UF IFAS Extension UNIVERSITY of FLORIDA

SS-FOR-5

Trails, Bridges, and Boardwalks[1]

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Building Forest Recreation Opportunities

Figure 1. Forest recreation is a primary objective for many Florida landowners.
Credits: Tyler Jones, UF/IFAS

Recreation on forest land is an important concern for many public and private landowners. In some situations, it is the primary goal for land management. Elsewhere, recreation is supplemental to other objectives such as wildlife enhancement or timber production. Private landowners participating in the Forest Stewardship Program often include recreation as one of the primary objectives in their stewardship management plans. Whether on public or private land, recreational opportunities are expanding in many directions. Hiking, biking, fishing, hunting, horseback riding, nature observation, and geo-caching are a few of the leisure activities pursued on forest lands. Some folks even consider more strenuous activities such as backpacking and firewood cutting as forms of recreation. Recreational options may be exercised by individuals, large organized groups, or combinations between these two extremes.

Trails are an important component of the management plan and infrastructure. Trails represent the main route of travel for hiking, riding, and a variety of other pursuits. They are also important for access to recreational sites, such as the favorite fishing hole, archery target, beach, or camping spot. Environmental education and nature observation rely on trails as "classrooms" for study and learning. All of these important functions depend upon carefully designed, constructed, and maintained trail systems.

This publication will provide practical information for planning and developing recreational trails on forest land. Although the guidelines were collected from various sources listed at the end of the publication, they have been tailored to fit Florida conditions. We will describe general designs and construction methods as well as some of the structures that may be important components of your trails, such as bridges, boardwalks, and benches. Costs are mentioned with the cautionary disclaimer that they may be highly variable depending on how you implement your recreation plans. The references listed at the end of the paper will provide readers with additional details on many of these subjects.

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Trail Design

The location and characteristics of a trail represent "a balance between beauty and function" (Proudman and Rajala 2008). Initial planning for any trail system requires careful evaluation of the general purpose for the trails, as well as the types of people that will use them and activities they will conduct. The options for trail development vary widely depending on these goals and functions. Common trail amenities that meet landowner objectives include:

- wildlife observation,
- physical activity and exercise,
- scenery and vistas,
- natural history,
- cultural and historical resources,
- conservation and management features, or
- water resources and forest ecology.

Landowners may focus on individual themes or combine them to emphasize different educational, scenic, or recreational values.

Several other important considerations in initial planning will influence general trail design. Specific site conditions or natural features on the property might be either highlighted or avoided. For example, sinkholes can provide interesting changes in vegetation and good stopping points on well-marked educational trails. On the other hand, they might represent safety hazards. Similarly, historic farm sites are often key points of interest, but old wells or cisterns are safety hazards. Although wildlife observation may be a central theme for some trails, the landowner may need to locate the trails away from areas on which endangered species are protected. The landowner should identify conditions or situations that should be featured or avoided in trail design and location.

Trails on private lands are frequently used only by the landowner, immediate family and friends, or groups that are granted permission to use the trails. However, some landowners also open their land for public use. If the latter is your intention, you may need to follow trail guidelines and specifications that meet requirements of the Americans with Disabilities Act (ADA). For example, under ADA, general-use trails need well-packed or hard surfaces and gentle grades. Ensuring that a trail complies with ADA standards does not have to be arduous or costly and should not deter landowners from building a trail or inviting the public to use a trail. ADA is a rather flexible law, and landowners should seek professional advice on current ADA standards as they design trails that will be open to the general public. The most important rule is to alert potential users to trail conditions before they embark on their journey so that they can make an informed decision whether to attempt the trail. Proper signage at trail heads and along trails informs users of conditions that they may not be suited to handle. The ADA deems this sufficient accommodation for users with personal challenges.

Other considerations during initial planning may include the availability of funds for construction and maintenance, the availability of natural (on-site) material that can be used for structures and trail surface, and whether to use building materials from commercial sources. Other resource constraints on design and function include site characteristics such as heavy brush in some areas, swamps and marshes, or rail or fence lines that would necessitate styles or other crossing structures. Know all the possible limitations on trail design before you undertake detailed planning. Careful study of the trail and consideration of potential setbacks during the conceptual phase will eliminate expensive surprises and unexpected labor or materials costs during the construction and maintenance phases.

After initial planning is complete, the trail design process shifts to deciding where to locate the trail and what general construction features you will need. In many instances, trails suffer degradation as a result of poor initial layout and design of the trail, rather than the use of the trail. Important trail attributes that must be defined include the shape, or format, and the structural components of the trail corridor. Alternatives for trail format are loops, horseshoes and lines, as illustrated in the figure below.

Loops return trail users to their starting point without their having to re-trace part of the trail. They are good trails for nature study, day hikes, and use by horses, hikers and bikes. Although day-use trails are generally less than 2 miles in length, longer loops or stacked loops can be designed for more adventurous users. Horseshoe-shaped trails are good designs for separated trailheads connected by easily accessible transportation. Another form of horseshoe trail, called a spur trail, can offer users different routes to the same end point, or it could be used to re-direct users from an overused portion of trail to let it rest and recover or to route them around hazards such as flooded areas or fallen trees after a storm.

A third trail format is a line between the trailhead and the destination. With this design, users can only return to the starting point by retracing their steps. Examples range

from a short access trail to a point of interest such as a lake or campsite, to the Florida National Scenic Trail, which extends 1,400 miles through Florida.

