NOAC 2024 CU Boulder

SEEK NEW HEIGHTS

Arrowman Conservation School

Levels 1 & 2 – Conservation (Trail Building) Track

Trainers:

Bradley Ellis (Trail Building) • Joshua Hipps (Trail Building)

ACES Training Lead Luke Williams • Adviser Bradley Ellis

Meet Your Trainers

- Aal-Pa-Tah Lodge (Lodge Chief 2000-2001)
- Jupiter, FL (currently Sarasota, FL)
- Florida State Circuit Court Civil Magistrate
- OAWV Foreman (2004-2006)
- Board Chair, American Hiking Society (2019 & 2020)
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Meet Your Trainers

- Atta Kulla Kulla Lodge
- Greenville, SC (Currently Park City, UT)
- Works at Park City Mountain Resort
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NOAC 2024 UC Boulder

SEEK NEW HEIGHTS

Trail Feature Construction

[Trainer Name] • [Trainer Email]

Foreword

In this training we will be discussing the processes and features associated with trail building. During the course please keep in mind that while the processes to complete a feature will generally align with what we discuss, it is quite common for unseen issues to arise on trails like unexpected massive boulders or roots.

Because of this we would like to stress that trail building is as much an art as it is a science.

In trail building you will often need to find creative solutions in order to solve a problem, examples of which are limitless. We hope this training gives you a solid foundation which will help you utilize some or all of these trail features in unique ways in order to better your camps, parks, and forests.

1. Cutting Bench

Full Bench

The primary focus on new trail building is cutting the bench. In this process we take untouched hillsides and valleys and make a sustainable path for everyone to use. The process of cutting the bench can be broken down into 3 simple steps: brushing/clearing, excavation, and finishing. While the three steps sound simple there is plenty that goes into each.

An effective way to look at cutting bench is as an assembly line where each person has their job, and with each step a trail gets closer and closer to completion.

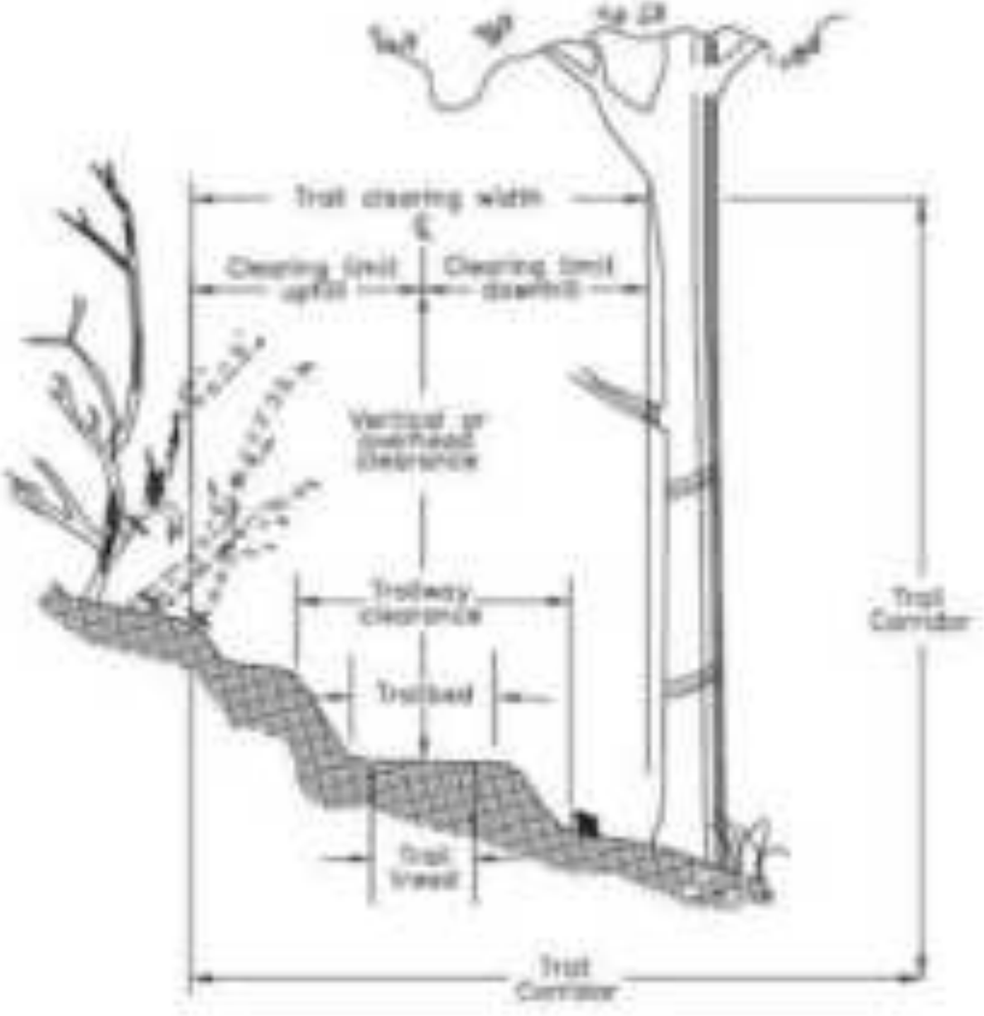
We will discuss steps of our assembly line, but keep in mind that not all trails will be able to follow such a simple pattern as the soil type, slope, and landscape will play an integral role in deciding how many additional features will be necessary. In this case the crew should cut and finish the trail to the best of their ability, and then go back to work on specific features.

Full Bench - Pioneering

Have crew member(s) clear the small limbs and bushes along the corridor of surveyed trail. This gives space to work and allows the rest of the crew to understand what area they are working in. This can be done with a pair of loppers and/or a bow saw.

Different trail types require differing amounts of space, but a good rule for typical hiking trails is to take a pair of loppers and cut back anything in the way if you hold them to the side or above your head, this should give plenty of clearance for the most users of the trail.

For equestrian, portage, and mountain bike trails there will need to be additional space to account for, and many established trails or recreation areas have their own trail specifications.



Full Bench - Excavation

Have scouts use a fire rake, hazel hoe, McLeod, and/or adze end of a pick or cutter mattock to clear out the organic material in the trail. This includes small roots and all of the foliage that is layered on the ground.

Once the organic material is removed doing a rough cut into the ground indicates where the tread will be and is the initial ground breaking for the finishing work that will take place.

This step is also when large roots and stumps are cut out of the ground and large rocks in the way are removed. Be sure to completely cut out roots so they cannot begin growing again in the middle of the trail.

Note: Flagging should always be on the downhill critical edge. Sometimes you will also flag the uphill in-slope edge if you want to insure your workers do not remove certain natural features, or if you want to choke or corral the trail.

The workers in this picture are standing on the down-slope critical edge and the crew appears to have also destroyed their down-slope flag line. Both such practices should be avoided. The up-slope flag line in this picture is an example where both sides might be flagged to mark a Choke or to preserve Corralling features.

Full Bench - Excavation

The worker in this picture is standing on the down-slope critical edge and the crew appears to have also destroyed their down-slope flag line. Both such practices should be avoided.

- Pro-Tip: Do not step on, walk on, or even rough cut the outslope critical edge (aka critical point) until the rest of your rough cutting is finished. If you prematurely do any of the foregoing, the critical edge will collapse, resulting in your tread width narrowing, and forcing you to cut more backslope (the critical edge will continue to collapse in a horrible cycle). You will also prematurely loose your flag-line point of reference. Once your tread and backslope are rough-cut and your tread is mildly compacted from use, you can shape your tread out to the outslope critical edge.

Full Bench- Finishing

In this step, you are cutting into the backslope and creating the tread with every swing. Usually a hazel hoe or mattock is best for cutting the tread. The excavation team should have removed any small rocks or roots in the way. As the tread is cut, someone should come behind with McLeod and/or tamping rod to grade the trail and ensure it is packed well.

The backslope should have an approximately 45 degree slope, and should tie-in to tread that contains an approximate 5 percent outslope. Having a properly cut backslope allows the hillside to shed water while minimizing the effect of erosion. A backslope too steep is more likely to washout the inside of the tread and cause a gulley that will run down the trail and cause issues later.

As you remove soil, keep in mind that it cannot be replaced once broken and still maintain the same strength; keep this in mind as it is very easy to dig too deep. Once the tread is cut, someone with a scraping tool like a McLeod (or top of a garden rake) will come through to smooth out the trail, and also possibly tamping with the McLeod and other tools like a tamping pad.

Note: 45 degrees is typical for back-sloping, depending on the angle of repose for your soil type.

Top: Back-sloping too steep, and may erode or collapse.
Bottom: Back-sloping appropriate for soil type (but appears slightly less than 45 degrees).

Partial Bench

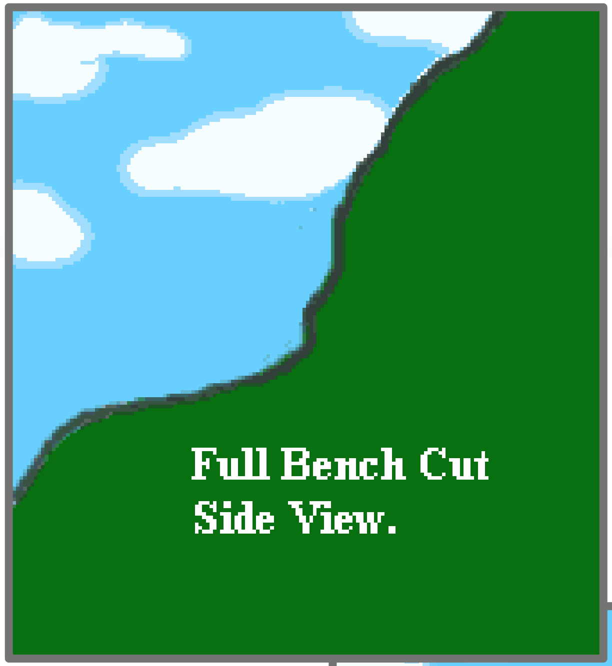
In the OA, we strive to build trails that will stand the test of time, and adequately handle the tests mother nature throws our way, and full bench should be built whenever possible.

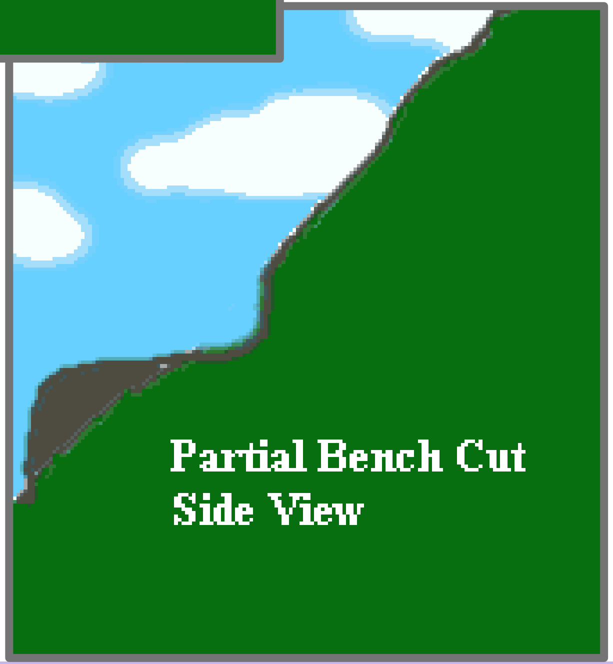
However, in some cases there may not be enough time to complete a trail project and a temporary solution may be needed for a short period of time.

This is where a partial bench cut may be useful. A partial bench cut uses the dirt removed from the inside of the tread to create the outside of the tread. This method, while quick, leads to significantly more trail erosion due to the nature of not having an outside edge packed as hard and/or held in place by vegetation.

Some people will try and retain this material with cribbing, which can work for trails that have the resources for regular maintenance but to stand the test of time it is best not to cut corners.

Example of partial bench use: USFS fire crews will sometimes cut partial bench for access trails on active fires.





Cribbed Bench

When cutting a new trail, sometimes the slope of the critical edge or the soil make-up doesn't give enough stability to keep the trail from falling apart. In this case it may be necessary to add a rock wall and backfill the tread with gravel and dirt. This creates a stable tread that will not wash out easily with a retainer in place.

The picture is an example of an unfinished trail that requires a single layer of rocks to maintain the integrity of the edge of the trail. Notice how the larger rocks are backfilled with smaller gravel and will eventually be covered in dirt and tamped to give a consistent trail.

Cribbed Bench

Example of Cribbed Bench from OATC

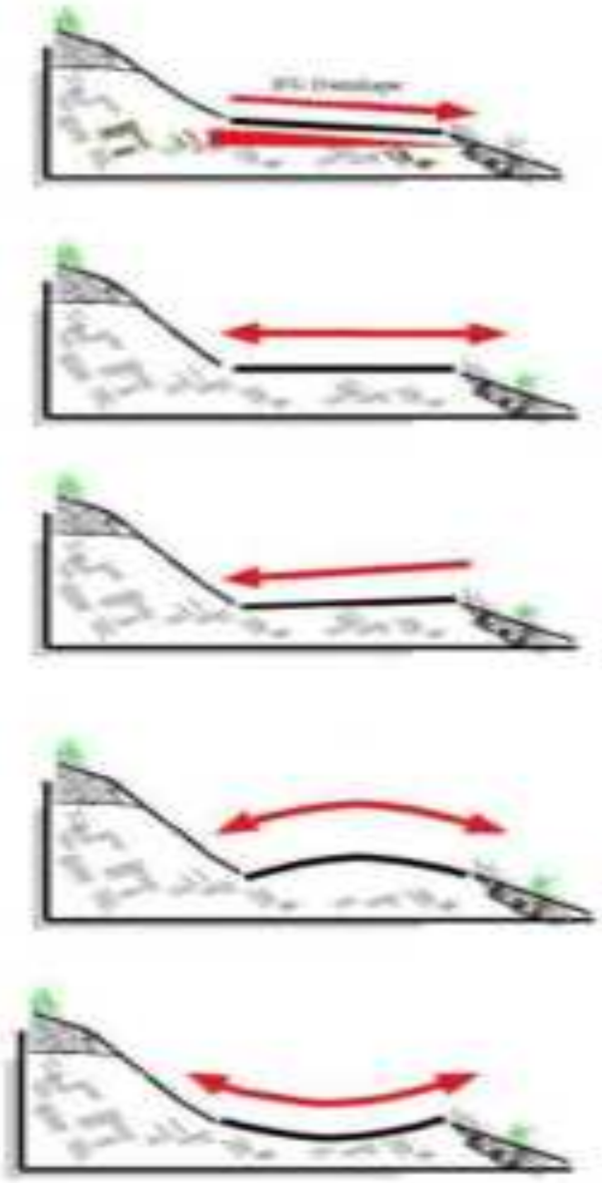
2. Tread

Tread

Once rough cutting has been completed, it is time to construct the tread and the outslope.

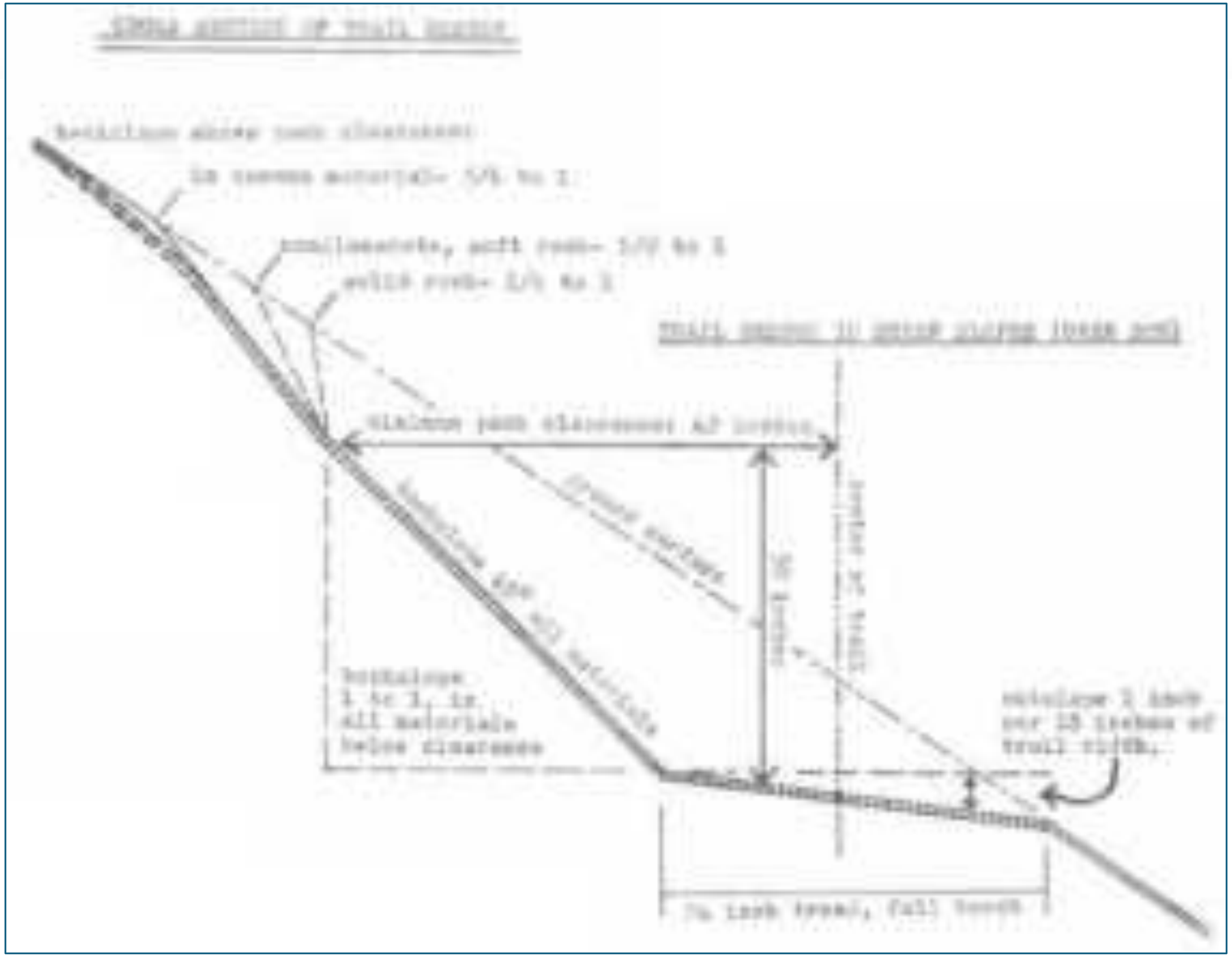
The two key considerations of tread are:

1. Solid Compaction.
   a) Tread should be undisturbed mineral soil (highly compacted), but additional compaction might be needed.
2. Positive Drainage.
   a) You should have a target trail slope (gradient) from your surveying.
   b) The tread should be only be slightly cross-sloped (outsloped or insloped) to ensure water flows off of the trail (approx. 5%)
   c) If you stand on the trail and you can feel the slope, then it is too great.



Tread

OATC Bench Specifications for Steep Sideslopes (over 20%)



Re-Tread

Over time a trail loses tread, which can result of further deterioration of the trail. The middle of the trail becomes a low point when the trail loses tread and can hold water.

When the trail holds water, it becomes muddy and can result in more material being tracked away and deepen the depression. Eventually, people will start walking off the trail, traveling on unproven ground and impacting the surrounding environment.

To re-tread a trail, simply fill with golf ball sized rocks (if necessary), then gravel, then finishing gravel, then crown the trail with dirt.

Re-Tread

- Example: Knife-Vera Portage (BWCAW).
- Golf ball rocks in place.

Re-Tread

- Example: Knife-Vera Portage (BWCAW).
- Gravel in place.
- Dirt in progress.

Common Trail Features:

Armoring

Armouring

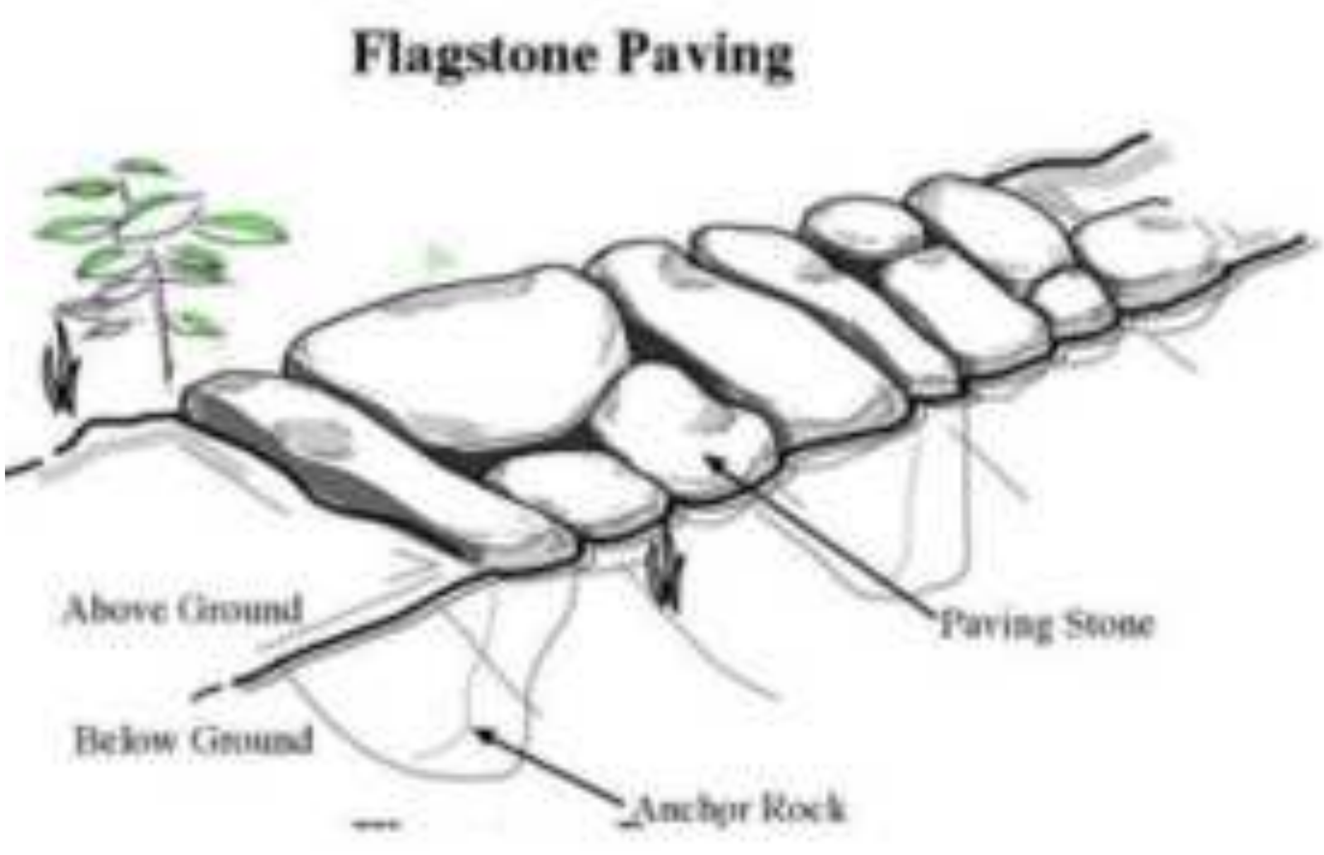
- There are 3 main types of Armouring.
  - Flagstone Paving
  - Boulder Causeways
  - Pitching
- Overall Goals
  - Often found on trails that have heavy bike traffic.
  - Priority is to harden the trail without causing ruts, soil loss, or erosion damage.
  - Looking for naturally dry climates.
- May want to consider trail reroute prior to hardening the trail.

