Ice Age National Scenic Trail

Trail Structures Notebook

ICE AGE NATIONAL SCENIC TRAIL

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Introduction

The focus of this notebook is on trail structures made of wood and rock that are within the capacity of volunteers to build by hand.

Wood can be shaped for many purposes but is not as durable as rock. Rock endures but is cumbersome to work with. Regardless of what materials are used, everyone — leaders, workers and observers — should always put "Safety First!" in thought and action when building and maintaining trail structures.

Trail structures enable passage into and through scenic areas that may otherwise be bypassed or hidden from view. From a well-sited and well-crafted bridge or sinuous boardwalk, trail users often pause to view wetland environments and perhaps be renewed by the murmur of a passing summer day; from a comfortable bench, to take in the sounds of spring peepers or sandhill cranes; from an informational kiosk, to learn about landscape and cultural features. Whether someone has physical mobility challenges, is a seasoned hiker, or is new to the outdoors, trail structures serve as anchors that safeguard and inform the Ice Age Trail experience.

The Trail Notebook series is available online at http://www.iceagetrail.org. Content is based on *Ice Age National Scenic Trail: A Handbook for Trail Design, Construction and Maintenance*, available online at www.nps.gov/iatr/parkmgmt/trail_handbook.htm.

We are indebted to the Volunteers for Outdoor Colorado (*Crew Leadership Manual*, 2002), the Appalachian Trail Conservancy (*Appalachian Trail Design, Construction, and Maintenance*), the Appalachian Mountain Club (AMC's *Complete Guide to Trail Building & Maintenance*), the Student Conservation Association (*Lightly on the Land: The SCA Trail Building and Maintenance Manual*, 1996), various United States Forest Service publications, and many other sources nationally for shared insights and wisdoms contained herein.

This Notebook may be revised in the future, and we anticipate posting online more drawings, technical details, pictures, and references than can be included here. The Ice Age Trail Alliance welcomes your suggestions for improving this Notebook and gratefully extends a sincere thank you for all you do for the Ice Age National Scenic Trail!

Tim Malzhan, IATA Director of Field Operations, April 2012

Visioning

The afternoon quiet was suspended by a troupe of excited girls and boys released from their classroom to enjoy a hike on the Ice Age National Scenic Trail (NST). Rounding a bend in the trail, the fourth-graders caught sight of a swiftly flowing creek and the handsome bridge that spans it. On the bridge, some leaned hard against and then climbed atop the sturdy handrails to peer into the water. Others jumped up and down in unison, repeatedly. Soon, voices softened. Across the way, hidden from view by the girth of a towering white pine tree, I overheard stories of family fishing trips, misadventures in the Boundary Waters Canoe Area, and how all rivers and waterways are the home and lifeblood of resident plants and animals. In due time the children passed, and it was my turn to peer into the depths. William E. Wickenden's statement, written in 1937 as the introduction to *Bridges in History and Legend*, came to mind: "Craftsmanship, science, the art of design, human aspiration, social utility and striving after beauty, as expressed by trail builders, are here fused into one…"

When complete, the Ice Age NST will be about 1,200 miles long. Throughout the Trail, structures are necessary for user safety, to protect fragile soils, for passage over wet areas, and to provide access to and information about the trail. Trail structures should be built in response to user safety and environmental protection issues, not for user convenience. Built structures can add to or detract from the outdoor experience. They must be designed to fit the trail setting while serving the intended users' needs. To be sustainable, structures should be built of high-quality, long-lasting materials designed to harmonize with the environment.

Before deciding to build, first take a few steps back and ask, Is a structure necessary? Is the overall trail alignment in an optimal location? Does trail right-of-way (public or private landownership) allow enough room to potentially reroute the trail and make a structure unnecessary? One example of this would be a timber stairway that was built straight up the prevailing slope of a hill (the fall line). This structure may not be needed if the trail is rerouted to incorporate sidehill tread construction to gradually climb the hill and attain the required elevation. The art and science of trail layout and design will not resolve every grade change or change the course of waterways, however. Building trail structures is not something to shy away from, but the decision to build or not to build should be carefully considered in light of the questions above.

Trail structures require a commitment of money, volunteer time, and Ice Age Trail Alliance (IATA) and partner staff time, and a maintenance plan that specifies who shares in maintenance responsibilities. Significant structures such as clear span bridges, extensive boardwalks, multicourse rock walls, and other substantial development projects should be built only on land where trail right-of-way is permanently protected. If permanent protection for the trail is not in place, stakeholders should reconsider priorities and holistically determine how limited resources used on the trail today will benefit the trail experience tomorrow.

What you need to know:

- Trail layout and design considerations will either identify the need for trail structures and specify their locations or determine that they are not necessary or not practicable.
- Depending on the size and scope of the trail structure to be built, allow 6 to 18 months lead time for planning and project development before actual building takes place.
- Plans and permits must be approved by the landowner, regulatory agencies, and the IATA, before starting work.

Regulatory & Permit Processes

Specific regulatory and permit requirements are associated with trails. Because the Ice Age NST is administered and assisted by both state and federal governments, state and federal rules and laws regarding the disturbance of ground, plants, animals, waterways, and wetlands govern trail building, maintenance, and conservation activities, including building and maintaining trail structures. The United States Army Corps of Engineers (Corps), the Wisconsin Department of Natural Resources (WDNR), the National Park Service (NPS), and, importantly, local county, town, and city agencies, each have specific authorities to regulate these trail activities.

Ice Age NST construction and maintenance projects begin with completion of the Project Review Form (PRF). The PRF helps to answer three critical questions: Will the trail proposal negatively impact archeological and cultural resources? Will the trail proposal negatively impact threatened and endangered species or species of special concern? Will the proposal impact waterways or wetlands?

- The PRF and accompanying maps identify where a project will take place and describe the natural and cultural features of the project area, the work proposed to be done, who will do it, and when it will be done.
- IATA staff submits PRFs to the NPS in November, March, and July each year. When a PRF is submitted, a project is positioned to move from "wish list" to "in queue" status. The PRF serves as a touchstone for agency and regulatory communications thereafter.
- The PRF is available online at http://www.iceagetrail.org/resources-for-iata-leaders

Section 106 (Archeological/cultural compliance) applies to ground-disturbing activities. The NPS has final responsibility to make this determination for the Ice Age NST.

Section 7 (Natural Heritage Inventory—Threatened and Endangered Species and Species of Special Concern) applies to flora and fauna. The WDNR, with input from the U.S. Fish and Wildlife Service and the NPS, has final responsibility to make this determination for the Ice Age NST.

Clean Water Act and Chapter 30/General Waterway Permits apply to bridges and wetland structures. The WDNR, Corps, and local government planning and land use offices determine what regulatory and reporting needs are required.

Definitions Used in the Regulatory Process

- **bridge (clear span)** — a trail structure with a continuous span built so that no portion of the structure or other support material is located within the waterway. The length of a clear span is defined as the distance between the inside surfaces of the supports over the waterway (cribs or sills), not by the overall length of the structure. Spans greater than 35 feet generally exceed the capacity of IATA volunteer projects.

- **wetland fill** — gravel, rock, dirt, soil, lumber, or metal material(s) placed in a waterway or wetland. Bridges that completely span wetlands, or boardwalks elevated on pilings so that natural water flow is not restricted, are typically not regulated as wetland fill. In Wisconsin, puncheon is considered wetland fill.
- **puncheon** — a trail structure built to rest on sills that are placed directly on the ground/wetland surface.
- **piling** — a weight-bearing column or post driven into or installed in the ground.
- **boardwalk** — an elevated trail structure built on wooden or metal pilings.
- **navigable waterway** — Two guiding principles are used to determine navigability. If a body of water (pond, wetland, lake, stream, river, slough, flowage, or ditch) 1) has a discernible bed and banks or 2) is capable of floating a canoe on a recurring basis, it is navigable.

- **ordinary high water mark** — based on physical and biological indicators; the point on a bank or shore up to which the presence and action of water is so continuous as to leave a distinct mark by erosion, destruction of terrestrial vegetation, or other recognized characteristic.

Avoid wetland impacts when possible. When not possible, minimize impacts by routing the trail to have the shortest length of wetland crossing possible or span the waterway with a bridge or elevated boardwalk.

Working Smarter, Not Harder

The best way to help reviewers and trail partners to understand a trail proposal is to provide a clear statement of the problem, the proposed solution, and the methods to be employed to implement the solution. Photographs of the site and surrounding area, and accurate maps and measurements, are invaluable communication and planning tools.

A pre-application meeting with Corps and/or WDNR staff to explain the proposal, get preliminary feedback, and obtain additional information to help design an approvable project and prepare application materials is highly advisable. Corps staff is available for site visits and project planning advice upon request. If the project has been designed to avoid any discharge of wetland fill, Corps staff will issue a letter saying that no permit is needed. Field visits by WDNR staff may be conducted on a case-by-case basis but generally do not occur until a completed permit application is received.

Determining whether or not trail projects include wetland fill is the responsibility of the Corps. Jurisdictional determinations (Corps-WDNR-county-town) are best answered by the Corps and WDNR staff for the county in which the project is located. Work with IATA staff throughout all phases of the permitting process and do not overlook the importance of and the need for local town and county government approvals before building trail structures.

Planning Recommendations

Prepare the following documents:

- **Written project description**, including linear trail distance, total surface area of land disturbance, names of waterways and/or wetlands that will be crossed or are nearby, how and when wetlands were identified, and number and size (length and width, square feet or acres) of proposed wetland and waterway crossings.
- **Detailed site map(s)** identifying the trail alignment and locations of streams, lakes, and wetlands in the vicinity of the project. To do this, flag trail alignment options, then record their GPS coordinates and create the maps.
- **Detailed project plans(s)** including the location and size of existing and proposed bridges, boardwalks, puncheons, culverts, wetland crossing, or user support facilities; the existing and/or proposed trail, including tread width; and the location of wetlands, streams, etc., proposed to be crossed.
- Site-specific **erosion control plan** that clearly shows the locations and types of measures that will be used to protect nearby streams, lakes, and wetlands from construction-related runoff and surface drainage during and after the project. (http://dnr.wi.gov/runoff/pdf/stormwater/3500053a.pdf)
- **Project timeline** for sequential vegetation clearing, land disturbance, trail construction, and site stabilization, including reestablishing vegetation.
- **Practicable alternatives analysis** (see below).

Practicable Alternatives Analysis

"Practicable alternatives" means options that are available and capable of being implemented after taking into consideration cost, available technology, and logistics in light of overall project purposes.

1. State what the preferred trail proposal is and why. Describe:

- location considerations — why the trail structure is needed, constraints such as connections to existing trail(s) and support facilities (examples include parking lots, access points, campsites), land ownership/trail right of way, topography and vegetation, anticipated amount of trail use, and safety concerns;
- design choice — factors that affect the structure's design, such as wetland type, soil type, topography, hydrology (e.g., regular flow), weight-bearing needs, aesthetics, and the length of the crossing;
- costs — estimates for both construction and ongoing maintenance, including materials and labor;
- available technology — technological issues that limit or support the preferred wetland crossing; and
- logistics — factors such as construction methods, equipment access, maintenance needs, and volunteer labor that limit or support the preferred wetland crossing.

2. State alternate location(s) and designs that were considered. Describe the pros and cons of other trail alignment options considered to avoid or minimize wetland impacts; describe alternate structure designs that were considered to minimize wetland impacts — for example, building a clear span bridge or elevated boardwalk instead of turnpike or puncheon.

3. No action – not pursuing the project.

Steps to Identify Wetlands

Step 1: Office Screening

An office screening consists of examining project plans, soil surveys, topographic maps, wetland inventory maps, air photos, and other information with Corps staff to determine the potential presence of a wetland, identify its type, and/or sketch its approximate boundaries.

Step 2: Field Review

A field review involves visiting the site with Corps staff for collection of field data and verification of resources to determine the potential presence of a wetland and identify its type and/or its boundaries.

Step 3: Wetland Delineation

Wetland delineation may be required for projects involving wetland fill or where uplands and wetlands are not clearly distinguishable. Wetland delineations are conducted by a consultant or agency staff with professional credentials and training in wetland delineation.

Application Example	Recommended Steps
Projects confined to easily identifiable upland areas, and not adjacent to stormwater protective areas or in areas mapped as having wetland indicators	Step 1: Office Screening
Identification/evaluation of alternative routes or locations	Step 1: Office Screening Step 2: Field Review
Maintenance work on existing wetland crossings	Step 1: Office Screening Step 2: Field Review
Projects confined to upland areas but in or immediately adjacent to stormwater protective areas or in areas mapped as having wetland indicators	Step 1: Office Screening Step 2: Field Review
New wetland crossings in easily identifiable wetland areas	Step 1: Office Screening Step 2: Field Review
New wetland crossings in difficult or complex wetland areas	Step 1: Office Screening Step 2: Field Review Step 3: Wetland Delineation

Tamarack fen, as seen from the Ice Age Trail, Polk County.