The trail "corridor" is the total environment of the trail. It consists of the walking surface (tread); the right-of-way (trail bed), including all area cleared for passage of the trail user; and the buffer zone, which is the area on both sides of the right-of-way that shields the trail from outside influences. Except for long-distance vistas and scenery, the trail corridor includes the immediate features that influence trail difficulty and the environment that is visible to the trial user. Thus, trail location and construction are inseparably related to the desired corridor conditions.

Route Selection

Once the general design and characteristics of the trail have been determined, the next step is on-the-ground location of the best route to meet the objectives and design requirements. Reconnaissance to identify and evaluate alternative routes begins with your own knowledge of the area, but satellite imagery, topographic maps, or other maps can also be helpful. If you are planning a long trail, satellite imagery of the planning area is available online and can provide an initial understanding of the trail route. This imagery can help to identify exact locations of important features such as openings in forests, existing trails, old roads or railroad grades, sinkholes, and old home sites. It can be used to map vegetation types and special features on other base maps. Topographic maps provide additional information on slopes, waterways, and the location of special features that might not be visible on aerial photos. A Geographic Information System (GIS) can also be a useful tool in trail planning. See the publication *Introduction to Geographic Information Systems*, https://edis.ifas.ufl.edu/fr356, for an introduction to GIS.

A detailed property survey and analysis will assist with creating a map with information to include all items that might be considered in locating trail routes as either features or drawbacks for a particular trail location. Alternative routes can be drawn on the map to make the most of the best features and avoid, or at least minimize, potential hazards and hassles.

Armed with the property map, the landowner should walk through all the alternative routes identified on the map. It is often helpful to conduct this walk-through with resource professionals who can provide valuable input and suggestions. During the on-site inspection, check all points of interest to be sure they are worthy of being featured along the trail. Also carefully check all possible water and road crossings to be sure stream banks are stable and road crossings are visible for at least 500 feet in both directions.

Figure 2. Topographic maps, aerial photos, and satellite imagery can be used to find the best trail route to meet the objectives and design requirements.
Credits: UF/IFAS

A variety of environmental conditions that will influence trail location can be identified in both the preliminary mapping and field evaluations. Saturated soils and high water tables need to be noted and checked after long periods of rainfall. Trail location should generally avoid such sites because a trail through those areas would be liable to become flooded and impassable. Clay soils are more prone to erosion than are other soil types and are therefore suboptimal for walking trails, but it's not always possible to avoid them. Trail routes on clay soils need to be identified to plan for erosion control measures if they are on sloping land. Preferred soil conditions include sandy and loamy soils with no shallow hardpans. Ridges and high topographic routes generally are drier, require less construction and maintenance, and can provide panoramic views. Ravines, by contrast, should for the most part be avoided for safety and environmental protection, although they can provide points of interest. Trails in ravines must be located and constructed to allow for their protection and to keep users of the trail safe. Dense vegetation in these areas is also a problem for initial construction and maintenance.

Along waterways it is usually best to avoid the floodplain and if possible situate the trail on a "fluvial terrace" instead. A fluvial terrace, also called a "bench," is the remnant of a

river or stream's old floodplain after centuries of erosion. It's usually at a higher elevation than the stream and will therefore flood less frequently. You can provide trail users access to the water by means of short spur trails, but the main trail should run parallel to shorelines with a modest setback and should follow the topographical contours for the approach and exit. If your proposed trail routes happen to traverse moderately sloping ground, routes should follow contours, winding gently and gradually rather than directing users straight up or down the slope.

Evaluate vegetation along proposed trail routes for aesthetic and environmental protection concerns. For aesthetic purposes, plant diversity is often a desirable trail characteristic, and trail planners should favor routes that expose trail users to as many different plant communities as possible. Thick understory, found near streams or ponds, may block views, decrease aesthetic values, and require more frequent trail maintenance than lighter vegetation. On the other hand, such thick vegetation can sometimes be desirable. It can be used to channel and contain hiker traffic, retard soil erosion (due to the abundance of roots under the tread), provide shady relief from the summer sun, and act as a buffer between incompatible activities.

Figure 3. Favor trail routes that expose trail users to as many different plant communities as possible.
Credits: Tyler Jones, UF/IFAS

Final route selection involves connecting as many of the positive features as possible. The route can be identified with plastic flagging or pin flags, which will allow the trail location to be adjusted during actual layout of the trail as described later in this publication. Conditions to favor in route selection include the following:

- Well-drained soils
- Natural openings and scenic vistas
- Open timber and light brush and understory
- Special historical or ecological features
- Access to, and view of, waterways
- Seasonal differences in vegetation
- Safe crossings of roads, railroads, and waterways
- Good access from parking
- Minimal conflict with existing land use

Avoid trail location in areas with the following drawbacks:

- Drainage constraints such as wet, flat, or frequently flooded depressions (unless they are highlighted for nature study, or have crossings of some type)
- Unstable or fragile soils (erosive or slides)
- Steep slopes, bluffs, and cliffs
- Dense vegetation requiring excessive clearing and maintenance
- Vegetation and wildlife habitats that might be adversely affected (e.g., endangered species)
- Cultural and archeological sites that need to be protected and are not featured
- Timbered areas subject to blowdown, falling limbs, or other dangers
- Old mine areas or other man-made hazards (wells, cisterns, etc.)
- Frequent stream crossings
- Existing farmlands

Basic Construction Practices

Trail construction involves clearing the vegetation along the right-of-way, cleaning or surfacing the tread, and building any planned structures. A variety of tools and materials can be used for these construction practices. Labor and costs will be significantly influenced by the selection of tools and materials. Be sure to carefully select the right equipment for each particular task.

