Trails Overview

Source materials drawn from Volunteers for Outdoor Colorado/Crew Leadership Manual; Trail Services LLC (Lester Kenway); NPS: the Ice Age National Scenic Trail, a handbook for trail design, construction and maintenance; and (tm) IATA-trail layout and design notebook *draft.*

Generally, the shape of the *trail alignment* influences trail outcomes more than any other factor.

Property Rights

Sustainable trail layout and design begins with verifying property ownership, identifying management goals associated with the property, and physically determining boundary boundaries.

Who owns the land? Plat maps and county websites are excellent resources to help determine who owns a parcel of land.

Who manages the property and are there multiple interests involved? Examples of this include leased hunting rights, managed forest law requirements, handshake agreements of varying natures, and easements. Easements are legal documents that outline a subset of fee title ownership rights. If a property is encumbered by easement, be aware that every easement is unique, and probably the most complicated property rights type.

Where, exactly, are the property boundaries? Are the boundaries where landowner thinks they are or where the deed and the county land office say they are? Do not rely on fence lines, old or new, to be accurate property boundary markers. Research, a good sighting compass, brush resistant clothing, a written legal description, conversations with adjacent landowners, Google Earth and GPS units are each part of a matrix of tools to verify and mark property boundaries before delving deeply into the trail design and land management questions.

Themes

Think of Themes as being a composite of what the cultural and natural features of a given site are that are most special, or, as the strongest lines of a great story. Themes develop and take shape through the process of macro and micro site analysis. Should the intricacies of detail, confusion, dead-ends, frustrations and more start to overwhelm you, remind yourself of the principal theme, or themes, you are striving to align the project with and make decisions that support strengths.

Control Points

These are positive or negative natural or cultural features that determine where a trail may or may not be desirable to locate. A grand vista is an example of a positive control point. An expanse of impenetrable swamp is an example of a negative control point. Control points may have both positive and negative attributes; property boundaries are an example.

The One Over Three Rule

The one over three rule states that if the running grade – the rise or fall - of the trail is one third or less then the cross slope, water will 'sheet' across the trail without being captured by the trail if the trail is properly constructed and maintained. For example, if the cross slope measures 30%, a 10% trail grade will likely maintain a positive state of balance concept. In this case, the trail is said to be 'hydrologicaly invisible".

In loose, unconsolidated soils (sand is a prime example), or in open terrain lacking forest canopy the one over three ratio may need to increase to one over four. Be especially cautious in gentle, flat, terrain where cross slope is in the 5 - 15% range. In these deceptive fall-line settings, the trail alignment needs to fight for every foot of subtle elevation gain possible, and meander often, to persuade water to change direction.

Measure cross slope as follows: position yourself at a low point in the trail; ask your partner to stand and face you from the nearest high point directly upslope of you, on the trail centerline. If working alone, go to this point and tie a ribbon flag at eye level. Next, stand one step below the planned trail centerline and, with a clinometer, measure to your partners "zero point", or to the ribbon flag hung at your eye level. The resulting percentage tells you how steep the cross slope is…or in many cases, isn't.

Trail grade is the objective measurement of steepness. Grade is expressed as a percentage – the elevation gained divided by the linear distance taken to do so.

Measure trail grade as follows: you and your partner stand on the planned centerline of the trail. One person stands at a local crest, or rise, in the trail, and one stands at the nearest trough, or low point, in the trail. The resulting measurement tells you the percentage of rise over run for this distance. This are is also the tread watershed. Repeat this practice throughout the entire project area.

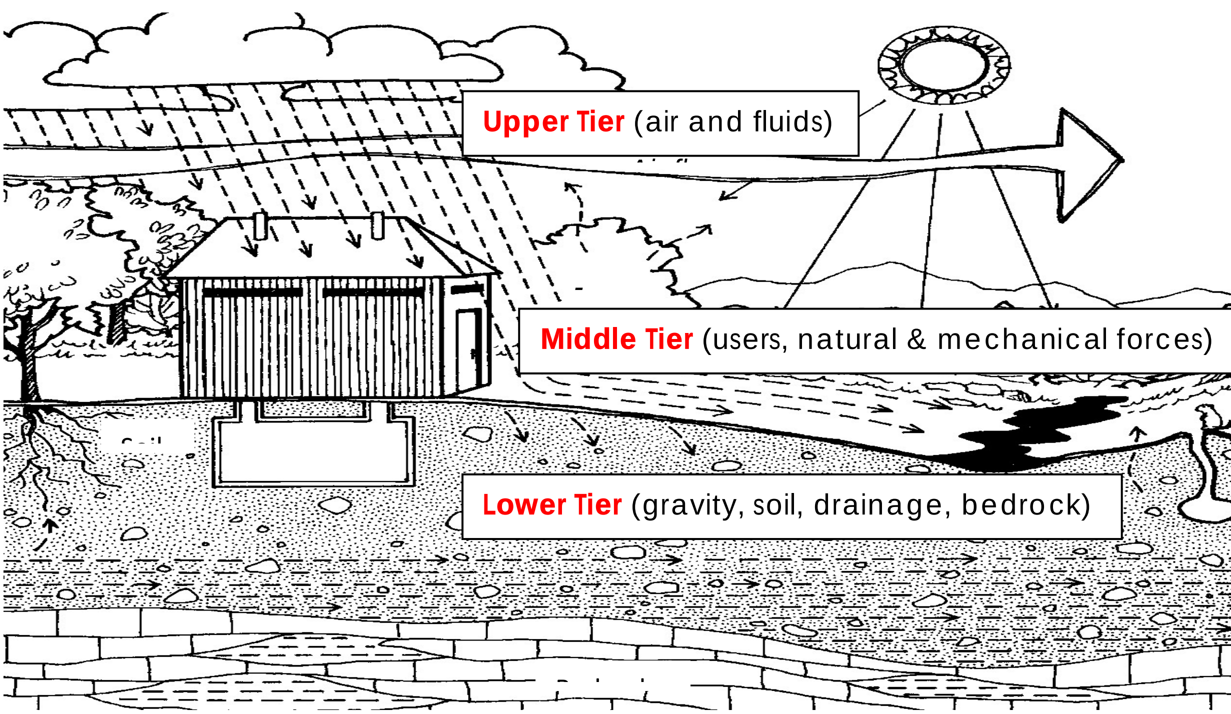
Trail alignments that incorporate frequent rolling grade dips and which undulate and meander accommodate the natural forces of water-based erosion better then trail alignments which do not incorporate these essential design features. These design features also tend to be more playful, more interesting, and a more endearing trail experiences for users.

