APPENDIX D: SUSTAINABLE TRAIL DESIGN

Sustainable Trail Construction

Sustainable trails are defined by the US Forest Service as trails having a tread that will not be easily eroded by water and use, will not affect water quality or the natural ecosystem, meet the needs of the intended users and provide a positive user experience, and that do no harm to the natural environment.

Sustainable trails can be used by a variety of non-motorized users including hikers, trail runners, equestrians, off-road cyclists, and cross-country skiers. Motorized vehicles are normally prohibited unless operated by trail crews or a land manager.

Prior to constructing a new trail, need for the trail should be determined based on condition and routes of existing trails. Surveys should be conducted of trail users to determine user expectations and rudimentary design guidelines.

Natural surface trails are dynamic systems that are constantly being re-shaped by a complex set of human-caused and natural forces. To be sustainable, trails must strike a balance between multiple elements. Type of use, amount of use and user behavior combine with natural factors to determine trails impacts and long-term sustainability.
The following design guidelines can be adapted to specific site conditions including soil texture, slope, topographic position, existing vegetation, etc.
The guidelines are most useful for the planning and construction of new trails, but can also be useful for restoration and reconstruction of existing trails.

A. Width
Natural surface trails are usually a "singletrack" trail, with a tread width is typically 12"-36" . Trails are designed for users to travel single file. Overall clearing limits will be roughly three times the width of the tread, and the trail way will be roughly twice the width of the tread. Singletrack clearing limits are typically 6 feet wide and 8 feet high.

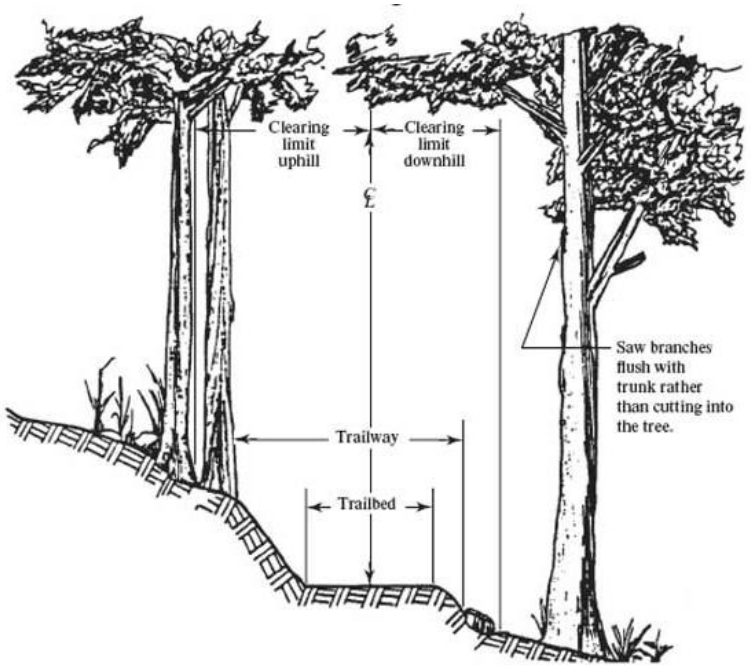
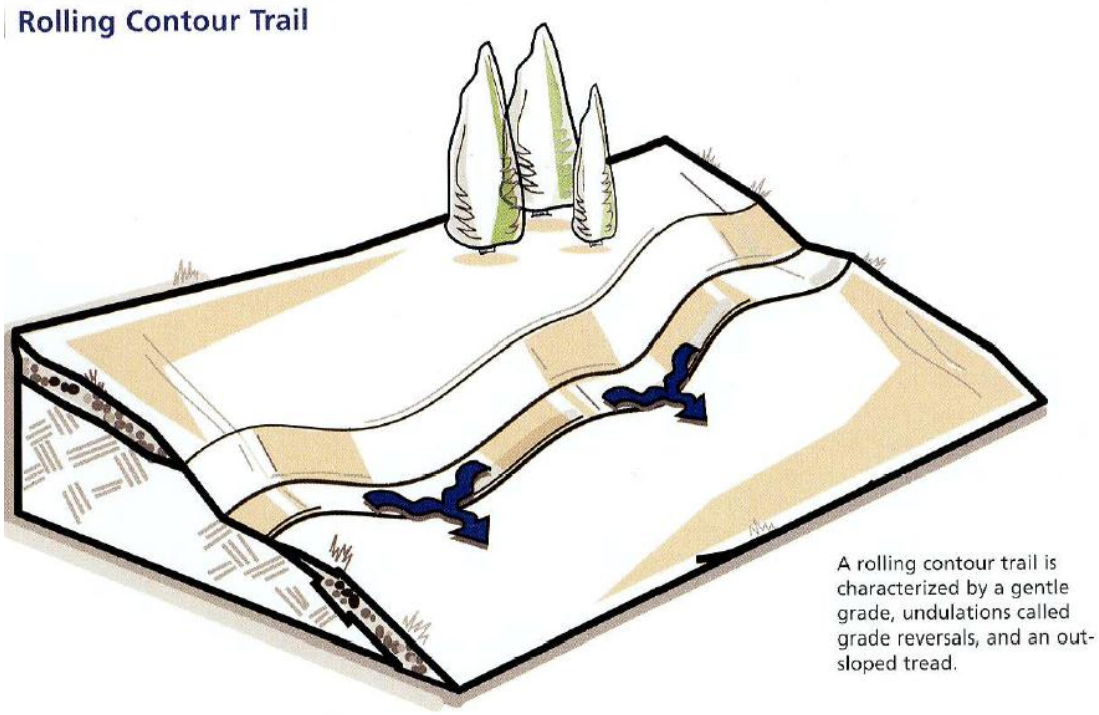


