Chapter Seven

Tools in the Toolbox: Structures

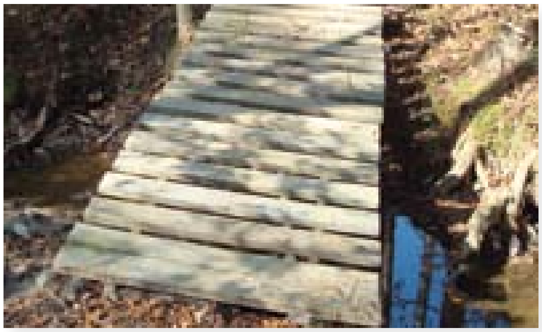
Smart Enough to Ride? Smart Enough to Get Trained

A large part of the success in the engineering of a trail system is to know what to do in a particular situation. Certainly with a new trail location or the relocation of an existing trail, the first option is to avoid potential issues. However, there are a multitude of structures available that can help mitigate almost any circumstance.

Structures help meet two of the three elements for successful OHV trail systems: provide for the riders' needs and design for sustainability. Many structures enhance the OHV experience by providing variety either visually or in tread surface character. Structures provide a more stable, durable trail tread, which increases rider safety and the fun factor. Increasing stability and durability is what designing for sustainability is all about: protecting resources while providing a quality recreation experience. OHV management is facilitated when riders want to and are able to stay on the trail.

Here are some key points to remember when selecting and designing structures:

- The vehicle specifications (width, weight, etc.) critical to the trail design may not be those of the OHV using the trail; they may be the trail dozer used to construct or maintain the trail, or the snow groomer in the winter.
- Some agencies use structures as a management tool to limit the width of the vehicle that can use the trail, for example, making a bridge 24" wide to preclude use by ATVs. Structures can be expensive and this tactic can be short-sighted when larger vehicle access is needed for maintenance or reconstruction; vehicle sizes or types change; or management direction changes. Proper entrance management is a better option.
- Many structures require professional engineering calculations on material strengths, vehicle loads, snow loads, and watershed analysis to determine bridge, culvert, or arch sizes. This is not a place to cut corners since under-designed structures can lead to catastrophic failures and public safety issues. Manage risk and liability by having your structures properly engineered.
- The need for multiple structures can be a red flag indicator of poor trail location. Explore other options if they are available.



Neither of these bridges has been designed to accommodate the vehicles that need to use them. Hardhats may need to be substituted for helmets in certain cases.

- Structures require regular inspection and maintenance. The cost and personnel to perform these tasks must be built into the operation and maintenance (O&M) program.
- The longevity of most structures depends on use type, use level, soil type, climate, proper design, proper installation, and proper maintenance.

Section 1: Water Control Structures

An essential key for a durable trail is managing water. Structures help drain water off the trail, allow water to flow under the trail, help raise the trailbed above the ground water level, drain water across the trail, and drain it away from the trail; all of which help manage water.

Draining Water Off the Trail

There are several ways to help get water off the trail: rolling dips, outsloped sections or kinks, and waterbars.

Rolling dips are man-made grade reversals constructed on existing trails with long sustained grades or steep grades to reduce the size of the tread watershed. They are also used in new construction where there is no other opportunity to reverse grade to provide drainage. The key to good rolling dips is just that, keep them rolling.

This is a nicely constructed rolling dip. Notice the distance from the sag to the crest and notice how the grade smoothly rolls into and out of the dip.

Here are some general points about rolling dips:
- Any manmade structure requires maintenance. A rolling dip will never be as effective and as maintenance free as a grade reversal.
- Rolling dips must roll. The shorter the distance from the sag to the crest, the more abrupt and less functional the rolling dip will be. If it feels like a rider will fall into a hole when riding, the dip is too short.
- The structure will fail more rapidly in non-cohesive soils like sand or cobble rock or a sand and rock mix.
- Armoring a rolling dip with mechanically compacted crushed aggregate will increase the effectiveness and longevity of the rolling dip by: a) reducing the velocity of the water so it can be more easily diverted off the trail; b) hardening the trail tread to reduce rutting; and c) protecting the crest from displacement.


The best way to start building a rolling dip is to borrow as much material for the crest as possible by using lead-off ditch or drainage sump excavation. Excavating the sag to build up the crest increases the grade going into the dip, reduces the flow of the dip, and can make it more difficult to drain water out of the dip.

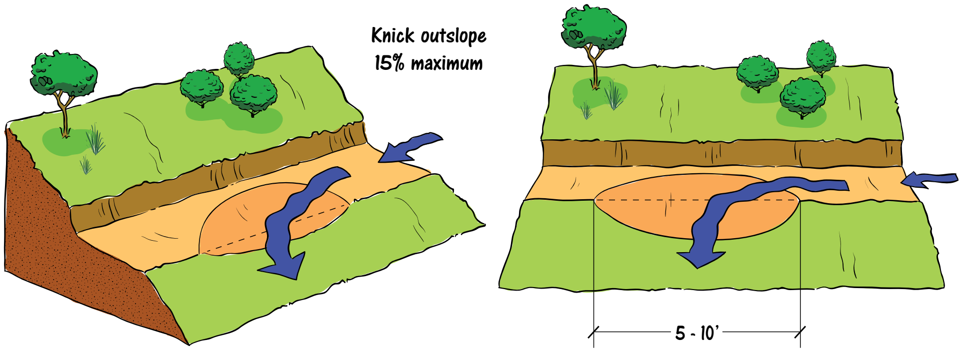
When controlling water with rolling dips:
- Use the trail alignment to help turn the water. Place the structure either on a tangent, or better yet, on a curve that turns in the direction the water should go. Trying to turn the water in the opposite direction of the curve will usually result in failure.
- Locate the rolling dip where there is a break or flattening in the grade. This will help slow the water down so it can turn and flow off the trail.
- Drain the water off the trail before the grade and after the grade, not mid-grade.

Rolling dips and grade considerations:
- Avoid installing rolling dips mid-slope on grades over 15 percent. The approaches become too steep and riders lose most of

their momentum. Riders must roll on the throttle to get going again, which results in tread impacts and increased maintenance.
- On steeper grades, rolling dips can invite riders to make jumps out of them.
- Generally, as grade increases, tread watershed size increases, or soil quality decreases; the spacing between dips needs to decrease.
- As the grade increases, the transitions into and out of the rolling dip must proportionally increase.
- The steeper the grade, the more difficult it is to make the dip reverse grade. Often, the best that can be achieved is a grade break, which can easily be breached by rutting when the soils are saturated and most vulnerable.

Use the trail alignment to help you turn the water. This dip is trying to move the water in the opposite direction of the curve. The gradual formation of superelevation on the outside of the curve will work to defeat the flow of water in that direction. This installation will work briefly. Then the formation of a berm will block the lead-off ditch and water will pond up in the sag of the dip. This pond will build in depth until it saturates the crest. Tire ruts forming in the soft crest will lead to breach and failure of the structure.

An outsloped section or knick is a short piece of trail that has been steeply outsloped at 8 to 10 percent or more to provide drainage. These are best used in grade sags or flat low areas that tend to puddle water. The difference between a knick and a rolling dip is that there is no sag and crest in a knick. Instead, a section of the trail is cut away in a "C" shape and the excavated material is removed from the site. A dip forces water off the trail while a knick allows the water to run off the trail. Knicks can be effective on flatter grades up to about 5 percent, but on anything steeper, too much



The flatter the trail grade, the more functional and durable the dip will be. This one is perfect: long, flowing, and deep.

Though this dip rides nicely, it wasn't constructed with enough elevation difference from the sag to the crest. Due to the soft, non-cohesive soils, displacement from a few motorcycles has already created a rut deep enough for the rolling dip to fail.

outslope is needed to turn the water. In these situations, riders will tend to hug the uphill side of the trail, and water carried by tire ruts will soon deform and breach the structure. Rolling dips are a far better alternative.

Avoid flat ground. Even with outslope, the water won't drain off the trail if it has no place to go. This lead-off ditch has plugged up or was under-sized and needs maintenance. A drainage sump may be a better alternative.

This trail has been outsloped to provide drainage. The rocks at the outlet serve as energy dissipaters and are a nice touch.

