ALLEGHENY LAND TRUST

Civil & Environmental Consultants, Inc.

Conservation Management and Stewardship Master Plan for Wingfield Pines Conservation Area

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Wingfield Pines Conservation Area
Conservation Management and Stewardship Master Plan

Allegheny Land Trust

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1.0 Introduction | Executive Summary

Allegheny Land Trust (ALT) contracted Civil & Environmental Consultants, Inc. to develop a conservation management and stewardship master plan for Wingfield Pines Conservation Area to guide future management and stewardship of the site. The purpose of CEC's work was to develop a plan that addressed ALT's three primary areas:

- **E**cological resources
- **E**ducational opportunities
- **R**ecreational attributes

ALT will use the plan to guide future management and stewardship efforts at Wingfield Pines with the goal of continuing the on-going restoration of the property while optimizing and balancing ecological priorities, passive recreational opportunities, and environmental educational programming.

Resource Analysis

Today, Wingfield Pines is a natural refuge, framed by forested hillsides that amplify the natural beauty and tranquil isolation of the site. Visitors explore this natural oasis via a network of trails winding through each of the nine unique habitats within the site, including a popular boardwalk through a bur-reed marsh. Historically, this 87-acre conservation area has been used for purposes that are more intensive. Originally forest and then farmland, the site underwent extensive mining throughout the early twentieth century—a legacy evident in the sheer slopes (high wall) that border the site on the east and the abandoned mine drainage (AMD) that flows into Chartiers Creek at the northern end of the site. Throughout the latter half of the twentieth century, Wingfield Pines was redeveloped as a popular local golf and swim club. Many remnants of that era are still visible today, including the parking lot, swimming pool and pavilion area, and artificial golf course ponds.

Though very early in its reversion to a more natural habitat, Wingfield Pines already exhibits a diverse plant and animal community indicative of its position as a floodplain. The created ADM treatment ponds and wetlands in the north combined with the golf course ponds and naturally developing wetlands in the south create a substantial wetland refuge whose preservation and enhancement should be guiding force behind management of the property.

Wingfield Pines has numerous trails that weave throughout the property. These trails are a popular destination for walkers, birdwatchers, dog walkers, and nature enthusiasts. The trails are generally well maintained but include numerous areas that would benefit from improvement and more ecologically sensitive maintenance techniques. Large portions of the trail network are almost perpetually flooded and often unusable. While the existing trail network traverses most of the site, access to interesting site features like the ponds, the sycamore/boxelder forest, the early successional forest, and the adjoining Chartiers Creek could be improved.

Conservation Management and Stewardship Master Plan

The Conservation Management and Stewardship Master Plan for Wingfield Pines includes maintenance and improvement recommendations grouped into four major categories.

Ecological Habitats

Of the nine ecological habitats identified at Wingfield Pines, three are dedicated to AMD treatment or site maintenance activities. Of the six remaining habitats, five are appropriate habitat for their location and compatible with ALT's overall

goals for Wingfield Pines. The existing Maintained Meadow habitat is not providing significant ecological functions and visitor use is minimal. Converting this habitat to a marsh would provide additional valuable habitat and further the role of Wingfield Pines as a wetland refuge.

Trail System

The existing trail system provides access to key areas and most habitats on the property. Maintenance is variable depending on habitat and circumstances but there is an opportunity to implement more ecologically sensitive maintenance plans. Visitor use of the southern portion of the site will be enhanced by an expansion of the trail network into the Sycamore/Boxelder Forest and Early Successional Upland Forest (currently not included on any trails) and the addition of a boardwalk allowing improved access to the Ponds.

Educational Infrastructure

CEC recommends creation of an Education and Recreation Hub incorporating the infrastructure remaining from the former Wingfield Pines Golf and Swim Club with the addition of:

- Scalable pavilion - A 1,500-square foot pavilion, using cost-efficient and durable materials with a compacted gravel floor, ample covered area for classroom functions, and a simple wooden partition wall in the rear of the pavilion to screen the educational area from restroom facilities.
- Reused and improved parking area - Reusing the parking area that served the former Golf and Swim Club. This area already has compacted base material and can be improved for minimal cost with a one-time investment in gravel to cover the existing lot area, then an annual fill of any low areas.
- Rain Garden and/or Synoptic Wetland Plant Collection – Within the existing swimming pool area, a simulated Rain Garden receiving runoff from the pavilion and maintenance build roofs would demonstrate in a very visual way this important stormwater management best practice. Alternatively, or in combination with the Rain Garden concept, a collection of representative wetland plant species from areas throughout Wingfield Pines can be planted here to create a concentrated orientation and learning experience that would simplify and reduce site-wide signage.

Signage

High-quality educational signs are currently in place within the Maintained Landscape and AMD treatment habitats. These signs focus on the AMD treatment process. Expanding educational signage to include all nine habitats would enhance the visitor experience, and the addition of wayfinding signs at major trail intersections would aid visitors as they navigate the property.

2.0 Existing Resource Analysis

Red Bat, Courtesy Chris Harshaw

The master planning team began their review of the ecological resources at Wingfield Pines in April 2018 with a group meeting of scientists with experience conducting investigations at the site. To understand and evaluate existing site conditions and uses, CEC met with community stakeholders and ALT staff in August. These initial meetings and follow up were supplemented by multiple site visits throughout the summer, fall, and early winter 2018.

2.1 Species Inventory

Wingfield Pines attracts many interested residents, amateur naturalists, and professional scientists who identify, study, and report on their findings and research at Wingfield Pines. Individuals, participants in a 2017 Wingfield Pines BioBlitz event, and professional scientists have contributed to online data platforms such as iNaturalist and eBird to develop a biological inventory for Wingfield Pines. These species inventories, together with additional data provided by David Yeany, Conservation Planning Specialist at The Western Pennsylvania Conservancy; Scott Schuette, Inventory Manager, Pennsylvania Natural Heritage Program at The Western Pennsylvania Conservancy; Dr. Brady Porter, Associate Professor of Biology at Duquesne University; Dr. Matthew Opdyke, Associate Professor of Biological Sciences at Point Park University; and Ed Schroth, Adjunct Instructor of Biology at Duquesne University; enabled CEC to compile a Wingfield Pines Conservation Area Master Species Inventory (Appendix A).

In addition to the above-named resources, CEC ecologists visited Wingfield Pines to complete onsite assessments of three previously identified priority fauna groups and the plant community.

2.1.1 Bats

The existing Master Species Inventory includes a single bat species, the eastern red bat *(Lasiurus borealis)*. Craig Rockey, a state- and federally permitted bat biologist did not observe any bats during a daylight site visit on July 9, 2018, and existing bat boxes appeared unused. In the past, little brown bats have been observed using bat boxes on the property. The open habitat present throughout the central portions of Wingfield Pines and the dominant tree species in the forested southern portion of the site are not conducive to supporting a significant bat population. It is likely, however, that local bat populations funnel into the Chartiers Creek corridor to move to and from offsite roosting and foraging areas. Temperature and humidity are key factors in bat occupancy of structures, and sometimes subtle changes in structure position and orientation can improve the chances of use.

2.1.2 Birds

Birds are probably the most intensively observed taxa at Wingfield Pines. To date, 190 species have been reported, including the following species that are uncommon in western Pennsylvania: American bittern *(Botaurus lentiginosus)*, black tern *(Chlidonias niger)*, least bittern *(Ixobrychus exilis)*, marsh wren *(Cistothorus palustris),* sora *(Porzana carolina*), and Virginia rail *(Rallus limicola)*. Wingfield Pines is the only known breeding location of Virginia rail in Allegheny County.

Virginia Rail, Courtesy Michael L. Baird

Ornithologist Robert Mulvihill of the National Aviary categorized avian species at Wingfield Pines based on their primary habitat. This analysis showed that at least 60 of the 190 bird species present at Wingfield Pines are wetland

species (including open water and shoreline species) and at least 71 are forest edge species. These two habitats are responsible for almost 70 percent of the bird species observed at Wingfield Pines. Statewide, the majority (70 percent) of Pennsylvania's bird species of conservation concern nest or forage in wetland habitats; therefore, wetland habitat management should be prioritized. Other primary avian habitats at Wingfield Pines included early successional (regenerating forest), forest, and grassland.

2.1.3 Reptiles, Amphibians, and Crayfish

Painted Turtle, Courtesy Scot Campbell

This faunal group includes crayfish, frogs, salamanders, snakes, toads, and turtles. During a site visit by David Foltz, a federally permitted mussel and crayfish biologist, on July 6, 2018, three species not appearing on previous inventories were identified: bullfrogs *(Lithobates catesbeianus)*, rock crayfish *(Cambarus carinirostris)*, and black rat snake *(Pantherophis alleghaniensis)*. Three additional crayfish species, Allegheny crayfish *(Orconectes obscurus)*, little brown mudbug *(Cambarus thomai)*, and blue crayfish *(Cambarus monongalensis)*, are likely present based on potential habitat, observed burrow structures, or known presence within Chartiers Creek. High water in pools, wetlands, and Chartiers Creek flooded many burrows and prevented visual confirmation during the onsite visit. Abundant painted turtles *(Chrysemys picta)* were observed in all standing-water wetlands, which is unusual as the non-native invasive red-eared slider *(Trachemys scripta elegans)* often displaces this native species.

2.1.4 Plants

Of the 660 taxa listed on the current observed species inventory for Wingfield Pines, 280 species (40 percent) are plants. During three site visits, David Quatchak, a U.S Fish and Wildlife Service-qualified and Pennsylvania-permitted botanist and horticulturist, believes this is likely an undercount of plant species present at the site. Wetland habitats often limit access for plant observation and identification and several genera, notably *Carex* (sedges), seem under-represented on the current inventory, based on available habitat.

White troutlily *(Erythronium albidum)* appears on the Wingfield Pines inventory and is a Pennsylvania Department of Conservation and Natural Resources (DCNR) species of concern. Its proposed status in the commonwealth is Pennsylvania Rare. This species can best be differentiated from the common yellow troutlily *(E. americanum)* by flower color, and identification of this species should be confirmed. If confirmed, the population should be documented and reported to the Pennsylvania Natural Heritage Program.

Swamp Milkweed

Wild Geranium

Table 1: Summary of Noteworthy Species at Wingfield Pines Conservation Area

Scientific Name	Common Name	Comment
Birds		
Botaurus lentiginosus	American bittern	Uncommon
Chlidonias niger	Black tern	Uncommon
Cistothorus palustris	Marsh wren	Uncommon
Ixobrychus exilis	Least bittern	Uncommon
Porzana carolina	Sora	Uncommon
Rallus limicola	Virginia rail	Only known breeding location within Allegheny County
Reptile		
Chrysemys picta	Painted turtle	Uncommon
Plants		
Erythronium albidum	White troutlily	Proposed Pennsylvania Rare

2.1.5 Invasive Species

While there is no official definition of an invasive species, there are two consistent criteria that organisms generally considered to be invasive have in common:

- They do not naturally occur in a specific location (an introduced species)
- They have a tendency to spread to a degree believed to cause damage to the environment, economy, or human health

Table 2 lists 34 plant species on the Wingfield Pines Master Species Inventory that are currently listed as invasive in Pennsylvania and appear on the Invasive Plants list provided on the DCNR Invasive Plants website.[1]

One alien and potentially invasive species of fish, mosquito fish *(Gambusia affinis)*, is established at Wingfield Pines. It was likely released into the environment to reduce the mosquito population. Potential control options, however, would be very disruptive to the aquatic ecosystem, and control is not recommended at this time.

[1]http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20033694.pdf Accessed October 12, 2018.

Table 2: Summary of Invasive Plant Species at Wingfield Pines Conservation Area

Scientific Name	Common Name	DCNR Rank*
Trees		
Acer ginnala	Amur maple	Watch List Species
Ailanthus altissima	Tree of heaven	Severe Threat
Pyrus calleryana	Callery pear	Significant Threat
Shrubs and Woody Vines		
Berberis thunbergii	Japanese barberry	Severe Threat
Elaeagnus umbellata	Autumn olive	Significant Threat
Euonymus alatus	Burning bush	Significant Threat
Euonymus fortunei	Wintercreeper	Significant Threat
Frangula alnus	Common buckthorn	Severe Threat
Hedera helix	English ivy	Lesser Threat
Lonicera japonica	Japanese honeysuckle	Severe Threat
Lonicera maackii	Amur honeysuckle	Severe Threat
Lonicera morrowii	Morrow's honeysuckle	Severe Threat
Rosa multiflora	Multiflora rose	Severe Threat/Pennsylvania Noxious Weed
Herbs		
Aegopodium podagraria	Goutweed	Lesser Threat
Alliaria petiolata	Garlic mustard	Severe Threat
Butomus umbellatus	Flowering-rush	New to Pennsylvania but highly invasive in Great Lakes region
Cardamine impatiens	Narrow-leaved bittercress	Lesser Threat
Cirsium arvense	Canada thistle	Significant Threat/Pennsylvania Noxious Weed
Conium maculatum	Poison hemlock	Severe Threat/Pennsylvania Noxious Weed
Coronilla varia	Crownvetch	Significant Threat
Fallopia japonica	Japanese knotweed	Severe Threat
Hesperis matronalis	Dame's rocket	Significant Threat
Iris pseudacorus	Yellow flag	Significant Threat
Lysimachia nummularia	Moneywort	Lesser Threat
Lythrum salicaria	Purple loosestrife	Severe Threat
Microstegium vimineum	Japanese stiltgrass	Severe Threat
Pastinaca sativa	Wild parsnip	Significant Threat
Phalaris arundinacea	Reed canarygrass	Significant Threat
Polygonum caespitosum	Oriental lady's thumb	Lesser Threat
Ranunculus ficaria	Lesser celandine	Severe Threat
Stellaria media	Common chickweed	Lesser Threat
Typha angustifolia	Narrow-leaved cattail	Severe Threat
Viburnum opulus	Guelder rose	Lesser Threat
Vinca minor	Periwinkle	Lesser Threat

*DCNR Rank Definitions

Severe Threat - Exotic plant species that possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation. Includes species that are or could become widespread in Pennsylvania.

Significant Threat - Exotic plant species that possess characteristics of invasive species but are not presently considered to spread as easily and aggressively into native plant communities as those species listed as Severe Threat.

Lesser Threat - Exotic plant species that spread in or near disturbed areas, and are not presently considered a major threat to undisturbed native plant communities.

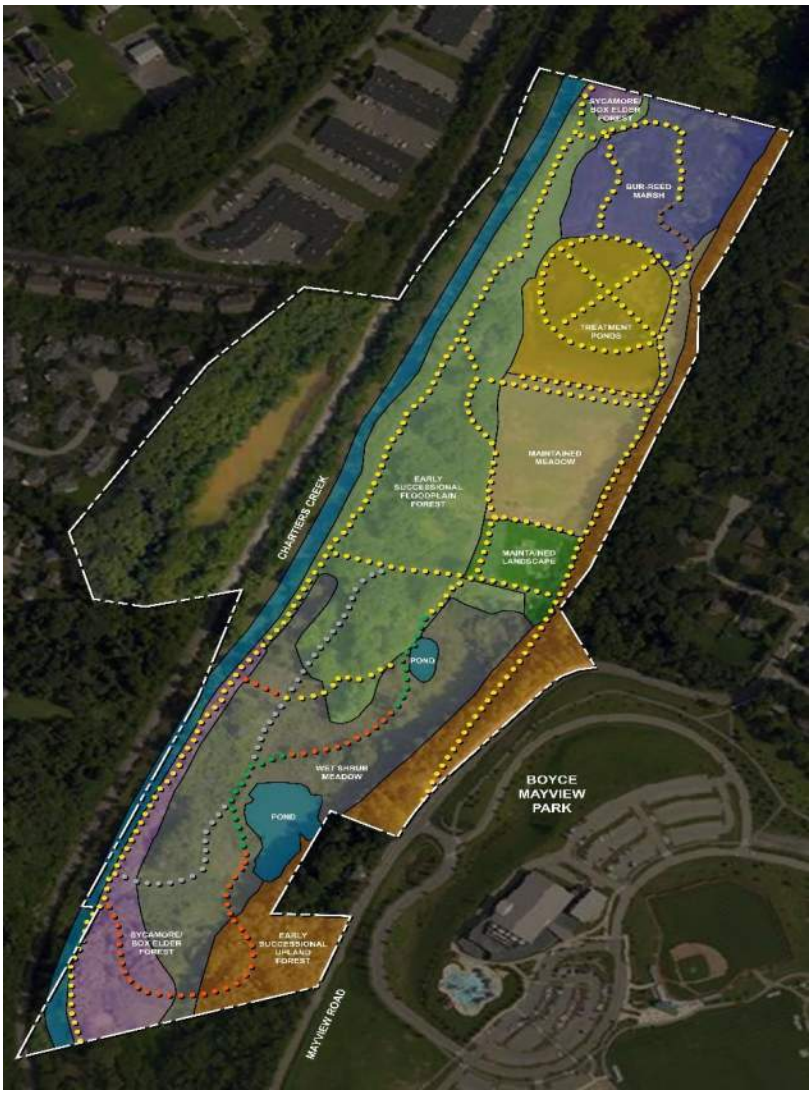
2.2 Existing Habitats

Flowering Dogwood

There is a long history of human activity on Wingfield Pines property. For the purposes of this section, the overall habitat at Wingfield Pines is best discussed as being broadly divided into the created and maintained habitats associated with the AMD treatment at the northern end of the property and the less recently disturbed, natural successional habitats at the southern end of the property.

Constructed wetlands occupy approximately 10 acres at the northern end of Wingfield Pines. These wetlands receive and treat 1,500 to 2,000 gallons per minute of AMD water from the former Montour Mine. These wetlands, including their plant communities, serve a specific purpose in the treatment process.

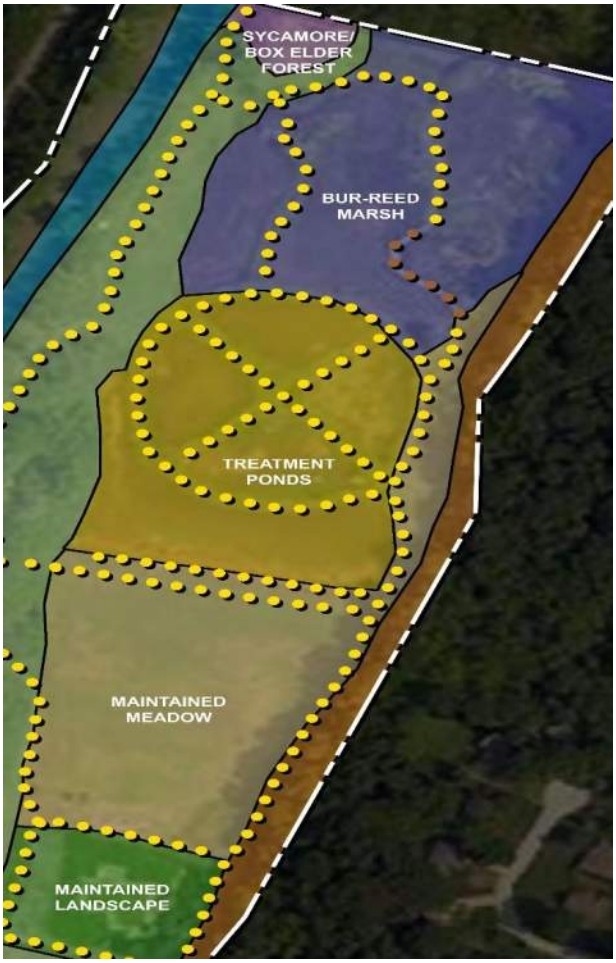
The approximately 70 acres south of the treatment wetlands, excluding the former swimming pool area, have been gradually reverting to a more natural state since 1997. Before 1997, grading activities associated with agricultural and mining activities, and more recently construction and maintenance of a golf course, have left relics such as ponds, mounds, sand traps, large old trees, and a long levee adjacent to much of Chartiers Creek. Today, this area represents a complex of mixed river floodplain, basin wetland, and vernal pool ecological communities along with a narrow band of early successional forest along the former high wall and steep slopes on the eastern edge of the property. Within this broader community complex, CEC studied landforms and plant communities to identify sub-habitats that are more specific. Standard references, such as *Terrestrial and Palustrine Plant Communities of Pennsylvania*[2], are intended to define natural plant communities and are of limited use when describing anthropogenic and abandoned landscapes or very early successional communities such as those at Wingfield Pines. Consequently, CEC has defined and mapped nine management sub-habitats, which are somewhat unique to Wingfield Pines



[2]*Terrestrial and Palustrine Plant Communities of Pennsylvania*, Second Edition. Zimmerman, E., T. Davis, G. Podniesinski, M. Furedi, J. McPherson, S. Seymour, B. Eichelberger, N. Dewar, J. Wagner, and J. Fike (editors). 2012. Pennsylvania Natural Heritage Program, Pennsylvania Department of Conservation and Natural Resources, Harrisburg, Pennsylvania.

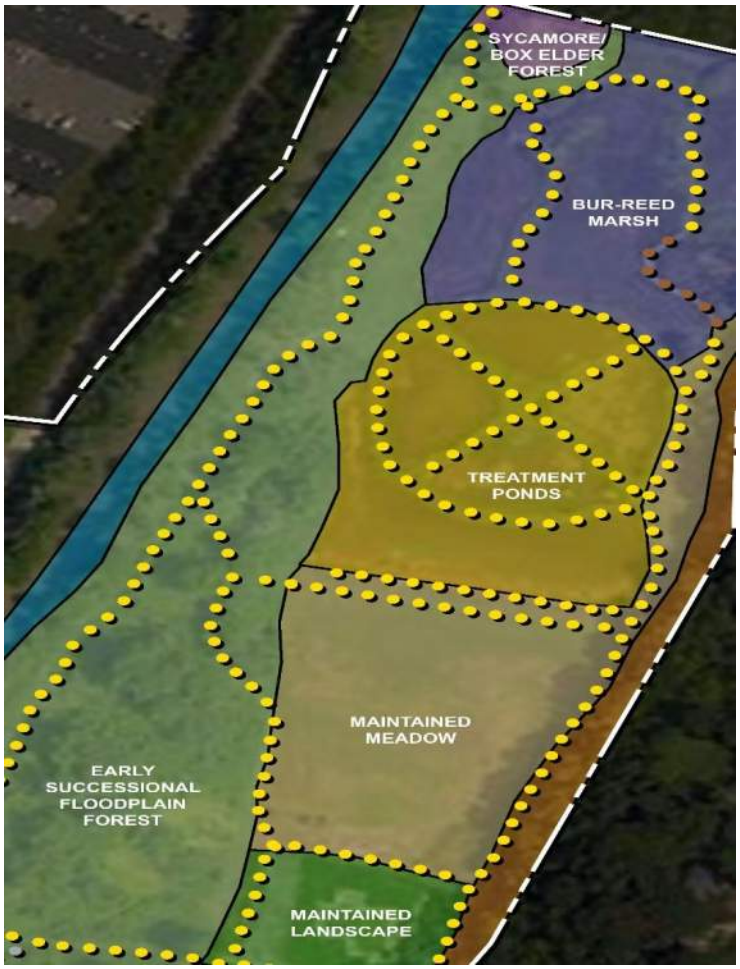
2.2.1 Treatment Ponds

These five constructed ponds were designed to treat AMD discharge. Maintenance and routine access dictated by the needs of the treatment process preclude managing these areas as natural plant communities.



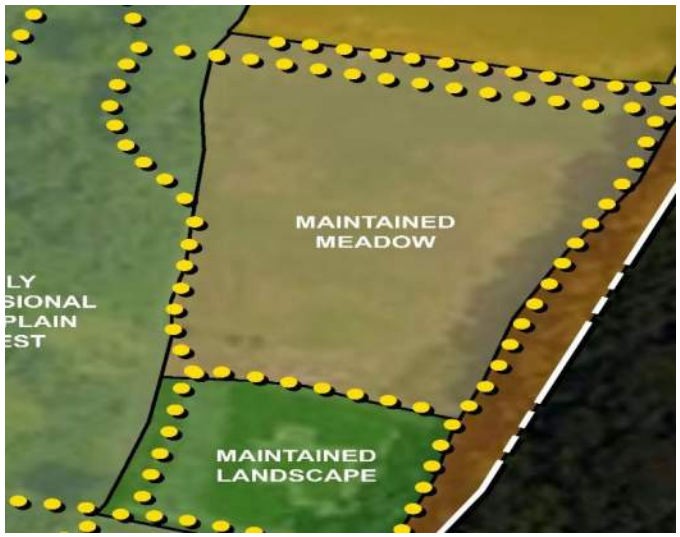
2.2.2 Bur-reed Marsh

The bur-reed marsh is a permanently flooded constructed wetland (AMD finishing wetland) dominated by bur-reed (*Sparganium eurycarpum*). It receives outflows from the Treatment Ponds and discharges to Chartiers Creek. This approximately four-acre marsh is the probable prime habitat for the majority of uncommon wetland bird species identified at Wingfield Pines. It appears to be stable and providing quality habitat with a very low density of cattails (*Typha species*). Which when over dominant, can displace other wetland species and reduce diversity.



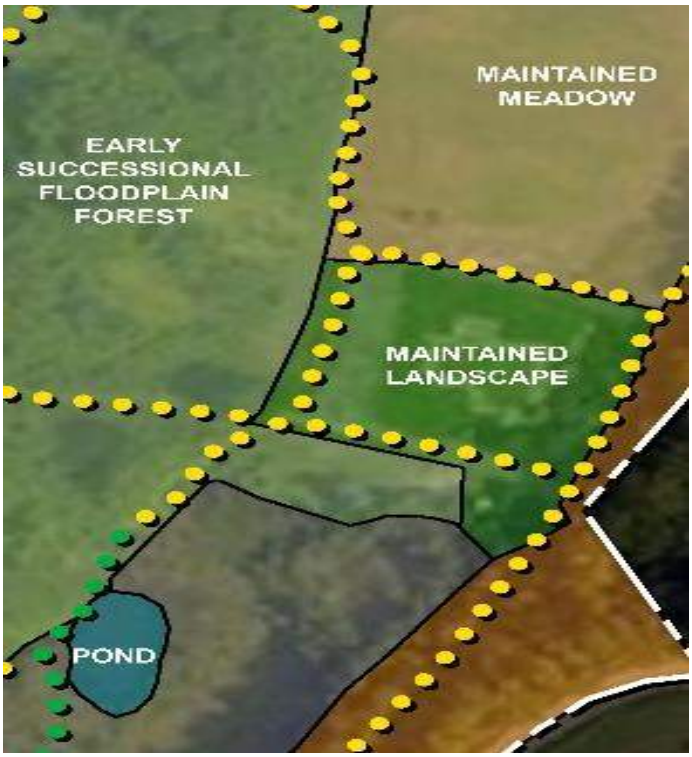
2.2.3 Maintained Meadow

An approximately four-acre area in the central portion of Wingfield Pines is referred to as the meadow. This habitat is an open, low-diversity herbaceous meadow dominated by reed canarygrass (*Phalaris arundinacea*) maintained by annual mowing. Native soils were strip-mined. Topography suggests this area is occasionally flooded with surface water rarely being present. The only trails present include those that direct visitors around this largely unused area. The meadow's small size and lack of natural features limits its availability to support a unique plant and animal community.



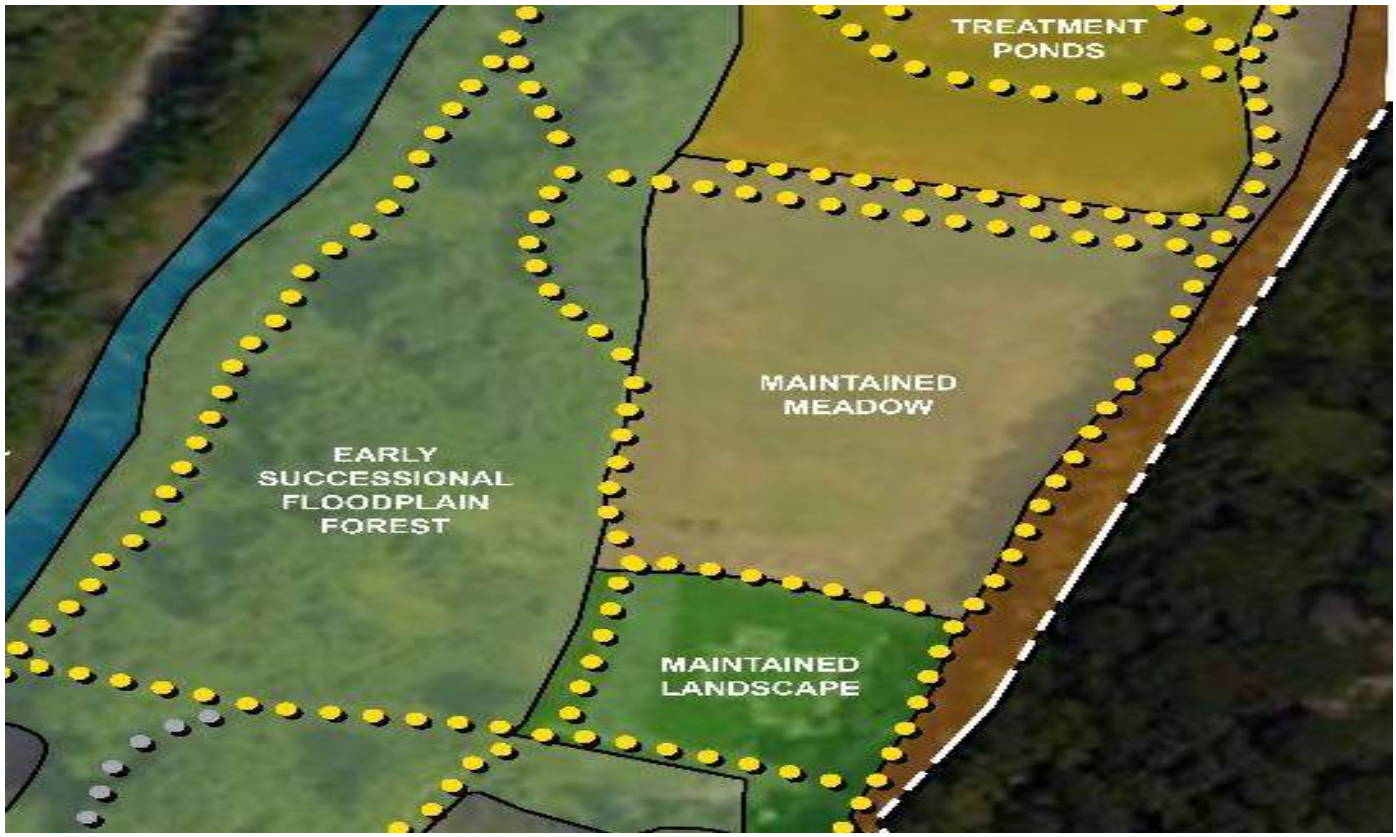
2.2.4 Maintained Landscape

This small, maintained area is not a natural plant community but a centrally located support area for visitors, site access, and a small maintenance building.



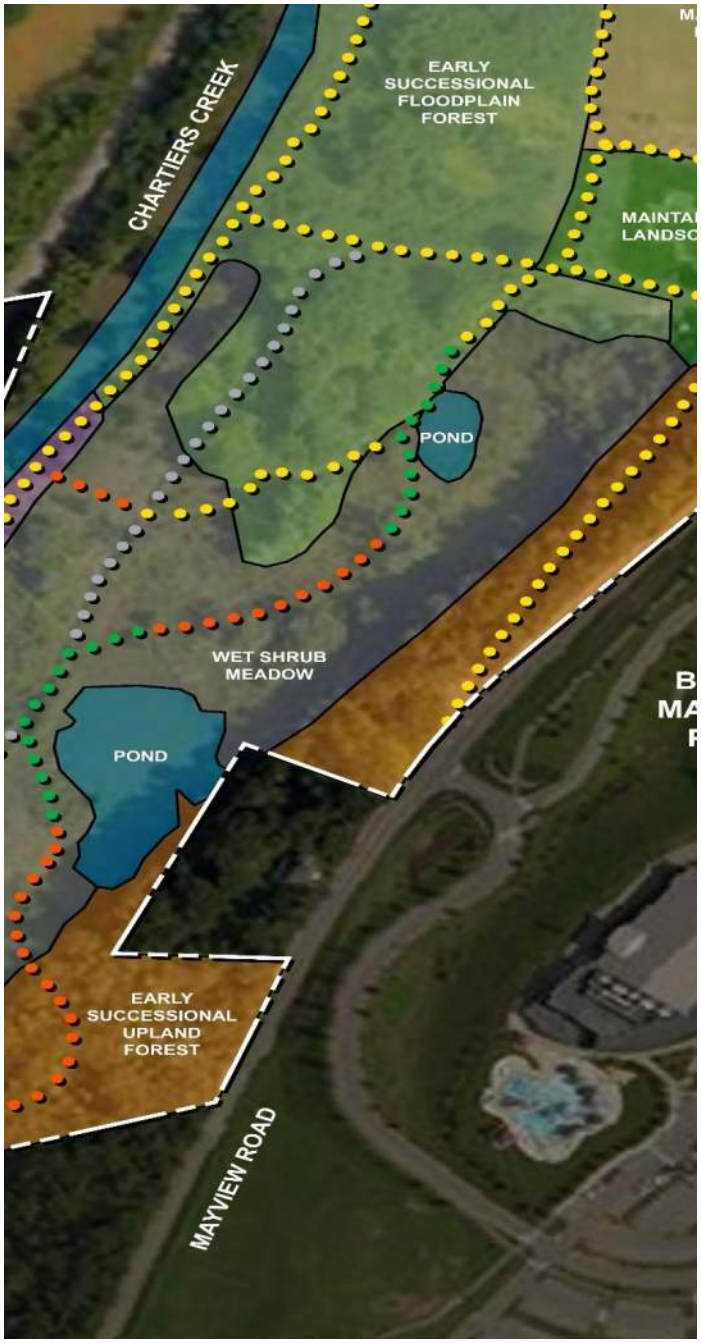
2.2.5 Early Successional Floodplain Forest

Portions of the Chartiers Creek floodplain that average four to eight feet higher than surrounding areas are infrequently flooded and rarely exhibit surface water. This habitat includes many mature sycamores (*Platanus occidentalis*) along Chartiers Creek, mature white pines (*Pinus strobus*), and various early successional woody plant species, including invasive species such as abundant Callery pear (*Pyrus calleryana*). Soils are strip mined. Common early successional upland and facultative wetland herbaceous plant species, including invasive species, are wingstem (*Verbesina alternifolia*), cultivated grasses, goldenrods (*Solidago* spp.), invasive crownvetch (*Coronilla varia*), and other common meadow species.



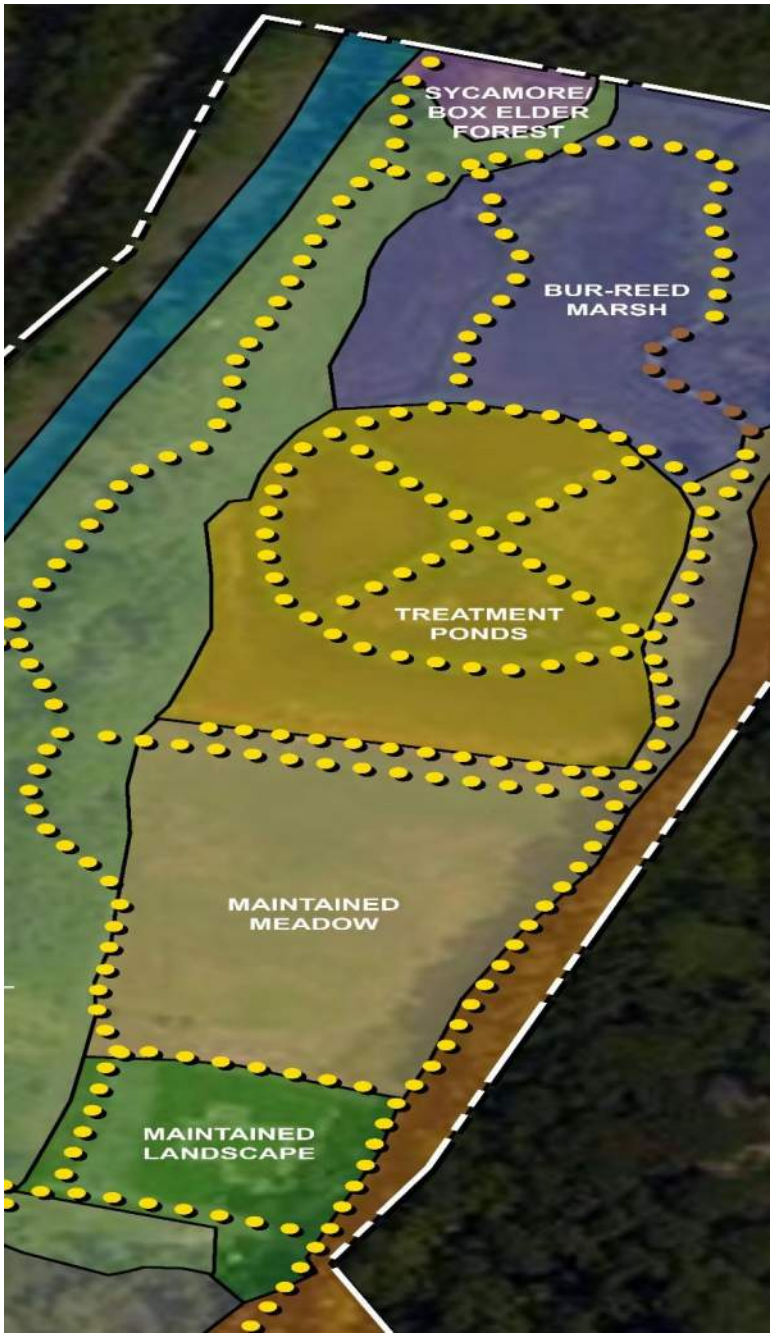
2.2.6 Wet Shrub Meadow

This broadly defined habitat contains the two former golf course ponds, several seasonal (vernal) to semi-permanent un-vegetated ponds, two reed canarygrass marshes, and one small cattail marsh. These diverse microhabitats are embedded within an approximately 12-acre, early successional wet shrub meadow developing on presumably amended strip-mined soils from the former golf course. The overall habitat is temporarily to seasonally flooded with typically saturated soils during the growing season. Trails within this habitat must be able to withstand inundation and sediment accumulation. Open meadow areas are succumbing to colonization by red maple (*Acer rubrum*), silver maple (*A. saccharinum*), boxelder (*A. negundo*), willows (*Salix* spp.), sycamores, American elm (*Ulmus americana*), and abundant and invasive Callery pear. Reed canarygrass dominates the herbaceous community.



2.2.7 Sycamore/Boxelder Forest

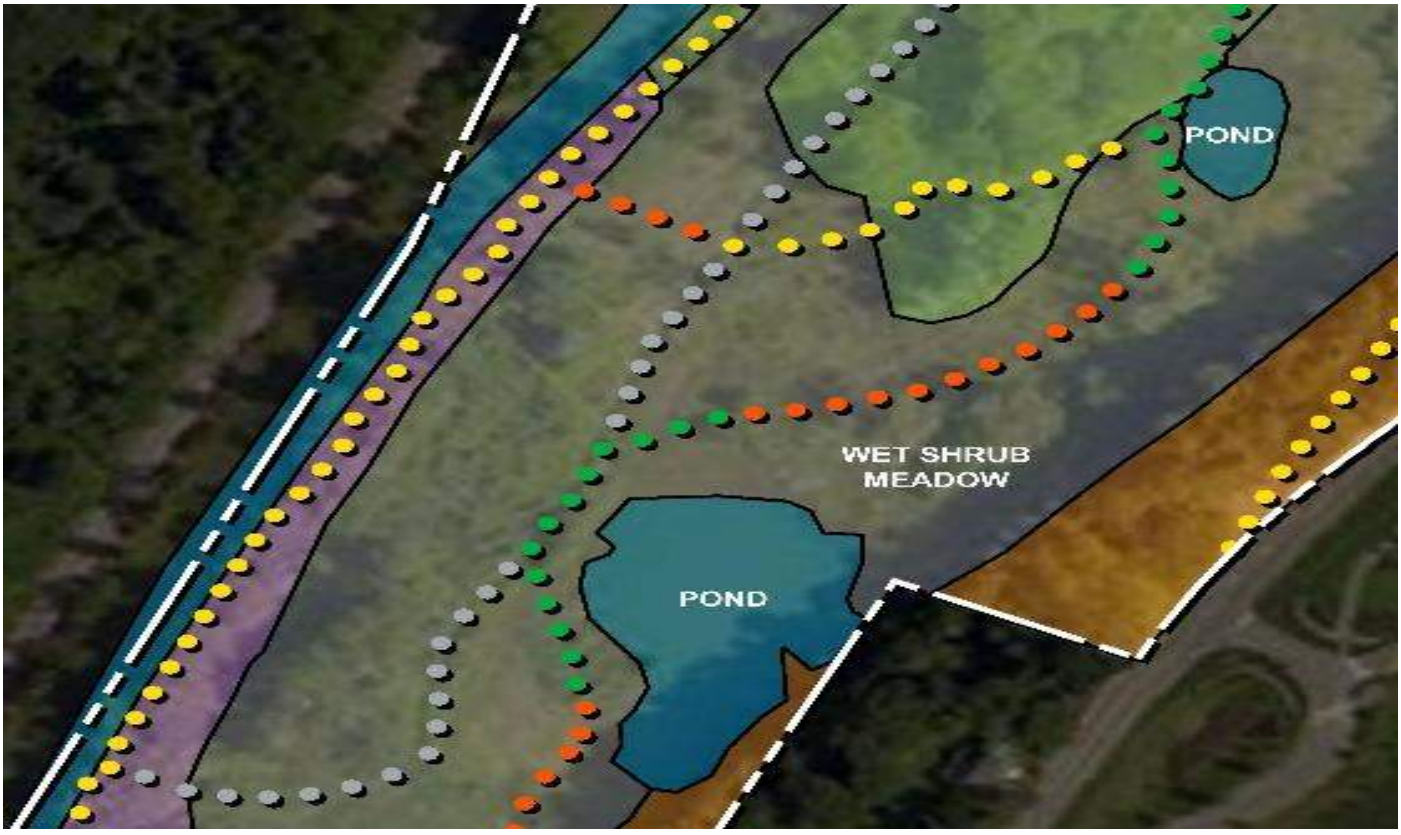
This plant community, dominated by sycamore and boxelder, exists along Charters Creek on the western side and southern end of the property on Lindside Silt Loam and the constructed levee. It is best exemplified at the southern end where it extends the width of the floodplain, and it has been less altered by human activity. Mature sycamores, some estimated to be over 100 years old, are present at the southern end of the property, along the upper banks of Chartiers Creek, and at the northeastern property boundary approaching Lynch Ponds. These areas are subjected to temporary flooding of Chartiers Creek and withstand high water flows that deposit debris and damage herbaceous and young woody vegetation. Trails within this habitat must be able to withstand flowing water, inundation, and sediment accumulation, and the only observed trail in the area runs along the top of the levee along Chartiers Creek and extends offsite.



2.2.8 Ponds

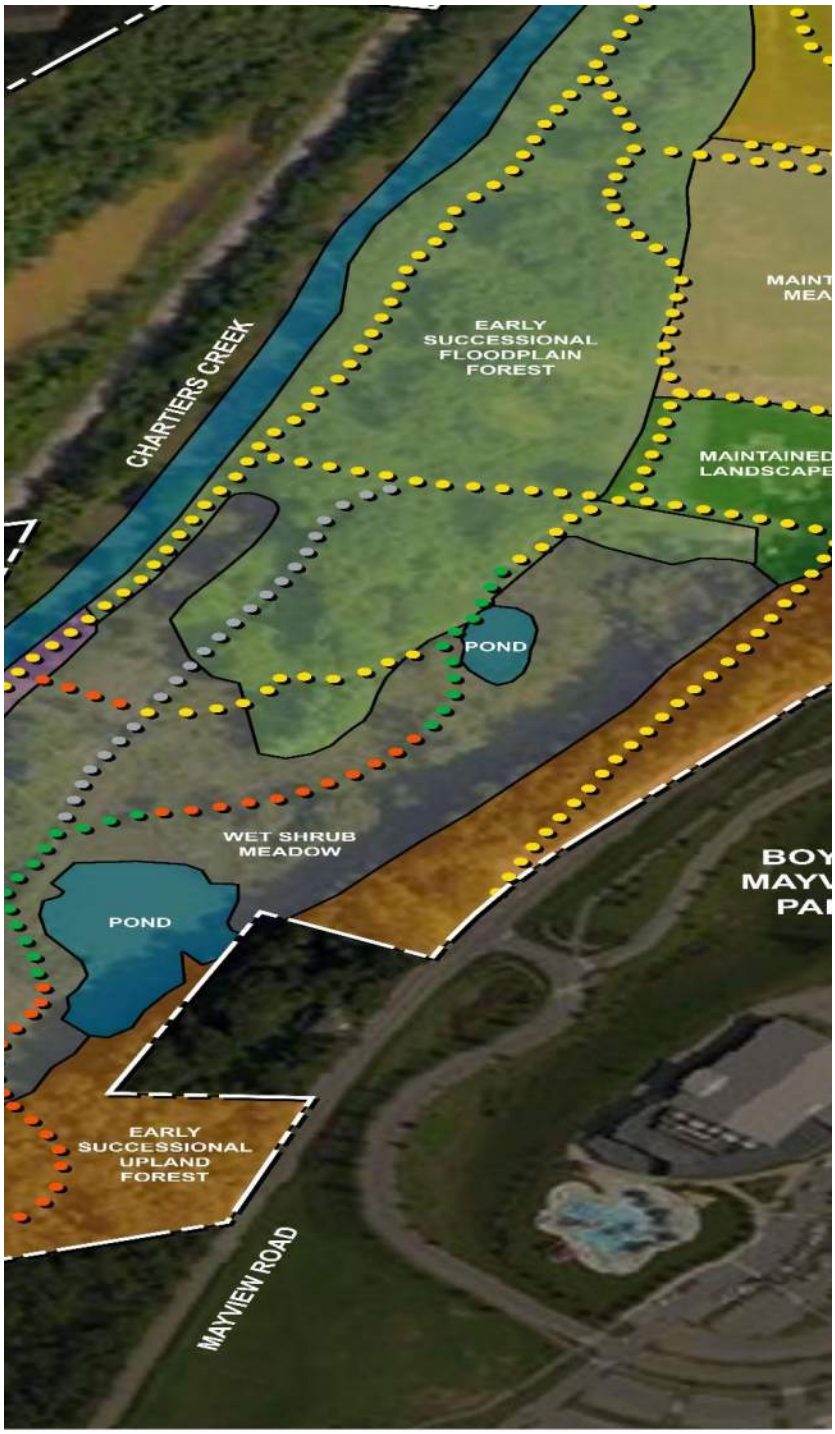
Two relic golf course ponds remain at Wingfield Pines. A third pond, south of the existing maintenance building, occasionally appears on older maps, but sedimentation has reduced the size and depth of this area such as it is perhaps better categorized as an un-vegetated seasonal pool.