Image from "Trail Construction and Maintenance Notebook: 2007 Edition"

B. Rolling Contour Trails

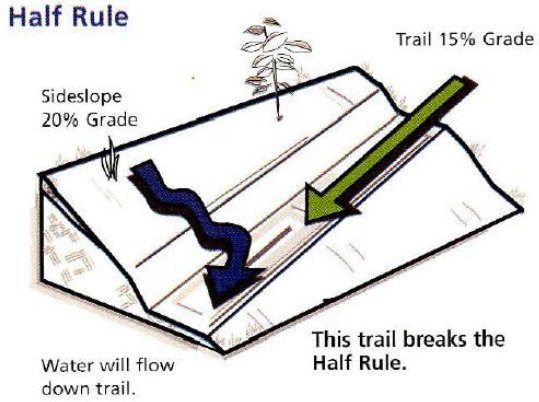
Build paths to traverse hills cross-slope, characterized by a gentle grade and utilizing grade reversals and an outsloped tread. Trails should avoid following fall lines at all costs, and should always be constructed on at least a slight slope to allow for drainage.



C. Elements of Sustainable Trails

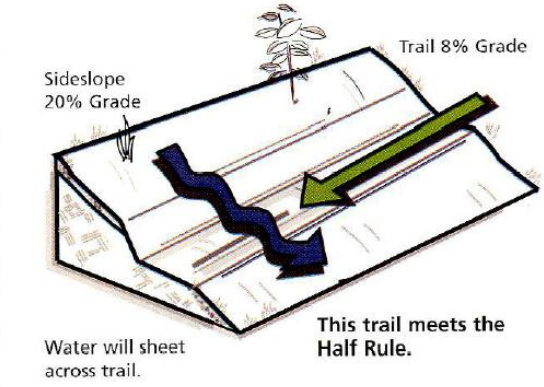
1. The Half Rule

Trail grade should never exceed half the grade of the hillside the trail traverses. Trails that exceed half the sideslope are considered fall line trails and funnel water, destroying the trail and causing greatly increased erosion.