Why Amour a Trail?

Flagstone Paving

Large, flat-faced stones are placed directly on a mineral soil base or an aggregate base (a mixture of sand, gravel, pebbles, and small rocks, with no organic material within or beneath base). Each stone's largest and smoothest face is placed up and at grade to form the tread. This is the most common and simple armoring technique.

Larger stones referred to as *anchor rocks* should be used at each end and dug deep into the ground to provide stability to the inner, smaller stones. For longer paving features, more than 2 anchor rocks may be required.

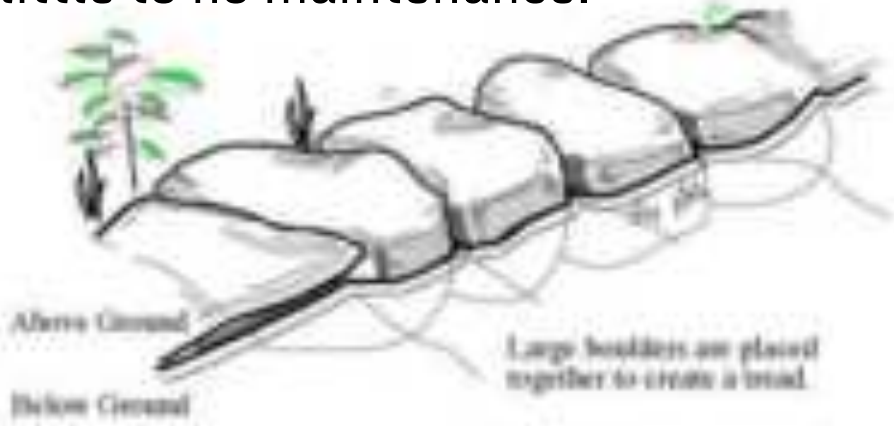


Flagstone Paving (cont.)

Boulder Causeway

A boulder causeway is basically the same as the flagstone paving technique, except giant boulders and large rock slabs are used to raise the tread.

This method is more difficult to construct than flagstone paving, and requires a supply of large boulders. However it is much more durable and should require little to no maintenance.



Pitching

Usually in trail building we try to maximize the surface area or breadth of a rock in order to make stable walls, tread, or ability to hold material. In pitching we do the opposite.

Pitching is compromised of taking longer relatively flat rocks and putting them into the ground so that the outside edge is all that is showing. This particular type of trail feature allows a maximum amount of strength without the need to place endcaps or backfill with gravel and dirt. This feature is especially useful in areas subject to washing out from rain or going through streams which some trails must out of necessity.

Rocks pitched within a step in the Grand Canyon National Park where the use of mules on trail made it necessary to have a stronger surface thank simply gravel and dirt.

Pitching

Pitching comes in two forms, with retainers and without.

With retainers, you are using heavy capstones to create horizontal compression on your pitched rocks between the capstones. You may or may not also have side retainers in place. Pitching is fastest if you already have a “box” of retainers or a “gardeners box” of soil, and then you pitch the vertical stones to fit inside the box.

Without retainers, a small space is dug for each rock to slide into. Rocks should be relatively parallel allowing water to flow through the top without jeopardizing the stability of the sunken area of rock which is safely in unbroken ground. While the process may be tedious it prevents the need for an endcap to hold rocks in place as a wide endcap would potentially get washed out over time or impede the natural flow of water.

A combination of both methods may be necessary depending on your specific need.

A good way to understand pitching is to think of a rock as a nail that has been driven into the ground. And in some cases you will literally need to tamp rocks further down in order to maintain uniform height through the pitched section of trail.

(Example Pitching from BNRTC)

Pitching BNRTC

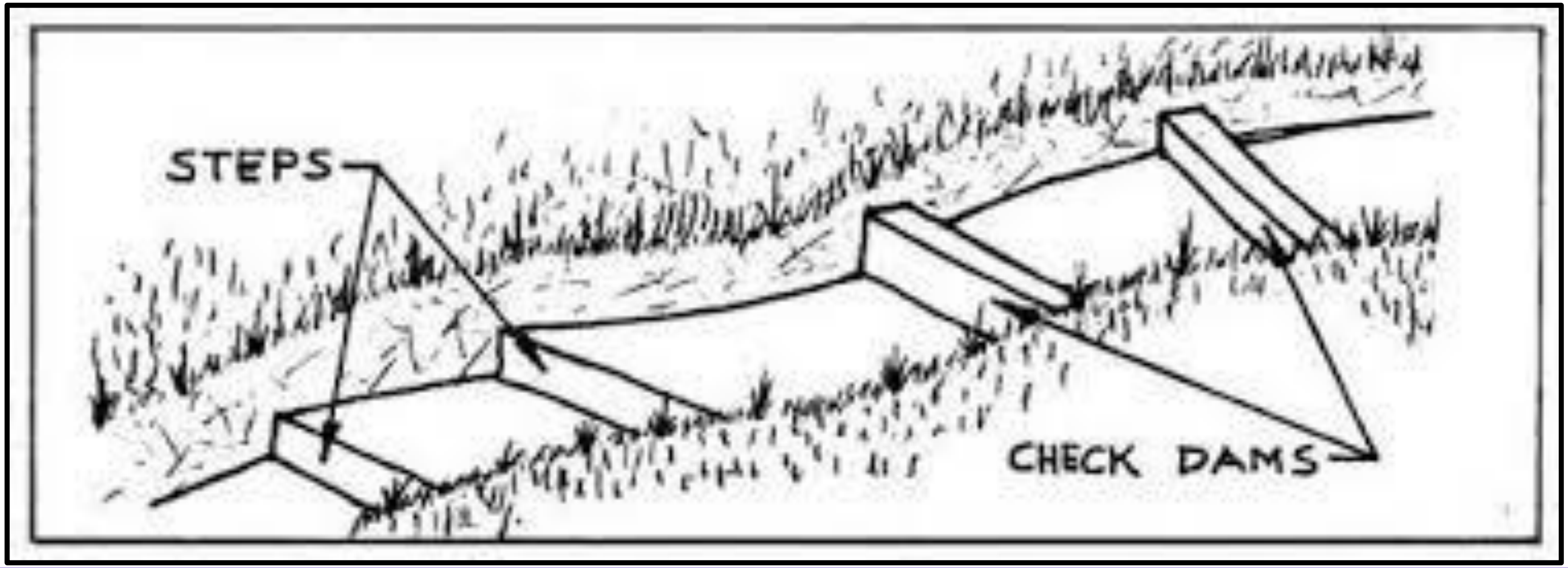
- Video of completed reinforced pitching section at the Buffalo National River Trail Crew
- https://www.dropbox.com/s/nwjy7ogvv6fakjv/IMG_0740.MOV?dl=0

Check Dams

Check Dams

A Check Dam slows water on the trail to help prevent erosion (and allow sediment to build up & settle behind trail features). If water is moving quickly, other features become less effective. For example, fast moving water can simply flow over a water bar. Check dams allow you slow down water to have more control over it's flow.

They are not ideal for use on trails traversed by livestock, bicycles, or motorized vehicles due to a sudden change in trail height and the stress those modes of transportation put on the feature.

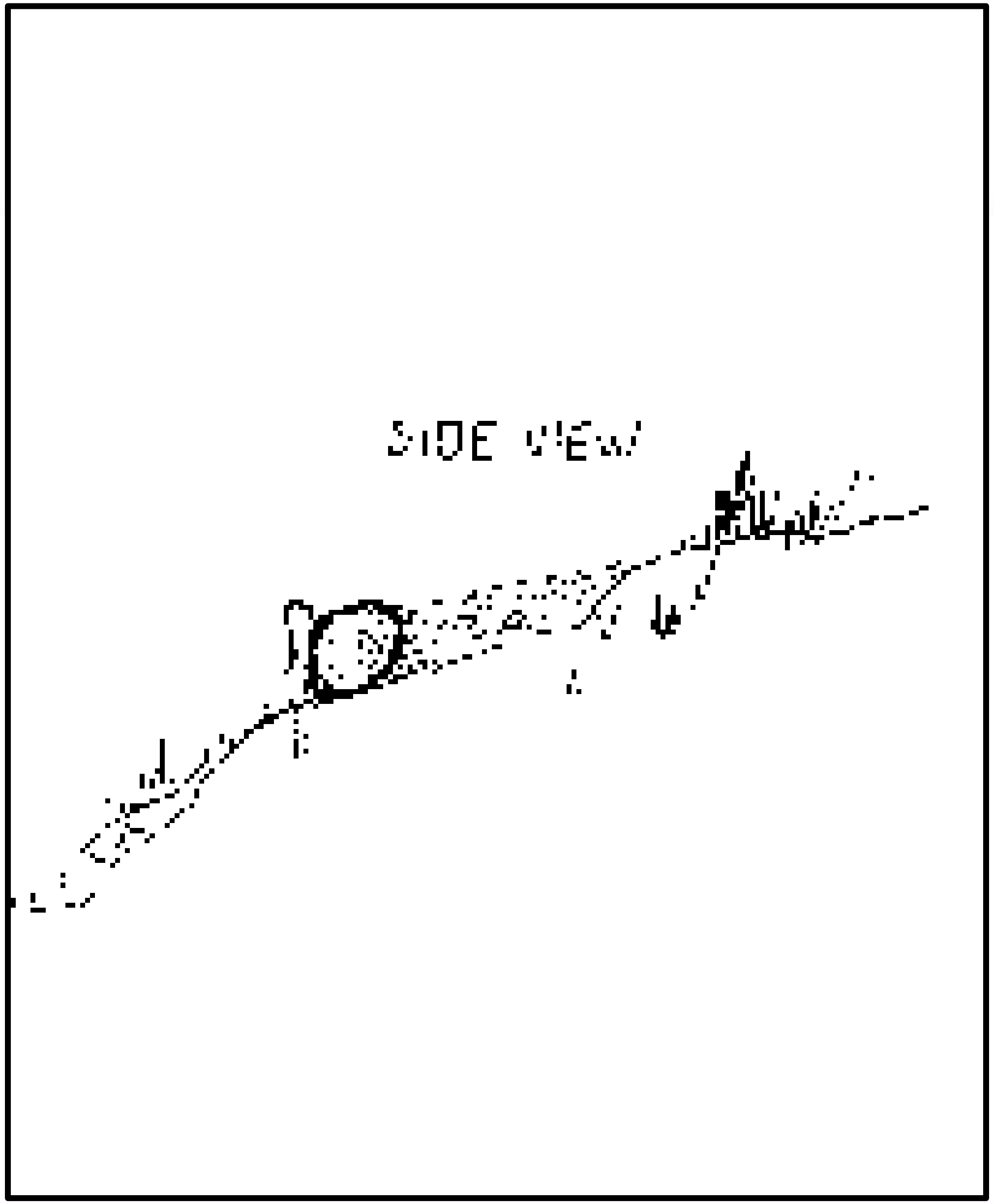


Check Dams (cont.)

Check dams can be built with logs, large rocks, or geosynthetics, and should expand wider than the trail so water does not travel around them. Start by digging a trench to set the log or rock(s) into. Your log or rock should be set solid in place without any movement under stress, prior to backfilling and gravelling. You should dig down to solid soil by cutting into the trail. Place your material to create a defined edge. The slope should be very small in order to slow the water down as much as possible almost like a step. Backfill any empty space on the uphill slope and tamp.

Check Dams (cont.)

- Used to slow the flow of water in locations where diversion off the trail is not achievable.
- Erosion control.
- Check dam should be achieved with a single large rock set stable in the ground.
  - Should withstand multiple hard test kicks without movement.
- Backfill with gravel and dirt, leaving a small 1-2 inch lip.
- Target height 8-10 inches.
  - Maximum height of 12 inches.



Water Bar

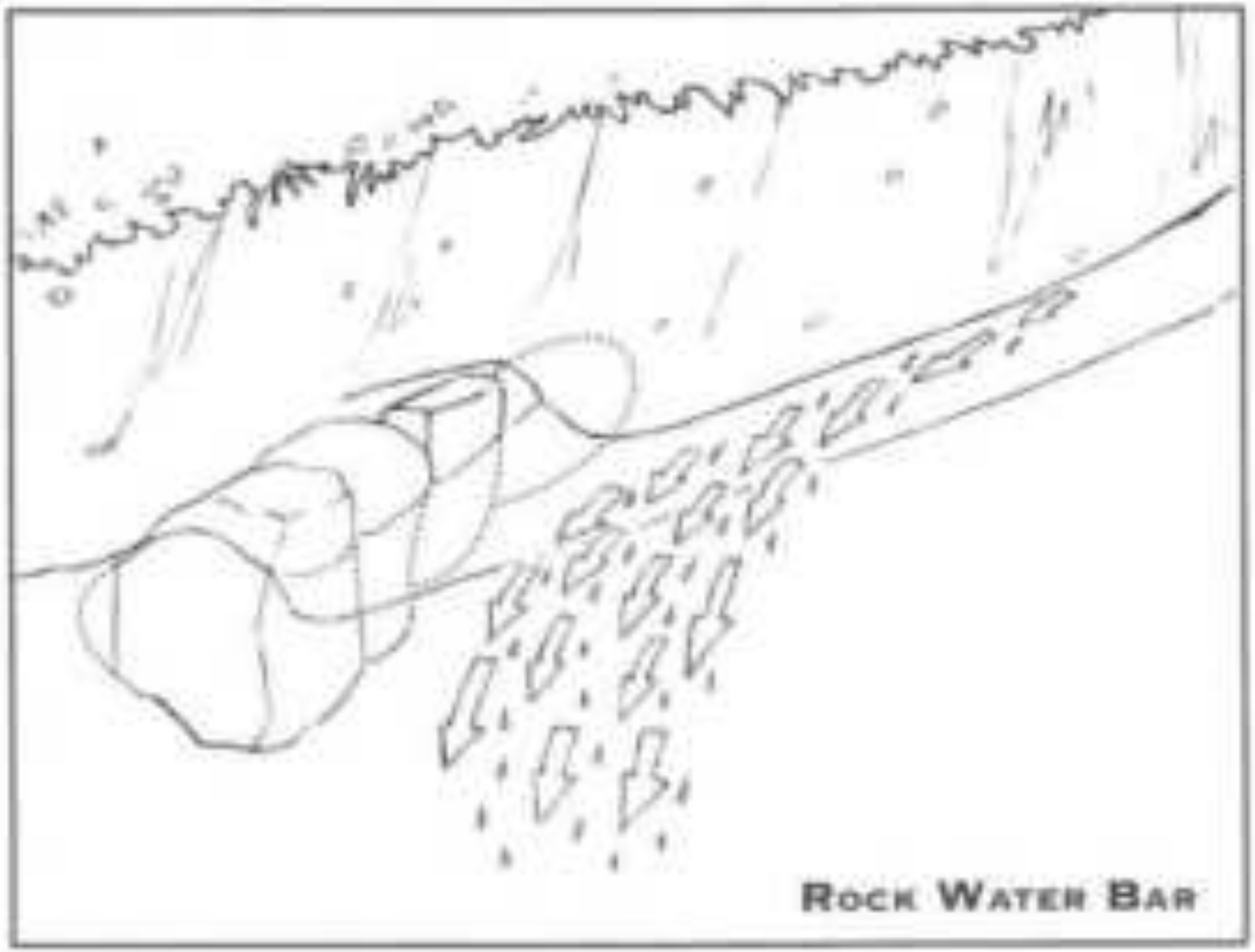
Water Bars

The last defense against water on a trail system, water bars should be used when gradient or drain dips cannot do the job, and consist of three parts:

1. A log or stone that raises a couple of inches above the tread
2. Five feet or more of tread called an apron that is shaped to direct water off the tread.
3. An outlet ditch.

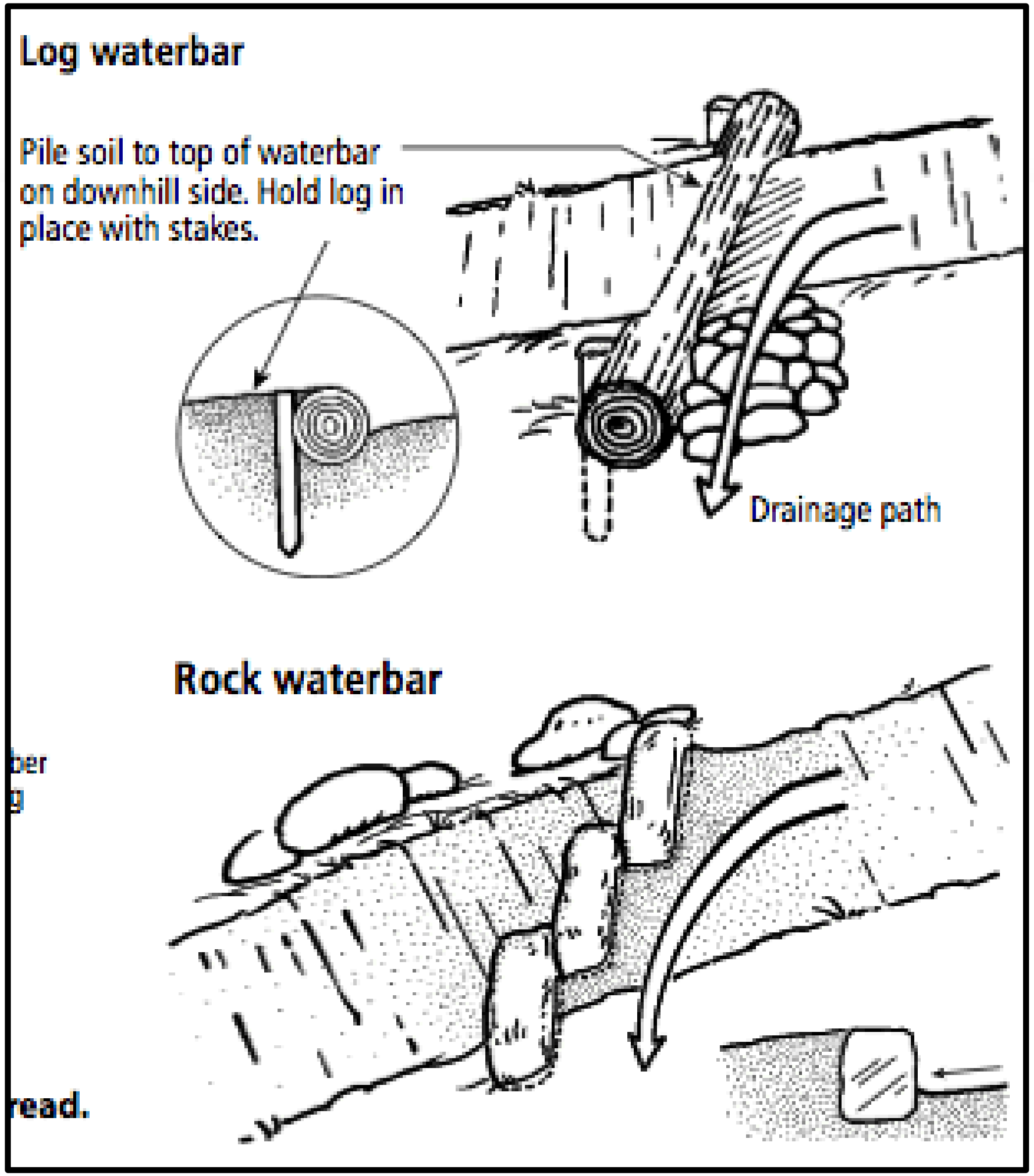
If using wood, the outward side of the log should be secured with a stake or natural feature like a log. Stakes should be tilted inwards.

If using rock, try to set rocks in a shingled pattern so water doesn't pool up behind or to the side.