The northern pond has a surface area of approximately 0.25 acre, and the southern pond surface area is approximately 1.25 acres, though both ponds' water levels and sizes are dependent on rainfall and inundation of the encompassing Wet Shrub Meadow habitat. Both ponds appear to have been originally excavated with steep sides, unknown depths, and no littoral zones. They appeared somewhat eutrophic during summer 2018. Reports indicate both ponds are overpopulated with an abundance of stunted bluegill (*Lepomis macrochirus*).



2.2.9 Early Successional Upland Forest

This forest on moderately steep to steep slopes extends along Mayview Road the length of Wingfield Pines, from the high wall at the northern end of the property to the less-disturbed slopes at the southern end. Central and southern portions are on Gilpin, Weikert, Culleoka channery silt loams and Dormont silt loam. These soils tend to be rich, especially Dormont silt loam, and are capable of supporting diverse plant communities. Very steep slopes, greater than 25 percent, have limited previous human disturbances, and the area is largely unused. The access road to Mayview Road traverses this habitat, but there are no official trails currently exploring this habitat.



2.3 Existing Conditions and Uses

Wingfield Pines is a popular community amenity that provides a unique natural refuge in a metropolitan environment. The site is a natural floodplain along Chartiers Creek and framed by forested hillsides that amplify the natural beauty and tranquil isolation of the site. Visitors can explore this natural oasis via a nearly three-mile network of trails winding through each of the nine unique habitats within the site, including a popular boardwalk through a bur-reed marsh. This trail system is relatively flat and highly walkable and includes a variety of experiences.

Many visitors to the adjacent Boyce Mayview Park, which provides many active recreational and athletic opportunities, walk or drive across Mayview Road to enjoy the passive recreational and educational aspects of Wingfield Pines.

2.3.1 Existing Infrastructure and Constraints

The earliest known use of the current Wingfield Pines site was as agricultural land. A natural abundance of coal led to significant surface and underground mining at Wingfield Pines throughout the 1940s. After mining activities ceased, the site was left unused for several years. In the late 1960s, the site was acquired by a private company that restored the site to create the Wingfield Pines Golf and Swim Club, which operated from 1968 to 1983. By 1997, the entire site was essentially abandoned and ecological successional processes began, but untreated AMD from the previous underground mining operations continued to flow directly into Chartiers Creek.

Remnants of these past uses, particularly the golf and swim club, are evident at Wingfield Pines, including remnants of the original parking lot, swimming pool, and sidewalks, as well as two ponds constructed for the golf course.

Since acquiring the site, ALT has made both minor changes—adding a utility shed and constructing a trail network—and major changes, such as constructing the 10-acre passive AMD treatment system on the northern end of the site. Funded through a $650,000 grant from the Pennsylvania Department of Environmental Protection and completed in 2009, the treatment system directs mine drainage through a series of wedge-shaped ponds and two wetlands to precipitate and capture iron oxide from the AMD before they reach Chartiers Creek. Prior to construction of the system, 43 tons of iron oxide sediment were entering Chartiers Creek each year.

The dominant feature of Wingfield Pines, however, is not its industrial and commercial past, but its geomorphic position in the landscape: Wingfield Pines is located almost entirely within the 100-year floodplain of Chartiers Creek. This reality affects everything that occurs at Wingfield Pines, from the ecological habitats that develop and the recreational and educational uses it can support. Only a small relatively level useable area within the Maintained Landscape Habitat is above the defined 100-year floodplain. (While the limited Early Successional Upland Forest are also above the floodplain, this area is excessively steep).

Being a floodplain, Wingfield Pines experiences frequent flooding and many areas remain saturated or underwater throughout the year. This affects both current uses and potential enhancements to the site. Trails are affected by ongoing sediment deposition or erosion during flooding. Municipal zoning and floodplain development regulations limit placement of structures to areas outside or above the 100-year flood elevation.

Existing Trail System

Wingfield Pines contains a well-developed network of trails that guide visitors through the AMD treatment ponds and wetlands at the northern end of the property and most of the larger, but less-visited areas, at the southern end of the property. It also provides access to Chartiers Creek and unofficial connections to Boyce Mayview Park to the south and Lynch Ponds to the north. Trail width and maintenance vary based on level of use, the surrounding habitat and environmental conditions, and maintenance requirements. Most trails are subjected to periodic flooding and, at the southern end of the property and the AMD outflow to Chartiers Creek, potentially destructive water flows. Significant portions of the major north-south trail at Wingfield Pines run atop the levee constructed along Chartiers Creek. The treatment wetland trail is partially an elevated wooden boardwalk.

2.3.3 Existing Uses and Users

Wingfield Pines attracts visitors throughout the year. While these visitors rarely use the site for just a single purpose, there are several key user groups.

Anglers

Chartiers Creek is a warmwater fishery noted for small and largemouth bass fishing. Wingfield Pines provides convenient access to the creek.

Birdwatchers

The extensive wetlands at Wingfield Pines attract an unusual diversity of birds, both migrant and resident species. These birds, in turn, have attracted large numbers of birdwatchers and Wingfield Pines is rightly known as a birdwatching destination. The existing trail network provides excellent access for birdwatching, and the recent restrictions on dog walking have improved the experience for dedicated birdwatchers.

Canoers and kayakers

A small number of canoers and kayakers use the Wingfield Pines Landing water access point to put in or take out during seasonal high flows on Chartiers Creek.

Dog Walkers

Dog-friendly trails attract many dog walkers and their dogs. Substantial portions of the existing trail network are open to dogs, both on and off leash, and direct access to Chartiers Creek allows dog walkers and their dogs to access the stream.

Photographers

The beauty and diversity of Wingfield Pines and its natural inhabitants makes it a popular destination for local nature and wildlife photographers.

Researchers

Staff, professors, and research students with the Western Pennsylvania Conservancy, Duquesne University, Point Park University, and others are currently collecting ecological data at Wingfield Pines and maintain active research plots.

Students

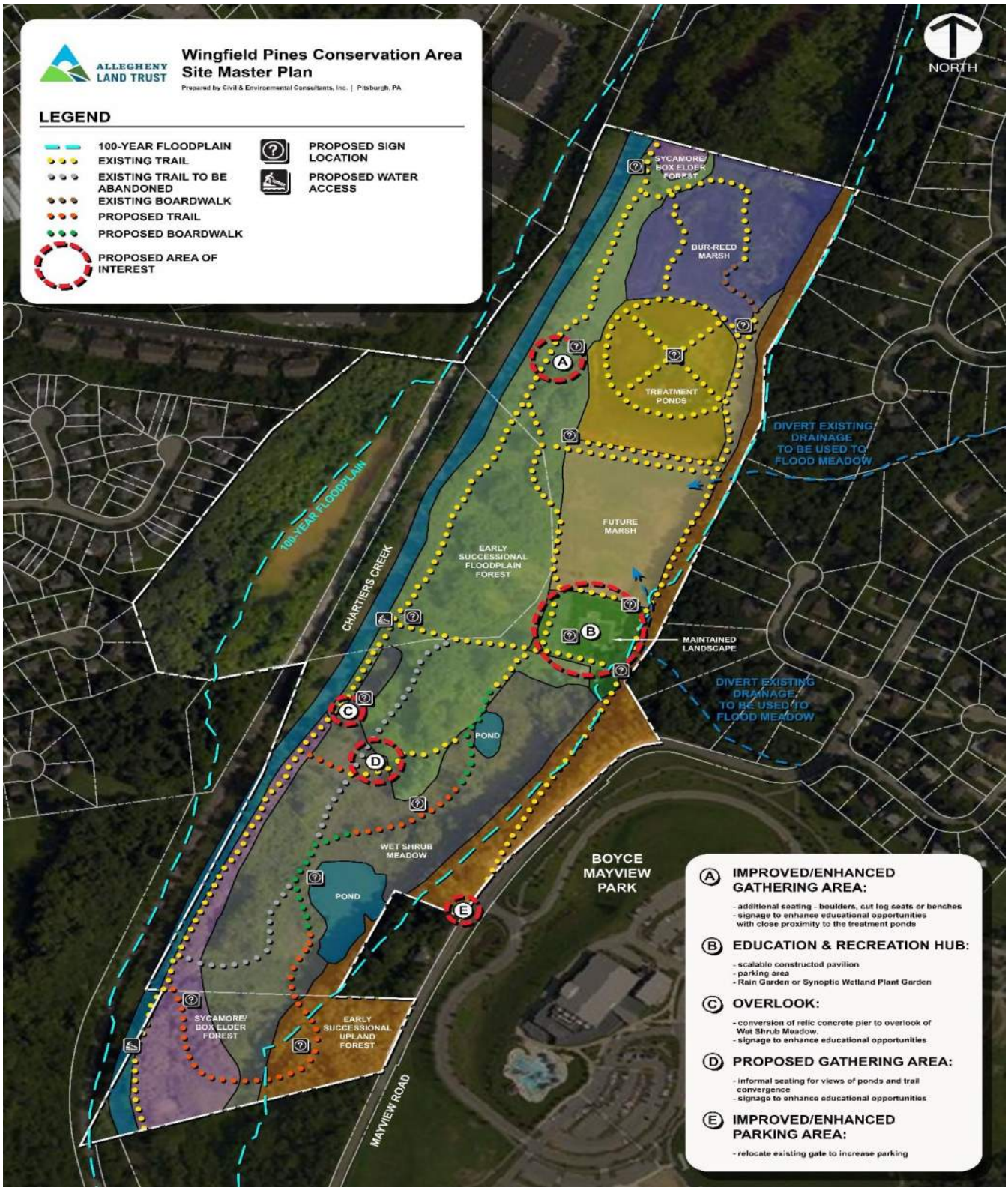
ALT and local school districts, particularly Mt. Lebanon, currently use Wingfield Pines for children's educational activities typically in spring. Student visit durations are limited by policies requiring shelter and toilet facilities.

Walkers

Wingfield Pines is scenically beautiful and users experience a feeling of isolation from the surrounding suburban neighborhoods. Direct access to Chartiers Creek creates a general opportunity for users to access the stream to observe aquatic life or enjoy the sound of flowing water. The existing trail network is easy to walk and provides walkers with many options for creating an experience tailored to their abilities and stamina. This makes Wingfield Pines a popular destination for walkers.

3.0 Conservation Management and Stewardship Master Plan

The proposed master plan for Wingfield Pines addresses three key areas: habitat management and improvements, trail system improvements, and educational and recreational improvements.



3.1 Habitat Management and Improvement

The first step in implementing a management action plan is to assess the existing habitats and determine their alignment with organizational goals and overall sustainability within those goals. Of the nine habitats CEC identified, eight are appropriate and sustainable within—or functionally required by—ALT's goals for Wingfield Pines. See Appendix B: Maintenance Calendar.

American Lotus

3.1.1 Treatment Ponds

Management strategies and improvements that support water treatment is the primary goal for this habitat.

- Maintain trails according to the Trail/Trail Shoulder Mowing Scheme to minimize habitat impacts.
- Investigate the potential use of American lotus *(Nelumbo lutea)* and fragrant waterlily *(Nymphaea odorata)* to control algae growth without reducing water flow rates in ponds 3, 4, and 5. These native species grow in deeper water habitats and their foliage is on or elevated above the water surface to minimize disturbance to the designed water flows through these ponds, while providing shade to reduce algae growth
- Institute an ongoing annual trapping program to control the muskrat (*Ondatra zibethicus*) population and limit damage to dams and levees.
- Investigate the feasibility of introducing American mink *(Neovison vison)* to Wingfield Pines to control the muskrat population.
- Continue to limit dog access and off-trail visitor access to protect sensitive habitat and limit disturbance to special-concern bird species in this habitat.
- If compatible with water treatment requirements, place submerged structures, such as logs, boulders, and floating or anchored trees within ponds 3, 4, and 5 to serve as basking locations for numerous frogs and turtles currently present in these ponds.

3.1.2 Bur-reed Marsh

Management practices in this habitat should focus on maintaining the existing trails/boardwalk, continuing to restrict dog access, and reducing the presence of invasive plant species.

- Maintain trails according to the Trail/Trail Shoulder Mowing Scheme to minimize habitat impacts.
- Continue to limit dog access and off-trail visitor access to protect sensitive habitat and limit disturbance to special-concern bird species in this habitat.
- Remove existing bat box and relocate to edge of Early Successional Floodplain Forest to improve chance of occupancy.
- Conduct invasive plant surveys in June and September to identify targeted invasive plant species populations in this habitat and promptly begin control actions. Targeted species to include: flowering rush, purple loosestrife, and reed canarygrass. See Appendix C: Invasive Plant Management.

3.1.3 Maintained Meadow

The Maintained Meadow is largely unused by visitors, and its ecological value appears to be low. CEC recommends reevaluating the purpose and benefits of maintaining this area as a meadow. Currently, its greatest value may be aesthetic rather than ecological.

Wingfield Pines is almost synonymous with wetlands. Its geomorphic position in an increasingly urbanized landscape makes it increasingly valuable for those plant and animal species for whom it has become a refuge. ALT can further increase that value by converting the Maintained Meadow into a Future Marsh to provide additional wetland habitat.

A diverse wetland plant community

CEC recommends that ALT investigate the options for redirecting water from two ephemeral channels entering Wingfield Pines from the east near the northern and southern limits of the current meadow. Flow from the northern channel is currently directed northward toward the Bur-reed Marsh. Flow from the southern channel is directed into a culvert that drains directly into Chartiers Creek. These sources could provide sufficient hydrology to sustain this area as a wetland if a berm is constructed in the southwest corner of the current Maintained Meadow to create a shallow impoundment.

Converting the Maintained Meadow into wetland could provide an additional four acres of diverse wetland habitat that would expand existing habitat and potentially create greater habitat diversity without the restrictions imposed by water treatment concerns. An appropriate design could create habitats designed to attract targeted plant and animal species, including select Pennsylvania Rare and Threatened plant species. Dog access in the future wetland should be restricted.

3.1.4 Maintained Landscape

Most of the educational and recreational infrastructure improvements included in the Wingfield Pines Master Plan are proposed for the current Maintained Landscape area. Any turf within the Maintained Landscape should be maintained using the rough-cut turf mowing practice, and any future landscaping should include only plant species native to southwestern Pennsylvania.

3.1.5 Early Successional Floodplain Forest

Maintenance activities within this evolving habitat are directed at encouraging the ongoing natural plant succession and improving animal habitat.

Management activities:

- Maintain trails according to the Trail/Trail Shoulder and Modified Trail/Trail Shoulder Mowing Schemes to minimize habitat impacts.
- Maintain gathering points using rough-cut lawn to maintain current functions.
- Place large slab boulders in sunnier areas to provide cover and basking areas for native snake species.
- Maintain fine gravel and sand areas along trails near the wetlands to serve as turtle nesting sites.
- Erect bat box from Bur-reed Marsh habitat here to increase chance of occupancy.
- Inspect bat boxes annually. Relocate/reorient boxes if unused during previous year to increase chance of occupancy.
- Erect and maintain eastern bluebird nesting boxes in open areas.
- Initiate invasive plant surveys in May and September to identify targeted invasive plant species populations in this habitat and promptly begin control actions. Targeted species to include: Callery pear, autumn olive, common buckthorn, Japanese honeysuckle, Amur honeysuckle, Morrow's honeysuckle, multiflora rose, Canada thistle, and poison hemlock. See Appendix C: Invasive Plant Management.

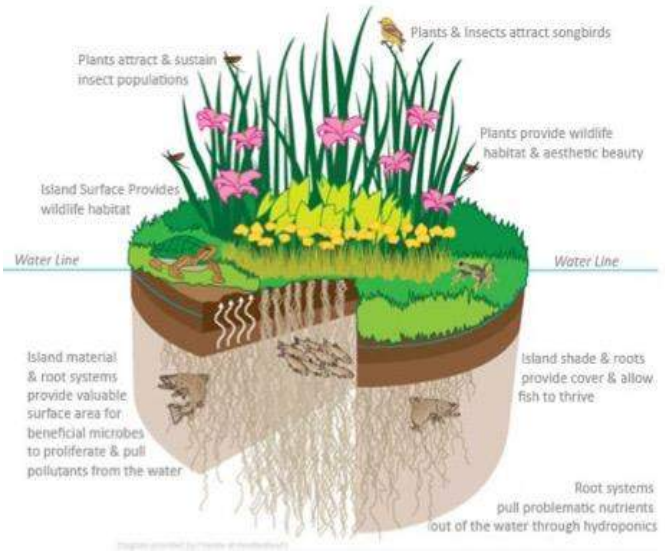
Bat box

3.1.6 Wet Shrub Meadow

As with the Early Successional Floodplain Forest, maintenance activities in the Wet Shrub Meadow are directed toward fostering the natural succession process and improving wildlife habitat. The control of invasive plant species within this habitat must become a priority as their densities and spread are beginning to affect the natural succession process.

Management activities:

- Maintain trails according to the Trail/Trail Shoulder and Modified Trail/Trail Shoulder Mowing Schemes to minimize habitat impacts, as flooding permits.
- Inspect bat boxes annually. Relocate/reorient boxes if unused during previous year to increase chance of occupancy.
- Erect and maintain eastern bluebird nesting boxes in open areas.
- Initiate plant surveys in May, June, and September to identify targeted invasive plant species populations in this habitat and promptly begin control actions. Targeted species to include: Amur maple, Callery pear, flowering rush, poison hemlock, purple loosestrife, and Japanese stiltgrass. See Appendix C: Invasive Plant Management.



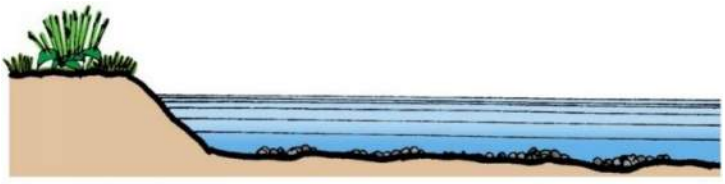
Floating Wetland Courtesy of Floating Island International, Inc.

3.1.7 Sycamore/Boxelder Forest

The Sycamore/Boxelder Forest is one of the more mature habitats at Wingfield Pines. The main management objective is to preserve its integrity by controlling threats. In this habitat, those threats are floodwaters and invasive plant species.

Management activities:

- Maintain trails according to the Forested Trail Maintenance Scheme to minimize habitat impacts.
- Inspect trails after each flooding event to identify any flood damage for repair and to remove debris deposited by floodwaters.
- Initiate invasive plant surveys in April, May, June, and September to identify targeted invasive plant species populations in this habitat and promptly begin control actions. Targeted species to include: Callery pear, Amur honeysuckle, Japanese knotweed, Japanese stiltgrass, and lesser celandine. See Appendix C: Invasive Plant Management.



3.1.8 Ponds

The two former golf course ponds were presumably excavated. They are steep sided with little to no littoral zones. Their location within the broad, flat former golf course area causes routine inundation of substantial nearby areas when water levels rise. Improving wildlife habitat is the focus of management and improvement.

Management activities:

- Maintain trails according to the Trail/Trail Shoulder and Modified Trail/Trail Shoulder Mowing Schemes to minimize habitat impacts.
- Place submerged structures, such as logs, boulders, and floating or anchored trees within each pond to serve as basking locations for frogs and turtles. With careful placement, these structures could also provide a reliable connection between the aquatic and nearby terrestrial habitats.
- Conduct electrofishing surveys of the ponds to assess the fish community. Use the results to consult with the Pennsylvania Fish and Boat Commission on possible stocking options to introduce predator species with the goal of establishing a balanced fish community.
- Plant fragrant waterlily, spatterdock *(Nuphar lutea)*, water shield *(Brasenia schreberi)*, and various floating pondweeds *(Potamogeton spp.)* at appropriate water depths to control algae growth and improve habitat.
- Construct a floating wetland to reduce available sunlight and absorb dissolved plant nutrients to control algae and improve habitat. See Appendix D: Floating Wetland Information.

3.1.9 Early Successional Upland Forest

The slopes at the southern end of this community were less affected by past human activity at the site and, together with portions of the Sycamore/Boxelder Forest, represent the more mature habitat. This area represents the only true upland habitat at Wingfield Pines. Management activities are focused on preservation of the existing plant community and preventing erosion on the steep slopes.

Management activities:

- Maintain future trail according to the Forested Trail Maintenance Scheme to minimize habitat impacts.
- Conduct annual litter cleanup of debris along and downslope of Mayview Road.
- Initiate invasive plant surveys in May and September to identify targeted invasive plant species populations in this habitat and promptly begin control actions. Targeted species to include: tree of heaven, Callery pear, Japanese barberry, burning bush, wintercreeper, Amur honeysuckle, Morrow's honeysuckle, and lesser celandine. See Appendix C: Invasive Plant Management.

3.1.10 Invasive Plant Species Management

Numerous invasive plant species are present within Wingfield Pines, and restoration to an all-native ecosystem is not practicable. However, by evaluating a species' ecological threat, existing density, rate of spread, and likelihood of eradication, invasive plant target species can be identified and management strategies can be adopted. An ALT staff member or professional ecologist should be designated to implement, coordinate, and adaptively manage the plan.

A successful invasive plant management plan includes four key concepts:

- Conduct surveys for the target species: Professional ecologists and trained volunteers can identify the locations and densities of target species. Different invasive species require different survey seasons and frequencies.
- Choose a control strategy or a combination of strategies: ALT should consider cost and organizational preferences to select appropriate controls, including mechanical, cultural, and chemical methods. Proper timing of control, particularly for non-chemical methods, is essential to success. Often, missing a control window by just few days can negate years of previously effective control. Suggested control strategies are provided in Appendix C: Invasive Plant Management.
- Define areas for control: Tackling too large of an area for control is a frequent cause of failure. Good control in a smaller area will provide superior long-term results compared to poor control over a larger area, which frequently provides no lasting control. Success should be achieved in a zone before efforts are expended in additional zones. A suggested Management Zones map is provided in Appendix C: Invasive Plant Management. An ALT staff member or professional ecologist should be designated to oversee this task.
- Implement control strategy: Trained volunteers or volunteer leaders can often implement non-chemical control methods. Government regulations typically require the use of professional pesticide applicators for chemical control methods.

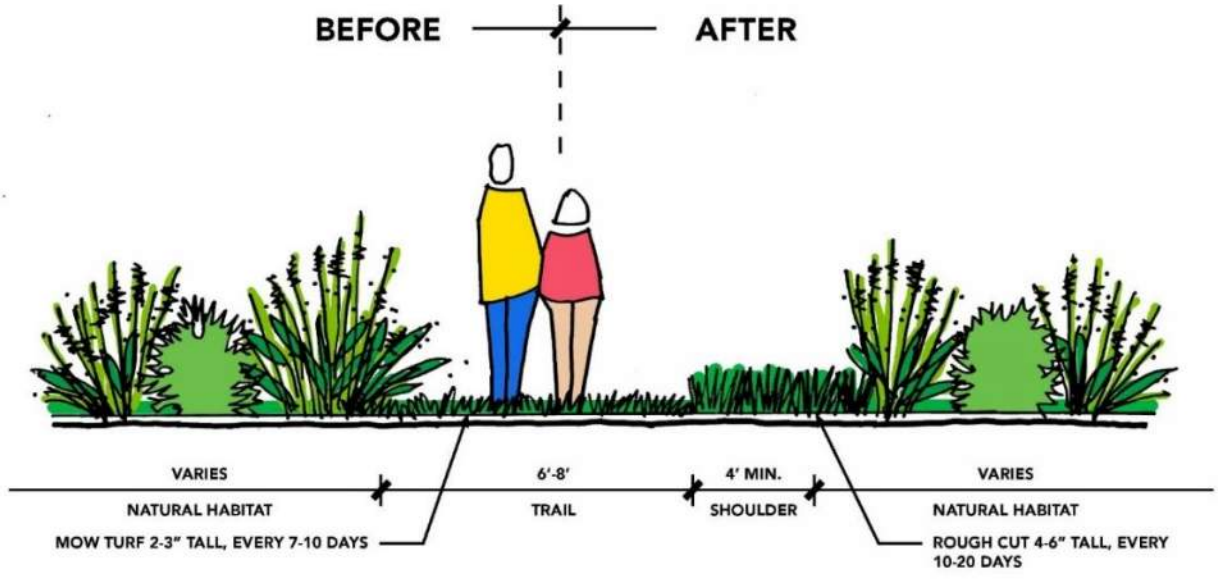
CEC identified 14 invasive plant priority species at Wingfield Pines. ALT should consider engaging a firm to develop a complete Invasive Plant Management Plan for Wingfield Pines. See Appendix C: Invasive Plant Management.

3.1.11 Trail Corridor Enhancement and Management

Ongoing trail maintenance is necessary to ensure a safe and enjoyable visitor experience. To minimize the ecological impact of the trails, they should be only as wide as necessary to facilitate safe movement. Due to different habitat requirements, three trail mowing schemes are recommended for Wingfield Pines.

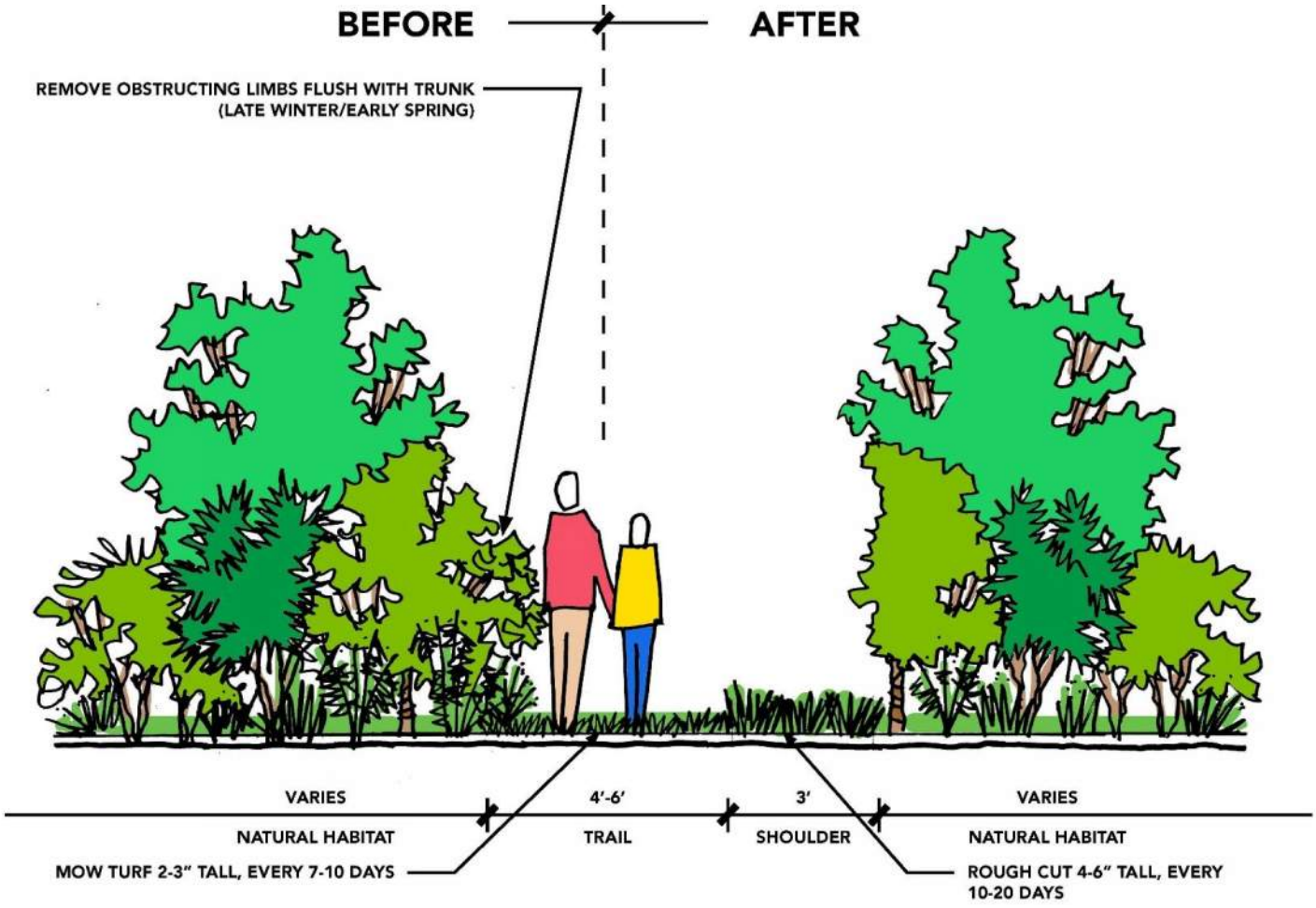
Trail/Trail Shoulder Mowing Scheme

Within the Treatment Ponds, Bur-reed Marsh, and Maintained Landscape habitats, a Trail/Trail Shoulder Mowing Scheme will permit necessary pedestrian access but will reduce the mowing footprint. Trails are mowed at a typical height of two to three inches every seven to 14 days. The trail shoulder is mowed (rough cut) at a typical height of four to six inches every 10 to 20 days. (Mowing frequencies are dictated by weather and turf height.)



Modified Trail/Trail Shoulder Mowing Scheme (successional areas)

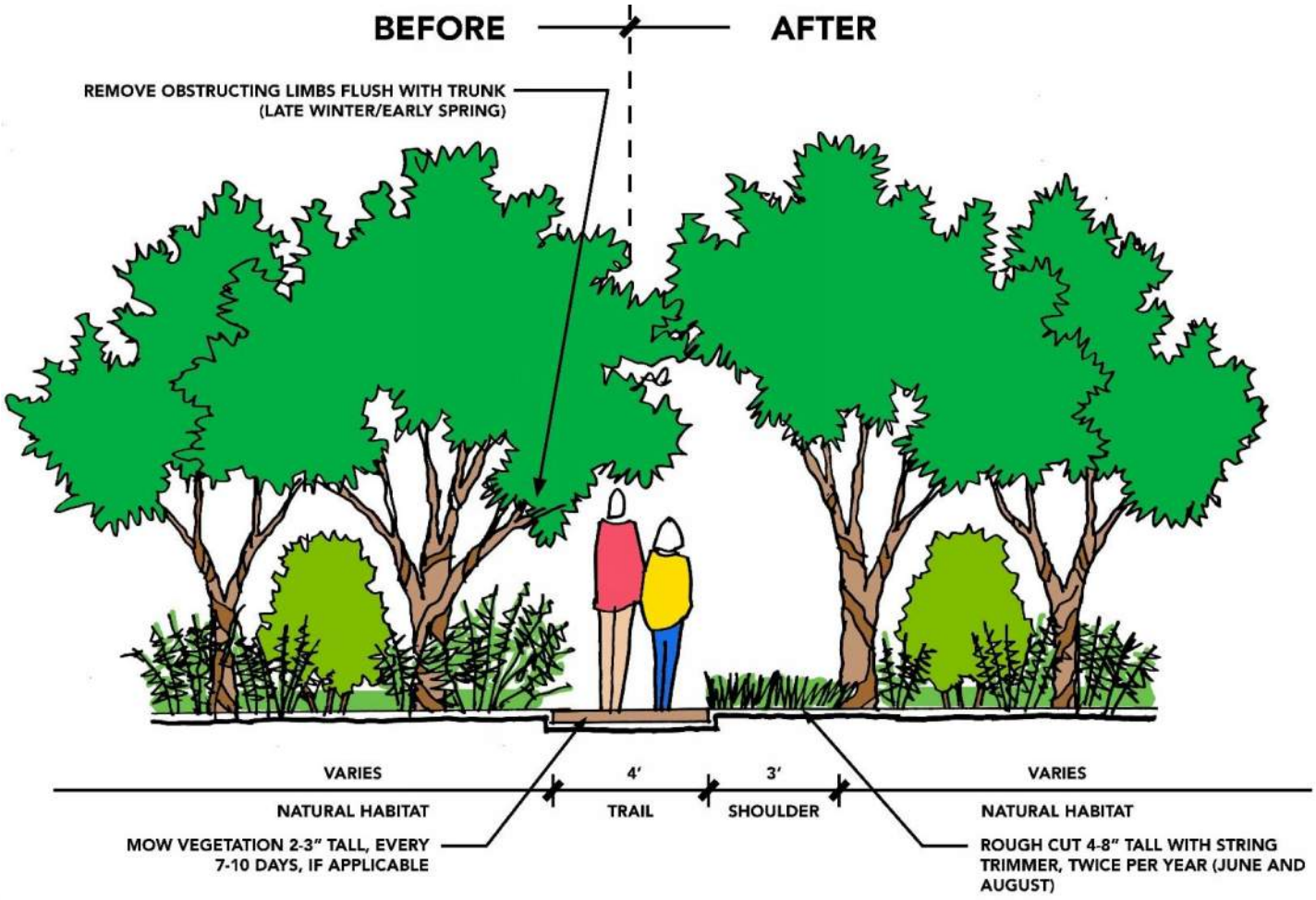
Trails within the Wet Shrub Meadow and portions of the Early Successional Floodplain Forest are maintained using a Modified Trail/Trail Shoulder Mowing Scheme with the addition of tree limb removal. The limbs of saplings obstructing the trail or trail shoulder are pruned off, flush with the tree trunk. These trees are not removed to avoid widening the trail corridor more than necessary. As these habitats mature, the tree canopy should be encouraged to close over above the trail at a safe and appropriate height above eight feet. Trails are mowed at a typical height of two to three inches every seven to 14 days. The trail shoulder is mowed (rough cut) at a typical height of four to six inches every 10 to 20 days. (Mowing frequencies are dictated by weather and turf height.) Obstructing limbs on trees outside the trail shoulder are removed annually in late winter/early spring. See Appendix C2.



Forested Trail Maintenance Scheme

DR String Trimmer Mower courtesy of Country Home Products, Inc.

The Sycamore/Boxelder Forest and portions of the Early Successional Floodplain Forest already possess partial to full tree canopies above many portions of their trails or future trails. These trails are maintained using the Forested Trails Maintenance Scheme. This scheme uses a traditional mower to mow any turfgrass on the trail as necessary and includes two seasonal mowings to prevent growth of tree seedlings and tall herbaceous weeds along the trail shoulder. A string trimmer mower, rather than a traditional lawnmower, is used for mowing the trail shoulder. This scheme can also be very effective at limiting the spread of invasives (Japanese stiltgrass, poison hemlock), if mowing times are timed appropriately. Trails are mowed at a typical height of two to three inches every seven to 14 days, if vegetation is present on the trail. (No mowing is necessary for un-vegetated trails.) The trail shoulder is mowed (rough cut) with a string trimmer mower at a typical height of four to eight inches twice each growing season (early June and August). (Mowing frequencies are dictated by weather and plant height.) Obstructing limbs on trees outside the trail shoulder are removed annually in late winter/early spring.



3.2 Trail System Improvements

3.2.1 Trail Network Maintenance

Future Overlook

Ongoing trail maintenance is necessary to ensure a safe and enjoyable experience for Wingfield Pines visitors. Portions of some trails need to withstand periodic inundation and, in a few areas, temporarily flowing water. Ongoing, routine trail maintenance includes removing debris, downed tree limbs and branches, and ensuring the trail surface is free of loose rocks. While an informal reporting system is in place, a more formal schedule of walking the trails to identify maintenance concerns would more consistently and perhaps more quickly alert ALT to trail issues. From April to October, biweekly inspection walks of the entire trail network by a volunteer or ALT staff member would identify potential concerns along any of the trails. During the remainder of the year, monthly walks would be appropriate. During these maintenance inspection walks, minor issues, such as small downed twigs and branches and debris, can often be addressed during the inspection. For more significant concerns, the *USDA Wetland Trail Design and Construction: 2007 Edition* provides numerous options for addressing trail construction and repair. See Appendix D.

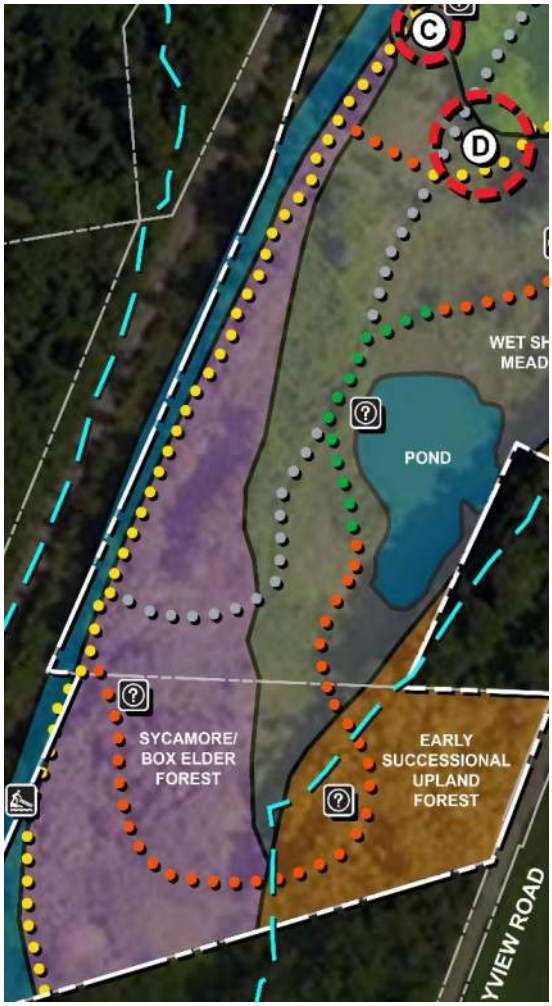
3.2.2 Trail Network Improvements

The trail network north of the Maintained Landscape is well developed and leads visitors throughout the treatment ponds and wetland. Erosion has removed the trail connection to the Lynch Ponds property to the north. The former culvert or bridge and reconstruction of the trail link should be replaced.

South of the Maintained Landscape, one dominant trail creates a narrow loop along Chartiers Creek with a parallel return. Several smaller less-distinct trails wander off or dead end, but these footpaths do not appear to be official mapped trails. Overall, trails in this area do not allow visitors to fully explore the various habitats present in the southern half of Wingfield Pines especially during periods of inundation.

The existing trail on top of the levee along Chartiers Creeks passes by distinct microhabitats within the Wet Shrub Meadow to the east, but visitors are seldom aware of it due to the understory within the Early Successional Floodplain Forest. There is an opportunity to convert an existing trailside relic pier into an observation point where visitors can look out over the adjacent Wet Shrub Meadow, or a small overlook and opening the canopy could be created to provide views into an adjacent reed canarygrass marsh.

Extending the existing levee trail beyond its current turnaround point would allow visitors to more fully explore the Sycamore/Boxelder Forest. Extending the trail southward would lead visitors beyond the levee, across a small intermittent stream, and permit a natural water-level access point with Chartiers Creek among some of the tallest sycamores at Wingfield Pines.



An eastward turn of the trail toward Mayview Road would lead visitors to the Early Successional Upland Forest, a habitat currently not included in any mapped trail. Steep slopes would limit trail expansion in this habitat and a quick westward return would be necessary to allow a meandering northward trek to the west of the two Ponds, as passing east of the Ponds is very difficult. This trail would continue northward to end in the Maintained Landscape.

Due to consistent saturation and frequent flooding in these southern areas, a raised Turnpike-style trail is suggested to improve access and use (See Appendix D). Near the Ponds, an elevated boardwalk trail, like that in the Treatment Wetland, is suggested to allow a more close-up view of the unique habitat the Ponds provide.

3.2.3 Water Access Opportunities and Improvements

Current use of Wingfield Pines Landing as a canoe and kayak launch is light (partially because of a limited high-water floating season on Chartiers Creek). Repurposing the current location as a Water Access Point expands its purpose beyond launching boats to serving as a riparian educational opportunity.

The current Landing accesses a shallow, gentle-flowing segment of Chartiers Creek that would provide a suitable location for the observation of stream life, such as fish, crayfish, and other aquatic organisms that do not reside in Wingfield Pines' extensive wetlands. Underwater viewers would provide students and adults with the opportunity to observe the underwater life of Chartiers Creek.

While steep streambanks generally limit access to Chartiers Creek outside of Wingfield Pines Landing, a natural inside meander bend in Chartiers Creek at the southern end of the property provides a natural beach-like access point within the Sycamore/Boxelder Forest.

Renaming and repurposing the current Wingfield Pines Landing to Wingfield Pines Water Access and creating a new water access point in the Sycamore/Boxelder Forest would facilitate stream access and create new educational opportunities for ALT and Wingfield Pines visitors.

3.3 Education and Recreation Improvements

This Conservation Management and Stewardship Master Plan is the result of a strategic goal to create and implement property management plans and create policies of enhancing visitor experiences, educational opportunities, and volunteer engagement.

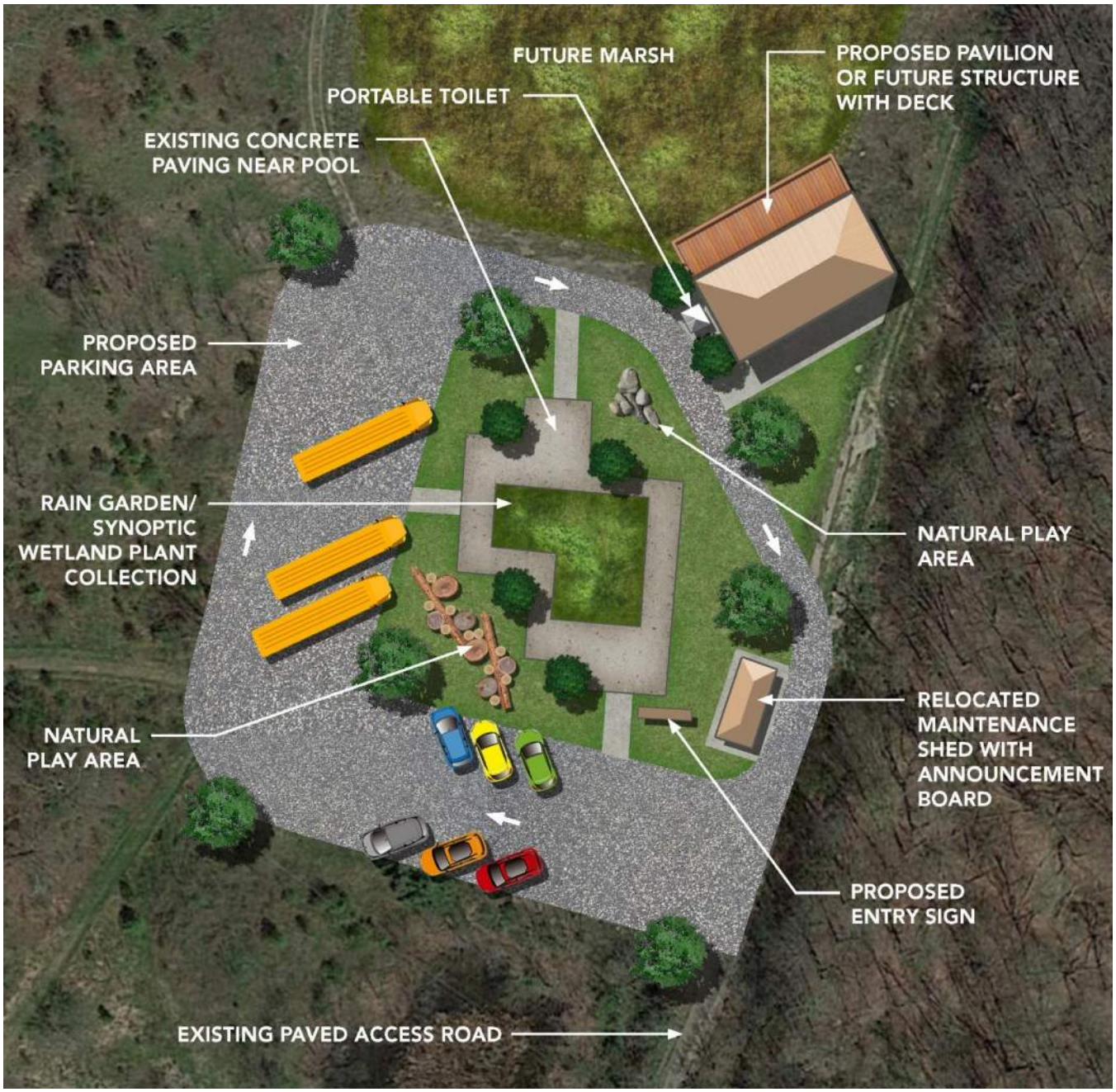
ALT achieves this blend of conservation, recreation, and education by prioritizing investments in passive infrastructure investments, such as trails and educational signage, while limiting physical improvements and alterations to the existing landscape. This Plan balances the desire to support recreational and educational users while maintaining and enhancing the natural conditions at Wingfield Pines.