2. The Ten Percent Average Guideline

Trail grade should average 10 percent or less for the length of the trail. Average grade should be calculated by dividing total elevation gain by total length, multiplied by 100. For trail conditions without sustained



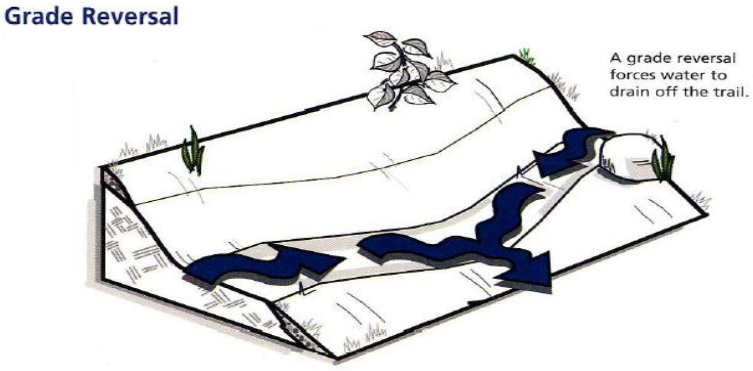
elevation gain, average trail-segment grades should be calculated in areas where the trail climbs. An average 10 percent slope will allow for a stable, erosion free slope for most soil types caused by both water and users.

3. Maximum Sustainable Trail Grades
Maximum grades are considered to be the steepest section trail 10 feet or more in length. Maximum grades varies depending on the following factors:

a. The grade of the existing sideslope
b. Existing soil type
c. Existing solid rock
d. Annual rainfall amount
e. Liberal use of grade reversals
f. User groups / numbers
g. Designed difficulty

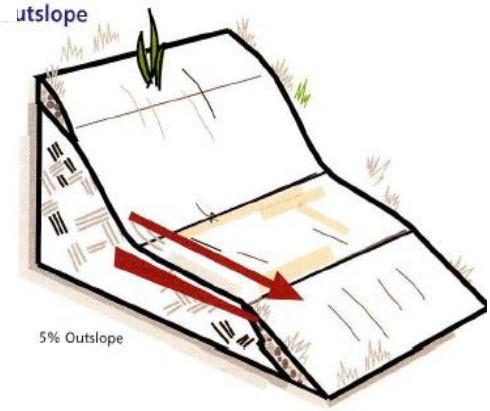
4. Grade Reversals

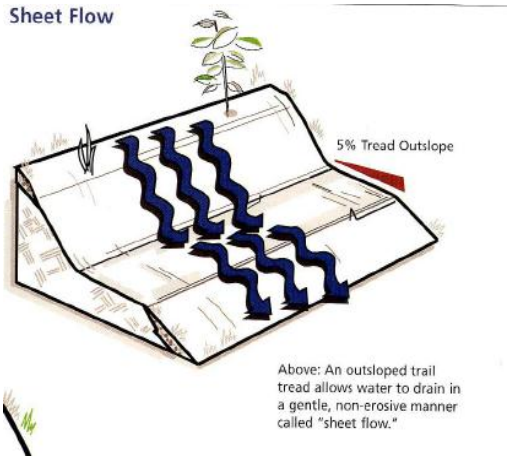
Grades reversals are areas of a climbing trail levels, changes directions, drops slightly down slope for 10-50 linear feet, and rises again. Grade reversals should be used on any trail climbing or traversing a sideslope, and should occur on average every 20-50 feet.

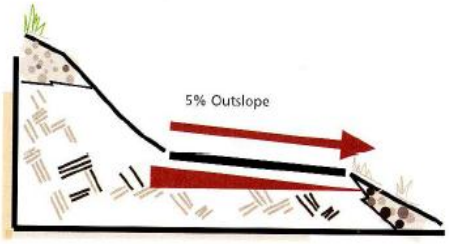


5.Outslope

Trails that traverse or climb a sideslope should always be graded so that the tread slopes slightly down and away from the high side of the slope. Creating an outslope will allow water to sheet flow across the trail and down the slope rather than funneling and creating ruts. A 5-percent cross slope is considered best when grading an outslope. If the soil type is loose where the trail is constructed, numerous grade reversals will be necessary to avoid erosion and maintain the tread and outslope.