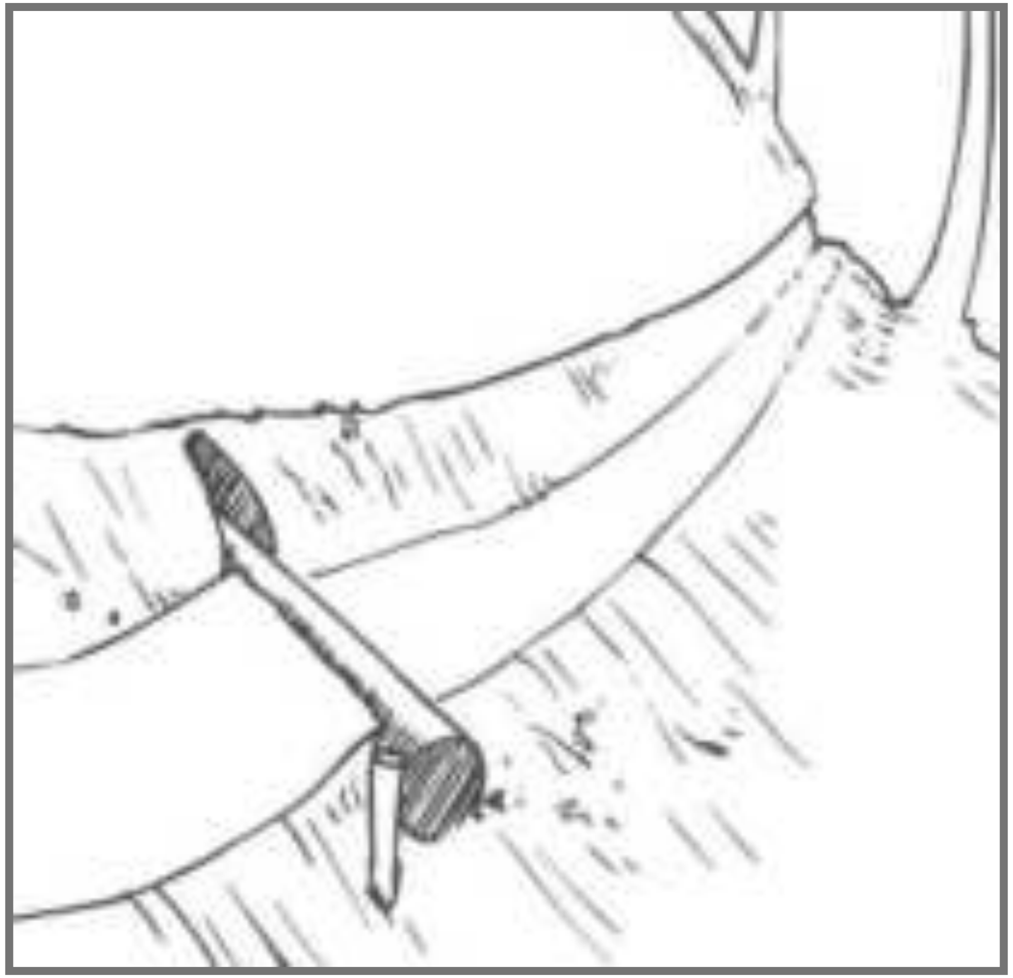


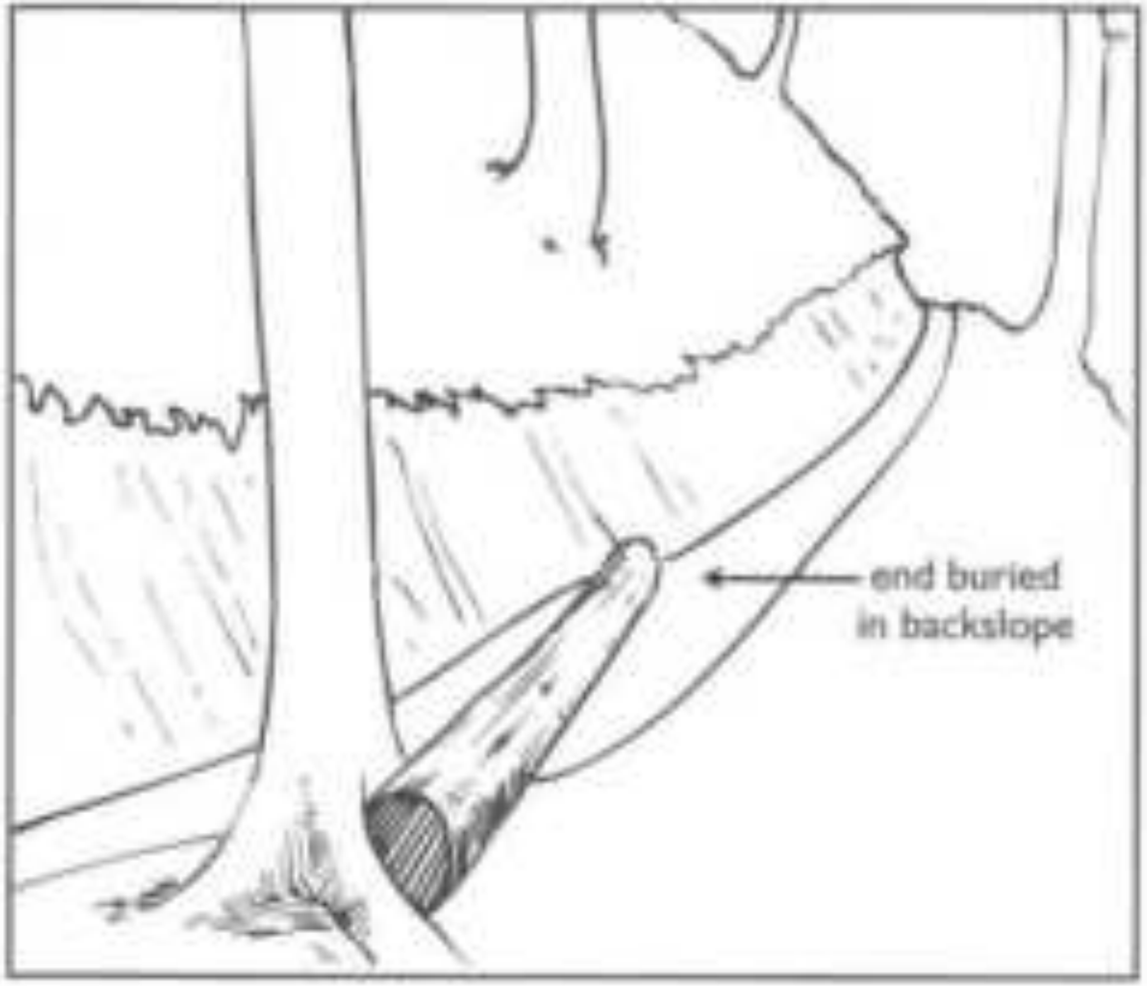
Water Bars (cont.)

- Used to divert water off the trail.
- Erosion control.
- Majority of water diverted by a dip and gravel and dirt mounding in front of the rock itself.
    - Water should only reach the rocks themselves in extreme water event.
- Rocks must be shingled so the water runs with the grain and not against the grain.
- Rocks must extend beyond the trail edge to prevent water going around the waterbar and remaining on the trail.
- Backfill with gravel and dirt, leaving a small 3-4 inch lip.



Log Water Bars





Water Bars

- Example unfinished rock water bar from the BWCAW
- The picture shows shingling from the downhill before the feature was completely backfilled.

Water Bar in the BWCAW

- Pro-Tip: To minimize the amount of backfill needed, dig a trench that results in your waterbar rocks being set are the correct final height, then backfill as necessary. Setting the rocks on top of the existing trail height will necessitate excess backfill.

Water Bar in the BWCAW

- Kekecabic-Strup Portage

Water Bar in the BWCAW

Water Bar transferring water from the in-slope drainage of a Switchback in the Grand Canyon National Park

- Note: This waterbar does not depict proper shingling.


Culverts

Culverts

A culvert is a drainage structure designed to allow water to flow beneath the trail surface.

Their advantage over ditches and water bars is that they do not interrupt the tread, and are unlikely to be disturbed or damaged by hikers

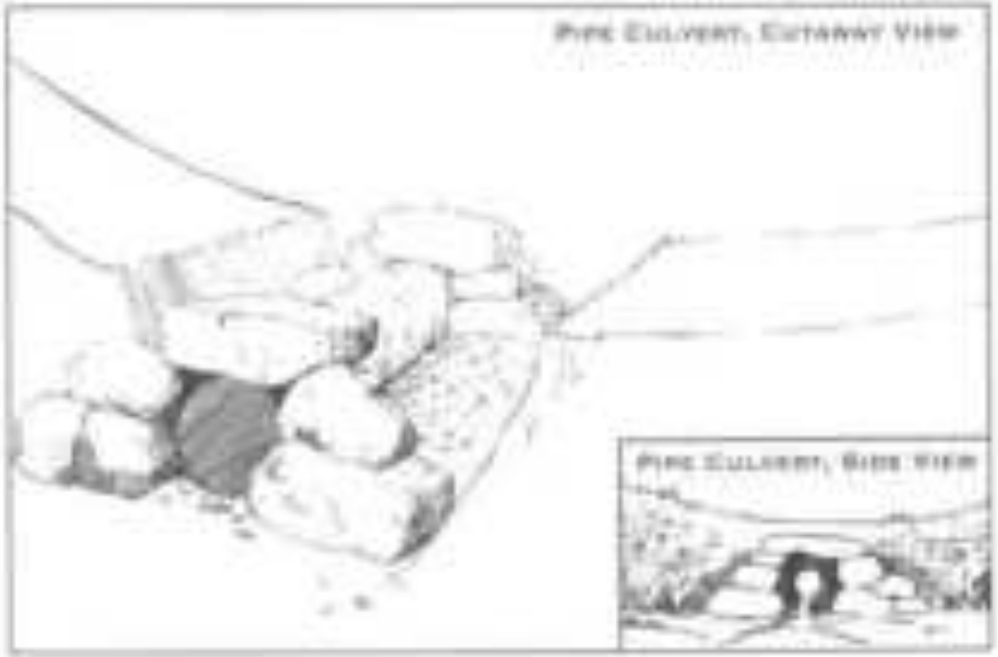
There are essentially three types: pipe, wood, and rock.

(Example Open-Face Culvert with hardened bottom, in the Smoky Mountains National Park)

Pipe Culverts

Pipe Culverts are the easiest type of culvert to build.

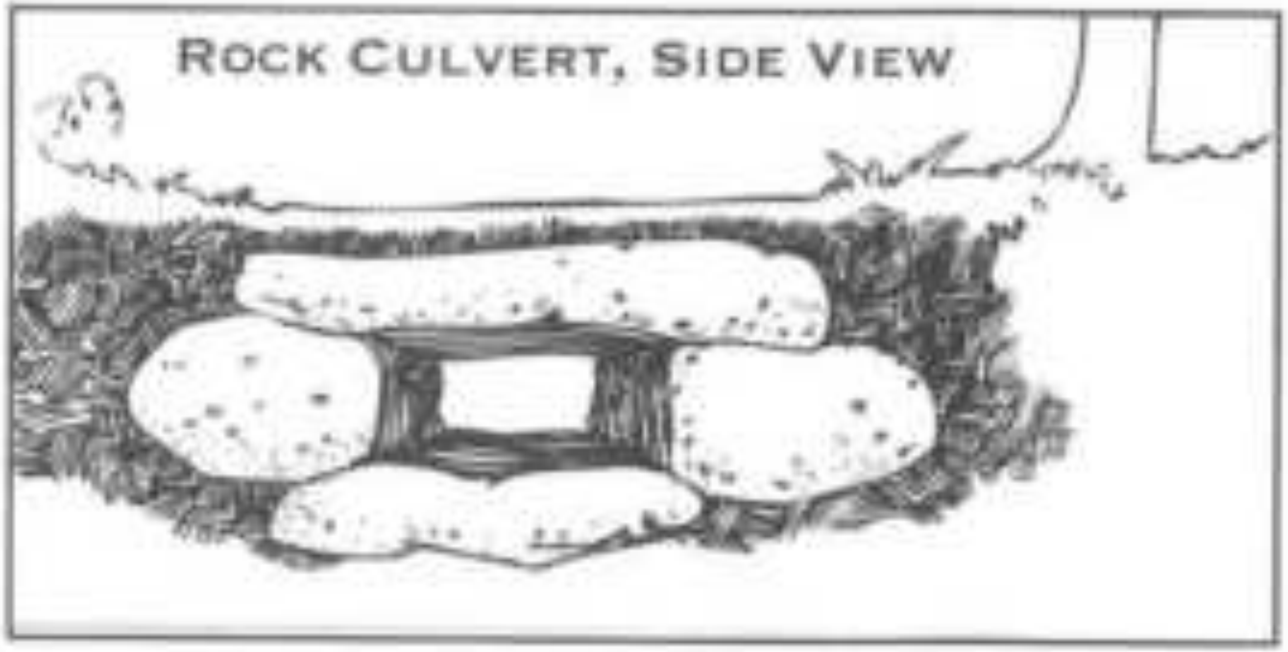
- Cut a pipe to the width of the tread.
- Bury the pipe at least a foot under the tread to protect it from hikers.
- Build a rock facing around the edges of the pipe to keep it in place.
- Plastic is often preferred to metal as it is easier to transport to the worksite and blends in more. Metal piping can be painted to blend in to the surroundings.

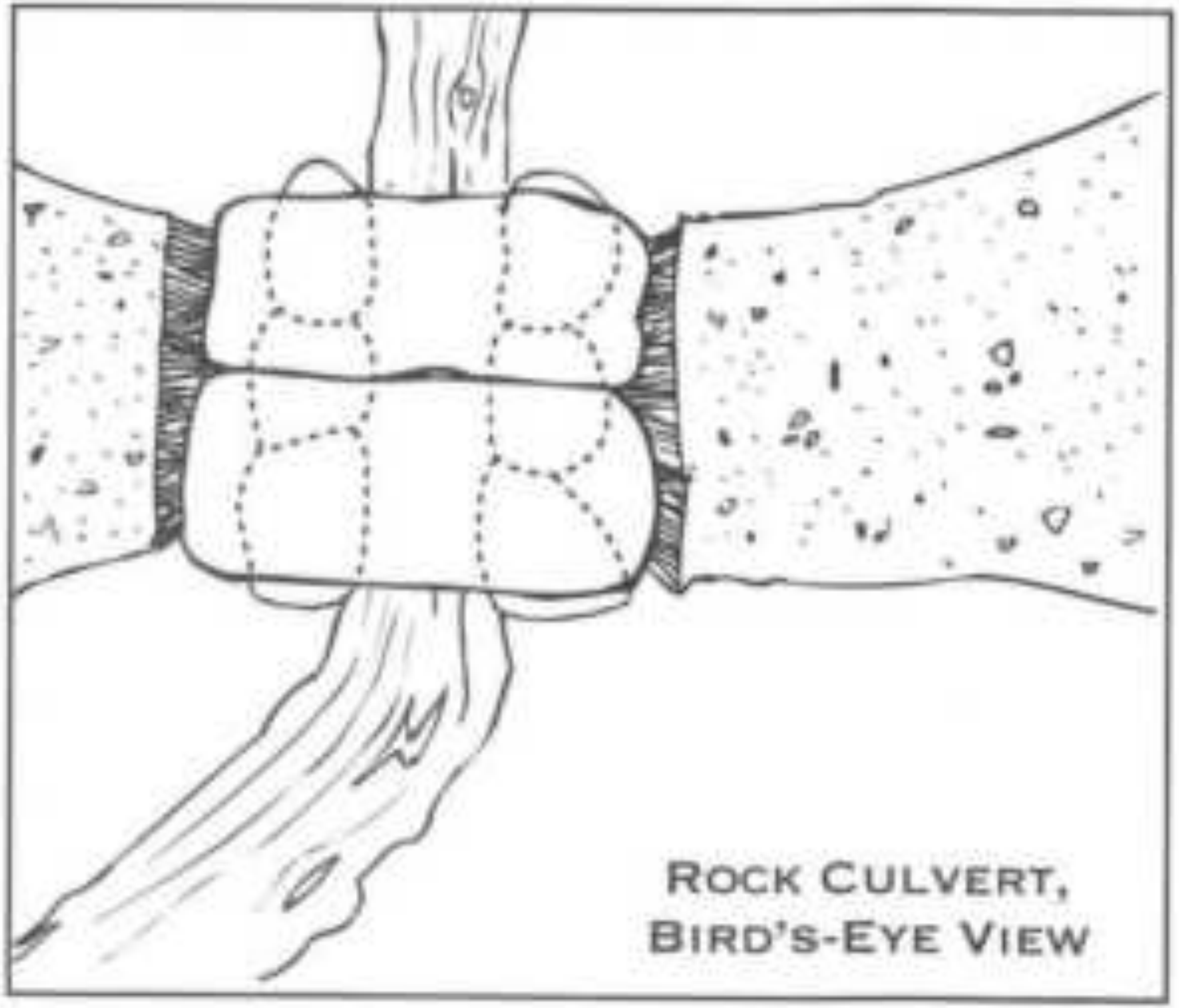


Rock Culverts

Rock Culverts are the most durable variation of culvert, but require large, well-shaped rocks, and can be difficult to construct.

- Begin by laying large flat stones in the trench to form the culvert floor.
- Install large, well-matched stones along the side of the trench, at least a shovel's width apart
- Complete the culvert by spanning the trench with large flat stones

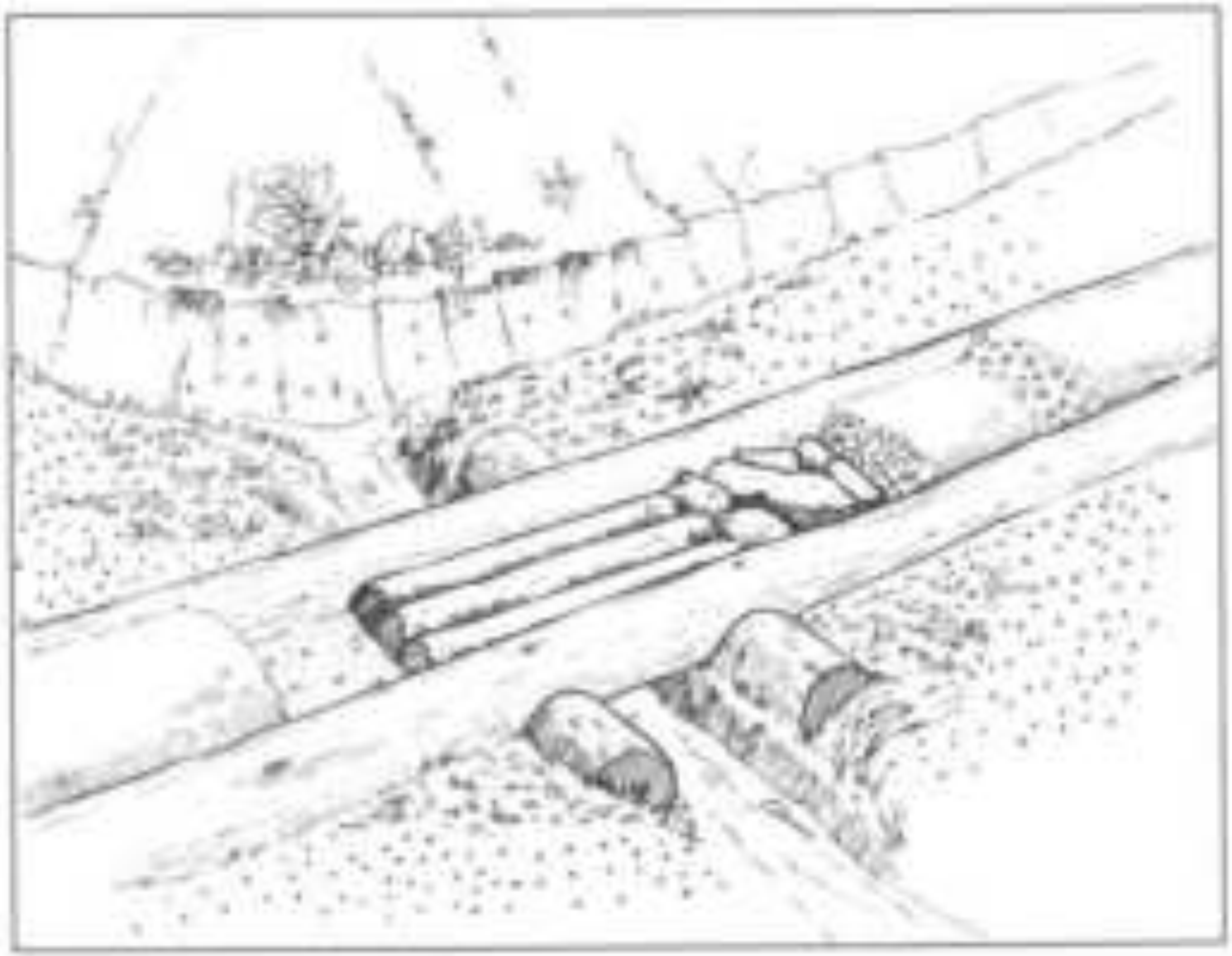



ROCK CULVERT,
BIRD'S-EYE VIEW

Wood Culverts

Culverts can sometimes be made with wood, although this is the least durable material and will need frequent maintenance, due to it's constant contact with water.

- Line each side of the trench with planks at least 4"x12"
- Place planks of similar dimensions spanning the top of the trench.
- Build a rock facing around the edges of the pipe to keep it in place.



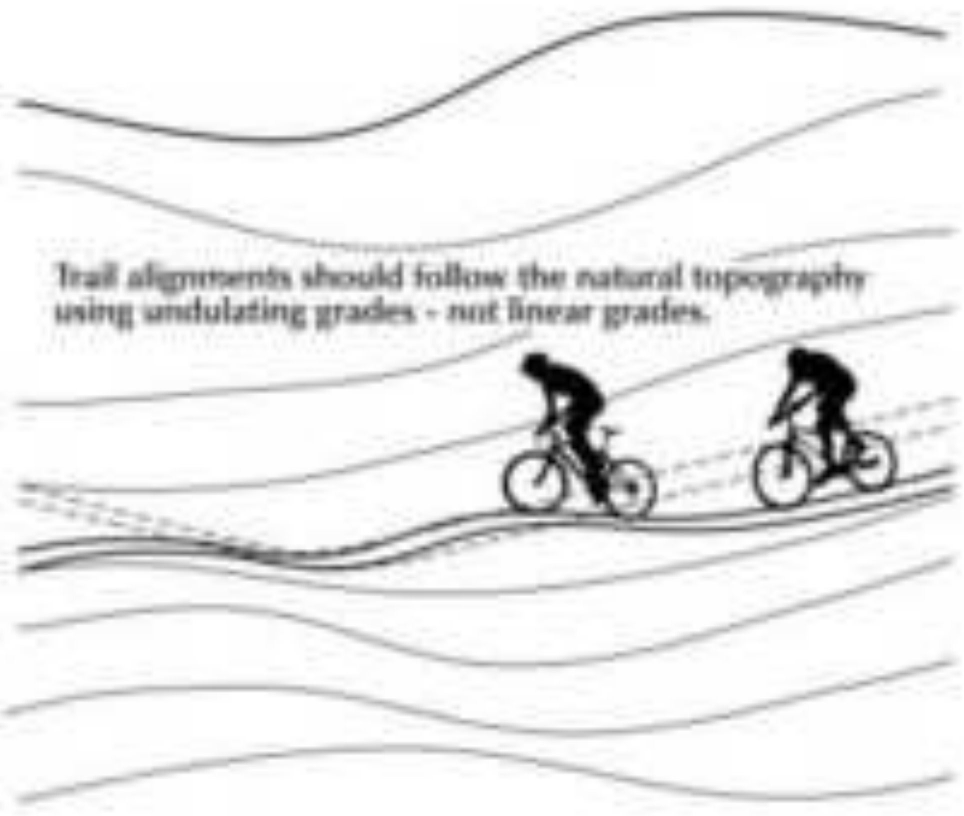
Grade Reversals

Grade Reversals

Grade reversals are a series of changes of the gradient down a hill to control the flow of water.

They are used on downward gradients where trail features like water bars and check dams can't be used. They are most often used for mountain bike trails. They direct water off the trail surface and are self cleaning.

Grade reversals are effective before a water crossing, because they divert water and sediment off the trail before they can reach the stream.