ALT's Mission Statement

We conserve and care for local land for the health and well-being of current and future generations

3.3.1 Education and Recreation Hub

Creating an Education and Recreation Hub will provide the opportunity to enhance the existing user experience and provide a focus for educational activities at Wingfield Pines. The Hub concept can be scaled to accommodate ALT's current recreational and educational objectives, while allowing for efficient future investment in facilities should they become necessary.



Conceptual Site Plan for future Education and Recreation Hub.

The proposed Education and Recreation Hub includes several distinct components:

- A scalable pavilion
- Reused and improved parking area
- Rain Garden and/or Synoptic Wetland Plant Collection

Locating the Hub within the existing Maintained Landscape leverages existing conditions, and limits capital improvements, while avoid unnecessary impacts to the broader site.

Reuse of Existing Infrastructure

The former Wingfield Pines Golf and Swim Club parking lot and swimming pool area can be repurposed to suit ALT's goals. Reusing these features will further limit impacts to the site.

While the parking area has deteriorated over the years, it is still heavily compacted and can be rehabilitated for less cost than constructing a new parking area. By removing overgrowth and loose asphalt and using the existing concrete and subgrade materials, ALT can create a parking area to fit its needs and budget. This approach limits the creation of additional impermeable surfaces.

The Maintained Landscape area is also serviced by the existing access road and would not require any additional road construction.

Topography/Floodplains

Any siting of a permanent structure at Wingfield Pines is dictated by floodplain elevations. The 100-year flood elevation for the site is 837 feet, and the municipal ordinance sets the lowest proposed floor elevation one and a half feet above this flood elevation. The final floor elevation (FFE) of any permanent structure must therefore be at or above 838.5 feet. The majority of Wingfield Pines has an elevation range of between 826 and 834 feet, which greatly constrains building placement. The area around the parking lot and pool could accommodate a constructed facility at the proper elevation.

Access

Placing a structure within the Maintained Landscape positions the structure as an effective "trailhead" for birdwatchers, students, walkers, and other visitors.

Former Swimming Pool Site

The former swimming area remains a prominent feature at the site, and the paved sidewalks around the swimming pool remain. This presents an easy, low-cost opportunity to construct an educational amenity at this location. See Section 3.3.4.

Viewshed

The Maintained Landscape area provide expansive views to the north, including the entire Maintained Meadow and portions of the Early Successional Floodplain Forest.

Separation of Uses

The existing boundaries of the Maintained Landscape area, created by the perimeter of the former parking lot and the natural site elevation, create a natural boundary that separates the Recreation and Education Hub from the more

natural areas to the west and south. To the north, however, the design, placement, and orientation of an education structure should integrate the structure into the Future Marsh both aesthetically and physically. Effort should be made to position the building as close to the Marsh as possible, with perhaps a deck extending into the Marsh. If building code and design constraints cause the parking area access lane to pass between the structure and the Future Marsh, the gravel lane should be restricted to the minimum width necessary to accommodate vehicles in an attempt to link the structure and marsh as closely as possible.

Alternative Locations

It would be possible to construct an educational facility, parking area, or access road elsewhere on the site, and CEC evaluated alternative locations. A standalone educational facility constructed elsewhere on the site would have several important limitations. A constructed option would require significant elevation and thus significant investment to get to the required FFE for the site. If ALT desires handicap accessibility, it would require a complex ramp and substantial paving of trails. A site could be cleared of brush and rendered useable by a temporary installation, such as a tent or a yurt, to be assembled and removed each time it was used. During periods of flooding, the alternative sites would be unusable. As such, the Maintained Landscape is the only feasible site for the investment.

Similarly, parking could be accommodated elsewhere on the site. However, it would require destruction of natural landscape and additional construction of access roadway from the existing point of ingress to the parking site, and it would also be more prone to flooding. This alternative is impractical.

Clustering these investments around an already improved area, leaves the maximum extent of the site untouched and best meets ALT's passive usage goals.

Locating the proposed Education and Recreation Hub within the existing Maintained Landscape creates an interesting blend of compatible uses.

- The existing impervious surfaces or adjacent area can become the location of an educational facility.
- The former parking areas can be rehabilitated to provide improved access and parking near future facilities.
- The existing maintenance building can be upgraded and moved adjacent to the former swimming pool to provide stormwater for a Rain Garden and/or Synoptic Wetland Plant Garden.
- The former swimming pool can be repurposed as a Rain Garden and/or Synoptic Wetland Plant Garden.
- Distinct areas of the existing parking lot can provide pavilion access.
- The remaining areas of turf can be used as a natural play area.

3.3.2 Educational Facility

Based on our stakeholder interviews and understanding of the current utilization of the site, we understand that the educational facility investment needs to meet only one criterion: provision of shelter. Facilities ranging from temporary shelters to fully enclosed, climate-controlled structures could accomplish this goal.

The Wingfield Pines site will be used by the following groups for various educational purposes:

- ALT administrative personnel (number varies)
- Naturalists and other researchers (approximately one to four at a time)

- K-12 student field trips (approximately 100 students plus teachers)
- Public educational events hosted by ALT

The naturalist/researcher groups would likely visit the Wingfield Pines site at various times during the year; duration of visits may vary from hours to weeks. The K-12 student groups would likely visit in the early fall and late spring. In some cases, flexibility in scheduling may be needed if both groups are present during events.

Based on this input, the facility must include a covered area to protect children from rain/storms, an assembly space for approximately 100 people, tables and benches, and restroom facilities (portable toilets).

We analyzed three general facility scenarios based on ALT's needs. The first two scenarios look at solutions that skew specifically in one of these two directions: (1) a scenario that minimizes site impact as much as possible and (2) a scenario that maximizes educational opportunities as much as possible. Finally, we present our recommended scenario that balances these objectives.

Passive Use Maximization Concept

This is the lowest cost concept and represents a minimal improvement at the site. The concept would include anchoring new posts in the existing concrete pad to accommodate either a large tent or yurt. One or two portable toilets would be located adjacent to it.

Pros
▪ Low cost ($10,000 to $25,000) ▪ Minimal environmental impact ▪ Ability to remove structure in seasons of low utilization
Cons
▪ Higher potential for damage from wind/storms/flooding/vandalism ▪ General wear and tear of tent/yurt and replacement schedule ▪ Minimal windows in yurts limit views of wetlands areas as part of learning experience ▪ Potential damage to anchoring points (filling with sediment, etc.) ▪ Least attractive option

This concept meets ALT's passive use goals, but the relatively high cost of a quality tent/yurt, the potential for damage, and the difficulty in using it well for educational purposes outweigh that benefit. A simple constructed option, such as an open-sided pavilion, would only be modestly more costly and would be much more structurally sound and more easily accommodate a large classroom setting.

CEC recommends that if this option is pursued by ALT, an open-sided pavilion would be a better investment since the open sides would allow for viewing of the site during presentation.

Educational Use Maximization Concept

A high-cost iconic education building that accommodates all possible educational needs of visitors would require a substantial capital investment.

A proposed full-service Education Building is conceptually planned to provide approximately 1,600 gross square feet (gsf) in floor area with approximately 1,800 gsf outdoor deck/amphitheater.

These spaces would accommodate the following activities:

- Entrance/reception area
- Office for ALT administrative personnel (one or two people)
- Storage space for furniture and equipment (e.g. mobile tables and chairs)
- Indoor assembly space for approximately 110 persons
- Area for indoor exhibits
- Temporary work area for naturalists/researchers
- Male and female restrooms
- Mechanical, electrical, and building service rooms
- Steps and ramps as required to descend approximately eight feet to the existing grade

The proposed building would have the following features:

- Resilient construction (i.e., built above the 100-year floodplain out of energy-efficient, durable materials and assemblies)
- Accessible per the building code and ADA Accessibility Guidelines (ADAAG)
- Sustainable construction to an established standard (i.e., LEED, WELL, Green Globes, International Green Construction Code, etc.)
- Ability to have sustainable features added over time as practicable, such as a stormwater management/green roof system, waterless urinals, rainwater collection, photovoltaic (PV) panels, geothermal ground loop HVAC, solar hot water, wind turbine, etc.
- Ability to add finishes (such as donated materials and/or systems) over time

In general, the proposed building is organized along a north–south axis; visitors enter the central entrance area and turn either left to the office/exhibit/presentation area or right to the outdoor amphitheater area. The north wing has expansive fenestration and a roof sloped at approximately 23 degrees to present the site's best views to visitors and to position the roof for best PV panel orientation. During clement weather, the fenestration would open up, allowing natural ventilation.

The south wing has more limited fenestration and a low-slope roof that could accommodate a future green roof installation. This area contains more opaque wall space allowing for controlled lighting for multimedia presentations, fixed exhibits/signs, and naturalist/researcher workstations. The building is designed for four occupancy modes:

- Administrative/idle mode
- Naturalist/research work area mode
- Educational/presentation mode
- Combination mode

Pros
▪ Signature building ▪ All-season educational capabilities ▪ Additional office space for ALT or researchers ▪ Indoor, enclosed, heated restrooms ▪ Viewing platforms ▪ Storage areas
Cons
▪ High construction cost ($350,000 to $500,000) ▪ Unknown sewer connection potential ▪ ALT mission issue: substantial construction on “Preserved Space” ▪ Holding costs (utilities/insurance/maintenance) ▪ Long-term commitment to expanding education offerings ▪ Unknown market demand for this resource

This concept shows a facility that best accomplishes the educational possibilities of the site. While the proposed building for Wingfield Pines is much smaller, it has some similarities to the education center constructed by Tree Pittsburgh on its tree nursery site in Lawrenceville and the Pittsburgh Parks Conservancy in Frick Park.

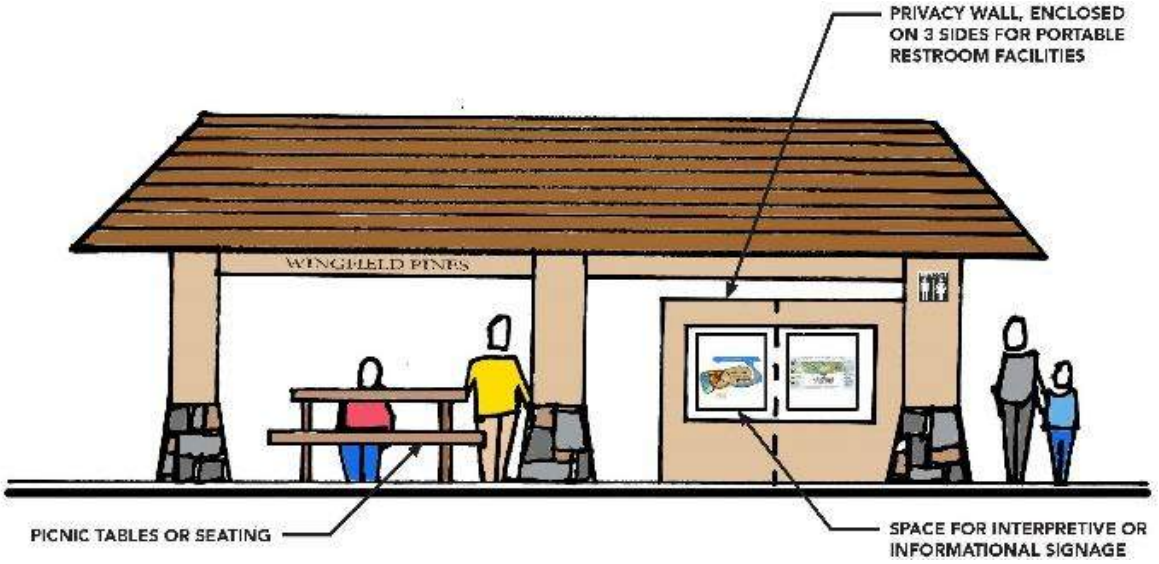
This option shows how a more robust educational use of the site could be accommodated.

Hybrid/Scalable Concept Option (Recommended)

The recommended concept is a balance of minimizing site impact, while accommodating educational needs of site users. Our proposal is for a large, constructed pavilion with the following features:

- Constructed of materials based on cost efficiency and durability
- Approximately 1,500 SF of covered area under the roof
- A compacted gravel floor
- Ample covered area for classroom functions
- A simple wooden partition wall in the rear of the pavilion to screen the educational area from the portable toilets.

This concept best balances the existing educational and recreational needs of the site with the desire to minimize the level of development on an ALT conservation site. It would be situated in the existing parking/pool area of the site and would not result in any destruction of current green space. Seating could be in the form of picnic tables under the pavilion.



The siting of the pavilion would allow for students sitting under the roof to look out across the site as educational lessons are provided. The proposed partition wall would be an excellent location for educational materials—either permanent or temporary.

The pavilion's construction would also be cost efficient as it is substantially more durable and safe than a temporary solution but not at the high cost of an enclosed building. This cost efficiency extends to sunk costs; the cost of building the pavilion would not be lost if future facility upgrades are necessary. The following improvements can be easily added:

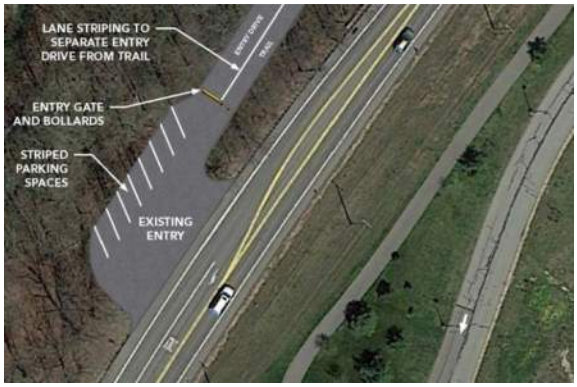
- A poured concrete floor
- Enclosed restrooms (using simple cinder block construction) at the eastern edge of the pavilion. This would be contingent on the ability to access municipal sewer for the necessary plumbing.
- Viewing decks built out from the pavilion and extending over the Maintained Landscape area
- Enclosure of the pavilion, including windows and a climate-controlled interior

This allows the ALT to only make those improvements which are necessary to meeting the needs of the educational and recreational users of the site and to minimize the impact on the conservation area.

Pros
▪ Best blend of minimal site impact/educational needs ▪ Able to be improved cost effectively in future, if necessary ▪ Durability, resistance to flood/vandalism damage ▪ Moderate Cost ($100,000 to $150,000)
Cons
▪ Maintenance and storage costs ▪ Seasonal use ▪ While minimal, still development

3.3.4 Parking and Accessibility

Pedestrian and vehicular access to Wingfield Pines is via Mayview Road. Visitors typically park vehicles in an unstriped upper parking area at intersection of the Wingfield Pines access road and Mayview Road. Adding stripes of curb stops to delineate parking spaces will increase efficient use of the available space. To eliminate visitors needing to maneuver around the existing access gate, bollards can be installed for pedestrian access, along with a new narrower gate for vehicle access. This will maintain existing vehicle access while creating a safer and easier entry for visitors. The gate and bollard combination will prevent unwanted vehicle access while providing unrestricted access to visitors on foot.



Although the existing lower parking area at the site is badly deteriorated, the compacted subsurface base is sound, and the area can be reused by placing compacted gravel in appropriate areas. This allows efficient reuse of the existing access road and removes the need to construct any additional access roads on the site. Yearly maintenance would include topdressing with more gravel in parking areas and under the constructed pavilion.

3.3.5 Rain Garden and/or Synoptic Wetland Plant Collection

The former swimming pool and exposed coping present a unique challenge. While its historical nature is understood, its prominent location within the Education and Recreation Hub requires a greater role than a simple nod to Wingfield Pines' past. Two different, though not incompatible, options for turning this feature into an educational opportunity are available.

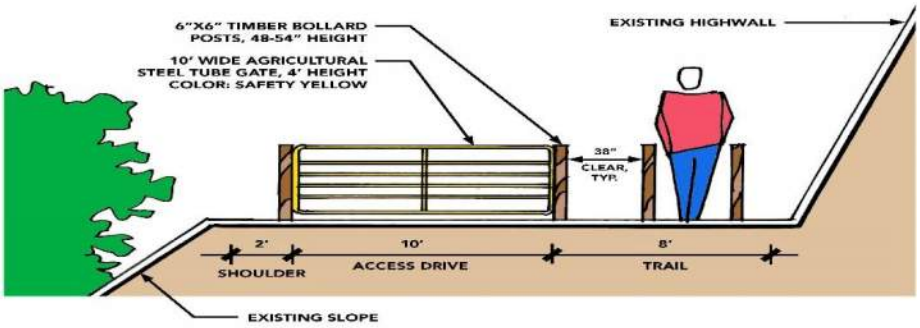
While rain gardens are typically constructed with a carefully blended mixture of soil, geotextiles, and other drainage features to facilitate water absorption, the former swimming pool and coping provide a simple and very effective way to mimic a true rain garden. Construction of the garden would require removal of approximately one foot of fill from the existing swimming pool and replanting of the area with recommended rain garden plant species. Rainwater from a new, relocated maintenance building directed into the rain garden via a downspout would quickly communicate the purpose and function of a true rain garden.

A second option converts the existing space within the exposed coping into a Synoptic Wetland Plant Collection. This alphabetically arranged representative collection of plants growing at Wingfield Pines can be used to identify common plant species, discuss interesting ecological information (e.g. insect/host plant relationships), illustrate various plants' adaptations to life in a wetland, or serve as the basis for a site scavenger hunt. Properly identified plants within the Synoptic Wetland Plant Collection would be keyed by number to plants found along trails, simplifying plant signage to a corresponding simple numbered stake, reducing visual clutter.

3.3.6 Accessibility

CEC reviewed the accessibility report provided by Lehigh Valley Center for Independent Living and concurs with their findings and recommendations. The Education and Recreation Hub addresses several issues identified in the report. The site is level, well compacted, firm, and slip resistant, and it is large enough to provide reserved parking areas able to accommodate vans. At least one of the portable toilets should be handicapped-accessible.

The trails must be better maintained and compacted to improve accessibility, and the report recommendations provide excellent guidelines for improving accessibility. CEC's trail improvement recommendations incorporate these key concepts by identifying trail sections in need of better drainage and compacting, and areas that are candidates for structured walkway construction.



3.3.7 Natural Play Area

Many existing areas at Wingfield Pines serve as passive natural play areas: the boulders within the northern gathering area and the boardwalk and stepping stone walkway in the Bur-Reed Marsh, as examples. These existing areas will be enhanced by additional boulders and natural benches in the northern gathering area, additional boardwalks adjacent to the Ponds, and additional natural benches or boulders within the restored southern gathering area. The Education and Recreation Hub will provide additional natural play opportunities with the future Rain Garden/Synoptic Wetland Plant Garden, log seating, and climbing logs.

3.3.8 Site Signage

An effective signage system for facilities such as Wingfield Pines consists of wayfinding and education. Wayfinding signs are largely non-existent at Wingfield Pines. Existing education signage would benefit from a consistent design (this could be easily expanded to all appropriate ALT properties), approach, and placement.

An overall trail map, including ecological habitats and points of interest, prominently located in the Education and Recreation Hub would allow visitors to plan their visit. Directional wayfinding signs, indicating any dog restrictions, should be located at major trail intersections. These signs should be relatively small and mounted on wooden posts similar to some existing signs used to communicate dog access.

Placing educational signs within each of the nine ecological habitats would improve a visitor's understanding of the diverse habitats at Wingfield Pines. Existing signs are of generally high quality with only minor inconsistencies, but they focus on the AMD treatment process. Additional signs are needed to address each habitat within the Wingfield Pines ecosystem.

Other sign system improvements

- Relocate the large Wingfield Pines identification sign with green roof to a more prominent location during implementation of the Education and Recreation Hub.
- Evaluate the current location of each existing educational sign to determine its best location
- Determine new educational signage required to implementation of Education and Recreation Hub (Rain Garden or Synoptic Wetland Plant Garden)
- Install one or more permanent sign holders designed to hold temporary messages that can be inexpensively and efficiently changed as needed

4.0 Recommendations

The chart below summarizes all the key improvements recommended for Wingfield Pines. ALT, like most non-profit organization, relies heavily on donations of labor, materials, and professional services. The chart includes potential opportunities for these types of donations and volunteer opportunities. Projects likely to require grant funding are also identified, but donated materials and labor can reduce the amount of funding requested. Projects that will require dedicated ALT staff time to better forecast staff requirements in coming years are also listed.

The potential enhancement of the ecological habitat or visitor experience (as appropriate) of each recommendation is categorized as High, Medium, or Low. The level of effort required to implement a recommendation is qualitatively estimated High, Medium, or Low.

	Donation Opportunities						
	Fundraising Required	Volunteer Labor	Materials & Supplies	Professional Services	Staff	Impact	Effort
Ecological Improvements							
Algae Growth Control Investigations				✓	✓	Med	Low
Muskrat Population Control Plan				✓	✓	Med	Low
Treatment Ponds Habitat Enhancement		✓	✓		✓	Low	Low
Bat Box Inspections and Relocations		✓				Low	Low
Invasive Plant Species Management		✓		✓	✓	High	Med
Snake Basking Habitat						Low	Low
Future Marsh	✓			✓	✓	High	High
Bluebird Nesting Boxes		✓	✓			Low	Low
Pond Habitat Enhancements ▪ Turtle/Frog Habitat ▪ Electrofishing Survey ▪ Aquatic Planting Plan ▪ Floating Wetland		✓	✓	✓	✓	Med	Med
Trail Corridor Mowing/Maintenance Plan ▪ Adjustable-Height Mower ▪ String Trimmer Mower					✓	Med	Low
Litter Cleanup						Low	Low
Educational and Recreational Improvements							
Education Pavilion	✓	✓	✓	✓	✓	High	High
Hub Parking and Access Improvements	✓	✓	✓	✓	✓	High	High
Relocated Maintenance Shed						Med	Med
Natural Play Enhancements	✓	✓	✓		✓	Low	Low
Rain Garden/Synoptic Wetland Plant Collection		✓	✓		✓	Med	Low
Southern Informal Gathering Point		✓	✓			Low	Low
Entrance Parking Improvements (Mayview Road)			✓	✓	✓	Med	Med

	Donation Opportunities						
	Fundraising Required	Volunteer Labor	Materials & Supplies	Professional Services	Staff	Impact	Effort
Trail System Improvements							
Trail Corridor Mowing/Maintenance Plan ▪ Adjustable-Height Mower ▪ String Trimmer Mower		✓			✓	Med	Low
Trail Overlook		✓	✓	✓	✓	Low	Low
New Trail Alignment and Ponds Boardwalk ▪ Connection to Lynch Ponds ▪ Southern Trail Extension ▪ Upland Forest/Ponds Loop Trail Expansion	✓	✓	✓	✓	✓	High	Med/ High
Water Access Enhancement and Expansion		✓	✓				
Signage Improvements							
Entrance Sign (Trailhead)		✓	✓	✓	✓	Med	Low
Educational Signage Plan	✓	✓	✓	✓	✓	Med	Low/ Med
Wayfinding Signage Plan		✓	✓	✓	✓	Low	Low

Figure 1
Habitat Map

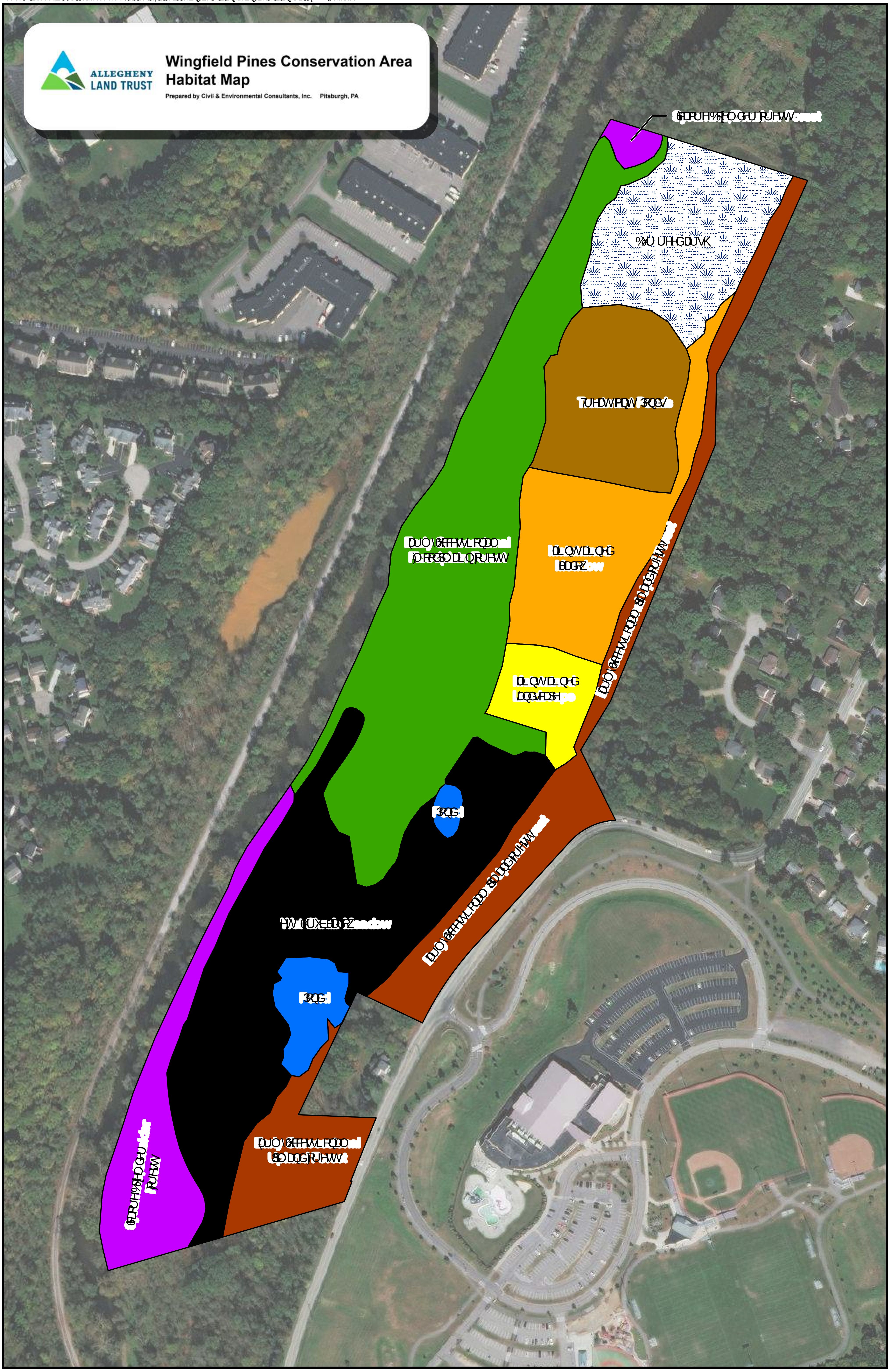

ALLEGHENY LAND TRUST
Wingfield Pines Conservation Area
Habitat Map
Prepared by Civil & Environmental Consultants, Inc. Pittsburgh, PA
Sycamore Boxelder Forest
Bur Reed Marsh
Treatment Ponds
Early Successional Floodplain Forest
Maintained Meadow
Maintained Landscape
Early Successional Upland Forest
Pond
Wet Shrub Meadow
Pond
Early Successional Upland Forest
Early Successional Upland Forest
Sycamore Boxelder Forest

Figure 2

FEMA Floodplain, Site Soils, and Contours

??VYU SLWWVEXUJK?SURMHFWV???,6'DS?$U,F6B3URFBDS?B QILHOGB3L QHV?B QILHOGB3L QHV DSU[3MKHFN

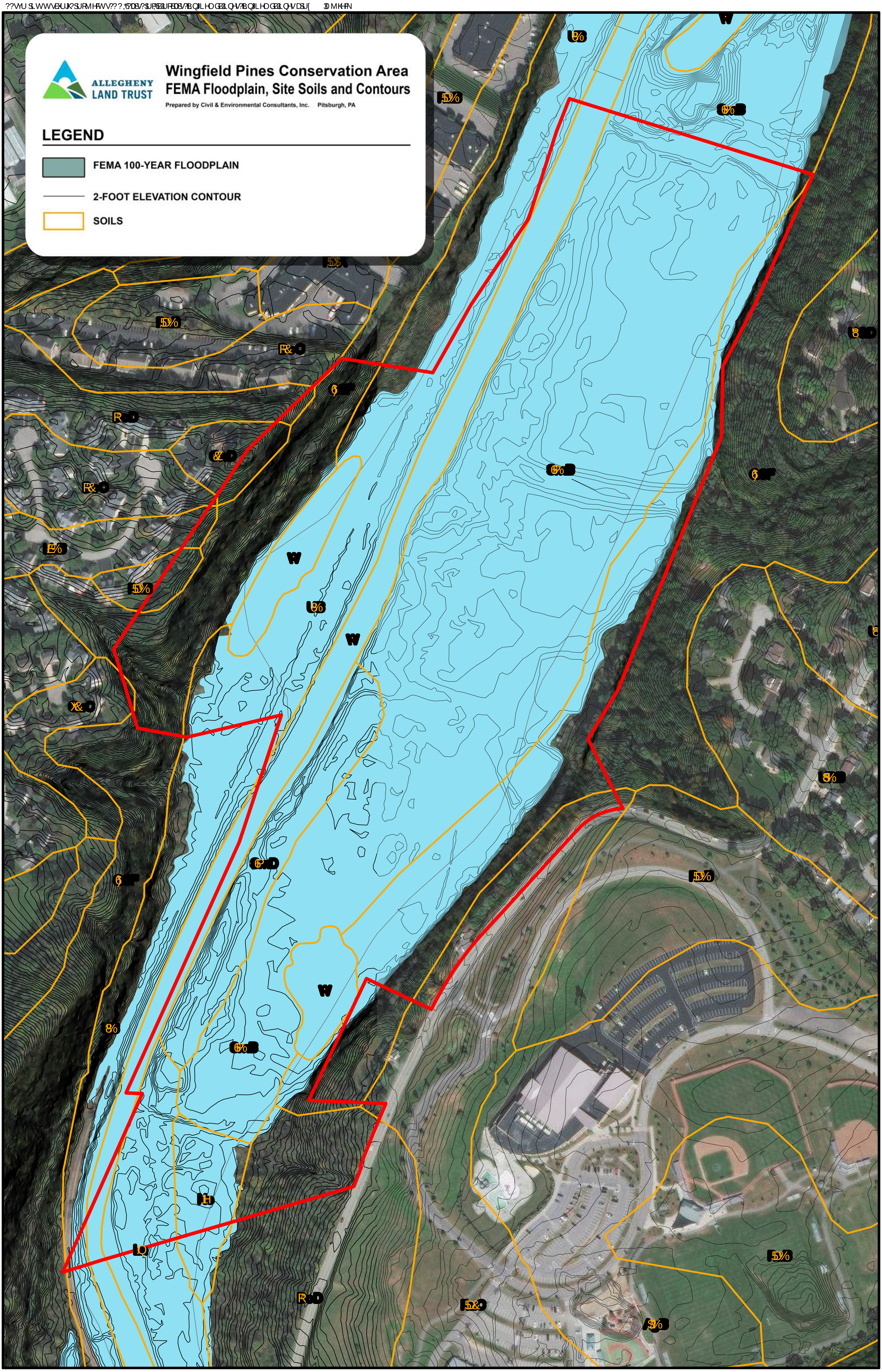


Figure 3
Site Master Plan

ALLEGHENY LAND TRUST

Wingfield Pines Conservation Area Site Master Plan

Prepared by Civil & Environmental Consultants, Inc. | Pitsburgh, PA

NORTH

LEGEND

- 100-YEAR FLOODPLAIN
- EXISTING TRAIL
- EXISTING TRAIL TO BE ABANDONED
- EXISTING BOARDWALK
- PROPOSED TRAIL
- PROPOSED BOARDWALK
- PROPOSED AREA OF INTEREST
- PROPOSED SIGN LOCATION
- PROPOSED WATER ACCESS

SYCAMORE/ BOX ELDER FOREST

BUR-REED MARSH

TREATMENT PONDS

DIVERT EXISTING DRAINAGE TO BE USED TO FLOOD MEADOW

FUTURE MARSH

EARLY SUCCESSIONAL FLOODPLAIN FOREST

100-YEAR FLOODPLAIN

CHARTIERS CREEK

MAINTAINED LANDSCAPE

DIVERT EXISTING DRAINAGE TO BE USED TO FLOOD MEADOW

POND

WET SHRUB MEADOW

POND

BOYCE MAYVIEW PARK

SYCAMORE/ BOX ELDER FOREST

EARLY SUCCESSIONAL UPLAND FOREST

MAYVIEW ROAD

(A) IMPROVED/ENHANCED GATHERING AREA:

- additional seating - boulders, cut log seats or benches
- signage to enhance educational opportunities with close proximity to the treatment ponds

(B) EDUCATION & RECREATION HUB:

- scalable constructed pavilion
- parking area
- Rain Garden or Synoptic Wetland Plant Garden

(C) OVERLOOK:

- conversion of relic concrete pier to overlook of Wet Shrub Meadow.
- signage to enhance educational opportunities

(D) PROPOSED GATHERING AREA:

- informal seating for views of ponds and trail convergence
- signage to enhance educational opportunities

(E) IMPROVED/ENHANCED PARKING AREA:

- relocate existing gate to increase parking

Appendix A

Wingfield Pines Conservation Area Master Species Inventory

Wingfield Pines Conservation Area
Master Species Inventory

Type	Scientific name	Common name	Comment
Amphibian	*Anaxyrus americanus*	American toad	
Amphibian	*Desmognathus fuscus*	Northern dusky salamander	
Amphibian	*Eurycea bislineata*	Northern Two-lined Salamander	
Amphibian	*Lithobates catesbeianus*	Bullfrog	
Amphibian	*Lithobates clamitans*	Green frog	
Amphibian	*Pseudacris crucifer*	Spring peeper	
Annelild	*Lumbricus terrestris*	Common earthworm	
Arthropod	*Aceria* sp.		
Arthropod	*Acrididae*	Short-horned Grasshoppers	
Arthropod	*Acrolophus* sp.	Grass tubeworm moths	
Arthropod	*Agrilus planipennis*	Emerald ash borer	
Arthropod	*Alydidae*	Broad-headed Bugs	
Arthropod	*Amorpha juglandis*	Walnut sphinx	
Arthropod	*Amphibolips confluenta*	Oak-apple Gall-wasp	
Arthropod	*Ancyloxypha numitor*	Least skipper	
Arthropod	*Aphis nerii*	Oleander aphid	
Arthropod	*Apis mellifera*	Western honey bee	
Arthropod	*Argia tibialis*	Blue-tipped Dancer	
Arthropod	*Arilus cristatus*	Wheel bug	
Arthropod	*Armadillidium vulgare*	Common Pill-bug	
Arthropod	*Atalopedes campestris*	Sachem	
Arthropod	*Atteva aurea*	Ailanthus webworm moth	
Arthropod	*Automeris io*	Io moth	
Arthropod	*Bombus impatiens*	Common eastern bumble bee	
Arthropod	*Caenurgina crassiuscula*	Clover looper moth	
Arthropod	*Calopteryx maculata*	Ebony jewelwing	
Arthropod	*Celastrina ladon*	Spring azure	
Arthropod	*Cercopoidea*	Spittlebugs	
Arthropod	*Chilopoda*	Centipedes	
Arthropod	*Chironomidae*	Non-biting Midges	
Arthropod	*Chrysochus auratus*	Dogbane leaf beetle	
Arthropod	*Cicadellidae*	Leafhoppers	
Arthropod	*Cicindela sexguttata*	Six-spotted Tiger Beetle	
Arthropod	*Cisseps fulvicollis*	Yellow-collared Scape Moth	
Arthropod	*Colias eurytheme*	Orange sulphur	
Arthropod	*Colias philodice*	Clouded sulphur	
Arthropod	*Conocephalus brevipennis*	Short-winged Meadow Katydid	
Arthropod	*Coreidae*	Leaf-footed Bugs	
Arthropod	*Danaus plexippus*	Monarch	
Arthropod	*Diabrotica undecimpunctata*	Spotted cucumber beetle	
Arthropod	*Dryocampa rubicunda*	Rosy maple moth	
Arthropod	*Eacles imperialis*	Imperial moth	
Arthropod	*Elateridae*	Click beetles	

Type	Scientific name	Common name	Comment
Arthropod	*Enallagma civile*	Familiar bluet	
Arthropod	*Epargyreus clarus*	Silver-spotted Skipper	
Arthropod	*Erynnis baptisiae*	Wild indigo duskywing	
Arthropod	*Erythemis simplicicollis*	Eastern pondhawk	
Arthropod	*Eurosta solidaginis*	Goldenrod gall fly	
Arthropod	*Galerucella* sp.	Purple loosestrife beetles	
Arthropod	*Gelastocoris oculatus*	Big-eyed Toad Bug	
Arthropod	*Harmonia axyridis*	Asian lady beetle	
Arthropod	*Hemerobiidae*	Brown lacewings	
Arthropod	*Hetaerina americana*	American rubyspot	
Arthropod	*Hydropsychidae*	Net-spinning Caddisflies	
Arthropod	*Hylephila phyleus*	Fiery skipper	
Arthropod	*Hypena madefactalis*	Gray-edged Snout	
Arthropod	*Hypercompe scribonia*	Giant leopard moth	
Arthropod	*Idia lubricalis*	Glossy black idia moth	
Arthropod	*Ischnura posita*	Fragile forktail	
Arthropod	*Laphria* sp.	Bee-like Robber Flies	
Arthropod	*Lasius* sp.	Citronella ants	
Arthropod	*Lestes rectangularis*	Slender spreadwing	
Arthropod	*Leucauge venusta*	Orchard orbweaver	
Arthropod	*Libellula luctuosa*	Widow skimmer	
Arthropod	*Limenitis archippus*	Viceroy	
Arthropod	*Lochmaeus bilineata*	Double-lined Prominent Moth	
Arthropod	*Lycidae*	Net-winged Beetles	
Arthropod	*Lymantria dispar*	Gypsy moth	
Arthropod	*Macaria aemulataria*	Common angle	
Arthropod	*Malacosoma americanum*	Eastern tent caterpillar moth	
Arthropod	*Megachile* sp.	Leafcutter, Mortar, and Resin Bees	
Arthropod	*Melanolophia* sp.		
Arthropod	*Membracidae*	Typical treehoppers	
Arthropod	*Myrmeleontidae*	Antlions	
Arthropod	*Nadata gibbosa*	White-dotted Prominent	
Arthropod	*Narceus americanus*	American giant millipede	
Arthropod	*Neanuridae*	Short-legged Springtails	
Arthropod	*Necrophila americana*	American carrion beetle	
Arthropod	*Nematocampa resistaria*	Horned spanworm moth	
Arthropod	*Nepidae*	Water scorpions	
Arthropod	*Noctua pronuba*	Large yellow underwing	
Arthropod	*Oncopeltus fasciatus*	Large milkweed bug	
Arthropod	*Order Ephemeroptera*	Mayflies	
Arthropod	*Orgyia* sp.		
Arthropod	*Pachydiplax longipennis*	Blue dasher	
Arthropod	*Pachypsylla venusta*	Hackberry petiole gall psyllid	
Arthropod	*Papaipema* sp.		
Arthropod	*Parallelia bistriaris*	Maple looper moth	
Arthropod	*Paraphidippus aurantius*	Golden jumping spider	
Arthropod	*Pentatomidae*	Stink bugs	

Type	Scientific name	Common name	Comment
Arthropod	*Phyciodes tharos*	Pearl crescent	
Arthropod	*Pieris rapae*	Cabbage white	
Arthropod	*Pisaurina mira*	American nursery web spider	
Arthropod	*Plathemis lydia*	Common whitetail	
Arthropod	*Polygonia comma*	Eastern comma	
Arthropod	*Polygonia interrogationis*	Question mark	
Arthropod	*Pompeius verna*	Little glassywing	
Arthropod	*Popillia japonica*	Japanese beetle	
Arthropod	*Pyrrharctia isabella*	Isabella tiger moth	
Arthropod	*Rhopalomyia* sp.	Midge	
Arthropod	*Scopula limboundata*	Large lace border	
Arthropod	*Simuliidae*	Black flies	
Arthropod	*Sitochroa palealis*	Carrot seed moth	
Arthropod	*Speyeria cybele*	Great spangled fritillary	
Arthropod	*Spilosoma* sp.		
Arthropod	*Strymon melinus*	Gray hairstreak	
Arthropod	*Syritta pipiens*	Thick-legged Hoverfly	
Arthropod	*Tenodera* sp.	Mantis	
Arthropod	*Theridiosoma gemmosum*	Spider	
Arthropod	*Tipulidae*	Large crane flies	
Arthropod	*Toxomerus* sp.	Hoverfly	
Arthropod	*Trichodezia albovittata*	White-striped Black	
Arthropod	*Udea rubigalis*	Celery leaftier moth	
Arthropod	*Xylocopa virginica*	Eastern carpenter bee	
Arthropod	*Xysticus* sp.	Ground crab spiders	
Arthropod	*Zale* sp.		
Avian		Mallard × American Black Duck	
Avian	*Accipiter cooperii*	Cooper's hawk	
Avian	*Accipiter striatus*	Sharp-shinned hawk	
Avian	*Actitis macularius*	Spotted sandpiper	
Avian	*Agelaius phoeniceus*	Red-winged Blackbird	
Avian	*Aix sponsa*	Wood duck	
Avian	*Ammodramus* sp.	Sparrow	
Avian	*Anas acuta*	Northern pintail	
Avian	*Anas crecca*	Green-winged teal	
Avian	*Anas platyrhynchos*	Mallard	
Avian	*Anas rubripes*	American black duck	
Avian	*Anser caerulescens*	Snow goose	
Avian	*Anser rossii*	Ross's goose	
Avian	*Anthus rubescens*	American pipit	
Avian	*Archilochus colubris*	Ruby-throated hummingbird	
Avian	*Ardea alba*	Great egret	
Avian	*Ardea herodias*	Great blue heron	
Avian	*Aythya affinis*	Lesser scaup	
Avian	*Aythya americana*	Redhead	
Avian	*Aythya collaris*	Ring-necked duck	
Avian	*Aythya marila*	Greater scaup	

Type	Scientific name	Common name	Comment
Avian	*Aythya* sp.	Duck	
Avian	*Aythya valisineria*	Canvasback	
Avian	*Baeolophus bicolor*	Tufted titmouse	
Avian	*Bombycilla cedrorum*	Cedar waxwing	
Avian	*Botaurus lentiginosus*	American bittern	Uncommon
Avian	*Branta canadensis*	Canada goose	
Avian	*Branta hutchinsii*	Cackling goose	
Avian	*Bubo virginianus*	Great horned owl	
Avian	*Bucephala albeola*	Bufflehead	
Avian	*Buteo jamaicensis*	Red-tailed Hawk	
Avian	*Buteo lineatus*	Red-shouldered hawk	
Avian	*Buteo platypterus*	Broad-winged hawk	
Avian	*Butorides virescens*	Green heron	
Avian	*Calidris melanotos*	Pectoral sandpiper	
Avian	*Calidris minutilla*	Least sandpiper	
Avian	*Calidris pusilla*	Semipalmated sandpiper	
Avian	*Cardellina pusilla*	Wilson's warbler	
Avian	*Cardinalis cardinalis*	Northern cardinal	
Avian	*Cathartes aura*	Turkey vulture	
Avian	*Catharus fuscescens*	Veery	
Avian	*Catharus guttatus*	Hermit thrush	
Avian	*Catharus ustulatus*	Swainson's thrush	
Avian	*Chaetura pelagica*	Chimney swift	
Avian	*Charadrius vociferus*	Killdeer	
Avian	*Chlidonias niger*	Black tern	
Avian	*Chordeiles minor*	Common nighthawk	
Avian	*Chroicocephalus philadelphia*	Bonaparte's gull	
Avian	*Circus hudsonius*	Northern harrier	
Avian	*Cistothorus palustris*	Marsh wren	
Avian	*Coccyzus americanus*	Yellow-billed Cuckoo	
Avian	*Coccyzus erythropthalmus*	Black-billed cuckoo	
Avian	*Colaptes auratus*	Northern flicker	
Avian	*Columba livia*	Rock pigeon	
Avian	*Contopus virens*	Eastern wood-pewee	
Avian	*Coragyps atratus*	Black vulture	
Avian	*Corvus brachyrhynchos*	American crow	
Avian	*Corvus brachyrhynchos*	Fish crow	
Avian	*Corvus corax*	Common raven	
Avian	*Cyanocitta cristata*	Blue jay	
Avian	*Cygnus columbianus*	Tundra swan	
Avian	*Dolichonyx oryzivorus*	Bobolink	
Avian	*Dryocopus pileatus*	Pileated woodpecker	
Avian	*Dumetella carolinensis*	Gray catbird	
Avian	*Egretta thula*	Snowy egret	
Avian	*Empidonax alnorum*	Alder flycatcher	
Avian	*Empidonax flaviventris*	Yellow-bellied flycatcher	
Avian	*Empidonax minimus*	Least flycatcher	