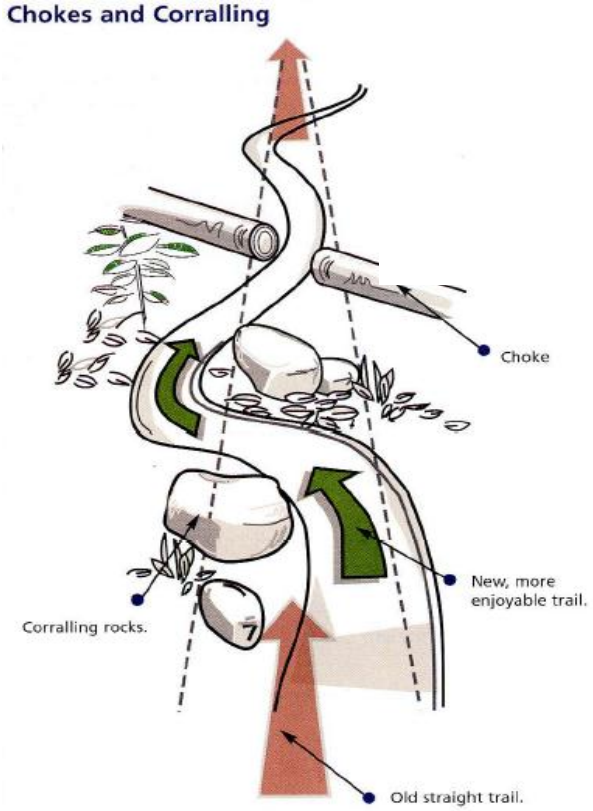






D. Design Speed

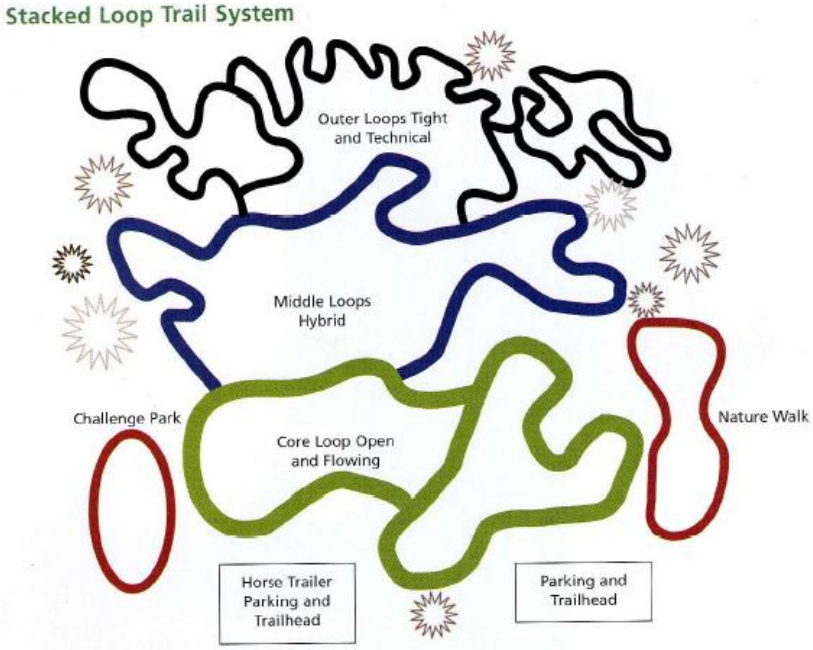
Managing user speed on trails designed for mountain bikers is best done with design elements. Trails which are constructed with many turns and grade changes will allow users to feel that they are moving faster than they are. Large, concrete objects should be used to define trail edges and turns; often boulders, logs, and plants work best. Objects should serve as both physical and visual barriers. Chokes should be created when the trail is approaching a point where users will need to slow down; examples include intersections, stream crossings, or merging trails. Chokes are points in the trail where the tread narrows to force reductions in speed. These areas should appear to be natural and well defined to avoid users defining their own paths.



E. Trail System

Unless designing a single-user trail system, a system of looped trails should be designed to accommodate a variety of users. Main entry trails should be smooth and wide to appeal to all users, and provide either a standalone loop for beginners or a jump-off point for more advanced users. These primary trails may have a gravel surface to provide for accessibility and wet-weather use. Designing a trail system with multiple trailheads also allows for better control of user-conflicts and spreads traffic more evenly over a trail system. Restricting challenging trails to secluded and more difficult terrain will please all site users. Maintaining turns and choke points along all trails will continue to control speed and cut down further on potential user-conflicts.