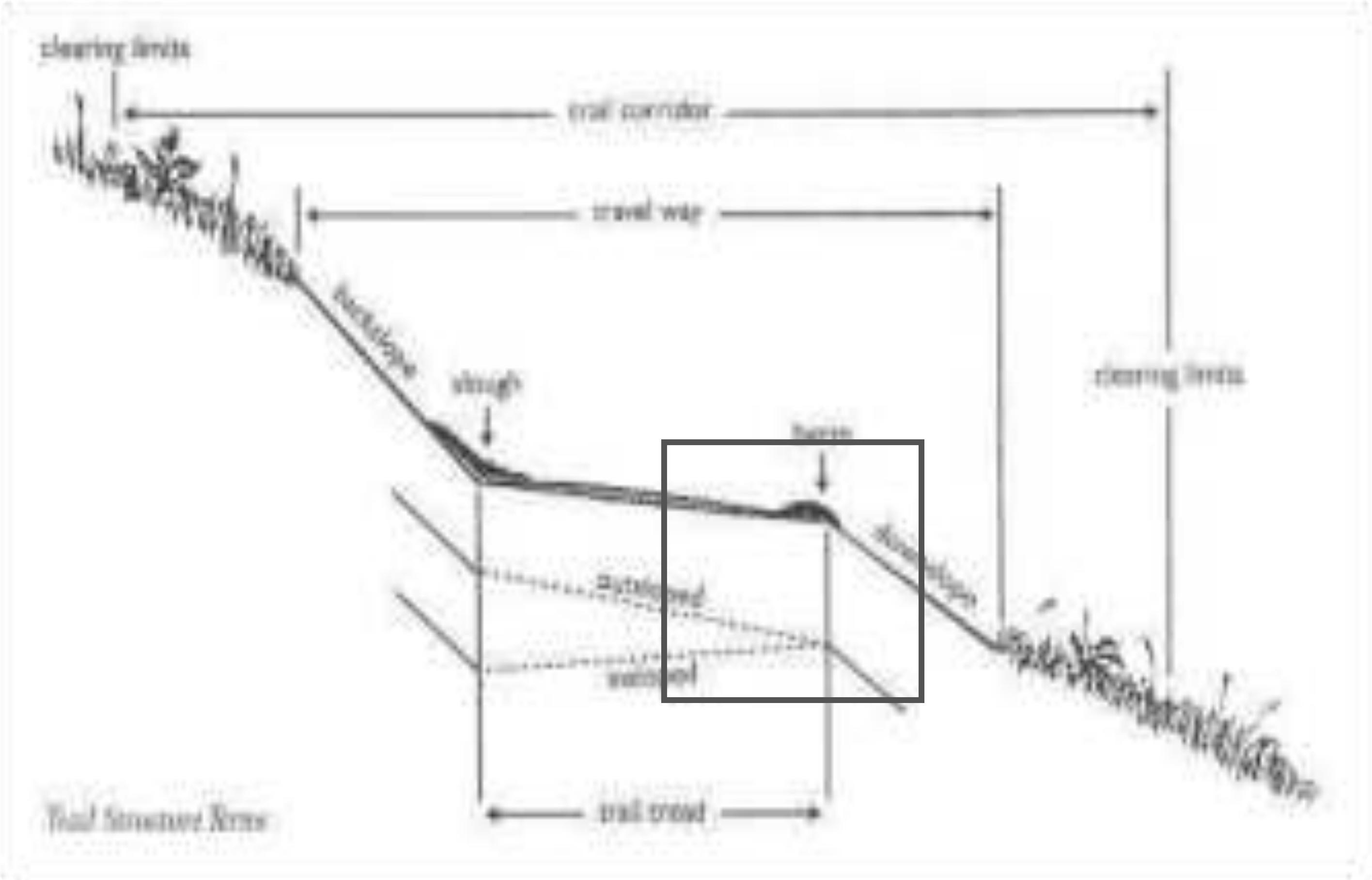


Deberming

Deberming is the act of removing the berm of the trail to regain your outslope so water can flow off the trail.

Debris will build up on the edge of a trail over time, so this will have to be done regularly as part of trail maintenance to ensure the trail features are working as expected.

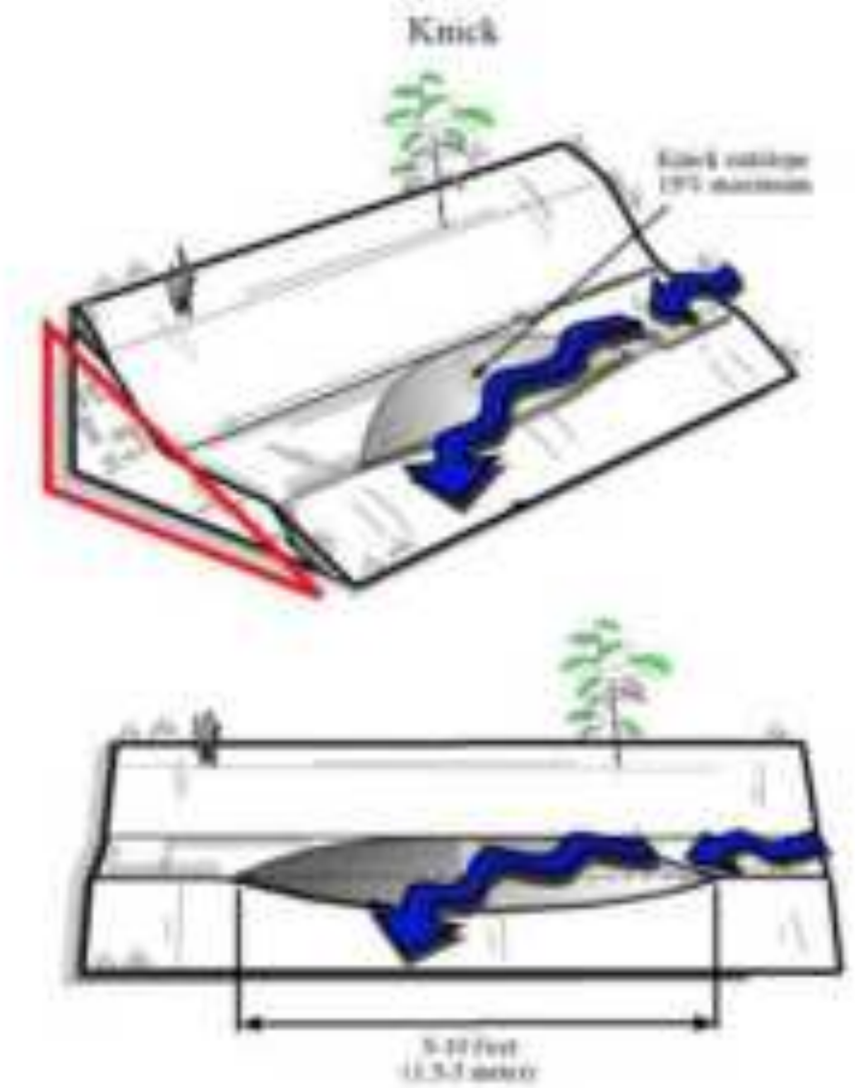
Remove the buildup of material by scraping with a McLeod or Hazel hoe. If the berm is dirt or gravel that came from the trail it is ok to put pull it back onto the trail and tamp down. If it is vegetation, spread it downhill.



<u>Knicks</u>

A knick is a semi-circular, shaved down section of the trail, about 10 feet wide, that is titled to the outslope. A knick should be smooth, subtle, and many users won’t even notice it’s presence.

The center of the knick should be outsloped to about 15 percent to allow water to drain off the trail. For a knick to be effective, there must be lower ground adjacent to the trail so the water has a place to drain.



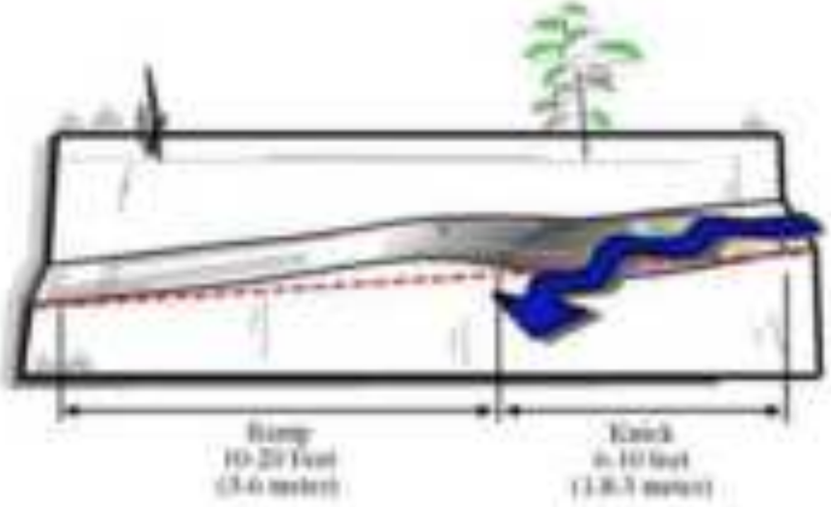
Rolling Grade Dip

A rolling dip is like a knick, but is followed by a long, gently sloped dirt ramp. The dip should be 6-10 feet long, and the material extracted from the dip should be used to build the ramp. The ramp should be 10-20 feet long, depending on the steepness of the tread.

Proper placement of the feature is crucial. You should identify naturally occurring dips and accentuate them with this feature. On steep trails, several rolling grade dips will be needed. You should not use a rolling grade dip on a turn.

If the soil you removed for the knick has too much decomposed granite (e.g. pea gravel) or sand, you will not be able to use it for the ramp, and you will need to source other soil.

Properly built rolling grade dips require little maintenance.



Naturalizing

Naturalizing

Simply put, naturalizing is returning the land around your worksite to its original state.

This is usually a subjective process, but the primary idea is to make it look like the trail is naturally there.

While naturalizing or the restoration of your work area is typically the final process of a project, it is good to keep in mind that (when possible) you should move around the area as to minimally impact the land around your trail. Having set dig sites for dirt, quarry sites for making gravel, or even lunch spots can decrease impact on the immediate area and allow for everything but your trail to become as it was giving trail users a more authentic wilderness experience.

Depending on the impact of your work naturalization can be as simple as spreading sticks and leaves to cover tracks of the crew coming and going off the trail. In most cases the changing of the seasons from Summer to Autumn will be the best possible way to cover tracks of the crew with the falling of leaves. However in some cases, depending on the amount or type of trail work needed there may be additional steps beyond scattering foliage.

Naturalizing (cont.)

Two examples of work requiring more significant naturalization are when building switchbacks/super elevated curves and when working on a trail that has succumbed to "trail creep" over the years.

Switchbacks/Super elevated curves: It is often said that people, like water, will usually take the path of least resistance. When building these features it is common for the area between the trail to get completely torn apart due to the nature of the work.

"Trail Creep": When a trail is originally build without proper drainage it often holds water and users tend to walk around the centerline on dry ground. This causes the trail to widen and over time become giant mud pits making the area lateral to the trail much wider and barren than it should be.

To combat trail users from cutting switchbacks or walking off trail it can be helpful to do a couple things before spreading foliage.

- Place large rocks, logs, stumps, etc… in the open space where someone might wander
- Transplant small bushes/grasses and even trees (depending on space) to help restore the area more quickly while adding a living/growing barrier.
- In open areas, there may even be a need to spread seed of native grasses and plants

Retaining Walls

<u>Retaining Walls</u>

Retaining walls, especially those of the rock variety all serve a common purpose: to hold something.

We will discuss the different types of retaining walls and compare/contrast their uses and where they are most effective.

Top: Smoky Mountains National Park.
Bottom: Grand Canyon National Park

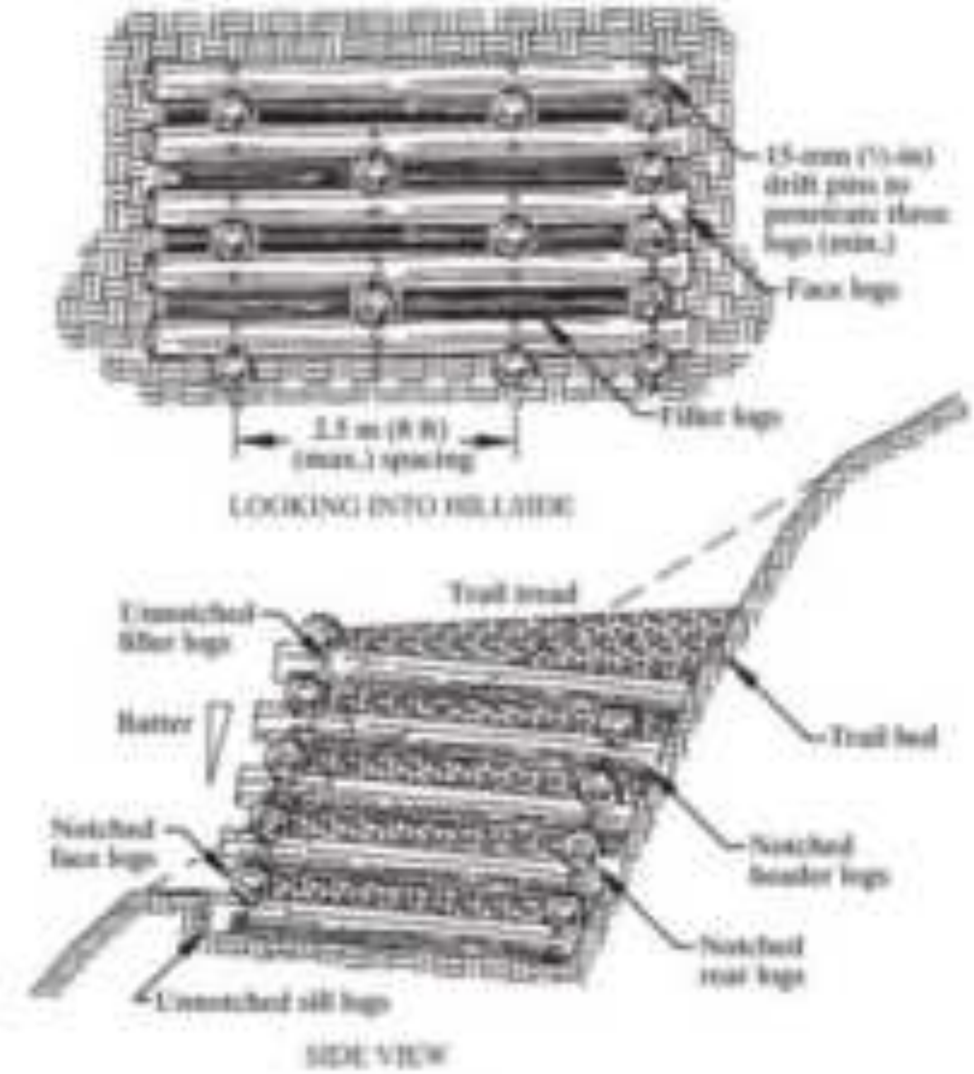
Crib Wall

A crib wall is built when there is nothing to build a trail on. They can be built with logs or rock, but rock is preferred due to it's durability.

Start by digging an inward slope of roughly 16 degrees to start building your crib on.

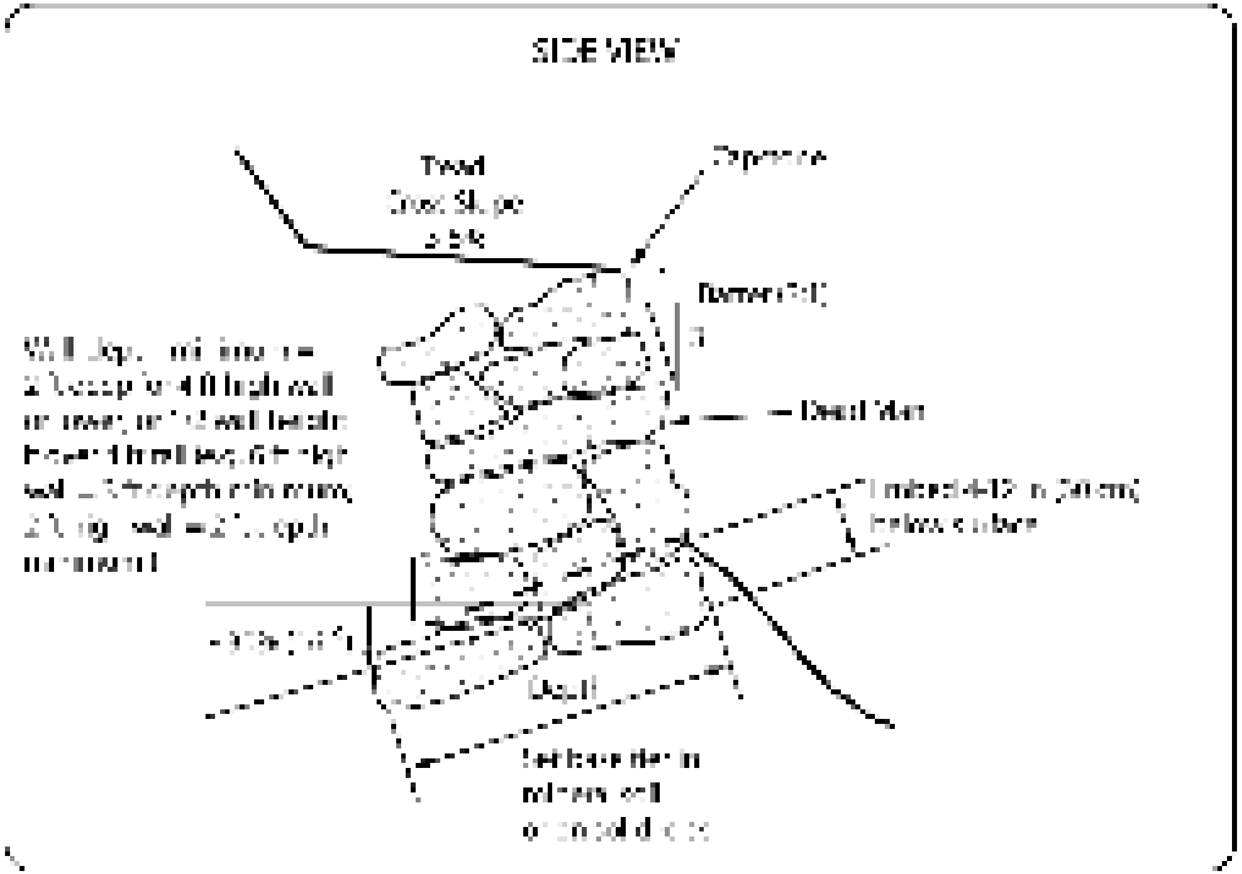
When using logs, you will stack them in a rectangular pattern. Use filler logs if there is more than 8 feet of spacing between logs. Notch the face, rear, and header logs to ensure the structures hold firm.

Fill the structure with rock to allow proper drainage.



Crib Wall (cont.)

When using rock, start the same way as log by digging your in-slope of roughly 16 degrees. Use large rocks for the base, and embed them below the surface. You will also need to set a large 'dead man' stone about halfway up your wall to ensure the smaller rocks below don't slide out. Also be sure to use a large capstone at the top that can withstand the force of the trail tread.



Rock Wall

Simply put, rock walls are a series of rocks set in a layer or many layers in order to hold something back or up. Typically we see rock walls built to hold up the tread of a trail in a small or large area, or even to hold back the upslope in an area so steep that the desired backslope can't be achieved. In rock wall construction there are a few keys to keep in mind:

- Use big rocks when possible. While smaller rocks can be used intermittently throughout a wall, having a base an top layer of larger rocks will help keep everything in place.
- In-slope the foundation. In-sloping allows the rock to sit back into the hillside without the fear of falling out and collapsing the entire wall. Because of how the base is set, the additional layers will also have an in-sloped pitch.

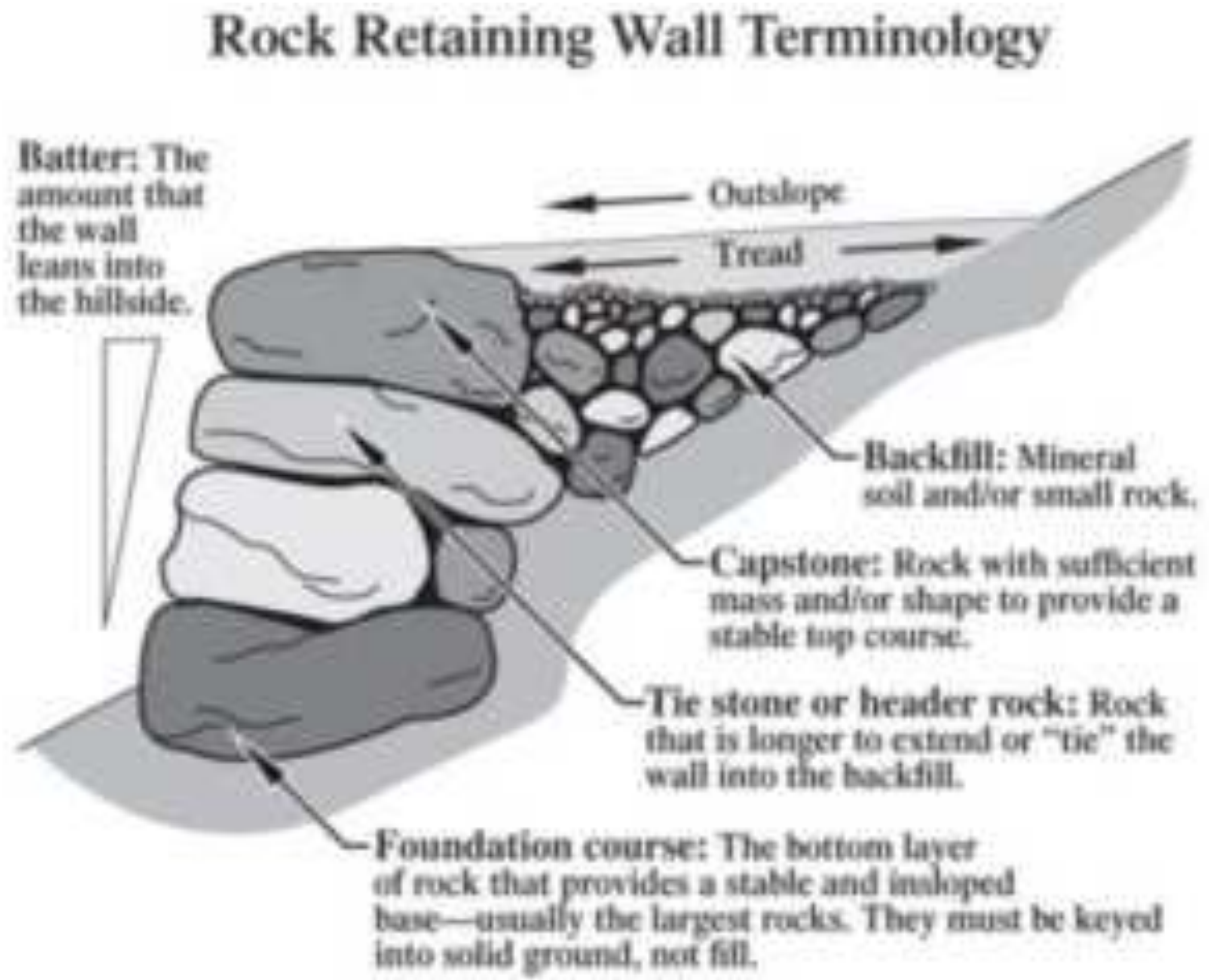
(Example Rock Wall in progress at Philmont Scout Ranch)

Rock Wall

- Each tier of rocks should "break the joints" of the rocks below, like a brick wall there shouldn't be joints that aren't covered by the next tier.
- Backfill the wall with large and small rocks, not forgetting to tamp along the way to help settle the material. For taller walls it is a good idea to backfill as you go. As long as rocks are set so they wont roll out of the front of the wall, the fill material will keep them from collapsing back into the wall.
- Regardless of wall height, the final layer should be set in a ways that the rocks aren't easily dislodged. A good rule of thumb is to test each rock for stability before setting the next layer. This will keep you from possibly having any weak links.