Type	Scientific name	Common name	Comment
Avian	*Empidonax traillii*	Willow flycatcher	
Avian	*Empidonax virescens*	Acadian flycatcher	
Avian	*Euphagus carolinus*	Rusty blackbird	
Avian	*Falco columbarius*	Merlin	
Avian	*Falco sparverius*	American kestrel	
Avian	*Fulica americana*	American coot	
Avian	*Gallinago delicata*	Wilson's snipe	
Avian	*Gallinula galeata*	Common gallinule	
Avian	*Gavia immer*	Common loon	
Avian	*Geothlypis trichas*	Common yellowthroat	
Avian	*Haemorhous mexicanus*	House finch	
Avian	*Haemorhous purpureus*	Purple finch	
Avian	*Haliaeetus leucocephalus*	Bald eagle	
Avian	*Hirundo rustica*	Barn swallow	
Avian	*Hylocichla mustelina*	Wood thrush	
Avian	*Icteria virens*	Yellow-breasted chat	
Avian	*Icterus galbula*	Baltimore oriole	
Avian	*Icterus spurius*	Orchard oriole	
Avian	*Ixobrychus exilis*	Least bittern	
Avian	*Junco hyemalis*	Dark-eyed Junco	
Avian	*Larus argentatus*	Herring gull	
Avian	*Larus delawarensis*	Ring-billed gull	
Avian	*Lophodytes cucullatus*	Hooded merganser	
Avian	*Mareca americana*	American wigeon	
Avian	*Mareca strepera*	Gadwall	
Avian	*Megaceryle alcyon*	Belted kingfisher	
Avian	*Megascops asio*	Eastern screech-owl	
Avian	*Melanerpes carolinus*	Red-bellied Woodpecker	
Avian	*Melanerpes erythrocephalus*	Red-headed woodpecker	
Avian	*Meleagris gallopavo*	Wild turkey	
Avian	*Melospiza georgiana*	Swamp sparrow	
Avian	*Melospiza lincolnii*	Lincoln's sparrow	
Avian	*Melospiza melodia*	Song sparrow	
Avian	*Mergus merganser*	Common merganser	
Avian	*Mergus serrator*	Red-breasted merganser	
Avian	*Mimus polyglottos*	Northern mockingbird	
Avian	*Mniotilta varia*	Black-and-white warbler	
Avian	*Molothrus ater*	Brown-headed Cowbird	
Avian	*Myiarchus crinitus*	Great crested flycatcher	
Avian	*Oreothlypis peregrina*	Tennessee warbler	
Avian	*Oreothlypis ruficapilla*	Nashville warbler	
Avian	*Oxyura jamaicensis*	Ruddy duck	
Avian	*Pandion haliaetus*	Osprey	
Avian	*Parkesia motacilla*	Louisiana waterthrush	
Avian	*Parkesia noveboracensis*	Northern waterthrush	
Avian	Parulidae sp.	Warbler	
Avian	*Passer domesticus*	House sparrow	

Type	Scientific name	Common name	Comment
Avian	*Passerculus sandwichensis*	Savannah sparrow	
Avian	*Passerella iliaca*	Fox sparrow	
Avian	*Passerina cyanea*	Indigo bunting	
Avian	*Petrochelidon pyrrhonota*	Cliff swallow	
Avian	*Phalacrocorax auritus*	Double-crested cormorant	
Avian	*Pheucticus ludovicianus*	Rose-breasted grosbeak	
Avian	*Picoides pubescens*	Downy woodpecker	
Avian	*Picoides villosus*	Hairy woodpecker	
Avian	*Pipilo erythrophthalmus*	Eastern towhee	
Avian	*Piranga olivacea*	Scarlet tanager	
Avian	*Podilymbus podiceps*	Pied-billed grebe	
Avian	*Poecile atricapillus*	Black-capped chickadee	
Avian	*Poecile carolinensis*	Carolina chickadee	
Avian	*Polioptila caerulea*	Blue-gray Gnatcatcher	
Avian	*Porzana carolina*	Sora	Notable
Avian	*Progne subis*	Purple martin	
Avian	*Quiscalus quiscula*	Common grackle	
Avian	*Rallus limicola*	Virginia rail	Notable
Avian	*Regulus calendula*	Ruby-crowned Kinglet	
Avian	*Regulus satrapa*	Golden-crowned kinglet	
Avian	*Riparia riparia*	Bank swallow	
Avian	*Sayornis phoebe*	Eastern phoebe	
Avian	*Scolopax minor*	American woodcock	
Avian	*Seiurus aurocapilla*	Ovenbird	
Avian	*Setophaga americana*	Northern parula	
Avian	*Setophaga caerulescens*	Black-throated blue warbler	
Avian	*Setophaga castanea*	Bay-breasted warbler	
Avian	*Setophaga citrina*	Hooded warbler	
Avian	*Setophaga coronata*	Yellow-rumped Warbler	
Avian	*Setophaga discolor*	Prairie warbler	
Avian	*Setophaga dominica*	Yellow-throated Warbler	
Avian	*Setophaga fusca*	Blackburnian warbler	
Avian	*Setophaga magnolia*	Magnolia warbler	
Avian	*Setophaga palmarum*	Palm warbler	
Avian	*Setophaga pensylvanica*	Chestnut-sided warbler	
Avian	*Setophaga petechia*	Yellow warbler	
Avian	*Setophaga pinus*	Pine warbler	
Avian	*Setophaga ruticilla*	American redstart	
Avian	*Setophaga striata*	Blackpoll warbler	
Avian	*Setophaga tigrina*	Cape May warbler	
Avian	*Setophaga virens*	Black-throated green warbler	
Avian	*Sialia sialis*	Eastern bluebird	
Avian	*Sitta canadensis*	Red-breasted Nuthatch	
Avian	*Sitta carolinensis*	White-breasted Nuthatch	
Avian	*Spatula clypeata*	Northern shoveler	
Avian	*Spatula discors*	Blue-winged teal	
Avian	*Spinus pinus*	Pine siskin	

Type	Scientific name	Common name	Comment
Avian	*Spinus tristis*	American goldfinch	
Avian	*Spizella passerina*	Chipping sparrow	
Avian	*Spizella pusilla*	Field sparrow	
Avian	*Spizelloides arborea*	American tree sparrow	
Avian	*Stelgidopteryx serripennis*	Northern Rough-winged Swallow	
Avian	*Strix varia*	Barred owl	
Avian	*Sturnella magna*	Eastern meadowlark	
Avian	*Sturnus vulgaris*	European starling	
Avian	*Surnia ulula*	Northern hawk owl	
Avian	*Sympetrum vicinum*	Autumn meadowhawk	
Avian	*Tachycineta bicolor*	Tree swallow	
Avian	*Thryothorus ludovicianus*	Carolina wren	
Avian	*Toxostoma rufum*	Brown thrasher	
Avian	*Tringa flavipes*	Lesser yellowlegs	
Avian	*Tringa melanoleuca*	Greater yellowlegs	
Avian	*Tringa solitaria*	Solitary sandpiper	
Avian	*Troglodytes aedon*	House wren	
Avian	*Troglodytes hiemalis*	Winter wren	
Avian	*Turdus migratorius*	American robin	
Avian	*Tyrannus tyrannus*	Eastern kingbird	
Avian	*Vermivora cyanoptera*	Blue-winged warbler	
Avian	*Vireo flavifrons*	Yellow-throated Vireo	
Avian	*Vireo gilvus*	Warbling vireo	
Avian	*Vireo griseus*	White-eyed Vireo	
Avian	*Vireo olivaceus*	Red-eyed Vireo	
Avian	*Vireo solitarius*	Blue-headed vireo	
Avian	*Zenaida macroura*	Mourning dove	
Avian	*Zonotrichia albicollis*	White-throated Sparrow	
Avian	*Zonotrichia leucophrys*	White-crowned sparrow	
Bacteria	*Nostoc* sp.	Star jelly	
Crustacean	*Cambarus carinirostris*	Rock crayfish	
Crustacean	*Cambarus* sp.	Crayfish	
Fish	*Aeshna umbrosa*	Shadow darner	
Fish	*Cyprinus carpio*	European carp	
Fish	*Gambusia affinis*	Mosquito fish	
Fish	*Lepomis macrochirus*	Bluegill	
Fish	*Micropterus salmoides*	Largemouth bass	
Fish	*Semotilus atromaculatus*	Creek chub	
Flatworm	*Tricladida*	Planarians	
Flora	*Acalypha virginica*	Virginia Threeseed mercury	
Flora	*Acer negundo*	Boxelder maple	
Flora	*Acer nigrum*	Black maple	
Flora	*Acer saccharinum*	Silver maple	
Flora	*Achillea millefolium*	Common Yarrow	
Flora	*Actaea pachypoda*	White baneberry	
Flora	*Actaea racemosa*	Black cohosh	
Flora	*Aegopodium podagraria*	Goutweed	Invasive

Type	Scientific name	Common name	Comment
Flora	*Aesculus glabra*	Ohio buckeye	
Flora	*Ageratina altissima*	White snakeroot	
Flora	*Agrimonia parviflora*	Swamp agrimony	
Flora	*Ailanthus altissima*	Tree of heaven	Invasive
Flora	*Ajuga reptans*	Carpet bugle	Invasive
Flora	*Alliaria petiolata*	Garlic mustard	Invasive
Flora	*Allium cernuum*	Nodding onion	
Flora	*Allium schoenoprasum*	Chives	
Flora	*Allium tricoccum*	Small white leek	
Flora	*Allium vineale*	Wild garlic	
Flora	*Ambrosia artemisiifolia*	Common ragweed	
Flora	*Amphicarpaea bracteata*	American hog-peanut	
Flora	*Anemone acutiloba*	Sharp-lobed hepatica	
Flora	*Apocynum androsaemifolium*	Spreading Dogbane	
Flora	*Apocynum cannabinum*	Hemp dogbane	
Flora	*Arabis laevigata*	Smooth rockcress	
Flora	*Arctium lappa*	Greater burdock	
Flora	*Arenaria serpyllifolia*	Thyme-leaf Sandwort	
Flora	*Arisaema triphyllum*	Jack-in-the-pulpit	
Flora	*Artemisia vulgaris*	Common mugwort	
Flora	*Asarum canadense*	Canadian wild ginger	
Flora	*Asclepias incarnata*	Swamp milkweed	
Flora	*Asclepias syriaca*	Common milkweed	
Flora	*Asimina triloba*	Common pawpaw	
Flora	*Asplenium rhizophyllum*	Walking fern	
Flora	*Athyrium filix-femina*	Lady fern	
Flora	*Barbarea vulgaris*	Bitter wintercress	
Flora	*Berberis thunbergii*	Japanese barberry	Invasive
Flora	*Bidens frondosa*	Devil's beggar ticks	
Flora	*Boehmeria cylindrica*	False nettle	
Flora	*Brachythecium* sp.	Moss	
Flora	*Butomus umbellatus*	Flowering-rush	Highly Invasive
Flora	*Calystegia sepium*	Hedge bindweed	
Flora	*Campanula americanum*	Tall bellflower	
Flora	*Cardamine concatenata*	Cut-leaved toothwort	
Flora	*Cardamine impatiens*	Narrow-leaved bittercress	Invasive
Flora	*Carex comosa*	Bristly sedge	
Flora	*Carex plantaginea*	Plantainleaf sedge	
Flora	*Carex tribuloides*	Blunt broom sedge	
Flora	*Carex vulpinoidea*	Fox sedge	
Flora	*Carpinus caroliniana*	American hornbeam	
Flora	*Carya* sp.	Hickories	
Flora	*Castanea* sp.	Chestnuts	
Flora	*Catalpa* sp.	Catalpas	
Flora	*Caulophyllum thalictroides*	Blue cohosh	
Flora	*Celtis occidentalis*	Common hackberry	
Flora	*Cercis canadensis*	Eastern redbud	

Type	Scientific name	Common name	Comment
Flora	*Cichorium intybus*	Chicory	
Flora	*Cirsium arvense*	Canada thistle	Invasive
Flora	*Claytonia caroliniana*	Carolina spring-beauty	
Flora	*Claytonia virginica*	Virginia spring beauty	
Flora	*Clematis virginiana*	Virgin's-bower	
Flora	*Clinopodium vulgare*	Wild basil	
Flora	*Conium maculatum*	Poison hemlock	Invasive
Flora	*Conopholis americana*	American cancer-root	
Flora	*Convolvulus arvensis*	Field bindweed	
Flora	*Conyza canadensis*	Horseweed	
Flora	*Cornus amomum*	Silky dogwood	
Flora	*Cornus florida*	Flowering dogwood	Encourage
Flora	*Coronilla varia*	Crownvetch	Invasive
Flora	*Crataegus* sp.	Hawthorns	
Flora	*Cryptotaenia canadensis*	Honewort	
Flora	*Cystopteris* sp.	Fragile ferns	
Flora	*Daucus carota*	Wild carrot	
Flora	*Delphinium tricorne*	Dwarf larkspur	
Flora	*Desmodium* sp.	Tick trefoil	
Flora	*Dianthus armeria*	Deptford pink	
Flora	*Dicentra canadensis*	Squirrel corn	
Flora	*Dicentra cucullaria*	Dutchman's breeches	
Flora	*Dipsacus fullonum*	Fuller's teasel	Invasive
Flora	*Dryopteris carthusiana*	Spinulose wood fern	
Flora	*Duchesnea indica*	Indian Strawberry	
Flora	*Echinochloa crus-galli*	Barnyardgrass	
Flora	*Echinocystis lobata*	Wild cucumber	
Flora	*Elaeagnus umbellata*	Autumn olive	Invasive
Flora	*Elymus hystrix*	Bottlebrush grass	
Flora	*Entodon seductrix*	Seductive entodon moss	
Flora	*Epifagus virginiana*	Beechdrops	
Flora	*Epilobium ciliatum*	Fringed willowherb	
Flora	*Epilobium coloratum*	Purple-leaf Willowherb	
Flora	*Equisetum arvense*	Field horsetail	
Flora	*Erigeron annuus*	Daisy Fleabane	
Flora	*Erigeron philadelphicus*	Philadelphia Fleabane	
Flora	*Erythronium albidum*	White trout lily	PA-listed/False ID?
Flora	*Erythronium americanum*	Yellow trout lily	
Flora	*Euonymus alatus*	Winged euonymus	Discourage
Flora	*Euonymus atropurpureus*	Wahoo	Uncommon
Flora	*Euonymus fortunei*	Fortune's spindle	Discourage
Flora	*Eupatorium perfoliatum*	Common Boneset	
Flora	*Eurybia divaricata*	White wood aster	
Flora	*Eutrochium purpureum*	Sweet Joe-Pye-weed	
Flora	*Fallopia japonica*	Japanese knotweed	Highly Invasive
Flora	*Fissidens* sp.	Pocket mosses	
Flora	*Floerkea proserpinacoides*	False mermaidweed	

Type	Scientific name	Common name	Comment
Flora	*Fragaria* sp.	Strawberries	
Flora	*Frangula alnus*	Alder buckthorn	Invasive
Flora	*Fraxinus pennsylvanica*	Green ash	
Flora	*Galium aparine*	Catchweed bedstraw	
Flora	*Galium tinctorium*	Stiff marsh Bedstraw	
Flora	*Galium triflorum*	Fragrant bedstraw	
Flora	*Geranium maculatum*	Wild geranium	
Flora	*Geum canadense*	White avens	
Flora	*Glechoma hederacea*	Ground Ivy	
Flora	*Hackelia virginiana*	Stickseed	
Flora	*Hedera helix*	Common ivy	Discourage
Flora	*Helianthus tuberosus*	Jerusalem Artichoke	
Flora	*Heliopsis helianthoides*	Smooth Oxeye	
Flora	*Heracleum maximum*	Common Cow parsnip	
Flora	*Hesperis matronalis*	Dame's-violet	
Flora	*Humulus* sp.	Hops	
Flora	*Hydrangea arborescens*	Wild hydrangea	
Flora	*Hydrophyllum canadense*	Broad-leaf Waterleaf	
Flora	*Hygroamblystegium* sp.	Moss	
Flora	*Hypericum perforatum*	Common St. John's wort	
Flora	*Hypericum punctatum*	Spotted St. John's wort	
Flora	*Hypnum* sp.	Moss	
Flora	*Impatiens capensis*	Common jewelweed	
Flora	*Impatiens pallida*	Pale jewelweed	
Flora	*Iris pseudacorus*	Yellow flag iris	
Flora	*Juglans nigra*	Eastern black walnut	
Flora	*Juncus canadensis*	Canada rush	
Flora	*Juncus effusus*	Soft rush	
Flora	*Juncus tenuis*	Slender rush	
Flora	*Justicia americana*	American water-willow	
Flora	*Laportea canadensis*	Canadian wood nettle	
Flora	*Lapsana communis*	Nipplewort	
Flora	*Lathyrus latifolius*	Perennial Pea	
Flora	*Leucanthemum vulgare*	Oxeye daisy	
Flora	*Lindera benzoin*	Northern spicebush	
Flora	*Lobelia inflata*	Indian-tobacco	
Flora	*Lonicera japonica*	Japanese honeysuckle	Invasive
Flora	*Lonicera maackii*	Amur honeysuckle	Invasive
Flora	*Lonicera morrowii*	Morrow's honeysuckle	Invasive
Flora	*Lotus corniculatus*	Bird's-foot trefoil	
Flora	*Lycopus americanus*	American bugleweed	
Flora	*Lysimachia ciliata*	Fringed Loosestrife	
Flora	*Lysimachia nummularia*	Creeping Jenny	
Flora	*Lythrum salicaria*	Purple-loosestrife	Highly Invasive
Flora	*Maianthemum racemosum*	False Solomon's-seal	
Flora	*Malus prunifolia*	Pear-leaf Crabapple	
Flora	*Medicago sativa*	Alfalfa	

Type	Scientific name	Common name	Comment
Flora	*Melilotus alba*	White sweetclover	
Flora	*Melilotus officinalis*	Sweetclover	
Flora	*Menispermum canadense*	Moonseed	
Flora	*Microstegium vimineum*	Japanese stiltgrass	Invasive
Flora	*Mimulus ringens*	Allegheny monkeyflower	
Flora	*Monarda fistulosa*	Wild bergamot	
Flora	*Monotropa uniflora*	Indian pipe	
Flora	*Myosotis scorpioides*	Water forget-me-not	
Flora	*Oenothera biennis*	Common evening-primrose	
Flora	*Oenothera gaura*	Biennial beeblossom	
Flora	*Onoclea sensibilis*	Sensitive fern	
Flora	*Ornithogalum umbellatum*	Common star-of-Bethlehem	Invasive
Flora	*Orthotrichum* sp.	Moss	
Flora	*Oxalis stricta*	Yellow Oxalis	
Flora	*Packera obovata*	Roundleaf ragwort	
Flora	*Paronychia* sp.		
Flora	*Parthenocissus quinquefolia*	Virginia creeper	
Flora	*Pastinaca sativa*	Wild parsnip	Invasive
Flora	*Peltandra virginica*	Green arrow arum	
Flora	*Phalaris arundinacea*	Reed canary grass	Invasive
Flora	*Phaseolus polystachios*	Thicket Bean	
Flora	*Phleum pratense*	Timothy	
Flora	*Phlox divaricata*	Blue phlox	
Flora	*Phlox paniculata*	Fall phlox	
Flora	*Phryma leptostachya*	American lopseed	
Flora	*Physalis longifolia*	Longleaf Groundcherry	
Flora	*Phytolacca americana*	American pokeweed	
Flora	*Picea abies*	Norway spruce	
Flora	*Pilea pumila*	Canadian Clearweed	
Flora	*Pinus strobus*	Eastern white pine	
Flora	*Plagiomnium cuspidatum*	Woodsy Thyme-moss	
Flora	*Plantago lanceolata*	Narrowleaf Plantain	
Flora	*Plantago major*	Greater plantain	
Flora	*Platanus occidentalis*	American sycamore	
Flora	*Podophyllum peltatum*	Mayapple	
Flora	*Polygonatum pubescens*	Hairy Solomon's-seal	
Flora	*Polygonum caespitosum*	Oriental Lady's Thumb	Invasive
Flora	*Polygonum hydropiperoides*	Swamp Smartweed	
Flora	*Polygonum pensylvanicum*	Pennsylvania Smartweed	
Flora	*Polygonum persicaria*	Spotted Lady’s thumb	
Flora	*Polygonum virginianum*	Jumpseed	
Flora	*Polymnia canadensis*	Leafcup	
Flora	*Polystichum acrostichoides*	Christmas fern	
Flora	*Pontederia cordata*	Pickerelweed	
Flora	*Populus deltoides*	Eastern cottonwood	
Flora	*Populus grandidentata*	Bigtooth aspen	
Flora	*Porella* sp.	Liverwort	

Type	Scientific name	Common name	Comment
Flora	*Potamogeton crispus*	Crisp-leaved Pondweed	Invasive
Flora	*Potentilla norvegica*	Rough cinquefoil	
Flora	*Potentilla simplex*	Common Cinquefoil	
Flora	*Prunella vulgaris*	Common selfheal	
Flora	*Prunus pensylvanica*	Pin cherry	
Flora	*Prunus serotina*	Black cherry	
Flora	*Pyrus calleryana*	Callery pear	Highly Invasive
Flora	*Quercus alba*	White oak	
Flora	*Quercus palustris*	Pin oak	
Flora	*Quercus rubra*	Red oak	
Flora	*Ranunculus ficaria*	Lesser celandine	Highly Invasive
Flora	*Ranunculus repens*	Creeping buttercup	
Flora	*Rhus typhina*	Staghorn sumac	
Flora	*Robinia pseudoacacia*	Black locust	
Flora	*Rosa multiflora*	Multiflora rose	Invasive
Flora	*Rubus allegheniensis*	American blackberry	
Flora	*Rubus occidentalis*	Black Raspberry	
Flora	*Rudbeckia fulgida*	Orange Coneflower	
Flora	*Rudbeckia laciniata*	Cutleaf coneflower	
Flora	*Rumex britannica*	Greater water dock	
Flora	*Rumex crispus*	Curled dock	
Flora	*Rumex obtusifolius*	Broad-leaved dock	
Flora	*Rumex verticillatus*	Swamp Dock	
Flora	*Salix nigra*	Black willow	
Flora	*Sanguinaria canadensis*	Bloodroot	
Flora	*Sanicula marilandica*	Maryland Black-snakeroot	
Flora	*Sanicula odorata*	Clustered Black snakeroot	
Flora	*Saponaria officinalis*	Common soapwort	
Flora	*Schoenoplectus pungens*	Three-square bulrush	
Flora	*Schoenoplectus tabernaemontani*	Soft-stemmed bulrush	
Flora	*Scirpus pendulus*	Nodding bulrush	
Flora	*Scrophularia* sp.	Figwort	
Flora	*Scutellaria lateriflora*	Blue Skullcap	
Flora	*Sedum ternatum*	Woodland stonecrop	
Flora	*Setaria faberi*	Giant foxtail	
Flora	*Setaria pumila*	Cattail grass	
Flora	*Sicyos angulatus*	Bur-cucumber	
Flora	*Silene latifolia*	White campion	
Flora	*Silene noctiflora*	Night-flowering Silene	
Flora	*Silene stellata*	Starry campion	
Flora	*Solanum carolinense*	Carolina horse-nettle	
Flora	*Solidago altissima*	Late goldenrod	
Flora	*Solidago flexicaulis*	Broad-leaved goldenrod	
Flora	*Solidago rugosa*	Rough-stemmed Goldenrod	
Flora	*Sparganium eurycarpum*	Big bur-reed	
Flora	*Staphylea trifolia*	American bladdernut	

Type	Scientific name	Common name	Comment
Flora	*Stellaria media*	Common Chickweed	Invasive
Flora	*Symphoricarpos* sp.	Snowberries	
Flora	*Symphyotrichum ericoides*	Heath Aster	
Flora	*Symphyotrichum lanceolatum*	Panicle Aster	
Flora	*Symphyotrichum lateriflorum*	Calico Aster	
Flora	*Symphyotrichum novae-angliae*	New England aster	
Flora	*Symphyotrichum shortii*	Short's Aster	
Flora	*Symphytum officinale*	Common Comfrey	
Flora	*Taraxacum officinale*	Common Dandelion	
Flora	*Teucrium canadense*	American germander	
Flora	*Thalictrum pubescens*	King of the meadow	
Flora	*Thalictrum thalictroides*	Rue-anemone	
Flora	*Tilia americana*	Basswood	
Flora	*Toxicodendron radicans*	Poison ivy	
Flora	*Tragopogon* sp.	Salsifies	
Flora	*Trifolium campestre*	Field Clover	
Flora	*Trifolium pratense*	Red clover	
Flora	*Trifolium repens*	White clover	
Flora	*Trillium sessile*	Toadshade	
Flora	*Tritoma* sp.		
Flora	*Tussilago farfara*	Colt's-foot	
Flora	*Ulmus americana*	American elm	
Flora	*Urtica dioica*	Stinging nettle	
Flora	*Uvularia grandiflora*	Large-flowered bellwort	
Flora	*Verbascum thapsus*	Great mullein	
Flora	*Verbena urticifolia*	White Vervain	
Flora	*Verbesina alternifolia*	Wingstem	
Flora	*Vernonia gigantea*	Tall ironweed	
Flora	*Viburnum dentatum*	Southern arrowwood	
Flora	*Viburnum opulus*	Guelder-rose	
Flora	*Vicia cracca*	Bird Vetch	
Flora	*Vinca minor*	Lesser periwinkle	Invasive
Flora	*Viola canadensis*	Canada violet	
Flora	*Viola pubescens*	Downy yellow violet	
Flora	*Viola sororia*	Common blue violet	
Flora	*Viola striata*	Cream Violet	
Flora	*Vitis riparia*	Riverbank grape	
Flora	*Zizia aurea*	Golden Alexander	
Fungi	*Amanita amerirubescens*		
Fungi	*Armillaria* sp.	Honey fungi	
Fungi	*Atrichum angustatum*	Lesser smoothcap	
Fungi	*Auricularia auricula-judae*	Jelly ear	
Fungi	*Bisporella citrina*	Yellow fairy cups	
Fungi	*Bjerkandera adusta*	Smoky polypore	
Fungi	*Boletaceae*	Boletes	
Fungi	*Cyathus striatus*	Fluted bird's nest fungus	
Fungi	*Daedaleopsis confragosa*	Thin-walled Maze Polypore	

Type	Scientific name	Common name	Comment
Fungi	*Daldinia* sp.		
Fungi	*Exidia glandulosa*	Black witches' butter	
Fungi	*Galerina marginata*	Funeral bell	
Fungi	*Ganoderma applanatum*	Artist's bracket	
Fungi	*Ganoderma lucidum*	Lacquered bracket	
Fungi	*Hypoxylon* sp.		
Fungi	*Irpex lacteus*	Milk-white Toothed Polypore	
Fungi	*Laetiporus sulphureus*	Chicken of the woods	
Fungi	*Lentinellus ursinus*	Bear lentinus	
Fungi	*Lenzites betulina*	Gilled polypore	
Fungi	*Lycoperdon perlatum*	Common puffball	
Fungi	*Marasmius rotula*	Collared parachute	
Fungi	*Morchella* sp.	Morels	
Fungi	*Oudemansiella sp.*		
Fungi	*Phellinus gilvus*		
Fungi	*Phellinus robiniae*	Cracked cap polypore	
Fungi	*Picipes badius*	Bay polypore	
Fungi	*Pleurotus ostreatus*	Oyster mushroom	
Fungi	*Pluteus cervinus*	Deer mushroom	
Fungi	*Polyporus squamosus*	Dryad's saddle	
Fungi	*Polyporus varius*		
Fungi	*Poronidulus conchifer*		
Fungi	*Russula* sp.	Brittlegills	
Fungi	*Sarcoscypha occidentalis*		
Fungi	*Schizophyllum commune*	Splitgill mushroom	
Fungi	*Scleroderma citrinum*	Common earthball	
Fungi	*Scutellinia scutellata*	Eyelash cup	
Fungi	*Steccherinum ochraceum*	Ochre spreading tooth	
Fungi	*Stereum hirsutum*	Hairy curtain crust	
Fungi	*Stereum ostrea*	False turkey-tail	
Fungi	*Trametes elegans*	White maze polypore	
Fungi	*Trametes versicolor*	Turkey-tail	
Fungi	*Xylaria polymorpha*	Dead man's fingers	
Lichen	*Caloplaca* sp.	Firedots	
Lichen	*Candelaria* sp.	Candleflame lichens	
Mammal	*Lasiurus borealis*	Eastern red bat	
Mammal	*Microtus* sp.	Meadow voles	
Mammal	*Procyon lotor*	Common raccoon	
Mammal	*Sciurus niger*	Fox squirrel	
Mollusk	*Anguispira* sp.		
Mollusk	*Cepaea* sp.		
Mollusk	*Corbicula fluminea*	Asian clam	
Mollusk	*Lymnaea* sp.		
Mollusk	*Succineidae*	Amber snails	
Reptile	*Apalone spinifera*	Spiny softshell	
Reptile	*Chelydra serpentina*	Common snapping turtle	
Reptile	*Chrysemys picta*	Painted turtle	Unusual, encourage

Type	Scientific name	Common name	Comment
Reptile	*Coluber constrictor*	North American racer	
Reptile	*Diadophis punctatus*	Ringneck snake	
Reptile	*Pantherophis alleghaniensis*	Black rat snake	
Reptile	*Thamnophis sirtalis*	Common garter snake	
Slime mold	*Ceratiomyxa fruticulosa*	Honeycomb coral slime mold	
Slime mold	*Stemonitis splendens*	Chocolate tube slime	
Slime mold	*Trichiaceae*	Slime mold	

Appendix B

Maintenance Calendar

Appendix B Wingfield Pines Conservation Area Maintenance Calendar

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
NOT TIME SENSITIVE							
	Early Successional Upland Forest	Install slab boulders for basking	Staff				
	Ponds	Conduct electrofishing survey	Staff	Consultant or PFBC			
	Treatment Ponds	Investigate use of lotus or waterlily to control algae.	Staff				
	Treatment Ponds	Trap muskrats.	Staff				
	Treatment Ponds	Investigate use of mink to control muskrats.	Staff				
	• Treatment Ponds • Ponds	Install basking structures	Staff				
FEBRUARY							
February	• Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	Install/Clean bluebird boxes	Trained volunteer	• Adult volunteers • Youth volunteers			
MARCH							
March	• Sycamore/Boxelder Forest • Early Successional Upland Forest	Identify/treat lesser celandine populations	Trained volunteer/ Certified pesticide applicator	n.a.			
March	• Sycamore/Boxelder Forest • Early Successional Upland Forest	Identify/treat lesser celandine populations	Trained volunteer/ Certified pesticide applicator	n.a.			
March	Bur-reed Marsh	Relocate bat box to Early Successional Floodplain Forest (2018)	Trained volunteer				

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
March	Early Successional Floodplain Forest	Erect bat box relocated from Bur-reed Marsh (2018)	Trained volunteer				
March	• Bur-Reed Marsh • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Prune obstructing tree limbs along trails and entry road, as necessary	Staff or trained volunteer	• Trained adult volunteers • Professional arborist for large trees/ limbs			
March	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
APRIL							
April	• Early Successional Floodplain Forest • Sycamore/Boxelder Forest • Early Successional Upland Forest	Survey for white troutlily, report to PNHP if ID confirmed	Trained volunteer	n.a.			
April	• Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Identify and flag Callery pear trees for control	Trained volunteer	Trained adult volunteers			
April	Maintained Landscape	Mow as required	Staff	Staff			
April	Sycamore/Boxelder Forest	Inspect trails for flood damage	Trained volunteer	Adult volunteers			
April	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
MAY							
May	Maintained Landscape	Mow as required	Staff				
May	Ponds	Plant aquatic vegetation	Staff or Trained volunteer	Adult volunteers			
May	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			
May	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
JUNE							
June	• Bur-reed Marsh • Wet Shrub Meadow	Treat/remove purple loosestrife	Certified pesticide applicator/ Trained volunteer	• Adult volunteers • Youth volunteers			
June	• Bur-reed Marsh • Wet Shrub Meadow	Survey for and assess invasive cattails	Trained volunteer or botanist	Trained volunteers			
June	• Bur-reed Marsh • Wet Shrub Meadow	Survey for and assess reed canarygrass	Trained volunteer				
June	• Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Cut and treat/Remove Callery pear	Certified pesticide applicator/ Trained volunteers	n.a./Adult volunteers			
June	Early Successional Floodplain Forest	Identify and flag autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Trained volunteer	Adult volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
June	Early Successional Floodplain Forest	Treat/Remove autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Certified pesticide applicator/ Trained volunteers	n.a./Adult volunteers			
June	Early Successional Upland Forest	Identify and remove tree of heaven, Japanese barberry, burning bush, wintercreeper, Amur and Morrow's honeysuckle	Trained volunteer	Adult volunteers			
June	Maintained Landscape	Mow as required	Staff	n.a.			
June	• Maintained Meadow • Early Successional Floodplain Forest	Spot treat Canada thistle	Certified pesticide applicator	n.a.			
June	• Maintained Meadow • Early Successional Floodplain Forest • Wet Shrub Meadow	Remove flower/seed stalks from poison hemlock	Trained volunteer	Trained volunteers			
June	Sycamore/Boxelder Forest	Inspect trails for flood damage	Trained volunteer	Adult volunteers			
June	Sycamore/Boxelder Forest	Survey for and remove Japanese knotweed	Trained volunteer	Trained volunteers			
June	Sycamore/Boxelder Forest	Survey for and remove Japanese knotweed	Trained volunteer	Trained volunteers			
June	Sycamore/Boxelder Forest	Identify and control Amur honeysuckle	Trained volunteer	Adult volunteers			
June	Wet Shrub Meadow	Identify and flag autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Trained volunteer	Trained adult volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
June	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
JULY							
July	• Bur-reed Marsh • Wet Shrub Meadow	Treat/remove purple loosestrife	Certified pesticide applicator/ Trained volunteer	• Adult volunteers • Youth volunteers			
July	• Bur-reed Marsh • Wet Shrub Meadow	Survey for flowering rush	Trained volunteer	Trained volunteers			
July	• Bur-reed Marsh • Wet Shrub Meadow	Treat flowering rush	Certified pesticide applicator	n.a.			
July	• Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Cut and treat/Remove Callery pear	Certified pesticide applicator/ Trained volunteers	n.a./Adult volunteers			
July	Early Successional Floodplain Forest	Identify and flag autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Trained volunteer	Adult volunteers			
July	Early Successional Floodplain Forest	Treat/Remove autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Certified pesticide applicator/ Trained volunteers	n.a./Adult volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
July	Maintained Landscape	Mow as required	Staff	n.a.			
July	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			
July	Sycamore/Boxelder Forest	Identify and control Amur honeysuckle	Trained volunteer	Adult volunteers			
July	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
AUGUST							
August	• Bur-reed Marsh • Wet Shrub Meadow	Remove seed heads from flowering rush	Trained volunteer	• Adult volunteers • Youth volunteers			
August	• Bur-reed Marsh • Wet Shrub Meadow	Treat/remove purple loosestrife	Certified pesticide applicator/ Trained volunteer	• Adult volunteers • Youth volunteers			
August	• Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Cut and treat/Remove Callery pear	Certified pesticide applicator/ Trained volunteers	n.a./Adult volunteers			
August	Early Successional Floodplain Forest	Identify and flag autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Trained volunteers	Adult volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
August	Early Successional Floodplain Forest	Treat/Remove autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Certified pesticide applicator/ Trained volunteer	n.a./Adult volunteers			
August	Maintained Landscape	Mow as required	Staff				
August	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			
August	Sycamore/Boxelder Forest	Identify and control Amur honeysuckle	Trained volunteer	Adult volunteers			
August	• Wet Shrub Meadow • Sycamore/Boxelder Forest	Cut (weed whack) Japanese stiltgrass to ground level	Staff	• Staff • Adult volunteers			
August	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
SEPTEMBER							
September	• Early Successional Floodplain Forest • Wet Shrub Meadow • Sycamore/Boxelder Forest • Early Successional Upland Forest	Cut and treat/Remove Callery pear	Certified pesticide applicator/ Trained volunteer	n.a./ Trained volunteers			
September	Early Successional Floodplain Forest	Identify and flag autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Trained volunteer	Trained volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
September	Early Successional Floodplain Forest	Treat/Remove autumn olive; common buckthorn; Japanese, Amur, and Morrow's honeysuckle; and multiflora rose for control	Certified pesticide applicator/ Trained volunteer	n.a./ Trained volunteers			
September	Early Successional Upland Forest	Litter clean up	Trained volunteer	• Adult volunteers • Youth volunteers			
September	Maintained Landscape	Mow as required	Staff				
September	• Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	Clean bluebird boxes	Trained volunteer	Volunteers			
September	Maintained Meadow	Mow meadow	Staff				
September	Sycamore/Boxelder Forest	Inspect trails for flood damage and remove debris	Volunteer	Volunteers			
September	Sycamore/Boxelder Forest	Identify and control Amur honeysuckle	Trained volunteer	Volunteers			
September	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
OCTOBER							
October	• Early Successional Floodplain Forest • Wet Shrub Meadow	Inspect bat boxes for use. Reposition/ relocate unused boxes	Staff	Adult volunteers			
October	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			

Month	Habitat	Activity	Lead	Team	Area*	Start Date	Completion Date
October	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
NOVEMBER							
November	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			
November	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			
DECEMBER							
December	Sycamore/Boxelder Forest	Inspect trails for flood damage	Volunteer	Adult volunteers			
December	• Treatment Ponds • Bur-reed Marsh • Maintained Meadow • Maintained Landscape • Early Successional Floodplain Forest • Wet Shrub Meadow	After heavy rains, inspect trails and perform casual maintenance as required	Trained volunteer	• Adult Volunteers • Youth volunteers			

*See Appendix C Wingfield Pines Management Zones

Appendix C

Invasive Plant Management

- Control Strategies
- Management Zones

APPENDIX C
INVASIVE PLANT MANAGEMENT CONTROL STRATEGIES

While not intended to take the place of a full invasive plant management plan, the following guidelines will assist ALT staff in understanding important management priorities and strategies.

Amur Maple

Amur maple is a DCNR Watch List Species and is present at very low densities at Wingfield Pines. Eradication is possible. Trained individuals should locate trees during the growing season. Marked trees should be cut down and their stumps removed or treated with herbicide to prevent re-sprouting.[1]

Callery Pear

The abundance of Callery pear at Wingfield Pines is threatening the normal regeneration of the Early Successional Floodplain Forest and Wet Shrub Meadow. Trained individuals should locate trees during the spring blooming season. Small saplings and their roots may be removed by hand. Larger saplings and trees may be cut down and their stumps treated with herbicide to prevent re-sprouting.[1]

Japanese Honeysuckle

Small areas of Japanese honeysuckle are present in brushy areas. Trained individuals can identify this species year round. Since this species does not effectively climb large tree trunks, young trees eventually grow above its reach and the resulting shade results in the honeysuckle's slow decline. Hand removal of vines in heavily infested areas and removing brushy growth (which provides scaffolding for honeysuckle to climb) in favor of the taller remaining trees may be sufficient to limit the harmful effects of this species.

Amur Honeysuckle

This honeysuckle is widespread along the upper banks of Chartiers Creek. Trained individuals can identify this species throughout the growing season. Cutting back the shrubs anytime throughout the year, followed by removal of the stump, is a slow but successful way to extricate this plant from the young forest. Large canopy gaps created during removal should be carefully observed to prevent

[1]Kochenderfer, Jeffrey D.; Kochenderfer, James, N.; Miller, Gary W. 2012. *Manual Herbicide Application Methods for Managing Vegetation in Appalachian Hardwood Forests*. Gen Tech. Rep. NRS 96. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

reestablishment or colonization by other invasive plant species. Foliar application of herbicide may be practical on isolated specimens.[2]

Morrow's Honeysuckle

Lower densities of Morrow's honeysuckle are present along Chartiers Creek and on the steep slopes of the Early Successional Upland Forest. Trained individuals can identify this species throughout the growing season. The control strategies for Amur honeysuckle are applicable for this species. Morrow's honeysuckle is very weak wooded and weak rooted. Even larger plants can be easy to break apart and pull out.

Flowering Rush

Flowering rush presents a serious threat to the wetlands at Wingfield Pines. Flowering rush foliage closely resembles bur-reed. A certified professional should treat flowering plants with appropriate herbicides in July. After treatment, all flower/seed heads should be removed. Early eradication should be attempted as likelihood for re-infestation may be reduced.

Poison Hemlock

Moderate densities of poison hemlock are present throughout the periphery of the Treatment Ponds and Bur-reed Marsh and along trails and open areas within the Maintained Meadow, Early Successional Floodplain Forest, and Wet Shrub Meadow. Regeneration of this biennial species requires annual reseeding, and appropriately protected, trained volunteers can remove developing seed heads each summer to prevent reseeding and control the population.

Japanese Knotweed

Only a few young plants exist in the southern portion of the site. Trained volunteers should conduct June and September surveys for this species, and any identified individuals should be dug out and removed from the property. Control should be coordinated with the owner of the small parcel between of southern end of Wingfield Pines and Mayview Road to prevent encroachment. Eradication is possible at Wingfield Pines with constant vigilance.

[2] Kochenderfer, Jeffrey D.; Kochenderfer, James, N.; Miller, Gary W. 2012. Manual Herbicide Application Methods for Managing Vegetation in Appalachian Hardwood Forests. Gen Tech. Rep. NRS 96. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Purple Loosestrife

Ongoing control efforts have resulted in low densities of purple loosestrife at Wingfield Pines. As this species often goes unseen unless in bloom, multiple summer surveys should be conducted to identify and remove or treat plants. Eradication is unlikely, but persistent efforts can limit purple loosestrife to low densities and low impacts to the ecology at Wingfield Pines.

Japanese Stiltgrass

Large pure stands of stiltgrass are present within the Wet Shrub Meadow, but the full extent of this species' presence within Wingfield Pines is currently unknown. Trained volunteers can survey for this species in June and July. Many cultural, mechanical, and chemical control options are available, but all depend on thoroughness and persistence to be successful.

Reed Canarygrass

Nearly pure stands of reed canarygrass are limiting diversity in the Maintained Meadow and Wet Shrub Meadow. Many cultural, mechanical, and chemical control options are available, but reed canarygrass rebounds quickly if control strategies are inconsistent or irregular. Spot herbicide treatments or repeated cutting (weedwacking) may be effective in the Wet Shrub Meadow. Multiple mowings per year will weaken plants in the Maintained Meadow and foster greater plant diversity.

Lesser Celandine

Lesser celandine spreads very aggressively and successful management requires an aggressive approach. Eradiation is possible if the few observed populations treated as directed with approved in March and April.

Invasive Plants in Pennsylvania

Amur Maple

Acer ginnala

Photo: Paul Wray, Iowa State U., www.invasive.org

Background:

Amur Maple is a native of central and northern China, Manchuria and Japan, and was introduced into the United States in the 1860s. It is still being sold commercially for ornamental use as well as for wildlife and shelterbelt plantings.

Range:

In the United States this tree ranges from Maine to North Dakota and as far south as Kentucky. It is considered invasive across most of its U.S. range.

Image courtesy of USDA PLANTS Database

Description:

Amur maple is a small tree that grows up to 20 feet high with a broad crown, but sometimes pruned as a hedge. Twigs are smooth and light colored. Leaves are opposite, longer than they are wide, and have three shallow lobes and double-toothed edges. Fall leaf color is a brilliant red. Fragrant flowers appear in loose clusters in May and June. Fruit are numerous reddish, two-winged, inch long samaras that mature in late summer and persist on the tree until late fall.

Photo: Leslie Mehrhoff, U. of Connecticut, www.bugwood.org

Habitat:

Often found in early successional forests, forest edges, open disturbed areas, roadsides and as planted ornamentals in yards and gardens. Amur maple tolerates a wide range of soils and pH values. It grows best on moist-well drained soils.

Biology and Spread:

Amur maple spreads primarily though wind-dispersal of abundant winged samaras in late summer and fall.