Stacked Loop Trail System



F. Bench Cut Trails

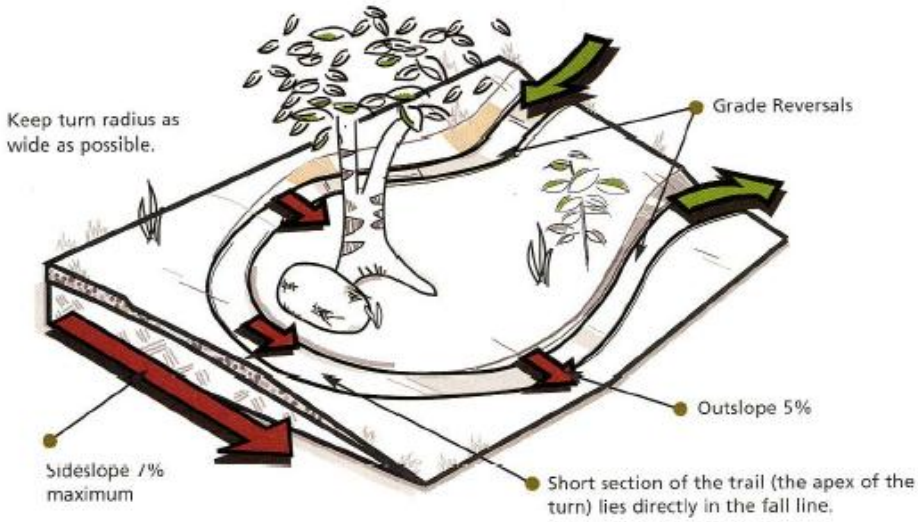
To create a durable and sustainable tread, creating a full bench trail is the most recommended option. The entire trail surface is compacted, native mineral soil with rounded and compacted backslope and downslope fill. Partial bench cut treads are a second option but should only be constructed as a last resort, as half of the tread is compacted fill, which does erodes easily over time and often fails to compact. Partial bench treads are not considered to be a form of sustainable trail construction.

G. Turns

1. Climbing Turns

To be used on sideslopes of 7 percent or less as the trail will briefly follow the fall line, increasing the chance for erosion. Design the turning radius with a minimum width of 20 feet with natural barriers placed on the inside of the trail curve to control users speed and keep them on trail. Construct grade reversals above and below the curve to minimize water flow on the fall line. Construction of a choke point on the high side of the curve will also lessen user-wear erosion by reducing user speed on the curve.