Web Resources

- Wisconsin Department of Natural Resources (WDNR) Wetland Toolkit (http://dnr.wi.gov/wetlands/locating.html)
- US Army Corps of Engineers Wetland Brochure (http://www.mvp.usace.army.mil/regulatory/brochures/Wetlands_brochure_proof.pdf)
- US Army Corps of Engineers Pamphlet "Recognizing Wetlands" (http://el.erdc.usace.army.mil/wetlands/pdfs/wetbroc.pdf)
- Corps contact information and staff assignments can be found on the Corps website: http://www.mvp.usace.army.mil/regulatory/default.asp?pageid=1716
- Background and instructions can be found on WDNR's website at: http://dnr.wi.gov/waterways/shoreline_habitat/wetlands.html.
- WDNR Surface Water Viewer http://dnrmaps.wi.gov/imf/imf.jsp?site=SurfaceWaterViewer

Working with Wood

Exposed wooden structures have a long tradition in all countries where timber has been readily available. In Europe, the oldest exposed wood structures still in service date back to the 11th century. In Switzerland about 250 covered bridges are still in good working condition; fire and man, not wood decay, claimed most of the victims not standing today. Wood has tremendous versatility and can be shaped with precision. Helping to plan and build a clear span bridge, a sinuous boardwalk, or a handsome bench can be a very rewarding and enriching experience that provides real and immediate benefits to trail users.

Most weather-exposed wooden structures do not fail due to structural errors but due to decay. How durable any given wood structure will be depends on design and location, the materials used, the level of craftsmanship demonstrated during construction, and the effectiveness of periodic maintenance afterward.

Wood decay is caused primarily by fungi that cannot survive without air, moisture, and food. Remove any one leg of that triad and fungi cannot become established. The influence of joinery methods on rate of decay is significant. Lap joints provide greater end-grain absorption of water and do not dry as quickly as some other kinds of joints. The following mechanisms and sequences lead, in time, to the failure of wood structures.

Cause	Effect
sunshine	wood shrinks
internal stress	longitudinal cracks
rain, snow, and ice	water seeps into cracks
swelling	cracks get deeper
moisture stays	fungi develop
fungi action	internal decay
strong decay	loss of strength

To prevent or delay deterioration of wood structures, cut surfaces should be treated with a preservative and joints and cracks should be caulked.

Dimensional Lumber

Most wooden Ice Age NST structures are built with pressure-treated dimensional lumber, commonly called "green-treat." Tips for working with pressure-treated lumber:

- Use only recommended fasteners — hot-dipped galvanized or stainless steel. Stainless steel is expensive but should be used in demanding structural applications and in environments where wood moisture is likely to be greater than 20 percent. GRK fasteners (http://www.grkfasteners.com/en/selection_guide.htm) are a good choice for decking and ledgers.
- Thoroughly wash exposed skin that has come in contact with treated wood, especially before eating and drinking; launder clothing before reuse.
- Wear gloves, a dust mask if sawing or sanding, and appropriate eye protection.
- When the top surface of a board is likely to be drier than the bottom surface, screw or nail the board crown side up; the annual growth rings visible at the butt end of the board should arc upward, like a rainbow.
- Drill pilot holes when fastening near the edge or end of a board.
- Do not burn treated wood; clean up scraps and sawdust daily.
- Inspect boards upon delivery and before using. Warped, twisted, or checked boards should be set aside and returned to the seller for credit.

Native Timber

Traditional skills involving notching and joinery are, unfortunately, increasingly distant in the 21st-century trail builder's skill set. The opportunity to learn and apply these skills does not, however, justify native timber construction for its own sake. The decision to build with native timber should be based on the setting, the availability of appropriate material, the amount of anticipated use, and case-by-case logistics. Generally, native timber structures are appropriate only in remote or semi-primitive settings on the Ice Age NST.

Recommended rot-resistant tree species to use for building native timber trail structures in Wisconsin are white oak, black locust, northern white cedar, and eastern red cedar. Although moderately resistant to rot, the following tree species are not recommended for structural, or weight-bearing, use: honey locust, eastern white pine, and tamarack. Aspen, basswood, beech, birches, elms, hackberry, hemlock, hickories, maples, red pine, spruces, ash, black oak, and red oak should not be used because they are nonresistant or only slightly resistant to decay.

When working at remote sites, take extra care to plan tool, food, and water needs. Quality and crew morale are impacted for the worse if crucial items aren't available when needed. Whether the site is five miles or half a mile in from supplies, before sending runners to retrieve miscellaneous items, explore ways to meet the need in a simpler way using available resources if doing so is safe and maintains the design standard.

Built Wood Structures

Trailside benches should be stable. Informational kiosks should be attractive and contain up-to-date information. Timber retaining walls and staircases must be sturdy and safe. When building bridges and boardwalks, the entire wet area must be spanned or ramps built to ensure dry-to-dry land coverage. When in doubt, go a little farther.

Recommendations

- Wood structures require periodic maintenance: check and tighten nuts and bolts; inspect sills and connections for rot, and remove debris. Inspect bridges every three years and vigilantly monitor them for hazardous conditions between inspections. Document inspections and report them to the IATA office.
- Trail structures should be barrier-free and designed to accommodate the numbers of users expected, including users in wheelchairs even on trail segments that aren't specifically designed to be barrier-free or fully accessible. The standard deck width the IATA designs and builds is 40 inches. Open ramps at the ends of bridges and boardwalks are preferred over steps, and are usually required by permitting agencies.
- The regulatory review process will determine whether bridge or boardwalk handrails are necessary. The minimum height for a pedestrian handrail is 42 inches. Generally, if the distance from the deck surface to the waterway or ground is 2 feet or greater, handrails are required. Handrail systems with diagonal braces function as a structural truss feature that reduces deflection (bounciness or sponginess).

Tools and Situational Awareness

Perhaps the best tool at our disposal when undertaking any trail building project is communication. Reviewing and discussing with coworkers how, why, and in what order a task is to be done builds trust, knowledge, safety awareness, and enthusiasm. Guard those qualities closely and always insist that if a task is not safe, it should not be done.

Start every project by having the proper safety equipment available and in use by workers. Provide ear plugs, safety glasses, and work gloves for everyone on the site; use dust masks as appropriate. Provide and use chain saw safety/personal protective equipment (PPE), including chaps when using an adz. Hard hats are highly recommended.

Being aware of one's surroundings and noticing and responding to small details that may become major problems if walked away from is known as "situational awareness."

- Evaluate the site and eliminate hazards before starting work. Examples include widow-makers or less-than-sound trees, bee and wasp nests, poison ivy or poison oak, loose rocks, slippery surfaces, obstacles overhead and underfoot, eye-poker branches, and holes or divots.
- When staging tools and materials, allow room for several people to work on several tasks simultaneously.
- Operate a clean, organized worksite at all times. Clean and store tools nightly.
- Wear PPE — hard hats, sturdy boots, leather gloves, hearing protection, and eye protection.
- Use tools that are in good working condition, and use the correct tool for the job.
- Always choose the lowest-impact route when moving materials.
- If a rock (or timber) load being moved or transported escapes, do not try to stop it; repeatedly and loudly yell "Rock!" or "Timber!" to alert others that there is danger.
- Watch your dime — the 10-foot-wide circle of safety — or circle of danger — immediately around you. Passage through someone else's "dime" requires his or her acknowledgment. Yell, "Coming through!" in advance, and wait to proceed until the person whose dime you will pass through tells you it is okay to do so.

Hardening the Trail Surface

Saturated soil in poorly drained terrain is quickly churned into mud by trail use — a condition that means the soil no longer has binding (cementing) power. Many trail users instinctively bypass soggy spots, unknowingly widening the trail in the process. Sustainable tread-hardening techniques focus use on the trail, help prevent trailside vegetation from being trampled, and keep soils in place. Tread-hardening techniques include building boardwalks, drainage ditches, puncheon, steppingstones, and turnpikes; armoring with rock; and building culverts.

One of the most comprehensive resources available describing the many trail design considerations, building methods, and materials involved in building wetland trail structures is the United States Forest Service (USFS) publication *Wetland Trail Design and Construction*. It is available online at http://www.fhwa.dot.gov/environment/fspubs/01232833/toc.htm. Hard copies can be requested directly from the USFS.




Elevated boardwalk.

The primary difference between boardwalk and puncheon is that boardwalks are elevated off the ground on vertical support posts (pilings) whereas puncheon rests on horizontal sills that are in direct contact with the ground.

Frame layout: Puncheon on sills.

The advantages of boardwalks are that they are less likely to change surface water flow and that increased air and light penetration underneath the deck surface dries the underside of the deck boards, thereby increasing the usable lifespan of the structure while also promoting natural vegetative growth. The permitting process for a boardwalk is considerably less complicated than that for puncheon because boardwalks are not considered wetland fill by the Corps and regulatory agencies.

Puncheon may be preferred when exceptionally rocky or boulder-laden subsurface conditions make it impractical to install pilings or when soil conditions (deep muck, for example) require pilings to be installed at depths greater than 4 feet. Due to the increased surface area that a puncheon rests on, puncheon may be more stable than boardwalk in these environmental settings. The technology required to build boardwalks over deep muck soils using helical pilings is expensive and beyond the scope of this notebook.

Alternatives to building wood structures in wet or muddy areas include steppingstones (they work well to harden short muddy stretches — but be aware that they create a barrier); drainage ditches dug parallel to the tread; turnpikes (using rock, gravel, and earthen fill to elevate trail tread when soils are poorly drained but do not have standing water as found in a wetland — also referred to as causeways); armoring with rock (reinforcing the surface with rock); and culverts (they provide equalized cross drainage without constricting water flow).

Tread hardening with rock.

Boardwalk with armored drainage.

What you need to know:

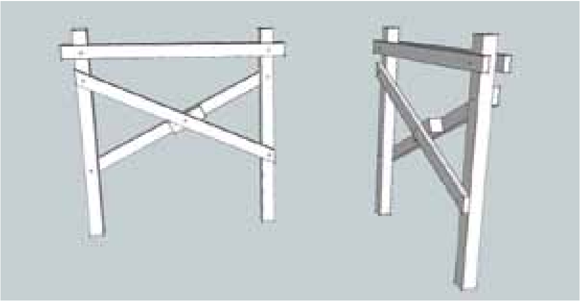
- Build boardwalk or puncheon when there are no other options to drain the trail.
- Ensure that wood structures span from dry land to dry land.
- Build boardwalks in graceful curves rather than straight-line shapes.
- Strive to achieve a minimum 12 inches clearance between the bottom of the boardwalk deck and the ground surface.
- Limit the elevation rise of a boardwalk to a maximum slope of 8 percent, or 1 foot of rise over a 12-foot run.

Frost Heave and Expansion and the Power of "X"

Water increases in volume approximately 9 percent when frozen. Ice expands toward the surface, in the direction of heat loss. Frost heave occurs when ice moves from below grade toward the surface, lifting and pushing pilings, posts, and rocks nonuniformly in the process. Finer-grained soils, like silt and loam, are more susceptible to frost heave than coarser-grained soils like clay, gravelly crush, and coarse sand.

Preventive measures include installing pilings as deep in the ground as practicable — 3 feet is the minimum standard — and employing the power of "X."

When the deck of a boardwalk is 2 feet or higher above grade, cross-bracing each pair of adjacent support posts/pilings is recommended. The "X" cross brace joins the pilings together laterally and significantly reduces torsional stress on the structure.



A typical "X" brace.

Trail Bridges

When considering building a trail bridge, there are many valid design, material, and construction methods to model and learn from. Two methods are discussed in this notebook.

Task number one is to site the bridge in a sustainable location. Avoid problem areas such as multithreaded channels and flood plains, alluvial fans, actively degrading/aggrading stream bank sections, and sharp bends. Questions to ask include: How well do the trail and bridge alignment mate with the stream alignment? Is the stream channel stable? If the stream moves laterally, how will that affect the crossing? How does the stream transport sediment and wood?

A bridge should span the full width of a stream with no pilings in the waterway. The approach to a bridge should be straight on for 10 feet or more. The bottom of a bridge must provide enough clearance for high water, ice, and storm debris and for recreational navigation to pass underneath during normal flow conditions. Undersized or poorly constructed structures are prone to failure and will probably need to be removed and rebuilt.

Some terms to know:

Live load: the active forces and combined weight a bridge is designed to support at any one time; it includes the weights of people, snow, and ice and the forces applied to the bridge by wind.

Dead load: the static load imposed by the weight of materials that make up the bridge structure itself.

This clear span bridge rests on timber cribs filled with rock; stringers are reclaimed 45-foot cedar telephone poles. Handrail and decking is rough-sawn white oak; elevated boardwalk approaches (note the "X" brace) are pressure-treated material. Wheat straw covers bare soil.

Right: Use stakes and string lines to lay out structure locations. Here, stakes mark the back of the stringer/crib.

Left: Install silt-fencing before doing any excavation. Use wheat-straw or erosion control matting to cover bare soil. Excavate a level pad per crib/sill specs.

Cribbing and Sills

Cribbing is used to support and elevate bridges and boardwalks to gain more height between the waterway and the bottom of the structure. Sills are cross members that rest directly on the ground, usually at or below grade. Sills support bridge stringers and puncheon frames.

Cribbing is especially important when soils are unstable and periodically wet. Cribs disperse weight across a larger surface area than sills do. A third benefit of cribs is that they allow a shorter clear span than would be possible if the structure rested on sills. Each of the above reasons means that a clear-span structure with cribs is more stable because it is supported over a broad footprint. Stable equals sustainable.

The following information applies to bridge construction but is also applicable to boardwalk construction.

- One crib is connected to the next crib (or sill) by stringers. Carefully determine support locations so that the cribs/sills are oriented parallel to each other and spaced the correct length apart. No part of the cribbing and/or sills can be within the ordinary high water mark.

- To build a crib, mate 2x12 pressure-treated stock to the bottom side of 6x6 pressure-treated base course timbers. Lay the base course so that the top course of the crib will be perpendicular to the bridge or boardwalk frames. Level and plumb the first course. Repeat to the desired height, pre-drill, then drive 3/8" x 10" pole barn spikes at the corners of each course. Fill each crib 3/4 full of medium-size rock to help keep it in place in the event of a flood or high water. If rock is in short supply, use it to riprap the base of each crib instead of putting it inside the crib.
- Pressure-treated 2 x 12 stock is commonly used as sills. To install a sill, excavate a level pad, tamp small rock (golf ball to grapefruit size) into the excavated area for drainage, then set and level the sill. In bridge or puncheon construction it is recommended that each sill be staked with 3 feet of 1/2-inch rebar to prevent the sill from shifting sideways.