Photo: Stacey Leicht, U. of Connecticut, www.bugwood.org

Ecological Threat:

Amur maple can displace native shrubs and understory trees in open woods, and shades out native grasses and herbaceous plants in more open habitats. This plant has been widely planted for its hardiness and tolerates a wide range of hardiness zones (zones three through eight).

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How to Control this Species:

Mechanical control

Prescribed fire will set back Amur maple, but not eliminate it. Small infestations can be controlled by grubbing out individual plants.

Chemical Control

These trees can be controlled using a cut-stump treatment with glyphosate herbicide or the cut-stump or basal bark treatment around the trunk with triclopyr herbicide.

Look-A-Likes:

Amur maple is most easily mistaken for a small red maple (*Acer rubrum*). The terminal leaf lobes in Amur maple tend to be more elongate. The undersurface of Amur maple leaves are light green, while red maple tends to have a much paler light color. Amur maple flowers are white and fragrant, while red maple flowers are non-fragrant and red. Amur maple samaras have nearly parallel wings and persist into late fall, while red maple samaras have more angled wings and tend not to persist.

Native alternatives:

A number of native alternatives are similar in size or fall color including mountain maple (*Acer spicatum*), American hornbeam (*Carpinus caroliniana*), pagoda dogwood (*Cornus alternifolia*), fireberry hawthorn (*Crategus chrysocarpa*), pin cherry (*Prunus pensylvanica*), nanny-berry (*Viburnum lentago*) and high-bush cranberry (*Viburnum trilobum*).

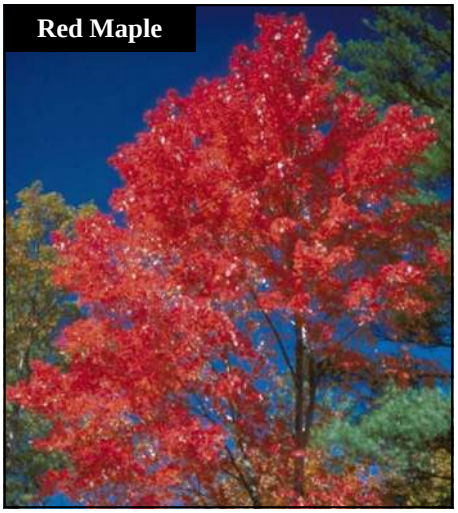

Photo: Robert Anderson, USDA FS, www.forestryimages.org

Photo: Rob Routledge, Sault College, www.forestryimages.org

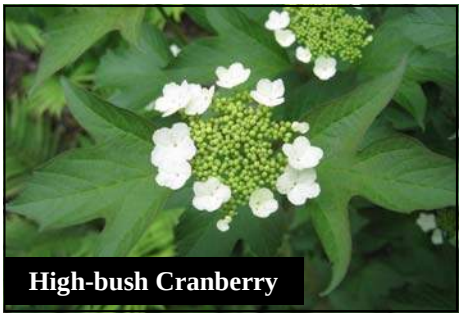

Photo: Rob Routledge, Sault College, www.forestryimages.org

Photo: John Ruter, U. of Georgia, www.forestryimages.org

References:

Amur Maple fact sheet: http://www.dnr.state.mn.us/invasives/terrestrialplants/woody/amurmaple.html

U.S. Forest Service Weed of the Week: http://na.fs.fed.us/fhp/invasive_plants/weeds/armur-maple.pdf

Invasive Plant Atlas of New England: http://nbii-nin.ciesin.columbia.edu/ipane/icat/browse.do?specieId=31

Invasive Plants in Pennsylvania

Callery or Bradford Pear

Pyrus calleryana

Photo: Dan Tenaglia, Missouriplants.com, www.invasive.org

Background:

Callery pear is native to Asia and was brought to Maryland in 1918 as rootstock for cultivated pears. A non-spiny seedling was selected and named "Bradford." This tree became the second most popular tree in America by the 1980s.

Range:

Reports of this tree as invasive in southeast Pennsylvania are starting to surface, but further south in Maryland, Virginia and beyond they have been dealing with this issue for much longer. These trees can also be found throughout the south and Midwest.

Description:

This ornamental, deciduous tree can grow up to 40 feet in height. The shiny green leaves are alternate, simple and two to three inches long. Their margins are wavy with a slightly-toothed margin.

Photo: Chuck Bargeron, U. of Georgia, www.invasive.org

The overall shape of the tree is often described as tear-dropped or spade-like. The bark is scaly and gray-brown in color. Abundant small, malodorous, white flowers appear in spring before the leaves emerge. Fruits are under half an inch in diameter and green to brown in color.

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Habitat:

Typically found along roads, rights-of-way and old fields where they have escaped from landscape plantings. Callery pears will tolerate a wide range of soil conditions and pollution. It prefers full sun but will tolerate partial shade.

Biology and Spread:

The "Bradford" variety of pear was supposed to produce sterile fruits, but more recent cultivars were created to resist splitting by wind and snow. These trees were able to cross pollinate and produced viable seeds that are spread by wildlife. It also spreads vegetatively.

Ecological Threat:

Naturalized callery pears compete with native early successional trees in old fields and hedgerows.

Photo: Britt Slattery, US Fish and Wildlife Service, www.invasive.org

How to Control this Species:

Manual and Mechanical

Seedlings and shallow-rooted trees can be pulled when soil is moist. Small trees will need to be dug up or pulled out with a Weed Wrench tool to ensure removal of all roots.

If cutting down the tree is not possible, it can be girdled during the spring or summer by cutting through the bark all around the trunk, about six inches above the ground.

Chemical

Cutting the tree, followed by an immediate application of a triclopyr or glyphosate herbicide to the cut stump, is the most practical means of control.

Herbicide can also be applied to a girdled tree if total removal of the tree is not possible.

References:

Center for Invasive Species and Ecosystem Health: http://www.invasive.org/browse/subinfo.cfm?sub=10957

Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/callery_pear.htm

U.S. Forest Service Weed of the Week: http://www.na.fs.fed.us/fhp/invasive_plants/weeds/callery_pear.pdf

For More Information:

Plant Invaders of Mid-Atlantic Natural Areas, National Park Service: http://www.nps.gov/plants/alien/pubs/midatlantic/midatlantic.pdf

Invasive Plants Field and Reference Guide, U.S. Forest Service: http://na.fs.fed.us/pubs/misc/ip/ip_field_guide.pdf

USDA PLANTS Database: http://plants.usda.gov

Native Alternatives:

There are a variety of native ornamental trees that provide food for wildlife or beauty in landscapes, such as:

Allegheny Serviceberry
(*Amelanchier laevis*)

Photo: Dow Gardens, www.forestryimages.org

White Fringetree
(*Chionanthus virginicus*)

Photo: Dow Gardens, www.forestryimages.org

Sourwood
(*Oxydendrum arboretum*)

Photo: Richard Webb, www.forestryimages.org

Invasive Plants in Pennsylvania

Japanese Honeysuckle

Lonicera japonica Thunb.

Photo: Chuck Bargeron, U. of Georgia, www.invasive.org

Background:

Also known as Chinese honeysuckle, this Asian plant was first introduced into Long Island, NY in 1806. It has been planted as an ornamental, for wildlife habitat and for erosion control, especially on farms.

Range:

Japanese honeysuckle is very common on the eastern third of the U.S. from Southern Maine to Florida. Isolated patches can also be found from Texas west to California, in Washington state and Hawaii.

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Description:

This evergreen to semi-evergreen woody vine can grow up to 80 feet in length. It has opposite leaves that are typically oval in shape, although the leaves close to the ground may be lobed (*see photo below*). Fragrant white to yellow flowers appear from the leaf axils between April and July. Small, shiny black fruits develop in the fall.

Photo: James Miller & Ted Bodner, Southern Weed Science Society, www.invasive.org

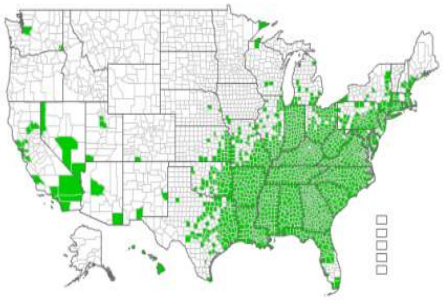

Image courtesy of EDDMapS

Photo: Charles Bryson, USDA, www.invasive.org

Habitat:

This vine can be found in a variety of habitats including forests, wetlands and disturbed habitats like farm fence rows, roadsides and rights-of-way.

Biology and Spread:

This vine spreads both vegetatively through runners and roots as well as by seeds within the black fruits. Birds and other wildlife readily consume the fruits.

Ecological Threat:

The vines can girdle and kill small saplings and form dense mats in tree canopies, shading native vegetation below.

How to Control this Species:

Manual and Mechanical

For small patches, repeated pulling of entire vine and root system may be effective, especially when the soil is moist. Mowing is NOT recommended, as it stimulates growth and leads to denser mats of vegetation.

Prescribed burning will remove the above-ground growth but will not kill the rhizomes, leading to re-sprouts. Grazing by goats has been used in the past but has a similar effect as mowing does, increasing the chance of root sprouts.

Chemical

There are several systemic herbicides that will work on Japanese honeysuckle including glyphosate and triclopyr. Apply a two percent glyphosate or triclopyr and water mix to the vine's leaves from spring through fall (fall is best). A 25 percent solution of herbicide and water can be applied using the cut stump method.

Regardless of the chosen control method, repeated monitoring and sprout removal may be necessary.

References:

Center for Invasive Species and Ecosystem Health: http://www.invasive.org/browse/subinfo.cfm?sub=3039

Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/Japanese_honeysuckle.htm

USDA Forest Service Weed of the Week: http://www.na.fs.fed.us/fhp/invasive_plants/weeds/japanese_honeysuckle.pdf

For More Information:

Plant Invaders of Mid-Atlantic Natural Areas, National Park Service: http://www.nps.gov/plants/alien/pubs/midatlantic/midatlantic.pdf

Invasive Plants Field and Reference Guide, U.S. Forest Service: http://na.fs.fed.us/pubs/misc/ip/ip_field_guide.pdf

Native Alternatives:

Many native vines can be used in place of Japanese honeysuckle:

Virginia creeper
(*Parthenocissus quinquefolia*)

Photo: Theodore Webster, USDA, www.forestryimages.org

Cross vine
(*Bignonia capreolata*)

Photo: Rebekah Wallace, U. of Georgia, www.forestryimages.org

Trumpet creeper
(*Campsis radicans*)

Photo: Charles Bryson, USDA, www.forestryimages.org

Invasive Plants in Pennsylvania

Shrub Honeysuckles

(Amur, Morrow's, Bells, Standish, and Tartarian)

Lonicera maackii, L. morrowii, L. x bella, L. standishii, and *L. tatarica*

Chuck Bargeron, University of Georgia, www.bugwood.org

Background:

Shrub or bush honeysuckles were introduced to North America for use in landscaping, erosion control and wildlife cover. Unfortunately, these plants then spread throughout much of the country.

Range:

The nonnative bush honeysuckles are native to eastern Asia, Europe and Japan. Currently, they can be found in a variety of habitats from the Great Plains to southern New England, and south to Tennessee.

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Description:

Nonnative bush honeysuckles grow to heights of six to 20 feet. Their stems are thornless with a hollow brown pith. Their leaves are opposite and egg-shaped. Their flowers, which bloom from May to June, are fragrant, tubular and less than an inch long. They range in color from white to yellow to pink to red. The berries are small and red or yellow.

Leslie J. Merhoff, University of Connecticut, www.bugwood.org

Habitat:

Nonnative bush honeysuckles are relatively shade-intolerant, and often occur in disturbed woods or edges, roadsides and abandoned fields where more light is available. Morrow's and Bell's honeysuckles are capable of invading bogs, fens, lakeshores and sandplains.

Biology and Spread:

Nonnative bush honeysuckles produce large numbers of small fruits, particularly when growing in open sunlight. These are eaten by birds, which then spread the seeds in their droppings. Once a population establishes, vegetative sprouting continues the spread of these plants.

Ecological Threat:

These invasive species compete with native plants for sunlight, moisture and pollinators. And while birds eat the fruit, it is poorer in fats and nutrients than fruits from native plants, so the birds do not get enough nutrients to help sustain long flights during migrations.

Leslie J. Merhoff, University of Connecticut, www.bugwood.org

How to Control this Species:

The two main methods of controlling nonnative bush honeysuckles are mechanical and chemical. Smaller populations can be removed by hand, making sure to include the roots. Larger populations should be cut to ground level at least once per year, in either early spring or late fall.

Glyphosate can be sprayed onto the leaves, or could also be applied to cut stems in order to kill the root system.

No biological controls are known that would target solely nonnative bush honeysuckle species. In open areas, prescribed fire may help to eradicate this species. In order to optimize this approach, however, the burn should be conducted prior to late summer in order to prevent seed dispersal.

Look-A-Likes:

Native bush honeysuckles exist throughout North America. The natives generally have solid stems, as opposed to the hollow pith of the invasive ones. Be very cautious when buying so-called "native" honeysuckles from a nursery or online.

Native Alternatives:

There are a large variety of shrub-sized, berry-producing, deciduous alternatives for landscaping purposes. These include species such as spicebush (*Lindera benzoin*), dogwoods (*Cornus* spp.) and chokeberry (*Aronia* spp.). These species will all provide food and cover for wildlife.

Photo: Jessica Sprajcar, DCNR

Photo: Chris Vans, River to River CWMA, www.forestryimages.org

Photo: Richard Webb, www.forestryimages.org

References:

Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/bush_honeysuckles.htm

University of Wisconsin, Invasive Plants of Wisconsin: http://www.uwgb.edu/biodiversity/herbarium/invasive_species/lonxbe01.htm

Plant Conservation Alliance's Least Wanted List: http://www.nps.gov/plants/alien/fact/loni1.htm

University of Connecticut Plant Database: http://www.hort.uconn.edu/plants/index.html

Robert W. Freckmannn Herbarium: http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=LONTAT

Invasive Plants in Pennsylvania

Poison Hemlock

Conium maculatum

Pedro Tenorio-Lezama
www.forestryimages.org

Background:

In the 1800s, poison hemlock was brought to the United States from Europe as an ornamental. In ancient times, it was probably used to poison Socrates, a famous Greek philosopher.

Range:

Poison hemlock is native to Europe, western Asia and North Africa. It is now wide-spread throughout much of North America. It has also been introduced to other continents, such as South America and Australia.

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Description:

Poison hemlock is a biennial herb with hollow, purple-spotted stems that can reach eight feet in height. Its finely dissected leaves emit a foul, parsnip-like odor when crushed. Plants begin as a rosette of leaves and flower in the second year of growth. The small, white flowers are borne in umbrella-shaped clusters.

Eric Coombs, Oregon Dept. of Ag.
www.forestryimages.org

Habitat:

This plant commonly occurs in dense stands along roadsides, field margins, irrigation ditches and waste areas. It also invades native plant communities in riparian woodlands, open floodplains and along stream banks.

Biology and Spread:

A single poison hemlock plant can produce over 30,000 seeds. These seeds can adhere to farm machinery, vehicles, fur and clothing, as well as be carried by water, and to a limited extent, wind. Poison hemlock is capable of rapid establishment, particularly in disturbed sites.

Ecological Threat:

Poison hemlock can be a tenacious weed, particularly in moist sites. As a pioneer species, it quickly colonizes disturbed sites, displacing natives. All parts of the plant, especially the seeds, are extremely poisonous to humans and livestock.

John D. Byrd, Mississippi State U.
www.forestryimages.org

How to Control this Species:

Physical

Hand-pulling works best for wet soils with small infestations. Because poison hemlock is not a perennial, removal of the entire root system is not necessary.

Mowing or cutting the plant close to the ground just before flowering is often effective, but may require retreatment if new growth is produced at the base.

Poison hemlock remains toxic for several years after being pulled. Ensure that the material is kept out of reach of children and wildlife.

Chemical

The application of herbicides, such as glyphosate and 2,4-D can effectively control large infestations.

Complete eradication may be difficult if a viable seedbank is present.

Barry Rice, sarracenia.com
www.forestryimages.org

Pedro Tenorio-Lezama
www.forestryimages.org

Look-A-Likes:

Poison hemlock is sometimes confused with the invasive giant hogweed (*Heracleum mantegazzianum*) and our native water hemlock (*Cicuta maculata*). Deaths have occurred from mistaking the roots for wild carrots.

Steve Dewey, Utah State University
www.forestryimages.org

References:

Center for Invasive Species and Ecosystem Health: http://www.invasive.org/browse/subinfo.cfm?sub=4365#maps

USDA Forest Service: http://www.invasive.org/weedcd/pdfs/wow/poison-hemlock.pdf

For More Information:

DCNR Invasive Species Site: http://www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm

DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/poison_hemlock.htm

Invasive Plants in Pennsylvania

Japanese and Giant Knotweed

Fallopia japonica Sieb. & Zucc. and
Fallopia sachalinensis F. Schmidt ex Maxim.

Photo: Leslie Mehrhoff, U. of Connecticut, www.forestryimages.org

Background:

Both species of knotweed were introduced into North America for ornamental use and for forage and erosion control in the late 1800s.

Range:

Both Japanese and giant knotweed come from Japan. They can be found throughout much of the United States and Canada, as well as Europe.

Habitat:

These plants are found at sites with varying combinations of sun, moist soil and human disturbance, such as stream and river banks, wet meadows, roadsides, railroad and utility rights-of-way, vacant lots and waste places.

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Description:

Both are annual, herbaceous perennials with erect, hollow stems that are light green, smooth, jointed and swollen at the nodes (resembling bamboo).

Early in the season, new shoots can grow three to four inches per day. Knotweed grows three to 12 feet tall. The two species are known to hybridize, so ID can sometimes be difficult. The shape of the leaf base is the best characteristic—Japanese knotweed leaves are squared-off, giant knotweed's are heart-shaped.

The plant's greenish white flowers are functionally unisexual, grow approximately four inches in length and appear from August to October. The fruits are papery and contain a three-sided shiny, brown seed.

Photo: Leslie Mehrhoff, U. of Connecticut, www.forestryimages.org

Biology and Spread:

Knotweeds spread primarily by rhizomes. The rhizomes can be dispersed by natural causes, such as flooding and erosion, and also by man-made disturbances to the soil. Cut or broken stems will also root if left on moist soil or put directly into water. It produces only small amounts of viable seed that are dispersed mainly by gravity, wind and water.

Photo: Tom Heutte, USDA FS, www.invasive.org

Ecological Threat:

Knotweeds are capable of quickly forming dense stands where they can crowd out native vegetation. Thickets can clog small waterways and displace streamside vegetation, increasing bank erosion and lowering the quality of riparian habitat for fish and wildlife. Once established, these stands are very difficult to eradicate.

How to Control this Species:

The key to successful knotweed management is controlling the rhizomes.

Manual and Mechanical

Mechanical methods alone are largely ineffective. It may be possible to grub or pull single plants if they are not well established and soil conditions allow for complete rhizome removal. Small portions of the rhizome system not removed have the potential to resprout.

The herbaceous stems of knotweed can be cut or mowed quite easily. Cutting alone will not control the plant but when performed after June 1 will significantly reduce the height of the regrowth.

Chemical

Several herbicides, such as glyphosate, are effective in controlling this species. If the plants grow in a wetland, be sure to use an aquatic approved herbicide. Check label directions and state requirements.

Foliar herbicide applications made after July 1 and before the first killing frost are most effective at injuring the rhizomes. During this time of year carbohydrates produced in the leaves are moved to the rhizomes for growth and storage. Foliar applied herbicides move through the plant with the carbohydrates.

References:

USDA Forest Service Invasive Plants website: http://www.na.fs.fed.us/fhp/invasive_plants

Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/japanese_knotweed.htm

For More Information:

Plant Invaders of Mid-Atlantic Natural Areas, National Park Service: http://www.nps.gov/plants/alien/pubs/midatlantic/midatlantic.pdf

Invasive Plants Field and Reference Guide, U.S. Forest Service: http://na.fs.fed.us/pubs/misc/ip/ip_field_guide.pdf

Native Alternatives:

Once knotweed is removed, you must plant other vegetation to prevent re-establishment of knotweed. The following are useful native plants:

Shrubs - winterberry holly (*Ilex verticillata*), spicebush (*Lindera benzoin*), buttonbush *(Cephalanthus occidentalis*), silky willow (*Salix sericea*), pussy willow (*Salix discolor*)

Photo: John Byrd, Mississippi State U., www.forestryimages.org

Herbaceous species - wild-rye (*Elymus villosus*), big bluestem (*Andropogon gerardii*), switch grass (*Panicum virgatum*), wingstem (*Verbesina alternifolia*), joe-pye-weed (*Eupatorium fistulosum*)

Photo: Jessica Sprajcar, DCNR

Invasive Plants in Pennsylvania

Japanese Stilt Grass

Microstegium vimineum

James H. Miller, USDA Forest Service
www.forestryimages.org

Background:

Japanese stilt grass was first documented in Tennessee in 1919. Its introduction into the United States was accidental, likely a result of its use as a packing material for porcelain.

Range:

Native to Asia, this successful invasive has colonized most of the eastern United States, as far west as Texas.

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Description:

Japanese stilt grass is an annual that typically grows one to three feet in height. Despite its branching, sprawling, mat-like manner, it resembles a small, delicate bamboo. Leaves are narrow and lance-shaped with a distinctive, pale, silvery stripe of reflective hairs on the upper surface. Flower spikes appear in September.

James H. Miller & Ted Bodner, SWSS
www.forestryimages.org

Habitat:

Japanese stilt grass occurs in a variety of habitats, including moist ground of open woods, floodplain forests, wetlands, uplands, fields, thickets, roadsides, and ditches. It readily invades areas subject to regular disturbance. Stilt grass appears to prefer moist, acidic to neutral soils that are high in nitrogen.

Biology and Spread:

Stilt grass reproduces exclusively by seed. One plant may produce 100 to 1,000 seeds that typically fall close to the parent plant. Seeds may be carried by water during heavy rains or move about in contaminated hay, soil or mud stuck in footwear. Stilt grass seeds remain viable in the soil for five or more years and germinate readily.

Ecological Threat:

When Japanese stilt grass invades a site, it can quickly crowd out native plant species. Invasions can also change soil nutrient cycling processes, inhibit tree survival and growth, and reduce light availability. After it dies back in late fall, it forms a thick layer of smothering thatch that is slow to decompose. Because stilt grass is relatively unpalatable, it may encourage heavier deer browsing on native plant species.

Chris Evans, River to River CWMA
www.forestryimages.org

How to Control this Species:

Physical

Japanese stilt grass is quite shallow-rooted and can be easily pulled by hand, especially when the soil is moist. Pulling is easiest in late summer when plants are mature. Stilt grass can also be mowed. Follow up monitoring and treatment will be necessary for years.

Hand pulling and mowing should be done in late summer when the plants are just about to flower. Performing these activities earlier in the summer months encourages flowering and early seed dispersal.

Chemical

For extensive infestations, a systemic herbicide can be used quite effectively. Using an herbicide leaves the plants and soil in place, minimizing the likelihood of additional germination of stilt grass seed.

Grass-specific herbicides, such as quizalofop, limit damage to native plants.

Be careful when treating stilt grass in wetland sites. Make sure you use an herbicide suitable for wetlands.

Chris Evans, River to River CWMA
www.forestryimages.org

Look-A-Likes:

The native perennial Virginia cutgrass (*Leersia virginica*) is quite similar. Japanese stilt grass may also be confused with some smartweeds (*Persicaria* sp.).

Leslie Mehrhoff, U. of Connecticut
www.discoverlife.org

References:

Plant Conservation Alliance's Alien Plant Working Group: http://www.nps.gov/plants/alien/fact/mivi1.htm

Purdue University Cooperative Extension Service: http://www.btny.purdue.edu/weedscience/2011/Microstegium-01.pdf

Wisconsin Department of Natural Resources: http://dnr.wi.gov/invasives/fact/japanstgrass.htm

For More Information:

DCNR Invasive Species Site: http://www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm

DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/Japanese_stiltgrass.htm

Invasive Plants in Pennsylvania

Purple Loosestrife

Lythrum salicaria

Richard Old, XID Services, Inc.
www.forestryimages.org

Background:

Purple loosestrife was intentionally introduced into North America in the early 1800s as an ornamental, as well as accidentally by way of discarded ship ballast. It is now banned as a noxious weed in most states.

Range:

Native to Eurasia, purple loosestrife can now be found throughout much of the United States, especially in the northern and western regions.

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Description:

Purple loosestrife is a perennial herb with square, woody stems, which may grow anywhere from four to 10 feet high, depending on conditions. Its lance-shaped leaves occur in opposite or whorled arrangements. Magenta-colored flower spikes are present throughout much of the summer.

Eric Coombs, Oregon Dept. of Ag.
www.forestryimages.org

Habitat:

Purple loosestrife prefers open wetlands, and is capable of invading freshwater wet meadows, tidal and non-tidal marshes, river and stream banks, pond edges, reservoirs and ditches. It is a hardy plant that can tolerate a range of soil pH, as well as drought.

Biology and Spread:

With an extended flowering season, from June to September, and an unusually high number of flowering stems, each purple loosestrife plant is capable of producing two to three million seeds per year. Research has shown that cultivars, advertised as sterile, are capable of producing viable seed. This plant can also reproduce vegetatively by underground stems at a rate of one foot per year.

Ecological Threat:

An enthusiastic invader of wetlands, purple loosestrife outcompetes native plants, including some federally endangered orchids, forming dense homogeneous stands. These monocultures reduce habitat for waterfowl, clog waterways, disrupt nutrient cycling and collect debris, eventually displacing the entire wetland.

Agriculture and Agri-Food Canada
www.forestryimages.org

How to Control this Species:

Prevention

Early detection and prevention are the best approaches to managing purple loosestrife. Monitoring watersheds yearly to identify new infestations is critical, and can be most easily conducted in late July and August when the plant is in full bloom.

Clean seed and plant parts from animals, equipment and clothing before entering wetland areas.

Prevent nearby infestations from going to seed. Use native competitors as barriers.

Physical

Hand-pulling is only effective for seedlings with small roots.

Mowing is not recommended, but may reduce the production of seeds.

Flooding kills seedlings; established plants must be inundated for weeks. Unfortunately, this also kills desirable vegetation.

The site may need to be replanted with native, competitive vegetation.

Chemical

Glyphosate is effective against purple loosestrife. Be sure to use an herbicide permitted for wetland use. Herbicides can be applied directly to cut stems to reduce collateral damage.

Biocontrol

Although they will not eradicate purple loosestrife, biocontrols can reduce the severity of an infestation. Four species of beetles from Europe, which are fairly host-specific on purple loosestrife, are currently available for control efforts.

Look-A-Likes:

From a distance, purple loosestrife may resemble some native flowering plants, such as blazing star (*Liatris* sp.) and obedient plant (*Physostegia virginiana*). These also make great native garden alternatives.

John D. Byrd, Mississippi State University
www.forestryimages.org

References:

Center for Invasive Species and Ecosystem Health:
http://www.invasive.org/browse/subinfo.cfm?sub=3047

Plant Conservation Alliance's Alien Plant Working Group:
http://www.nps.gov/plants/alien/fact/lysa1.htm

University of Nevada Cooperative Extension:
http://www.unce.unr.edu/publications/files/nr/2002/

For More Information:

DCNR Invasive Species Site: http://www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm

DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers:
http://www.dcnr.state.pa.us/forestry/invasivetutorial/Purple_loosestrife.htm

Invasive Plants in Pennsylvania

Reed Canary Grass

Phalaris arundinacea

Leslie J. Mehrhoff, U. Connecticut
www.forestryimages.org

Background:

Both Eurasian and native ecotypes of reed canary grass are thought to exist in the United States. Invasive populations may be descendants of non-native cultivars or ecotypes, although this is not clear. Aggressive strains have been planted throughout the United States since the 1800s for forage and erosion control.

John M. Randall, The Nature Conservancy www.forestryimages.org

Description:

Reed canary grass is large and coarse, reaching up to nine feet in height. Its flat, blue-green leaves are roughly textured. In June and July, large flower plumes are produced, which are green with a purplish tinge, eventually becoming light tan in color. The stems do not remain standing though the winter.

John M. Randall, The Nature Conservancy www.forestryimages.org

Habitat:

Reed canary grass can be found growing in most types of wetlands, including marshes, alluvial meadows, stream and river banks, shores and ditches. This plant does best in fertile, moist, organic soils in full sun. It has been known to occasionally grow in dry soils in partial shade in upland habitats.

Range:

This wetland grass is native to temperate regions of Europe, Asia and North America. Non-native strains have become naturalized throughout much of the northern half of the United States, and are still being planted on steep slopes and created wetlands.

Biology and Spread:

Although it produces few viable seeds, which are wind, water, animal and machine-dispersed, reed canary grass manages to colonize new sites quite easily. Once established in a wetland, it spreads aggressively by way of rhizomes.

Ecological Threat:

Reed canary grass forms large, monotypic stands that harbor few other plant species and are little use to most native wildlife. It constricts waterways by promoting silt deposition, yet may also encourage erosion of soil beneath its dense mats in places where water flows rapidly. Overtime, it builds up a tremendous seed bank that will erupt when sites are treated for this invasive.

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How to Control this Species:

Physical

Small patches may be effectively dug up or hand pulled. They may also be covered by black plastic for at least one growing season. Be watchful of rhizomes spreading beyond the edge of the plastic.

Mowing twice yearly (early to mid-June and early October) can help control dense stands.

Disrupting the roots every two to three weeks weakens established plants and depletes the seed bank.

Chemical

In small populations, glyphosate can be applied directly to cut stems to avoid collateral damage to native plants nearby.

Herbicide is best applied in early spring when most native species are dormant.

Before applying herbicide, remove dead leaves from the previous year to maximize growing shoot exposure. Use a formulation of glyphosate designed for wetlands.

Native Alternatives:

Many native grasses and monocots are available for wetland restoration.

Dave Powell, USDA Forest Service
www.forestryimages.org

James H. Miller & Ted Bodner, SWSS
www.forestryimages.org

Look-A-Likes:

Reed canary grass could be confused with many grasses, including the non-native orchard grass (*Dactylis glomerata*) and native bluejoint grass (*Calamagrostis canadensis*).

Dave Powell, USDA Forest Service
www.forestryimages.org

References:

Center for Invasive Species and Ecosystem Health:
http://www.invasive.org/browse/subinfo.cfm?sub=6170

Global Invasive Species Database:
http://www.issg.org/database/species/ecology.asp?si=394

Wisconsin Department of Natural Resources:
http://dnr.wi.gov/invasives/fact/reed_canary.htm

For More Information:

DCNR Invasive Species Site: http://www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm

DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers:
http://www.dcnr.state.pa.us/forestry/invasivetutorial/reed_canary_grass.htm

Invasive Plants in Pennsylvania

Lesser Celandine

Ranunculus ficaria

Leslie J. Mehrhoff, University of Connecticut
www.forestryimages.org

Background:

Lesser celandine was introduced into the United States as an ornamental plant. It is still commercially available. All varieties should be assumed to be invasive.

Range:

Native to Eurasia, lesser celandine can now be found in the Northeast and Pacific Northwest regions of the United States.

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Description:

Lesser celandine is a perennial herbaceous plant that forms low-growing mats. Plants consist of a basal rosette of dark green, kidney-shaped leaves. The bright yellow flowers are borne singly on stalks that rise above the leaves. Abundant, finger-like tubers are produce by the roots.

Leslie J. Mehrhoff, University of Connecticut
www.forestryimages.org

Habitat:

Lesser celandine is characteristic of moist alluvial soils in forested floodplains. It can also be found in low open woods, meadows, roadsides and waste places. It seems to prefer moist, sandy soils. Less frequently, it will invade drier soils.

Biology and Spread:

Lesser celandine spreads primarily through vegetative means. Its abundant tubers and bulblets may be unearthed and scattered by animals, well-meaning weed pullers and flood events.

Ecological Threat:

An exotic vernal plant, lesser celandine is aggressive and emerges earlier than most native species. It easily displaces native spring ephemerals with its thick carpet of vegetation. This, in turn, negatively affects native pollinators, which rely on spring ephemerals for nectar and pollen during a time when other food sources are scarce.

John M. Randall, The Nature Conservancy
www.forestryimages.org

How to Control this Species:

Physical

Lesser celandine is very difficult to control. Persistence is key.

Small infestations may be pulled up by hand or dug up with a trowel. Be sure to remove all bulblets and tubers. Deal with small infestations early before things get out of control.

Physical removal causes soil disturbance, which can lead to further infestation by lesser celandine and other invasives. Keep this in mind when dealing with high-quality natural areas.

Chemical

The window of opportunity for the chemical control of lesser celandine is very small. Herbicide should be applied in late winter to early spring (March through May) in order to minimize impacts to native wildflowers. Be careful to apply the herbicide to lesser celandine only, and be aware of the site's proximity to breeding amphibians.

Use a wetland-approved concentration of glyphosate, which is a systemic herbicide that will kill the roots.

Native Alternatives:

Many beautiful native spring-flowering plants are available.

Rob Routledge, Sault College
www.forestryimages.org

Wendy VanDyk Evans
www.forestryimages.org

Look-A-Likes:

Lesser celandine closely resembles marsh marigold (*Caltha palustris*), a native wetland plant. Please take steps to ensure proper identification before any treatment is initiated.

Joseph O'Brien, USDA Forest Service
www.forestryimages.org

References:

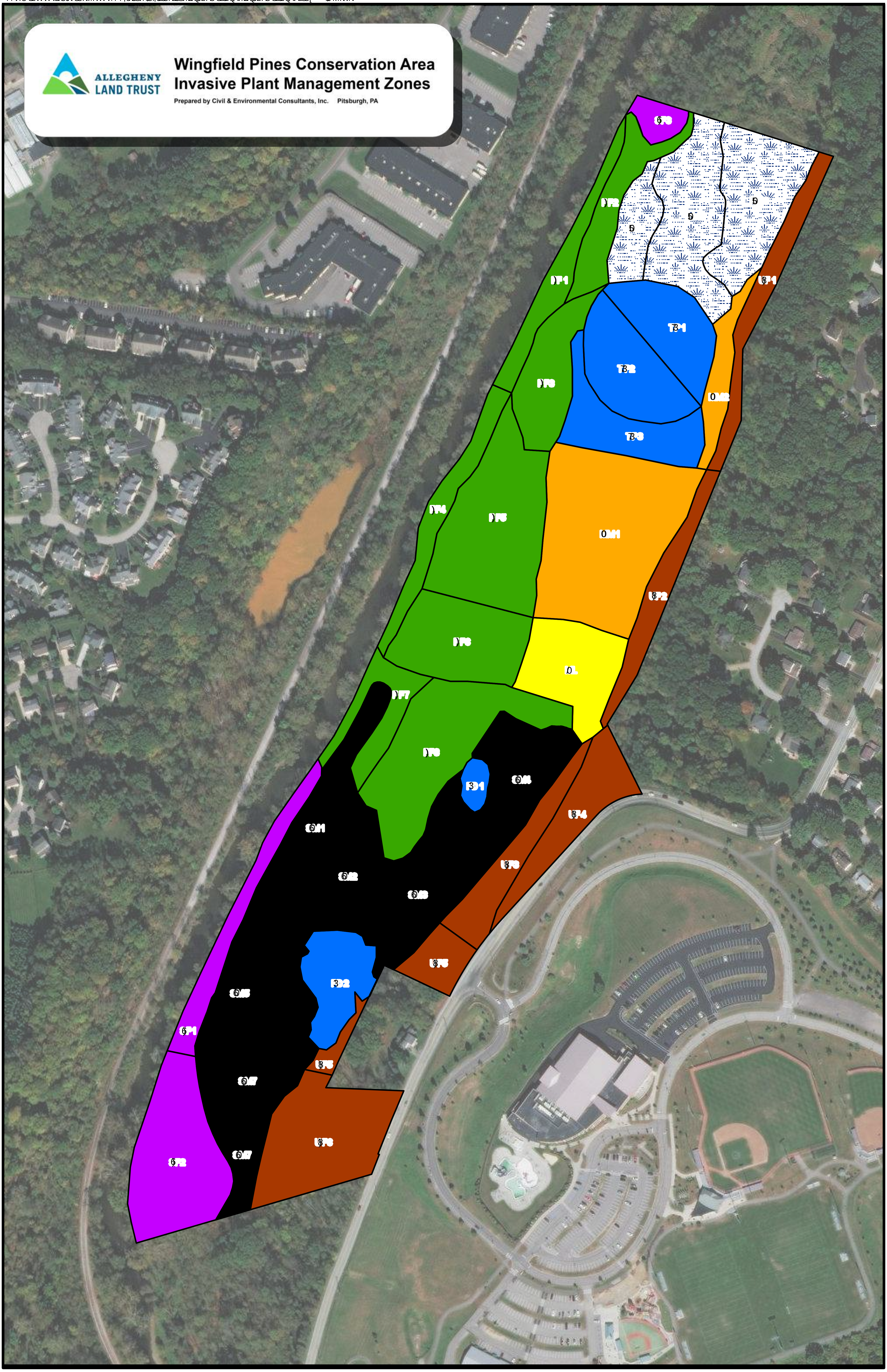
D&R Greenway Land Trust: http://www.drgreenway.org/documents/Invasives/Lesser%20celandine%20fact%20sheet.pdf

Plant Conservation Alliance's Alien Plant Working Group: http://www.nps.gov/plants/alien/fact/rafi1.htm

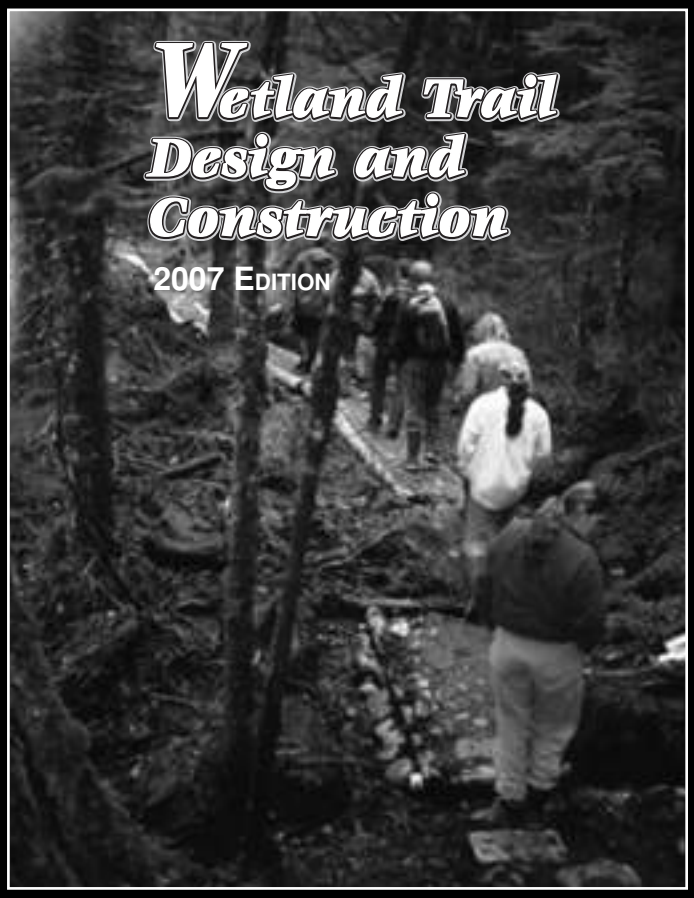
For More Information:

DCNR Invasive Species Site: http://www.dcnr.state.pa.us/conservationscience/invasivespecies/index.htm

DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers: http://www.dcnr.state.pa.us/forestry/invasivetutorial/Lesser_Celandine.htm


ALLEGHENY LAND TRUST
Wingfield Pines Conservation Area
Invasive Plant Management Zones
Prepared by Civil & Environmental Consultants, Inc. Pitsburgh, PA

Appendix D
Wetland Trail Guide



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Missoula, MT

8E82A3—Trail Treatment for Wet Areas

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Acknowledgments

Any document concerning trail construction must recognize the men and women who do the field work—whether they are professionals or volunteers. Some of the most unforgettable and fun-loving people we have known have worked on trail crews.

None of the construction techniques in this document are new. Most have been used for decades. Fortunately, trail crews took the time to explain and demonstrate the construction techniques to us. The techniques described in this manual have occasionally been modified slightly to make it easier to work with contemporary materials.

Christy Fischer was responsible for the initial editing of this manual. Thanks also to the staff at the USDA Forest Service Missoula Technology and Development Center (MTDC), who obtained additional photographs, scanned figures, provided review and additional content, and edited, laid out, and printed this document. In this revised edition, the work involved Bert Lindler, Sunni Bradshaw, James “Scott” Groenier, and Jerry Taylor Wolf. Bob Steinholtz drew the illustrations used throughout this manual. Thanks also to the U.S. Department of Transportation’s Recreational Trails Program for funding the revision and additional distribution of this manual.

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Introduction

Most experienced trail crews try to avoid wetlands because of the construction and maintenance problems they pose. Little has been published on wetland trail construction, and materials that are available are often outmoded or are too regionally focused. By pulling this information together from our experiences, we hope to answer questions you didn't even know you had.

In this manual we have described the common techniques for building a wetland trail. We have also included information on some of the more unusual materials and tools.

Some of the techniques and tools we describe are suitable for wilderness situations where mechanized equipment cannot be used. Others are suitable for urban greenbelts where a wider range of techniques, material, and equipment can be used. Somewhere in between are the back-country sites where machines are permitted, but access and logistics are challenges. Although this book is written for wetland trails, the techniques described can also be used for correcting other poorly drained low areas in existing trails.

The manual is written for those who are untrained and inexperienced in wetland trail construction, but those with experience may learn a few things, too.

The 2007 edition incorporates minor changes to this report, first published in 2001 (0123–2833–MTDC). The changes primarily involve wood preservative treatments and construction details. The list of references has been updated.

Types of Wetlands

Wetland managers and specialists recognize 30 or more different types of wetlands. From a trail construction viewpoint, there are only six types of wetlands, perhaps seven. The basic differences in construction techniques for wetland trails depend greatly on the geologic, hydrologic, and vegetative factors influencing the site and, to a degree, on the wildlife species that live there.

Local indicator plants can help identify whether a site may be a wetland. Test holes and rod soundings can help determine the capability of the soil to support a trail. By studying the soil, the wildlife, and the subsurface water at the site, you can select the appropriate trail layout and construction techniques.

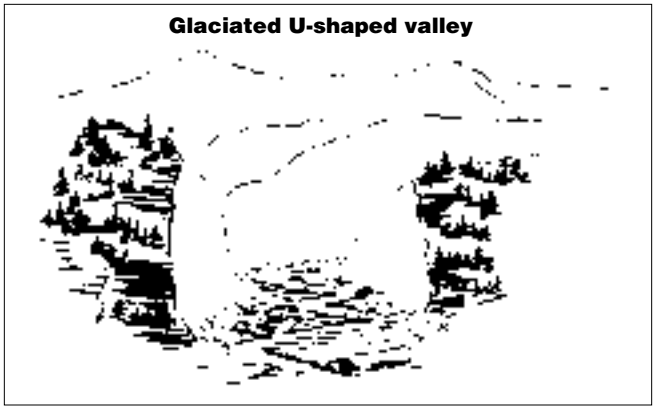


Figure 1—Glacial soils can be expected in U-shaped valleys typical of areas shaped by glaciers.

Wetlands Formed by Glacial Action

Generally, trails are easiest to construct in wetlands formed by glacial action. As a glacier melts, sand, gravel, boulders, and occasional blocks of ice are deposited in a narrow area in a mountain valley. The melting glacier creates a large creek or river that drains the valley. During spring runoff, adjacent wetlands may be underwater, but the ground will still be solid. Although you may be working in standing water, you will not sink in the soil. As the wetland dries out, the surface may be dry and solid. However, water will be just a few inches to a few feet below the surface. During the dry season, the level of the groundwater will normally drop, but it will fluctuate depending on upstream runoff.

Look for this site condition in northern areas that were glaciated during the Ice Age, or in U-shaped mountain valleys. Such valleys indicate previous glaciation (figure 1). To avoid being misled, dig a 4-foot-deep test hole to see whether characteristic sand and gravel are present.

Occasionally, small deep pockets of organic silt and clay are found within wetlands of glacial origin. When these occur near a river or creek, the soil mixture becomes saturated with groundwater and is extremely fluid. These pockets are rare, usually easily visible, and should be avoided. They can be extremely treacherous, especially if covered with a thin layer of ice or snow. One such pocket encountered on a trail project in the Rocky Mountains was 10 feet long, 8 feet wide, and more than 4 feet deep.

Wetlands With Organic Silt and Clay Soils

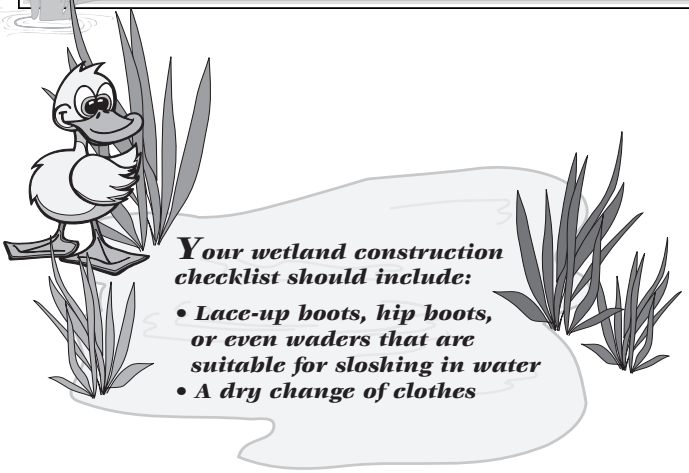
This type of wetland may be the most common. A test hole will indicate that the soil is not sand or gravel, but silt or clay—soils with fine particles. The silt and clay in most wetlands of this type are from organic materials such as leaves, bark, and wood. The terrain traps runoff and the soil particles hold this water, making the area soft underfoot.