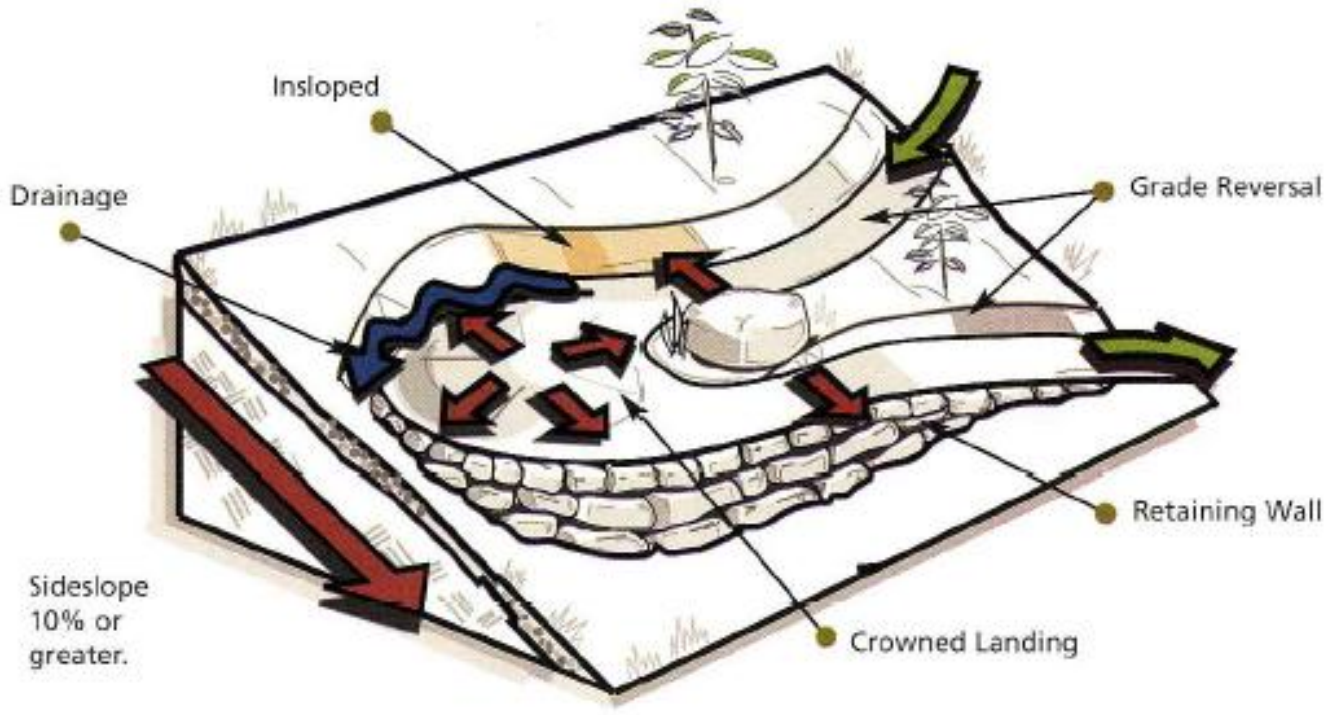
Climbing Turn



2. Switchbacks

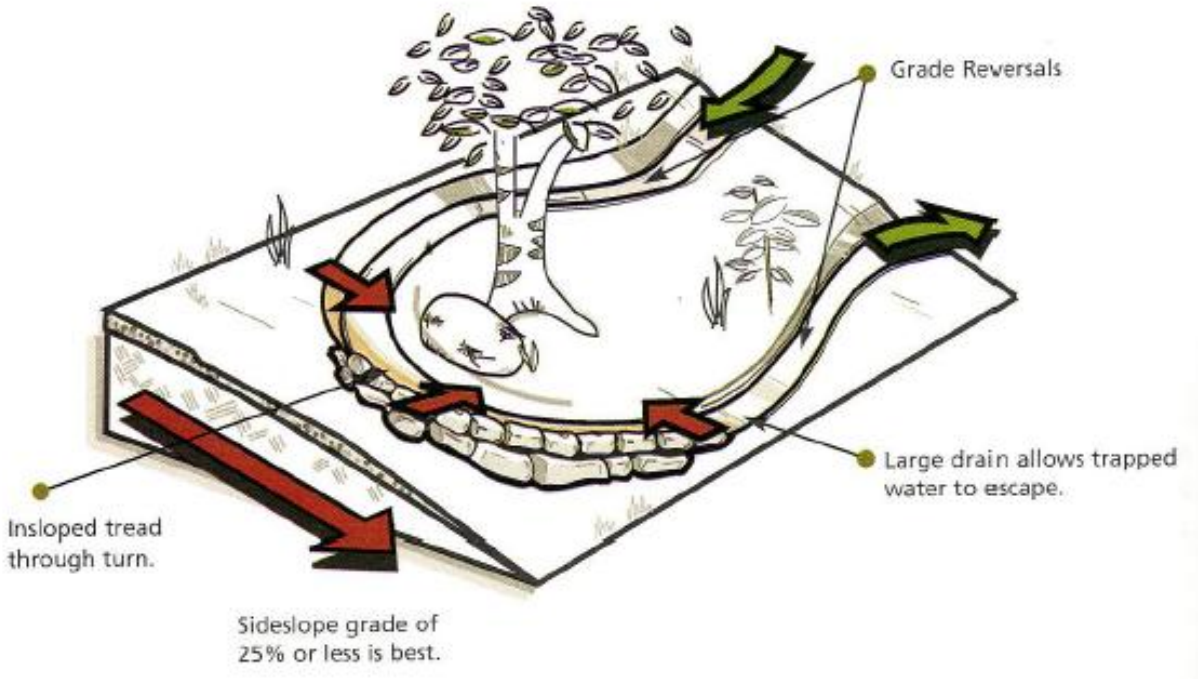
A rolling crown switchback is similar to a climbing turn but is used on steep slopes and involves construction of a retaining wall to create a mounded, level platform at the apex of the curve. Construct the upper trail tread insloped toward the high side of the slope to drain water across the top of the curve and prevent it from sheeting to the lower trail. The lower tread should be outsloped as in usual construction. Fill from excavating the upper tread is used to construct the turning platform, and is compacted and mounded for even drainage. A retaining wall should be constructed of stone found on site or large timbers, preferably treated or found on site. Grade reversals should be used above and below the curve to minimize water flow on the switchback itself. Switchbacks should be staggered as a trail ascends a slope to prevent users from creating shortcuts and disperse water flow more evenly along the hill.