Initial clearing and subsequent maintenance often requires cutting logs and various forms of vegetation. Axes, brush

hooks, and machetes are used for small-diameter (less than 2 inches across) stems and branches.

Saws provide smoother cuts and are generally more efficient than axes or machetes for large-diameter stems and logs. Chainsaws are, of course, the fastest, but they are heavier than the other alternatives and require more care, maintenance, and attention to safety than the others. Pruning, bow saws, lopping shears, and hand-held pruning shears are the best option for many small- to medium-diameter stems and branches, and permit pruning branches flush with stems so as not to leave any stubs. Gasoline-powered brush cutters or mowers with circular blades are often the most common tool for public agencies and are especially helpful for medium- to long-distance trails. They do leave ragged cuts and stumps above ground line, however, which means that other tools will likely be necessary to completely clear the trail.

Roots stabilize the soil and should be left intact whenever possible. Proper trail planning should avoid areas where roots create hazard and maintenance issues.

Trail construction often uses various materials for trail surfaces or borders, steps, signs, or more complex structures such as bridges. In general, natural and native materials are preferred for such purposes, mostly because they help the trail to blend with surroundings, but also because they're free. In areas subject to standing water or high humidity, make sure to use rot-resistant woods such as cypress, black locust, or live oak. Trail surfacing is not necessary for all trails, but should be considered for trails that will be heavily traveled or that cross poorly drained spots or clay soils that may be slippery or easily eroded. Sawdust, shavings, wood chips, and mulch provide a soft surface for walking and prevent erosion, trail wear, and re-sprouting of the roots under the tread. However, they are expensive to spread on long trails because they have to be either transported from drop points or mulched on site. These materials also need regular replenishment, which means additional regular costs for supplies and labor for re-spreading new material. Pine needles and regular leaf litter can provide the same effects and may be on the trail surface already or might be easy to collect from adjacent stands without disrupting aesthetic values along the trail. Rakes and plastic or burlap bags work well for such local collection and redistribution.

Gravel and rock are more expensive to purchase, transport, and spread, but may be important in local spots of poorly drained or slippery soils. Gravel should also be considered for short trails that will receive heavy public use, if a solid packed surface will not otherwise be provided. Larger rocks may be used for a number of other trail purposes. Rocks with at least one flat surface serve as steps or stepping stones across wet areas, and more irregularly shaped rocks can be used as ballast in building up trail subsurfaces or as anchors for waterbars, wood steps, bridges, and other structures. Geotextiles can also be placed across poorly drained spots before laying down gravel or rock and will substantially reduce the amount of rock that is needed for surfacing. Rock is more expensive initially and requires more time to install correctly, but the reward is in less maintenance and greater longevity.

Wood structures rely on either logs cut near the trail or pressure-treated lumber or railroad ties. Native logs blend nicely with trail environments and can be cut in whatever sizes are needed in trail construction. Cedar and cypress logs will generally last longer than pine or most of the hardwoods. Peel the bark off of logs to reduce rot and increase their useful life. Pressure-treated lumber, posts, and beams have a much longer in-use life than untreated logs. However, they are obviously more expensive to use than native materials, and they must be transported to the trail site. While treated lumber may be more durable, trail planners should consider possible unintended consequences of using it, particularly in the construction of bridges, boardwalks, and any structures that will sometimes be immersed in water. Evaluate the conditions and status of the waterbody to be bridged because wood treatment solution may leach contaminants into the water.

Trail Construction

Standards for Construction and Maintenance

These standards have been compiled from a number of trail manuals and are guidelines for enhancing a trail user's experience and for minimizing safety hazards. Trail construction standards will depend on the intended trail user group. The width of the clearing for the trail walking surface should be a minimum of 3 to 4 feet for most lightly used trails, with additional clearing of vegetation for 1 to 2 feet on either side of the walking surface. Consider cutting back fast-growing brush species an additional foot or two to reduce maintenance frequency. For trails that will receive heavy or group use (e.g., interpretive trails), clear a walking-surface width of at least 8 feet.

Where some type of surfacing material is added to the trail, the width of the surfaced tread should be at least 18 to 24 inches for long-distance trails with single-file traffic; 2 to 3 feet for bike trails; and 2 to 5 feet for nature trails. For

barrier-free trails that will be used by people with special needs, the ADA requires 4 feet of smooth tread surface.

Overhead vertical clearance (hanging branches, vines, etc.) should be at least 7 to 8 feet for hiking trails, 8 feet for bike trails, and 10 to 11 feet for equestrian trails. A slope, or grade, is often expressed as a rise/run percentage. For example, a 10% grade would be a 1 foot vertical rise in elevation over a 10 foot horizontal run. Although most forest land in Florida has only gently sloping topography, if your land includes some steep grades, trail grade should be maintained at less than 10% except for very short pitches, as with spurs into large sinkholes or ravines. Steps may be necessary for such short steep grades to prevent soil erosion during heavy rains. For long runs with steep grades, follow contour lines or if following the contour lines is not possible, create a series of switchbacks and maintain less than 10% grade except at each switchback turn.