When constructed, this trail was outsloped so the small drainage entering from the left would drain across the trail. Through compaction, displacement, and lack of maintenance, the trail bed is now lower than the ground on the downhill side, so the water runs down the trail. Now, a rolling dip should be installed here. In reality, there was an error in the initial location and the alignment should have pitched up on the arrow line to create a grade reversal and positive drainage.

When constructed, this low spot was outsloped to drain water. Through compaction, displacement, and lack of maintenance, the trail bed is now lower than the ground on the downhill side. So the water ponds up in the trail which is causing trail braiding. The trail now requires reconstruction and armoring with rock to help maintain the shape and provide additional bearing when it is wet.

One of the biggest issues with waterbars is that, given a choice, riders will go around them. Here a log was brought in to force riders over the waterbar, but riders are going around it also. Due to lack of use, note how green the original trail tread is between the waterbars.

Earthen water berms can be a quick fix for OHV trails, however they don't last long and need to be replaced often.

Waterbars are shallow structures that are used to drain water off the surface of a trail or road. They can be made out of a combination of rubber belts, logs, rocks, treated timber, or dirt. They are usually installed at about a 30 degree angle so that water will hit the structure and be directed off the trail. As a drainage structure on a motorized trail, none of these are effective because they are too abrupt and they fail due to the tires rolling over the structure. Logs are slippery at an angle and dislodge, rocks become dislodged, and dirt gets displaced. Though widely used historically, they are now being replaced with rolling dips, which are far more effective.

This log reinforced waterbar is currently working. A couple of reasons for that are that riders are forced to go over the waterbar because vegetation prevents going around it, and because the trail is wide enough for riders to square up and avoid hitting the potentially slippery log at an angle. Note the sediment being deposited (arrow) as the water slows before it flows off the trail.

A belted waterbar has a piece of conveyor belt sandwiched between two 2"x 6" treated boards. The belt sticks up out of the boards a minimum of 6" and the structure is buried in the trailbed so that only about 3" of the belt protrudes above the surface. The belted waterbar has long been thought to be an effective drainage structure option for wheeled trails, but that has not proven to be the case. The main reason for their failure has been misuse of the structure.

There are six main reasons why waterbars fail:

1. Most belted waterbars are not constructed properly and have too much exposed belting, which becomes ripped or flattens over and becomes slippery.

2. Most installations are not long enough and invite riders to ride around them.

3. Most are not installed in the proper location where the trail alignment or grade will help them work.

4. Many have been installed on a fall line trail in an effort to make a non-sustainable trail more resistant

This log waterbar is doing nothing but putting an obstacle in the trail. With the amount of water coming down from above, the need for this waterbar is a red-flag indicator of a much bigger problem.

to degradation. Waterbars can be an aid in some situations, but not a cure-all. Other options like relocation should be considered first.

5. Many have been installed on excessive grades (hillclimbs) and the tires damage them or water rushes over them.

6. Lack of maintenance. Any manmade structure requires maintenance and eventual replacement. Waterbars require frequent maintenance.

The fact is that the need for any waterbar is a red flag indicator of a bigger problem. Water is running down the trail due to excessively steep grades, excessively long grades, excessively large tread watersheds, or failure to recognize and seize other drainage opportunities. Rolling dips are a better option, but in most situations, the best long-term solution is trail relocation.

This treated timber waterbar provides a formidable obstacle from below (blue arrow) and being full of sediment, it provides ineffective drainage (yellow arrow). The issue: the tread watershed is too large. Poor soils cannot sustain this grade that is too steep for too long. The solution: relocation.

Draining Water Under the Trail

Several structures are available to help direct water under a trail, including bridges, arches, culverts, headwalls, catch basins, and trash racks.

Bridges are used to span streams or other terrain that cannot be traversed on the ground like a deep, rocky ravine; and they can add to the aesthetic beauty of a trail and the quality of the recreation experience. There is a wide array of materials available for bridge building, including steel, treated timber, log stringer, fiberglass, and other composites. Many are prefabricated, which aids in transport and assembly. Choice of materials can depend on local availability, local preference, or conformance with a local or agency architectural theme. Fiberglass, though not as aesthetically pleasing as other materials, is lightweight and easier to transport and assemble at the bridge site. Its initial cost can be higher than other materials, but transport and assembly costs are much lower.

This prefabricated steel bridge is durable and has a natural appearance in this open setting.

Things to think about for bridges:

- There are specific criteria for bridge site locations and they are critical to the longevity and integrity of the structure. Seek help from a bridge specialist, engineer, or hydrologist.
- Most bridges will require a permit of some kind. Find out what is needed and what the requirements are for erosion control, etc. Get permitting started as early in the process as possible. It can take some time.
- Many streams have conditions or restrictions for operating equipment in or near the stream. Gather the information before mobilizing materials, equipment, and personnel.
- Time and unusual weather events can negatively affect a bridge's integrity. Public safety trumps

With transport and assembly advantages, a fiberglass pony truss bridge can work well in a variety of settings.

This log stringer and treated timber bridge spans an extremely sensitive creek that was a hotbed of controversy. Though there were less expensive design options, its beauty and functionality was worth the cost as it allowed this project to move forward.

If there is no railing, rub rails provide a margin of safety on OHV bridges. This is a nice, low-profile treated timber bridge.

cost, so manage risk. Regular bridge inspections by a qualified engineer must be conducted and documented.

- Make the bridge large and durable enough for the largest vehicle using the bridge. In most cases this is construction or maintenance equipment, including snow groomers.
- In wet conditions, tires, especially OHV tires, can slide across the boards of a bridge. Ensure a rail or a rub rail is on the bridge to catch the tires before they go off the side.

Arches are used to allow water to flow under the trail. They are slightly elliptical and come in either an open or closed bottom configuration. Open bottom arches are most common in trail work. They have a flange on the bottom edge that allows them to be pinned in place with rebar. Arches are available in a variety of sizes and come in corrugated galvanized metal or corrugated high-density polyethylene (HDPE) plastic. Plastic is usually preferred due to its lighter weight and ease of transport and installation. Arches have a wide and low profile that gives them several advantages: a) the streambed or drainage bed is left in its natural condition; b) the flow of water is less restricted, yet the capacity to carry water is one-third more than a similar sized culvert; c) the wider mouth of the arch is less likely to plug up with debris; d) the width of the arch makes it easier to clean out; and e) the arch shape is stronger than a round shape.

Durable, lightweight, and easier to clean out, an arch is a good choice for trail projects.

Culverts are another structure that allows water to run under the trail. The most common culverts are corrugated metal pipe, often referred to as CMP, and corrugated plastic pipe, commonly referred to as CPP. The metal pipe is aluminum or galvanized steel. The plastic pipe is HDPE. Metal pipe comes in a variety of shapes: round, elliptical, box, pipe arch, and arch. Round corrugated aluminum is the most common metal culvert for trails since it is 70 percent lighter than steel and just as strong. Plastic pipe comes in round and arch shapes. The round pipe is available with a single wall, which is corrugated inside; or a dual wall, which has a smooth interior.

There are two types of corrugations: annular and spiral. Annular is easier to band together, but each corrugation can become a sediment trap. Spiral tends to clean itself out better since one corrugation leads to the next.

Plastic culverts are usually preferred for trails due to their light weight and ease of transport. They are also easier to cut in the field. Most culverts come in 20-foot lengths and have available bands to connect sections together as well as elbows, flared inlets, drop inlets, downspouts, and other attachments.

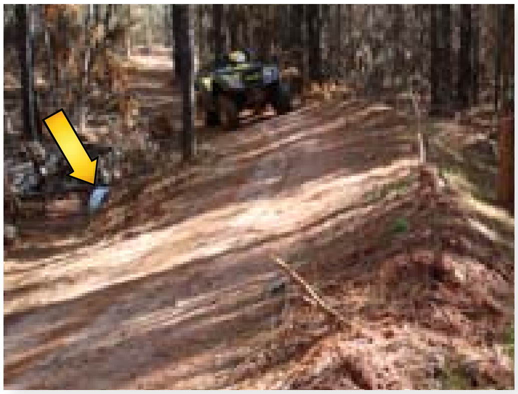
There are drawbacks, but culverts allow water to drain under the trail and keep the tread dry.