Rolling Crown Switchback



3. Insloped Turns

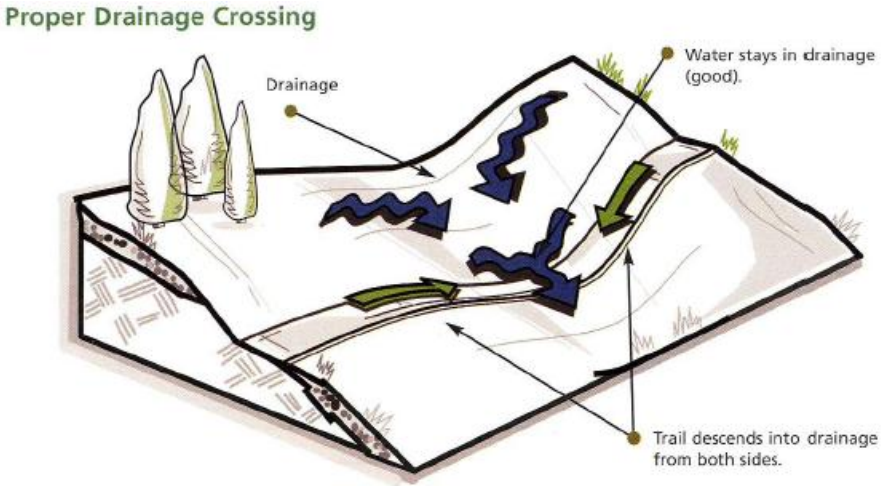
It situations where users are or are predicated to cause lateral displacement of tread material, construction of an insloped turn is recommended. Properly designed and constructed insloped turns will improve tread life by reducing skidding and soil displacement by improving user flow along the trail. Curve banks of an insloped turn should be very well compacted and constructed in layers to prolong tread life and minimize soil displacement. A well designed grade reversal above the curve is necessary to reduce water flowing down slope. Construct a choke point above the turn as users can traverse an insloped turn with greater speed than switchbacks or climbing turns. Vegetation should be kept low in the center of the curve to maintain sightlines from the upper trail to lower trail.



Insloped Turn

H. Water Crossings

If at all possible, water crossings should be avoided or minimized due to water quality issues, impact to stream or river ecosystems, increased chance of erosion, cost, and safety of users and trail crews. If a water crossing is necessary, it should be carefully sited at a riffle point and where banks slope gently to the water. Sideslopes where water crossings are located should be a maximum of 8 percent. Trails entering a water crossing should always descend into the crossing and include well designed and constructed grade reversals to prevent sediment from washing down the trail into the watercourse.



1. Fords

Well-constructed fords in streams that have a depth of less than 3 feet during high water will last for decades with minimal maintenance and will have little impact on the surrounding ecosystem if properly constructed. Fords should be built in wide, shallow portions of the watercourse and mimic the bed and width of the stream. The constructed tread should be level and made of rock found on site. The US Forest Service recommends placing rocks a minimum of 130 lbs downstream of the crossing to keep the tread in place. Rocks of a similar size should be placed in the tread 12 inches apart, upstream, to provide a stepping-stone crossing. The tread should be constructed of gravel and rock smaller than 3 inches in diameter. Armoring the approaches to the crossing with rock for a minimum of 12 inches past the high water line will further minimize erosion.