PROPERTIES OF EROSION

Erosion is a natural and ongoing process that moves soil from one place to another. We recognize the effects of erosion by soil loss and soil movement. *Every* trail experiences some degree of erosion. As trail designers, builders and stewards our efforts are aimed toward accommodating, not eliminating, erosion. The two primary means to accommodate erosion are to design resistive trail alignments and to shape and maintain the surface of the trail to limit the effects of and how much erosion occurs.

HOW EROSION WORKS

Tiers are flow systems that occupy different levels of space above, at and below the surface.



Each flow system originates somewhere off-site, passes through where you are standing, and then continues off-site.

Soil loss and soil movement is the end result of a combination of physical forces: Water, Wind, Gravity, Compaction and Displacement.

- *Active physical forces* include precipitation, airflow, solar radiation, surface and sub-surface hydrology, infiltration, direction, velocity, mass, and force.

Over time, *compaction and displacement* modifies every tread shape. Tread material characteristics (soils) are a major factor that influences how much compaction and displacement will affect the tread surface. All natural surface trails are modified by nature and use and require tread maintenance to stand the test of time.

Compaction is the downward force of a trail user's weight and modalities on the tread surface. Compaction is caused by vertical force. One positive aspect of compaction is that tread becomes more resistant to displacement as it hardens. The downside is that as trails compact, they cup and there-by take on the shape of a vessel, become U-shaped, and then capture and channel water.

Displacement is the horizontal movement of trail tread material (soil, rock, etc.) caused by friction and subsequent lateral lifting by boots, tires, hoofs, etc. Displacement is caused by horizontal force. Faster speeds and torque increases displacement. Soil that mounds along the outside edge of trails in the form of a low berm is an outcome of displacement.

Soil Characteristics

Soils are of special interest to trail designers because soils are our most basic building material. Although soil science is a sophisticated discipline, for most trail building purposes, a basic understanding will suffice. Soil maps available from on-line resources http://websoilsurvey.nrcs.usda.gov/app/ are a great help in this process.

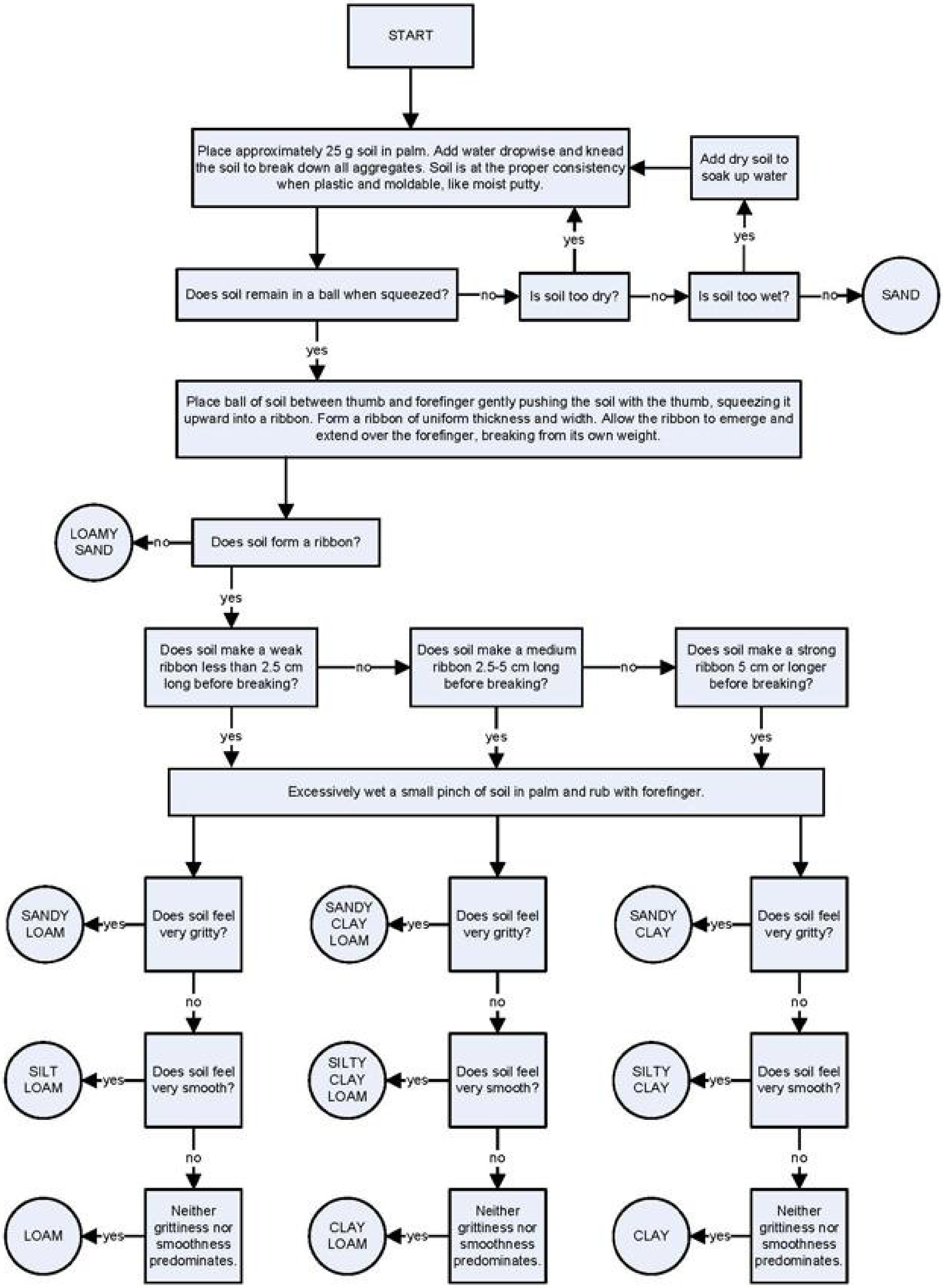
The best soils for trail building are well-drained soils with moderate amounts of sand (drainage and strength), clays (binding agent), and high mineral content. Avoid areas with high clayey, silty, and organic content; likewise with pure sand, thin or delicate soils.