Trails should follow the contour, minimize stream crossings and felling of large trees, and stay at least 35 feet from stream banks except at crossings. The Suwannee River Water Management District requires all trails on their lands to be at least 75 feet from the river bank. Areas cleared to expose scenic vistas should be no more than 100 feet in length, while areas cleared for access to riparian zones and waterways should be less than 8 feet wide. To minimize erosion, avoid "fall line" trails that send users directly downslope across contour lines.

Layout

Now it is time to implement all the preparation and planning. Trail layout involves marking the exact trail route on the ground so that construction can begin. The preliminary route selection should have left plastic flagging at distant intervals. Exact location of the complete trail is marked with additional brightly colored flagging or pin flags. A compass and clinometers or Abney level, or Global Positioning System (GPS) with elevation data may be used to relocate small portions of the trail or to locate the trail at the correct gradient if it traverses steep slopes.

Walk through the proposed route and hang flagging on live trees or branches or place brightly colored stakes or flag pins frequently enough to make the route clearly visible. Even in open forest conditions, the distance between stakes or flagging should probably be a maximum of 100 feet so that construction crews will always be able to see where they are headed. Once the complete trail is marked, re-walk the route from both directions to check visibility, aesthetics and all featured items, and move flagging if necessary. It may be beneficial to have others walk the trail route to be sure it meets all your objectives. When you finish, remove all flagging or other markings except along the final selected route.

The following guidelines will be useful as you develop the exact route:

- **Bend the trail** around obstacles such as large trees and any areas with many dead trees or other hazards.
- **Vary direction**, with frequent gentle curves and zig-zags to avoid long, straight trail sections.
- **Space curves** far enough apart to discourage short-cutting between curves.
- **Blend with the surroundings** as much as possible, providing opportunities for users to enjoy the trail environment.
- **Do not follow motorized trails** or old road beds unless they are impassable to any further motorized traffic.
- **Provide resting areas** and opportunities for scenic vistas.
- **Follow contours on slopes** as much as possible; otherwise, keep trail grades less than 10%, and change the grade periodically to vary the hikers' experiences. A properly laid out trail needs little or no erosion control measures such as water bars.

Clearing and Preparation

The initial preparation of the trail involves clearing trees and brush out of the trail right-of-way. Use any of the cutting tools described previously, but be sure to select tools that will allow the task to be completed both efficiently and safely. First aid kits should always be immediately accessible to crews doing the clearing. Pine trees and other plants that will not sprout from stumps or roots can be cut flush with the ground line. Stumps and roots of plants that will sprout should be dug out of the ground if you can do it without substantially disrupting the trail surface. If vegetation outside the cleared part of the trail is so thick that visibility is restricted, you might selectively remove enough of it to facilitate hikers' views or consider applying prescribed fire to the stand, which will reduce understory vegetation and enhance plant and wildlife diversity near your trail. When clearing, disperse cut materials away from and out of sight of the trail. Mechanized equipment can be used for the clearing, but avoid disturbing the site or leaving unsightly stumps and cut material behind.

Once the initial clearing is completed, the trail can be used. However, additional preparation will enhance trail quality.

Cut overhanging tree branches flush with tree trunks and remove other overhanging vines and vegetation, *especially poison ivy*! Cut sections out of fallen trees or logs when they cross the trail so that users don't have to clamber over them, and remove loosely embedded rocks if they pose an obscure tripping hazard. Sometimes it's better to detour the trail around, or over, large obstacles, and sometimes you might deliberately leave a few such obstructions in the trail to offer a challenge to hikers or to deter use of the trail by ATVs and other motorized vehicles. (In cut logs, make the cut-out sections just wide enough for hikers but not motorized vehicles to pass through.) Create small clearings or turnouts near points of interest in the trail to give groups a spot to gather for instruction.

The last step in trail preparation involves installation of water drainage features, if necessary, and surfacing the tread on trails that will require more than the natural surface that is left after clearing. This can be the most time-consuming and laborious stage in trail construction, but it may not be necessary for many nature trails in Florida's flat topography. Water drainage features will be discussed more completely in the next section because they are a critical method to prevent soil erosion from water that is channeled down a sloping trail. If you will be adding off-site surface materials to the tread, first rake any loose materials that might stick through the surfacing from the tread surface. You can use a wheelbarrow and rake or small, low-ground-pressure machinery like a utility vehicle or a skid-steer to spread mulch, chips, gravel, or other surfaces to meet the minimum tread specifications for your particular trail. Mowing may be all that is necessary where trails pass through grassy vegetation.

Erosion Control Measures

As previously mentioned, water drainage features are necessary to prevent erosion along trails on slopes and to avoid standing water on trails on flat ground. The most effective methods to control erosion are to design trails so that they avoid low, wet areas and follow the contour rather than traveling directly up and down a slope. Any slope will result in water movement, loss of trail surface, and, eventually, soil erosion. However, at some point trails need to traverse a slope, even in Florida. When drainage features are necessary, they should be designed to be safe and to minimize visual evidence of construction efforts. The frequency, size, and type of control structures depend on the erosion potential of the soils under the trail. For example, sandy soils are less erodible than clay soils because of the large grain size and porosity of sands (water sinks quickly into the soil without displacing the particles). Two other important factors include the velocity of water along the trail, which depends on the slope, and the length, both in time and in distance, that running water remains on the trail. Most erosion control measures are designed to reduce the velocity with which water travels and/or the distance of trail under running water.