2. Culverts

Culverts can be successfully used in trail construction when properly sized and designed. Culverts must be sized to match or exceed the channel width, match existing slope, and should be sunk into the stream bed to allow a natural bed surface to form. It is imperative that a culverts width matches of exceeds the channel width to prevent flow constriction, increased stream velocity, and blockage. Culverts can be constructed of pipe or of rock found on site. Culverts are among the most often failing water crossing, and should be carefully designed and maintained annually to prevent debris accumulation and blockage. A minimum of 12 inches of fill above the crossing is desired, and large boulders should be placed upstream to amour the edges of the crossing to prevent undercutting of the tread and water low around the pipe.

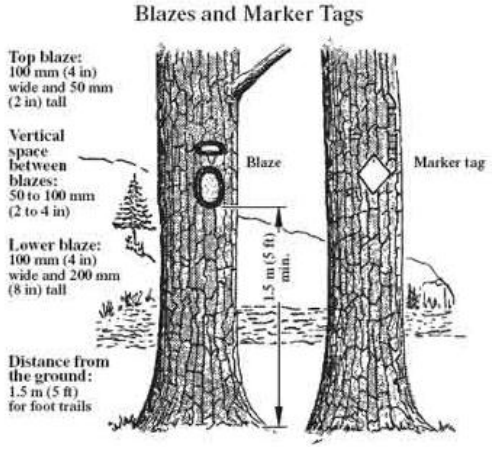
3. Bridges

In areas where the watercourse is too deep or wide to allow for safe construction of a ford or culvert, bridges may be necessary. Bridges may range from log foot bridges to complex suspended or truss structures. Use of handrails is always recommended no matter a bridges length, and an engineer should inspect all bridge plans prior to construction and use.

I. Reassurance Markers

1. Trail Blazes

Trail blazes should be used if the correct trail path is not obvious or if it may be covered with snow at any point of the year. Blazes should be placed as often as necessary, and should be clearly visible from any point where the trail could be lost.



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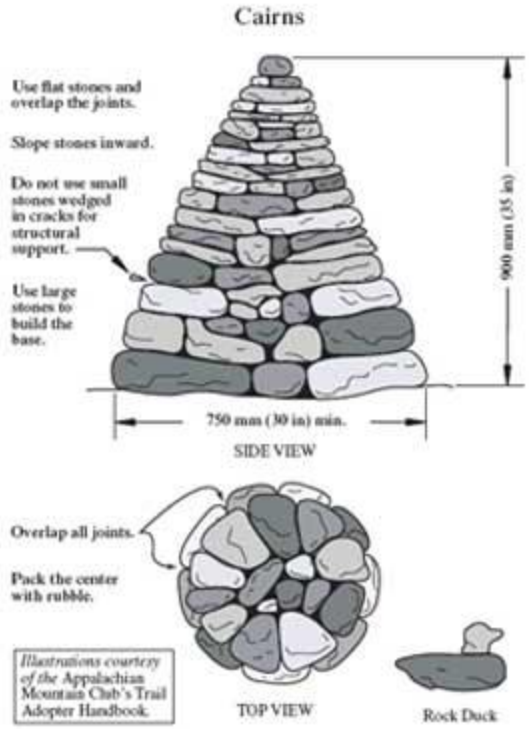
2. Cairns

Cairns are carefully constructed pyramids of rock that should be a minimum of 35 inches tall. They used be used in open areas where low visibility or snow cover may cause the tread to become difficult to follow or lost.



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References:

Hesselbarth, Woody. Trail Construction and Maintenance Notebook: 2007 Edition. July 2007. http://www.fhwa.dot.gov/environment/fspubs/07232806/index.htm

International Mountain Bicycling Association. 2004. Trail solutions: IMBA's guide to building sweet singletrack. ISBN: 0-9755023-0-1. Boulder, CO: International Mountain Bicycling Association. 272 p.

All images from Trail Solutions unless otherwise noted.