In the field, **identify soil types** using the hand-cast method by squeezing a partial handful of dampened soil into three basic shapes:

Cast: a lump formed by squeezing a sample in a clenched fist; **Thread:** a pencil shape formed by rolling soil between the palms; **Ribbon:** a flat shape formed by squeezing a small sample between the thumb and index finger

Field test	Soil type				
	sandy loam	**silty loam**	**loam**	**clay loam**	**clay**
CAST	Must be carefully handled without breaking	can be handled without breaking	can be handled easily without breaking	solid, easily handled	can be molded without breaking
THREAD	thick, crumbly, easily broken	thick, soft, easily broken	can be finely pointed, easily broken	strong thread, can be easily rolled	strong, plastic thread, easily rolled
RIBBON	will not form a ribbon	will not form a ribbon	forms short thick ribbon that breaks under its own weight	forms thin ribbon that breaks under its own weight	long, flexible ribbon that does not break under its own weight

Sandy soils and larger particle size are conducive to drainage, clayey soils are characterized as "poorly drained" and are generally highly erosive; silty soils and soils with a high organic content are also poorly drained and erosive. Obviously-moist areas also may indicate the presence of springs, seeps, intermittent streams, etc. and such areas require special consideration.


START
Place approximately 25 g soil in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.
Add dry soil to soak up water
Does soil remain in a ball when squeezed?
Is soil too dry?
Is soil too wet?
SAND
yes
no
Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.
LOAMY SAND
Does soil form a ribbon?
Does soil make a weak ribbon less than 2.5 cm long before breaking?
Does soil make a medium ribbon 2.5-5 cm long before breaking?
Does soil make a strong ribbon 5 cm or longer before breaking?
Excessively wet a small pinch of soil in palm and rub with forefinger.
SANDY LOAM
Does soil feel very gritty?
SANDY CLAY LOAM
SANDY CLAY
SILT LOAM
Does soil feel very smooth?
SILTY CLAY LOAM
SILTY CLAY
LOAM
Neither grittiness nor smoothness predominates.
CLAY LOAM
CLAY

PROPERTIES OF WATER

- Volume + Velocity = Damage
- Water 'takes on' the shape of its' container
- Water doesn't like to change directions
- Water clings to itself and other surface areas
- Keep water in sheet (laminar) flow and don't allow it to focus energy
- Water must be micro managed
- Drainage is either Positive or Negative
- Water always flows downhill
- Trail alignments need to be *resistive* (tread watershed) and composed of *resistant* (durable) materials.
    - Resistive landscapes resist change from normal environmental activities.
    - Resilient landscapes have the ability to recover quickly from impacts.
    - Fragile landscapes are impacted easily and are slow to recover.

HYDROLOGICALLY INVISIBLE: What did water do before the trail was built? What is it doing now? If hydrology patterns are functioning the same after the trail is built and while the trail is in use as before the trail was built, the trail is considered "hydrologically invisible" on the landscape.

TREAD WATERSHED: A watershed is the total land area that drains into a given body of water; a *TREAD WATERSHED* is a linear segment located between a local high point (crest) and the next low point (trough). A trail that undulates and meanders will have a higher number of tread watersheds and thus create more *positive drainage* opportunities. There are innumerable tread watersheds throughout the length of any given segment of trail.

- The *length* of a tread watershed is determined by the local crests and troughs of and in the tread, be they naturally occurring or constructed.

- The *height* of a tread watershed is from the critical edge of the tread to the top of the closest topographic basin to the tread.