When culverts are undersized, the results can be disastrous and expensive. Spend the money up front to do it right the first time.

It is dry now, but this runs a lot of water in the winter. Two plastic pipes in this shallow drainage keep the trail fill low and provide a safety net to handle unusually heavy flows. Two pipes have to be carefully bedded to prevent water from running between them.

The first culvert (yellow arrow) was properly installed in the drainage. The second culvert was added later possibly to drain a spring but was not installed properly due to rocky ground. Manage your risk. The second culvert does nothing but create a safety hazard and an opportunity to ruin what was a good section of culvert. A side ditch draining into the first culvert may have been a better solution here.

A flared inlet and headwall are being added to this culvert to help funnel the water into the inlet. Though a small diameter culvert like this may be adequate to handle the flow of water, it is very hard to keep cleaned out.



This heavily superelevated curve is a blast to ride, but water runs to the inside, gets trapped, and ponds up. The solution? Add a culvert.

Here are some key points on culverts:

- Culverts need to be sized correctly to accommodate the maximum high flow events from the drainage area. Failure to do this can result in a catastrophic failure.
- Any pipe less than 18” in diameter is more prone to getting clogged with debris and harder to clean out. Ensure there is routine inspection and maintenance for these structures.
- Culverts can fail in a significant weather event causing the culvert and the trail to wash out. This may result in not only a severe trail impact, but also has the potential to impact sensitive habitats or fish-bearing streams below. For these reasons, fords or armored drains are usually a better alternative if management allows tire and water contact.
- Dual wall plastic pipe with the smooth interior tends to flush itself out during rain events or can be flushed out manually with a hose.

- Check the classification of the stream before installing a culvert. Some small streams, even ephemeral ones, are classified as fish-bearing and may require a bridge or other mitigations to allow fish passage.
- Cover depth will be lost through erosion, wheel displacement, and maintenance. To minimize the risk of having an exposed structure, culverts should have a minimum of 12” of fill over the top of them.
- Installing two smaller diameter culverts rather than one large one can increase the flow without increasing the height of the fill required to adequately cover the pipe.

A headwall is a structure that surrounds the inlet of a culvert or arch and has three functions: 1) to keep the trail fill from sloughing or eroding off and blocking the entrance of the culvert; 2) to help funnel the water into the culvert inlet; and 3) to dissipate the energy of the water and protect the toe of the trail fill from eroding. Headwalls are normally constructed of rock, but bags of pre-mix concrete are also used.

A catch basin is often constructed as part of a culvert or arch installation, especially where the water needs to turn in order to enter the culvert. It usually consists of a headwall and an “L” shaped berm or wingwall either made of or lined with cobble rock. The water enters the catch basin, hits the back of the berm where its energy is dissipated, and then is allowed to turn and enter the culvert. Catch basins will fill up with debris and sediment and require routine inspection and maintenance.

Culvert headwalls are always a nice touch. This rock headwall supports the trail fill.

When rock is not available or when extra support or protection is needed, bags of premix stacked dry will make a solid headwall. They will absorb moisture over time and solidify into a concrete block wall. Do not use sandbags since the bags will eventually rot and your structure will disintegrate.

Note how water is running past this culvert rather than flowing into it. This installation would be more effective if there was a rock catchbasin to help turn the water into the culvert.

As the wrappers fall off, a premix headwall can look a little shoddy, but that is temporary. To avoid that, the wrappers can be torched off after the concrete has set.

This trash rack is properly placed in advance of the inlet and the widely spaced bars will let water and smaller debris through.

This trash rack has been placed directly over the culvert inlet. The slots in the expanded metal are too small and will catch finer debris. Through a lack of maintenance, it is becoming overgrown with brush which will inhibit its effectiveness. With the next high water, the dead sticks and limbs could easily plug up this structure.

A trash rack is installed in advance of the inlet of some culverts or arches to collect sticks, logs, and debris to prevent them from blocking the inlet. They are usually widely spaced metal screens or vertical metal bars. Sometimes, they are placed directly over the inlet, but this defeats the purpose as debris can plug up the culvert inlet. By preceding the inlet, the debris gets collected, but water can still flow through or around the debris to get to the culvert inlet. As with many structures, the key to their effectiveness is regular inspection and maintenance.

Elevating the Tread Above the Water

Sometimes, it is desirable or necessary to cross broad wet areas. Boardwalks, corduroy, side ditches, puncheons, and turnpikes can all be used to elevate the tread above the water.

A boardwalk is essentially a trail on stilts that keeps the trail above the water level and out of sensitive riparian vegetation. Though expensive to construct, boardwalks allow access through sensitive environments, provide interpretive opportunities, are extremely aesthetic, and provide a unique riding opportunity that adds to the quality of the trail experience. Riders will remember the boardwalk and talk about it around the campfire.

This boardwalk is being built over a wet trail area. The boards are placed length-wise to help keep OHM tires from slipping across wet boards.

Though more expensive to design and construct, placing bends in the boardwalk improves the look and feel of the structure and enhances the rider experience.

Corduroy is an old technique of placing logs perpendicular to the wet area so that water runs through the voids of the logs and the vehicle tires run on top of the logs. This is generally not a long-term solution since the logs will eventually rot. There are two basic configurations for corduroy: logs placed on stringers and logs placed directly on the ground. Both can provide an uneven, slippery surface. When placed directly on the ground, some logs will sink or heave. In high water, they can float providing an unstable trailbed. Both methods can be rudimentary, but if properly installed and consistent with the management objective for the trail, they do work and will offer a unique riding experience and challenge that can add to the quality and excitement of the day's outing.

This poorly crafted installation was thrown together during an exceptionally wet spring. It is too short, too narrow, and some of the logs are floating. Some ditching should have been done to help drain the water better. This is a good example of the issues usually associated with corduroy: poor patch jobs that don't address the problem and usually degrade into a hazardous situation.

This is nicely constructed with poles of the same length and diameter. Unfortunately, it isn't long enough. This is a common and costly problem with many tread structures.

Corduroy anchored onto stringers will last longer and create a more stable tread. This is an example of a poor quality installation. The stringers already show signs of rot and the corduroy logs should have been cut into even lengths.

This is a well done installation that is fun to ride and adds to the rider experience.

In the backcountry, corduroy is sometimes used as a bridge. This is not a recommended practice and should be considered a temporary bandage due to its structural instability. Grade should be avoided with corduroy, especially in wet climates. The slippery, uneven logs on this installation make it a liability.

A puncheon is basically a bridge that lies on the ground. It has stringers, deck, and rub rails that are laid on mud sills. It looks like boardwalk, but a boardwalk is on stilts which elevate it off the ground. Puncheons are typically used to cross wet, boggy, or seasonally wet areas. They can be used to bridge small creeks and protect sensitive resource areas like threatened or endangered plants or cultural sites. Materials are generally logs, sawed timber, treated timber, or a combination of those materials. Depending on how soft the ground is, the mud sills are placed directly on the ground or in shallow trenches that are dug down to firm ground, filled with rock or gravel, or filled with gravel on top of geotextile for increased bearing. The most common fault of puncheon installations is that they are too short and mudholes develop on each end. Be sure to terminate them on firm or higher ground. The approaches to structures like this are still subject to compaction and displacement, which creates low spots. To avoid this, the approaches should be hardened with rock or a geosynthetic with a rock cap. Puncheons can be slippery when wet, so grades need to be kept to less than 5 percent and approaches need to be on a tangent, not a curve. As with many other structures, puncheons enhance the riding experience while protecting resources.

One of the oldest trail structures, puncheons can be beautiful, functional, and fun to ride. Note the muddy spots where the structures end too soon (arrows). These should be filled with rock or hardened with a geosynthetic and a rock cap.

It's harder to construct, but a curved line usually fits the landscape better than a straight line plus it enhances the rider experience.

Side ditches generally run parallel to the trail and help drain the trail tread by allowing ground water to seep into the ditch. The lower the groundwater level is, the drier the trail tread will be. When converting roads to trails, a good practice in wet areas is to use whatever excess width is available for a ditch. This helps drain the trail, enhance the trail experience by having a narrower trail width, and reduce the surface area of the trail. Like ditches along roads, side ditches need cross drains at regular intervals to reduce water volume and velocity and to help maintain the natural hydrology of the landscape.

