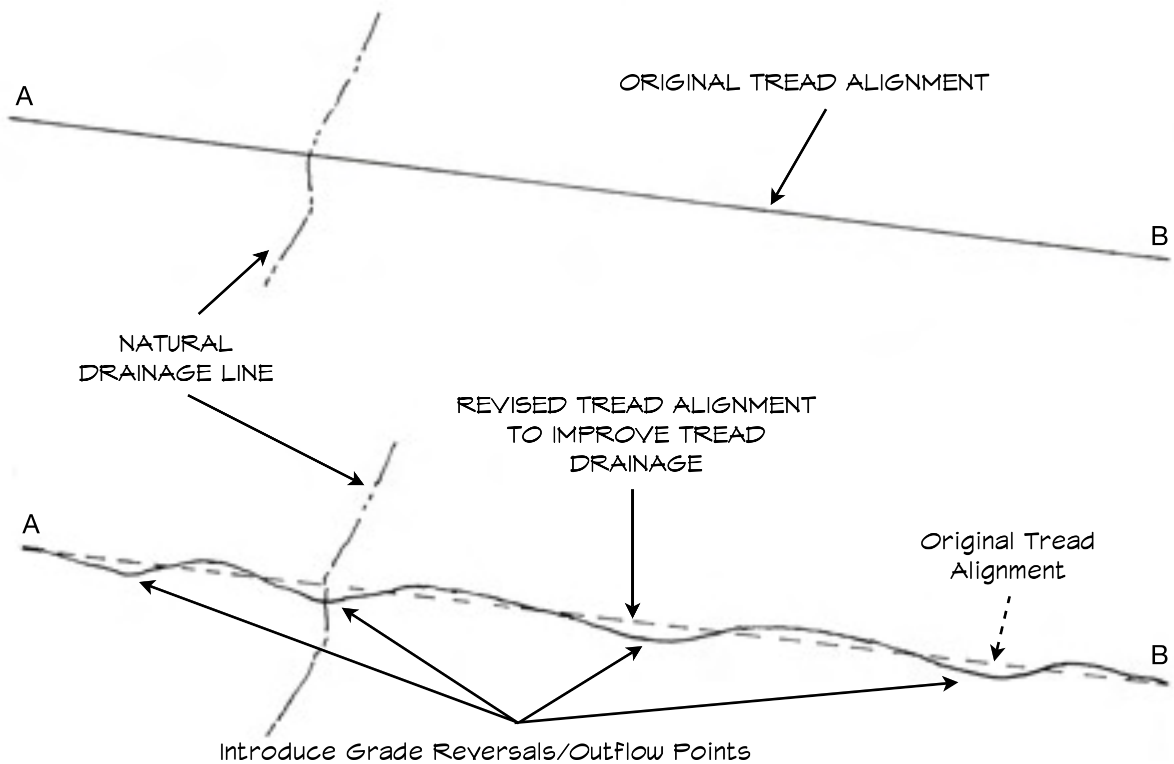


FIGURE 10. Schematic Illustration of Introduced Grade Reversals

How to add a drain dip or adjust an existing layout at the time of construction

If the tread is expected to transport much more water than it sheds directly across it, any given reach should look like a series of connected undulations or dips. Two questions to ask in the field: Do more dips (grade reversals) need to be added? Are existing and newly flagged dips pronounced enough to work? Any design tweaking should not take away from the quality of the trail experience. Undulations can add interest to a trail, but they can be over done.

There are no established metrics for calibrating the ideal number of grade reversals. Look for natural dips that have not been considered; if necessary, add more low points based on the distance between those already marked. The tread leading down to the low point should not exceed the maximum allowable trail grade for the area, except for a short distance.

Very shallow drain dips can break down in several ways. Trail user traffic may hollow out the tread on a downward trending trail to a point where the outflow of a grade reversal is bypassed. Each drain dip must drop far enough downhill to prevent water from continuing any further down the tread. Depositing of soil on the tread's low point, as water enters the low point and looses speed, exacerbates this problem. The ramp climbing out of the low point, though short, will be relatively steep and thus subject to heavier user impacts. Harden the ramp, preferably with a single large tread-wide rock, at the place where it blends back into the existing tread. If it is necessary to build a tread-wide berm or mound to prevent water from passing through and beyond a low point, it must be hardened as shown in Figure 12.