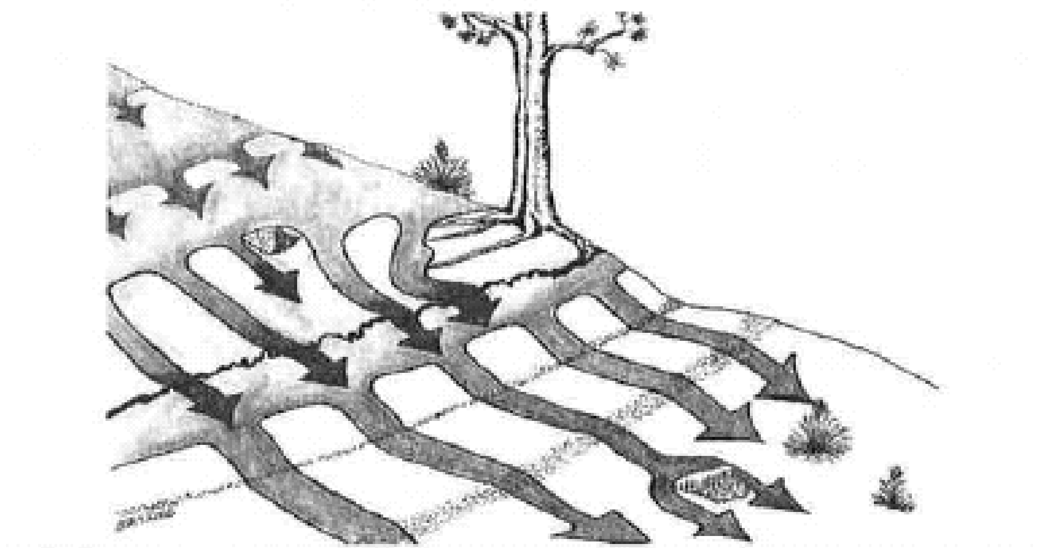
SPLASH EROSION describes the cumulative effect of individual raindrops as they strike the tread and displace soil particles. Splash erosion is more pronounced in open areas compared to similar tread protected overhead by tree canopy. The steeper the tread grade, the more that splash erosion contributes to displacement.

MAINTENACE MUST-HAVE'S

Whether a trail segment was well designed and properly built at the start of its life or came into being informally then was adopted for recreational use, the three most effective tread maintenance techniques either type of trail needs are:

- De-berm the critical edge, clean existing trail drainage structures of debris and sediment, and allow light and air to freely circulate within and through the trail corridor prisim by keeping the trail corridor clear of overhanging vegetation.

Sheet Flow and Tread Outslope in Action

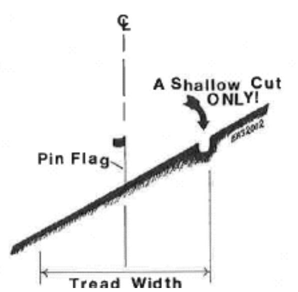


Well-designed and well-crafted trails are not exempt from erosion - the tread surface is continually being acted upon and modified by the physical forces of water, wind, gravity, compaction and displacement. Most trail erosion problems are the result of water staying on the trail *(Velocity + Volume = Damage)* versus flowing across it.

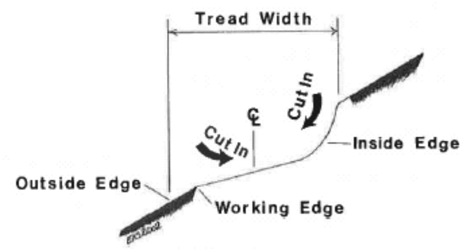
The Critical Edge

The art of crafting sustainable sidehill tread construction is shown in the "4-step" summary below:

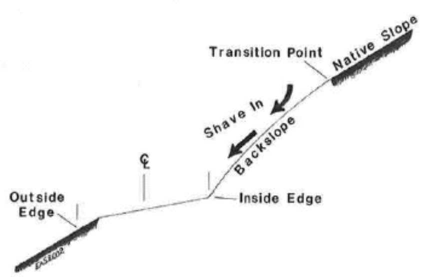
STEP 1: Establish the inside edge of the tread



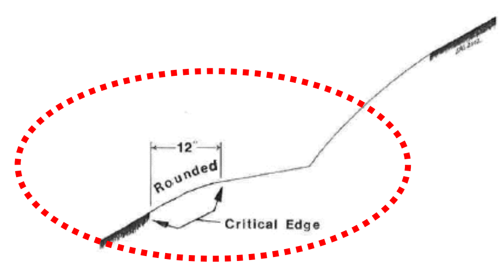
STEP 2: Cut outsloped tread with a vertical backslope