A side ditch was cut along this trail to help drain the trail tread. However, it does not have adequate cross drains so the water is running too long and too fast which has resulted in erosion. Cross drains need to be added here or the ditch lined with rock to dissipate the water's energy and protect the ditch side walls.

Water will always take the path of least resistance. A mudhole developed by water from this spring saturating the soil below it. A ditch was cut towards the log (arrow) to drain the spring water away from the trail. There was a layer of solid rock that prevented the ditch from being cut lower than the trail tread, so even though some water flows down the ditch, gravity will still pull water down the impermeable rock layer and into the trail. An alternative is to blast the ditch lower or install a French drain in the trail.

This trail runs up a draw which has springs on both sides of the trail. In the wet season, this flat area at the outlet of the draw would become a saturated mudhole. Ditches were cut down both sides of the trail to intercept the spring water and drain the trail tread. The excavated material was used to raise the trail elevation of the tread and a culvert was installed to drain the ditch water under the trail (arrow).

Three years later, the trail tread is high and dry and lush vegetation is growing in the ditches. Use the 4Es. Evaluation is a valuable tool to show what is working (or what isn't). Pictures like these can give managers positive encouragement, can mollify critics, and build support with stakeholders.

Turnpikes have myriad variations, but the principle is always the same: use fill to raise the trail tread above the water table. The higher the tread is, the drier it will be. There are two configurations of turnpikes: ditched and ditchless. Ditched turnpike is most common and uses parallel side ditches to lower the water table. The excavation from those ditches is used as borrow to raise the elevation of the trail tread. However, there are times when sensitive resources prevent the excavation of a ditch or where the side ditches will interfere with the natural subsurface hydrologic flow of water by changing its direction. In these situations, a ditchless turnpike, called a causeway, can be used.

A combination of log and rock causeway. One advantage of rock is that it is easier to make curves. This installation flows very nicely and the structure is in harmony with the site.

An example of ditched turnpike. Ruts are forming in the trail tread because either the ditches are not deep enough, or the ditches do not drain under the trail at regular intervals. If water is allowed to pond in the ditches, it may saturate the trail tread.

Tip, Trick or Trap?

Trap: The process of creating a great OHV trail does not end with construction

It must be followed with long-term monitoring, maintenance, and management

Most turnpike installations start with a layer of geotextile to separate the fill material from the underlying mud or poor quality native material and to increase the load-bearing capacity of the structure. Some installations encapsulate the fill with the geotextile, often called the sausage or burrito technique. Most turnpikes have logs, rocks, or treated timber to confine the fill to keep it from sloughing off into the ditches. The best surface, if available, is gravel or crushed rock with a shallow cap of soil to provide a durable tread surface and to help maintain the shape of the trail tread.

Ditched turnpike may require cross drains, culverts, and lead-off ditches to drain the side ditches. Over time, the ditches will slough in and collect debris, so regular inspection and maintenance is needed to retain the shape, depth, and function of the ditches.

This ditchless turnpike has been in place 10 years and has crushed gravel on top of geotextile. Much of the gravel has worn away or has been displaced and it's time to maintain this structure with another load of gravel. Note the wet spots appearing next to and behind the ATV.

Causeways can work well in seasonally wet areas with soils that drain well. They may not work well in perpetually wet areas with saturated soils since

This is a drier site and the ditches are very shallow, but probably adequate. This may have been an old road corridor. If not and the trail was located here, it is way too straight and does not look natural. Create a trail experience, not a transportation experience.

the structure may slowly sink into the ground. The use of a wider geotextile base or other geosynthetic materials may remedy this.

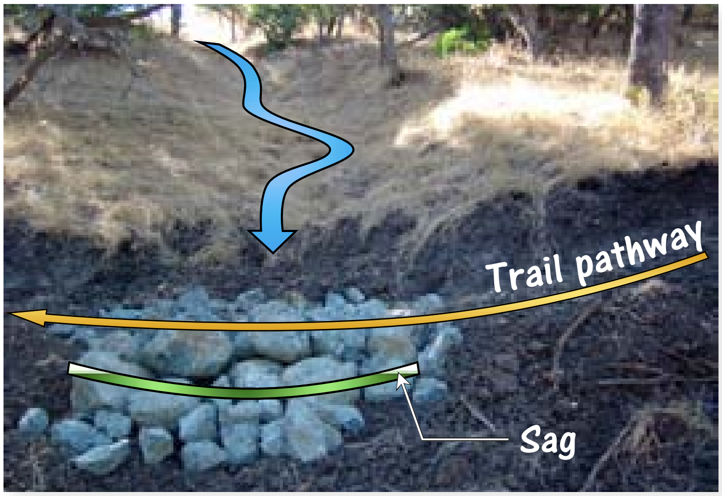
If a supply of mineral soil is available, a turnpike can be cheaper and easier to build than a puncheon, have less maintenance, and have a longer lifespan. Like many other structures, riding on a turnpike is different and adds to the rider experience.

As with many structures, there are short-term impacts upon implementation. Don't let those impacts deter your design decision. Above, a section of recently constructed turnpike on a road-to-trail conversion. Right, the same section one and a half years later. High, dry, and a great single-track experience.

Moving Water Across the Trail

Water from springs, seeps, or ephemeral streams can saturate the trail tread and create mudholes. There are two ways to move the water across a trail: drains and fords.

Drains are structures that carry water across the trail either on the surface or under the surface. Surface drains are a trench outsloped so the water runs across the trail and the trench is filled with cobble rock that provides weight bearing for the vehicles while allowing water to flow through the voids in the rock. These voids will eventually fill up with sediment and the water will then flow over the surface of the rocks. The most common subsurface drains are the French drain and curtain drain. The French drain is usually used to carry water under the trail from a point source of water like a seep or spring. It is a trench dug laterally across the trail, lined with geotextile, filled with clean drain rock, and then the geotextile is folded over the top. Usually, a perforated drain pipe is added as well to help carry the water. Unfortunately, the geotextile usually plugs up over time at

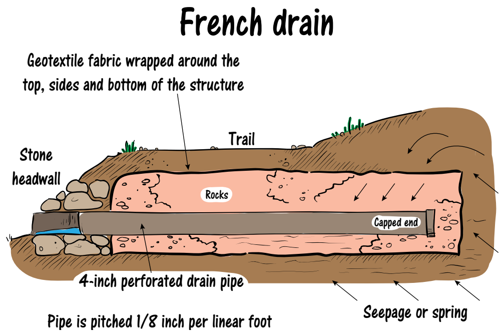


At some point, water will run down this drainage way, either from a thunderstorm or snowmelt. A hardened drain protects the tread and any fillslope from erosion. A properly designed trail would have a grade sag here so the tread drains from both directions at this point.

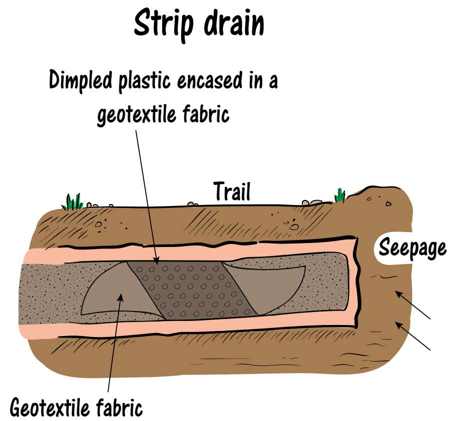
This seasonally wet crossing has been hardened with cobble-sized rock. This is simple and effective and there is no culvert to clean out or plug up. In arid country, runoff from a high-intensity thunderstorm can wash out a culvert, but a hardened drain will likely endure.

This area has pistol-butted trees above the retaining wall (red arrow). This is an indication that the ground is slowly moving or slumping. Trail locators should watch for these indicators and avoid the area if possible. For this area, relocation was not an option and a curtain drain has been installed within the retaining wall to collect and drain water seeping out of the bank. The pipe exits off to the side (yellow arrow).

the inlet causing the structure to fail. Also, if drains are not installed deep enough or if the cover material is not maintained, displacement will expose the geotextile and the integrity of the structure will begin to fail. For these reasons, a culvert or an armored surface drain may be a better alternative.