Micro-dip
In the section on Soil Assessment (see *Tread Construction and Maintenance*) the idea of a "micro-dip" was introduced. Where soils are reasonably compactable, any small undulation in the surface that allows for a slightly exaggerated tread out-slope over a short distance (18 to 24 inches) can be an opportunity to shed some accumulated water.

Swale
A swale is a grade reversal appropriate for low points along a tread that is itself on a very low slope. Because water will not easily drain from such places the outflow opening is extra wide - several feet. A swale in an area with weak soils will tend to clog as flow slows and transported soil is deposited. Hardening some or all of the tread along the opening and down into the drain itself may help, but can be a major undertaking.

What about waterbars?
The waterbar is a legacy device consisting of a rock or log barrier set diagonally across a tread in order to "bar" water from traveling down the tread. An outflow device (drain) is added to carry water off of the tread. Waterbars are a form of grade reversal, but their function can generally be better handled by a dip. Waterbars are hard to build correctly and trail users do not like having to cross over obstacles placed diagonally across the tread. Attempts to build a smooth ramp up and over the rock or log spine are frustrated in many locations because use and weathering wear such ramps away.

Outflow

As water flowing down a tread arrives at the low point or bottom of a grade reversal it needs to quickly exit the trail. If the tread is on the side of a hill, water will naturally tend to leave the tread at any low point. Even where this will occur, there still may be problems if the flow downhill, below the tread, initiates erosion.

Soil characteristics are a primary determinant of what is needed to get water off the tread at a low point. Outflow problems are least likely to occur where a tread is built on soils that compact well. For one thing, some water will leave the tread before it arrives at a low point. Tread on soils that do not compact well are most vulnerable to outflow problems.

Three different ways in which things may go wrong at the outflow and possible solutions are listed below in order of likely occurrence.

1. *Tread hollowing out is deep enough to break through the uphill ramp leading out of the low point, which sends water further along rather than off the trail.* There is no outflow. This failure may also reflect poor layout. The grade coming into and leaving the low point is too shallow.

   Apply one or more of these solutions:

a. Lower the outflow point. That is, drop the line of the tread down hill to create a taller ramp leaving the low point.
b. Increase the slope from the inside edge to the outside edge of the tread at the outflow to speed flow and flush out sediment.
c. Harden the tread at the top of the uphill ramp beyond the low point with a single heavy tread-wide rock.
d. Harden the full tread leading into and off the tread at the bottom of the grade reversal. Tread hardening is discussed below.

Figure 11 illustrates the introduction of a hardened tread in the uphill ramp (solution c) and the bottom of a grade reversal (solution d) built in non-compactable soil. The solid line is the edge of the tread and the dashed line is the center of the trail users dominant travel line, which has dropped because of severe hollowing out. In the top part of the figure, hollowing out has proceeded to the point where water traveling down the tread will start continuing past the low or outflow point. While the hardening features should enable water to get off the tread at the outflow, some of this additional work might have been unnecessary if the vertical distance between the low point and the top of the uphill ramp were greater.