STEP 3: Cut the backslope

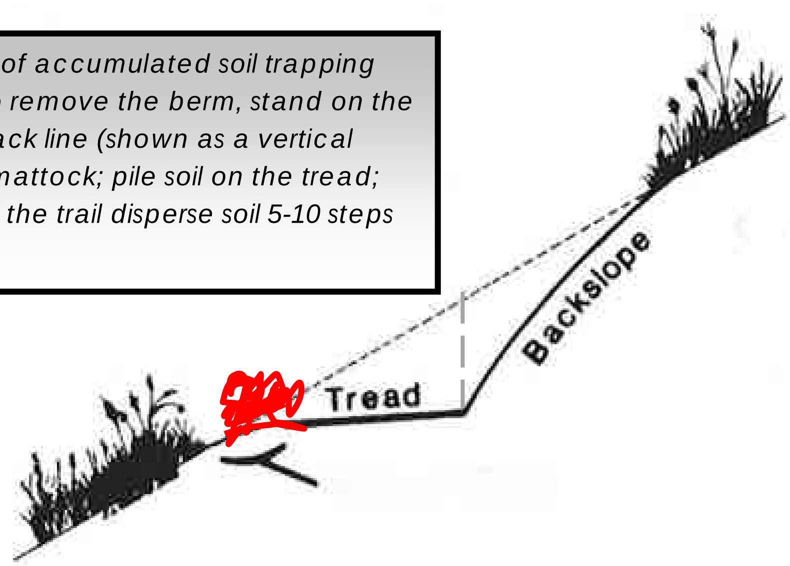


STEP 4: Establish the critical edge

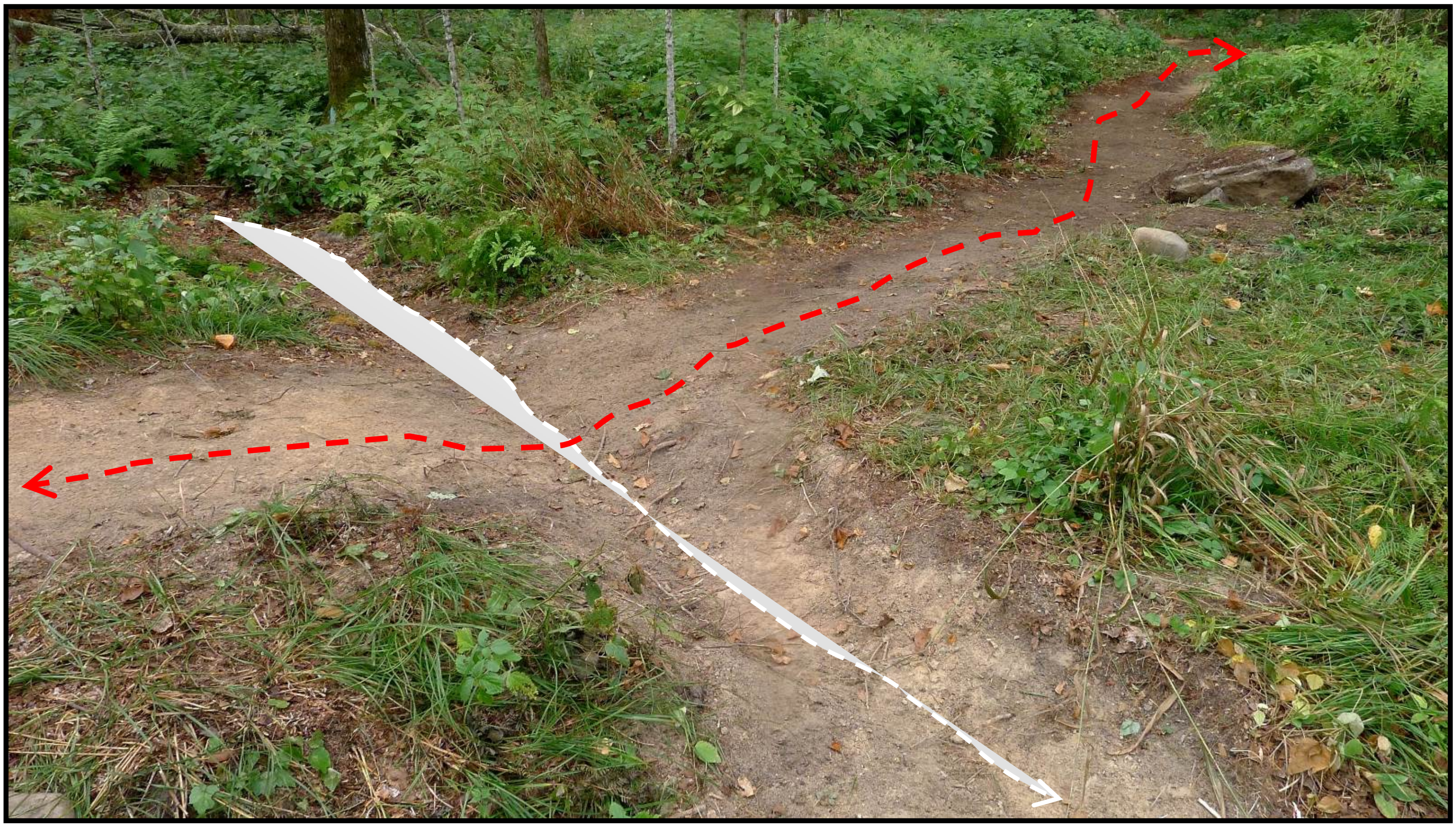


Trail use modifies the shape of the tread by compacting and displacing particles of soil. Cumulative use of a trail, year-in and year-out, is akin to beating the ground with a hammer. This causes the tread surface to harden and to sink relative to adjacent areas. As each boot or sneaker lifts off the tread, a small amount of soil is transported horizontally, toward the edge of the trail. Soil accumulates and becomes a berm. The berm obstructs sheet flow, keeping water on the trail. When sheet flow is

"Red" represents a low berm of accumulated soil trapping water at the critical edge. To remove the berm, stand on the tread and cut towards the back line (shown as a vertical gray dash mark) with a pick mattock; pile soil on the tread; round the outside shoulder of the trail disperse soil 5-10 steps away from the trail.



Swales



Shown above is a swale built as a component of new trail construction. Trail grade is less than 5%; cross slope is less than10%; soils are of high organic content; setting is a recently logged area w/25% canopy cover; user group is foot travel.

Swales are an excellent trail plumbing choice in relatively 'flat' terrain that challenge us to tune-up our "Trail Eyes" to recognize and enhance subtle, naturally occurring topographic characteristics inherent in the landscape.