Curtain drains are installed longitudinally above the trail or along the inside shoulder of the trail. They intercept a sheet flow of subsurface water to prevent it from saturating trail tread or from pumping up through the trail tread with repeated traffic. Depending on the depth of the subsurface water layer, these trenches can be considerably deeper than those of a French drain. They're usually lined with geotextile on the sides and bottom and filled with clean gravel or drain rock. They may or may not have perforated pipe in the bottom. Since they typically intercept a linear water source rather than a point water source, they can be 100 feet or more in length. For lengths greater than 50 feet, the water that is collected needs to be drained across the trail at regular intervals. The cross-drains can be surface drains at a grade reversal or rolling dip, or subsurface drains like culverts, or French drains.



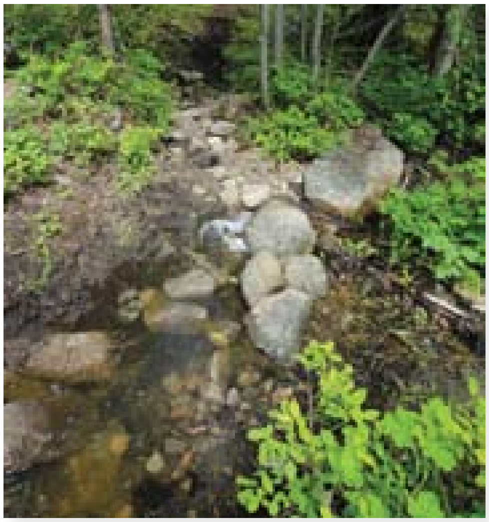
Prefabricated geocomposite sheets or strip drains are also available that function just like curtain and French drains only they're a whole lot easier to install, less expensive, and easier to replace if necessary. They are a piece of dimpled plastic encased in a geotextile fabric and they are available in rolls of various widths and lengths. The trench for these is much smaller and is backfilled with correspondingly smaller volume of sand rather than rock. Strip drains can be an alternative to the traditional trench drains that may be worth considering. Note: If too close to the surface, they can collapse under the weight of vehicles.

As with any structure, these drains need regular inspection and maintenance. French drains especially can clog with sediment and debris at their input point.

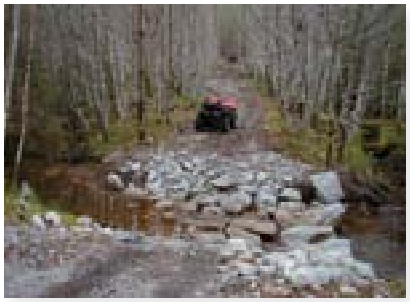
Fords are an on-grade, wet-tire crossing that can offer an alternative to the expense of a bridge or the risk of a culvert. They aren't appropriate in some settings and their use is not allowed everywhere. The biggest issue with fords is the potential for sediment delivery from vehicle tires directly into the stream. From a rider standpoint, fords can offer fun, challenge, and a unique riding experience. There are advantages of fords over culverts: fords don't have to be cleaned out, they can tolerate wide fluctuations in flow, and there is generally less risk of a major structure failure or washout.

This ford is hardened with concrete boat ramp planks. These are commonly used and they work quite well.

A flat stream gradient, gravel bottom, and gravel approaches make this a very suitable location for a ford. Low cost, natural appearance, and high rider experience are all benefits.



A few well-placed boulders on the downstream edge and this simple ford is complete. The cobble rocks in the bottom of the ford could have been removed and replaced with smaller rocks for a smoother crossing depending on difficulty level.



Boulders on the downstream side help reduce the gradient of this ford and the banks are well armored with large cobbles for stability and reduction of sediment delivery. However, if fish need to pass through this site, this design could be an issue and an option like a culvert may need to be considered.

Things to consider with fords:

- Fords work best on ephemeral or low-volume streams with low, stable water levels generally not exceeding 10” during the season of use.
- Check the classification of the stream before considering a ford. Fish-bearing streams or those with direct connectivity to community water intake will likely have restrictions or prohibitions on sources of sediment delivery. Some type of permit will likely be required.
- Check management plan direction, NEPA direction, agency policy, and state and local laws for restrictions and prohibitions before building a ford.
- As a general guideline, the farther upstream the crossing is, the more likely that a ford will be acceptable.
- For stability, the stream gradient must be very low or the ford will erode away.
- Trail approach grades should be low (4 to 10 percent) to minimize sediment delivery. Dropping off a steep bank into the creek creates a poor, non-sustainable approach.
- The stream bottom should be gravelly, not sandy or muddy. If it isn’t, then some type of hardening will be required.
- A stream bottom with small-sized cobble rock can work well. A crossing with larger sized rocks would need to be consistent with the difficulty level of the trail.

Redirecting Water Away From the Trail

There are three ways to carry water away from the trail and redirect the flow of water to a more desirable location: lead-off ditches, sumps, and sediment basins.

Lead-off ditches are commonly used to drain grade reversals, rolling dips, and outsloped sections. If the material is suitable, push excavated material from the ditch onto the trail to be utilized as tread material, not away from the trail. As in all structures, regular inspection and maintenance is required to keep the structure functional.

On flat ground, it can be difficult to ditch the water away from the trail. One solu-

A new trail on the contour intersects this old fall line trail. This ditch carries water from the closed trail and redirects it into the natural drainage using the cobble rock as an energy dissipater. Note the log across the ditch entrance to catch the riders’ eyes.

tion is to build a sump, which is essentially a hole in the ground that will collect any runoff water and allow sediment to drop. A sump will eventually fill up with sediment and will need to be cleaned out in order for the sump to remain functional. The trail tread material that a sump captures can be re-used on the trail. Sumps can also be used to keep runoff water from flowing into an area where it shouldn't go. When constructing a sump, it's important to make it big enough to accommodate the expected runoff volume from an average storm. As in leadoff ditches and rolling dips, when digging a sump never waste the excavated material. Instead, use it as tread material or as material to build up the crest of the rolling dip. Sumps make a good source for borrow material.

A nice lead-off ditch was constructed to drain a rolling dip, but as riders' eyes scan this area, it is difficult to determine a ditch or a trail going off to the right. A millisecond of uncertainty can draw a rider into the ditch. To avoid this, it is a good practice to place a small log across the ditch entrance so it spans the ditch without blocking the flow of water.

Similar to sumps, sediment basins collect runoff water from the trail and allow it to drop its load of sediment before flowing out over the spillway. The difference between a sediment basin and a sump is that a sump generally has no outlet. Sediment basins are usually used in the vicinity of streams to reduce sedimentation and hinder the direct connectivity of water from the trail to the stream. The basin should be of sufficient size and depth to handle normal runoff. In general, a sediment basin has some form of hardening. The entrance can be lined with cobble rock to dissipate the water energy. The back and side edges are usually an earthen berm lined with cobble rock. Sometimes the berm is reinforced with geotextile under the rock. The outlet or spillway is slightly lower than the rest of the berm and it is usually rock lined as well. The bottoms of the basins can be lined with rock, but this can hinder the maintenance task of periodically removing the deposited sediment. Sediment basins will fill up with debris and sediment and require routine inspection and maintenance.

Tip, Trick or Trap?

Tip: Tread material is a precious resource. Any suitable material excavated for a structure should be incorporated into the trail tread.

Before rehab efforts could begin on this heavily eroded trail, the source of the water had to be diverted away by ditching it into the natural drainage courses.

Due to the flat terrain, this rolling dip has little elevation difference between the sag and the crest. The lead-off ditch also has a flat gradient and it is almost full of sediment. Notice how the water is flowing past the entrance to the ditch and is almost breaching the rolling dip (arrow). If maintenance isn't performed shortly, this structure will likely fail.

Sediment basins allow a trail to drain water into the proximity of a stream and still protect the water quality of the stream. Notice the rock armoring in the outlet.

Without the sump, this water would just drain down to the trail below where it has the potential to gain more velocity and create more erosion. It would have been better if at least the back wall of this sump (arrow) was armored with rock. If it ever saturates and breaches, the flood of water could create unwanted and unnecessary impacts.