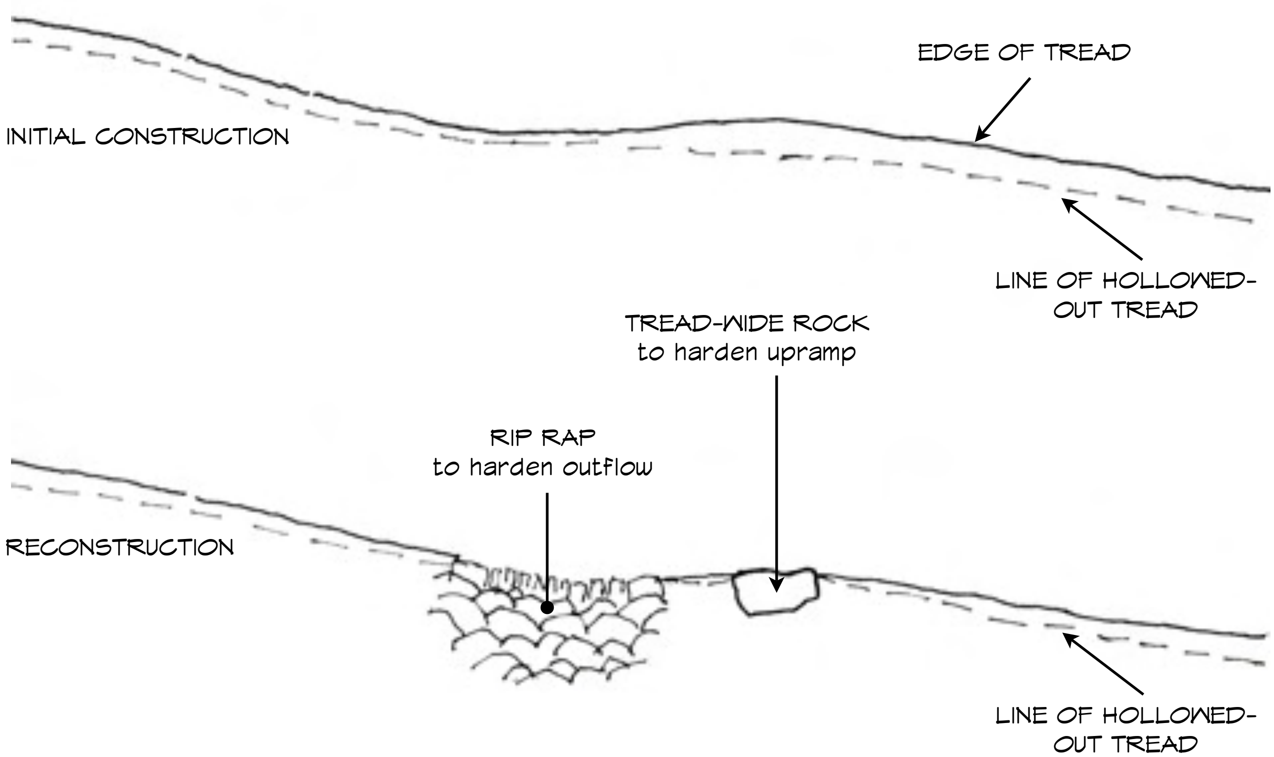


FIGURE 11. Profile View of the Reconstruction of a Hardened Tread

2. *Sediment builds and water pools at the low point. If and when water finally moves off the tread, it does so in the "wrong" place.* This problem is greatest for grade reversals on low sloping hill sides. Sediment-loaded flow slows as it reaches a low point and sediment settles. A berm or dyke may form, trapping water behind it. At some point water breaks through the sediment dyke and finds its way down hill. Tread hollowing also contributes to the formation of a sediment dyke and can yield essentially the same result on its own - the level of the tread drops too low to

preserve a planned line of flow off of the tread. In arid regions, trapped water itself may not be much of an issue, unless it remains long enough to drive traffic off trail.

Apply one or both of these solutions:

a. Increase the slope from the inside edge to the outside edge of the low point (bottom of the grade reversal). If the slope of the hill is too shallow this may not be possible without some significant excavation downhill from the tread.
b. Harden or armor the full tread leading into, through, and out of the low points to allow runoff from significant rain events to flush out sediment. (See below for additional guidance on hardening outflow areas.)

3. *Water flowing off the tread initiates erosion below the tread that may work its way back into the tread*. While the first two problems are significant only where the tread can be expected to transport significant flows, erosion is a potential problem even where the volume of water is likely to be modest if soils are easily eroded (predominantly clay).

   Apply both of theses solutions:

   a. Make certain that problems #1 and #2 will not occur. Water must leave the tread at the intended spot.
   b. Add an un-erodible area of rock armor below the tread.[36]

An outflow configuration is shown in Figure 12.

Hardening a tread surface to capture water is tricky. In soils that compact well, hardening may be achieved by compacting the native soil and adding in additional small rock to increase the resilience of the surface. The edge of tread hardened in this manner may need a one-rock wall to keep the edge from breaking down. As soils become harder to compact, large flat rocks, rip rap, or stone pitching may be used to form the surface.

Hardening a tread surface can backfire if it fails to keep water on the hardened surface until it reaches a non-erodible outflow point. The goal of hardening tread through the bottom of a grade reversal is for water to flow onto the hardened surface and pick up a little speed as it and the material it is transporting move off the tread.