Trails that follow an undulating contour rather than a long steady grade will provide frequent points of water drainage and avoid increases in water velocity. Features called drain dips or reverse-grade dips can be intentionally installed but do require occasional maintenance. Similarly, a trail that is descending a slope can be curved, using switchbacks, to follow the contour for a short distance before continuing down slope. At the curve where the direction of the trail switches, called a "water curve," the trail tread is sloped outward so that water will run off the trail into adjacent vegetation. On slopes less than 5 to 10%, you can create the same effect by sloping the trail tread to the outer (downhill) side, and/or by crowning the middle or inside of the trail so that the center of the trail is higher than the edges.

Drainage dips, or turn-outs, can also be constructed on gentle slopes to reduce water flow along a trail. Dips are small trenches dug across a trail, usually at an angle toward the downhill side. Soil from the trench is mounded on the downhill side of the trench to ensure that water running down the trail will be directed into the trench and off the trail. The mound can be stabilized by burying logs or rocks under it. Rocks on the outflow end of the trench will prevent additional erosion as the water flows from the trench. Other small drainage ditches may be used to drain water from wet areas through which trails pass before a problem develops.

A water bar is a mounded version of the drainage dip. Water bars are used on trails and roads that exceed 10% grade. As with drainage dips, the basic objective is to divert water off the trail without increasing erosion downslope from the trail. The number of water bars on a particular slope will depend on the grade and soil type. Place the first water bar close to the source of water that is entering the trail, and subsequent water bars at distances that will prevent the development of any gullies in the trail. Rock, peeled logs or railroad ties are angled 30 to 60 degrees across the trail, and are partially buried or anchored with soil, steel pins, reinforcing bar, wooden stakes, or large rocks. Logs should be at least 6 to 8 inches in diameter at the small end, and stakes should be driven in at both ends of the log(s), in an inverted V shape to hold the log in place.

Figure 4. Water bars divert water off the trail without increasing erosion downslope from the trail.
Credits: Melvin Baughman

The water bar must extend 1 to 3 feet beyond the outside edge of the treadway to be sure water doesn't return to the trail. A ditch may be needed for this extension to ensure drainage off the trail. The trail on the upgrade side of the water bar must be well below the top of the barrier to be sure water running down the trail does not run over it instead of being diverted off the trail. The downgrade trail tread can be built up with packed soil and rock to be flush with the top of the barrier. Install a rock spillway where water runs off the trail to disperse the erosive energy into surrounding vegetation.

Wherever the trail crosses small drainages, culverts located under it will channel water and prevent washouts. Corrugated metal, concrete pipe, or wood boxes can be used as culverts; they must be large enough to handle the maximum anticipated flow. Culverts should be installed so that the bottom is at ground level, with a rock spillway on the downslope end to disperse the water as it exits the culvert.

On short, steep grades, install steps. Steps work like water bars to control erosion, and as a bonus they assist hikers climbing up and down steep slopes. You can build steps with flat-sided rocks (at least 50 to 100 lbs each), treated wood (but remember that treated wood can leach and create problems), or native logs. Logs need to be well-anchored and buried at least one third of their diameter for stability. The top surfaces of each step must be rough, and should slope into the uphill side slightly to reduce slipping. Steps should extend beyond the edge of the trail to prevent erosion along the trail edge. The surface between steps should have a slight downhill slope to avoid water settling between the steps, and it should also slope to one side to reduce the effect of water cascading down the steps. Widely spaced steps may be installed above water bars to prevent clogging the water bars with sediments. Such steps should also be sloped to the outside of the trail to divert water off the trail. Steps should not exceed a maximum rise of 16 inches per step, but preferably less than 12 inches.

Maintenance

Maintenance is important to protect your investment in time, money, and effort creating your trail. In many of Florida's vegetation communities, trails that are not maintained regularly will become overgrown and disappear in just a few years. Perform maintenance at least annually to keep it from becoming a big chore. Biannually is even better: once during winter months when temperatures are cool and visibility is good, and once again in the late spring or early summer to control sprouting shrubs. Cutting them after they have leafed out and when starch reserves in the roots are at their lowest level keeps them in check longer. Maintenance activities include: clearing new vegetative growth; removing loose rocks, roots, or dead trees; repacking surfacing material if necessary; litter cleanup; and sign repair. It is especially important to remove dead trees or branches that could fall on, injure, or impede the progress of trail users.

Trail width and clearance should be returned to original standards by pruning, cutting through or removing blowdowns, and removing new growth from the trail tread. Just as you did during the initial clearing, select the right tool for the type of vegetation and clearing work, do not leave pointed stubs and stumps, and scatter (don't pile) cut material off the trail, out of obvious sight. Clean out water bars, ditches, and other erosion control structures at least annually. Put material you excavate from above the water bar on the mound below the bar to reinforce it.