The excavation from this sump was used to construct the crest of this rolling dip. It appears that the sump could be bigger. Note the sediment (arrow) that has been deposited in the trail tread before entering the sump and how muddy the water is in the sump. This material can be reused.

Using Existing Structures to Control Water

Structures that are used to cross major streams can be very expensive to build and maintain. A strategy that can reduce those costs and reduce potential environmental impacts is to utilize infrastructure that is already in place, such as road or other trail crossings. This may not be desirable from a purist trail perspective, but it is desirable from a practicality and management perspective. The infrastructure could be a simple ford, a large multi-plate culvert, or a bridge. In many cases, the existing infrastructure is already in the best crossing location and other options may be limited or not as suitable. If it is a road structure, access would require mixed use of the road but this could be for just the minimum distance required to cross the stream and get to a point where there is good trail egress with flat grades and adequate sight distance.

Several things need to be in place before utilizing existing structures:

- The trail needs to be directed to the existing infrastructure and this is not always possible.
- When using the structures of an existing trail, determine if the trail uses are compatible with the existing structure and if the structure will safely accommodate the OHV width and weight.
- Existing stakeholders need to be consulted to flush out any concerns and to build and maintain stakeholder cooperation.
- Appropriate signing will be necessary to warn everyone that the structure will be multiple-use.
- When using existing road infrastructure determine if it is legal to have mixed use on the road.

The cost of a major culvert installation like this can be prohibitive, so routing the OHV use onto this road to share the structure only makes sense.

The strategy of using existing infrastructure has been implemented very successfully on many projects. Short-term benefits include reduced environmental analysis, reduced engineering costs, and reduced project implementation costs. But the long-term benefits can reap bigger rewards in reduced maintenance and replacement costs. It may also foster cooperative efforts between motorized and non-motorized stakeholders.

Erosion Control Structures

Erosion control structures are commonly used and often required on construction sites to prevent stormwater run-off from entering streams, riparian areas, or other sensitive areas. Their function is to reduce the velocity of the water and to trap sediment. They are also used to aid in closure; stabilization; rehabilitation of old trails; and any time the runoff is expected to be higher than normal and tax existing drainage facilities, such as after a wildfire, during or after a logging operation, or during an unusually wet rainy season. Erosion control structures are usually temporary structures since they do not have long-term effectiveness or durability.

This trench is a heavily eroded motorcycle trail in sandy soil. The sediment movement was halted by stabilizing the trenches. This was successfully accomplished with rock and log check dams, woody debris placed in the bottom, and ditches to drain water into its natural channel.

The most common types of erosion structures are check dams; energy dissipaters; silt fences; straw or coir wattles; and straw, hay, or other bales.

Check dams are used to close or rehabilitate heavily eroded trails or to stabilize the continuing erosion and growth of ravines. The word "dam" is a slight misnomer since most check dams allow water to percolate through them. The principle of the check dam is to reduce the velocity of the water so it will drop its load of sediment behind the dam. Eventually, the dam will fill up with sediment, which will help stabilize the floor and sides of the ravine or trench. The dams should be installed at regular intervals down the full length of the ravine or trench. Though check dams can be difficult to install, they are highly effective. Materials are usually cobble rock, logs, and treated timber, though steel guardrail has also been used. While curbing erosion from above, the dams also act as barriers to deter riding from below.

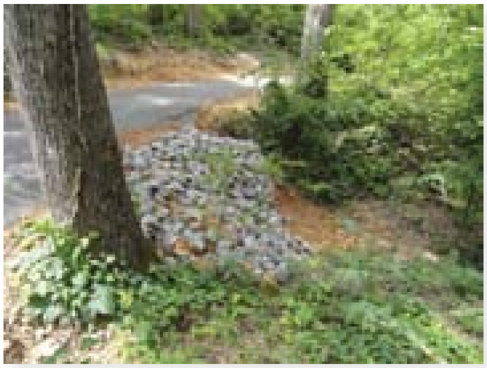
An energy dissipater is any structure that slows, redirects, or interferes with the flow of water. Water velocity is what erodes the soil, so the amount of sediment being carried by the water is directly proportional to the velocity of the water. The most common dissipater material is cobble-size rock or larger, but logs, steel, woody debris, or other materials can be used as well.

A dissipater should be considered at the outlet of any corrugated culvert installed on a grade exceeding 10 percent and on any smooth-walled culvert exceeding 5 percent. An energy dissipater should be considered at trail drainage

These log check dams were installed to stabilize and rehabilitate this old motorcycle hill-climb. After four years, use has been deterred and the impacts are starting to heal.

Above, material has started to fill in and revegetate behind this rock check dam. Rider access from the top and bottom was blocked and signed as closed.

Installing an energy dissipater at a culvert outlet points that have the potential to drain a high volume of water, especially if that drainage point is on a fill or a steep slope. Armoring the slope with rock reduces the velocity of the water and protects the slope from erosion.



A blanket of cobble rock at the drain point of this trail protects the fillslope from scour and erosion. This protection is especially important where there is the potential for high volume and high velocity water flows.

In order to get bridge materials and equipment up this old road, silt fence had to be installed any place there wasn't a vegetative barrier between the road and the stream.

Silt fence is a water-permeable geotextile fabric held upright and anchored to the ground by regularly spaced stakes. The fabric allows water to slowly seep through it, but filters out the sediment carried by the water. One advantage to using a silt fence is that it is readily available at most large home supply stores or farm and ranch stores. It can quickly become unsightly and should be removed after it is no longer needed.

Silt fence was installed at the base of this fireline to protect runoff and sediment from entering this sensitive stream. It often comes pre-attached to wooden stakes, but they will not last as long as metal T-posts.

Straw or coir wattles are commonly seen in the ditch lines along most road construction projects. They are net bags filled with straw or coconut fibers so they look like small logs. They come in a variety of diameters and lengths and are usually staked in a herringbone pattern at regular intervals in a drainage way. When used in trail or slope rehabilitation, they are placed on the contour at regular intervals down the slope. The steeper the slope, the shorter the interval. Wattles break the slope into smaller watersheds, which reduce water volume and velocity. The wattles trap sediment, but allow water to filter through slowly.

Wattles placed as part of the rehab of old hillclimbs. Between the wattle rows, the area is usually seeded and covered with mulch.

Bales have the advantages of availability, easy installation, and portability. Bales placed at regular intervals down a slope prevent water from gaining too much volume and velocity. This protects the seeding, mulching, and other erosion control efforts. In addition to straw bales, cedar shaving bales are also available. Cedar bales are heavier than straw, but they last longer and do not need to be certified as weed-free. Bales can also be used as a visual and physical barrier.

Above, rows of wattles staked closely together as part of the rehabilitation of this steep slope.

Bales are relatively easy to transport to the site and stake in place. They are effective erosion control devices and they provide more of a visual barrier than wattles.

Bales of cedar shavings work well, last longer than straw, and don't need to be certified weed-free.

Section 2: Terrestrial Control Structures

Retaining Structures

There are two types of retaining structures: gabions and retaining walls.

A gabion is a rectangular wire basket that is filled with rock. Once filled, a wire lid is secured in place. Gabions are support structures that are commonly used for bridge abutments, retaining walls, and stream bank protection. The top of the gabion should not be used for the trail tread since the wire mesh will eventually break and puncture tires.

Gabions are being used to support these two bridges. The baskets are a good alternative when there isn't a solid foundation.

Retaining walls hold material in place and include bin walls and crib walls. Bin walls are closed wall structures that are back filled to create a gravity fed retaining wall. Crib walls are created by stacking members (timber, steel, etc.) which creates a void that can be filled by rock or soil. Materials typically used for retaining walls include log, stone, treated timber, geocell, encapsulated geotextile (grass pavers which can be filled with dirt and stone to create a wall), interlocking concrete blocks, and steel guardrail sections. Often, the inside of the structure is lined with geotextile, which increases strength and helps contain fill material. Retaining wall kits are also available that provide durability, portability, and ease of assembly.

Log walls are classic and natural, but not as durable as other materials. This is a good example of a crib wall.

Common uses for retaining walls include the following:

- To support the trail fill when sideslopes are too steep, too unstable, or when full-bench construction is not desirable or feasible.