Stringers

Stringers provide strength and are what the deck and handrail system attach to. As the distance between supports, or bearing points, increases, so does the potential for unwanted deflection. Deflection increases as the cube of span: a 10 percent increase in span length gives a 33 percent increase in deflection.

When preparing a stringer (laying out and notching handrail-post mortise locations, drilling for through-bolts, pre-fitting handrail posts, and flattening the ends) lift the stringer off the ground to rest on secure H-frames or sturdy sawhorses. This provides a level, comfortable work surface. Work the timber crown side up.

An alternative method to notching stringers for inset vertical handrail posts is to employ an outrigger design (p 29).

Handrail Posts and Diagonal Braces

Handrail posts are usually 4 x 4s cut to 6 feet long. They are sized to allow 42 inches from the top of the deck to the top of handrail. They should extend 4 inches below the stringer to allow for post spreaders. For a short bridge, where diagonal braces are not needed, space handrail posts about 6 feet apart. When diagonal braces are used to stiffen the structure, use a beefier center post (usually a 4 x 6), and space posts at least 6 and no more than 8 feet apart. Diagonal post bracing should be angled so that the braces are even with the top of the adjacent post.

Notching Recommendations

Round stringers may be notched to create a flat surface so that handrail posts fit securely into the timber.

- Be sure that notches are level and plumb.
- Number each notch/mortise and its corresponding handrail post. Test-fit each handrail post and adjust fit incrementally as necessary using a 2-inch-wide chisel and a nonmetal mallet. Clearly mark which posts fit upstream stringers and which fit downstream stringers.

Drill through-bolt and other holes straight and plumb.

Flattening the bottom of a stringer.

- Mark two holes to be drilled per post within the mortise. Position the handrail post and drill straight. Insert a bolt. Then drill the second hole. Repeat for each post. When finished drilling, remove all hardware and posts.

Placing Stringers on Cribbing

If obstructions are minimal and there are no seasonal habitat concerns, a crew of approximately 8 to 14 workers using timber carriers and nylon straps can manually place stringers by lifting and moving forward caterpillar fashion. A Griphoist and rigging requires setup time but is often the safest method to move heavy timbers across waterways. Once stringers are on the cribs, immediately block and securely strap them in place.

Installing the Handrail Posts

Orient the through-bolts (threaded rod cut to length) so that the nuts face out. Place a washer and nut on one end. Drive the bolt/threaded rod through the stringer and handrail post. Do NOT thoroughly tighten the nuts yet. Repeat until all of the handrail posts on one side of the bridge are attached to the stringer. Sight down the line and adjust the posts so that they are in the same plane; then tighten the nuts.

Attaching Handrail Post Spreaders

Post spreaders connect opposing handrail posts underneath the stringers. Post spreaders strengthen the overall handrail system by providing lateral support for the vertical posts.

Installing Decking

Start at one end and work to the other. Loosely lay out deck boards to visualize needs. Maintain a uniform 1/4-inch gap between boards (use carpenter pencils or other uniform spacers to maintain consistency) and install boards crown up. Fasten the boards to the stringers using 2 1/2-inch or 3-inch star-bit deck screws. Place warning signs so that hikers and workers coming through know if deck boards are not secure.

Bridge Rehab

If the materials of an existing structure are still serviceable, but the structure is not compliant with current standards and trail maintenance needs, consider ways to upgrade it rather than building a new one. Review options with DNR and IATA staff for the necessary approvals.

The trail bridge shown below needed approach ramps and a wider deck in order for trail maintainers to be able to get a mower across the creek. After the old bridge was upgraded, volunteers were much better able to take care of that section of trail.

Bridge rehab before (left) and after (right).

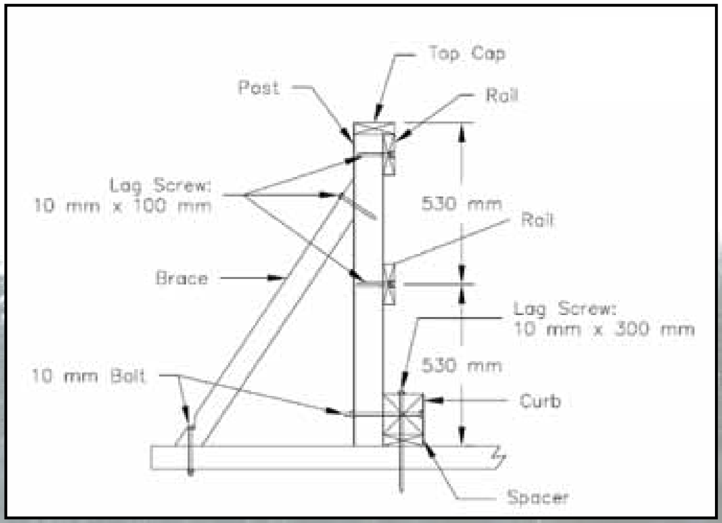
King Post Truss Design

The king post truss functions similarly to diagonal bracing. The king posts are centered and are sized larger (4 x 6 rather than 4 x 4) than the handrail posts. Each king post is connected to the stringer on its side of the bridge with through bolts and two diagonal boards (2 x 6s), forming a triangle. The king posts are also connected to each other underneath the stringer using two post spreaders.

Table Bluff Segment, Dane County.

Outriggers

Outriggers are used successfully on many trail systems internationally. Their purpose is to provide lateral support of handrail systems. Boardwalk designs will occasionally rely on outriggers to provide additional side-to-side stability as well. With bridges, for maximum strength, each handrail post should be supported by an outrigger.

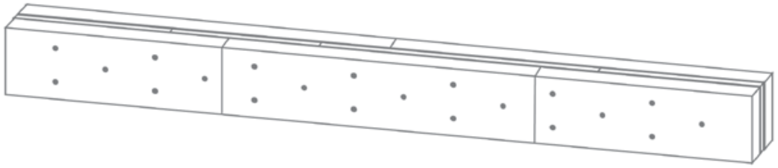


Laminated Stringers

Stringers for spans up to 22 feet can readily be manufactured by sandwiching 3/4-inch pressure-treated plywood between two 2 x 8 (for stringers up to 16 feet long) or 2 x 12 (for stringers up to 22 feet long) pressure-treated boards.

Recommendations

- At a location where power is available, rip the plywood to the length and width needed and then transport the cut boards to the site.
- Stagger the joints of the laminate components.
- Use 3-inch Torx screws in a staggered pattern (see below) to fasten the boards and plywood together, applying PL-500 Outdoor Project Adhesive (or equivalent) between the laminate components.



- Long boards (over 12 feet) are awkward and heavy to carry. Take care to ensure that the access route is clear of obstructions, and spread the load among a good number of shoulders and hands.
- Use ratchet straps to temporarily secure the laminated beams in an upright position when they are first placed on the sills/cribs. Secure the beams to the sills/cribs with blocks and/or appropriate hardware fasteners.
- The laminated beams will have a tendency to contort; it is a good practice to install cross braces that connect the laminated beams before decking the surface.

Timber Retaining Walls

Harvesting and shaping timber for on-site building applications is very satisfying from both craftsmanship and stewardship perspectives. If using white oak or black locust, peel the bark. If using eastern red or northern white cedar, it's okay to leave the bark on. Use at least 6-inch-diameter logs for timber walls. If the wall is three or more courses high, insert tiebacks (also known as deadmen) perpendicularly from the face of the wall into the hillside, beginning with the second course. Two tiebacks per 8 feet of length are sufficient — too many tiebacks will weaken the structure. Offset tiebacks as you work up the wall.

The first course should rest on well-compacted earth. To ensure good drainage through and behind the wall, place small rock and cobble between the timber and the native hillside, backfill in stages, and compact in layers. The angle of batter into the hill should be about 15 degrees.

Connect timbers using 1/2-inch rebar or pole barn spikes; pre-drill using a spiral or auger bit before driving the fasteners. Level each course as you build up, and offset the ends of timbers from those above and below. To finish, support the wall from behind with timber stakes, and riprap around the timber ends.

Working with Rock

The word geology comes from two Greek roots: geo (Earth) and logia (discourse, or study of). Rock is the primordial "deep time" foundation of Earth itself. Ojibwa legend has it that the preexistence of the world consisted of a conversation between stones. In the Ojibwa language the word for stone is *asisn*, which in English translates as animate.[1]

The terms "rock" and "stone" are often used interchangeably. Some sources suggest that rock becomes stone when put to human use. Rocks are used to support and/or harden tread, control erosion, or provide drainage; for edge definition of the trail tread; and to mitigate grade deviations. Trail structures built with rock include retaining, rubble, and back walls; steps; landings; cribbing; and trail plumbing (water drainage) features. When available in the right place and in the right size and shape, rocks are essential, sustainable, and aesthetically pleasing building materials.

1 Paraphrased from *Bedrock: Writers on the Wonders of Geology*, Trinity University Press

Dry Stone Construction

"Dry stone" construction means that mortar or another adhesive is not used. Instead, gravity, friction, and craftsmanship hold the structure together. Native rock indigenous to the site is typically used. Dry stone walls are always "in motion" due to temperature and moisture changes. Wall and step construction requires imagination, layout, and visualization skills as well as a lot of patience. Wear leather gloves and sturdy work boots (steel-toed boots are best) when moving and working with rocks. Always wear safety glasses when chiseling or hammering rock. Working with rock is tiring; it is better to start fresh in the morning rather than late in the day when a crew is physically and mentally spent.

What you need to know:

- How to select rock
- How to move rock
- How to use rock
- How to shape and dress rock
- How to estimate rock weights

Selecting Rock

Based on the height and length of the structure's layout, determine the quantity, size, and shape of the rock needed. Usually more rock is needed than is initially estimated. Rock-shop in the area where you will use the rocks; look uphill and laterally first. The shape and size of a rock is important. Well-defined edges and rectangular or blocky shapes are preferred. Rocks that have enough mass to be stable when placed and rocks that are not fractured or crumbly are best. Irregular and rounded rocks have uses but are difficult to fit together while ensuring two or more points of contact with neighboring rocks. Big rocks are generally better than small, and angular shapes are better than round. If the effort required to move one big rock won't result in a definitive structural gain, use two medium-size rocks instead. Select only rocks that can be safely moved by the people available to move them.

Moving Rock

When working with rock, a heightened awareness of self and body mechanics is essential. When lifting, keep your back straight and use your legs. "Head up, butt down" is the mantra. Be hypervigilant of surroundings, footing, and hand positions. Know and communicate the locations of people, tools, and obstructions. Hands, faces, fingers, and toes can be crushed in an instant; avoid reaching under rock and never reach under large rocks. Lift or carry only what you can handle. Eliminate hazards — loose rocks underfoot, toe-trippers, eye-poker branches — from the route before starting to move a rock or rocks.

Everyone involved in moving a rock — both hands-on workers and spotters — needs to know where the rock is being moved to and how to get it there step by step. The spotter is not part of the lift crew; he or she is the "eyes" for those who are lifting and moving the rock. The spotter calls out hazards while the move is in progress. Also identify one lift crew member as the "caller" — the person who vocalizes the lift count. The caller first asks if everyone is ready and then counts "One, two, three… lift." The crew short-lifts the rock to test for balance and weight distribution, adjusts as needed, and then all move forward. During the move anyone can holler "Set!" or "Down!" at any time. Crew members should maintain control of the rock and then lower it in unison. The crew members maintain eye contact with each other throughout the move.

Moving Smaller Rocks

Partially filled 5-gallon buckets are a good choice for transporting cobble or gravelly fill. Liberally employ the "bucket brigade" method: line up workers at arm's length or within a few steps of each other, and then pass the buckets from one person to the next. A wheelbarrow can be helpful in some situations.

Rock in the cantaloupe-/football-/basketball-size range can be moved by one person *by hand or by two or more people using a tarp doubled over for strength.*

Moving Larger Rocks

To move rock that is 8 inches in diameter or bigger, using skidding, controlled roll, a "Feldman," or hoisting equipment are four options.

The controlled roll is a good way to move small- to medium-size rock. The rock is turned end over end, or "flipped" sideways, staying in contact with the ground while being moved by hand. Keep hands on the rock at mid-height or higher — not underneath it — at all times to control direction and speed. Position yourself to the side of, not directly below, the rock. GO SLOWLY and maintain control of the rock.

The "Feldman" is a custom-sewn IATA device used to lift and safely transport rock. It is made of heavy nylon straps that form a web-patterned cradle attached to four steel handles. Two, four, or up to eight people can work together to lift one loaded Feldman; two Feldmans can be used in tandem. The Feldman is not OSHA rated to support airborne loads; therefore, it should not be used in rigging applications. Instead, use a lifting sling, available from Trailway Services, Inc., and other sources. To use a Feldman, spread the nylon cradle and pull the handles to the side. Roll or lever the rock into the center of the cradle. Adjust the rock in the cradle for balance, then lift and move the rock as described above. It is often helpful to slide two rock bars through the steel handles to enable more people to share the weight. Slide two more bars perpendicular to the first two bars (total is now four) and eight people can lift the rock. Generally, taller and stronger people should be on the downhill side. Keep approximately equal distance between the handles and the ends of the bars — the shorter the distance from the end of the bar to the handle, the more weight the person(s) on the short end carries. When setting down a rock cradled in the Feldman, maintain tension until the load is at rest and secure.