The place where hardened tread surface ends and native tread surface resumes is potentially vulnerable. Over time, water flowing down the tread toward the low point (outflow) will likely start to erode the soil side of this junction. If the line of the junction slopes toward the inside edge of the tread, water will be forced onto the hardened surface where it will proceed down to the outflow. This is illustrated in Figure 12. However, if water is allowed to flow toward the outside edge of the tread, it may find an unprotected exit above the outflow and initiate a head cut that can work its way back onto the tread.

In arid landscapes, concentrating flow in order to flush the outflow point will erode the area below the tread where it is directed unless the force of the flow can be dissipated. Dense plant and grasses may provide the necessary roughness. An area of rip rap or rubble that is wide enough and shaped to contain the maximum possible flow will also work.

What to do when the outflow point dumps water onto a steep slope.
If a dip directs water onto a steep slope with little grass or other vegetation, erosion may result and the outflow point and the tread could eventually be undermined. Find a place down hill where the grade flattens and a broad stable dispersing apron of rock can be laid in. Above that, armor a broad area of the

36 Dips are usually built with a rock outflow structure. In erosive soils these become a barrier to outflow as hollowing out lowers the tread line to below the top of the rock outflow structure. In such circumstances, the drainage structure must be extended across the full width of the tread.

steep slope for the water to run over. The rock facing must be broad enough and shaped to contain all of the water coming off the tread, as illustrated in Figure 12. If significant flow makes its way off to the edge of the rock facing, erosion and collapse of the structure leading all the way back onto the tread may occur.