- To contain or stabilize the cut bank in steep ground, unstable soils, or loose rock like scree.
- To minimize the footprint (size of cut slope and fill slope) of the trail to enhance aesthetics or to protect resources.
- To contain trail fill material on bridge approaches and abutments so soil doesn't leach into streams, riparian areas, or other sensitive resources.

If available, rock is certainly the most aesthetic material, but it is best suited for small structures unless skilled crews are available to construct multi-tiered installations.

The Sutter retaining wall is a kit that uses treated lumber and prefabricated channel posts and caps. With ease of transport and installation, it can significantly reduce the cost of a retaining wall.

Interlocking concrete blocks (sometimes called no-pins) are a common material when there is good equipment access to the site. This wall was built to protect a trail from road fill slough. It is a new installation, so its success is not yet determined, but it appears to be too short to accomplish the objective.

This bridge approach bin wall has nice clean lines and makes a beautiful installation. Once vegetation is re-established, it will blend well with the landscape.

Structures for Controlling and Directing Access and Use

Managing entrances and using tank traps, barriers, fences, gates, and cattle guards all help control and direct the riders' direction.

A couple of well-placed boulders can effectively send the message that this trail is for single track only.

Entrance management is accomplished with a structure or a combination of structures and signing to inform the rider of the type of vehicle or vehicle width allowed on the trail. Bollards, barriers, or sections of fencing are often used to restrict vehicles exceeding a certain width from entering the trail. Entrance management is also a technique used to inform riders of the actual difficulty they will be encountering on the trail. Too often, a more difficult or most difficult trail does not appear challenging at the entrance to the trail, so riders start riding the easier part of the trail and then encounter a section with a technical challenge that may be beyond their riding capabilities. With entrance management, technical features (often called

Treated wood bollards are commonly used for entrance management. However, there is too much space on either side if the goal is to stop larger vehicles from entering.

filters or qualifiers) consistent with the difficulty level are placed across the entrance of more or most difficult trails so riders immediately know the level of skill needed or the requirements of the vehicle for the trail to be successfully negotiated. This protects the riders, but also protects the trail from undue impacts. For risk management and for rider safety and enjoyment, this technique should be used at the entrance of any trail that does not appear to be as difficult as it is signed.

Steel pipe is vandal-resistant and sends a stronger message when one is needed.

Effective entrance management controls use and sets expectations by answering questions for the rider:

- Which trail is it? This is indicated by a trail marker that shows at a minimum a direction arrow, and the trail number.
- What is the difficulty level? This is shown on the trail marker and indicated on the ground by a filter when necessary.
- Who can use it (use types)? This is shown on the travel management sign and sometimes shown on the trail marker. Width-limiting devices or barriers can be used to prevent some types of uses from accessing the trail.
- When is it open or closed? If necessary, this can be shown on the travel management sign or other regulatory sign and is often indicated on the ground by a gate or barrier across the trail entrance.

Other information that is often provided at a trail entrance is a “Two-Way Trail” warning sign or “One-Way” or “Exit Only” regulatory signs when appropriate.

Simple, innovative, and effective.

A

This is a good example of an entrance management installation: well-placed barriers backed up with good signing. The 4Es at work.

Anyone could move these treated barriers out of the way, but they didn’t. The barriers are not pinned so maintenance equipment can still get through.

A note on width limiters

Limiters are objects that have been installed within the trail prism. As such, they can increase risk of rider injury and management liability. Limiters MUST be clearly visible. Install them on a tangent, never on a curve. Control approach speed by tightening the trail alignment or other method. Insure that there is adequate time for the rider to see the object, comprehend the object, and react accordingly. Apply reflective object markers if necessary.


Tires were placed as a filter at the entrance to these trails to provide an immediate indication of the difficulty. Good entrance management sets expectations and increases rider safety and enjoyment. It would be preferable to have the filters fit aesthetically with the landscape, but that is not always possible.

Entrance management gone awry…. This was a creative attempt to close a road to full-size vehicles and limit use to ATVs and OHMs. While it's been effective and is still in place, it is aesthetically displeasing, there is no signing or reflective markers, and it's the type of structure that could provide an unwanted "challenge" to an irritated operator of a full-size vehicle.

Tip, Trick or Trap?

Tip: Before designing or installing any gate or limiter, be sure to check for compliance with accessibility requirements

From the front, this tank trap just looks like a mound of dirt that could invite challenge…

…but riders launching themselves over that mound would be looking at a face plant in a vertical wall. These structures have caused serious injuries to riders.

A tank trap is a structure commonly used as entrance management to close or restrict motorized access to roads or trails. It is constructed by digging a hole and using the excavated material to build up a berm in front of the hole. Often called "Kelly humps," the combination of the hole and berm can create a formidable structure that can be 12 to 15 feet deep. There has been much debate on the use of tank traps. On the one hand, they do provide a visual barrier to indicate that the road or trail is closed. On the other hand, for OHV riders looking for challenge, a tank trap can look inviting and attract unwanted use. Just a mound of dirt does not effectively communicate a closure. Unintentional use on poorly located or poorly signed tank traps can result in severe injuries or death. Tank traps can be especially hazardous if the road or trail is closed in the summer to motorized use, but open in the winter to over-snow use. In poor light or blinding snow, a snowmobiler can unknowingly ride into a tank trap.

Tip, Trick or Trap?

Trap: Poorly located, constructed, and signed tank traps are just that- TRAPS

They should not be used on or adjacent to an OHV trail or trail system

Barriers are another management tool used to control and direct where the riders can or can't go. Riders' eyes are constantly scanning for the open route and the best line through that route. It does not take much of a barrier to catch the riders' eyes and deter use. As such, a low, unobtrusive barrier can be just as effective as a large

Boulders make a great natural looking barrier when available. This installation is not complete since the trail that is being blocked has not been ripped and disguised with debris.

visually obtrusive barrier. A variety of materials can be used for barriers, including dirt, vegetation, logs, wooden rails or poles, rocks, steel, tires, hay bales, or treated timber. The choice of materials usually depends on local availability, price, architectural theme, or factors such as the risk of vandalism. The material selected can either send a strong visual message or a subtle one. Once a material is selected, it should be used throughout the project so that a consistent message is sent to the riders.

When used for closure or rehabilitation, the most effective installations include a sign behind the barrier saying "Area Closed" or "Trail Closed."

Hay or straw bales can make good barriers to control and direct the use. Their portability makes them good for short term uses like trail closures. Bales may need to be certified as weed-free.

These large tires make an effective barrier. Though not aesthetically pleasing, there was a local source of supply and the price was right: free.

With no other materials readily available and in an area prone to vandalism, these pipe barriers are a good choice.

The spruce budworm provided an ample supply of logs for these beautiful and effective barriers.

A word about cable barriers…
On the pro side, cable barriers are easy to install, relatively inexpensive especially for large open areas like this, and are more vandal resistant than all wood structures. On the con side, they have the potential to create a safety hazard and increase your risk. Do not install these where grass or other vegetation can obscure the cable, in high dust areas, or where there is winter snowmobile use. It is not recommended that these be used in areas where there is a higher risk of operator error like around loading ramps, tot lots, or training areas.

Like barriers, fences are used to control and direct the trail use. Materials used to construct fences are often metal, chain link, barbed wire, plain wire, treated timber, rail, split-rail, and log. Material selection is often dictated by local supply, price, or architectural theme. Once a material is selected, it should be used throughout the project so that a consistent message is sent to the riders. As with barriers, fences can add to (or distract from) the aesthetics of an area. They can provide a subtle guide or a strong constraint. Fencelines should also be shown on the trail map to aid in orientation and rider awareness.

One issue that often occurs is a trail paralleling a barbed wire fence. Many factors need to be considered when siting a trail parallel to this type of fence, including speed, traffic volume, tread width, and smoothness of the tread surface. Consider also the consequences of a rider losing control. If the tread is narrower and the surface is loose rock, the risk goes up and that should be reflected in the difficulty level assigned to the trail.

Though not pretty, a requirement for this OHV park was that riders be contained and chain link was the best way to accomplish that.

For resource protection, it was essential to keep cows and riders out of a sensitive drainage and the barbed-wire range fence achieved that.