- Swales are analogous to culverts in that they help to provide equalized cross drainage, which in turn helps dry the surface of the trail. Swales should extend perpendicular across the tread as far as practical. Swales do a good job of mitigating reoccurring hydrological events and seeps where water tends to pool adjacent to the trail, leading to saturated (muddy) soils.

- Swales do not dispense of large volumes of water but to help take "a little from many places" adding to the cumulative net positive effect that focuses use on the trail, protects the surrounding ecology and enhances the user's experience because trail tread will be drier.

Armoring

Armoring is the use of rocks to harden and solidify areas where the soil is consistently wet or running water is present at various times during the year.

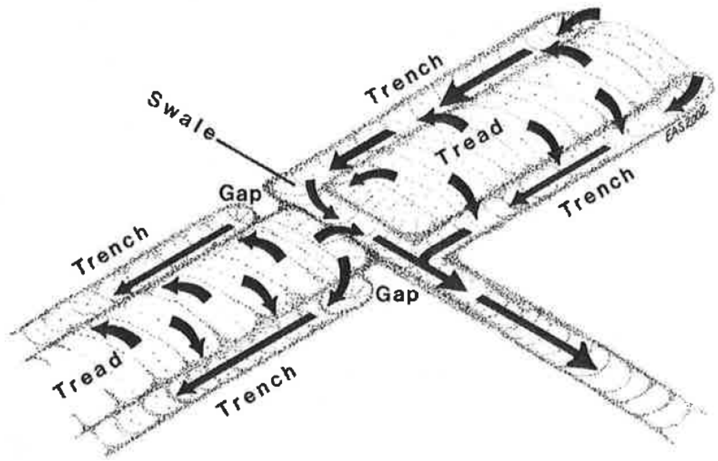
Trail Plumbing applications include:

- Create a step-landing on either side of a ditch or wet area
- Line the edge of a drainage ditch to help prevent scouring
- Reinforced water bars and swales
- Place flat stones across a drainage to mitigate erosion and provide stable footing when moving water is present

Below is an example of an armored landing

<u>ASSIGNMENT:</u> Describe what was done, why, what the potential maintenance needs, how often maintenance may be needed and other trail plumbing options that may have been considered by the builders.

Side Ditches and Trenches



Trail in flat terrain is one of the hardest trail plumbing scenarios trail stewards face because there are few options available to get water off the trail. One effective tactic is a combination of swales and trenches.

Plumbing Tips: study natural patterns, look for lighter colored soils washed atop tread, identify vegetation types, look upslope and down a considerable distance from and of the trail to observe and locate contributing factors; change your viewing perspective and occasionally drop lower to the ground, on your haunches, to gain a different perspective; think like water.

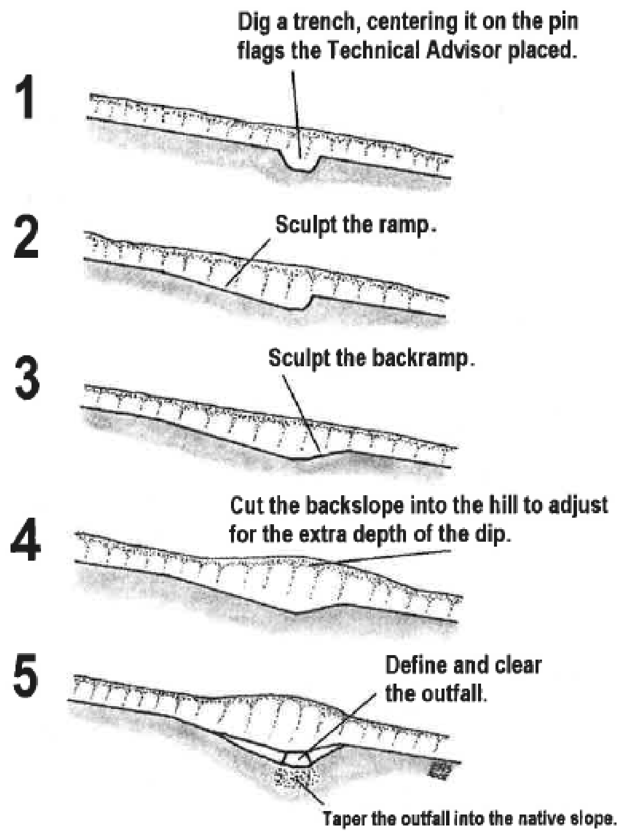
<u>ASSIGNMENT:</u> Name and describe the trail plumbing tactics used in the two photos above and what problem or potential problems you think the builders hoped to mitigate. Next, look at the vertical photo on the left and describe in what sequence you think the various trail plumbing tactics were performed, and why.

Trail Drainage Dips

Trail drainage dips are an essential trail plumbing structure used on modest (15% +) to steep (40% +) trail grades. Done correctly, dips require a substantial time and labor investment that includes moving a fair amount of dirt. Dips carry significant amounts of water off the trail and help prevent gullies and washouts of the tread. Dips need periodic maintenance to remove sediment and debris.

Core decisions include: deciding where to locate a dip and how many dips are needed.