Skidding: Rock bars or small-diameter round logs placed in front of and beneath a rock can serve as skid rails to reduce friction and prevent having to lift the full weight of a rock. In a controlled manner, two or more people use rock bars to push or "row" the rock forward on the skid rails from behind. To row a rock, slide the end of a rock bar(s) underneath the rock and "row" with a sideways motion across your body in the direction the rock should move. Add more rails before reaching the end of the first set of rails. Skid rock only for short distances, where the damage to the environment can be repaired. Do not skid rock when working in an ecologically sensitive environment.

Using Rock

Dry stone construction relies on gravity and friction to hold rocks together. The foundation layer is in-sloped and the wall is "battered," — tilted — into the slope.

1. Maintaining two or more points of contact keeps rocks in place. The more points of contact there are, the more friction holds the rocks together.
2. High and outside points of contact keep rocks from pivoting and keep fill material in place.
3. Overhangs on rock walls and steps lead to problems because part of the rock is not supported. If someone steps on the overhang, the rock may shift. Overhangs also create turbulent water flow, which erodes the soil underneath the rock.
4. Smaller rocks are more susceptible to movement than larger rocks. If shimming is absolutely necessary, it should be used only on the back sides of rocks. Avoid using shims when possible.
5. Bury rocks 1/2 to 2/3 of their depth into the ground to keep them stable and keep them from eroding out.
6. Stagger the joints using the "one over two" rule: place one rock over two. Do not stack rock so that a continuous vertical crack or "running joint" extends top to bottom between rock courses.
7. Tie-stones are long rectangular rocks placed with the longest axis perpendicular to the face of the wall and dug into the hillside at intervals along every second or third course. Tie-stones help to keep a wall from tipping backward. They are analogous to "deadmen" used in timber retaining wall construction.

Shaping Rock

Small knobs and protrusions on rocks can often be removed or reduced to improve fit and rock-to-rock contact. Granite tends to fracture along cracks or mineral bands. Sedimentary rocks such as limestone and sandstone tend to fracture along the layers the rock was deposited in. Essential rock-shaping tools are eye protection, 2- to 4-pound hand sledges, rock chisels, and stone points.

A rifting or slab-splitting hammer can be used to break larger rocks into usable material. However, without a hammer drill and feathers and wedges (use of which exceeds the scope of this notebook), the size of a rock that can be successfully split is about 12 inches or less in height, depending on the rock type. A rifting hammer has a large head that looks like the one on a wood-splitting axe, but rifting hammers are not designed to be swung. Instead, one person holds the hammer by its handle while another person strikes its head with a sledgehammer of equal or greater weight. This action sends a directed shock wave down through the rock, separating the crystalline bonds. The hammer (rifter) is moved back and forth across a line until the slab splits. This tool can make large, unusable slab rock usable by breaking it into smaller, flatter sections. Large slabs are first split in half, then split again to size. It is essential to wear safety glasses and hard hats during rock splitting and to keep other workers 10 or more feet away from those splitting the rock to avoid hitting someone with debris.

Estimating Rock Weights: Volume X Density = Weight

Know what's in store before trying to move a rock so that you don't attempt to move more than can safely be handled. There are 1,728 cubic inches in one cubic foot. Calculate volume by measuring the width, length, and thickness in inches and multiply. Example: a piece of granite is 8" x 18" x 24" = 3,456". Divide the volume (3,456 cu. in.) by 1,728 to get cubic feet.

Use an average weight per cubic foot as follows: sandstone = 140 lbs; granite, basalt and limestone = 170 lbs; dolomite =180 lbs. Volume of a piece of granite (in this example, 2 cubic feet) x density (170 lbs) = weight (340 pounds).

Notes About Rock Bars

Pinch point crowbars have a beveled end (creating a fulcrum), are 4 to 5 feet long, and weigh 16 to 26 pounds. Tamping bars have a flat blade at one end and a flat disk about 3 inches in diameter at the other. They are 5 to 6 feet long and weigh 16 to 21 pounds. Tamping bars are not as stiff as pinch point crowbars but are more versatile. The IATA uses both. In this notebook, "rock bar" is used to describe both styles of bar.

Rock bars are used to pry, lift, tamp, and compact. When using any bar, be aware that the bar is under pressure and can slip or recoil when pressure is released; therefore, do not straddle the bar. Bars that are laid carelessly on the ground are safety hazards. Use an open grip, not fingers tightly clenched, to handle bars. Press the handle down with your body weight positioned over your palms and let the weight of the tool and leverage work for you. Carry rock bars by your side with the tip forward. Two or more people using rock bars knowledgeably and in unison can move one rock accurately and safely. Flesh and rock bars don't mix — if a bar(s) is touching a rock, keep hands off the rock!

Griphoist and Rigging

Hoisting rock or timber using a Griphoist® and rigging setup is a specialized skill that requires training and experience. Do not operate beyond your limits of experience and knowledge.

Griphoists are mechanical devices used to control the lowering, raising, or pulling of rock and timber loads. A variety of rigging equipment is needed to accompany a Griphoist.

The IATA has relied on Griphoist and rigging setups to move rock on 70 percent cross slopes and across 100-foot-wide ravines, to move 45-foot timbers across rivers and streams, to move soil up steep slopes during tread construction, and to pull stumps from the treadway.

The four basic components of a Griphoist-powered rigging system are (1) one or more Griphoist winches with wire rope, (2) anchors, (3) accessories (slings, blocks, shackles, etc.) and (4) trees or towers (wood or metal tripods at least 8 feet tall).

Some terms to know:

Terms to know when helping to carry out a project using a Griphoist and rigging include

snatch block — a pulley, usually with a hook, whose side opens so that wire rope can be inserted

shackle — a U-shaped steel piece closed with a heavy pin used for connecting slings, chain, and wire rope

spar tree — a tree used as a vertical support for the rigging system

load — the object being moved

anchor — typically the base of a large, healthy tree, or a large boulder

brake and pull lines — ropes attached to the load that are used to control or create momentum

If you are unsure about setting up a rigging system and using a Griphoist, stop! Arrange for someone experienced with Griphoists and rigging to assist. Find another safe way to get the job done without the aid of rigging or wait until someone who has the experience and skills is available to help.

Rock Retaining Walls

The purposes of retaining walls are to support and hold trail tread and structures in place.

Rock walls solve many design problems. They quietly enhance trail continuity and sustainability, and it's not an exaggeration to say that they make it possible for a trail alignment to achieve greatness by enabling passage across slopes and areas not otherwise walkable.

The Foundation

Shaping the foundation (the dirt base where the foundation course will be laid) correctly will make the entire project go smoothly. To begin, determine where the end points of the wall are and where the lowest point of the wall will be. Two crews will be at work: one will rock-shop for suitable wall material while the other digs the foundation, reserving all mineral soil and cobble to reuse as fill.

Dig the foundation trench wide enough to provide sufficient batter (the tilt of the wall into the slope) as the wall rises. The trench should extend a few inches out from the rocks placed above the first course of rock. It's okay to dig more material out once the stones are in place using the smaller rocks as a depth gauge to determine how wide to dig. Work from the lower end of the wall and build up. Use rectangular or blocky rocks. Avoid rocks that are thin (less than 5 inches), crumbly, or fractured.

The trench needs to be only deep enough to fully support the foundation course of the wall and have adequate in-slope against the hillside.

When laying the foundation course, place the most irregular side of each rock face down and dig a pocket for it to fit in. Tip: take light steel wire (chicken wire, or pin flags twisted together) and mold the wire to fit over the irregular bottom face of a rock. Use this mold as a pattern to fine-tune the pocket the rock will sit in. As the wall rises, make sure that every rock has good contact with its neighbors (side to side and beneath). You want tight joints and no large gaps between rocks.

The angle of the batter will vary with the height of the wall. For example, a 12- to 24-inch-high wall should be battered back at a 1:5 ratio (1 inch back for every 5 inches of height).

Pre-fitting and Testing Rock

Segregate rocks by their potential placement (e.g., foundation, middle tier, tie, and cap rocks). Test-fit by turning, flipping, and rotating each rock to see which ones work and where they work best. If after three tries a rock doesn't work the way you want it to, use another rock in that location. After setting a rock, have the biggest person in the crew dance on it and try to wiggle it out of place. If it moves, it isn't properly seated.

Filling In

Walls need fill for support and to allow water to drain from the hillside inside and through the wall. When starting to fill, place and lightly tamp small (1-inch or less) crushed rock between the wall and the hillside; use gravelly mineral soil as you build up.

Stacking Rock

The biggest or most irregular rocks should be placed in the first tier (foundation course) and smaller rocks used in the middle tiers. As the wall goes up, be sure each rock has good contact with its neighbor. Remember the one-over-two rule and stagger the joints so that there are no continuous vertical cracks between rock layers, or courses. Multitiered walls 24 inches or higher may need tie-stones.

Capping Off

Finish the top of the wall with a tier of capstones. These rectangular rocks should be large enough and long enough to cover two or more rocks in the underlying tier. They must also be able to support and withstand users standing or walking on their outer edge without displacement. It's essential that capstones fit tightly together.

Smaller Scale But Just as Essential

Not all rock walls need to be massive structures. Often, the little things count most. The following types of rock walls are fundamental to the Trail experience.

- **monowall** — a single tier of rocks laid in a row along the critical edge of the trail tread. Monowalls work wonders to protect, anchor and define the trail shape. They are often built to support both sides of the trail as it leads into another trail structure.

- **backwall** — a wall that supports a steep backslope above the trail tread. The rock is laid directly against the backslope. When the angle of repose (the angle at which soil is self-supporting) is such that soil may be prone to slump (slide), a backwall is good insurance.
- **rubble wall** — similar to riprap, rubble walls are laid directly on the ground. They are used to stabilize slopes, discourage shortcutting, and slow erosion.

Stone Steps

Stone steps, like other stonework along trails, exhibit a beautiful harmony with the native environment. However, as grand and inviting as stone steps are, it must be recognized that steps and stairways are the ultimate barrier for users with mobility disabilities and challenges. Before building steps and stairways, whether of rock, wood, or any other material, consider every other option to gain elevation.

When there are no practical alternatives, stone steps allow for elevation gain where grade standards would otherwise be exceeded. Steps must be inviting and provide users with a clearly more desirable alternative than scrambling uphill or downhill by a route of their own choosing. Steps help to prevent erosion on steep grades and can help make the trail easier and safer to hike.

Some terms to know:

landing — a flat area between two steps. Try to have one landing every four to five steps.

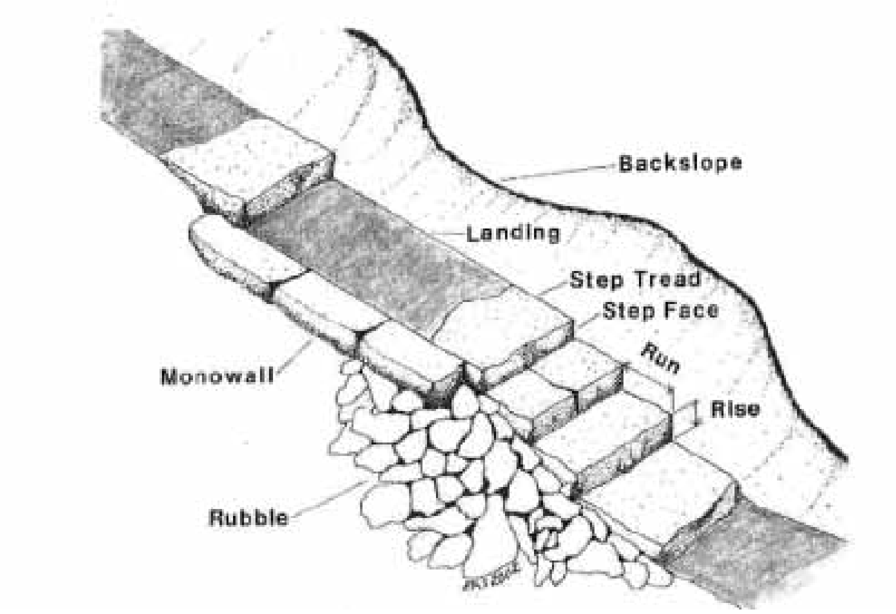
step face — the front side of a step. It should be fairly flat and square with the top of the step.

step tread — where users place their feet.

rise — the height of the step above the previous step or landing. The rise should be about 6 inches (and not more than 8 inches).

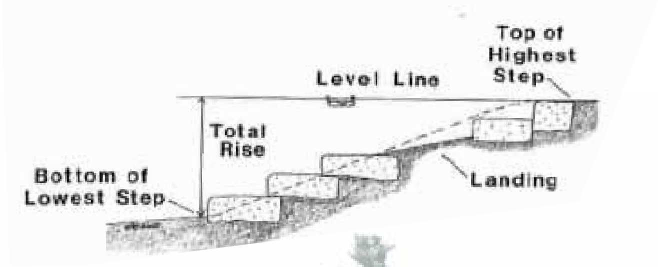
run — the front-to-back distance of the step tread. The run should be relatively flat and level and be between 8 and 16 inches. The ratio of the run to the rise should be 2:1 (1 vertical foot for every 2 horizontal feet).

rubble — loose rock used to line the sides of the trail, staircase, or wall to armor the slope and prevent shortcutting. It should be low to the ground and not protrude into the trail.



Getting Started

Review the flag line. Discuss the dimensions, the number of steps required, the desired shape, and the finished look of the staircase. Before placing the first step, be sure to know how much elevation gain is needed and the length of the staircase.