Silt and Clay Soils With Some Water

Anyone building a trail through this type of wetland will find that footprints quickly fill with water. Hikers may sink up to their ankles in the unstable soil.

Silt and Clay Soils With Considerable Water

This type of wetland is similar to the one described above. A test hole will indicate that the soil consists of the same silt or clay material; however, it has considerably more water mixed with it. Work is difficult when you immediately sink to your knees or even to your waist.



Your wetland construction checklist should include:

- ***Lace-up boots, hip boots, or even waders that are suitable for sloshing in water***
- ***A dry change of clothes***

A test hole should be as deep as possible. Due to the excessively wet soil, the sides of the hole will continually slough off. It may be impossible to dig deeper than 12 to 18 inches. In that case, rod soundings can help determine subsurface conditions.

Rod soundings are not too difficult to perform or to interpret. A 6- to 8-foot-long steel rod is driven into the ground with a sledge hammer. If the rod hits something solid, it will stop, or slow considerably. The rod may have reached a strata of rock or firm soil that will support construction, or it may have struck a root or an isolated boulder, a misleading indication of overall conditions. Take additional soundings nearby to determine the overall conditions.

An inexpensive and easily portable rod can be made from 2-foot lengths of galvanized, ½-inch diameter pipe. Screw a cap onto one end of one pipe section and screw a coupling onto the other end. Continue with 2-foot sections until at least 6 feet of pipe is assembled. Screw a T connection onto the upper end of the rod so that a ½-inch-diameter steel bar can be passed through the T for leverage in case the rod gets stuck in the ground. Tap the T with a hammer (figure 2).

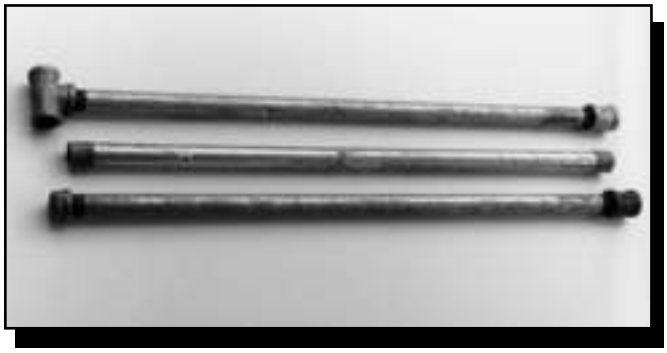


Figure 2—This sounding rod is inexpensive and easy to carry.

The rod can be made as long as necessary. Usually 6 or 8 feet of rod is enough to determine whether a soil problem exists.

River Deposits and Deltas

Soil deposited along rivers and in their deltas may include inorganic clay and an extremely high percentage of water. Walking in this type of wetland is almost impossible. This type of wetland is found along the Missouri River and in the Mississippi River delta, and should be expected along other large rivers.

Floating Wetlands—Trembling Earth or Quaking Bog

Another type of wetland is the result of water-tolerant sedge and sphagnum moss invading lakes. Basically, these wetlands are areas of land floating on water or water-saturated peat. Over the years leaves, needles, twigs, and seeds are carried into a wetland or lake by wind and runoff, eventually forming a layer of organic soil. In areas where the soil and water are extremely acidic, the high volume and acidity of the water keeps organic matter from rotting. As this soil layer builds, the seeds of less water-tolerant plants will begin to grow. After many years a miniature forest of slow-growing, stunted trees will be found on the site. Expect plants such as sedges, sphagnum moss, pitcher plant, cranberry, blueberry, and Labrador tea. Tree species that will tolerate this site condition are alders, balsam fir, black spruce, tamarack, willows, and baldcypress.

This soil will support little foot traffic. Often the ground will compress with weight and quake slightly underfoot. At the extreme, the ground will undulate as it would if someone was walking on a mattress. In the Okefenokee Swamp, this type of wetland is referred to as “trembling earth.” In the Adirondack Mountains and Canada, a similar site is called a “quaking bog.” A test hole may show a thin layer of organic soil, perhaps 1 foot thick. Below it will be a layer of sphagnum moss and peat. Rod soundings in these layers will meet little resistance. When the rod is hit with a 4-pound sledge hammer, people standing 2 to 5 feet away may feel the shock through the ground.

Wetlands on Mountains

Carrs

In mountainous areas, wet trail problems sometimes show up only after the trail has experienced heavy use. The terrain may slope, perhaps by as much as 10 to 20 percent. Problems become evident only when trail traffic wears through a thin layer of soil and exposes a wet, fluid soil that may be 1 to 3 feet thick. Trail crews often refer to these sites as carrs.

If test holes and rod soundings had been taken before construction, they would have revealed this thin layer of soil on top of fluid soil. The fluid layer may be so wet that it would have been impossible to dig a test hole without the hole's side walls continually caving in. Once the fluid layer is reached, the weight of the rod can cause it to sink 1 to 2 feet without being hit by a hammer. Leaning on the rod might cause it to sink 2 to 3 feet. The rod should be hammered until firm soil is reached or the rod has penetrated 8 feet of soil.

Carrs can often be identified by indicator plants. River birch, shrubby willows, and alders growing on what appears to be solid ground should alert a trail designer to the potential problem (figure 3) and the need for soil testing.

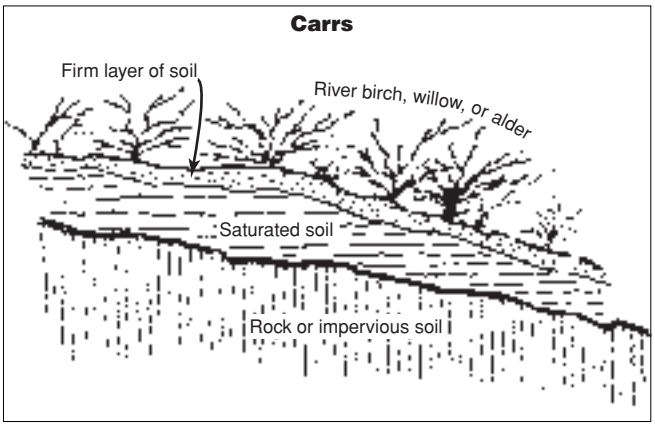


Figure 3—Carrs are characterized by a captive layer of saturated soil just under the surface that is sandwiched between two impervious layers.

Seepage

Some mountain wetlands are caused by subsurface water that seeps to the surface from a perched water table. A perched water table occurs where dense rock or an impervious soil layer is within inches to a few feet below the ground. Precipitation that would normally percolate deep into the ground is trapped near the surface and follows the slope of the impervious material downhill. This condition is common during the spring in high mountainous areas. In the dry season, the surface of the ground may be dry, but water will be only a short distance below. A trail designed and built in the dry season may be unsuitable during the wet season (figure 4).

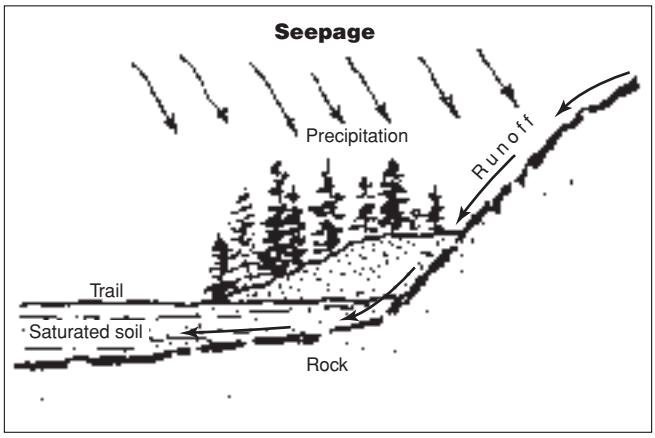


Figure 4—Seepage is sometimes caused by precipitation held in perched water tables.

Another more obvious condition occurs near limestone cliffs. Limestone covers millions of square miles of the Earth's surface, and some limestones are extremely porous. Water will percolate deeply through certain types of limestone. Other types of limestone may be highly fractured, permitting water to penetrate. Water will seep out of the exposed faces (figure 5). This condition also occurs in sandstone formations.

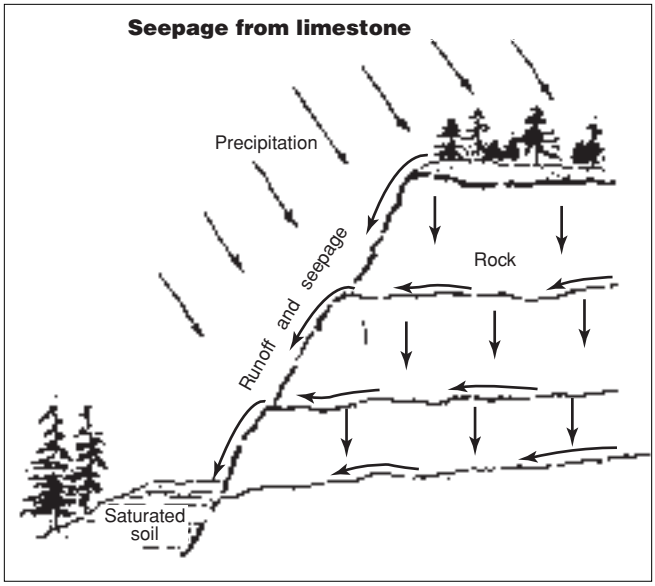


Figure 5—Limestone formations are very porous. Water will percolate through the limestone and seep out of exposed faces and cutslopes.

Spruce Bogs

The spruce bog is a forest type found in the northern United States and throughout Canada and Alaska. The forest often consists of pure stands of black spruce, a slow-growing tree that survives in dense shade where the water table is high. Walking through a mature stand of these trees is a unique experience. The trees may be 6 to 12 inches in diameter, 25 to 40 feet tall, 15 to 40 feet apart, and 200 years old. Because they can withstand shade, the trees are often densely branched to the ground.

In spruce bogs, roots spread on the surface, presenting a problem for trail construction. The roots may be 15 to 20 feet long and as big around as the tree. Large tree roots on one side of the trail spread out and cross into the root system of trees on the opposite side of the trail. Cutting the roots for normal trail construction would leave roots on either side of the trail and unbalance the trees' support. Hikers may trip over the roots if they are left in place. The surface soil is organic and breaks down quickly into ruts and mudholes. Hikers detour around these spots, creating a braided trail with two, three, or four alternative routes.

Muskeg

Muskeg refers to an area covered with sphagnum mosses and tufts of sedges. Muskeg is very common in Southeast Alaska, where all relatively open peat bogs with sphagnum mosses or sedges are called muskeg. The following information about muskeg is from the *Alaska Region Trails Construction and Maintenance Guide* (USDA Forest Service 1991).

Soils in Southeast Alaska maintain a thick, living, organic surface mat, a high percentage of iron oxides, and are often saturated with water. The soil structure breaks down readily under stress or disturbance.

Once the protective mantle and root layer are destroyed, the soil readily turns into water-muck. In some disturbed muskeg soils, there seems to be no limit to how far a person could sink. A site can go from solid footing to knee-deep muck after the trail crew makes just a few trips back and forth.

The volume of traffic these highly organic soils can support is directly related to the network of roots that exist in the soil. This network of roots strengthens the soil just as reinforcing bars strengthen concrete.

Wetlands With Wildlife That Bite Back

The last type of wetland has more to do with hydrology, climate, and wildlife than geology. Sites in the southeastern United States and tropical regions support species of wildlife that look upon man as prey. Building a normal wetland trail in these areas may be hazardous to the crew building the trail and to hikers unfamiliar with the potential dangers posed by local wildlife.

Alligators are often found in wetlands in the southern United States. Normally, alligators are not a problem to adult humans, but they may take an interest in a visitor's dog or small child. Little can be done to permanently keep them off the trail. Alligators may find a way through sturdy barrier fences that are improperly maintained, but may have a harder time finding their way off the fenced trail.

A loop trail should be considered in such areas. The loop trail provides the visitor with a route for hightailing it back to the trailhead, no matter where the alligator is encountered.

If alligators are the primary attraction for an interpretive trail, consider constructing an overlook. An overlook separates visitors from alligators and is an alternative to building a trail into the alligators' territory. In open areas, an overlook may be an effective way to see alligators. In areas with trees or dense brush, an overlook may not be worth the effort or expense. Guided boat trips might be another option for heavily-used locations.

Wetland trails in northern regions have their own potential wildlife challenges. Moose have a fondness for wetlands. Although usually docile, moose can be dangerous during some seasons. In the spring a cow moose is protective of her young. In the fall rutting season, a bull moose can be cantankerous and unpredictable. Moose have been known to attack people with no provocation and to follow wetland trails, including those with a wooden surface. Wetland trails in these areas might be designed with few abrupt curves and sight distances of at least 75 to 100 feet.

In the fall bull moose will demolish typical interpretive signs. One way to reduce sign damage is to use a vertical format for signs and place each sign on a single wide post (figure 6).

Wetlands with beaver, or where there is a possibility of beaver activity, pose different potential problems. Beavers are a natural draw for interpretive trails, but they might chew through wooden piles used to support the wooden deck of a trail. More importantly, they may change the water level of a wetland. A dam built upstream may reduce the flow of water into the wetland and reduce visitor enjoyment. A dam built downstream may raise the water level above the trail. Beavers may also plug culverts, weirs, and overflow structures. The level of the trail should be set higher to allow for higher water. A wetland trail that has been submerged because of beaver activity will require maintenance or reconstruction.

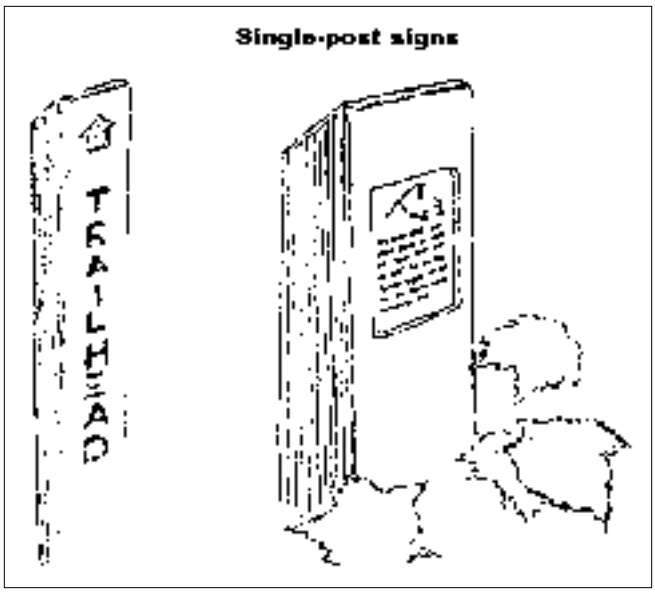
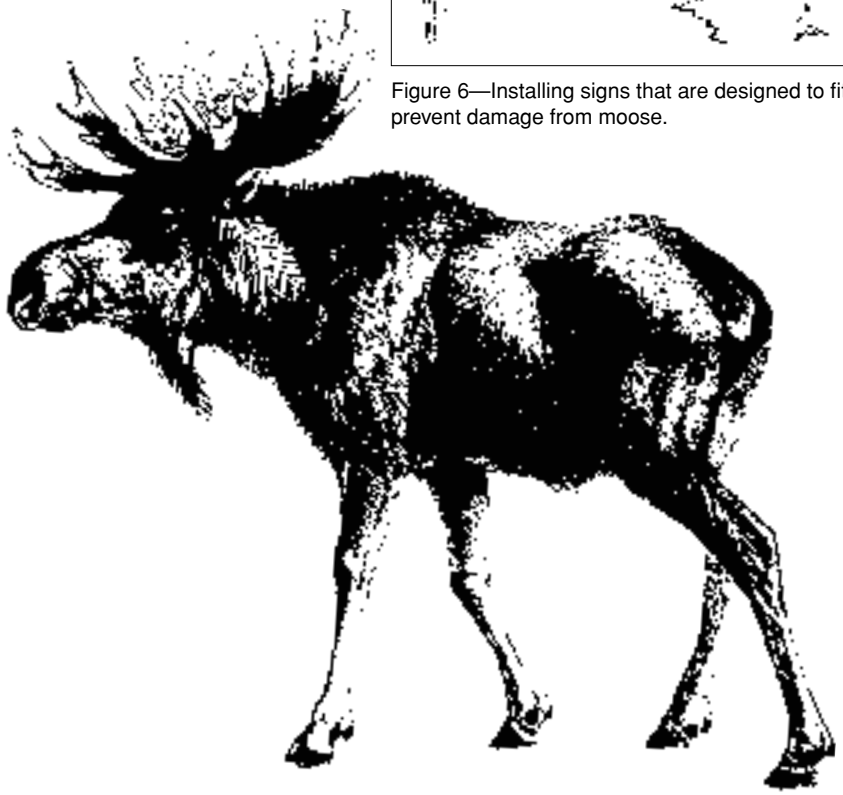


Figure 6—Installing signs that are designed to fit a single post helps prevent damage from moose.



Environmental and Accessibility Compliance

National Environmental Policy Act and Other Federal Laws

Laws, regulations, and management practices affect trail construction activities. Congress passed the National Environmental Policy Act (NEPA) in 1969. The purpose of this act is to ensure that Federal agencies consider the potential adverse effects their activities may have on the environment. The preservation of natural resources is the primary intent of this act, although the act covers cultural resources as well. The National Historic Preservation Act (NHPA) covers cultural resources. The Endangered Species Act (ESA) protects rare, threatened, and endangered plants and animals.

Trail construction on Federal lands, or lands where Federal funds are involved, must conform to these and other laws. Proposed trail routes should be walked by specialists knowledgeable about rare and endangered species of plants and animals. To avoid disturbing important cultural sites, archeologists and historians should be invited to participate. At some locations, cave specialists or fossil specialists will also be important. Trail planning needs to be coordinated with the land management agency that has jurisdiction over the trail.

Each U.S. Department of Agriculture, Forest Service jurisdiction must complete a formal environmental analysis before trail construction or major reconstruction. The process may be simple or complex, depending on the nature of the project and its affected environment. Checking with the District NEPA coordinator is a good first step. Other agencies will have similar review processes. Early in the planning stage, determine the regulations that govern development in the area being considered for construction. Where many agencies have jurisdiction, the agency with the most stringent regulations usually governs.

When Federal funds are not involved, professional ethics on the part of trail personnel suggests voluntary compliance with the intent of the NEPA and NHPA regulations.

The U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers governs construction in navigable waterways and wetland areas of the United States. The agency's primary concern in wetland areas is to limit the volume of fill and avoid filling that would interfere with normal runoff entering the wetland. For a wetland trail the procedure generally involves a letter to the local district headquarters, perhaps a site visit by a Corps representative, and the issuance of a Corps 402 or 404 permit. Generally, complying with Corps requirements also results in construction that needs minimal maintenance.

State and Local Agencies

Many States have enacted regulations controlling wetland development, including trails. More States can be expected to do the same. Some counties and municipalities have their own wetland regulations. More and more trail projects cross agency and property boundaries, so Federal project managers need to be aware of other laws and regulations that might apply.

Occasionally, large areas have been established with uniform regulations applying to many towns and counties. The Adirondack Park Agency is a good example. This agency's regulations apply to 6 million acres of New York State's Adirondack Mountains. Included are all or parts of 12 counties and more than 100 towns and villages. Roughly 45 percent of the land is owned by the State; the rest is privately owned.

Accessible Trails

Trails need to be accessible to people with differing physical abilities. All trails do not have to be accessible to all people, but accessibility is to be considered for new trail construction and major reconstruction. It is a legal requirement to do so.

In May 2006, the Forest Service Outdoor Recreation Accessibility Guidelines (FSORAG) and Forest Service Trail Accessibility Guidelines (FSTAG) became official direction for the USDA Forest Service on National Forest System lands. These detailed guidelines are based on the draft accessibility guidelines for outdoor developed areas created by the Architectural and Transportation Barriers Compliance Board.

To help field practitioners understand the FSORAG and FSTAG, the Forest Service produced the *Accessibility Guidebook for Outdoor Recreation and Trails* (Zeller and others 2006). This new guidebook is easy to use and is full of photos, illustrations, design tips, hotlinks, and valuable sidebars. Readers will have an easier time integrating accessibility into the outdoor recreation environment. The guidebook is available at:

http://www.fs.fed.us/recreation/programs/accessibility/.

Field Work

Turned Around

A legendary Maine guide, so the story goes, insisted that he had never been lost, but he admitted to having been "turned around real good once—for 3 days."

A wetland on an overcast day can easily provide an opportunity to get "turned around real good." Wetland terrain is often featureless. There are no hills, ridges, or rock outcrops, and no obvious slopes. Vegetation is often uniform. If the vegetation is dense and at least 6 feet high, everything looks the same. The problem worsens with fog, rain, or falling snow. Maps and even aerial photographs are useless. There may be no real danger of getting lost. However, it is frustrating and time consuming to lay out a route in the wrong direction or to learn that you are not where you thought you were.

In this situation, a compass is essential. Start using the compass ***before*** entering the wetland and ***before*** getting turned around. Bring vinyl flagging ribbon and a good sighting compass to the wetland on the first day. Hand-held global positioning systems (GPS) are another way you can keep track of your location (figure 7).

Figure 7—Knowing how to use a compass or GPS unit will help you locate the trail.

Sometimes the terrain and vegetation are so uniform you have to mark the general area that the trail will traverse. Using the compass and the vinyl ribbon, flag a straight line route on one particular compass bearing or azimuth. Tie the ribbon at shoulder to eye level. When standing at one ribbon, you should be able to see the next one (figure 8).

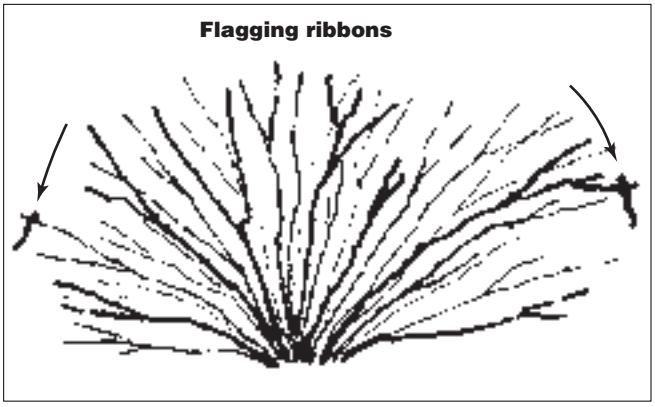


Figure 8—Dense, spreading shrubby plants such as willow and alder may require two flagging ribbons, one on each side of the plant.

Flag the outer perimeters of the general area wherever they are not obvious. Use different-colored ribbons as needed to help you find your vehicle at the end of the day. Not that *you* are likely to get turned around, of course.

Trail Layout

Reconnaissance

Reconnaissance (recon) involves walking over the area the trail will traverse and finding the places where the trail must go and the places you would like it to go. For example, there may be only one location where the trail can enter the wetland with minimal construction. This becomes a construction control point. There may be just one or two places where it is feasible to cross a small stream. These become construction control points. One of these points will probably be incorporated in the final route.

What about a location that provides a distant view? This becomes an esthetic control point. A small island in the wetland supports a variety of plant life that is of interpretive value. The island becomes another control point. A view of a sewer plant on the other side of the wetland is something to avoid. That location becomes a negative control point.

Preliminary Route (P-Line)

The trail must be laid out on the ground. The objective is to tie the control points together in a reasonable route, somewhat like connecting the dots, but on a much larger scale. This is normally done with vinyl flagging ribbon.

Few people use striped ribbon, so consider using it to mark the preliminary route. Carry at least two different combinations of colors (red and white stripes and orange and black stripes or other combinations) (figure 9).

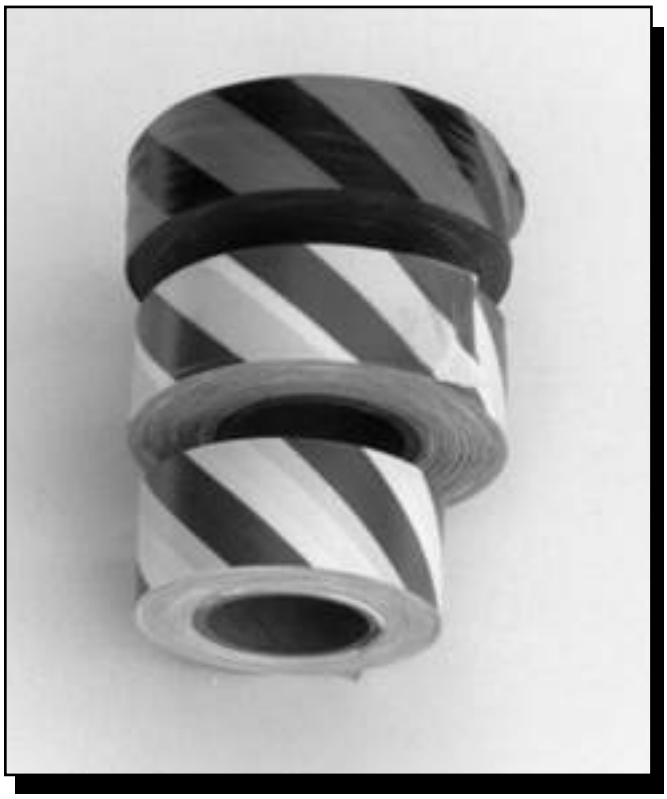


Figure 9—Vinyl flagging ribbon comes in many colors. Striped ribbon is good for marking the preliminary route.

If a portion of the route has to be changed, use the second color of ribbon. Do not tear down the ribbon for the first route that appears to be undesirable; it may prove to be better than the alternative route. Tie the new color of ribbon next to the piece of the first color where you want to depart from the first route. The outcome will be a preliminary route or P-line.

Coordination

The layout of an interpretive wetland trail should be a collaborative effort between people experienced in trail construction and those who will be responsible for the interpretation of the completed trail. All parties need to be brought in at the planning and layout stage. The interpretive staff is in the best position to identify interpretive points.

On an interpretive trail, the interpretive points will be among the control points. Routing any trail through all possible control points would result in a long, zigzag trail that would be expensive to build and would look ridiculous. Usually there must be a compromise between alignment, the length of the trail, construction cost, maintenance problems, and the number of esthetic and interpretive control points along the route. One 600-foot length of trail was built near a beaver dam for its interpretive value. Soon, that length of trail was under almost 2 feet of water and had to be rerouted. That location turned out to be a poor compromise.

After agreement on the P-line, the various compliance specialists should be contacted and, if necessary, brought in to walk the route. These may include specialists from your own agency, perhaps others from the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service, and cultural resource specialists such as historians and archeologists.

Blue Line

It helps to go back over the P-line and refine it with an eye toward reducing construction problems, views of the trail by other trail users, and views of constructed structures from the trail. Refine the alignment to avoid sharp turns and long straight sections.

Blue ribbon is often a good choice for this more precise line. Blue has proven to be the most visible color in areas of dense vegetation. Spending time flagging the blue line will make the final layout work easier and faster. In some agencies, specific colors of ribbon denote specific purposes. Be sure your blue flagged line isn't going to be confused with a logging unit boundary, for example. Sometimes, because of vandalism and removal of the ribbon, the proposed route should not be too obvious. Solid green or black-and-yellow striped ribbon are usually the most difficult to see against vegetation and less likely to be removed. Sometimes cattle and wildlife chew on the ends of the ribbon. You may be able to locate the flag line by looking for the remaining knots of ribbon.

Final Layout

The designer and one or two assistants measure the route and keep notes (appendix A) on distances and locations and on the lengths of items that will be needed during construction. This information is extremely important for preparing accurate cost estimates, ordering materials, tools and equipment, and determining the size of the construction crew.

Distances are usually recorded by station, an engineering measuring system used for roads, railroads, and utility lines. Traditionally, in this system 100 feet is written as 1+00; 1,254 feet is 12+54. The distances are measured with either a 100-foot or 50-foot measuring tape and are "slope measured" (measured along the slope). Wire flags are marked with the station distance and stuck in the ground at the approximate location that has been measured. Using metric measurements, 100 meters is written as 1+00; 1,254 meters as 12+54.

The trail grade (the slope of the trail route) is measured on the ground between stations and between obvious changes in slope. At most sites a clinometer or Abney hand level is sufficiently accurate for this work. Precision is not as critical for a trail as it is for a road.

Measure the slope as a percentage of grade (the vertical rise or fall in feet per 100 feet of horizontal distance, or meters per 100 meters of horizontal distance) and record it in the notes. Where the route rises, it is shown as a positive or plus grade. Where the route drops, it is a negative or minus grade. Appendix B has slope conversion information.

A crew of three is more efficient than a crew of two for doing final layout. A crew of three is almost essential in areas of dense vegetation.

The field notes can be kept on Rite-in-the-Rain waterproof paper and stored in a 4- by 6-inch ring binder (figure 10). A blank form that you can copy is included in appendix A.

Figure 10—This field notebook is a tried and true technology that works.

The form shown (figure 11) is 4¼- by 5½-inches or a half sheet of paper. After the workday, remove the notes from the ring binder and leave them in the office or at camp. Normal surveyor's notebooks are awkward for trail field notes—they keep trying to close up and they are difficult to copy.

The field notes should include important basic information: location, project, date, weather, first and last names of the crewmembers, job assignments, color of the flagging ribbons, and the location of the 0+00 station referenced to fixed objects on the ground. Clear and consistent handwriting and language skills are important. Standard abbreviations should be used and the abbreviations must be explained to others on the crew. Provide a legend for unusual abbreviations. Sketches and maps are also valuable sources of information. Eventually, the field notes will get to the office where someone else may have to interpret them.

What a waste of time it would be to go through all this work and end up with notes that are unusable. Paper is inexpensive compared to the time required to gather this information. Do not write notes too close to each other. When you make an error, put a single line through the mistake. Do not try to write over or erase it. Go to the next line and write in the correct information.

It is critically important to note the colors of ribbon that you used. Trail construction workers will need to know the color of ribbon they will be looking for. Six months after the field layout, even the workers who laid out the trail will not remember what colors were used.

Drawings, Specifications, and Cost Estimates

Regardless of who builds the trail, the field notes must be converted to drawings and specifications that can be used in the office for estimating costs and ordering materials, and in the field for construction.

Station & distance	Tread width	Sideslope (percent)	Gradient (percent)	Notes
				Pingree Park—Accessible
				wetland trail.
				9/10/97—Sunny, warm.
				Bob Pilk, Terri Urbanowski,
				Bob Steinholtz. Red
				ribbon/red flags.
				0+00-35' east of flag
				pole/north curb.
0+00				
	4'	25	5	
0+50				
	4'	30	5	
0+75				Enter willow brush
	4'	30	5	Heavy brush clearing
1+00				
		35	5	
1+76				Intersection with wetland
		10	4	loop—rt (south route)
				end willow brush clearing.
1+81				Begin bog bridge/piles
		0	4	
2+04				End piles, begin B.B. on
		0	-2	sleepers

Figure 11—Sample field notes are legible and have the information needed to locate the trail and plan for materials.

Station & distance	Tread width	Sideslope (percent)	Gradient (percent)	Notes
2+38				End B.B./begin turnpike.
		0	+2	
2+74				End turnpike/begin B.B. on
		0	+2	sleepers—medium willow
				brush clearing.
3+06				
		±10	0	Hummocky/begin B.B. with
				cribbing, some cribbing
				one side only.
3+58				Timber culvert: 8' span by
	4'	0	0	4' height
3+66				
		0	0	
3+86				River on rt. Suggest 20 lf
		10	-1	of Geoweb in turnpike.
4+19				End turnpike. Begin trail
				on
	4'	0	+2	solid ground.
4+97				Sta. 4+97 = 1+76

Figure 11—(continued).

The drawings should include the approximate layout of the route, indicating landmarks and major items of construction. A second drawing at a larger scale should indicate by station or distance where these items begin and end. These distances are subject to field adjustment. Several large-scale drawings may be needed to show the whole trail route.

Drawings with construction details will also be needed for cost estimates and construction. These large-scale drawings show the construction materials, their dimensions, how they are put together, and how they are attached.

A specification defining the quality of the materials and craftsmanship must also be written. For a simple project, this information can be included on the drawings. The specification is also needed by the cost estimator, the individual ordering the materials, the crew chief, and the project inspector.

Preparing drawings and a specification may sound like a lot of work, but preparation reduces the questions of the construction crew and the time spent by the designer in the field during construction. Such work also reduces the possibility that the wrong materials could be delivered to the worksite. Written drawings and specifications are essential for contracts. Forest Service employees should follow the format of *Standard Specifications for Construction and Maintenance of Trails* (USDA Forest Service 1996) and *Standard Drawings for Construction and Maintenance of Trails* (USDA Forest Service 1996).

If the work is to be done in-house with an experienced crew, sometimes the procedures can be simplified. It is still a good idea to have drawings and written specifications, because they can prevent misunderstandings.

Wetland Trail Structures

At least eight types of trail structures are commonly built in wetlands. Some of these are built with no foundation. Others have sleepers (sills), cribbing, or piles as foundations. Most of these structures are built of wood.

The oldest methods for building a wetland trail were corduroy and turnpike, which require no foundation. Turnpike may require constructing timber culverts, which involves building two small timber walls. The walls must rest on a buried timber sill. Planks span the space between the walls.

The various types of puncheon, gadbury, and the simplest form of bog bridge construction may be built on a foundation of sleepers, or on log or timber cribbing. Cribbing is more difficult to construct and is used occasionally where the terrain is hummocky (having small mounds of vegetation interspersed with depressions that hold water).

Bog bridges and boardwalks are often supported on pile foundations. Three types of pile foundations have been used for bog bridges and boardwalks: end-bearing piles, friction piles, and helical piles. Piles are the most labor-intensive foundation. Helical piles and some friction piles require specialized machinery for installation.

Floating trails are another, less common, technique. Where they are used, you need some form of anchorage.

In this manual we describe the structures more or less in historical order. The oldest are early in the list, and the newest or most difficult to construct appear toward the end. The older structures can be built without machines, although machines make the work go faster. The newer structures are easier to build if machinery is available.

Sustainable Design

Sustainable design essentially asks the trail designer or builder:

- Can we use the proposed construction technique and expect the materials and the various processes to be available years from now if we need to replace part of the trail?
- When the item is no longer usable, can any of the materials be recycled?
- Can recycled materials be used in the construction?
- Are recycled materials appropriate for the proposed use?

These criteria should be considered by all agencies, especially conservation agencies.

Corduroy

Corduroy was originally used to provide access through wetlands to areas being logged or mined. Essentially, the technique involved laying a bridge on the ground where the soil would not support a road. Two log stringers or beams were placed on the ground about 8 feet apart. Small-diameter logs or half logs were placed on the stringers, spanning them. The logs became the tread or surface of the road. They were spiked or pinned to the stringers (figure 12).

A variation of corduroy construction was to place the tread logs directly on the ground. No stringers were used, and the logs were not pinned or spiked to the ground or each other. Some excavation was required to ensure the tread logs were level. The tread logs eventually heaved up or sank, creating severe cross slopes in the tread.

Corduroy construction was often used in areas with deep shade and considerable rainfall. The combination of sloping, wet tread resulted in a slippery, hazardous surface. The stringers and tread logs soon rotted. With no support, the cross slope on the tread logs became worse and more hazardous.

When corduroy was laid directly on the ground, it interfered with the normal flow of runoff. Runoff was blocked in some areas and concentrated elsewhere. Erosion and relocation of minor streams resulted. No plants grew underneath the corduroy, further damaging the wetland resource. Many trees needed to be cut to provide the logs for the corduroy. In many cases, these impacts would be unacceptable today. The useful life of corduroy today is only 7 to 10 years. Corduroy is rarely replaced because suitable trees are even farther from where they are needed for the reconstruction job.

Corduroy did not represent sustainable design and required considerable maintenance. Corduroy is rarely used today. We do not recommend it.

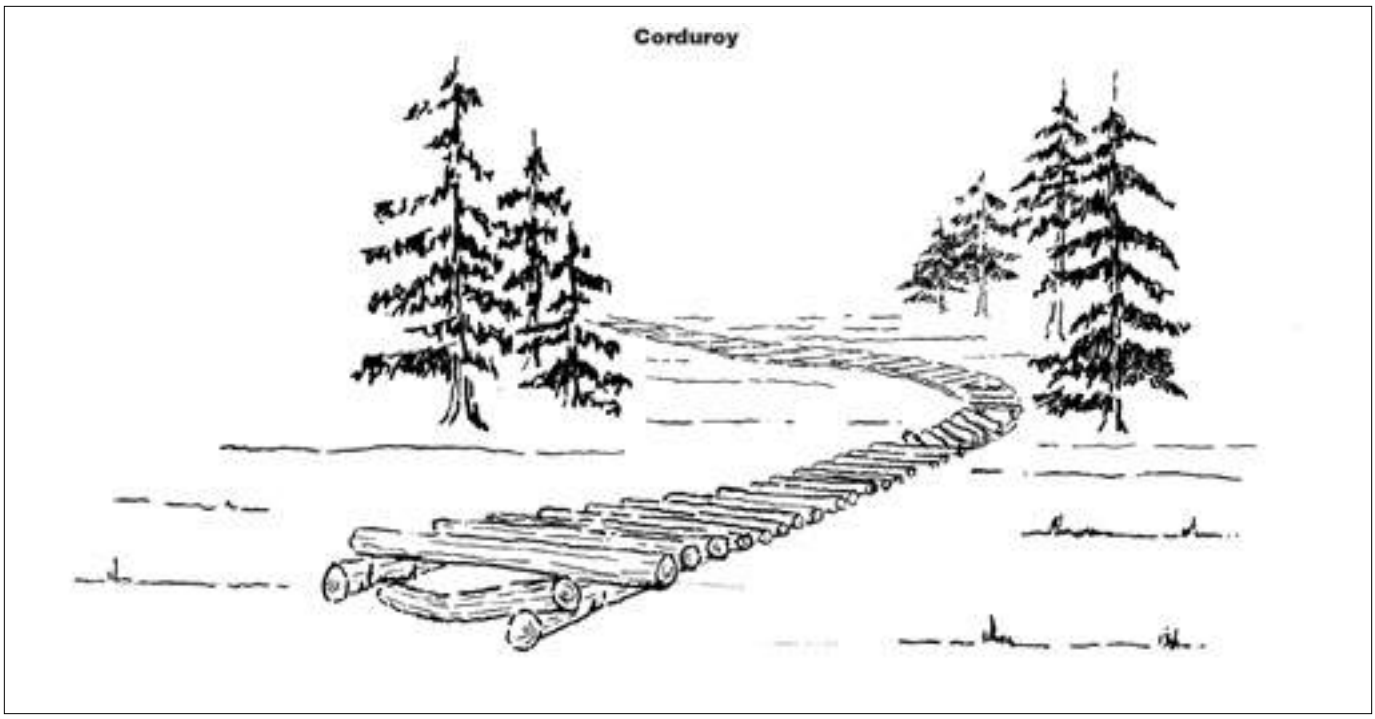


Figure 12—Corduroy requires a lot of native material, rots quickly to an unsafe condition, and is no longer recommended for new construction.

Turnpikes

Turnpikes are used to elevate the trail above wet ground. The technique uses fill material from parallel side ditches and other areas to build the trail base higher than the surrounding water table. Turnpike construction is used to provide a stable trail base in areas with a high water table and fair- to well-drained soils (figure 13).

A turnpike should be used primarily in flat areas of wet or boggy ground with a 0- to 20-percent sideslope. The most important consideration is to lower the water level below the trail base and to carry the water under and away from the trail at frequent intervals. Turnpikes require some degree of drainage. When the ground is so wet that grading work cannot be accomplished and drainage is not possible, use puncheon or some other technique. A turnpike is easier and cheaper to build than puncheon and may last longer. A causeway is another alternative where groundwater saturation is not a problem and a hardened tread is needed.

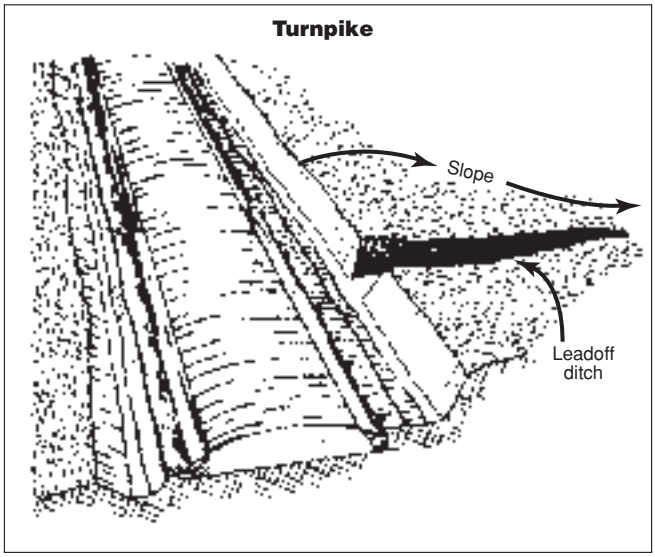


Figure 13—Trail turnpikes usually cost less than other techniques for crossing seasonally wet areas. Occasional culverts are needed for cross drainage under the turnpike.

Begin the turnpike by clearing a site wide enough for the trail tread and a ditch and retainer log or rocks on either side of the trail tread. Rocks, stumps, and roots that would protrude above the turnpike tread or rip geotextiles should be removed or at least cut flush below the final base grade.

Ditch both sides of the trail to lower the water table. Install geotextile or other geosynthetic materials and retainer rocks or logs. Geotextile and geogrid should go under any retainer rocks or logs (figure 14). Lay the geotextile over the ground surface with no excavation, then apply high-quality fill. An alternative method, one that not only provides separation between good fill and clay, but also keeps a layer of soil drier than the muck beneath, is called encapsulation (the sausage technique). Excavate 10 to 12 inches of muck from the middle of the turnpike. Lay a roll of geotextile the length of the turnpike, wide enough to fold back over the top with a 1-foot overlap (figure 15). Place 6 inches of crushed stone, gravel, or broken stone on top of the single layer of geotextile, then fold the geotextile back over the top and continue to fill with tread material.

Rocks or logs can be used for retainers. Rocks last longer. If you use logs, they should be at least 6 inches in diameter, peeled, and preferably treated or naturally decay-resistant. Lay retainer logs in a continuous row along each edge of the trail tread.

Anchor the logs with stakes or, better yet, with large rocks along the outside. The fill and trail surface keep the retainer logs from rolling to the inside.

The practices described above work best on turnpikes in mountain bogs or other areas that are not subject to periodic river flooding. In flood-prone wetlands, different techniques work better. One turnpike was flooded to a depth of 6 to 8 feet on two occasions in 1 month. Stones up to 1 cubic foot in an adjacent area of riprap were lost in the flood. The edges of that turnpike were logs pinned to the ground with diagonally driven driftpins that helped to keep the logs from floating up and away. The logs were still in place after the flood, but the fill material between the logs had been swept away. Geotextile fabric that had been installed between the fill and the ground was still in place. In retrospect, if geocell or geogrid had been placed on the geotextile fabric and stapled, nailed, or placed underneath the logs, most of the fill material would probably have remained in place (figure 16).

Wood used in turnpike construction should be either a naturally decay-resistant species or treated poles. Pinned as described, the logs or poles should survive some floods.

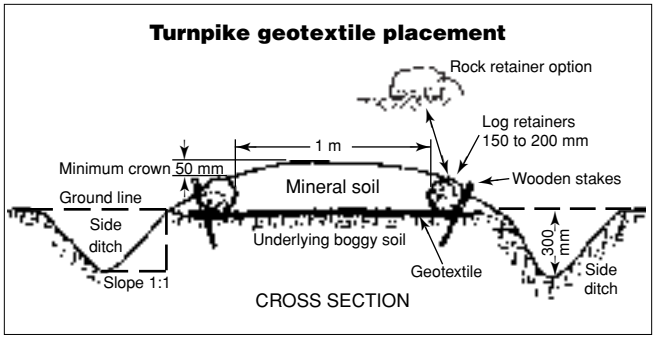


Figure 14—Place the geotextile under the retainer logs or rocks before staking it.

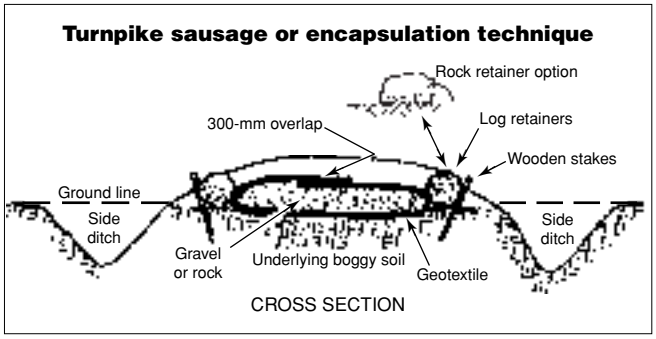


Figure 15—Sausage or encapsulation method.