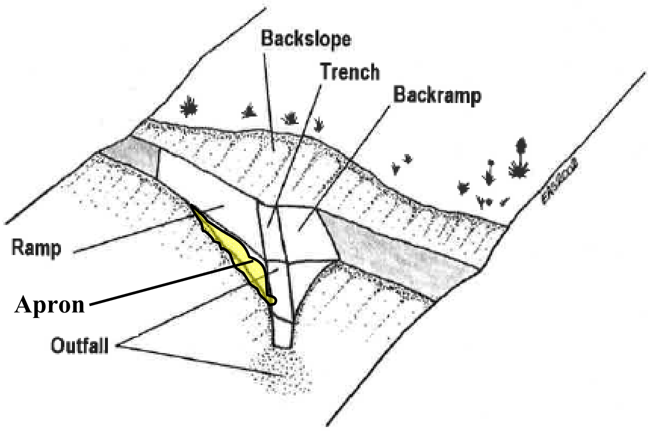
- Take time to study and plan where to located dips; build the trench at a 45 to 60 degree angle to the running direction of the tread
- Locate dips high, in the upper third of a steep run, to capture and remove water before it gains scouring velocity. Add dips as necessary downslope (middle and lower third)



The most common mistakes trail builders and stewards make when constructing a dip is not extending the trench (step one) past the backline, shaping too small of a backslope, and not extending the outfall of the trench far enough past the critical edge of the tread.

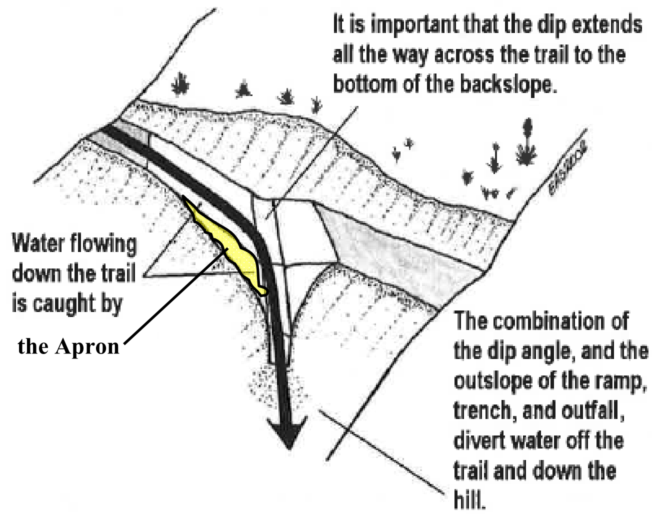
Dip anatomy may at first be deceiving because the downslope apron, not the trench, is the primary location where we want water to exit the trail. It is helpful to visualize a triangular pie shape upslope of the trench.

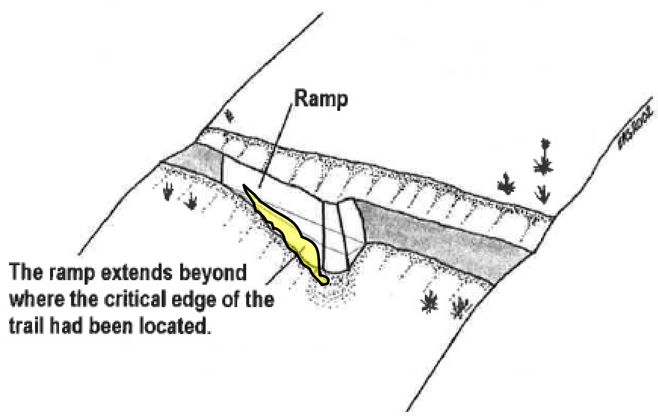
Drainage dips are known by various names throughout the country. “Bleeders” extend from the critical edge and do not include a ramp or backramp. They help, but are not nearly as effective as the full dip.

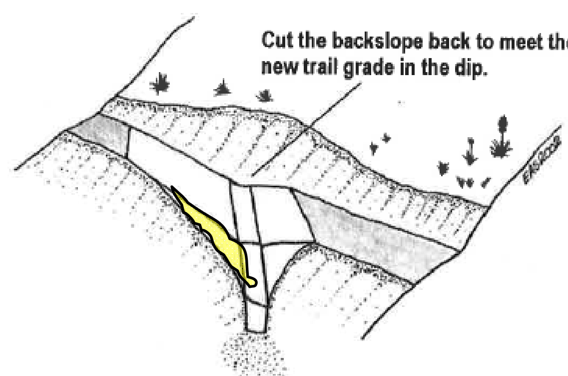


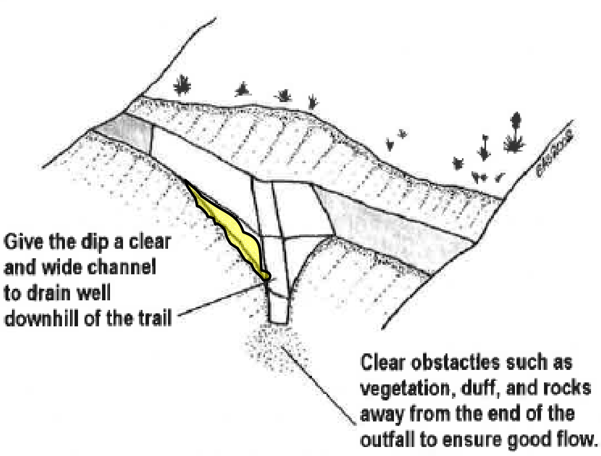
OVERVIEW AND TERMS

FIGURE 12.1: ANATOMY OF A DRAINAGE DIP.