Consider relocating trail segments that have turned into gullies or become wide and muddy if the relocation will not create the same conditions elsewhere. Otherwise, use log mats (short logs laid side by side), the rock treadway in the next figure, or one of the methods described in the following section on Bridges, Boardwalks and Other Wetlands Crossings, to stabilize the trail. Whatever method you use, you should also construct short drainage ditches into surrounding vegetation or use one of the erosion control measures described previously to reduce the source of water that caused the problem.

Gather wood, soil, or rock material used for maintenance from sites away from the trail, and cover or fill those sites with brush and debris when you're finished.

Bridges, Boardwalks, and Other Wetland Crossings

Sooner or later, many trails must cross rivers, streams, marshes, or other wetland areas. For trails designed to provide hikers with primitive conditions or challenges, natural trail crossings can be left unbridged or undeveloped. However, most trails will be used by people seeking safer, or at least drier, recreational pursuits. Crossing structures increase the likelihood the trail will be used, and they protect stream banks and wetland environments that are fragile and can't withstand many trampling feet. Trails through wet meadows and marshes are prone to a common pattern of breakdown in the local soil and vegetation. As trail use in these areas increases, trails become soggy and muddy and hikers tend to walk on the edge of the trail on drier ground. Gradually the trail widens as increasingly larger muddy holes develop, and presently your idyllic redwing blackbird marsh will become a mud wallow.

All stream crossings have several common requirements. Trail crossings should be located at the narrowest and most stable spots along a river or stream. Straight sections of the waterway, away from curves where stream banks tend to erode, are the most stable areas. The stream channel should be well defined at the point of crossing, and the gradient should be as flat as possible to avoid high-velocity water flow against the bridge. Slopes leading to the crossing on both sides of the stream should be stable and well-vegetated. Planning the best location for your crossing will save you money because they are expensive to build and to maintain.

Boardwalks provide interesting access routes into swamps and similar large wetlands, and are often designed for aesthetic and recreational purposes. Elsewhere, crossing structures may be used over un-drainable wet spots in trails that can't be relocated around the spot.

All crossings represent limitation to certain trail users, such as horses, bikes, and motorized vehicles. Constraints include weight limits and slippery or poor (for tire or hoof) surfaces. Potential users must be considered in designing all crossing structures, and weight limits should be well in excess of maximum expected loading. Also, most bridges and boardwalks can be expensive, so a realistic financial analysis must be conducted before committing to the construction of these structures.

General Construction Concerns

Crossing structures must be well-anchored to stream banks or dry spots, or in the underlying soil in the case of boardwalks. Footings or mud sills are usually perpendicular to the crossing logs or planks and anchored into stream banks with large rocks, long spikes or bars, or even concrete if the site is easily accessible. Wherever logs and planks are connected, spikes should be driven at least 3 inches into the second board or log and countersunk if the spike would be a tripping hazard.

Railings should be used on all crossings that are more than 2 feet off the ground or above water, and are advisable on many lower structures. They are usually 36 inches high and firmly attached to the crossing structure. The trail tread on any crossing should be at least 12 inches wide, although some narrower treads are acceptable for single-log bridges in marshes (where a slip would only muddy the user's feet). Make sure that the decking is wide enough to allow maintenance equipment, such as mowers, to pass through as necessary.

Simple Foot Bridges and Narrow Crossings

Although a variety of structures might be used for crossing distances of up to 15 feet, the three most common are log crossings, short bridges, and various rock structures.

Log crossings are basically one or more log stringers laid side by side, with a flattened top surface for the treadway. Stringers are usually at least 8 to 10 feet long. In "topped log" bridges, one side of logs 6 inches in diameter or larger is removed to provide a flat surface. Up to 1/3 of the diameter of the log is removed in this process. In "split log" crossings, larger logs are split in half to produce a flat surface. For both types, the ends of the stringers are supported by mud sills that are short logs (3 to 4 feet long and 8 to 10 inches in diameter) or squared timbers. The sills are notched to hold the rounded lower surface of the logs, and the logs are attached to the sills with pins or spikes with at least 4-inch penetration into the sill.

Small log cribs (logs stacked in a square pattern) can replace one or both mud sills if you need more height at one or both ends of the bridge. For better traction, roughen tread surfaces with pieces of wood nailed to the log surfaces, with tacked down chicken wire, or with tar and sand.

Short bridges, or catwalks, may be as simple as two logs laid across the water, 2 to 4 feet apart. Anchor them directly to the crossing banks at both ends or attach them to mud sills, then attach planks or small logs perpendicularly to the

logs for the walking surface. You can use large planks or beams in place of the logs and add handrails for safety and convenience.

In many areas, naturally occurring rocks and human-built rock structures are used for water crossings. However, naturally deposited rocks and rock outcroppings are a rare find in Florida's natural areas. In areas where rock structures are possible, they can be used for shallow stream and gully crossings. At stream crossings, a barrier of large rock is usually placed on the downstream side of the crossing, level with the trail tread. This barrier slows water flow over the crossing immediately upstream from it. Small rock, gravel, or flat stepping stones spaced no more than 2 feet apart serve as the crossing tread. The rock barrier should be extended at least 12 inches into the banks on both sides to keep water from flowing around the ends and undercutting the crossing. A peeled log extending 4 feet into each bank could also be used to anchor the gravel tread. Large native rock placed on the downstream side of the log will help hold it in place. For shallow crossings, rock barriers may not be needed, and stepping stones or a bed of gravel or rock may suffice for all except those who want a 100% guarantee of dry feet.