To calculate measurements for overall rise (vertical gain) and run (horizontal distance needed to obtain the rise), stretch a cord level from the high spot to a point over the lowest spot. Measure that height in inches and divide by the rise of the average step (6 inches). Round fractions up. Example: 120 inches (10 feet) divided by a 6-inch average step rise means that the front of the first step must be placed about 20 feet away from the front of the top step and that approximately 20 steps will be needed.

Rock-Shopping

Find rectangular stones with large mass (large length, height, and width), a flat top and a front face free of cracks. Each stone should extend beyond the width of the trail by approximately 6 inches on each side. This means that if the tread is 24 inches wide, a 36-inch-wide step is needed. Use two or more stones to achieve the necessary width if necessary.

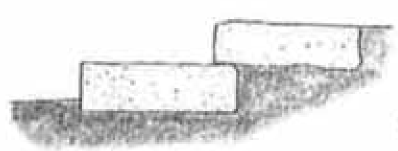
Placing Steps

Build staircases from the bottom up. It's important that the first step be placed in the right location. Locate the lowest (bottom) step and the highest spots of the staircase corridor.

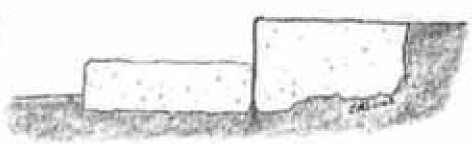
The lowest step should be embedded at grade and stable with its irregular surface down. Continue to place stones perpendicular to the centerline of the tread while maintaining a consistent rise and run. Adjust the layout as needed so that hikers' feet land evenly on the steps.

There are two basic ways to place stone steps: overlay and tuck-behind.

With the overlay method, each step overlaps the previous step by about 1/4 of the stone's run. Two drawbacks are that less of the stone's mass is buried, and over time, wobble can develop where stone rests on stone. With the tuck-behind method, each stone is buried on four sides. The rise of the step is adjusted by varying how deep each stone is embedded. The rise of one step begins immediately behind the run of the previous step. Steps do not overlap, eliminating potential wobble points. With either method, each step should have a slight forward and outward tilt.



Overlay (overlap about 1/4 of surface area)



Tuck-Behind

Steppingstones

Placing steppingstones in a river or stream requires Corps and WDNR approval. Steppingstones in waterways may be appropriate in some remote settings, but they are not encouraged or commonly employed on the Ice Age NST. If steppingstones are used, it is imperative that they do not function as a dam or trap debris. Choose a narrow crossing and use stones of sufficient height and mass to provide safe foot placement. Riprap the bank sides of the channel to prevent the stream bank from being undercut or further widened.

Check Dams

Building check dams is a remediation technique used on sections of trenched, or gullied, tread to slow or stop erosion. They promote sedimentation by slowing water flow velocities and may need to be built when sections of trail are abandoned in favor of a more sustainable alignment. Rock or timber can be used. Check dams are usually built as a series in the upper two-thirds of a gullied tread. Check dams are not used in streams or waterways.

Conclusions

Working with rock is a rich, traditional process with lots of opportunities for creative problem-solving, leadership development, and team building. Rocks are great teachers and tireless workers. They are forgiving to a point, but in the blink of an eye they can mercilessly claim fingers and break bones. Always treat rock with respect and *asisn* will quietly spin wondrous tales that enthrall trail users for decades.

Support Structures

Support structures are most often built at access points to the trail and thus are highly visible. The public often forms impressions about the trail based on the appearance of a trailhead. Support structures provide convenience, comfort, information about the trail, and trail access. Landowners and managers must approve construction in advance, and regulatory and permitting processes must be adhered to. Remember to call Digger's Hotline, 800-242-8511, for underground utility checks before digging.

Trailhead Parking

Parking areas should be located on public lands. The distance between trailhead parking lots varies depending upon the trail's current and desired future amount of use, trail connectivity, and trail maintenance and stewardship needs. Parking areas may also be connected to the Ice Age NST via blue-blazed access or spur trails and are excellent locations for informational kiosks and trail registers. Typical approvals required before building include driveway and erosion control permits and written approval of the landowner or property manager. The town and county zoning or land use approvals must also be obtained from local units of government.

SIZE: A rectangle approximately 45 feet wide x 106 feet long accommodates 10 cars.

Culverts

Culverts are cylindrical tubes that provide passage for water. They're made of non-rusting metal or plastic and come in various lengths and diameters. Culverts are most effective in flat areas with limited peak flows and are used to provide equalizing cross-drainage. They are not appropriate in locations where it is difficult to haul a large and heavy object to the site. The most common use of culverts is at parking lot entrances. Place culverts with a gentle downstream gradient of about 2 percent and properly bed them to ensure continued performance.

Informational Trail Kiosks

Imagine: volunteers who station themselves at trailheads, greeting visitors and providing them information about the Ice Age NST, 24 hours a day and 7 days a week. Sound intriguing? Kiosks are those volunteers.

Kiosks should be weather tight to protect display information such as maps and permitted and prohibited use of the trail. Maintain kiosk displays at least annually to provide a professional appearance and to keep people looking to the kiosk for information about events and volunteer opportunities. Install informational kiosks at all primary trailhead locations. If kiosks are double sided, site them so that people are able to easily view both sides and walk around the structure. Avoid cluttering the kiosk with too much information.

Basic kiosks.

Trail Benches

Benches are placed intermittently along the Trail as a convenience for users so that they can enjoy a view, catch their breath, or simply relax. Help all users of the trail to enjoy their experience by locating benches thoughtfully in locations that are easily accessible from the trail but not directly on the trail.

Theft and vandalism can be minimized by solidly anchoring benches to the ground. To secure a bench, drive a steel fence post 3 feet deep leaving 4 to 6 inches of the post sticking up. Drill a hole in the top of the post and another 6 inches from the bottom of one leg of the bench. Thread 1/4-inch-diameter wire cable through the fence post hole and one leg of the bench. Tightly loop each end of the cable through these holes and then securely fasten the ends with cable clips. Next, drive the fence post 2 to 3 inches below the surface of the ground with a sledgehammer. Finally, naturalize the area.

To secure a bench to a tree, leave part of the cable looped around the tree loose enough to accommodate growth. The cable should be buried 6 inches below grade between the tree and the bench and secured with cable clips as described above.

Dispersed Camping Areas

To help increase camping opportunities for long-distance hikers of the Ice Age NST, the IATA and Trail partners are increasing their focus on establishing Dispersed Camping Areas (DCAs).

DCAs are areas where multiday hikers can legally camp for a night within sight of the sign shown below. DCAs offer few if any user comforts. The ethos of DCAs is that visitors should leave no trace of their visit. No fires are allowed except for backpacking stoves unless posted otherwise. Six people at one time is the site capacity. Users are asked to dispose of human (and pet) waste in a 6-inch cathole if no facility is provided.

A DCA in Columbia County.

Recommendations in Selecting a DCA Location

- Good choices for DCAs are low knolls or gradual slopes that allow water to drain away. Soils should be able to withstand impacts with little erosion. Avoid low-lying areas and shorelines. Sleeping areas should be comfortably sloped and on the flatter side.
- Look for vegetation or topographic features that provide partial shade and shelter from the elements.
- The DCA should be located a reasonable distance, but not visible from, the Trail; it must be a minimum of 1/4 mile from a road or access point.
- An adequate year-round source of water for cooking and washing is desirable. For sanitary purposes, the water source should be no closer than 200 feet from the actual campsite.

Situations to Avoid

Temporary fixes come in all shapes and sizes. If an immediate hazard threatens the safety of Trail users, by all means address it as well as possible and as soon as possible. While temporary fixes are usually well intentioned, many times they have surprisingly long lifespans. Once "fixed," it is easy to put the problem on the back burner and move on to other needs.

Noncompliant or poorly built structures erode partner and public confidence in the Ice Age NST and the IATA. They may also compound an existing hazard for Trail users. Frequently, with a little more personnel and planning, doing the right thing at the outset will result in a product everyone is proud of and a solution that will not have to be revisited.

This bridge stringer was improperly secured.

Temporary crossings like this one are illegal.

This temporary crossing is unsafe.

The Last Ten Percent

In *Lightly on the Land*, the timeless trail-building and maintenance manual written by Robert C. Birkby for the Student Conservation Association (SCA) in 1996, the "last ten percent" is described: "Attention to final details and the cleanup of a site makes a great difference in the ultimate appearance and quality of a work project. Unfortunately, that final ten percent of effort is often neglected. Crew leaders should include time in their work schedule to allow for the last ten percent, and then motivate crews to take pride in giving their work the polish it deserves."

Resources

Appalachian Mountain Club Trails Department. *AMC's Complete Guide to Trail Building and Maintenance*. 4th Ed. Guilford, CT: The Globe Pequot Press (distributor), 2008. http://amcstore.outdoors.org.

Birchard, William, Jr., and Robert Proudman. *Appalachian Trail Design, Construction, and Maintenance*. 2nd Ed. Harpers Ferry, WV: Appalachian Trail Conference, 2000. http://www.atctrailstore.org/.

Savoy, Lauret E., Eldridge M. Moores, and Judith E. Moores, eds. *Bedrock: Writers on the Wonders of Geology*. San Antonio: Trinity University Press, 2006. http://www.geosociety.org/bookstore/.

Student Conservation Association. *Lightly on the Land: The SCA Trail Building and Maintenance Manual.* 1st Ed. Seattle: Mountaineers Books, 1996. http://www.mountaineersbooks.org.

Volunteers for Outdoor Colorado. *Crew Leader Manual.* 5th Ed. Denver: Volunteers for Outdoor Colorado, 2002. Contact VOC to request a copy.

Government Publications

U.S. Department of the Interior. National Park Service, Wisconsin Department of Natural Resources, and Ice Age Trail Alliance. *Ice Age National Scenic Trail: A Handbook for Trail Design, Construction, and Maintenance*. Madison, WI: National Park Service, 2001. http://www.nps.gov/iatr/parkmgmt/trail_handbook.htm.

US Department of Agriculture, Forest Service Technology & Development Program. *Locating Your Trail Bridge for Longevity*. Missoula: USDA Forest Service, 2010. http://www.fs.fed.us/eng/pubs/pdfpubs/pdf10232808/pdf10232808dpi72.pdf.

US Department of Agriculture, Forest Service Technology & Development Program. *Wetland Trail Design and Construction*. 2007 Edition. Missoula: USDA Forest Service, 2007. http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf07232804/pdf07232804dpi72.pdf.

US Department of Agriculture, Forest Service Technology & Development Program. *Trail Construction and Maintenance Notebook*. 2007 Edition. Missoula: USDA Forest Service, 2007. http://www.fs.fed.us/t-d/pubs/htmlpubs/htm07232806/index.htm.

Commercial Resources

Simpson Strong-Tie: Wood Construction Connectors Catalog, 2004. http://www.strongtie.com.

Trail Services, LLC, Catalog, 2012. www.trailservices.com.

Partner Resources

Appalachian Trail Conference: http://www.appalachiantrail.org

Appalachian Mountain Club: http://www.outdoors.org

National Park Service: http://www.nps.gov/iatr/index.htm

Pacific Crest Trail Association: http://pcta.org/help/volunteer/trail-skills-college/curriculum.asp

Pacific Northwest Trail Association: http://pnt.org

San Gabriel Mountain Trail Builders: http://sgmtrailbuilders.org

Student Conservation Association: http://www.thesca.org

US Forest Service trail drawings online: http://www.fs.fed.us/.ftproot/pub/acad/dev/trails/trails.htm

Volunteers for Outdoor Colorado: http://www.voc.org

Washington Trails Association: http://wta.org

Wisconsin Department of Natural Resources: http://dnr.wi.gov/org/land/parks/specific/iceagetrail/

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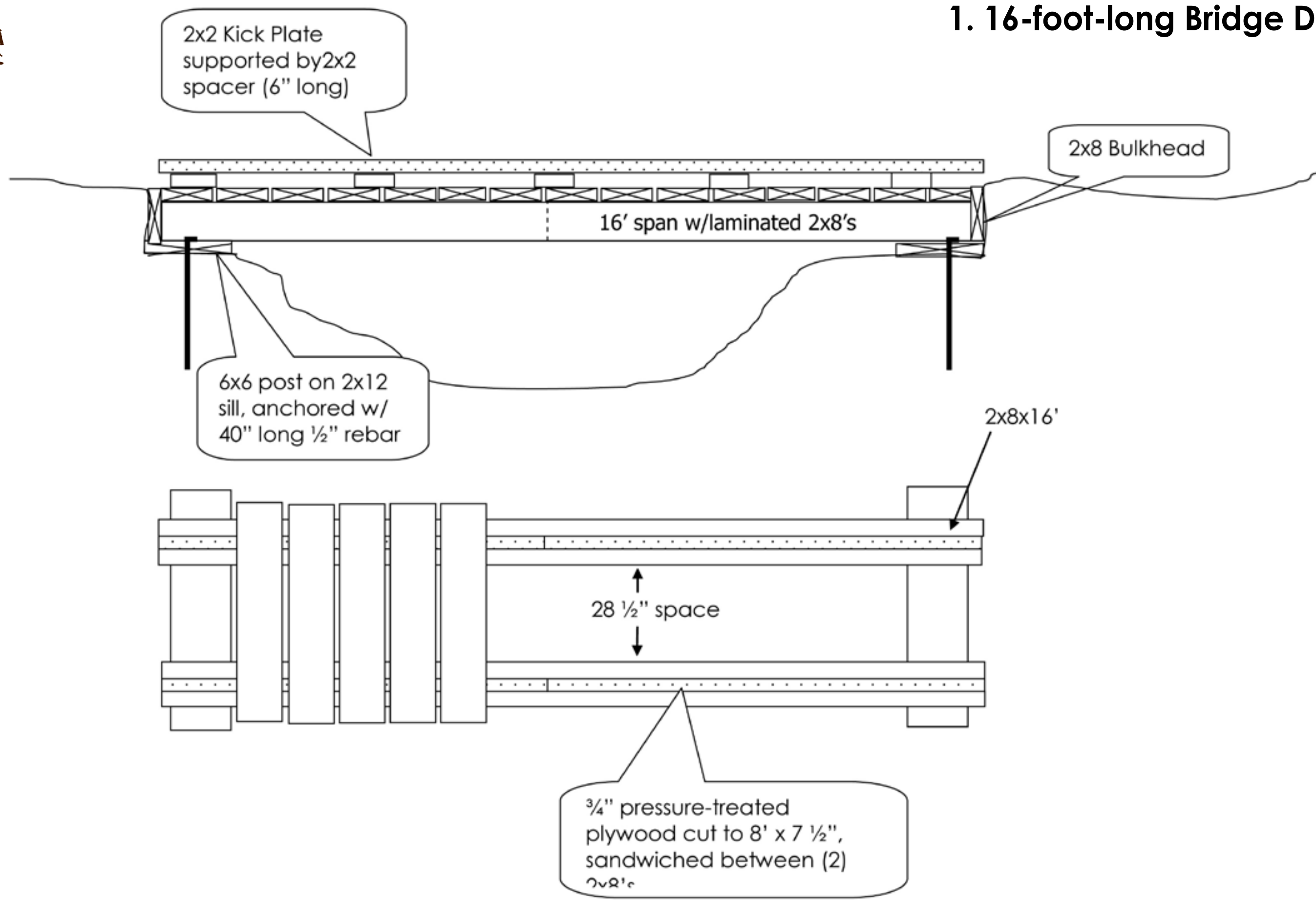
Appendix