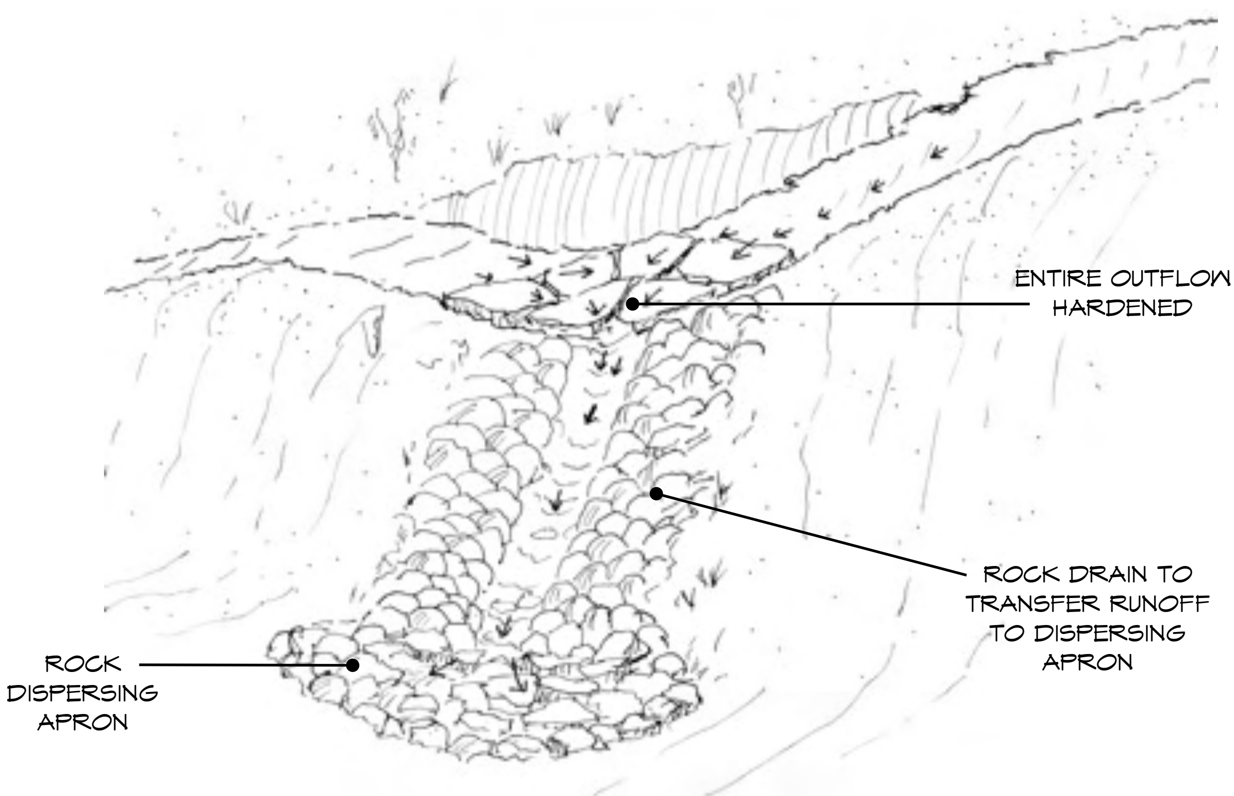


FIGURE 12. Grade Reversal (Drain Dip) with Extensive Hardening

Drainages

Intermittent and ephemeral streams[37] often play a major role in determining where a trail will be placed. Many are deeply incised and their banks are steep and unstable. Trail planners look for manageable crossing points.

Crossings

A drainage crossing should lie perpendicular to the line of flow. The approach - where the tread drops into the drainage - should not exceed the maximum acceptable tread grade, which usually means that the approaches to crossings should not be perpendicular to the flow. A line of approach into a drainage bottom heading up drainage makes it easier to maintain a gentle trail grade than an approach heading down drainage. However, care must be taken that this does not allow high volume flows to follow or undermine the tread.

If the actual channel crossing requires shaping to provide a stable and comfortable path across, study the size of the area drained and the gradient (slope) of the channel to gain some idea of the power of flow through the area during a major rain event. Look for high water marks like debris in trees and shrubs. Because it is hard to accurately predict how much water might flow though a given drainage and easy to underestimate its power, over-building crossing tread support is prudent. Do as little as possible to redirect the pattern of established flow, as this may result in unintended and undesirable outcomes.

If the tread within a crossing needs to be raised to provide a good tread surface, pave the tread area with of large stable flat rocks. Place the largest tread surface rocks along the down drainage edge. Fit rocks closely together as this will strengthen the entire configuration and enable it to resist the force of heavy water flow. A crossing paved with large solid rocks is preferred to back filling a one-rock dam. Cobble back fill is not good for horses. Gravel back fill is apt to be scoured out by heavy flow events.

A spillway on the down stream side of the tread structure should be built with heavy rubble to form a gently sloping apron down to the natural stream bed. This rock should be two to three times the size of rock likely to be transported through the channel by flood events. An idea of the appropriate size may be obtained by looking at that largest rocks lying in the channel. Channel flow can be assumed to carry material at least that size.

Stabilization

Indigenous inhabitants of Southwestern U.S. and Northern Mexico used a variety of rock structures in arid landscapes to capture and retain runoff and protect and nourish agricultural plots. This type of practice has been used by subsequent settlers for these purposes and in attempts to control erosion. During the depression, the Civilian Conservation Corps blanked many areas of the Southwest with “check dams”. Check dams are typically one or two courses of large rock placed at the bottom of drainages that experience ephemeral or episodic flow. One reason for doing this was that overgrazing stripped many of these landscapes of native grasses and their ability to resist the erosive power of rainfall and rapid runoff. These days when one comes across these check dams they have often lost their utility. Sometimes, they have simply been blown out. A single row of rock provides limited resistance to the force of a flash flood event. If a check dam is not blown out, it can fail in another way.

---

37 Intermittent streams flow during wet seasons though sub-surface flow may be perennial. Flow in intermittent streams is often sub-surface flow forced to the surface by bed rock. Ephemeral streams flow only during major rain events—flash floods. Perennial (always flowing) streams are less common in arid lands. Most perennial streams in arid lands have relatively low base flow and present minor problems to trail users. Stream crossings are difficult to improve using only hand tools and native materials. Stepping rocks are bound to be relocated in a stream subjected to flash floods. Trail manuals published by the Student Conservation Association and the Appalachian Trail Association cover perennial stream crossings in depth. The word “drainage” is used in this guide because it sounds strange to call a channel that rarely flows, a “stream.”

Small rock and soil carried down a drainage following a rain event accumulate at check dams. Sometimes these dams fill with sediment after a single rain storm. Additional flows will then start to go around one or both ends of the dam, and proceed to down-cut. The result is a wider erosion channel with a curious looking rock island setting in the middle.