(Example Rock Wall in progress at Philmont Scout Ranch)

Rock Wall (cont.)



Wire Basket

A wire basket, or Gabon, is a retaining wall built with a metal cage filled with rock, concrete, or sometimes sand or soil. The wire frame contributes a very good building block to use to construct a wall without the difficultly presented by differently shaped boulders.

Retaining Wall BNRTC

- Video of retaining walls at the Buffalo National River Trail Crew
- https://www.dropbox.com/s/veopjax6b4e6v44/IMG_0817.MOV?dl=0
- https://www.dropbox.com/s/ilciqb81l0r9hae/IMG_0798.MOV?dl=0

Steps

Steps

Steps are the best feature to use when there are steep sections of trail that require significant climbing without the option of rerouting with switchbacks where the grade is too steep to be sustainable without some feature.

Similar to check dams steps can help to slow and control the flow of water in areas with bad drainage/runoff however that is not their primary purpose.

Depending on resources available steps can be made of stone or wood, but you must ensure the step is set properly as to not be easily kicked out my users of the trail.

(Example stone steps in the Smoky Mountains National Park).

Steps (cont.)

Building steps:

- Be sure to clear all organic material up the length and width of the trail requiring steps.
- Start your steps at the lowest point of the trail so that as you place a step you build your way up without compromising the stability of any steps above.
- Maximum rise of ten inches (10”).
- Using rocks or debarked logs, check that your material spans the width of the trail and gives an even surface area for the trail users. When setting the step the rock(s) or logs need to be laid in a way that keeps them from being kicked out of place by an impact of a trail user. It is good to have the weight of the rock laying into the trail which will then be backfilled and strengthened even more.

Steps (cont.)

Building steps (cont.):

- Backfill your steps with rock/gravel and once build up close to walking level, add layers of dirt. Be sure to tamp the area after each back filled layer is added to ensure settling allowing the dirt and small rocks to sit in a concrete-like layer giving stability to the tread. In some cases where you have correct materials, large enough rocks are able to completely make up the steps without needing to backfill any space. When possible a solid rock staircase is preferable as it will be more stable over time.

Steps (cont.)

A few questions to consider before putting in steps:

- Is this feature necessary or would fewer check dams and water bars work?
- What is the primary use of the trail? Cyclists and horseback riders may not be able to navigate up or down the feature
- Do I have enough of the rock or log material to create a series of steps? Especially if the climb is very long and appropriate sized rocks are in short supply.
- Could I reroute this with switchbacks to achieve the climb with erosion as less of a factor? In some places like the Boundary Waters trails have to be straight for portaging canoes.

Good and Bad examples of Steps

- Properly set logs that were backfilled to form steps. This was a well thought out (Smoky Mountains National Park).

- Wooden blocks haphazardly staked into the ground with rebar. Organic material was not removed, nor the ground graded to properly accommodate these steps resulting in an unusable trail.

Turnpikes

Turnpikes

A turnpike is used to elevate the trail tread above the saturate soil. They are often used in wet, low laying areas.

Turnpikes are labor and material intensive, so it might be best to reroute the trail to higher and drier ground than to build a turnpike.

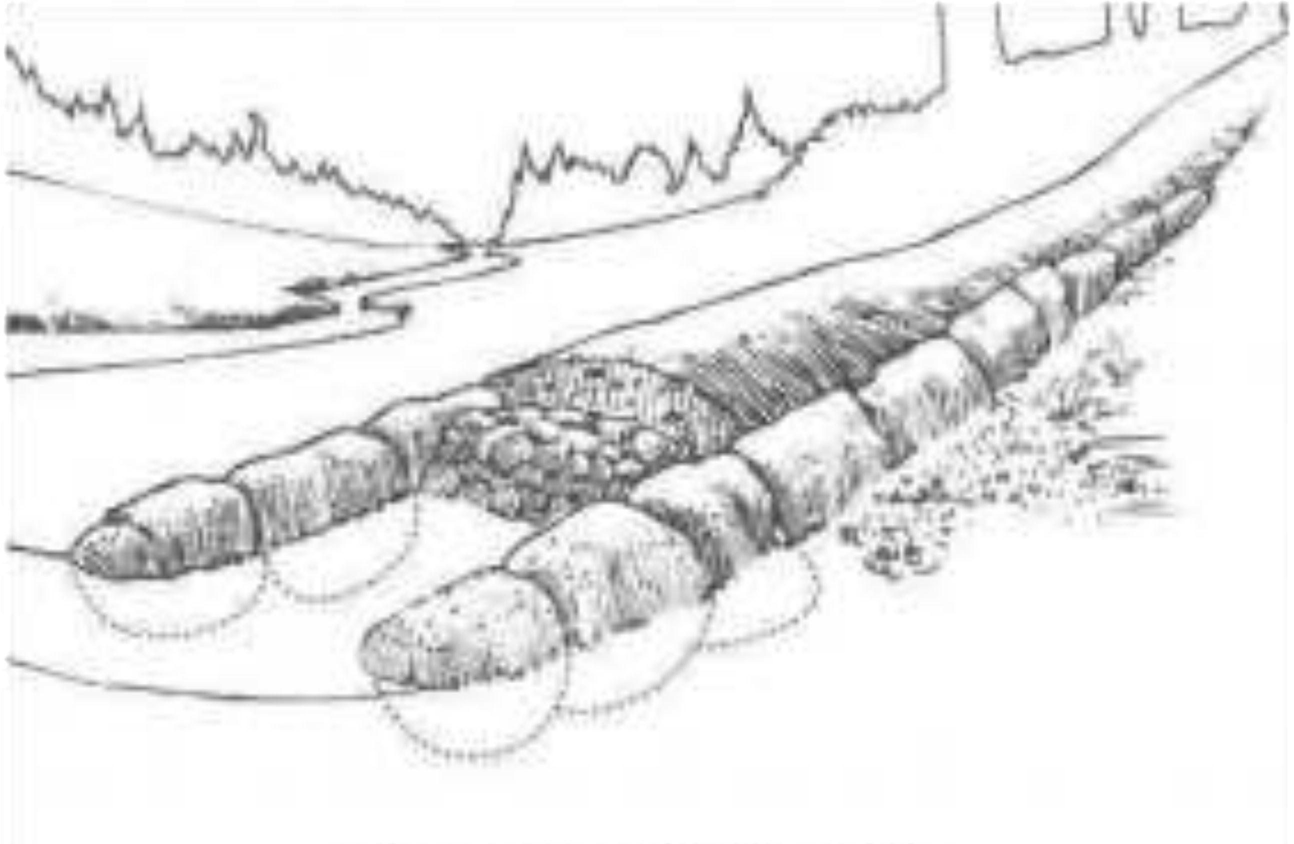
Start by setting a large rock, referred to as a "cap stone" at the start of your turnpike. Large ” retainer” rocks should be used along the length of the turnpike. Keep the desired width of the turnpike in mind when setting the edge rocks, being careful not to set them too far apart.

Pro-Tip: Crest to Crest of your retainer rocks or logs should be your desired tread width (not from inside retainer to insider retainer).

Turnpikes (cont.)

Pay careful attention while setting side retaining rocks to ensure there is as little space as possible between them. They should be considered ‘set’ when you are able to dance on top of them without them moving. Proceed with placing rocks on each side until you reach the end, then cap off the turnpike with another ‘cap stone’.

Now you are able to fill in the turnpike. You will use progressively smaller rocks as you fill it in. Start with softball sized rocks, then baseball, then golf ball, then gravel, and then fine finishing gravel. Lastly, top the trail with dirt to create a rounded ‘crown’ top, which will shed water off the turnpike.



ROCK TURNPIKE, CUTAWAY VIEW

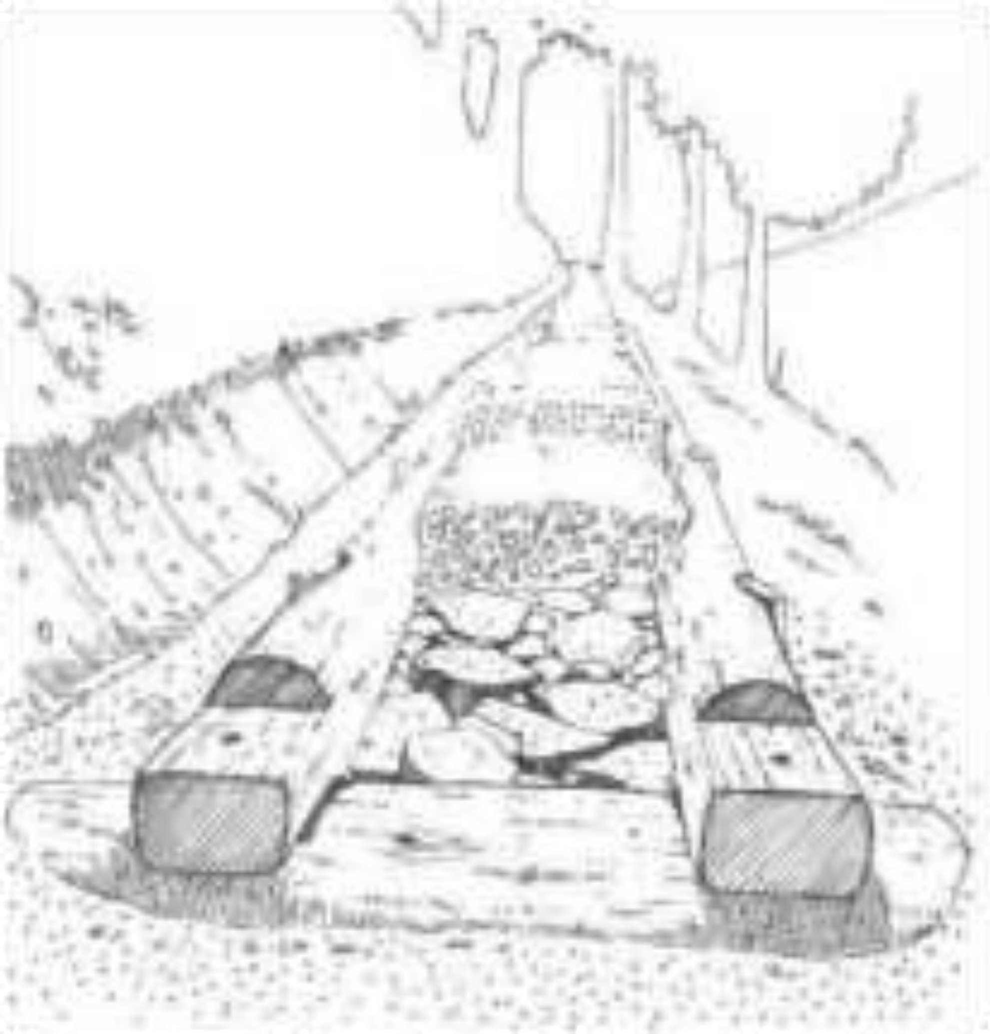
Turnpikes (cont.)

Turnpikes can also be made out of logs that have been peeled and are at least 10 inches in diameter.

Dig them partly into the ground, then insert a series of wooden peeled stakes on each side. Stakes should be staked angled into the logs, so that the stakes bite into the log and resist outward pressure.

If placing a log turnpike into a particularly moist location, consider placing sills under the logs at each end. You can place several log together end-to-end to construct longer turnpikes.

You fill a log turnpike the same as if it were a stone one.



Turnpike (cont.)

- Example #1
- Before
- Birch-Frog Portage (BWCAW)

Turnpike (cont.)

- Example #1
- Birch-Frog Portage (BWCAW)
- Culvert end-cap in place.

<u>Turnpike (cont.)</u>

- Example #1
- Birch-Frog Portage (BWCAW)
- Retainer rocks set.
- 1st Layer (football to softball rocks) in place.
- 2nd Layer (golf ball rocks) in place.
- Light gravelling in place.

Turnpike (cont.)

- Example #1
- Birch-Frog Portage (BWCAW)
- All gravelling in place.



Turnpike (cont.)

- Example #1
- Birch-Frog Portage (BWCAW)
- Dirt in place.
- Completed.
- Immediate Post-Work

Turnpike (cont.)

- Example #1
- Birch-Frog Portage
- 5 years later

Turnpike (cont.)

- Example #1
- Birch-Frog Portage (BWCAW)
- 12 years later

Turnpike (cont.)

- Example #1
- Birch-Frog Portage (BWCAW)
- 12 years later

Turnpike (cont.)

- Example #1
- Birch-Frog Portage
- 12 years later

Turnpike (cont.)

- Example #2
- Knife-Vera Portage (BWCAW)
- Pre-work

Turnpike (cont.)

- Example #2
- Knife-
  Vera Portage (BWCAW)
- Retainer logs skinned and set (staked).
- 1st Layer (football to softball rocks) in place.
- 2nd Layer (golf ball rocks) in place.

Turnpike (cont.)

- Example #2
- Knife-Vera Portage (BWCAW)
- Gravel in place.

Turnpike (cont.)

- Example #2
- Knife-Vera Portage (BWCAW)
- Dirt in place.
- Immediate Post-Work

Turnpike (cont.)

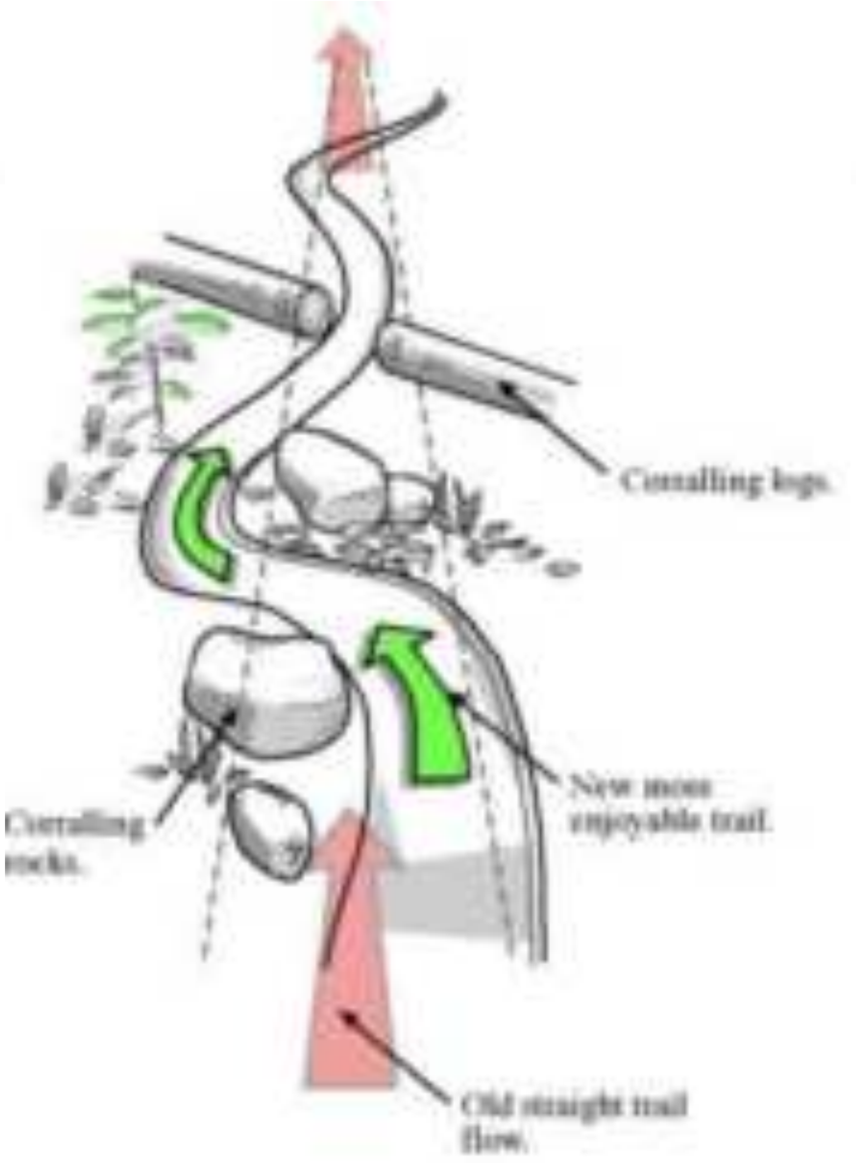
- Example #2
- Knife-Vera Portage (BWCAW)
- 8 years later

Building Turns

Corralling, Chokes, and Turns

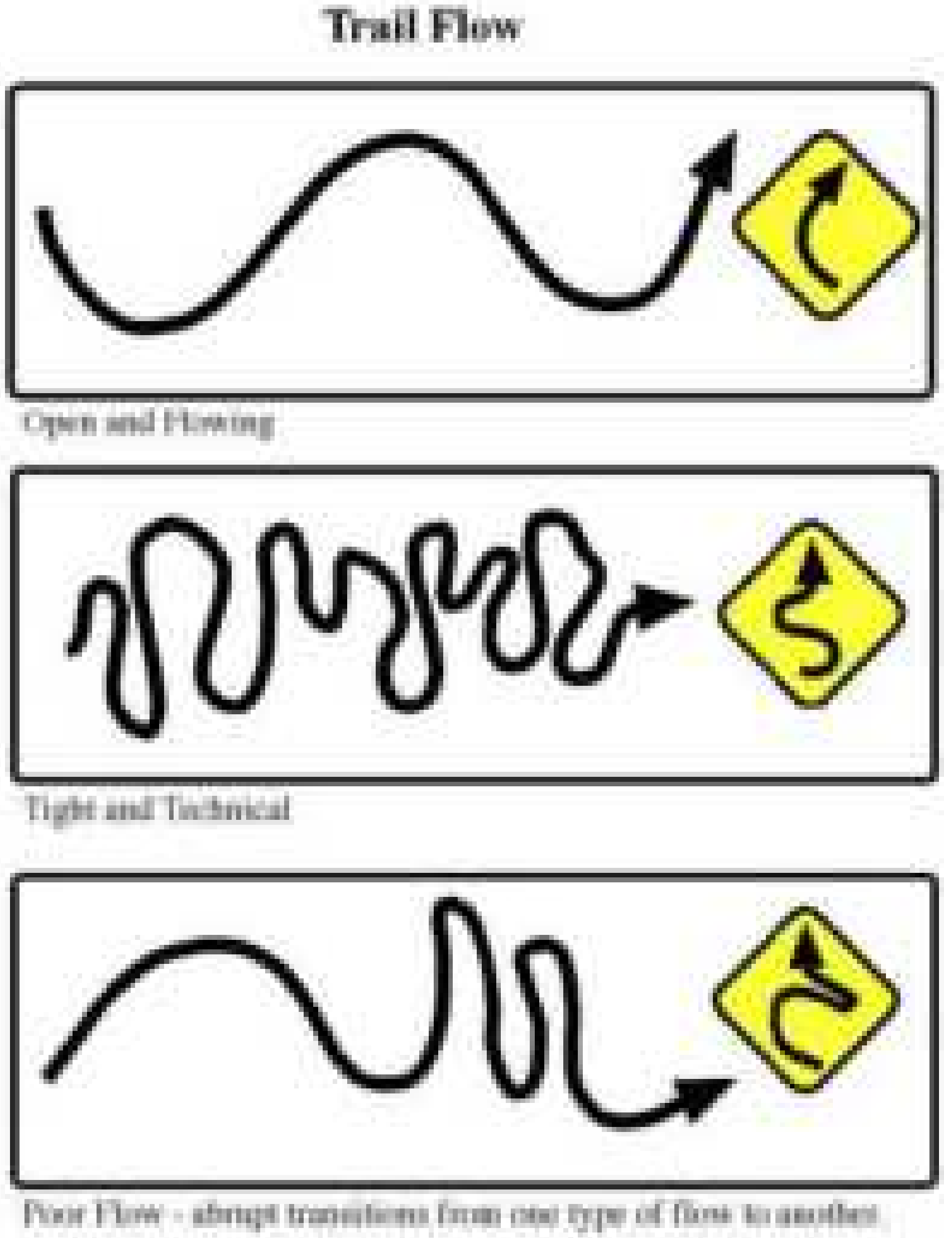
Include objects to define the sides of the trail and emphasize turns. Also called trail anchors, these can be large rocks, logs, trees, or other obstacles staggered on either side of the trail that serve as physical and visual barriers to keep users on the trail and slow riders.

Create a slight narrowing of the trail with rocks or plants to control speed. Also called gateways, these should be installed just prior to spots in the trail where users need to slow down, such as sharp turns or intersections. Chokes encourage riders to gradually apply their brakes well in advance of sensitive areas. Make sure the narrowing flows naturally with the trail. Otherwise users may find a way around it.

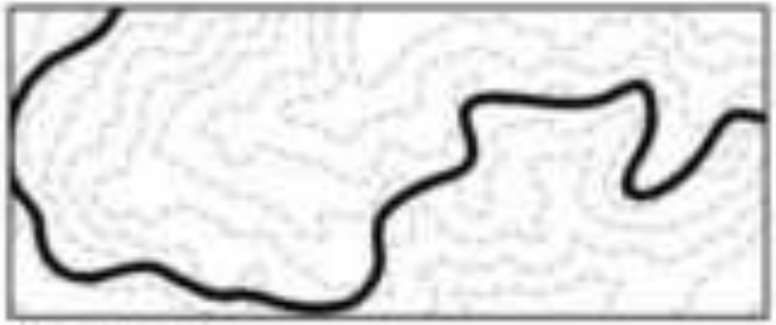


Trail Flow

You can also build a tight and twisty trail, with constant ups and downs, lefts and rights. Since trail users must stay focused on always-changing trail, they feel like they are going faster than they actually are. A tight and twisty single-track gives the illusion of speed without allowing trail users to actually go very fast. Always create gradual transitions between changes to trail flow.