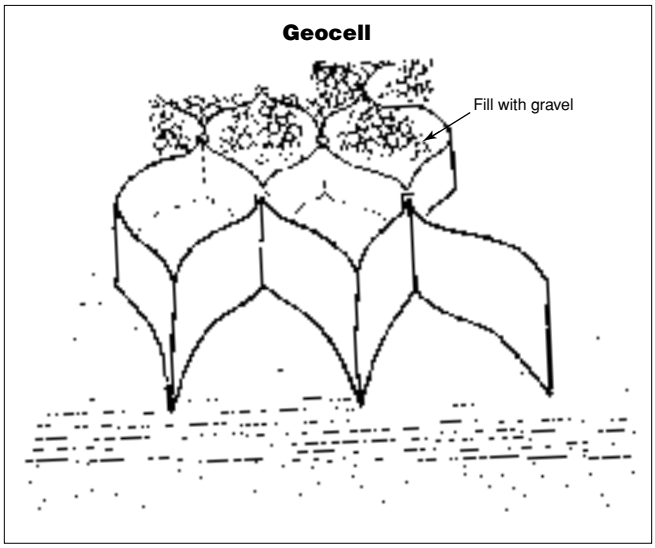


Figure 16—Geocell may help keep fill in place in areas prone to flooding.

Firm mineral soil, coarse-grained soils or granular material, or small, well-graded angular rock are needed for fill. Often, gravel or other well-drained material must be hauled in to surface the trail tread. If good soil is excavated from the ditch, it can be used as fill. Fill should not include organic material and should have minimal silt and clay components. Fill the trail until the crown of the trail tread is 2 inches above the retainer or outsloped a minimum of 2 percent. It doesn't hurt to overfill initially, because the fill will settle (figure 17). Compacting the fill—wet it first—with a vibratory plate compactor will help reduce settling.

Figure 17—A new turnpike will need additional fill as it settles, especially during the first year. This turnpike has a timber culvert.

Fill material imported from outside sources may contain seeds of invasive weeds. Instead, it is standard procedure to dig a borrow pit near the site. The pit and routes to it should be carefully located to avoid resource damage and a construction scar that will be seen for many years. The borrow pit should be dug into a slope so that the floor of the pit can slope out and carry runoff water out of the pit. After the trail has been completed, grade back the sides of the pit and revegetate the disturbed area with native plant material.

Keep water from flowing onto the turnpike by constructing a dip, waterbar, or a drainage structure at each end of the turnpike where necessary. Keep the approaches as straight as possible or widen any curves coming onto a turnpike to minimize the chance that packstock or motorbike users will cut the corners and end up in the ditches.

Turnpike maintenance, especially recrowning, is particularly important the year after construction; the soil settles the most during the first year.

Causeways

A more environmentally friendly relative of the turnpike is the causeway, essentially a turnpike without side ditches (figure 18). Causeways filled with broken rock have been successfully used throughout the Sierra Nevada and elsewhere to create an elevated, hardened tread across seasonally wet alpine meadows. Often, multiple parallel paths are restored and replaced with a single causeway. Causeways create less environmental impact than turnpikes because they do not require ditches that lower the water table. In highly saturated soils the causeway could sink into the ground, a problem that geotextiles can help prevent.

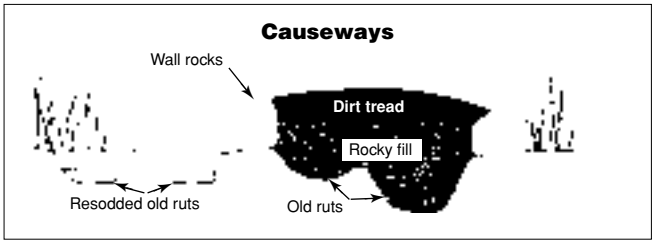


Figure 18—Causeways create an elevated, hardened tread across seasonally wet areas. Geotextiles may be added to help prevent the trail from sinking into the ground.

Improving Drainage
Dips or Ditches

Turnpikes and causeways interrupt the flow of water along and across the trail. You need to take measures to ensure that water flows away from turnpikes instead of saturating them. The tools to ensure that water flows away form turnpikes include: dips (or ditches), open drains, French drains or underdrains, and culverts.

Generally, dips are at least 12 inches deep, have flat bottoms, and sideslope ratios of 1:1. In many cases, the dip can be extended beyond the wet area to capture water that might flow onto the trail.

The simplest way to get water across a trail is to cut a trench across it. These open-top cross drains, or dips, can be reinforced with rocks or treated timbers to prevent cave-ins. These structures are not usually a good alternative because people and packstock stumble on them. One way to reduce this risk is to make the dip wide enough (at least 2 feet) so that packstock will step into the drain rather than over it (figure 19).

An open drain can be filled with gravel. Such a drain is called a French drain. Start with larger pieces of rock and gravel at the bottom, topping the drain off with smaller aggregate (figure 20). French drains are often used to drain a seep or spring underneath a trail bed. A perforated or slotted pipe in the bottom of the drain reduces the amount of fill material needed and drains the area more effectively.

Culverts

Culverts provide better and safer drainage across turnpikes than open drainage gaps or ditches.

Historically, culverts were built as small bridges, using stone or logs. Stone culverts require large stones and a skilled mason. Finding large stones is difficult. Today, dry stone masonry is almost a lost art. Well-built stone culverts can be extremely durable. Some stone culverts that are at least 100 years old are still in use.

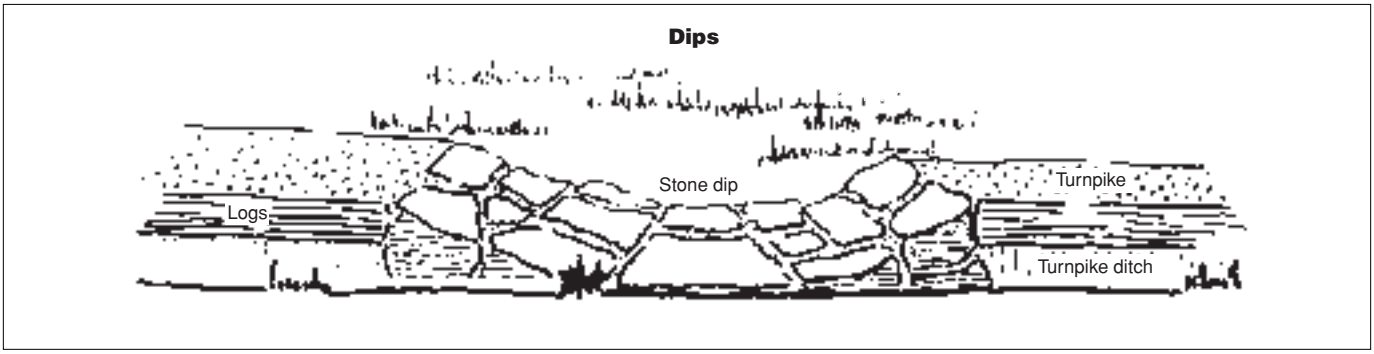


Figure 19—Dips and ditches are a simple and effective way to drain wet areas. The slope angle and depth vary with soil and water conditions. Stones help reinforce the dip. Geotextile may be installed under the stone dip to prevent fine materials from washing out.

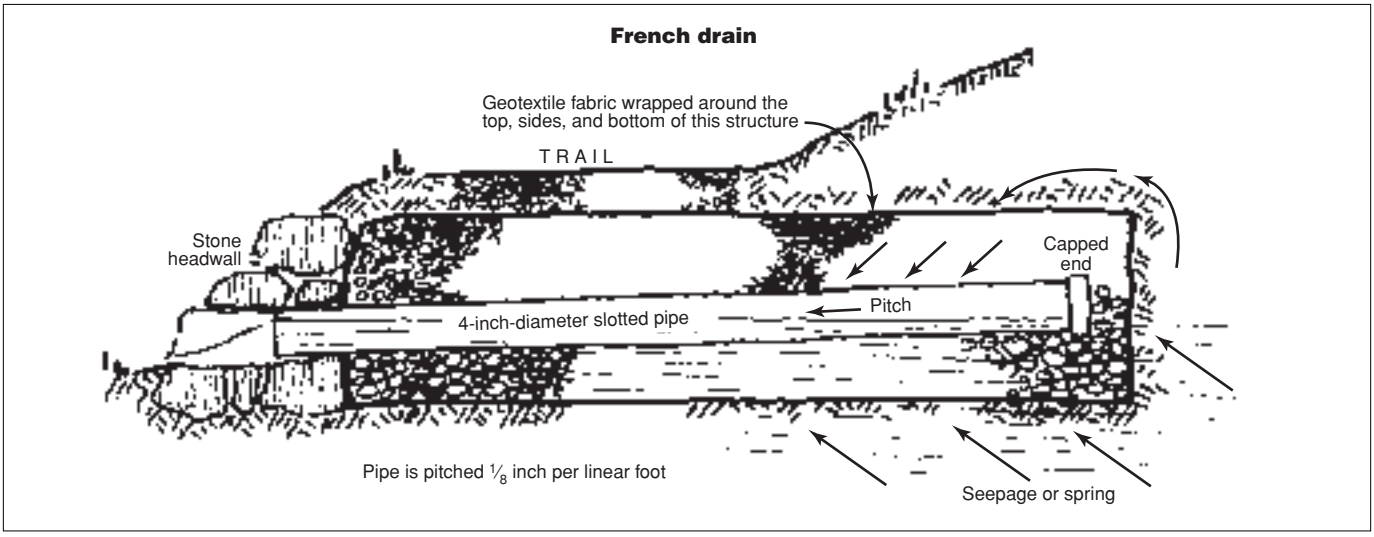


Figure 20—Wrapping French drains with geotextile helps prevent clogging. French drains or underdrains are used to drain springs and seeps that have a low flow.

Log culverts were used where stone (and stone masons) were not as readily available as logs. Construction crews may also have been more familiar with log construction. Log and timber culverts require less skill to build than stone culverts, but need maintenance. Expect to replace log culverts in 20 to 40 years, although they can last much longer.

Building a timber culvert is simple. We typically use 6 by 6 and 4 by 6 timbers, cutting them to any length suitable for the site and trail condition. Although old railroad culverts sloped the invert of their culverts, it may be difficult to do so in a wetland. In fact, it may be wise to build the invert level. This way the rising water from a creek or river can easily flow through the culvert as the water rises and recedes during a flood.

To build a timber culvert, two timber sleepers are placed in a shallow trench on each side of the trail, parallel to the trail centerline. The sleepers are pinned to the ground with at least two driftpins (figure 21). A timber wall is constructed on each side of the invert, resting on both sleepers. These walls can be as high or low as is suitable for the site condition. Notched 4 by 6 timbers are placed on the top of the walls to become the trail tread. The 4 by 6 timbers are spiked or pinned to the walls. Depending on materials available, the invert may be lined with stone or with planks resting on the sleepers. The invert should be flush with the bottom of the creek or wetland to allow aquatic organisms to move freely.

Normally, timber walls require deadmen going back perpendicular from the face of the wall into the earth behind the wall. The deadmen help keep the wall from collapsing. Because the walls for a timber culvert are only 6 to 8 feet long, installing deadmen is impractical. However, some bracing is needed to keep the walls from collapsing. For timber culverts with walls retaining 12 to 24 inches of earth, 4 by 6 timbers can be used for each side of the tread surface. The bottom of each 4 by 6 can be notched 1 inch deep at each end to fit over the two timber walls, forming a brace to support the walls. The area between these two 4 by 6s can be filled with 3-inch-wide planks (figure 22). Timber walls retaining more than 24 inches of earth should have notched 4 by 6s the full width of the tread surface.

Most lumberyards carry 4 by 6s only in 8-foot lengths. For efficient use of the wood, the 4 by 6s should be used to span distances of 8 feet, 4 feet, or 2 feet, 8 inches. The 2-foot, 8-inch length would provide a 20-inch-wide open area and is the minimum width recommended for timber culverts. The minimum clear height of the culvert should be 7 inches. Rough sawn 2-inch-wide lumber is adequate for the entire tread surface of the 2-foot, 8-inch culvert (figure 23).

The trail tread can be the surface of the top timbers of the culvert, or a curb can be added on each side and the space between the curbs can be filled with earth. The height and width of a timber culvert can be adjusted to fit site conditions and the expected volume of water. The spacing and number of culverts can also be adjusted to reduce the concentration of runoff and potential erosion problems. Timber culverts have an advantage over round pipe because the top timbers can be quite low and still provide the cross-sectional area of a large round pipe. Round pipe also concentrates runoff, while timber culverts spread the same volume of water over a wider area. Timber culverts work well with turnpike construction. Round pipe requires taller structures, a disadvantage.

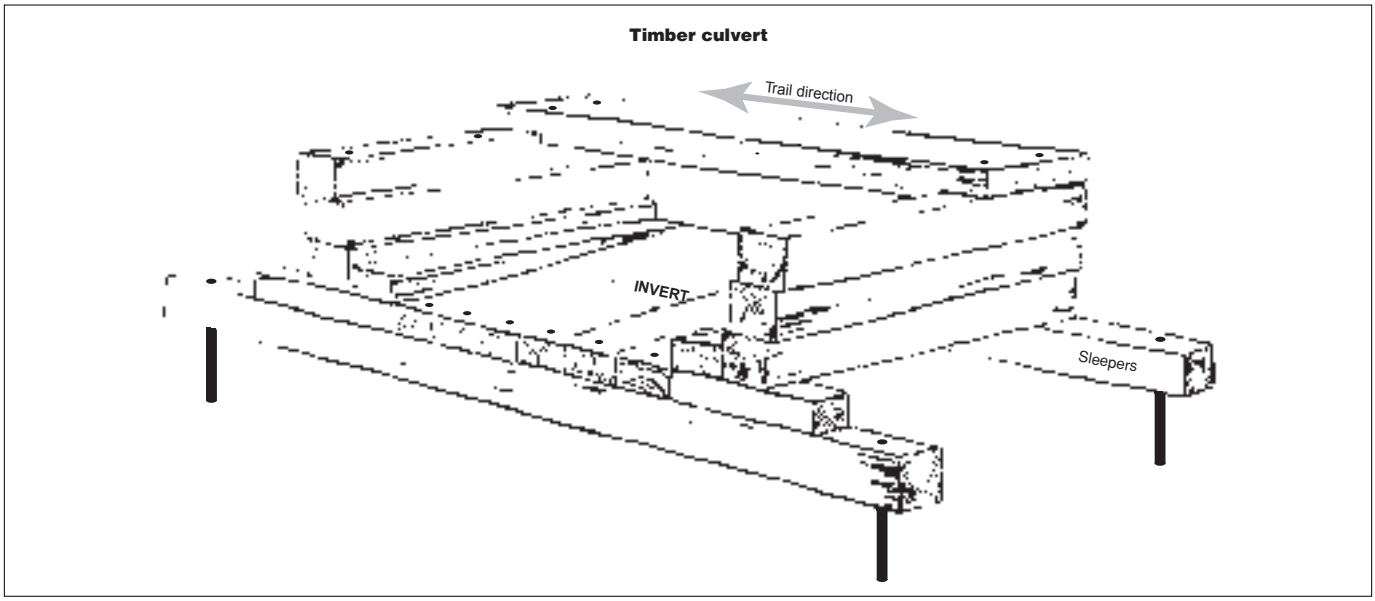


Figure 21—Timber culvert. The invert (bottom of the culvert) is often built level in wetlands because it is less likely to wash away in floods.

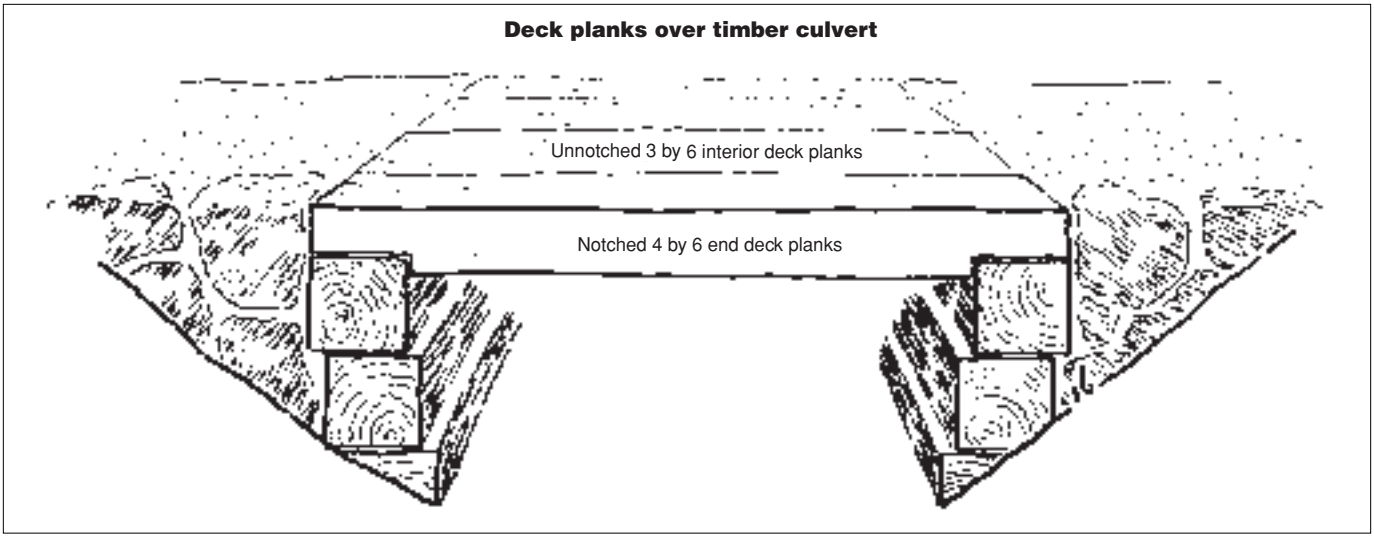


Figure 22—Notching the deck planks on both ends of the culvert (two planks with notches are adequate for a wall up to 24 inches high) helps to brace the walls.

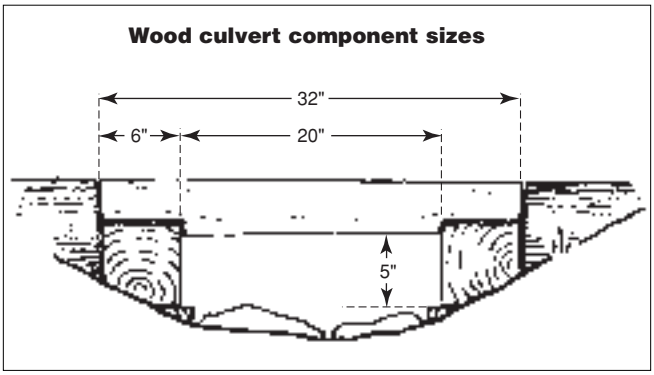


Figure 23—Minimum size recommendations for a wooden culvert designed to use standard timber sizes efficiently. Often larger culverts may be needed. This culvert has no constructed invert.

Pipe is not a traditional or visually compatible material for some backcountry trail culverts. Also, it is difficult to clean a small-diameter pipe with a shovel. A typical shovel blade is 9 inches wide and requires many passes to clean out a 12-inch-diameter pipe. You can do the job more easily with the smaller-diameter combi (combination tool). Make the rectangular opening of a timber culvert 20 inches wide and it will be much easier to clean than a round pipe. Pipes as small as 2 inches in diameter have been used to carry surface runoff beneath turnpike (appendix C compares round and rectangular culverts). Such pipes plug up within weeks and are impossible to clean. They should never have been installed.

Corrugated plastic culverts are sturdy, lightweight, and easy to cut. Although the culverts are not natural, the colors usually blend in with their surroundings better than steel. High-density polyethylene (HDPE) plastic culverts have become quite popular for trail work. However, some trail designers feel corrugated plastic culverts look out of place and they may not meet Recreational Opportunity Spectrum guidelines in remote sites. The ends can be framed by rock so they look natural, and plastic does not decay.

Timbers or logs used in culvert construction should be naturally decay-resistant or treated wood to help meet sustainability criteria. Treated wood should meet best management practices for aquatic environments.

Another culvert design that can be effective is an open-bottom culvert, essentially half of a round culvert. Open-bottom culverts need to be adequately supported under both edges.

Structures Requiring Foundations

Corduroy, turnpikes, causeways, and improved drainage are all constructed directly on the ground and do not require a foundation. The remaining techniques—puncheon, bog bridges, gadbury, and boardwalks—all require some sort of constructed foundation to raise the structure off the ground.

The type of foundation needed varies with the structure being constructed, materials available, and the site-specific soil and water conditions. More than one type of foundation may be appropriate for each structure, so we will discuss foundations first. These foundations include sleepers, cribbing, end-bearing piles, friction piles, and helical piles.

Sleepers (Sills)

The simplest foundation is to rest the tread plank or stringers on sleepers, also called sills, or mud sills. A log of a naturally decay-resistant wood or a large-diameter treated pole or post is used for the sleepers. Sleepers are used to support puncheon, gadbury, and bog bridge construction. The notching for each type of structure is different and will be discussed later in this chapter.

A sleeper (figure 24) is placed in a shallow trench at a right angle to the trail centerline. A second sleeper is placed in another trench parallel with the first sleeper. The distance between the two sleepers is the span. The span is determined with the help of someone with carpentry or structural engineering experience.

Pinning the sleepers to the ground with 24- to 30-inch driftpins is extra work, but it may reduce future maintenance in wetlands subject to flooding. Pinning is most important near streams or rivers where high water velocities may occur during flooding. Pinning may also reduce maintenance in areas of frequent slack-water flooding. The outer driftpins should be driven in holes drilled at opposing angles. Driftpins installed at these angles will resist flotation and uplift from frost and will also deter vandalism. If rebar is used for pinning, the hole can be $\frac{1}{16}$-inch smaller diameter than the rebar. Otherwise, the hole should be the diameter of the pin.

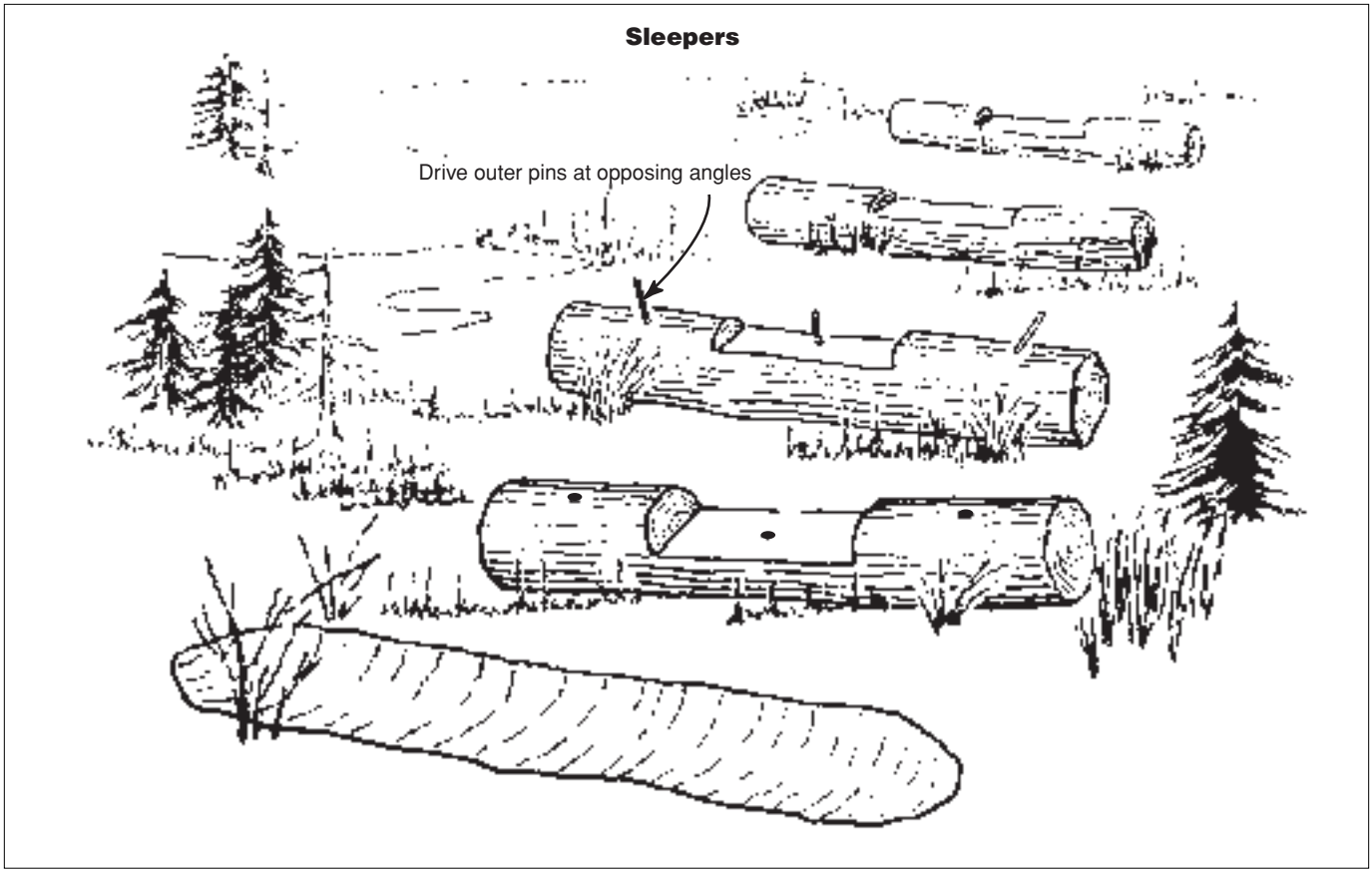


Figure 24—Place sleepers in a shallow trench and pin them at opposing angles so they won't float away during seasonal flooding.

Timbers are sometimes used instead of logs for sleepers. Timbers are easier to work with because they do not require notching. However, timbers do not have the same rustic quality as logs. Precast concrete parking bumpers and other precast concrete units have been used for sleepers, but they are far from rustic. Concrete bumpers weighing 150 pounds per cubic foot are difficult to bring to the site. In most wetland soils, they will eventually sink into the ground.

Sometimes the base for the sleeper can be strengthened by excavating deeper, wider, and longer; laying down geotextile; adding several inches of gravel on top of the geotextile; and folding the geotextile back over the top of the gravel to encapsulate it. Lay the sleeper on top of this foundation.

Cribbing

In hummocky terrain or when crossing a wide, low area, log or timber cribbing can be used to support a trail. Usually logs are used to construct cribbing (figure 25). Dig two parallel

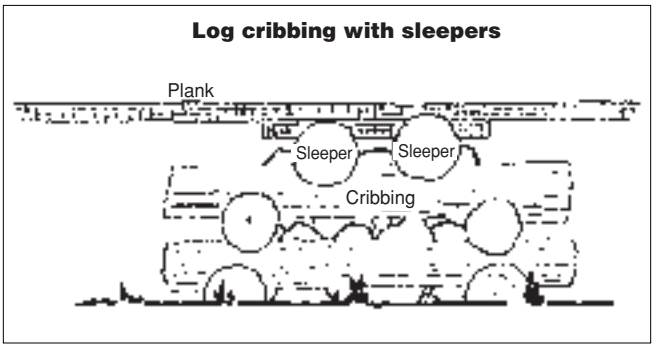


Figure 25—Log cribbing with two sleepers.

shallow trenches a few feet apart. Place a sleeper in each trench and diagonally pin it to the ground with three 30-inch driftpins. Drive the outer two pins at opposing angles. Depending on the width of the completed trail, the first layer (or course) may be 3- to 5-foot-long logs. A second course of two more logs is placed on the first course of logs, near their ends. Each course of logs is placed at right angles to the course below and spiked or pinned to it. The cribbing is built up until the proper height is reached. Lay the top course perpendicular to the centerline of the trail. Stringers or plank can either be nailed to each of the top logs or timbers, or a single, large-diameter log can be notched and pinned to the top logs (similar to the sleepers described earlier).

If you use logs, saddle notches may be used in the bottom of all but the sleepers. This will result in a solid wall of logs. A simpler technique is to use a square notch at the ends of each log that contacts another. This technique will leave a 3- to 6-inch gap between the logs (figure 26).

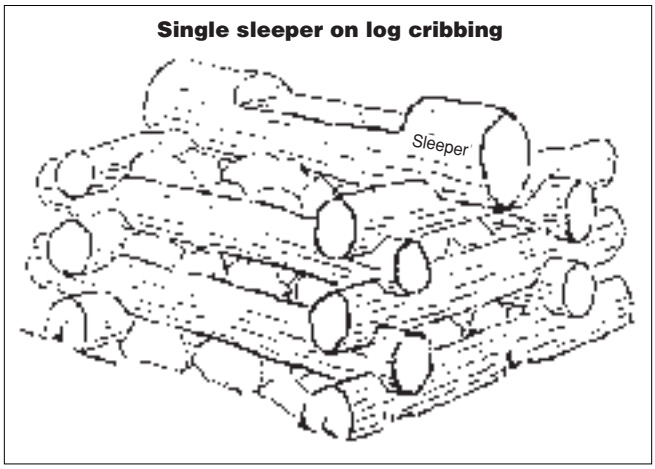


Figure 26—Log cribbing with a single sleeper. Do not notch logs that contact the ground.

Drive spikes or 12-inch-long driftpins into predrilled holes at the corners of the cribbing to hold it together. Avoid stacking the joints on top of each other. The joints must be offset or the driftpins from each course will hit the driftpins in the logs of the course below.

Timbers are easier to use than logs because they do not have to be notched. For greater stability and to prevent the cribbing from being washed away in floods, you can fill the open space in the core of the cribbing with stone.

Wire gabion baskets filled with rock also can be used for crib structures. Sleepers are placed on top.

Wooden Piles

Piles are another foundation technique. Three types of piles have been used for wetland trails. Structural engineers refer to these piles as end-bearing piles, friction piles, and helical piles (figure 27). Geotechnical engineers use a hand-operated relative density probe to help determine soil conditions. The probe is driven into the ground with a fixed force, allowing resistance to be calculated.

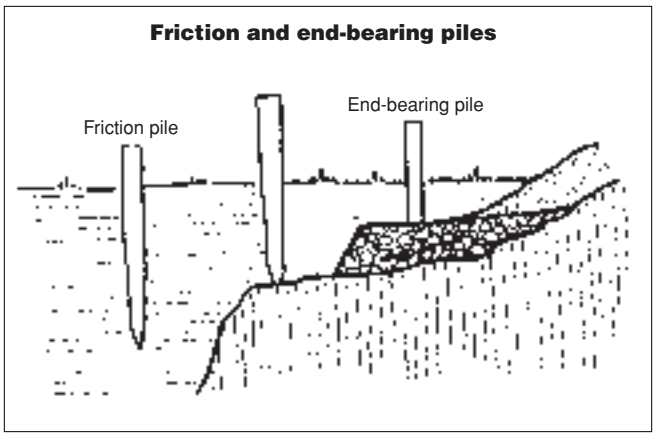


Figure 27—Friction and end-bearing piles. The pile in the middle began as a friction pile but became an end-bearing pile because it met solid resistance before fetching up.

End-Bearing Piles

End-bearing piles are used at locations where firm earth or solid rock is found 2 to 10 feet below the ground. Although the soil at these sites may support sleepers, piles can be used to support the tread at abrupt changes in grade when the tread must be 1 to 5 feet above the ground or water. Piles can also support handrails.

To place an end-bearing pile, excavate a hole a little wider than the pile to a point below the frostline. If you encounter solid rock in the bottom of the hole before reaching the frostline, the pile can rest on the rock. Power augers help make digging easier and faster. In wilderness areas or where only a few holes are needed, a posthole digger, manually operated auger, or shovel will do the job.

Place the pile upright and plumb in the hole. Place the excavated earth (or imported coarse sand or gravel) in the hole in 6- to 8-inch layers, equally on all sides of the pile, and compact it by tamping. A tamping bar is the best tool for compacting earth (figure 28).

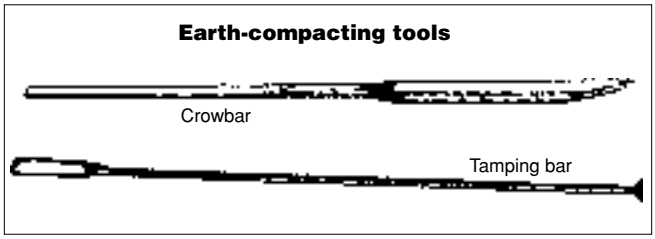


Figure 28—A crowbar (rock bar) and a tamping bar. The tamping bar is lighter than the crowbar and is best suited for loosening soil in holes and for tamping around posts.

End-bearing piles can be made from naturally decay-resistant or pressure-treated wood, steel, or concrete cast in sonotubes (disposable cylindrical forms). Wood is typically used because it is readily available and easier to use than steel or concrete. Connections to a wood pile are also much easier to make, and the tools needed for the job are lighter and more readily available. Timbers are the first choice for end-bearing piles because their flat, squared sides are easier to connect to than the round surface of logs. Usually, rough-sawn, pressure-treated 6 by 6s are adequate for this work (figure 29).

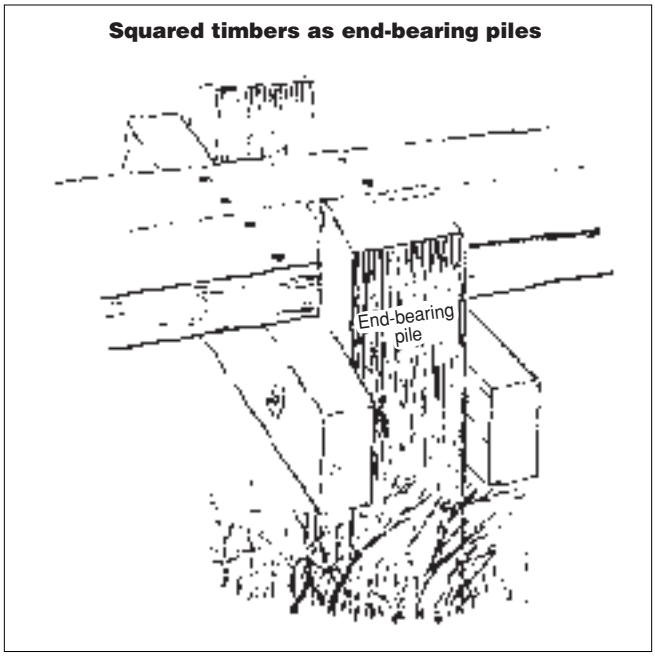


Figure 29—Using squared timbers for end-bearing piles makes connections easier than when round piles are used. Cut the tops at an angle so they will shed water.

Friction Piles

Friction piles are normally used when the ground is wet and sloppy—areas where you need logs or some kind of a deck to stand on while you work. Friction piles for trail work are usually at least 12 feet long and 10 to 12 inches in diameter. Friction piles are considerably heavier, more awkward to transport, and more difficult to install than end-bearing piles.

A friction pile should be a naturally decay-resistant log or a pressure-treated log or pole. Cut a point on the narrow end and dig a shallow hole where the pile is to go. The pile must be driven with the wide butt end up and the narrow end down. The pile should stand as plumb as possible.

For backcountry wetland trail construction, friction piles are driven by hand. Pile driving is done with a "hammer"—a 2½- foot piece of 12-inch-diameter steel pipe (figure 30). A cap is welded at the top and two ½-inch-diameter holes are cut in the cap to let air out. Two steel handles of ½-inch-diameter reinforcing bars are welded to the sides of the pipe. At one area where friction pile construction was common, two of these hammers were used to drive the piles by hand. One hammer weighed 90 pounds and the other 135 pounds. Using these tools builds strong bodies. Usually two persons work together when operating these manual pile drivers.

The theory of the friction pile is that the surface of the pile develops friction against the sloppy soil. The deeper the pile is driven, the more friction develops, until finally the pile "fetches up" and can be driven only fractions of an inch with each blow of the hammer. When that point is reached, pile driving stops, normally at depths of 6 to 10 feet. Sometimes firm soil or rock will be reached before the pile fetches up. At this point the driving stops and the pile becomes an end-bearing pile.

If the trail is being built progressively, 12- to 16-foot piles can be driven by a small, lightweight machine with a pile driver attachment. Building a wetland trail strong enough to support the pile driver may be worthwhile in coastal areas that are subject to hurricanes, northeasters, or typhoons. If the wetland trail can support the machine, it will probably withstand some severe storms. If longer piles are needed, a much heavier pile driver can be brought to some sites on a barge.

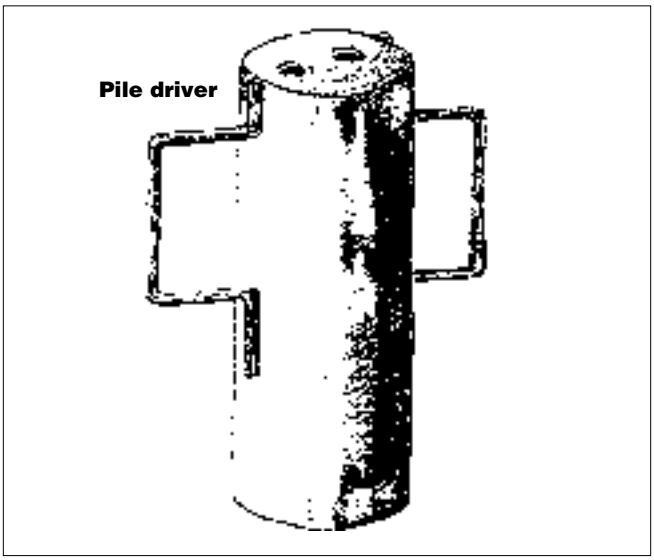


Figure 30—A pile driver (hammer) can weigh 135 pounds or more.

Bent Construction

Whether wood end-bearing or friction piles are used, once a pile is in place, the construction is similar. A second pile is placed on the opposite side of the trail centerline so that each is the same distance from the centerline. When both piles are in place, they are connected by one or two ledgers. The combination of ledgers and piles is called a bent.

On a one-ledger bent, the top of each wood pile is cut flat and level with the opposite pile. A 3 by 6 or 3 by 8 timber is placed flat on the top of both piles so that it extends a few inches beyond each of them. This timber, or ledger, is spiked to the top of each pile (figure 31).

When two ledgers are used, one is bolted to the front and one to the back of each pile, spanning the space between the piles. Drill a hole through each pile parallel with the trail centerline. These holes (and ledgers) should be level with each other. A 3- by 6-inch ledger is held in place on one side of the pile, and the hole in the pile is extended through the ledger. This is repeated until each ledger can be bolted to each pile. The ledgers should be level and level with each other.

Figure 31—A bent with one ledger. Spike the ledger to the top of each pile. The pile and ledger are collectively called a bent.

Another method for the same type of installation is to determine the proper height of the ledgers and clamp the pair of ledgers to each pile of the bent. Drill a hole through the ledger, the pile, and the opposite ledger, all at once. This is faster, but requires two large clamps that can open at least 1 foot (figure 32).

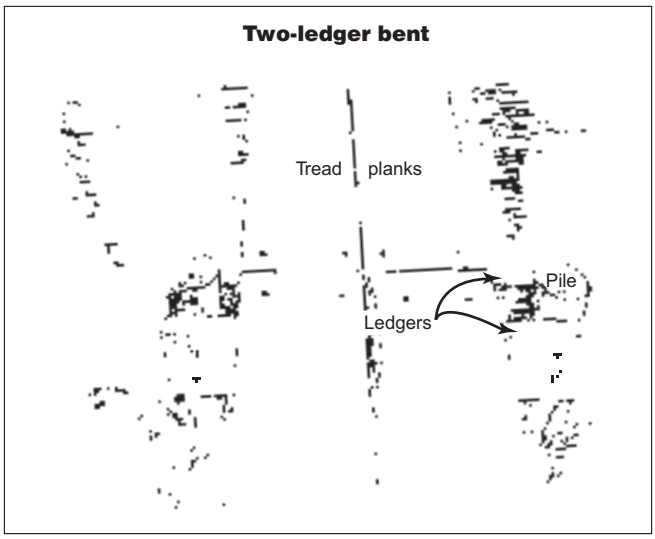


Figure 32—A bent with two ledgers. Trim the tops of the piles at an angle so they will shed water. The bolts go through the pile and both ledgers.

After installing a pair of bents, pressure-treated 3- by 12-inch tread planks are nailed to the ledger or ledgers as described for the bog bridge on sleepers. If the planks are more than 2 feet above the ground or water, the tread should be at least two planks wide for trails that do not have to meet accessibility standards. Collect and dispose of treated wood trimmings and sawdust.

Where the deck will be more than 3 feet above the ground, diagonal bracing is needed to connect the piles of a bent. A single diagonal brace is adequate if the deck is just 3 to 4½ feet above the ground (figure 33). If the deck is higher than 4½ feet, two diagonal braces are necessary. These braces should be installed as a cross brace, forming an X between the piles. Diagonal braces are normally wood (figure 34). The angle of the braces should be between 30 to 60 degrees to the horizontal to provide enough support. Angles of 30, 45, or 60 degrees, or a 3-4-5 triangle, make the mathematics of carpentry easier in the field.

Occasionally, the ground is well below the surface of the tread. If the tread is 4 feet or more above the ground and the space between the bents is 6 feet or more, diagonal bracing may be needed to connect consecutive bents. Bracing between bents is done with wood members from the right pile of one bent to the right pile of the next, and the left pile of the bent to the left pile of the next (figure 35). Keep in mind that braces impede waterflow and can contribute to debris and ice jams.

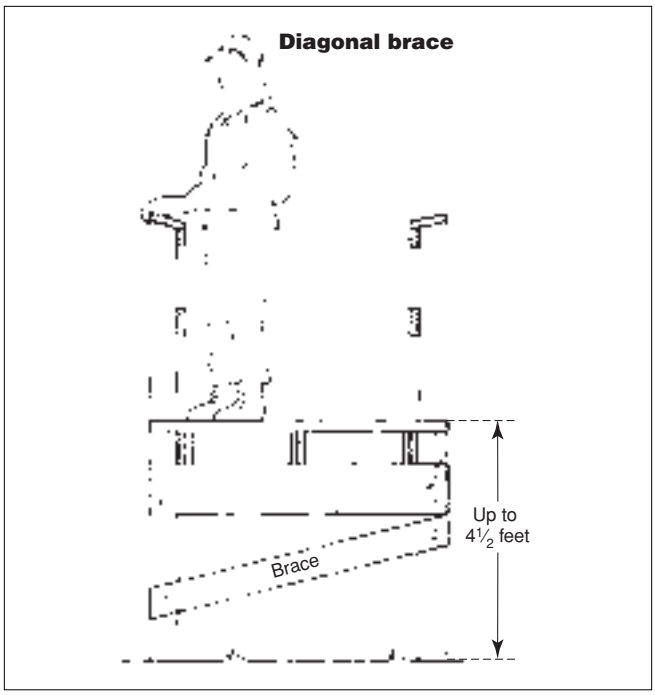


Figure 33—A single diagonal brace is adequate if the deck is no more than 4½ feet above the ground. Alternate braces on successive bents.

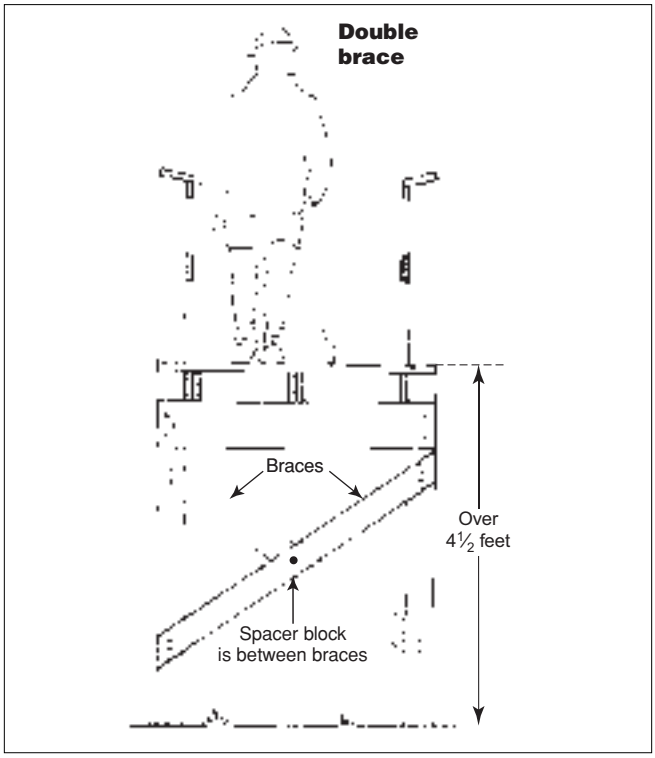


Figure 34—Use a cross brace if the deck is higher than 4½ feet above the ground. Extra-long braces can be bolted together using a spacer block to increase rigidity.