There are alternatives to check dams. One developed by Bill Zeedyk of New Mexico is called a "one-rock dam" (not to be confused with the one-rock wall previously described). This structure, illustrated in Figure 13, consists of a rectangular "blanket" of rock spanning the drainage that is wide enough to contain the largest possible flow. The rock is fit closely together, not just tossed onto the ground. In drainages with heavy flow, keying in (partially burying) the line of rock at the lower end of the dam can prevent that line from being peeled off, which could cause the entire structure to wash away. As with a crossing structure, this rock blanket tends to work as a structural unit - the whole is stronger than the sum of its parts, see Figure 13. One rock dams can stop down cutting and might be added above or below a trail drainage crossing to protect the crossing.

Additionally, one-rock dams are used by Restorationists because they foster plant recruitment and may even contribute to ground water recharge. A one-rock dam preserves moisture near the surface longer, as compared to bare soil. As small amounts of silt and seeds are deposited between the rocks, plant and grass regeneration is fostered by these higher amounts of moisture. Plants growing up between the rocks have some protection from scouring out while they establish their roots. As plant life rebounds, it provides roughness to further slow water as it flows across the dam, which in turn fosters infiltration that feeds plant life and, possibly, the water table.

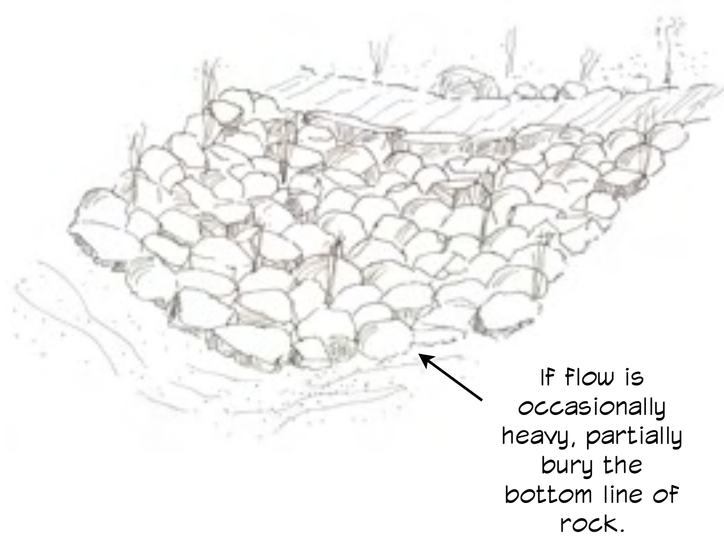


FIGURE 13. One-Rock Dam Below Shallow Drainage Crossing

Way Markers

The trail tread is the primary way marker for trail users. It may need to be augmented with signs and devices built of on-site native materials where tread location may not be that obvious. For example, in relatively flat areas with limited vegetation an infrequently used trail may blend back into its surroundings.

Guide Stones

Guide stones can be used to help trail users stay on a tread where tread location may become ambiguous. Guide stones may also be used to deter tread widening by pushing users away from the edge of a tread or otherwise containing trail traffic.

Guide stones should be:

1. About twelve inches in diameter or larger.
2. Partially buried with the weathered side up. About one-third of the stone should be below grade.
3. Placed on only *one* side of the tread, if this will do the job, and unevenly spaced to provide a more natural appearance.
4. Placed just outside, not within the tread.
5. Visible from both directions.

Guide stones should be obvious but not so overwhelmingly that they take away from the trail experience. Small stones lining the edge of a tread are not guide stones.

Cairn

A cairn is a rock cone built without mortar. It is not easy to build a cairn that will last. For this reason and because they are so unnatural looking, guide stones are preferred.

Cairns are sometimes the only practical way markers at wide drainage crossings where exit points may be difficult to see from the opposite bank. Cairn size and placement at drainage crossings must take into consideration the likelihood of high water flow. Building cairns within washes is not worth the effort. Cairns are sometimes used in areas where snowfall may periodically cover tread.

When building a cairn, use the largest available stones to build a cone at least two feet in diameter at its base and two feet tall. Each rock should have three points of contact with the rocks on which it rests. Lean each rock toward the center of the structure for added stability. It is often hard to find the rock needed to build to this specification; but, the goal is a stable attractive structure.