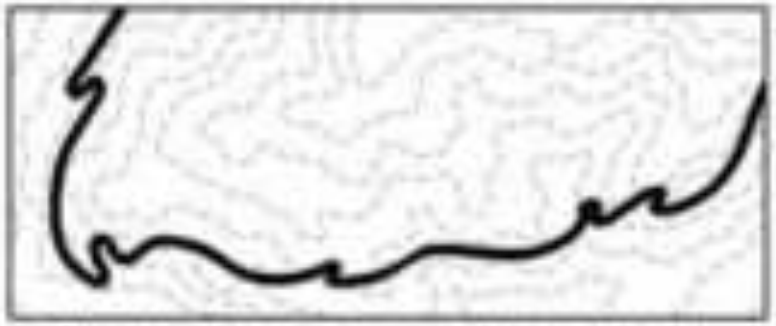


TRAIL FLOW



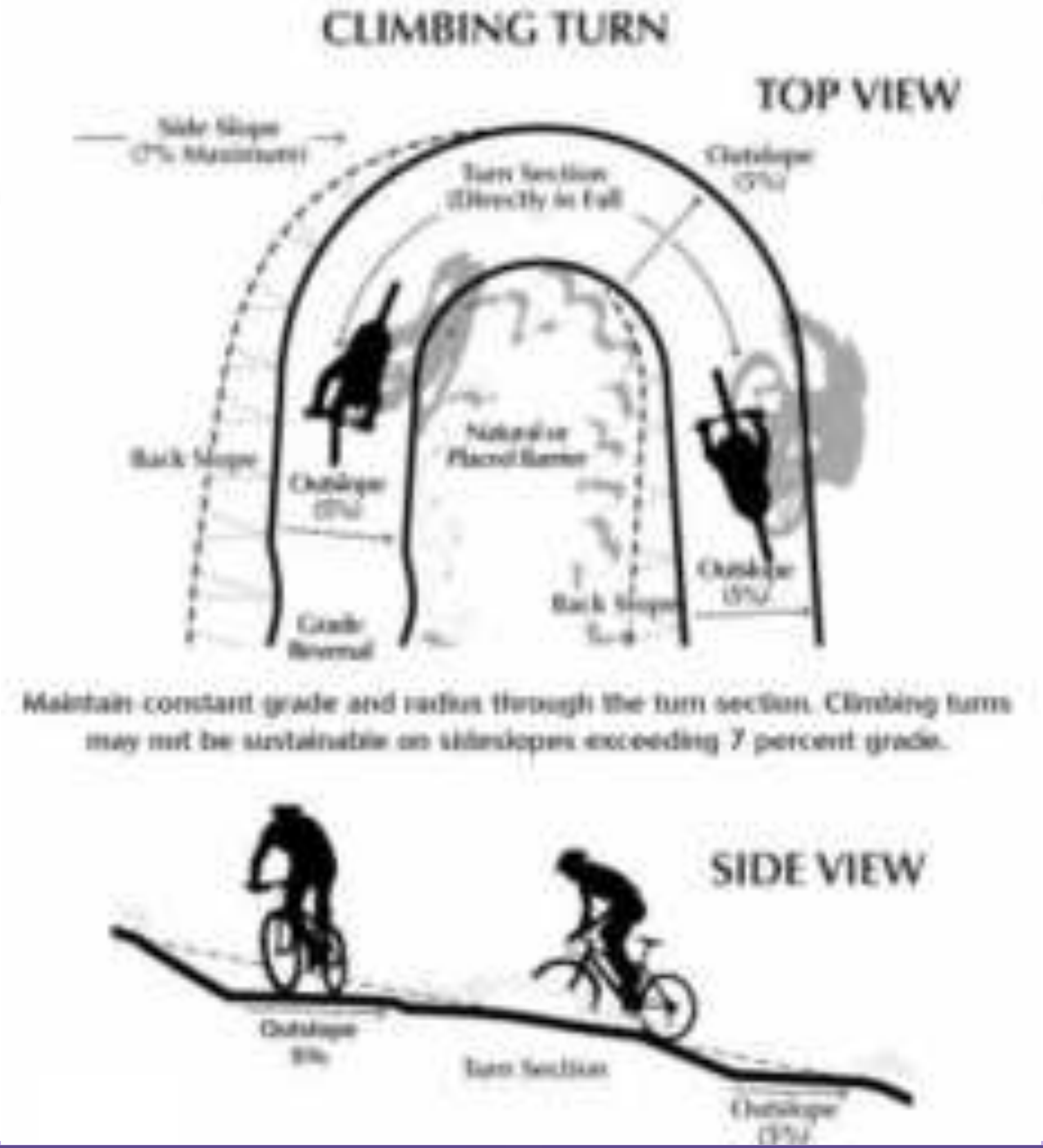
Open and flowing

Tight and Technical



Poor Design - Abrupt transitions from one type of design to another.

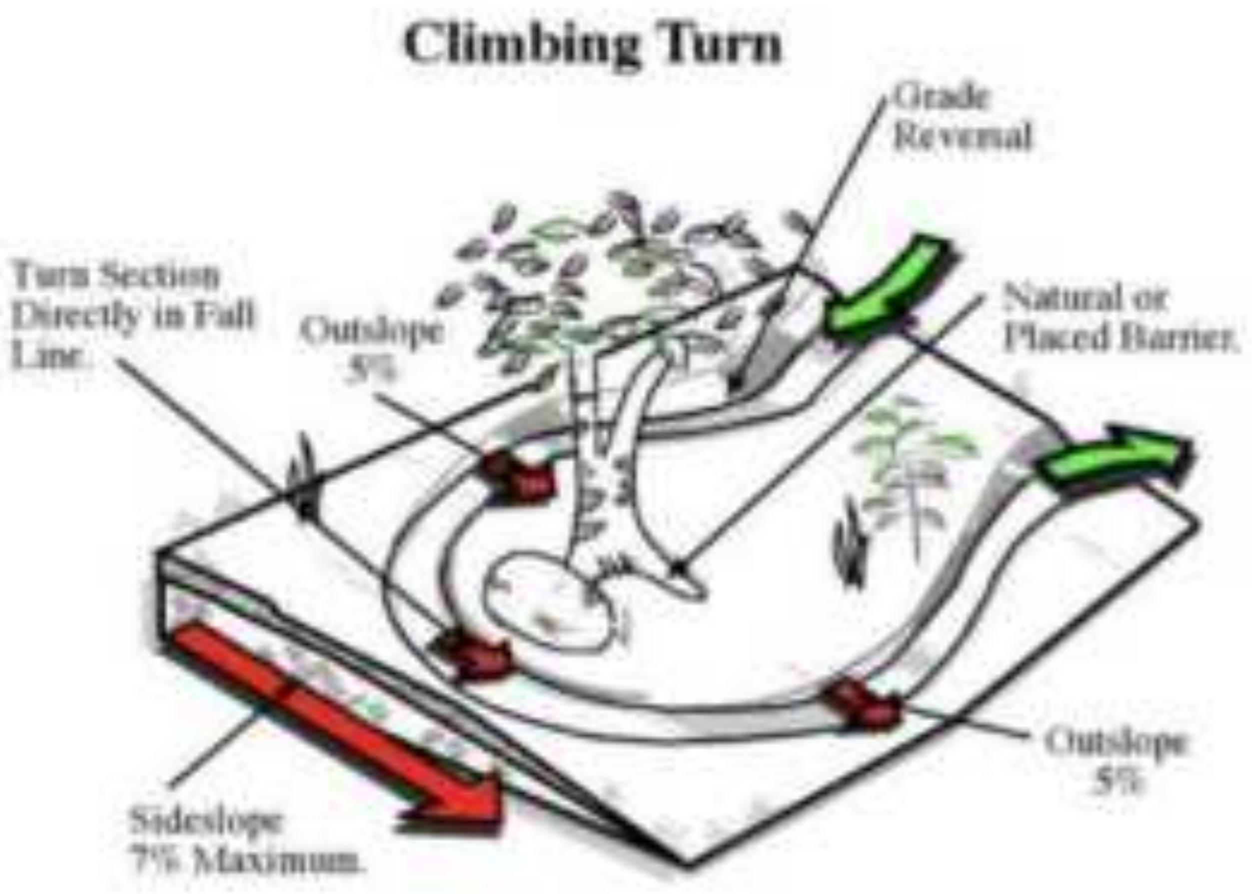
Stacked Loop trail System


CLIMBING TURN
TOP VIEW
Side Slope
(7% Maximum)
Turn Section
(Directly in Fall)
Outslope
(5%)
Back Slope
Outslope
(5%)
Natural or
Placed Barrier
Outslope
(5%)
Back Slope
Grade
Reversal
Maintain constant grade and radius through the turn section. Climbing turns may not be sustainable on sideslopes exceeding 7 percent grade.
SIDE VIEW
Outslope
5%
Turn Section
Outslope
(5%)

Climbing Turns

Climbing Turns should be built on shallow slopes of 7 percent or less. Climbing turns should be slowing and gentle to controls cyclists' speed and prevent skidding. Turns should be as wide as possible at 20-foot radius or more (and never less than 13-foot radius).

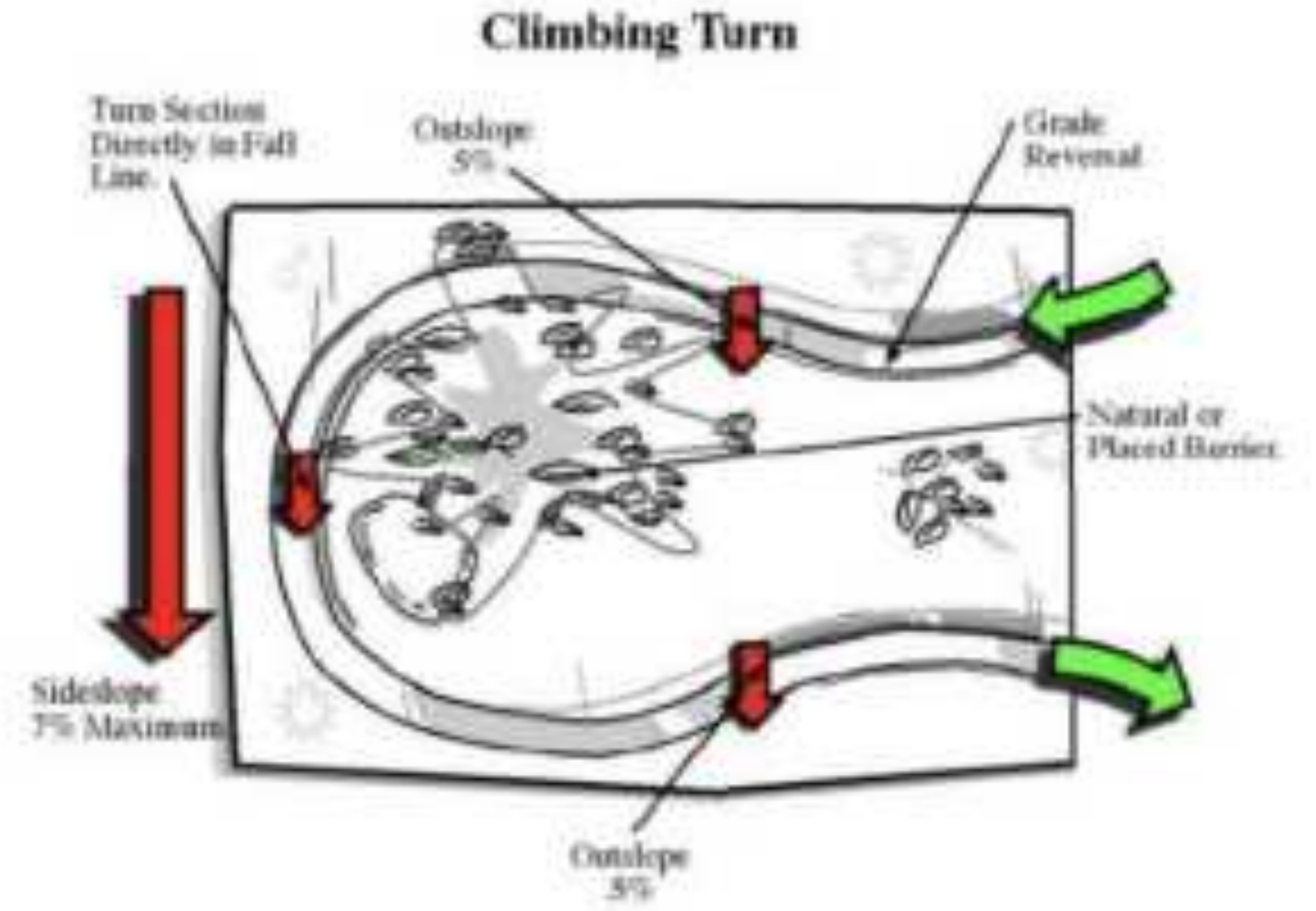
A common mistake in trail building is trying to construct a climbing turn on side-slopes that are too steep. Trail users descending through the turn are forced into the steep fall line. The braking action of feet and tires loosen the soil. Gravity and water removes the loosened soil and create a rutted damaged tread. This, in turn, causes trail users to avoid the damaged section of trail and may lead to trail widening or shortcutting.



Climbing Turns (cont.)

It is important to locate grade reversal just above the turn. The grade reversal diverts theater off the trail before it reaches the fall line section of the turn, and adding a choke point prior to the turn to slow riders down before they approach the turn.

Remember, if you want your climbing turn to endure the test of time, make sure the slide slopes are 7 percent or less. If the side slopes are steeper than 7 percent, it's time to build a switchback instead.



“Demon Drop” Super Elevated Curve at the BNRTC

BRNTC 2017

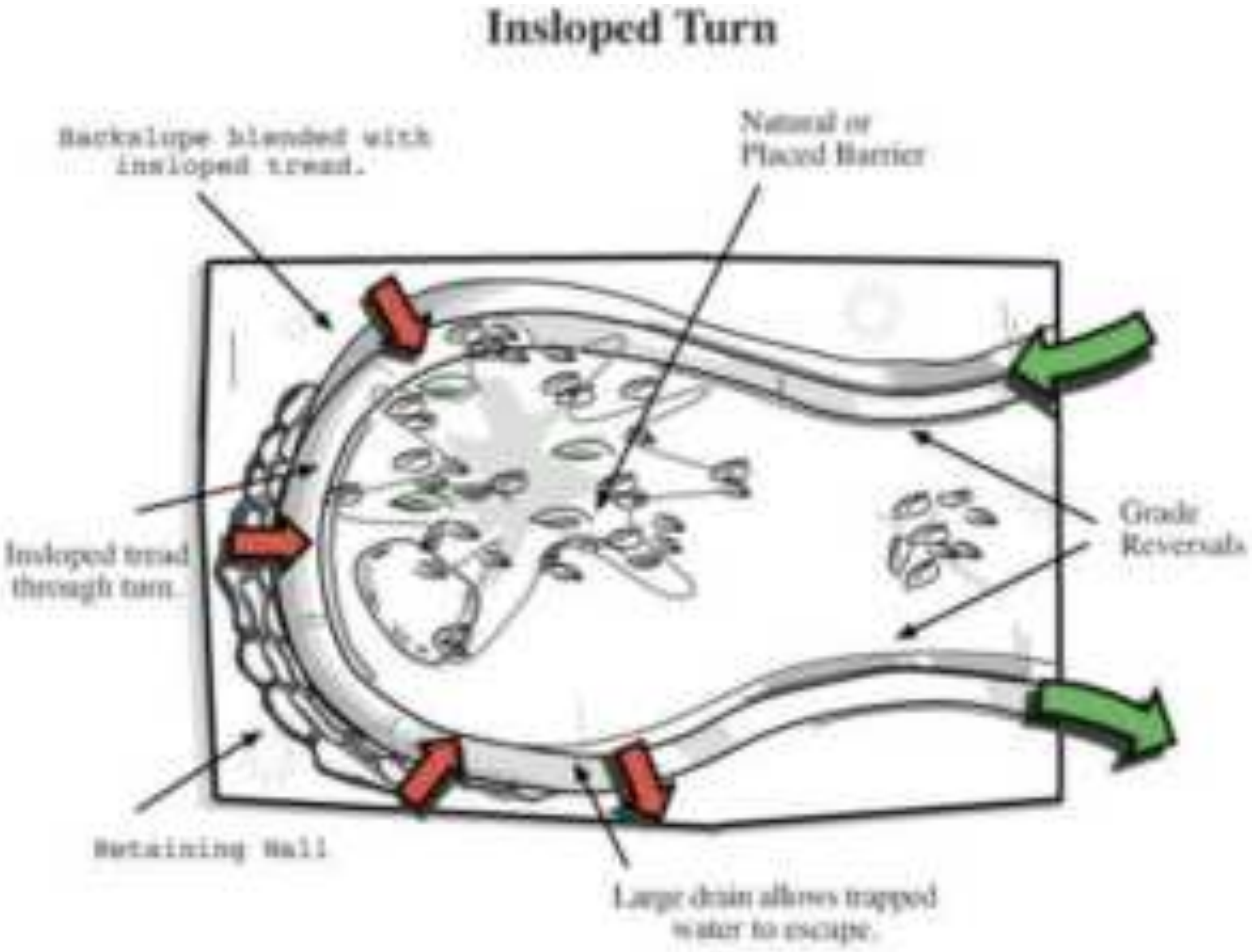
In-sloped Turns

Flat or out-sloped corners can be prone to ruts, widening, and tread creep from riders traveling to the outside corner and skipping to control speed and change direction.

Adding an in-slope to the corner can help keep riders within the tread and provide additional control for turning. Berm on the corner should not exceed two feet above tread level.

The in-sloped wall of the turn takes advantage of gravity and centripetal force to direct the user to the inner bank of the trail, helping to reduce the need to slow down and turn sharply.

In-sloped turns should not be used when the cross-slope grade exceeds 10% .



Backfilling an In-Sloped / Super Elevated Curve

BRNTC 2017

Backfilling a Super Elevated Curve

BRNTC 2017

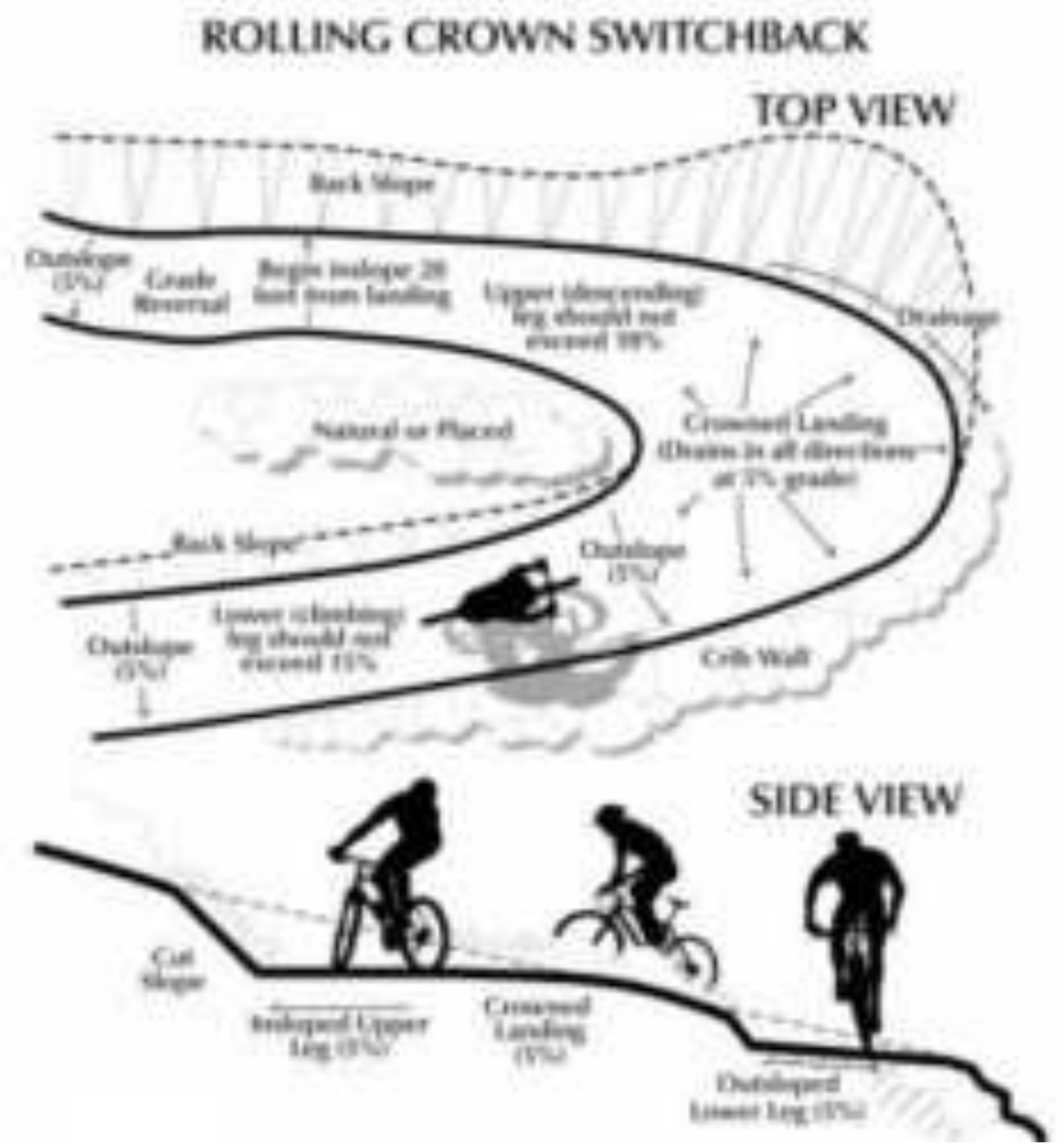
“The Shoots” Super Elevated Curve at the BNRTC

BRNTC 2017

Switchbacks

A Switchback reverses trail direction on a reasonably level built landing. Switchbacks are more difficult to build, but are more sustainable on steep sideslopes than climbing turns. On a switchback, users are not forced to turn direction on a fall line.

Instead, they can turn on a level platform. It is recommended to use a version called a Rolling Crown Switchback. It is carefully engineered for proper drainage.