Long Bridges

Spans of up to 40 feet can be crossed with long stringer bridges. Although single logs have been used, bridges more commonly use two or three logs supported at both ends by single base (mud sill) logs or cribs. Longer distances can be bridged with the use of midspan cribs. Minimum diameters of the stringers depends on the length of the span and tree species used for the logs. Tables in the US Forest Service's Trails Management Handbook and the Trail Manual of the Florida Trail Association define acceptable log diameters.

Once the logs are in place (which may require significant manual labor, winches or small, low-ground-pressure equipment) the top surfaces are patterned or shaved to provide a bearing surface at least 3 inches wide. Decking from small split logs or rough-sawn 2-inch planks is spaced to allow drainage and spiked to the logs with a minimum 3-inch penetration. If you use cribs to support the ends, construct them with logs that are at least 8 to 10 inches in diameter, and fill them with rock or soil as you go. Anchor them on the outside with large rocks. Anchor stringers to cribs or sills with large spikes or galvanized bolts. Handrails are advisable on all long bridges. You can cable one end of the stringers to nearby trees to save the bridge in case of a flood, but don't cable both ends because the pressure of flood water and debris is likely to destroy the bridge more quickly than if one end broke loose and the bridge swung against the bank.

For shorter spans (up to 24 feet), log stringers can be replaced by pressure-treated 2 x 10 lumber, bolted together. Pressure treated 2 x 8 planking may be used for the walking surface. Diagonal braces (2 x 10s) on the underside of the frame will provide additional support and reduce lateral movement. Other bridge designs are described in various trail manuals. If you are considering construction of any large bridge it would be wise to contact local engineers, contractors, utility companies, or even National Guard units for possible assistance with design or material.

Boardwalks and Other Wetland Crossings

Figure 5. Boardwalks are especially useful where trails traverse large areas with standing water, such as this swamp.
Credits: UF/IFAS

Boardwalks may be constructed as permanent fixtures or in easily transportable sections to facilitate relocation when necessary. Permanent boardwalks require pressure-treated posts, poles, or piers be sunk into underlying soils or rock for stability.

Cross braces or beams connect pairs of posts. Planks laid perpendicular to the cross braces and connected to them may serve as the walkway. Alternatively, only two planks might be used to connect adjacent pairs of posts and cross braces. Short planking laid perpendicular to the long planks would provide the walkway, and side rails could be added for safety. The size of posts, timbers, and planks used in boardwalk construction will depend on the intended use of the boardwalk and the numbers of hikers expected to use it.

Portable sections are constructed in a similar pattern except that the supporting vertical posts rest on the soil or sand surface and are only as long as necessary to raise the boardwalk the desired distance above the sand or water.

Individual sections can be connected end to end with planks and large bolts and should be small enough that two to four people can move them when necessary.

Boardwalks are especially useful where trails traverse large areas with year-round standing water. Elsewhere, trails may cross small areas that are only intermittently wet or have saturated soils without deep standing water.

Another simple crossing for saturated but not regularly flooded wetlands is a "bog bridge" consisting of logs extended end to end across the wet area. Logs should be topped or split to provide a flat walking surface and can lay flat on the ground or be mounted on notched mud sills. The crossings may be one or two logs wide. They do not require handrails because the tread is barely above the ground surface. Life expectancy may be 7 to 10 years with soft woods such as pine, cedar, or cypress, and shorter with most hardwoods.

Figure 6. A bog bridge like this can be used to cross a wet area. Credits: David Govatski, Cohos Trail Association

Maintenance

As with other parts of the trail system, all bridges and crossings should be checked at least annually; more frequent evaluation of bridges is recommended. Many of these structures represent the greatest safety hazard on a trail, and careful inspection and maintenance are essential. All connections should be checked for tightness. Lumber, planks, and logs should be monitored for cracking or rot and must be replaced if there is any likelihood of the structural component failing in the near future. Periodic treatment of wood components with paint or preservatives every three to five years should substantially prolong the life of the structure. Steel beams, cables, or other hardware should be treated with rust-resistant paint. Stainless steel or aluminum are more expensive but require less long-term maintenance.

Other Trail Structures

A variety of simple structures can add significantly to the enjoyment and use of your trail. Benches located at key resting points such as vista openings or nature-study areas offer both rest and a chance to ponder the surroundings from a different perspective. On barrier-free trails, benches should be located at approximately 150-foot intervals. Benches can have four posts for support, or be as simple as two posts with a log rail connected to the top of each post. Posts should be well buried for support and security.

Railings have been mentioned for bridges and other crossings, but they should also be considered where trails are adjacent to possible hazards such as the edge of a stream, steep sinkholes or pits, or cliff overlooks (which are rare, but not absent, in Florida), and when the ground elevation exceeds three feet. Railings can also provide a partial barrier for protecting endangered plants or portions of the trail that you might be rehabilitating. Most rails should be 26 to 30 inches high and secured to deeply buried, pressure-treated posts. When hazards exist, consider tightly spaced pickets or rubber-coated fence material (chain-link) to secure the gap between the decking and the top of the railing to prevent children and pets from falling though the opening.