Trail Closure and Landscape Rehabilitation

Closing social and retired trails involves blocking physical access and masking old routes from trail users, especially those who used these trails in the past. Rehabilitation of a landscape through which a closed trail has once passed contributes to the closure effort, but is primarily concerned with long term recovery of the land and control of any erosion associated with a closed trail.

Physical closure of a trail

1. Determine the objectives with respect to rehabilitation and mark the work area. If an entire trail (or road that may have served as a trail) is to be rehabilitated then the intersections with legitimate trails bound the work area. But, it may be that only the reaches visible to users of the legitimate trail are of concern. View the area from the legitimate trail while approaching from each direction to determine where users of the closed trail might venture.

2. Break down the old tread. Loosen (scarify) compacted tread soil with the hoe end of a mattock or Pulaski to a depth of a few inches. Don't turn the soil over. Pull loose soil and rock from the uphill side down onto the old tread.

3. If the old tread is rutted and will carry water onto the new tread or cause erosion, create dips that will safely drain the old tread.

4. Add barrier plants. Catclaw and New Mexico locust are good choices, but should not be planted so close to legitimate trail that they become a maintenance problem. The hoe end of a Pulaski is a good tool for grubbing and replanting barrier vegetation. Prune stems to six inches before digging. This allows plants to devote their energy to setting new roots rather than supporting top side growth. Trim roots beyond the ball. Set the plants in sunlight, if possible, and in patterns designed to achieve maximum coverage. Each plant should set in a small basin shaped to trap water. Press the soil down firmly after the plant is inserted. Water plantings if possible

   During rainy seasons, cholla balls and prickly pear pads can regenerate when placed in contact with the soil in a small water-retaining depression. Prickly pear pads should be allowed to sit exposed to air for 2-24 hours before replanting. If not and there is rainfall soon after transplanting, they may absorb more moisture than they can handle. Scoop out the surface to retain rainfall at the contact point.

5. Place limbs and small branches on an old tread after it is scarified. This creates a micro environment in which seeds may sprout and plants gain a foothold.

6. The final closure task is to create barriers within the area that needs to be blocked. Place large loose rock on the old tread and cover it with small branches and duff. Use large logs and tree branches to block access. It should not be possible to see what looks like a passable trail from anywhere on the legitimate trail. While a natural looking impenetrable barrier is ideal, go for obstruction over aesthetics if a choice must be made. If it works, users will accept the new route and any ugliness should fade over time.

Rehabilitation of desert landscapes is difficult. Bringing the terrain back to a prior "undisturbed" condition may not be practical. Desert shrubs are usually impossible to transplant because they need watering for up to a year. Don't attempt to transplant acacia, mesquite, and ironwood. These trees depend on taproots, which are usually at least double the height of the tree. Fortunately, many desert trees generated from seeds that are already present will grow fairly rapidly. Cactus may be successfully transplanted as long as you preserve the original orientation to the sun.

GLOSSARY

The terms included here are used in this publication or widely used by trail work junkies. Most of the terms in the table of contents have not been included.

Back slope Area immediately uphill from a tread.

Bark collar Bulge on the bottom side of the junction of a tree branch with the trunk that protects the tree from invasive microorganisms and insects entering the trunk from a damaged limb.

Base stem Stems emerging from the root ball of a shrub.

Berm A linear rise of the terrain that forms a barrier to water.

Borrow pit A place out of view of a trail where fill material required during trail construction and maintenance is obtained; barrow pits are closed once trail work is completed.

Branch point Where a new branch of shrub or tree emerges from an existing branch (not a base stem or trunk).

Check dam Narrow rock structure built across a shallow drainage to retain moisture and sediment.

Contouring Building along the natural contours with only modest changes in elevation.

Corridor An envelope (cross sectional area above a trail tread) sufficiently cleared of vegetation to permit unobstructed movement and good sight lines through turns.

Daylight edge flagging Practice of marking the alignment of a new tread along its downhill or outside edge so that flagging may remain in place and visible ("in daylight") throughout construction.

Duff Organic matter (leaves, twigs, pine needles) found on the surface at elevations where dense vegetation is present.

Fall line Imaginary line described by the unimpeded path water takes moving down a slope--the steepest part of any slope.