Gates can be a good management tool, but their primary use is to control access and facilitate travel management. Gates are commonly used for seasonal closures, such as deer winter range or snow melt; to protect resources in cases such as after a natural disaster or other storm events; or as part of entrance management.

This beautiful Russell fence actually enhances the rider experience while providing protection for a sensitive grassland environment.

This classic chilcotin fence harmonizes with the landscape. The mountain pine beetle created a surplus of poles, so why not use them to help manage the use?

There has been much discussion about the effectiveness of gates. They can foster ill will because those with a key can go in, but others are restricted, so they are prone to vandalism. Gate effectiveness uses three of the 4Es. A gate is an engineering structure, but it needs to be supported by education and maybe some enforcement. Most people will respect a closure if they understand the reason behind it. Put up a sign explaining the closure and back that up with information on the trailhead kiosk, the map, website, and other media. Time and effort spent on education will be rewarded with compliance, user satisfaction, and reduced risk of vandalism.

Chains and braided cables are sometimes used as an inexpensive alternative to a gate. DO NOT DO THIS. Gates are visible structures and most have signs or reflective markers on them to increase their visibility, but cables and chains hang low, are usually very thin, often poorly marked, and can be extremely hard to see in a storm or low light. They can be death traps, especially if the trail is also used in the winter by over-snow vehicles. Manage risk. Install the proper structures that will increase public safety and reduce liability.

Things to think about with gates:

- If possible, locate gates where vegetation or topography will inhibit bypassing.
- Use signing and education to inform riders as to why a gate is closed.
- Gates that are sometimes open or sometimes closed to manage access should have red and white retroreflective tape or object markers to increase their visibility. This is a simple step to help manage risk, and this protocol should be included in the project sign plan.
- Gates that are locked in the closed position should also be locked in the open position so that only management has control of the access.
- When gates are used for resource protection, ensure that they are opened in a timely manner when that protection is no longer needed. Similarly, when used for a seasonal closure, ensure they are opened on the date they should be opened.
- Gates should be fully closed or fully open and never in a partially open position. A partially open gate can be a serious safety hazard when there is limited visibility. Manage risk. Ensure that all gates have positive, functional latches or closure mechanisms.
- Work with human nature, not against it. If the complaint is that riders are leaving a range gate open, don't have a crude barbed wire gate closure that can shred expensive riding gloves and jerseys or is difficult to open and close. Use the 4Es. Improving engineering by installing a cam-lock gate closure device will increase compliance and facilitate OHV management.
- Never direct traffic around a locked gate without designating the side route as open, otherwise the public learns to ignore a locked gate.

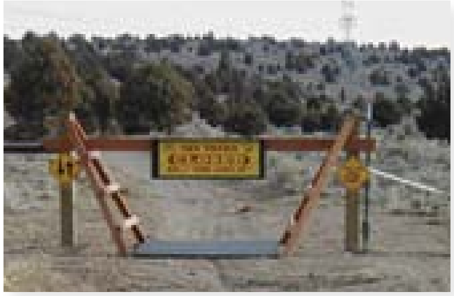
A Closer Look...

On the gate below, the reflective red and white panel with diagonal stripes is called an object marker. They're available in several shapes, colors, and sizes; guidance for their use can be found in most sign handbooks and in the Manual on Uniform Traffic Control Devices (MUTCD).

Gates that are left in a closed position while the trail goes around them teach the public to ignore closed gates.

It is better to have a designated trail path when closing a gate to one use but opening it to another.

This trail is on an irrigation ditch access road. The innovative gate restricts trail access, but allows access for full-sized maintenance vehicles.



Here are two examples of using other structures as "gates" to control access.

Cattle guards are often installed for livestock management. There are two basic configurations: arched and on-grade. Arches can be a good choice in rocky terrain or where resources preclude excavation. Having a dogleg in the trail alignment on each side of the cattle guard will control the speed of approach. The dogleg allows adequate sight distance but not enough distance to gain speed. On-grade structures can be easier to traverse, but they may require more frequent clean-out. A steel deck is far more durable than treated timber and a much better option.

All cattle guard installations should have a bypass gate to allow passage of equestrians, stock, pedestrians, or maintenance equipment. They can be very slippery when wet or icy. For rider safety and risk management, cattle guards should be installed on tangents, never on a curve, on the flattest grade possible, and level from side to side. Angled wings provide a margin of safety and allow room for transporting over-width materials or game.

Cattle guards are commercially available, but many agencies make their own. There is more science in design and rail spacing than one might think. Improper design such as too deep or too shallow trenches, sharp edges, slippery materials, too great an angle, etc., can pose a risk to both the cattle and the riders. Use caution when attempting to design a cattle guard.

This deck of this cattle guard has round steel tubing and a steel channel iron base. The strip of expanded metal down the center was intended to provide grip for motorcycles, but it is too narrow to be functional. The vertical wings are confining and provide no margin for error.

Above, this on-grade cattle guard has a 2"x 2" square tubing deck in an angle iron frame attached to a 2"x 12" treated timber base.

This arched cattle guard has an angle iron deck attached to a channel iron frame. Due to the forces exerted by tires on the deck ramp, it is essential that arched cattleguards are securely pinned to the ground.

Treated poles were used for this single-track cattleguard. The wood will provide a better grip than a steel deck, but note that this cattleguard in installed on a curve. Though slight, it is enough of a curve for a motorcycle with muddy tires to slide.

Need more? Learn more here...

Alaska Trails Training Modules: Mike Shields: *Slope Structures and Trail Stability,Trail Drainage: Structures and Hydrology, Trail Treadway Structures*

Best Maintenance Practices, Maine Motorized Trail Construction and Maintenance Manual, Bureau of Parks & Lands, Off-Road Division, May 2011

Locating Your Trail Bridge for Longevity, USDA Forest Service, Technology & Development Program, 1023-2808P-MTDC, June, 2010

Managing Degraded Off-Highway Vehicle Trails in Wet, Unstable, and Sensitive Environments, USDA Forest Service, Technology & Development Program, 0223-2821-MTDC, October 2002

Manual on Uniform Traffic Control Devices (MUTCD), http://mutcd.fhwa.dot.gov

Natural Surface Trails by Design, Troy Scott Parker, Natureshape, 2004

Standard Specifications for the Construction of Trail and Trail Bridges on Forest Service Projects, USFS National Technology and Development Program, October 2014

Trail Bridge Catalog, USDA Forest Service, http://www.fs.fed.us/eng/bridges/index.htm

Trail Construction and Maintenance Notebook, USDA Forest Service, Technology & Development Program, 0723-2806-MTDC, July 2007

Trail Planning, Design, and Development Guidelines, State of Minnesota, Department of Natural Resources, Trails and Waterways Division, 2007

Water Harvesting from Low-Standard Rural Roads, Bill Zeedyk, 2012

Wetland Trail Design and Construction, USDA Forest Service, Technology and Development Program, 0123-2833-MTDC, September 2001

A Look Back...

Here are some of the elements discussed in this chapter:

- Always start with the best location for the trail and be forced into utilizing a structure. Structures should be the last option, not the first, since good trail location will minimize the need for them. Structures are time consuming and expensive to build, maintain, and eventually replace.
- A principle element in achieving a durable trail is managing water. Structures help accomplish that by moving water off the trail, under the trail, across the trail, or away from the trail.
- When trying to drain water off a trail, use the grade and alignment to help you. Locate the structure where there is a break in the grade or in a curve where the natural superelevation will help turn and drain the water in the direction of the curve. Allow the water to run in its original direction as much as possible.
- The critical vehicle or design vehicle may not be the OHV using the trail, but the trail dozer or other equipment needed to maintain the trail
- Using entrance management to restrict or define difficulty level access may preclude future trail maintenance or management options
- Many structures require engineering calculations and design. Don't cut costs by short-cutting this step. Manage liability and risk by doing it right the first time.
- Any time that manmade structures are incorporated into a project, the potential risk to public safety goes up and the risk of liability goes up
- Structures require regular inspection and maintenance. The cost and personnel to perform these tasks must be built into the O&M program.
- The longevity of most structures depends on use type, use level, soil type, climate, proper design, proper installation, and proper maintenance. Failure to adequately assess and address any one of these elements may lead to structure failure.