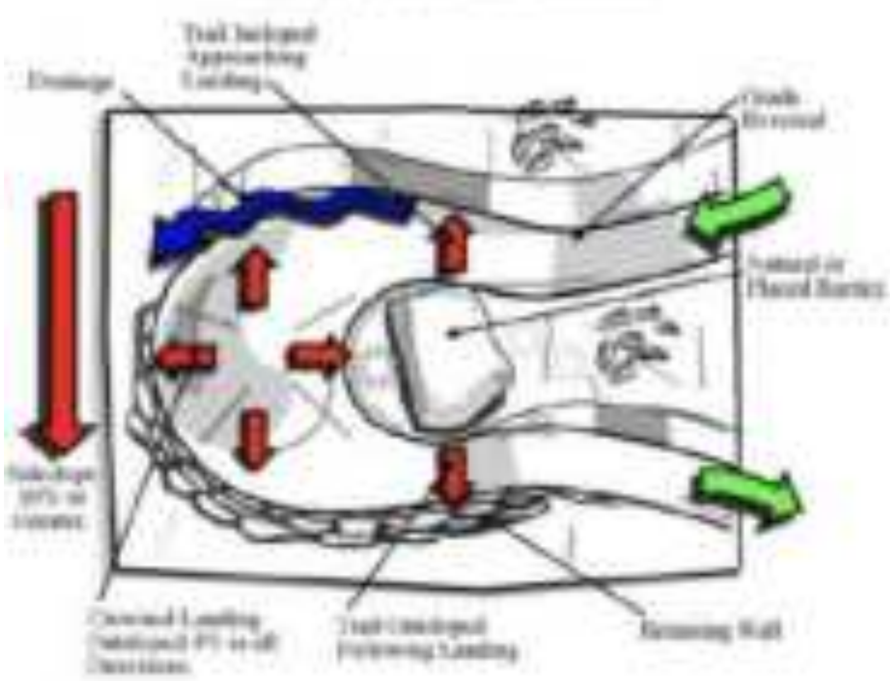


Switchbacks in the Grand Canyon

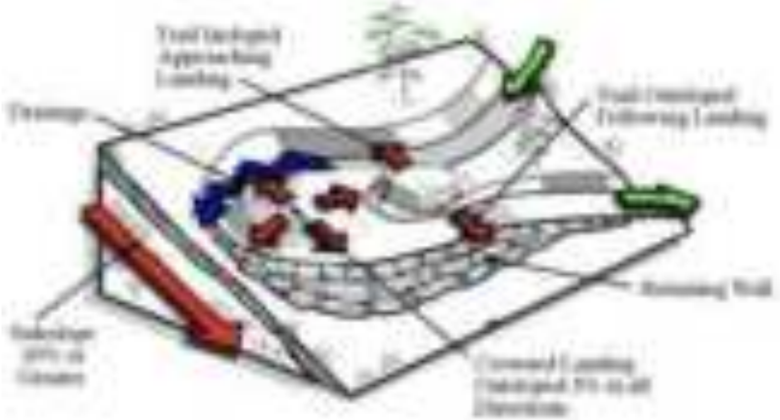
Key Features of a Rolling Crown Switchback

- Consider switch locations as control points
- Water drains from all sides of the turn.
- Turns occur on near-level platforms that are slightly crowned
- The trail stays on the contour on both approaches
- Bench cuts and retaining walls are used as needed
- Material excavated from the top approach is used to fill the bottom approach behind a retaining wall
- Retaining walls are carefully built to ensure stability
- The upper approach is unsloped to help drain water before the turn
- The lower approach is out-sloped
- Approaches should be designed to control user speed prior to entering turn
- Grade reversals should be used prior to approaches to help divert water
- Switchbacks should **not** be built directly above one another. They should be staggered on the hillside to prevent shortcutting and water accumulation.

Rolling Crown Switchback



Rolling Crown Switchback



Curves - BNRTC

- Video of curve before construction at the Buffalo National River Trail Crew
- https://www.dropbox.com/s/1rrdm8ikqkxl954/IMG_0442.MOV?dl=0
- Video of curves after completion at the Buffalo National River Trail Crew
- https://www.dropbox.com/s/4f14cku6ey40dbw/IMG_0778.MOV?dl=0
- https://www.dropbox.com/s/06vdaxj21tbeuum/IMG_0762.MOV?dl=0

Bridges and Planksways

Bridges

First, you must determine if you should build a bridge or not. Bridges require a significant amount of time and resources, and require a relatively high level of expertise to built a reliable one. Bridges also may require significant maintenance over the years and occasional replacement of parts or sections.

You should consider what uses the bridge will serve, and who will use it. A bridge should be considered if it provides more safety, but probably shouldn’t be considered if it will only serve a function of added comfort or ease.

Once a decision to construct a bridge has been made, the location of the bridge must be determined. The location is one of the most important things to be evaluated before construction. Some key factors you’ll need to consider for location are:

1. Seasonal high water?
2. Stable banks?
3. Banks close together?
4. Sunny location?
5. Potential hazards?
6. Acceptable approach trails?
7. Environmental impacts?

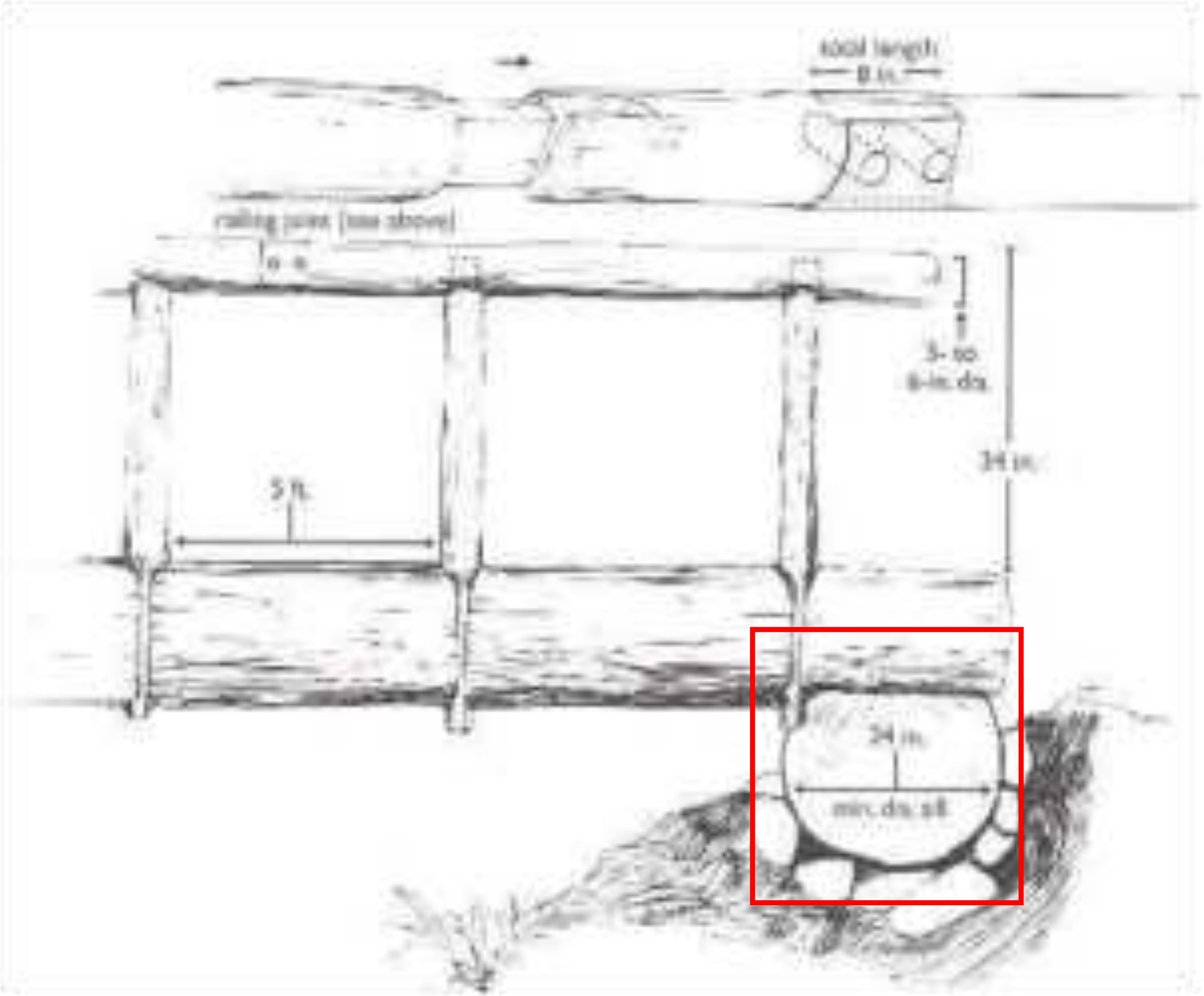
Bridges – Sills

The 2 main components of bridges are sills and stringers.

Sills are the beams that rest on the ground and support the stringers of the bridge. They can be natural wood, treated wood, wood and steel, or steel. The harder the material, the more durable it will tend to be.

You can cradle wooden sills in trenches of crushed rock so lift them off of the soil, which will help prevent erosion. If setting a sill on bedrock, you should drill ¼ inch holes through the sill and rock then insert rebab rods and fix with epoxy or mortar.

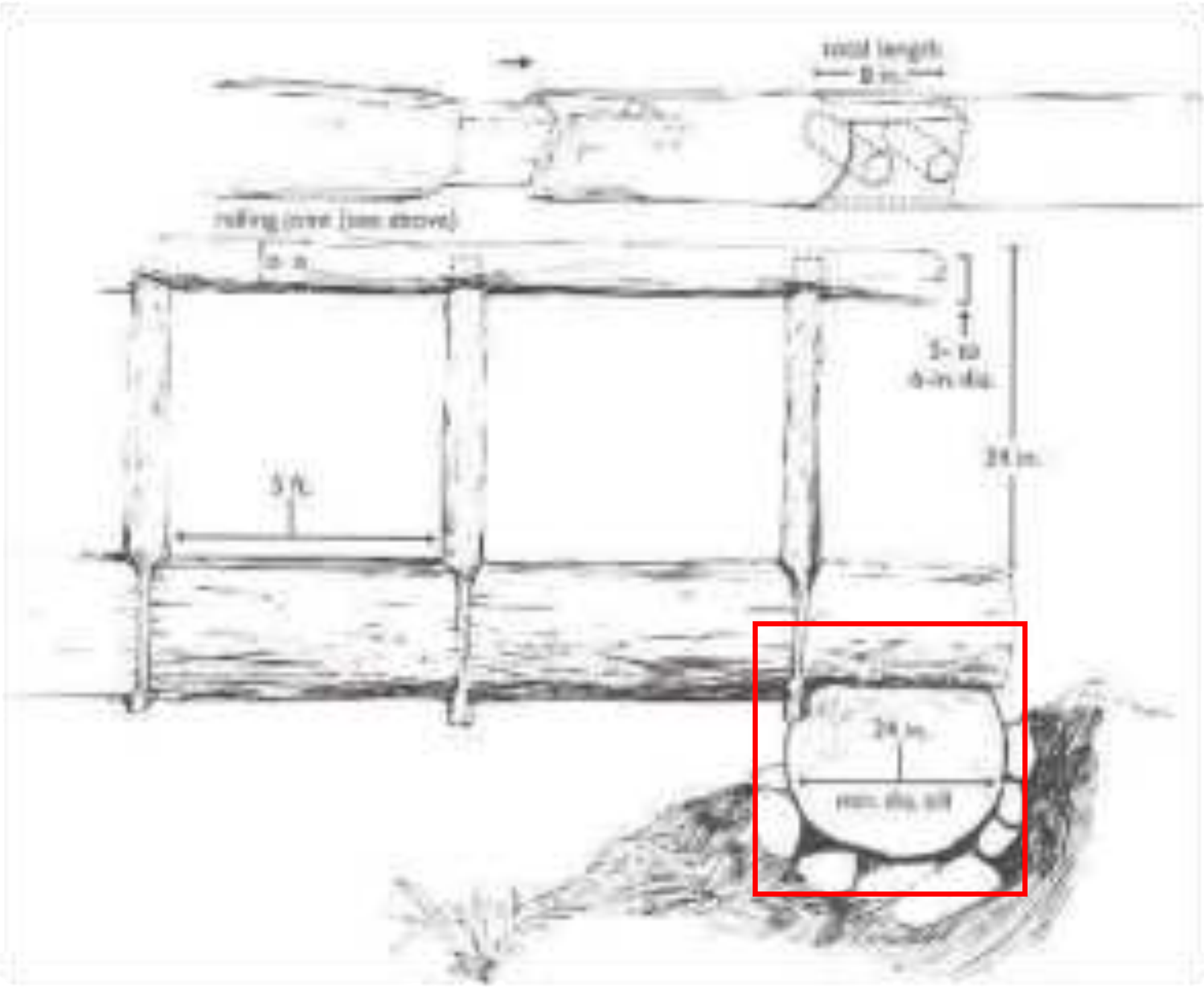
You can replace a sill without having to replace the entire bridge by lifting the bridge up and replacing the decayed sill.



Bridges – Sills (cont.)

If you are building a smaller bridge, you should place the stringers on the sills then check to if it is level.

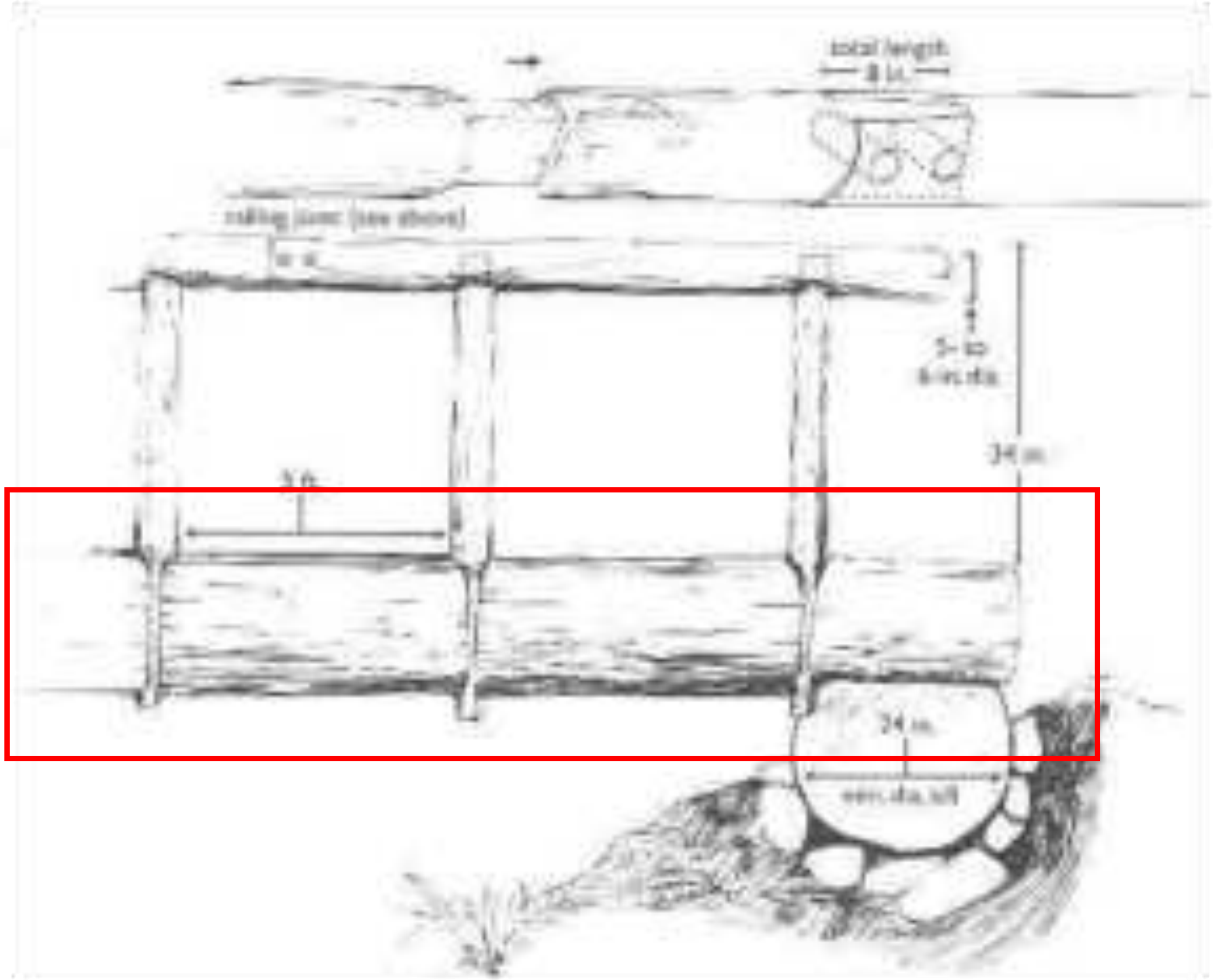
If building a larger bridge, it is vital to level the sills to 0 degrees before you place the stringers. Generally stringers are very heavy in larger bridges, so it is very difficult to reposition the sills once the stringers have been placed onto them.



Bridges – Stringers

Stringers are the part of the bridge which span the crossing the bridge covering.

Sills and stringers that are made of milled lumber or steel require little adjustments before they are fixed together. Log sills and stringers should be shaped to prevent them from rolling out of position. There are different opinions as to whether you should shape sills or the stringers.



Bridges – Designs

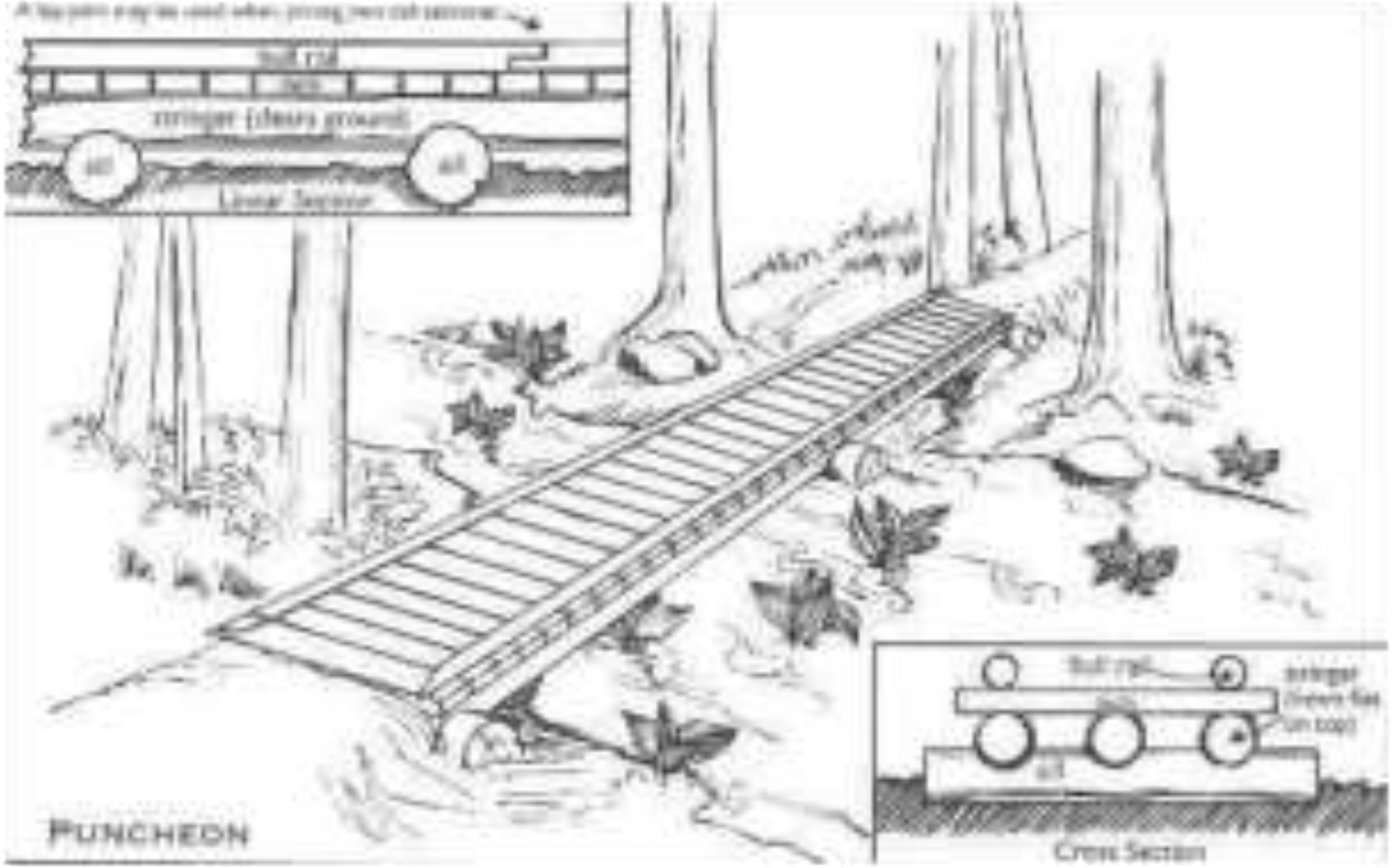
There are several different types of bridge designs, of which we will cover a few.

1. Puncheon Bridges

Should be used to lift a trail tread above areas unfeasible to drain and cannot be passed with a turnpike.

Make sure your sills are large enough and set high enough to ensure your stringers clear the ground. You may need more than 2.

The bridge is topped with a deck of lumber boards that normally need to be transported to the site. Make sure to leave a small space between the boards of the deck to allow for debris to pass through and to allow for the swelling of boards.