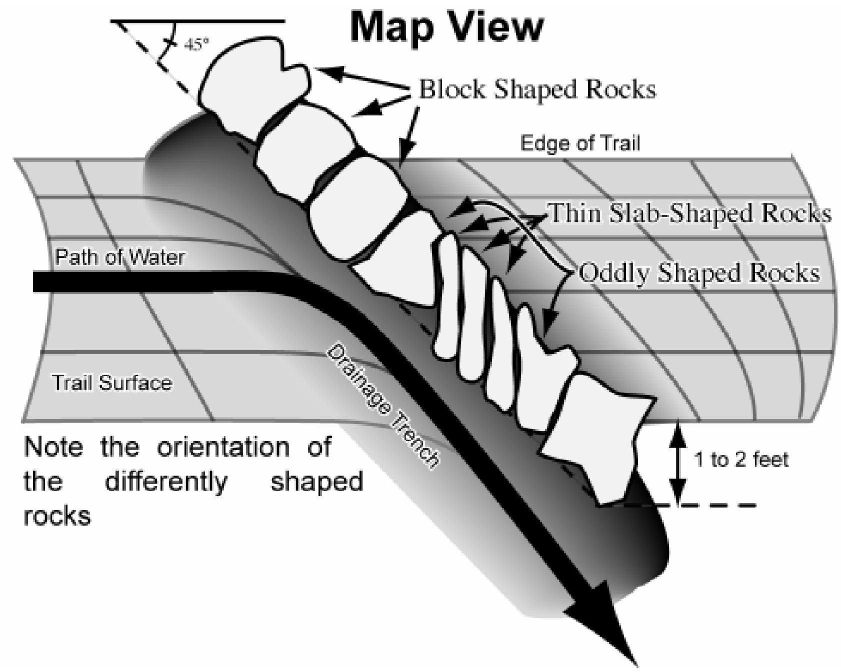






The Traditional and the Reinforced Waterbar

As sustainable trail design and construction methods have become more known and widely understood, drainage dips have supplanted water bars as the go-to trail plumbing structure. Traditional water bars are not without their merits; in particular, rock reinforced water bars are the right choice on steep or deeply gullied grades, including when an existing section of trail is decommissioned but needs remediation. Below is an example from Trail Services LLC, Maine.



Where, How Often, How Frequent???

The actual number of and spacing for drainage dips and water bars depends on the amount of water entering the trail, the steepness of slope, how resistive to water the trail alignment is, the availability of places to divert the water, and how resistant the tread surface is.

- The final placement of trail plumbing features is dictated by terrain.
- The greater the degree of slope and the more water channeled by the trail, the greater the need to force water to change directions.
- Construct Drainage dips, reinforced water bars and or swales above rock retaining walls and other constructed trail features, and below points where a significant amount of water enters the trail.
- On uniform, sustained grades, swales and dips should be built to divert water before it does damage.

Guide to Water Bar and Drainage Dip Spacing

Material Type	2% grade	4% grade	6% grade	8% grade	10% grade	12% grade
Loam	350'	150'	100'	75'-50'	50'-40'	40'-25'
Clay-Sand	500'	350'	200'	150'	100'-50'	50'-25'
Clay or Clay-Gravel	-	500'	300'	200'-150'	100'	75'

Trail Layout and Design Tools

Clinometer / Compass / Folding Hand Saw

Topo / Aerial / Site / Plat Maps

Black Sharpie Permanent Markers / Tape Measure(s) (16' & 50-100')

Weatherproof Notebook & Pens / Voice Recorder

First Aid Kit / Camera / Cellular Phone / Personal Items for comfort and safety
Plant and Tree Identification Book(s) / Masons Line & Line Level

Multiple Colors of Flagging Ribbon and Wire Stake (Pin) Flags

RESOURCES

USFS Trail Construction and Maintenance Notebook 2007 Edition
http://www.fhwa.dot.gov/environment/Fspubs/07232806/index.htm

Wetland Trail Design and Construction
http://www.fhwa.dot.gov/environment/Fspubs/07232804/index.htm
http://www.fhwa.dot.gov/environment/Fspubs/07232806/page10.htm

Additional US Forest Service on-line publications)
http://www.fhwa.dot.gov/environment/Fspubs/index.htm

Trail Design & Construction Contractors

Trail Design Specialists
http://www.traildesign.com/
Mike Ritter
678-410-8021
info@traildesign.com

Great Lakes Trail Builders
www.greatlakestrailbuilders.com
Willie Bittner
608 799 2389
willie.bittner@gmail.com

Ecological Management

EC3 Environmental Consulting Group, Inc.
www.ec3grp.com
Eric Schlender
608.497.0955

Integrated Restorations, LLC
Craig Annen
608-424-6997

See Also: http://dnr.wi.gov/files/pdf/pubs/er/er0699.pdf

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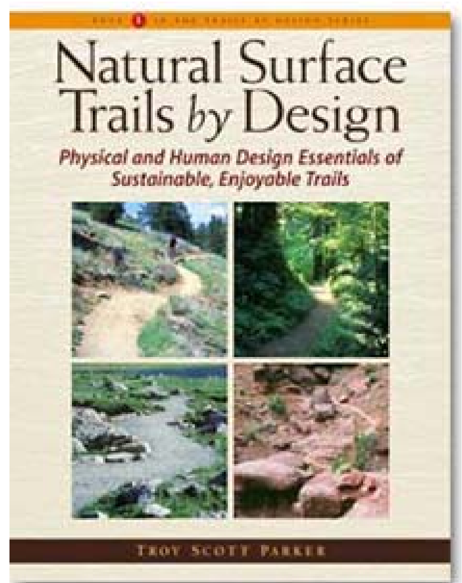

Ice Age Trail Alliance
http://www.iceagetrail.org/resources-for-iata-leaders
608-798-4453
info@iceagetrail.org
tim@iceagetrail.org
Tim Malzhan
608-592-1415

Thank you for participating!