Stiles come in many acceptable designs, all with the purpose of allowing hikers to cross over or walk through a fence without breaking it or defeating its purpose. A ladder stile consists of two vertical posts along the fence line (usually a wire fence), with steps nailed to the posts on both sides of the fence. A step stile resembles two ladders leaning against each other at the top of the fence. Rail stiles are triangular ladders leaning against fence posts with the widest step at the bottom. Different length posts or poles can also be partially buried along a fence to provide a series of "stepping "stones on both sides of a fence.

A narrow opening in a fence, with two short fence sections forming a sharply-angled V at the opening, will allow hikers to walk through the sharp V at the opening while preventing livestock and motorized vehicles from doing the same.

Trails can be marked with both signs and blazes to assist hikers following the trail or using it for nature study. Signs should generally be placed on pressure-treated posts and backs, and not nailed to trees. Signs can be created by routing and painting lumber such as redwood, or by printing information on material that is waterproofed with plastic, lacquer, or other laminates. Large signs, such as at a trail entrance, are often mounted vertically between two posts. Other locations for signs include warnings near features that might be safety hazards, such as sinkholes and road crossings, and trail junctions (to identify trail destinations and distances).

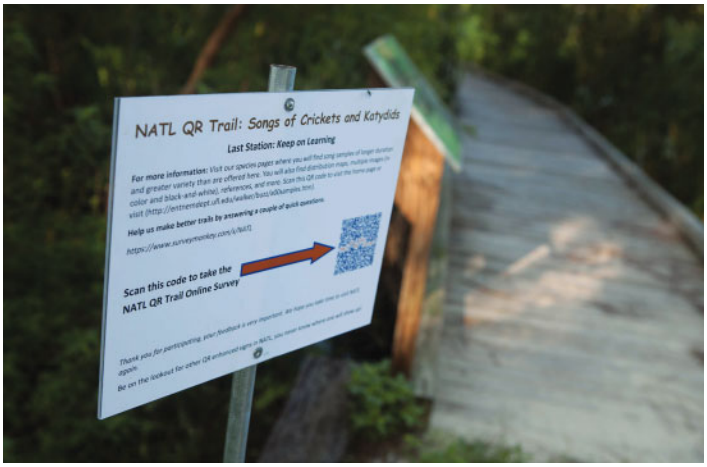

Figure 7. Directional or informative signs like this can be created by printing information on material that is waterproofed with plastic, lacquer, or other laminates.
Credits: Tyler Jones, UF/IFAS

On more primitive (less developed) trails, tree blazes are often used to clearly identify trail location. Blazes should be the same size and color throughout the trail, although colors may be varied for different trails within a larger trail system. Rectangles approximately 2 x 6 inches can be scraped on the bark of live, trail-side trees and painted with oil-based or other boundary-marking paints. Place blazes on both sides of the tree at eye level. The distance between blazes depends on the nature of the trail. A good rule of thumb is that hikers should never walk more than 100 paces without being able to see a blaze in front of or behind them. Another is that as a hiker passes one blaze the next blaze should be in view.

Costs

Cost estimates for construction and maintenance of trails and their associated structures are influenced by the level of improvement, site characteristics, and source of labor to carry out the work. For simple nature trails, the only major cost may be the landowner's time for clearing. On the other hand, bridge and boardwalk construction may require many hours of hired labor plus materials.

Legal Considerations

Planning for recreational opportunities on private land usually includes questions about landowner liability for trail-user accidents. The following comments were extracted from the Appalachian Mountain Club Field Guide to Trail Building and Maintenance. They provide important information on certain legal considerations but are not a substitute for counsel with an attorney concerning each individual situation.

Many questions about liability center on the concept of negligence, which is partially defined as the failure to prevent hazardous conditions or to warn visitors of hazardous conditions. Recreational users of private land generally fall into three legal categories, with landowners having different obligations for each category.

- "Trespassers" enter someone's property without invitation, often disregarding posted signs. The landowner has no legal duty toward these users, with the possible exception of young children.
- "Licensees" have been granted permission to use another person's property, but with no benefit of use going to the owner. Many hikers fit into this category when no entrance fees or other benefits are collected. For this category of user, the landowner should warn visitors about unseen hazards, but has no obligation to warn of obvious hazards.
- "Invitees" usually have provided a benefit to the landowner (such as an entrance fee.) Landowner responsibilities are much greater for invitees than for the other two user categories. Users must be protected against both known hazards and those that might be discovered during inspection of the land. Many states, including Florida, limit the liability of owners who open trails for public use without collecting fees in an attempt to maintain hikers in the "licensee" category, and to keep landowner liability insurance rates reasonable (see Florida Annotated Statute 375.251).

The state of Florida provides liability protection for private landowners whose property is designated as part of the statewide system of greenways and trails. See the Florida Department of Environmental Protection's Greenways and Trails page at http://www.dep.state.fl.us/gwt/ for more information.

In Closing

Trails represent the landowner's main routes for recreational activities such as walking, sightseeing, horseback riding, and bicycling. They provide access to, and through, forest land and other natural resources. They play an important role in protecting and preserving soil, water, and wild plants and animals. They can be the source of endless hours of enjoyment and relaxation. Plan your trails wisely, construct them carefully, and then enjoy them to the fullest.

Figure 8. *Oh may I go a wandering / Until the day I die / Oh may I always laugh and sing / Beneath God's clear blue sky.*
Credits: Lyrics from the song "Happy Wanderer," by Frank Weir; photo of North Carolina's Grandfather Mountain by Alan Long

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