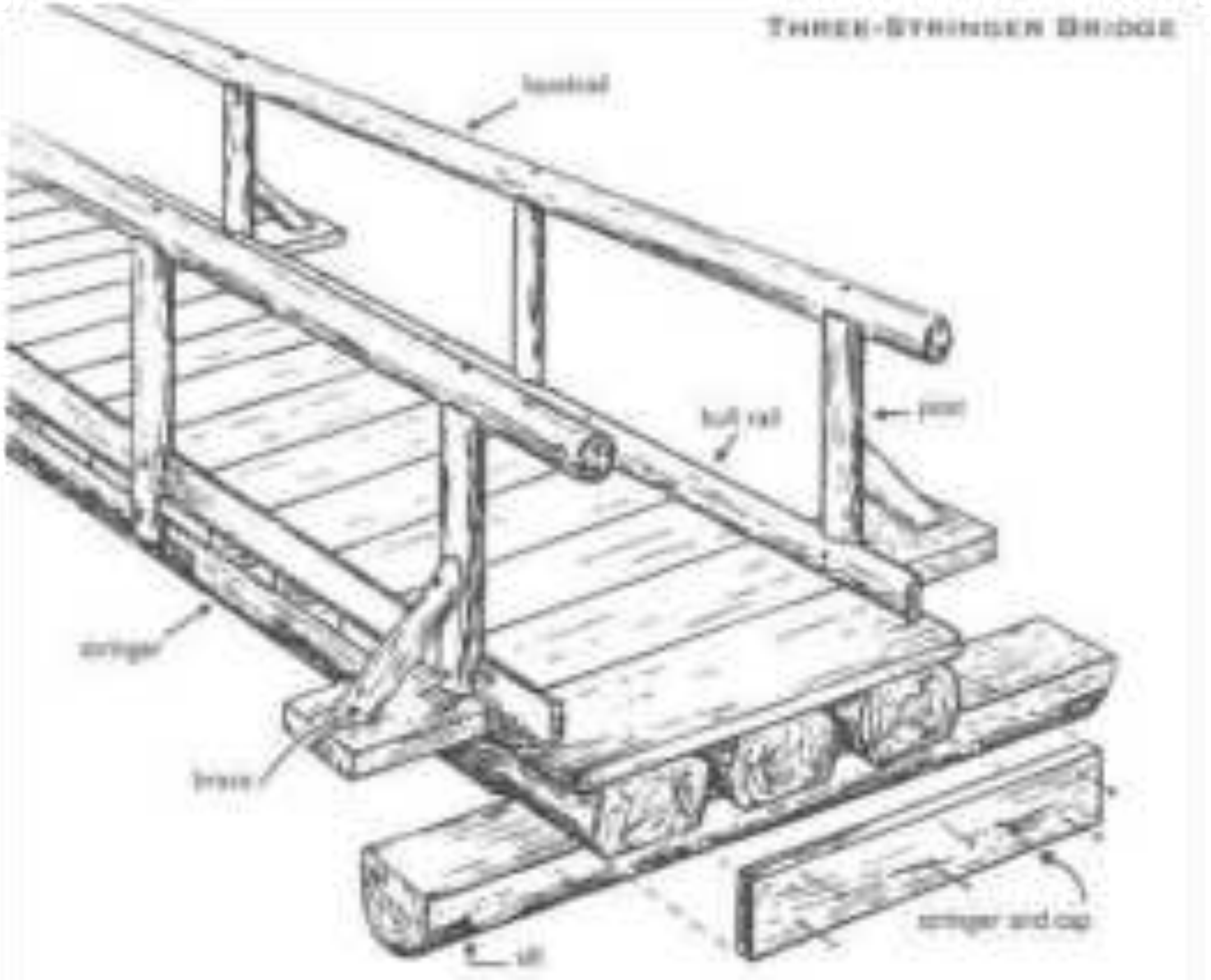


Bridges – Designs (cont.)

2. Stringer Bridges

Similar in design to puncheon bridges. With large enough timbers, stringer bridges can be used span gaps of 50 feet or more.

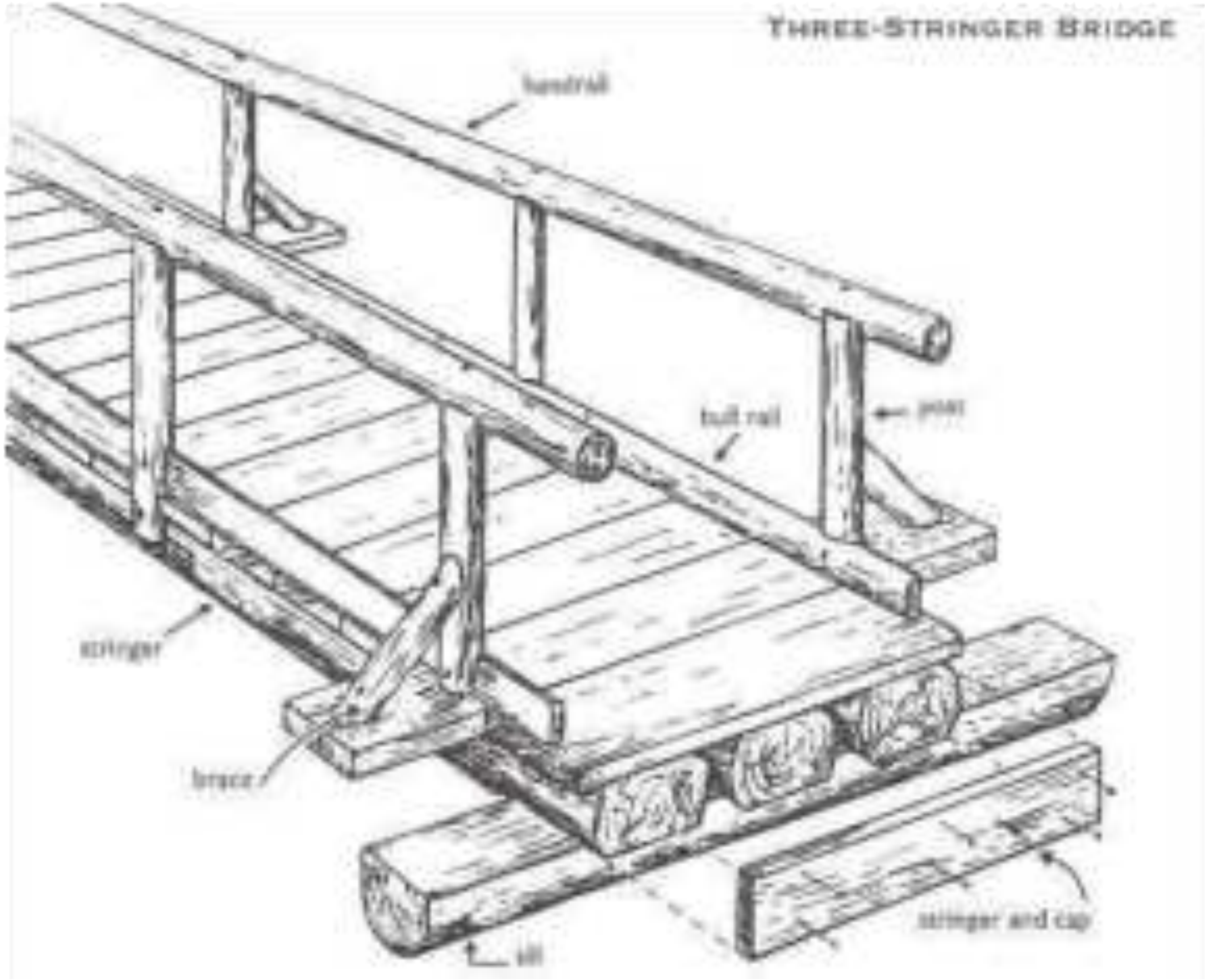
There are several key features that define a stringer bridge. One is the cap, simply a board that covers the ends of the stringers, which increase the longevity of the bridge. A bull rail, thick boards set about 2 inches higher than the deck, prevent animals hooves' from sliding off the deck (generally only be used for bridges to be used by animals). Another is that generally only 2 sills are used, one at each end. The number of stringers should depend on what the bridge is being used for. Hiker bridges normally only require 2, where animal and vehicle ones require 3 or 4.



Bridges – Designs (cont.)

2. Stringer Bridges (cont.)

Some have handrail to help prevent people from falling or sliding off the bridge. Handrails can also be reinforced with braces the bridge is used by animals.



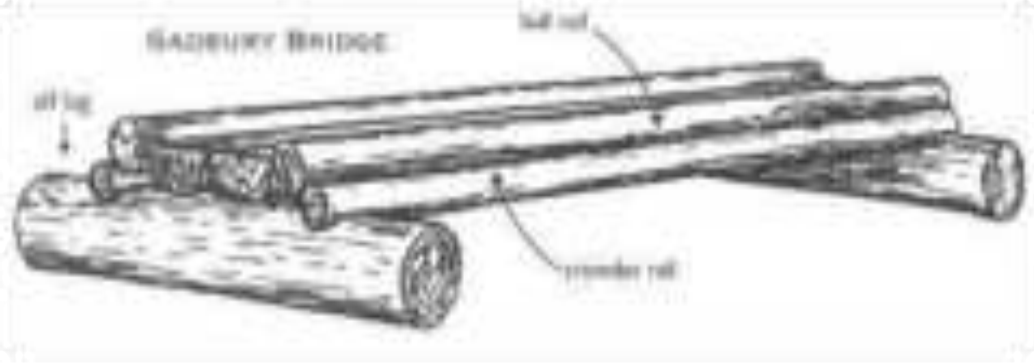
Bridges – Designs (cont.)

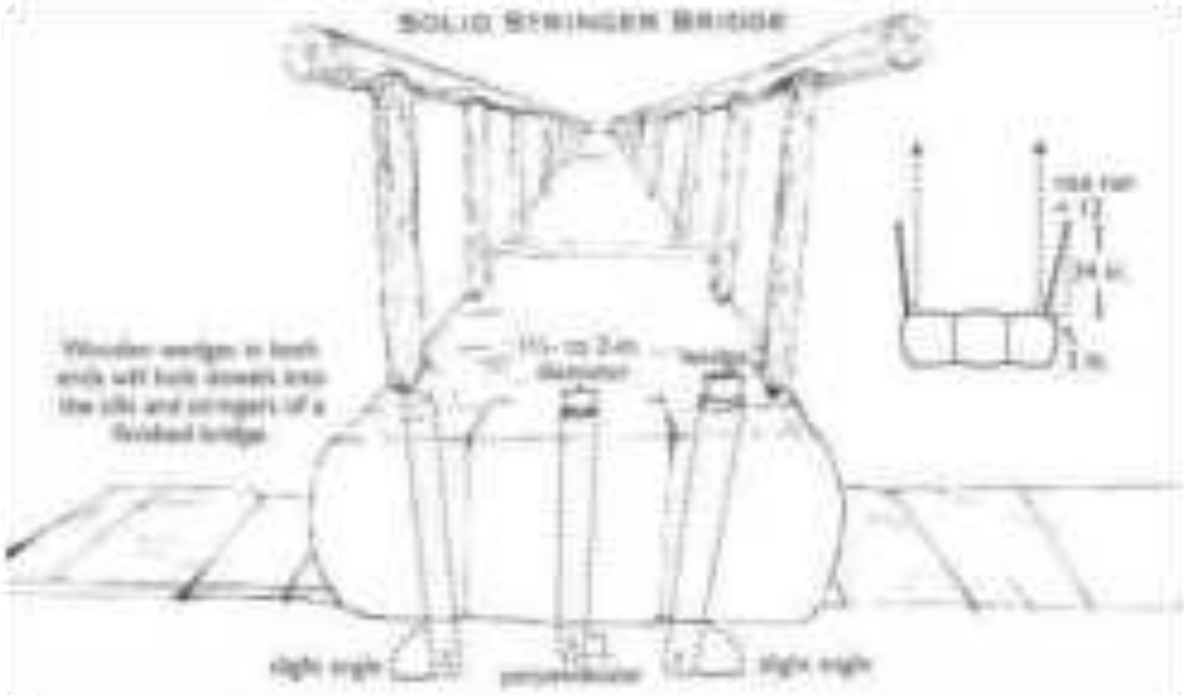
3. Gadbury and Solid Stringer Bridges

Gadbury bridges were among the first bridges to be used by the Forest Service. Simply a timber cut in half and set end to end and spiked into sills. When using large timbers, you can crave the inside faces to match tightly.

You can install a bull rail on these types of bridges. Those require you to also have to install a crowder rail on each side.

Solid stringer bridges are similar, but several stringers can be used and are cut flat on 3 sides so they fit together tightly.





Single Stringer bridge in Bridger Teton National Forest

ArrowCorps5 (2008)

Single Stringer bridge in Bridger Teton National Forest

4 years later (2012)

Single Stringer bridge in Smoky Mountains National Park

Bridges – Log Span Table

Log span tables should be consulted when building a bridge because different types of wood have different levels of strength and have different levels of durability in various regions.

All logs must be peeled, stripped of all bark, before they can be used for a bridge.

Make sure that any bridge you build meets all the required specifications of where your building it and the agencies that oversee that area/the project.

PACIFIC CREST TRAIL BRIDGE DESIGN STANDARDS—CHELAN RANGER DISTRICT, USFS

Bridge width: 6 feet

Loading assumption: snow 10 feet deep by 10 feet wide, 30 percent water content

Stringers		**Small End Diameter**		
Span Length (in feet)	Number of Stringers	Hemlock (in inches)	Spruce (in inches)	Cedar (in inches)
12	2	11	12	13
12	3	10	11	12
14	2	13	14	14
14	3	11	12	12
15	2	14	15	15
15	3	12	13	13
22	2	15	16	19
22	3	15	16	16
35	2	24	25	26
35	3	21	23	23

All logs must be peeled.

Sill logs shall be cedar unless there is an alternative agreed upon by the Forest Service.

Sill logs shall be 2 feet longer than bridge width and centered under the bridge.

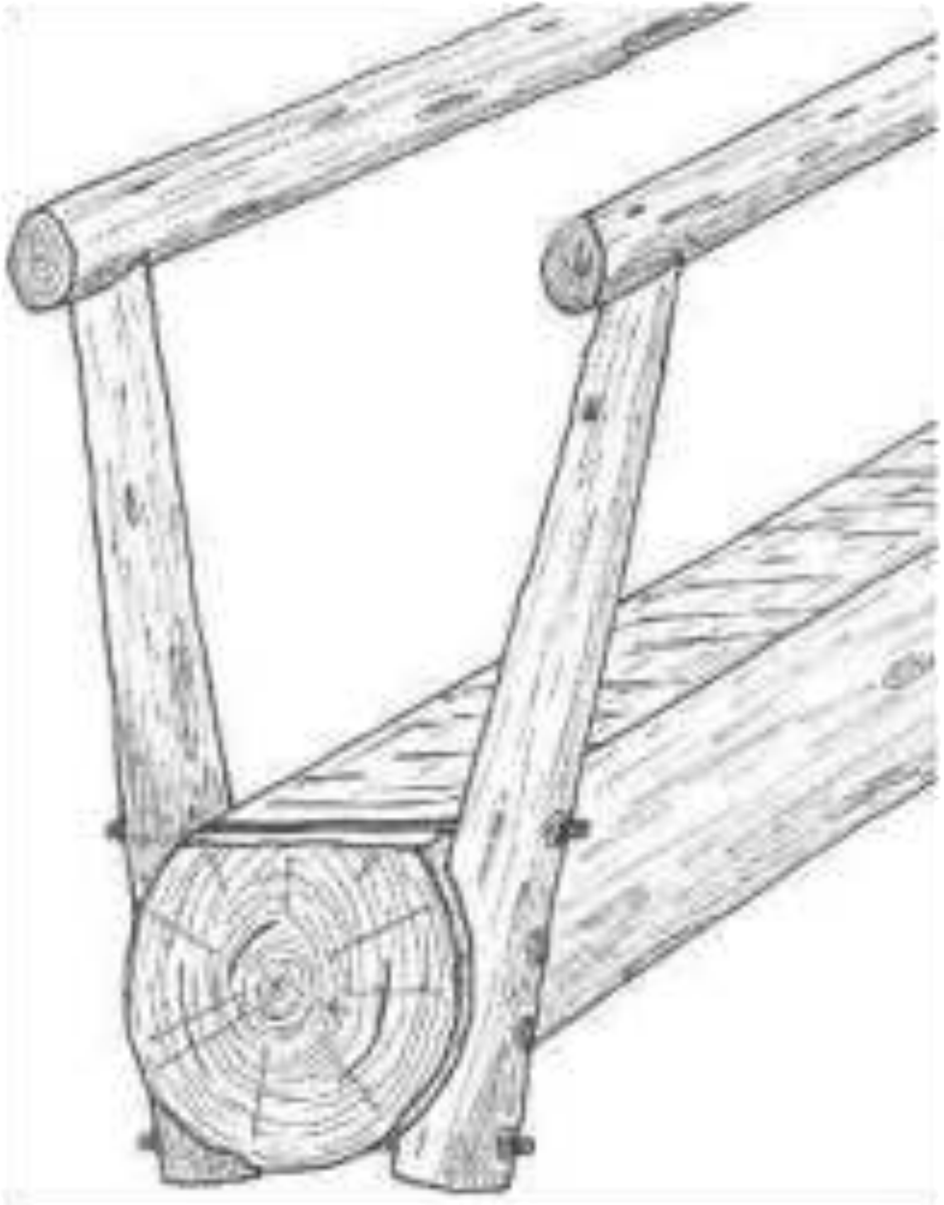
Sill log diameter shall exceed stringer log diameter by a minimum of 2 inches

Bridges – Handrails

The question of installing handrails is one of safety. You should consider the design of the bridge, the type of users the bridge will serve, and the location of the bridge.

The Forest Service’s guideline is “any trail that is not in a remote area with a drop of 4 feet of more, or a remote trail with a drop of 8 or more, should have a rail system. All trail brides that do not have a rail system must have a curb.” (*Trail Bridge Catalog,* U.S. Forest Service, 2003)

Again, check the governing requirements of your project and sure you meet all specifications.



Plankways

When working in remote areas, supplies can be difficult to get in. This can have a big impact when undertaking some projects. When trying to cover long distances in a remote area, especially in bogs, neither puncheon bridges or turnpikes may be appropriate. This could be a situation where plankways are the best answer.

Plankways are comprised of sills set 6-12 feet apart throughout the course of the path and connected with boards, generally 2 2X8's-2X12's.

It is best to use treated wood for these types of bridges, as they will have a high propensity to rot out.

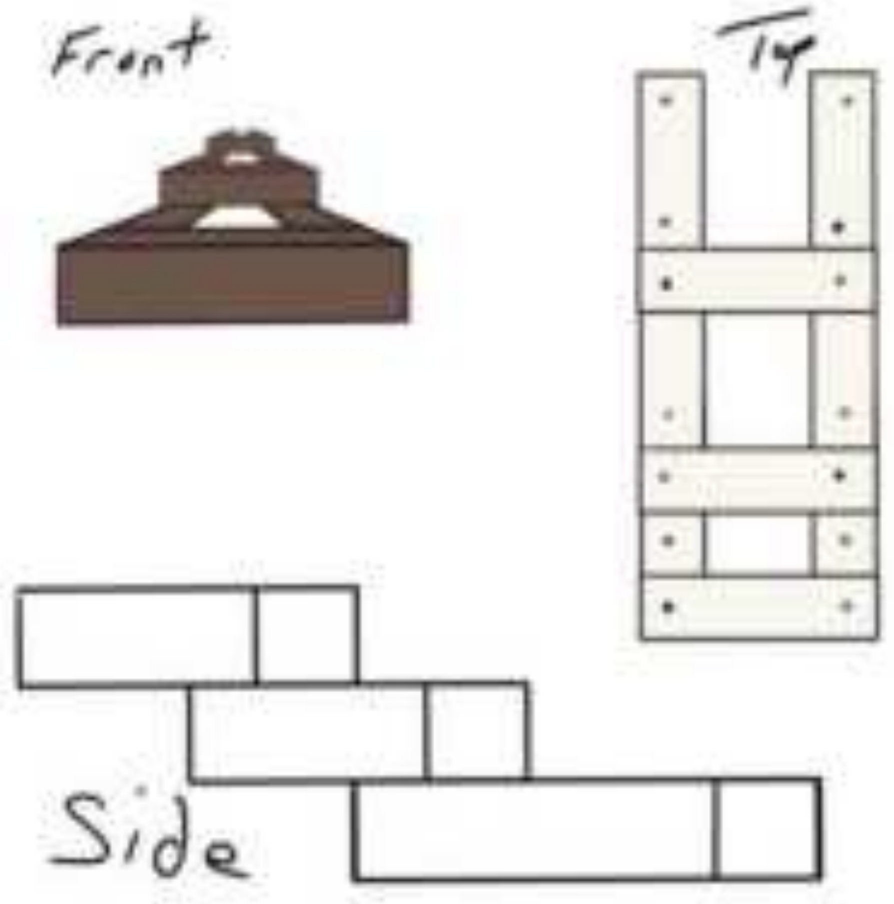
These are to be used for general hiking/travel.

Railroad Tie Check Dam/Steps

Railroad Tie Check Dams/Steps

Often, especially in areas where trail features are easily accessible for maintenance, land managers will ask for materials like railroad ties and rebar to be used for steps, check dams, and waterbars.

Steps should be put in from the bottom working upward. Be sure to backfill all open spaces with gravel and soil.



Railroad Tie Check Dams/Steps

Railroad Tie Check Dams/Steps

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An example to calculate how many steps we will need is:

- Using a standard railroad tie of 7” x 9” x 8.5’ HxWxL

- Step height of 7” / 12” = 0.5833’ H (conversion for our calculations)

- (Distance x Grade) ÷ Step Height = # steps needed for even Elevation Gain distribution.

Railroad Tie Check Dams/Steps

Ex A: Worksite is 24’ long with a 15% grade, therefore:

- 24’ (Distance) x 0.15 (Grade) = 3.6’ Elevation Change.
- 3.6’ ÷ 0.5833’= 6.17 steps.
  - We will round up to 7 steps.
- 24’ (Distance) ÷ 7 Steps = 3.4286’ step spacing for even elevation distribution

Ex B: Worksite is 48’ long with a 20% grade, therefore:

- 40’ (Distance) x 0.20 (Grade) = 9.6’ Elevation Change.
- 9.6’ ÷ 0.5833’= 16.46 steps.
  - We will round up to 17 steps.
- 40’ (Distance) ÷ 17 steps = 2.3529’ step spacing for even elevation distribution

Equestrian Design Considerations

- Equestrian trails will require wider and higher corridors.
- Open-faced culverts and immediate elevation changes should be avoided.
- Check Dams and Water Bars may be hard to navigate for horses.
- Turnpikes will need to be wider.
- Tread in general needs to be well compacted and may require a denser base of gravel in especially wet environments.

Mountain Bike Design Considerations

- Similar to equestrian trails, trails built primarily for mountain biking cannot include features with abrupt changes.
- With curves, bikes have a minimum turning radius mandating a minimum diameter.
- With in elevated curves, the trail may need to be in-sloped, requiring special drainage considerations.
- Depending on the space available, closed-face culverts/drains can be cut into the trail.
- Grade reversals, knicks, and rolling grade dips are the primary features used to help shed water off the trail.

Resources

- OA Foremen
- Above the Muck: A Portage Trail Maintenance and Repair Manual (2007)
- Lightly on the Land, The SCA Trail Building and Maintenance Manual; The Student Conservation Association (*1996*)
- *http://mountainbikemilitia.com/partial_bench_cut.html*
- *Building Better Trails; IMBA (2001)*
- *Sustainable Trail Development, A Guide to Designing and Constructing Native-surface Trails; IMBA (2009)*
- *Trail Construction and Maintenance Notebook; USFS (https://www.fs.fed.us/t-d/pubs/htmlpubs/htm07232806/toc.html)*
- *Incident Command System; US Dept. of Labor (https://www.osha.gov/SLTC/etools/ics/what_is_ics.html)*
- Crib Walls and *Retaining Walls (https://trailism.com/trail-science/crib-walls-and-retaining-walls/)*
- *https://en.wikipedia.org/wiki/Gabion*
- *https://www.urbankubez.com.au*
- *https://www.dec.ny.gov/docs/lands_forests_pdf/bikeguidance.pdf*

Takeaway Challenge

Go Build Some Trail!!!!!!