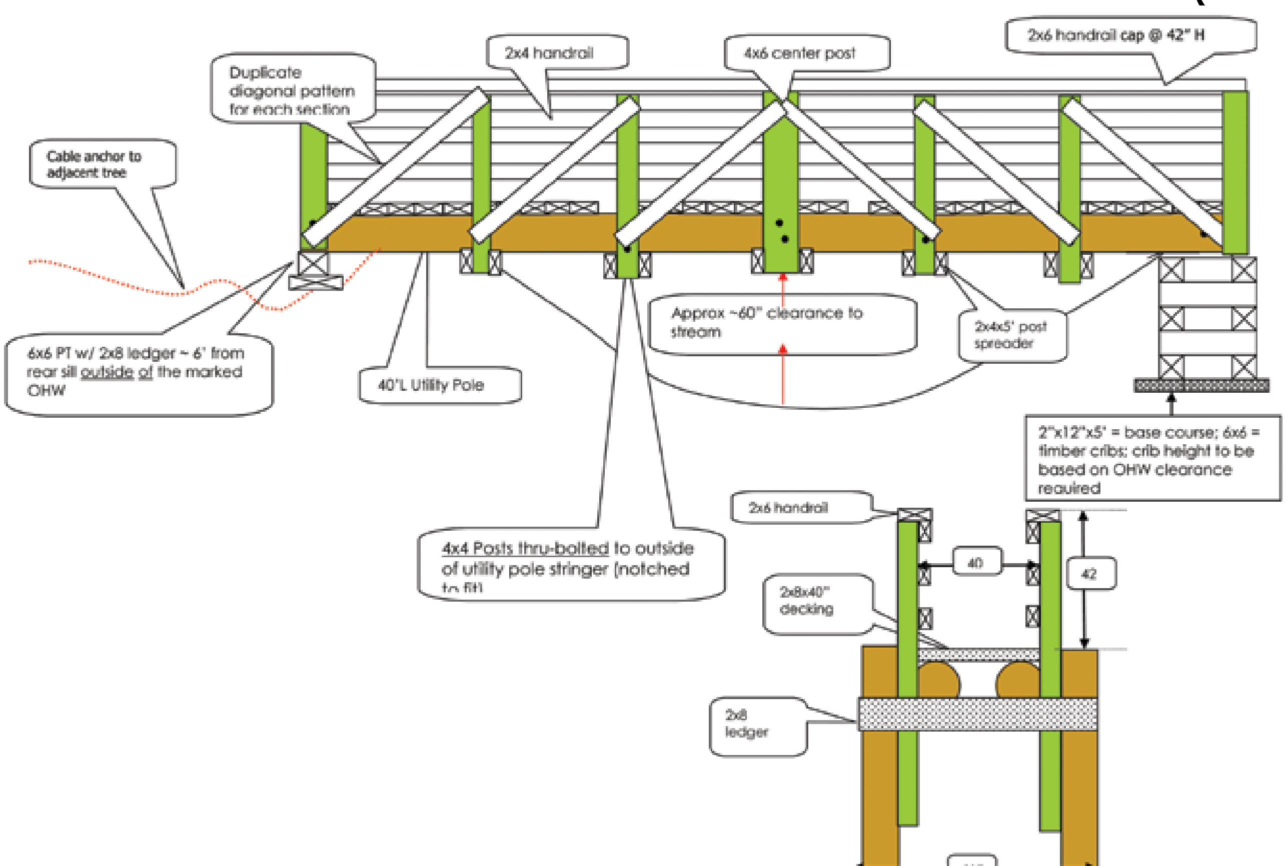
Trail Structure Drawings and Tables

1. 16-foot-long Bridge Diagram
2. 40-foot-long Bridge Diagram
3. Kiosk Construction Plan (a) and Alternate Drawing (b)
4. Boardwalk Schematic
5. Boardwalk Frame Template
6. Materials Estimator List
7. Puncheon Template
8. Parking Lot Drawings
9. Bench Drawing
10. Ice Age National Scenic Trail Standards for Trail Support Facilities
11. Ice Age National Scenic Trail Design Standards for Trail Structures

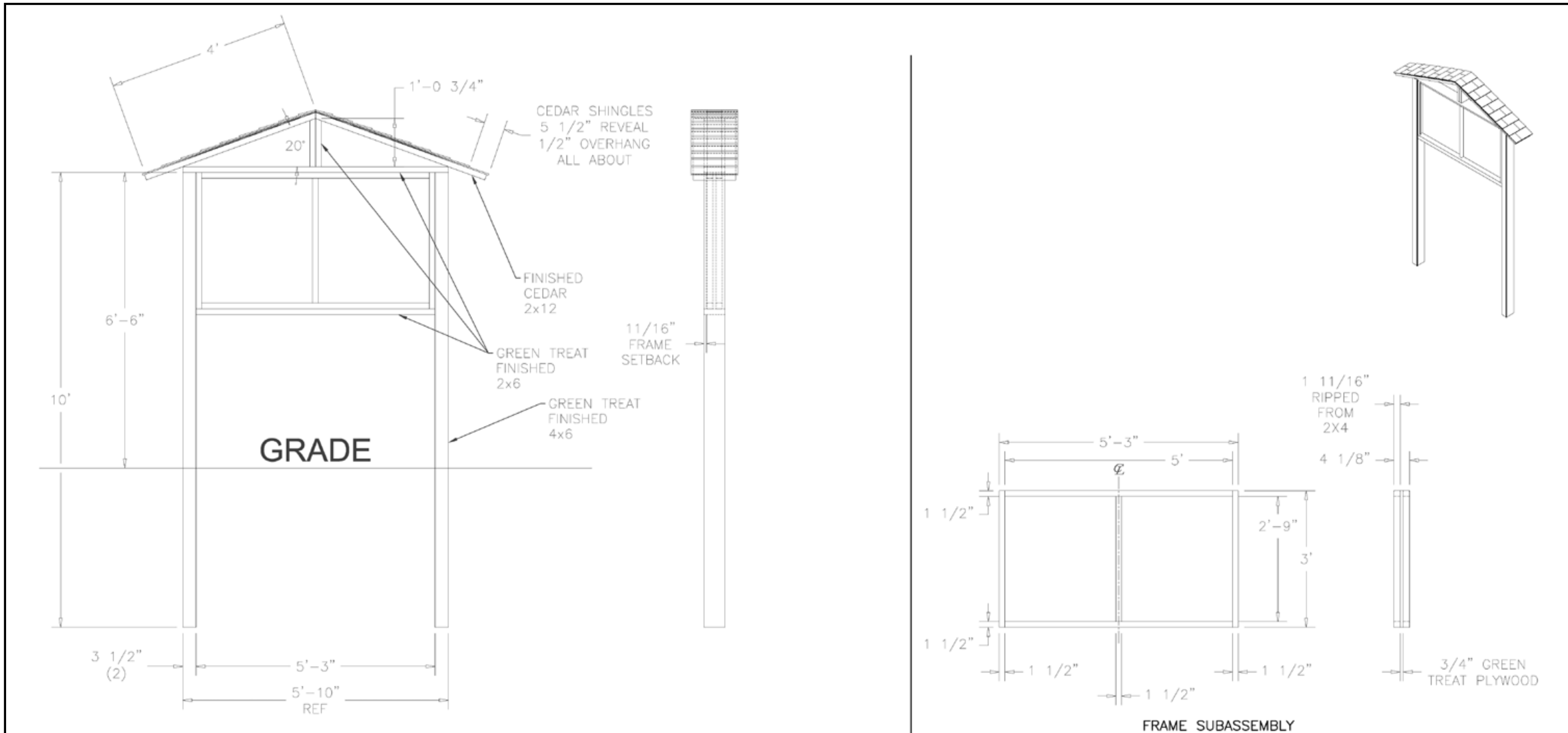
1. 16-foot-long Bridge Diagram



2. 40-foot-long Bridge Diagram (not to scale)



3. Kiosk Construction Plan (a)



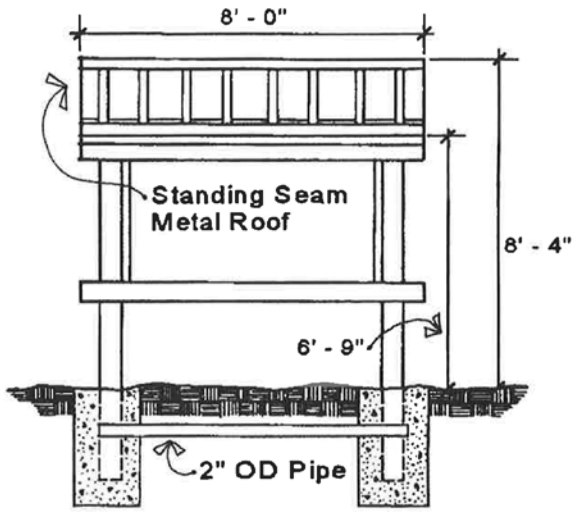
ITEM	QTY	DESCRIPTION	PART ID
6	1	BUNDLE CEDAR SHINGLES	
5	2	GREEN TREATED 2"x4"x10', RIPPED ON CENTERLINE	
4	2	GREEN TREATED 2"x6"x8'	
3	1	FINISHED CEDAR 2"x12"	
2	1	GREEN TREATED 3/4"x4'x8' PLYWOOD	
1	2	GREEN TREATED 6"x6"x10'	