Full bench tread construction Tread built by removing soil for the full width of the tread placing the finished tread on largely undisturbed soil.

Grade Vertical distance of ascent or descent of the trail expressed as a percentage of the horizontal distance, commonly measured as a ratio of rise to run.

Grade reversal Change in the vertical direction (grade) of a tread/trail. At grade reversals where downhill direction reverses and the tread/trail moves uphill water can be drawn off the tread. Also called "grade dip", "drain dip", "micro dip", "swale" or "waterbar".

Haircut The result of cutting straight through shrub growth that intrudes into a trail corridor rather than selectively trimming to preserve a natural plant profile.

Hat rack An improperly cut branch that is long enough to hang a hat on. This type of pruning can promote infection.

Hollowing out Combination of user traffic and water, resulting in the formation of a channel or trench (hollowing out) within the tread. Also called “cupping”.

Outflow Bottom of a grade reversal where water may be drained off of a tread.

Outslope Slope of the tread from its inside or uphill edge to the outside or downhill edge.

Sheet flow Rainfall on a slope that spreads and flows downhill in a thin sheet.

Slough Soil, rock, and plant debris that inevitably gathers along the uphill edge of a tread.

Social trail Trail created by users as opposed to those designed and built for use. Also called a “wildcat,” “bootleg,” or a “trail of use.”

Trail Entire set of trail elements—tread, trailway, corridor, other accoutrements, and aesthetic features.

Trail (or tread) “creep” Common process of tread breakdown where users favor the outside edge of the tread and wear in an increasingly wider tread. Slough, waterbars, weak soils at the outside edge, and low areas that trap water on the tread may all contribute to trail creep.

Tread Surface that trail users travel on.

BIBLIOGRAPHY

Austin, Steve, Ed Benson, et al. *Crew Leader Manual*, Fifth Edition. Denver, CO: Volunteers for Outdoor Colorado 2002.

Birchard, William, Jr. and Robert Proudman. A*ppalachian Trail Design, Construction and Maintenance*, Second Edition. Harpers Ferry, WV: Appalachian Tread Conference 2000, p. 229.

Birkey, Robert C. *Lightly on the Land: The SCA Trail-Building and Maintenance Manua*l, Second Edition. Seattle, WA: Student Conservation Association, Inc. 1996, p. 272.

Hesselbarth, Woody, Brian Vachowski and Mary Ann Davies. *Trail Construction and Maintenance Notebook*, 2007 Edition. Tech. Rep. 0023-2839-MTDC-P. U.S. Department of Agriculture, Forest Service, Missoula Technology & Development Center 2007, p. 139. On-line edition: http://www.fhwa.dot.gov/environment/fspubs/07232806

Parker, Try Scott. *Natural Surface Trails by Design: Physical and Human Design Essentials of Sustainable, Enjoyable Treads* 2004, p. 78.

The Complete Guide to Trail Building and Maintenance, Fourth Edition. Boston, MA: Appalachian Mountain Club Books 2008, p. 256.

Trail Solutions: IMBA's Guide to Building Sweet Singletrack. Boulder, CO: International Mountain Bike Association 2004, p. 274.

Treads and Wildlife Task Force, Colorado State Parks. *Planning Trails with Wildlife in Mind: A Handbook for Tread Planners.* Denver, CO: Hellmund Associates 1998, p. 54.

INTERNET RESOURCES

Due to the dynamic nature of the web, the validity of URL listings such as these may lapse over time.

American Trails
Design & Construction
http://www.americantrails.org/resources/trailbuilding
Tools
http://www.americantrails.org/resources/info/tools
The tools needed for various tread work tasks, if not self-evident, are identified near the beginning of sections.

Hancock, Jan,et al **Equestrian Design Guidebook for Trails, Trailheads and Campgrounds**. Federal Highway Administration, U.S. Department of Transportation, Recreational Trails Program
http://www.fhwa.dot.gov/environment/fspubs/07232816

International Mountain Bike Association
Trailbuilding and Maintenance
http://www.imba.com/trailsolutions

National Trails Training Partnership
http://nttp.net

NOTES

THE JOY OF TRAIL WORK
A Field Guide for Trails in Arid Lands
brought to you by
Volunteers for Outdoor Arizona
made possible by Recreational Equipment Inc and Arizona State Parks