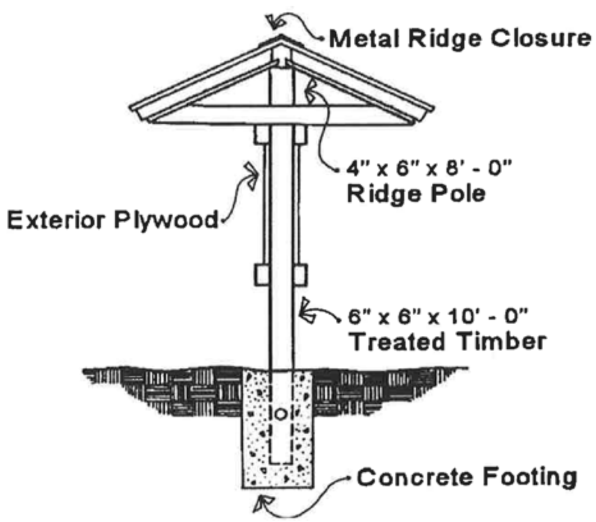
BILL OF MATERIALS

Add 4-bags of quickcrete
1lb - 2-1/2 deck screws
2lbs - Stainless ringshank 8d

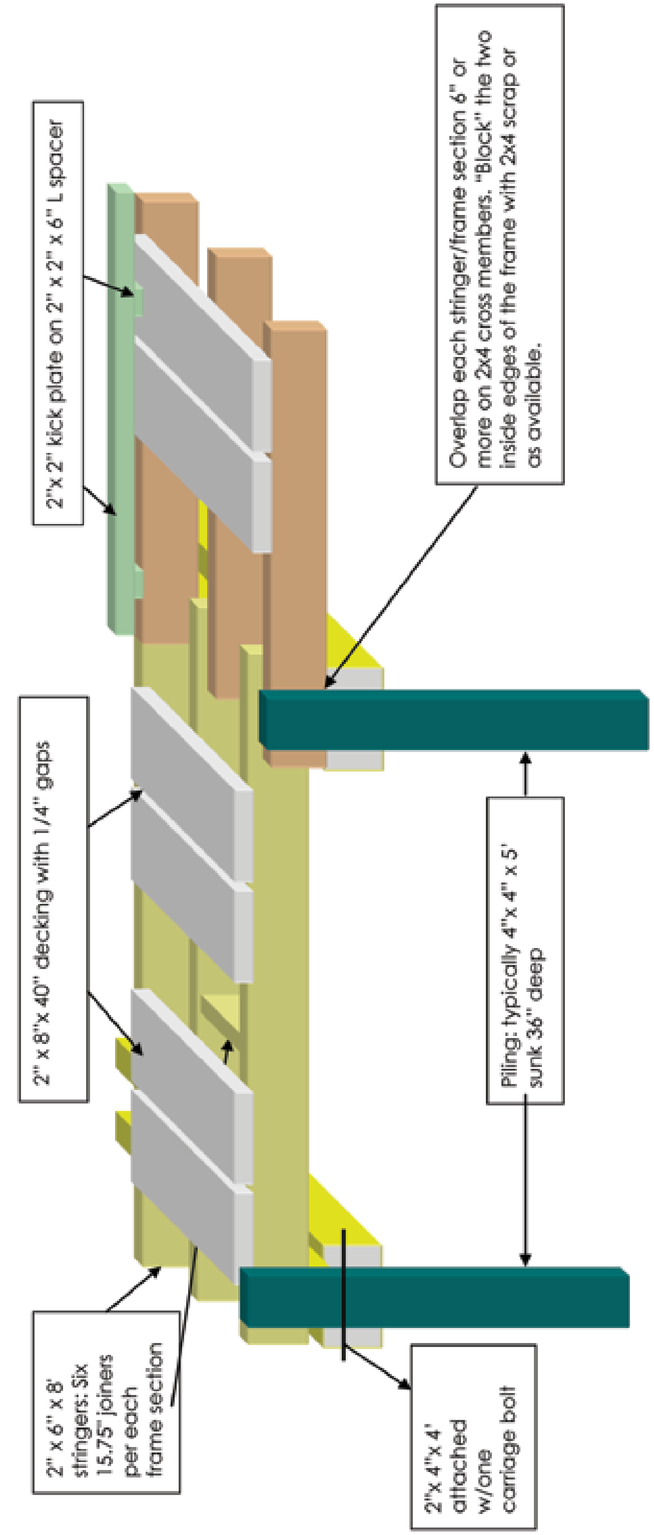
SCALE: 1/24	DWG TITLE: REVISED KIOSK
DATE: 27JUN09	
THIRD ANGLE PROJECTION	SHEET: 1 OF 1 / DWG NO.: / SIZE: B

Kiosk Construction Alternate Drawing (b)





4. Boardwalk Schematic



5. Boardwalk Estimator List

Boardwalk Material Estimator (40" wide)

total linear feet divided by 7 = total # of sections

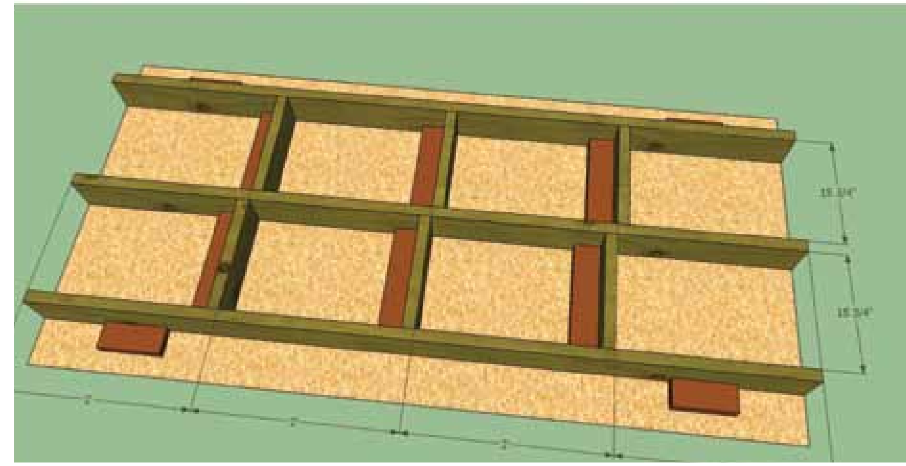
Purpose	Lumber	Multiplier per 8' section	# of sections	Total
Kick plates/ spacers	2x2x8	3	7	21
Decking	2x8x10	4	7	28
Frames	2x6x8	3.75	7	26.25
Cross Boards	2x4x10	0.72	7	5.04
Pilings	4x4x10	0.72	7	5.04
Fasteners	(2 1/2" or 3") Deck Screws (star head)	121	7	847
Attach 2x4 cross boards to 4x4 pilings	Hot dipped galvanized 3/8" x 7"L carriage bolts w/ one washer & nut per bolt	2	7	14

Puncheon Material Estimator (40" wide)

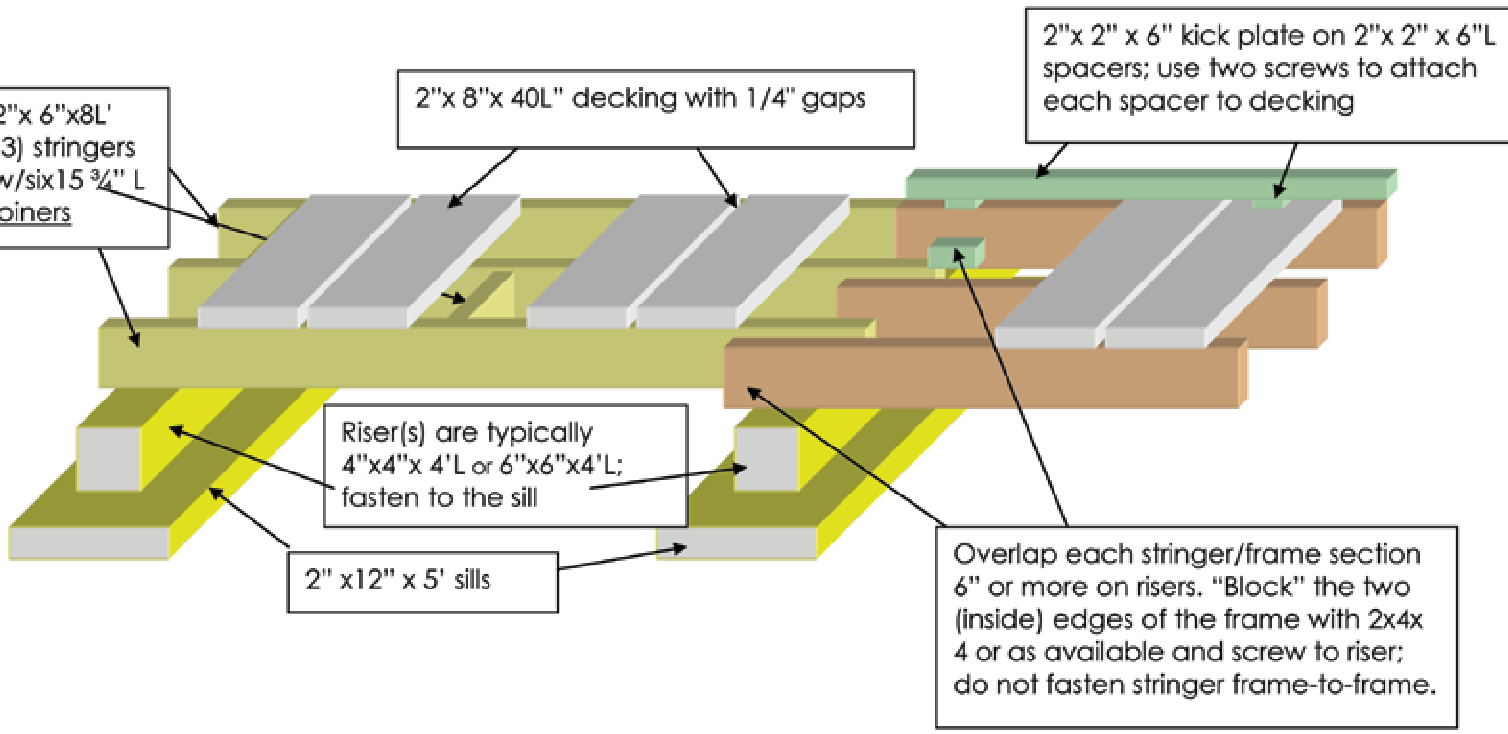
Purpose	Lumber	Multiplier per 8' section	# of sections	Total
Kick plates/ spacers	2x2x8	3	7	21
Decking	2x8x10	4	7	28
Frames	2x6x8	3.75	7	26.25
Risers	4x4 (or 6x6) x 8	0.36	7	2.52
Sills	2x12x10	0.5	7	3.5
Blocks	2x4x10	0.14	7	0.98
Fasteners	(2 1/2" or 3") Deck Screws (star head)	127	7	889
1/2" Rebar x 3'L pcs	Anchor sills to ground	2	7	14

6. Boardwalk Frame Template

When more than just a few boardwalk sections must be created, use a template to speed assembly and ensure uniformity. Materials needed are a 4 x 8 sheet of particle board (or equivalent), something to set it up on (sawhorses, stacks of lumber needed later, etc.), scrap pieces of 2 x 4 (the equivalent of 10 feet).

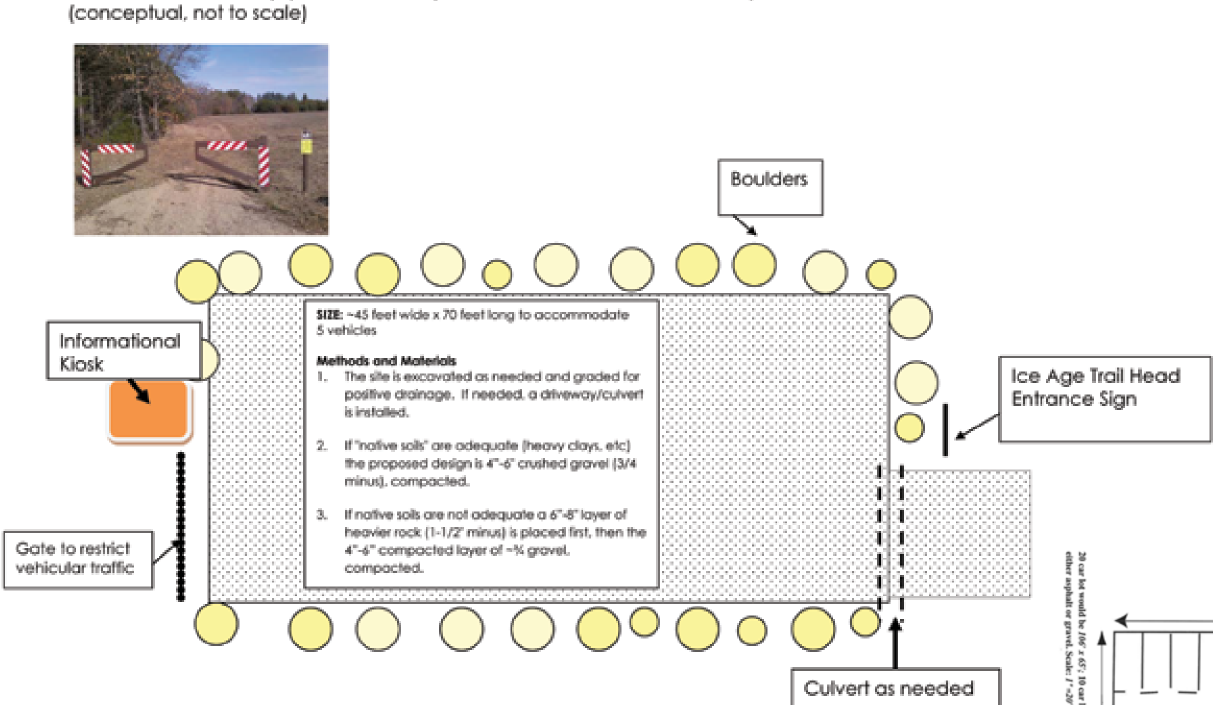


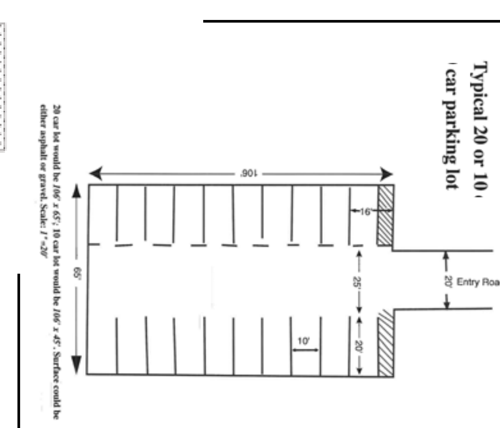
7. Puncheon Template



8. Parking Lot Drawings

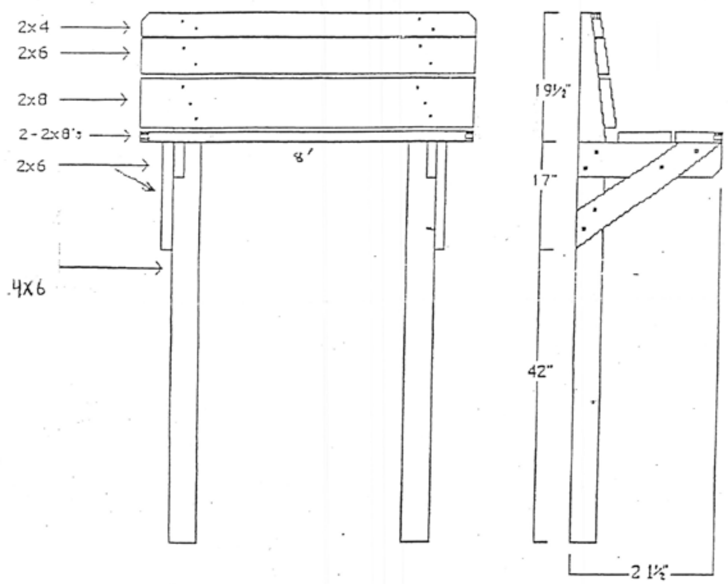
4-6 Car Parking Lot Example Drawing
Case x Case Approval Required from DNR, County & Town
(conceptual, not to scale)





9. Bench Drawing

Trail Bench



MATERIALS LIST

Treated Lumber
2-2"x4"x8'
2-2"x6"x8'
2-2"x8"x8'
2-4"x6"x8'

Hardware
8-3/8"x4" Carriage Bolts
4-3/8"x6" Carriage Bolts
12-3/8" Nuts
24-3/8" Washers
30-3" #10 Galvanized Screws

PARTS LIST
2-2"x6"x2 1½' Seat Supports
2-2"x6"x2 8½" Seat Braces
1-2"x4"x4' Back Rest
1-2"x6"x4' Back Rest
3-2"x8"x4' Back Rest, Seats
2-4"x4"x78" Support Posts

*NOTE
Support post needs to be notched out(1 1/2" deep) to receive seat support.

10. Ice Age National Scenic Trail Standards for Trail Support Facilities

Standards (minimum)	Recreation Opportunity Spectrum (ROS) Spectrum		
	Urban	**Rural & Roaded Natural**	**Semiprimitive**
Primary Trailhead	As needed	Spacing 5 miles or less when actual or desired use is high. Spacing 8-10 miles or more when actual use is low.	Spacing 10 miles or more.
Campsite/Shelter	Hotels, Bed and Breakfasts	Spacing 8-15 miles. Especially needed when dispersed camping along the route is not permissable.	Spacing 8-15 miles. Especially needed when dispersed camping along the route is not permissable.
Developed Water	Obtain from Public Facility	Spacing 10-15 miles when potable or treatable water is not available.	Spacing 20-30 miles when potable or treatable water is not available.
Toilet Facility	Obtain from public facility	At high-use areas, campsites, trailheads, and other public areas as necessary.	As needed for resource protection.
Parking Lots (composed of asphalt or gravel)	No less than 5 car spaces. (45'-50')	No less than 5 car spaces. (45'-50')	No less than 5 car spaces. (45'-50')

Primary trailheads provide parking for five or more vehicles and are generally located on well-traveled state, county and town roads. They have a bulletin board or kiosk for trail information and may provide water and toilets. They are frequently part of an existing facility.

Secondary trailheads typically provide parking for less than five vehicles, or even no parking because of trail design or safety considerations. Kiosks with trail information are encouraged, but water and toilets are optional. Secondary trailheads may be used when it is necessary to gain access to the NST via other trails. In this situation, the secondary trailhead may be located where the named trail intersects the NST, or at the beginning of the access trail. Typically, secondary trailheads are located on low-traveled roads.

11. Design Standards for Trail Structures

Standards (desired)	ROS CLASS		
	Urban	Rural & Roaded Natural	Semiprimitive
Bridges (width) Hiking Segment Accessible Segment	60" 72"	36" 48"	36" 36"
Bridge Railings Hiking Segment Accessible Segment	Y Y	(1) (1)	(1) (1)
Bridge Rail Height	42"	42"	42"
Bridge Kickplate Required (2) Hiking Segments Accessible Segments	Y Y	N Y	N Y
Puncheon (3) Hiking Segments Accessible Segments	N/A N/A	16-18" width N/A	16-18" width N/A
Boardwalk (4) Hiking Segments Accessible Segments	60" 72"	36" 48"	36" 36"
Culverts (5)	OK	OK	OK

(1) Whether a railing is required is subject to policies of managing authorities, site characteristics, and common sense. Railings are almost always needed except, if the bridge is very wide, the crevasse shallow, or the length of the bridge very short.
(2) Kickplates are often included for safety when handrails are not required.
(3) Puncheon rests on sills and is generally less than 1' high. Current standards call for a wider width.
(4) Boardwalk is generally less than 2' above water level and should have kickplates.
(5) Length must be calculated to provide for 2:1 fill slope beyond the normal trail clearing.
Size (engineering consultation) to accommodate peak flows. Water crossing permits often required.

Bridge and Boardwalk Tool List

Have and refer to all design drawings, material lists, and WDNR, Corps, and locally issued permits on site during construction.

Layout:

- Clinometers
- Calculators
- Chalk lines
- Combination and framing squares
- Compasses
- Pencils
- String line and line levels
- Permanent markers and lumber crayons
- Flexible rulers
- Utility knife and blades
- 25-foot tape measures
- 100-foot measuring tapes

Hand tools:

- Hand planes
- Assorted handsaws
- Hammers
- Rock/tamping bars
- Pick mattocks
- Pulaskis
- Gravel and transfer shovels
- Levels
- Wood chisels and mallets
- Adzes
- Adjustable ladders
- Tool belts
- Buckets
- Nail aprons
- Peavey Cant Hooks
- Timber carriers
- Sledge hammers
- Heavy-duty sawhorses
- Tarps
- Ratchet straps
- Wedges
- A variety of clamps with a 6- to 18-inch-wide clamping capacity
- Sharpening files
- 8-inch and 12-inch-plus spiral drill bits
- Post hole diggers
- Griphoists and rigging equipment if applicable

Power tools:

- 1/2-inch-drive 18V drills
- Electric 1/2-inch-drive (or larger) hammer drill
- Gas-powered auger drill
- Auger bits 12 to 18 inches or longer
- Circular saw
- Extension cords (#12, 50-foot minimum)
- Power strips
- Generator, fuel, and oil
- Chainsaw
- Power sander if possible

Hardware:

Per the materials list. Generally:

- GRK Torx fasteners
- 3/8-inch carriage bolts
- 1/2-inch threaded rods
- 2 1/2 to 3 1/2-inch deck screws
- Extra drive and drill bits
- 8-penny nails
- Lengths of ½-inch rebar
- Ledger locks
- Braided wire cable and fasteners to anchor a bridge on the upstream side;
- Silt fencing when called for

Miscellaneous:

- copper naphthenate wood preservative or wood sealer

A Typical On-Site Sequence of Events

After months or maybe even years, finally the big week is here. Let the excitement carry you, but also remember that the key to having a fun, safe, and successful build is to visualize the planned sequence of events, prepare accordingly, and continually talk through scenarios as a crew.

When feasible, it is helpful to leave the old structure(s) in place while constructing the new. If not feasible, carefully disassemble and dispose of all waste materials off-site at an approved facility. When practical, it is helpful to precut and preassemble wood structure components off-site ahead of time. Embrace "measure twice, cut once" and "plan the work, work the plan" maxims. Lastly, please budget time at the end of each workday to clean and store tools and equipment and to cover lumber and materials with secured tarps.

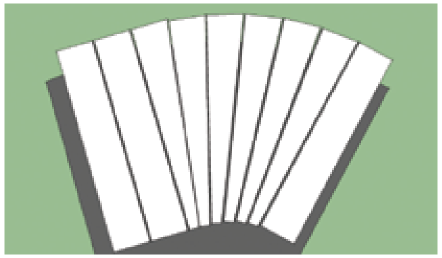
1. Remove obstructions and clear an access route to bring equipment and materials to the worksite. At the worksite, lay out work zones with an eye toward facilitating efficient transport and staging of building materials, structural components as they are assembled, and equipment. Allow ample room for each activity to progress simultaneously. Do not block emergency vehicle access or evacuation routes.
2. Clear the work and staging areas of overhanging brush and limbs to a height of 10 feet; grub toe-trippers and eye-pokers. You have now established and prepared dedicated areas to stage and store materials, cut lumber, and preassemble components.
3. If using a Griphoist and rigging equipment, determine anchor and spar locations, and with a pole saw, clear vegetation from high-line runs as needed.
4. Inventory, organize, and stage the lumber and materials delivered and cover it all with tarps.
5. If appropriate for the project, build and install temporary bearing supports to set the bridge stringers on for easier access and/or to assemble boardwalk frames on. Bearing supports should be level and 18 to 24 inches high. To support bridge stringers, use sound, heavy-duty wooden sawhorses, or build H-frames using 5-foot 4 x 4 posts buried 2 or more feet deep joined with 2 x 8 crosspieces.
6. Per the regulatory process, put erosion control measures into effect, and install silt fencing.
7. **BRIDGES:** Lift utility pole stringers onto the sawhorses/H-frames; orient the narrow ends in the same direction. If not using utility poles, create laminated stringers if called for. If constructing a native timber structure, fell appropriate timber, peel, and prep.

   Bridge stringer notes: Once the stringers are on the temporary supports, carefully inspect each one for rot, cracks, or defects; determine which side is the crown and orient the stringer crown-up; determine the usable length of each stringer. Mark which will be the upstream and downstream stringers; secure stringers with wedges and ratchet straps once on the supports; do not cut to length until both stringers have been fully prepped.
8. Excavate for cribs/sills and build to spec. Gentle reminder — it is critically important that cribs and sills are located exactly where planned. If needed, set up rigging and Griphoist systems.
9. When ready, rehearse the move and then lift stringer(s) across the waterway to rest on cribs; secure the stringers to the cribs with wedges and ratchet straps.
10. Install deck boards leaving a 1/4-inch gap between boards; install vertical handrail posts and horizontal handrail system members.
11. Build the approach ramps and, if not done previously, demolish the existing bridge.
12. **BOARDWALKS** (continuing from #6):
    Cut deck boards, kick plates, and spacers to length. Preassemble boardwalk frames per spec; place a few assembled frames along the flag line to better visualize and confirm the layout. Considering math (boardwalk frames should overlap about 6 inches) and aesthetics (diverse/sinuous shapes are more engaging than monotonous straight-line shapes), adjust the trial frames as needed. Flag/mark the locations of the vertical support pilings, typically located in pairs 5 feet wide at 7-foot intervals; start digging.
13. With a post hole digger and tamping bar, dig piling holes at least 3 feet deep. Reserve all soil, rock, and cobble for backfilling. If a rock is encountered that is too big to move or break, keep trying. You may need a pinch point bar (heavier than a tamping bar) to break it. If you can't make any headway and if the hole is down at least 2 feet, the options are 1) set the piling on the rock, or 2) dig another hole at a wider distance. Loosely set support posts in the holes — do not set them yet.
14. Run a string line from one end of the boardwalk to the other; stretch it taut along the inside face of the vertical posts/pilings. Measure the clearance between string line and grade. Army Corps approval will

specify what the acceptable limits are — if you're getting 12 inches of height throughout most of the run, you're probably in great shape.

15. Check the string line for level by attaching simple line level(s) in multiple locations.
    a) 8.33 percent (1 inch rise per 12 inches run) is the maximum allowable rise.
    b) If the string line noticeably dips or rises in comparison to the terrain, adjust the line up or down as needed, within the acceptable limits. If there is excessive rise, increase the total length of the boardwalk in order to make the necessary adjustments for level and rise.
    c) The string line represents the bottom edge of the boardwalk frames and the top edge of the cross member supports. If using 2 x 6 frames, the top of the finished boardwalk will be 7 inches higher than the string line.
16. Set and plumb vertical pilings. To prevent pilings from canting sideways or turning askew from their opposite mates while being installed, temporarily clamp or screw a 5-foot 2 x 4 crosspiece to the piling. Set the pilings and then tamp the excavated soil and cobble back into the holes with the piling. In some situations you may be able to drive the piling deeper with a sledgehammer, but this technique can splinter and mash piling tops as well as the occasional finger.
17. Remove the temporary crosspiece, tighten the string line, and check again for level and rise; mark where the string line hits each post with a pencil or Sharpie pen.
18. Clamp two 5-foot 2 x 4 horizontal cross boards to the vertical support pilings where marked (place the tops of the cross boards at the mark on each side of the piling). Level them into position, clamp in place, pre-drill, and secure with one 3/8"x7"carriage bolt per piling.
19. Set the boardwalk frames onto the support assembly. Overlap adjoining frames about 6 inches. If a turning radius is sharp, you may need to shorten/cut the inside of the frame. When a substantial number of frames are in place, screw a 4-inch 2 x 4 block to the horizontal cross members at the inside edge of the boardwalk frames. This prevents the assembly from shifting sideways, and the blocks will not be visible. Do not screw the boardwalk frames to each other. Before decking, treat all cut edges with copper naphthenate or a wood sealer for maximum longevity.

20. Now the fun — decking the boardwalk. Maintain a uniform 1/4-inch gap between deck boards and install them crown-up. Start by laying the boards onto the frames. Evaluate needs. Modest turns in the structure's shape may not necessitate ripping deck boards.
    a) Special care is required when decking a radius. Curves require slightly longer boards to cover the framing and make a curve. Overlap boards as you would hold playing cards in your hand. Arrange the boards to have roughly the same reveal. With a pencil, trace the edge of each board to mark the one underneath it. This is the cut line; cut each board along this line. Arrange the boards back on the boardwalk frame, on the radius, with even spacing between the boards to make a curve. Repeat to finish the radius. Fasten deck boards with two screws on each side and one in the center. After the boardwalk is completely decked, cut the ends of any boards that stick out too far.



Decking a radius.

21. Screw 2- by 7-inch spacers (four per 8-foot section, includes section overlap) flush with the outside edges of the decking. Fasten an 8-foot 2 x 2 to the spacers. A 2 x 4 ripped in half is more rigid than a standard 2 x 2, but the cut surface should be treated with a preservative. Naturalize and clean the site, pick up all garbage, and congratulate yourself!

ICE AGE TRAIL ALLIANCE

2110 Main Street

Cross Plains, WI 53528

www.iceagetrail.org