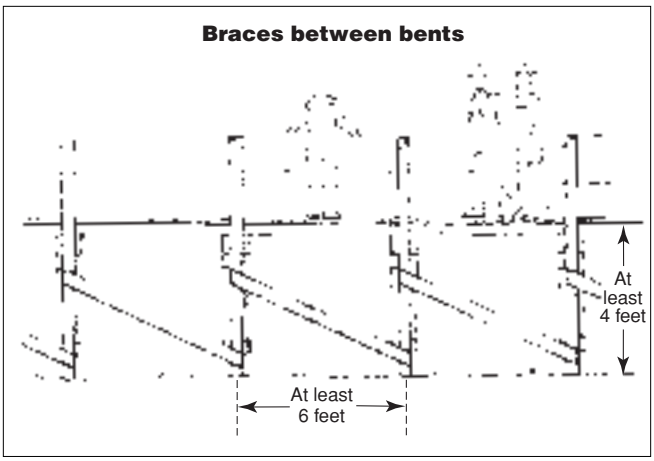
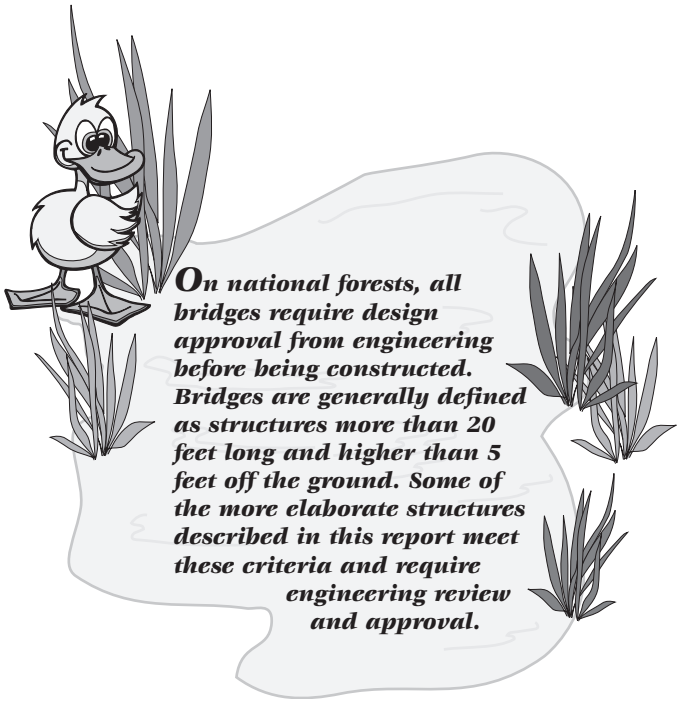


Figure 35—Bracing between bents is sometimes necessary.



On national forests, all bridges require design approval from engineering before being constructed. Bridges are generally defined as structures more than 20 feet long and higher than 5 feet off the ground. Some of the more elaborate structures described in this report meet these criteria and require engineering review and approval.

Helical Piles (Screw Piles)

Helical piles, or screw piles, are more accurate terms for a recent adaptation of an old construction technique using screw anchors. Screw anchors were originally used in poor soils, often with cable guy lines. The design of the screw anchor was modified to be used as a helical pile. Although technically incorrect, the term screw anchor is still used (figure 36).

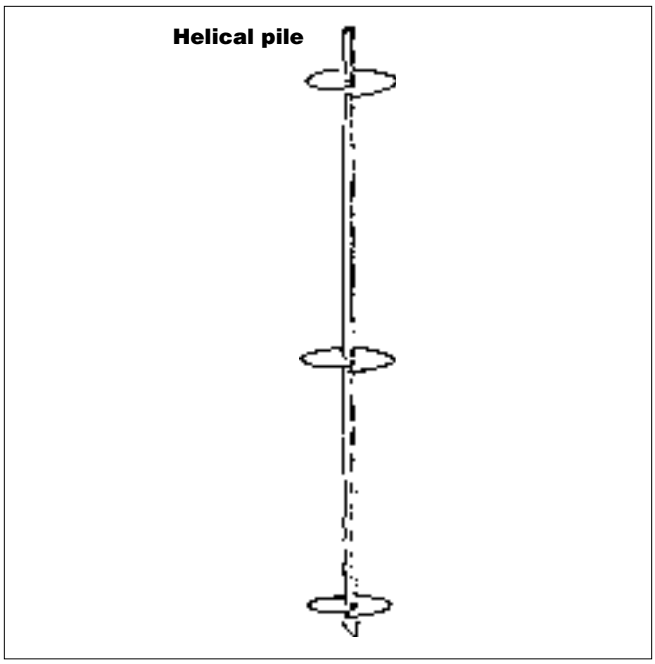


Figure 36—Helical piles are an alternative to friction piles.

Helical piles are now used to support anything from utility poles to large buildings built on poor wetland soils. They require special equipment and techniques to install. Many certified contractors are located throughout the country to allow for competitive bidding. Sometimes certified contractors will train volunteers to do the work. ***Helical piles are an excellent alternative to friction piles. They weigh less, are easier to install with portable equipment, and result in less ground disturbance. Their overall cost may be much less than friction piles*** (figure 37).

A helical pile includes a helical lead section and a beam saddle. The lead section is solid high-strength steel 3½, 5, or 7 feet long, pointed at the bottom. One, two, or three solid steel helices 8, 10, or 12 inches in diameter and spaced 2½ to 3 feet apart, are welded around a solid steel shaft. The diameter and number of helices depend on the loads to be carried and the soil conditions at the site. The helices are attached to the steel shaft with one edge of the slit lower than the other, creating a leading edge and a trailing edge. All the elements of a helical pile are hot-dipped galvanized. Bolt holes are provided at the end of each lead section for bolting another helical section to the lead section (figure 38).

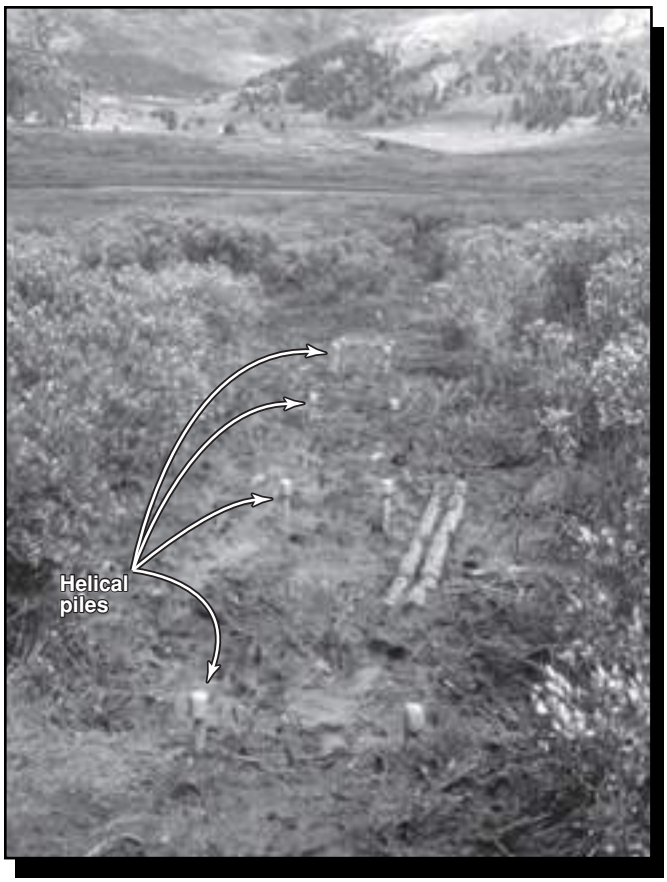


Figure 37—Helical piles installed in Colorado. The saddles are not yet attached. The ends are covered with temporary plastic caps for safety.

Figure 38—A helical pile was used for this boardwalk. Stringers are attached directly to the beam saddle, helping to keep the boardwalk close to the ground.

A 12-inch-long, L-shaped beam saddle fits into the end of the steel shaft of the helical pile where the sections are bolted together. The beam saddle consists of a steel angle welded to a pipe sleeve. Two bolt holes in the vertical leg of the steel angle are opposite two bolt holes in a steel side lockplate (figure 39). The side lockplate is held in place by two bolts through the steel angle, through a wooden ledger or stringer, and through the side lockplate. The beam bracket can be adjusted up to 3½ inches by tightening the nuts on the bolt. A custom saddle is often used to accommodate larger wood or steel ledgers.

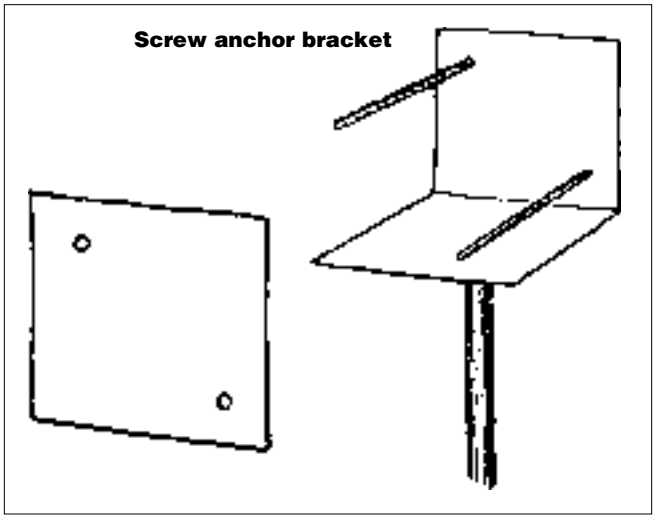


Figure 39—Screw anchor bracket for helical piles.

In poor soils, longer helical piles are sometimes used to achieve the needed load-bearing capacity. To reach that capacity, the pile is augered into the ground until a predetermined torque (the force needed to twist the lead section into the ground) is reached. Extensions can be bolted on to the lead section and augered into the ground until the correct torque is reached.

Helical Pile Assembly

Helical pile assemblies for wetland trails usually consist of two helical piles opposite each other, one on each side of the bog bridge or boardwalk, or they may be located under the boardwalk. The two piles may be tied together with a ledger or a pair of ledgers placed on edge, resting on the beam saddle of each pile. The ledgers are usually solid wood—3 by 6, 8, 10, or 12 inch, or two or three pieces of 2 by 4s or 2 by 6s nailed together. Ledgers may also be glulaminated. The ledgers are bolted to each beam saddle (figure 40).

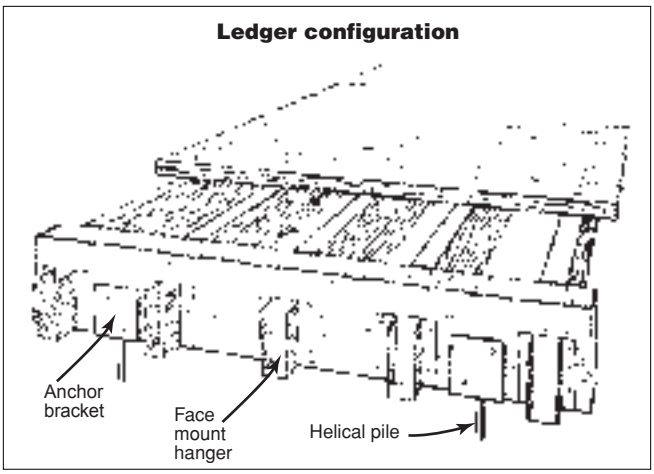


Figure 40—Typical ledger configuration of a helical pile assembly.

If the deck is 3 to 4½ feet above the ground, a diagonal brace is needed between the piles. If the deck is more than 4½ feet above the ground, two diagonal braces are needed, installed as cross braces. Diagonal braces may be additional helical piles (figure 41) or steel angles with diagonal cable attached to them. If bents are 6 feet apart or more, diagonal bracing between bents may also be needed. Consecutive bents may be braced diagonally from the left helical pile of one bent to the right helical pile of the next bent. The procedure is repeated to connect the bents' two remaining helical piles.

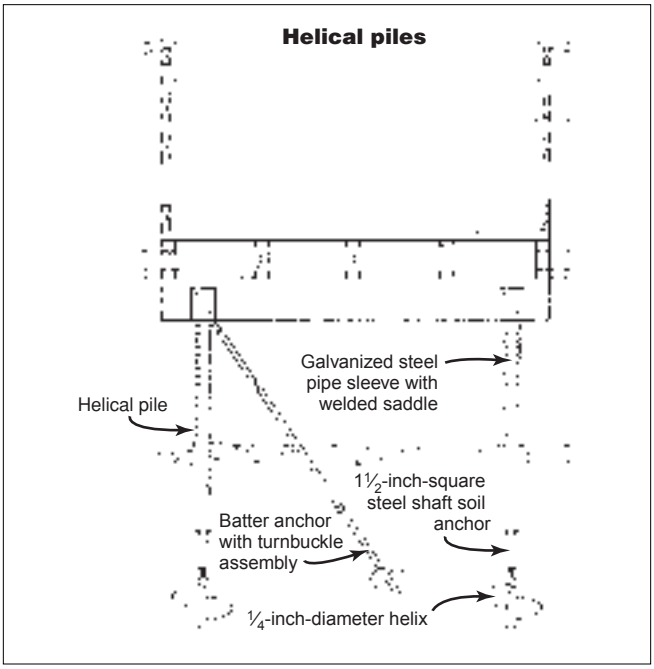


Figure 41—Typical helical pile assembly.

Special Site Considerations

A trail in a spruce bog requires adapting wetland construction techniques to the site. The most applicable technique is the bog bridge on bents. However, unlike construction in most wetlands, the location of each pile will have to be adjusted in the field to avoid roots.

Although the upper layer of soil is organic, the underlying soil may not be. Dig test holes along the proposed route to determine whether end-bearing piles, friction piles, or a combination of both is the best technique.

The spacing between piers will vary, as will the angle of the bents to the trail centerline. Some of the tread planks will be shorter than normal, and others will be longer. Starting with tread planks that are twice the normal length will permit cutting short pieces to fit one location, leaving longer pieces for use elsewhere (figure 42).

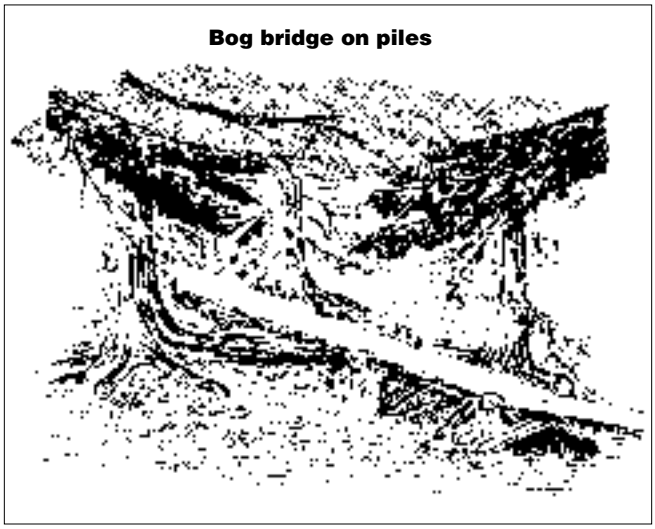


Figure 42—A bog bridge on a pile foundation. Protecting tree roots in a spruce bog requires careful placement of sleepers and piles.

Although this technique is described for northern spruce bogs, it may also have application in cypress swamps in the Southeastern United States and elsewhere.

If beaver are a problem, wrap piles with hardware cloth and staple it into place. The hardware cloth discourages beavers from chewing through the piles, timbers, or logs used in construction (figure 43).

Old beaver ponds present something of a problem in bog bridge construction, especially in mountainous areas. The

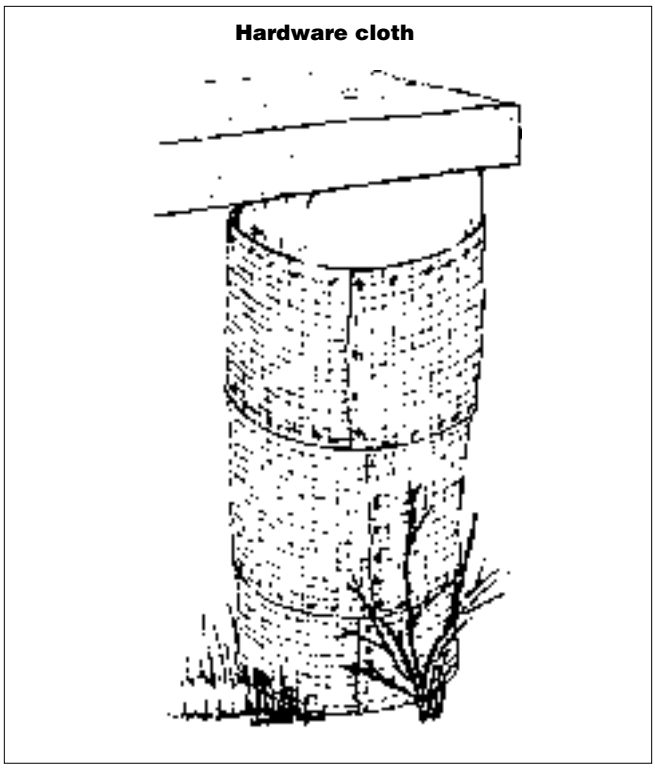


Figure 43—Hardware cloth stapled around piles helps discourage beavers.

original soil may have been of glacial origin and capable of supporting end-bearing piles. However, beaver dams trap silt, which drops to the bottom of their ponds. While end-bearing piles may work well in some locations in such ponds, friction piles are needed elsewhere. When concrete end-bearing piles were used at one pond, some settled 1 to 2 feet in 5 years. After 10 years, all concrete end-bearing piles had to be replaced with log friction piles (figure 44).

Figure 44—Know your soil conditions. Concrete end-bearing piles settled 1 to 2 feet here and had to be replaced with these log friction piles.

Puncheon

Puncheon are essentially short-span footbridges or a series of connected short-span footbridges. The term puncheon means different things to different people. Puncheon on the Appalachian Trail is not the same as puncheon built in the Cascades, Rocky Mountains, or Sierras. Puncheon built in easily accessible areas may not be the same as that built in the backcountry. Puncheon can be used where the soil is wet but does not contain enough water to seriously hamper trail work. The one thing common to all puncheon construction is the use of sleepers.

Type 1 Puncheon

On the Appalachian Trail, 3- to 6-foot-long logs are commonly used for the sleepers. The sleepers are notched to receive one or two tread logs and then placed in a shallow trench. The tread logs are hewn, split, or sawn, roughly in half, to provide a level plane for the walking surface or tread. The tread logs are spiked or pinned in the notch of the sleepers (figure 45).

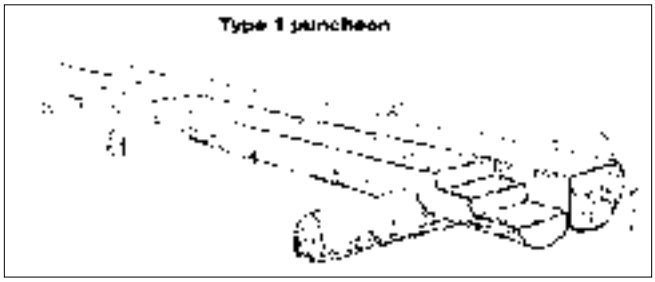


Figure 45—The rustic type 1 puncheon has sleepers and tread logs.

If the area to be crossed is longer than the logs available for the tread, the puncheon can be built as a series of connecting sections. Hiking any distance on single-tread-log puncheon can be unnerving because the hiker is looking down to avoid stepping off the tread. This is especially true if there is quite a drop from the tread to the ground or water below. Two tread logs placed side by side on longer sleepers will help. For two-tread-log construction, the inside face of each log should be hewn or sawn to butt closely to the adjacent log. A narrow gap between the two logs will help drain water, snow, and ice from the tread. This will reduce the chances of a slippery tread and retard decay.

Two or three small spacers can be nailed to the inside face of one of the logs to control the width of this gap. The spacers can be short, straight lengths of 2- to 4-inch-diameter branches or wood scraps, hewn flat on opposite sides to provide a piece of wood about 1 inch thick.

Type 2 Puncheon

In the Western States, puncheon uses log sleepers placed in a manner similar to that used on the Appalachian Trail. The sleepers are a few feet longer, however, and the space between them is spanned by two or three log stringers, or beams, spaced 1 to 3 feet apart (figure 46). The tread is made from 6- to 12-inch-diameter split logs, 4 to 6 feet long, or split planks. The split face becomes the tread. The bottom of the tread half-log is notched to rest on the stringer log, and the tread is spiked in place. If three stringers are used, do not spike the tread logs to the center stringer. The top of the three stringers will probably not be at the same height. Use a long carpenter's or mason's level to quickly determine the height of each stringer in relation to the others. Ideally the tread should be level from one side to the other. Handtools normally used in the field for construction make it difficult to get the tread perfectly level. Adjusting the depth of each notch, as needed, will allow for variations in stringer height. Shims under the decking also help to level the structure from side to side.

Half logs can be placed with their split sides facing up as a tread. Smaller half logs are placed split side facing down resting on the stringer and butted tightly against the tread log. These logs serve as brace logs, preventing the tread logs from wobbling. Succeeding tread log are butted snugly against the brace logs (figure 47).

If large logs are available, tread plank can be sawn from the logs, producing a number of pieces of plank of varying widths from one log. An Alaskan sawmill can be used at the site to produce planks with a uniform thickness. With this plank, there should be little—if any—need to notch or shim the stringers.

Excessive cross slope will make the surface very slippery. The meaning of excessive will vary, depending on the climate expected when the trail is being used. In a dry climate, the cross slope should not exceed ½ inch per foot of tread width; in a wet climate, or where snow, ice, or frost can be expected, the cross slope should be no more than ⅛ to ¼ inch per foot of tread width. If the trail leading to the puncheon is wet, no matter what the season, hikers will track mud onto the tread, making it slippery throughout the year.

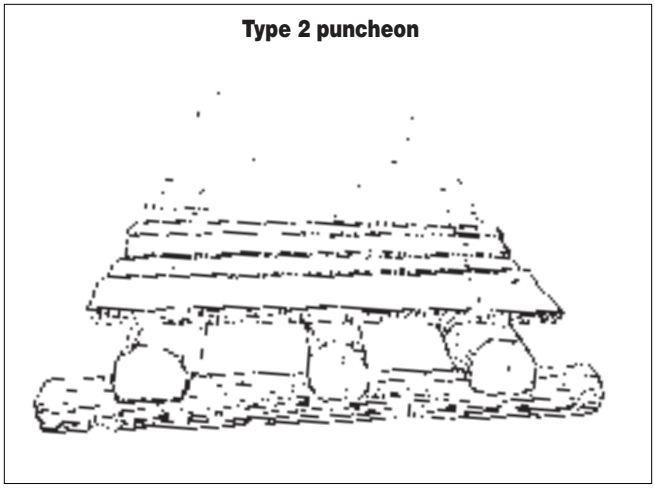


Figure 46—Type 2 puncheon has sleepers, stringers, and decking.

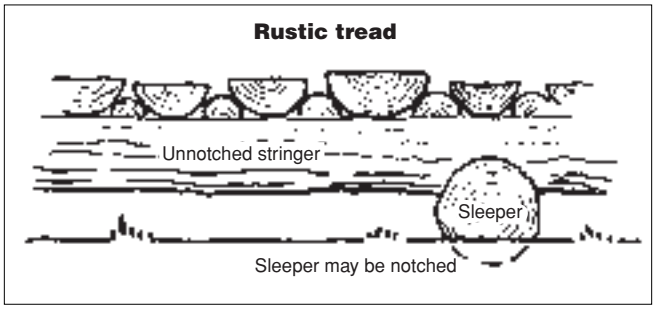


Figure 47—Rustic tread or decking made from half logs (logs cut in half lengthwise).

Type 3 Puncheon

Type 3 puncheon also uses sleepers to support the structure, but the material is sawn timber or lumber, which should be treated with wood preservative (figure 48). This construction is popular at more accessible sites where materials are easier to transport. The longevity of treated wood and the environmental consequences and labor of cutting trees onsite make the use of sawn, treated timbers increasingly popular at remote sites as well. Helicopters, packstock, all-terrain vehicles, and workers carry in the materials.

The sleepers can be either 6- by 6- or 8- by 8-inch-square timbers placed as previously described. Two or three stringers rest on the sleepers and may be toenailed to the sleepers and bolted or nailed to the stringer in the next span. The stringers may also be attached to the sleepers with steel angles and extended (cantilevered) a short distance beyond the sleepers.

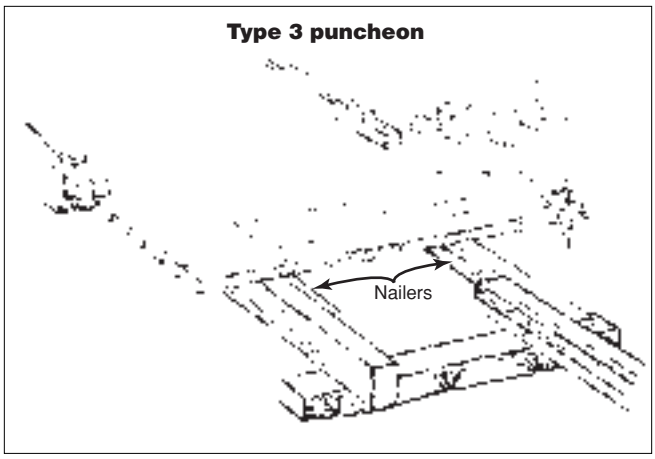


Figure 48—Type 3 puncheon is constructed from preservative-treated timbers. The nailer bolted to the inside of each stringer helps prevent decay by concentrating screw holes and associated decay in the easily replaced nailers instead of the stringers.

The size of the stringers is determined by the maximum weight they can be expected to support, which may be the snow load in snow country. For foot trails, usually the size of the stringers is calculated to support a live load of 85 pounds per square foot, the maximum weight expected for trail users standing on one section of trail. Heavier, wider puncheon is needed for horse and mule traffic.

On foot trails, the tread is often 2 by 6, 2 by 8, or 2 by 10 lumber nailed to the stringers. When three stringers are used, do not nail to the center stringer. The nails work their way out and pose a tripping hazard. The stringers are the most expensive and most difficult items to bring to the site. Do everything you can to extend their useful life; usually this means keeping them dry.

The tread will need replacement more frequently than any other portion of this type of puncheon. In some areas the wood tread will require replacement every 7 to 10 years. After three or four replacements of the tread, the top of the stringers will show signs of decay and wear. Water from runoff and condensation will follow the nails down into the wood, and repeated nailing in the same vicinity will soften the wood. To avoid this, a nailing board (nailer) of 2 by 4s or 2 by 6s can be nailed to the top or side of the stringer. A better solution is to bolt rough-sawn 2 by 4s or 3 by 4s to the side of the stringer with carriage or machine bolts. The bolts can be 2½ to 4 feet apart. The tread is nailed to the nailer instead of the stringer. Eventually, the nailer will require replacement, but the nailer is much easier to replace than the stringers. Esthetically, it is better to attach the nailers to the inside face of the stringers.

Puncheon Summary

The type 1 and 2 puncheon do not represent sustainable design. They damage the resource if onsite trees are cut to provide construction materials. Offsite timber materials may be from more sustainable commercial sources. The type 3 puncheon meets the criteria for sustainable design because the material used is more easily renewed. Although the tread may require replacement in 7 to 10 years, the heavy stringers have a much longer life expectancy.

All three types of puncheon are raised high enough above the ground to provide little interference with the movement of floodwater. The tread width of types 2 and 3 puncheon may affect the growth of plants under the tread.

Type 3 puncheon is the most likely of the three to meet accessibility guidelines.

Gadbury

Gadbury (figure 49), a structure similar to puncheon, was developed in the Pacific Northwest. Gadbury uses two half logs, as described for puncheon, and longer notched sleepers. The notch cut for gadbury must be about twice as wide as the notch cut for puncheon. The two half logs are placed on each side of the center of the notch with the flat surface up. Two full logs are placed in the notch on the outside of each of the half logs.

An experienced crew can construct gadbury without using spikes or steel driftpins. Such construction requires considerable skill and experience with woodworking tools. Lacking this experience, the pieces can be spiked or pinned together. Earth may be placed on the half logs and held in place by the full, outside logs.

Gadbury uses more wood than puncheon. From a standpoint of sustainable design, gadbury is less suitable than other techniques.

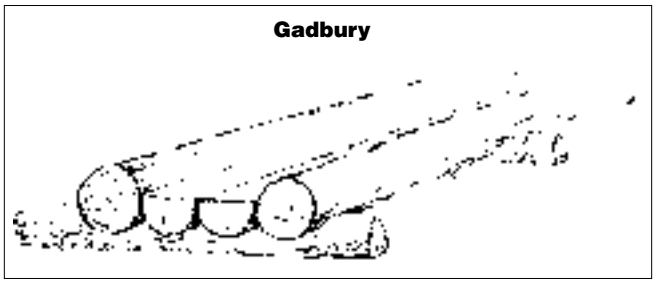


Figure 49—Gadbury is another rustic structure similar to puncheon. Use peeled logs for gadbury.

Bog Bridge

A bog bridge is a form of puncheon. Normally, bog bridges have a single- or double-plank tread surface resting directly on mud sleepers (figure 50), cribbing, or piles. A puncheon, by contrast, will usually have stringers resting on the mud sleepers, with tread decking nailed perpendicular to the stringers.

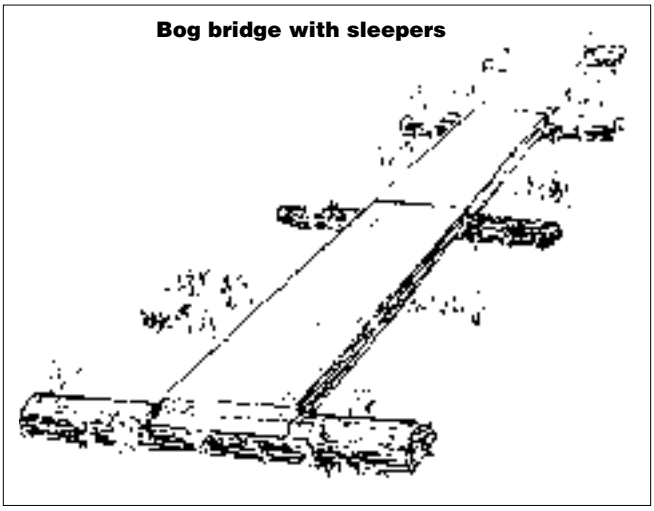


Figure 50—A simple bog bridge with sleepers. This common structure is also called a single-plank boardwalk in coastal Alaska.

To add to the confusion over terminology, in coastal Alaska, bog bridges are called boardwalks, or step-and-run boardwalks if spacers are used to create steps (figure 51). In other places, the term bog bridge is synonymous with puncheon. In parts of the Rocky Mountains and Sierras, bog bridge equates to turnpike, a structure we described as a raised walkway of stone and fill material. We define bog bridges as a series of connected, short-span bridges close to the ground.

The tread of a bog bridge is usually treated, rough-sawn 3- by 12-inch plank that is 6 to 9 feet long. The plank parallels the centerline of the trail and rests on closely spaced, lightweight foundations. This means that the tread of the bog bridge can be closer to the ground, perhaps only 6 to 12 inches above it, providing 3 to 9 inches of clear space below the tread. There is little to block the flow of water (in either direction) below the plank, and little to resist the force of floodwater going over it. In the backcountry, bog bridges are normally one 12-inch plank wide. A plank this narrow does little to interfere with plant growth underneath. The span of each of these small bridges will vary with the type of wood used for the plank, the thickness of the plank, and the anticipated weight on the plank. In areas of heavy, wet snow, the snow may be the heaviest weight on the bridge. Snow load may be as much as 300 pounds per square foot in such areas.

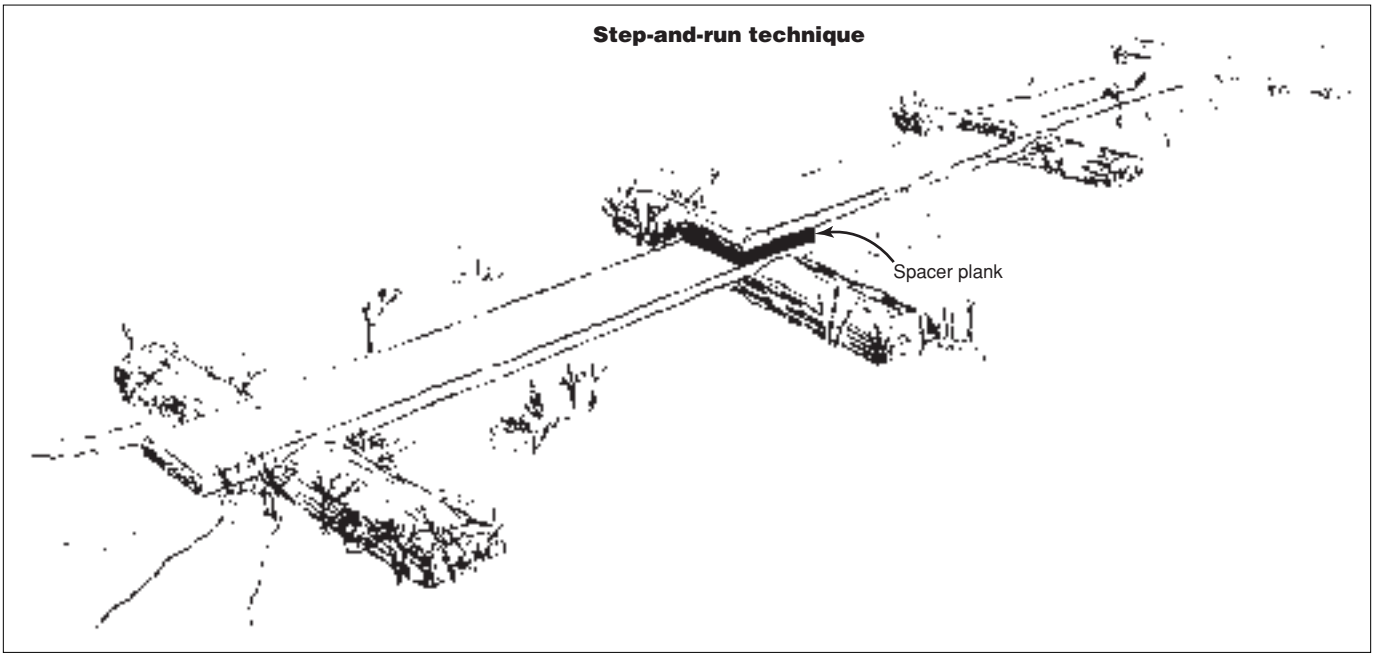


Figure 51—The step-and-run technique is a way of keeping planks level as elevation changes. Level planks help reduce slipping in wet climates.

Bog Bridge on Sleepers

In its simplest form, the plank of the bog bridge rests on sleepers. A sleeper is placed in a shallow trench at right angles to the trail centerline. A second sleeper is prepared and placed in another trench 6 to 9 feet away. This distance is the span, which is determined from older installations or with the help of someone with carpentry or structural engineering experience. Place the plank flat in the notches of the sleepers, with one cut end centered in line with the centerline of the log. Mark the plank where it meets the centerline of the next sleeper and saw it to the proper length. The plank is nailed to the sleepers at each end with two 50- or 60-penny (appendix D), ring-shank nails driven through previously drilled pilot holes. This process continues across the wetland.

Bog Bridge on Cribbing

Occasionally, log or timber cribbing can be used to support the plank of a bog bridge. Plank can either be nailed to each of the top logs or timbers, or one large-diameter log can be notched and pinned to the top logs (similar to the sleepers described earlier). If the bog bridge is more than 2 feet high, the plank should be two planks wide for safety.

Bog Bridge on Piles

Another technique for building bog bridges is to rest the plank on pile foundations. The three types of suitable piles are end-bearing piles, friction piles, and helical piles.

After installing a pair of bents or piers, pressure-treated 3- by 12-inch planks are nailed to the ledger or ledgers as described for the bog bridge on sleepers. The ledgers do not have to be notched. When piles are used, the plank may be more than 2 feet above the ground or water. In such cases, the tread should be two planks wide.

Bog Bridge Summary

Whether a bog bridge is built on sleepers, cribbing, or wood piles, it lends itself to backcountry construction. The materials are wood, steel washers, bolts, nuts, and nails. The pieces of wood are relatively small and can be carried by hand. Bog bridges as described here do not meet Forest Service accessibility guidelines, but are suitable where departures from these guidelines are allowed.

Boardwalk

For the purpose of this book, a boardwalk is a structure that uses widely spaced bents or piers as a foundation. Stringers, parallel with the centerline of the boardwalk, rest on the ledgers of the bents or piers. The stringers support the deck, which is usually 2 by 6 or 2 by 8 lumber laid perpendicular to the centerline and nailed or screwed to the stringers, or to nailers bolted to the stringers. Boardwalks usually have a curb or handrail along their edges (figure 52).

Basically, a boardwalk is a series of connected bridges, each with a span as long as is practical, perhaps 8 to 40 feet. At most wetland sites, longer stringers are not practical because they are difficult to transport. Also, building adequate foundations for the long spans often requires large pieces of specialized equipment that cannot negotiate unstable soil.

Figure 52—A typical boardwalk. Boardwalks are expensive and somewhat complicated, so seek the help of engineers and landscape designers during planning.

Stringers

At least two stringers or beams rest on the ledgers and span the space between consecutive bents or piers. As the space between bents or piers increases, a third stringer, or heftier stringers, must be used. Three stringers are always better than two. There's safety in redundancy.

Long, thick stringers are more expensive than smaller ones. However, they permit the bents or piers to be farther apart. Studies of soil conditions and problems of construction access to the site will indicate the costs for stringers compared to bents or piers. Bring in some engineering help to figure out

the most economical spacing of bents or piers. Large stringers should be bolted to steel angles that have been bolted to the ledgers. Nailers should be used to attach the deck, as described for type 3 puncheon (figure 53).

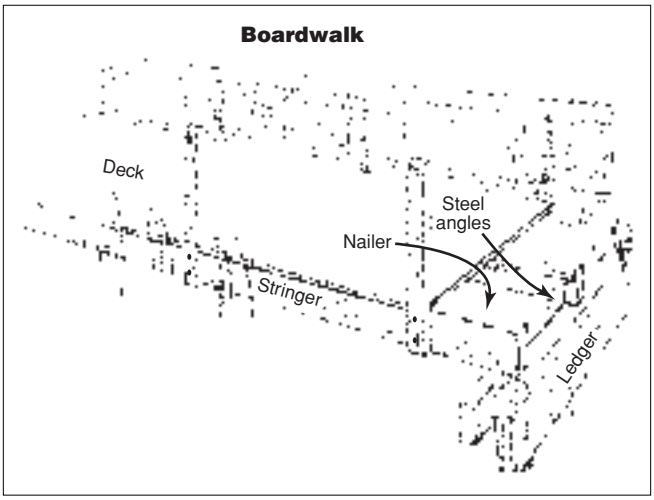


Figure 53—Details of boardwalk construction. Large stringers and ledgers connected with steel angles and nailers help increase the life of the stringers.

Ideally, the bottom of the stringers of a boardwalk should be above high-water levels, but this is often impractical. To reduce maintenance, the design of the boardwalk should avoid interference with the flow of floodwater and floating debris. To check for evidence of flooding, look for clusters of dead, broken branches stuck in shrubbery or the crowns of trees. Bark on the upstream side of trees may be scraped or stripped off. The height of anticipated floodwater may seriously affect the design of a proposed handrail. Joists can be toenailed to the ledgers, or steel top flange hangers may be nailed to the ledgers to support the joists (figure 54). Top flange hangers reduce the distance between the deck and the ground below, perhaps eliminating the need for a pedestrian railing.

Pressure-treated wood that is now available is highly corrosive to untreated metal hardware. Hot-dipped galvanized treatment is recommended for all fasteners and hardware.

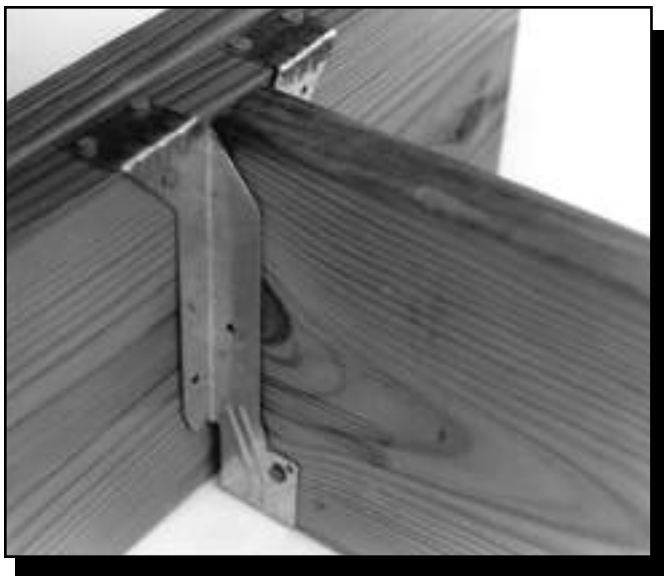


Figure 54—Supporting joists with top flange hangers helps keep a boardwalk closer to the ground.

Boardwalk Summary

Often boardwalks, as described here, are found around visitor centers, heavily used interpretive trails, or at other high-use sites. The sophisticated construction and materials needed for a boardwalk are less appropriate in the backcountry where the trail user expects simpler, more rustic construction and more challenging facilities.

During floods, the posts and rails can catch debris and form a dam. In most situations it is better to build as little as possible that will have to resist the force of high-velocity floodwaters. A decision on how much or how little to build should be based on the type and age of the visitors who will use the finished facility—schoolchildren, senior citizens, day hikers, or backpackers. Professional geotechnical and structural engineers and landscape architects are needed for effective design of these big-budget structures.

Finishing Details

Although constructing the basic structure right is most important, often the mark of craftsmanship is most evident in the finishing details. Most of the following discussion applies to boardwalks. However, some finishing work can be used with other construction techniques.

Decks

Plank used for a deck often contains heartwood and sapwood. If the plank is placed with the heartwood face up, alternating moisture and drying—and the effects of freezing and thawing—will cause knots and some of the annual rings in the wood to lift. To reduce tripping hazards and future maintenance, deck plank should be placed "green side up" (the heart face down and the bark face up) (figure 55).

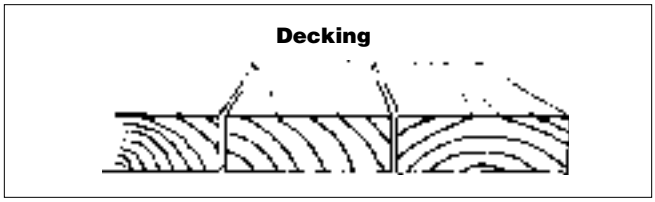


Figure 55—Place decking with the growth rings facing down to help prevent cupping. Cupping causes the wood to decay faster and creates a tripping hazard.

Posts

A pedestrian railing system may be needed along the edge of a deck to prevent visitors from falling off. Various building and highway codes call these railing systems "handrails," "guardrails," or "railings." If you are planning to install a pedestrian railing, the details of the installation of the posts need to be thought out before placing the deck. Railing posts need to be sturdy. They are a potential liability. Flimsy railings installed as an afterthought are the ones most likely to fail. Usually, it is the connectors, not the railing, that fail.

The deck, posts, and handrail are all closely related in their construction. As a minimum, 4 by 6 timbers should be used to support handrails. Actually 4 by 4s that are surfaced on all four sides are only 3½ by 3½ inches. They make a flimsy post. The deck should extend beyond the stringers to the back of the post, or at least 4 inches. If this is not done, people standing on the deck and leaning on the railing will have their feet sticking out beyond the deck (figure 56). In addition, the decking helps keep water off the stringers, reducing decay.

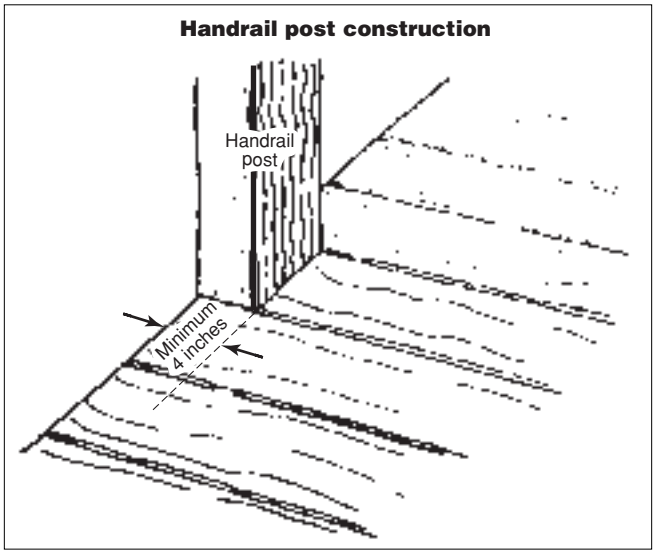


Figure 56—When the handrail post is attached to the stringer below the deck, the decking should extend at least 4 inches beyond the stringer.

There are two ways to install railing posts. The most common requires the deck to be in place. The posts are toenailed to a deck plank. By itself, this is a weak connection and requires an angle brace for support. Therefore the plank supporting the post must extend beyond the edge of the rest of the deck. If the plank is too short, the angle brace will be too close to vertical to provide much support (figure 57).

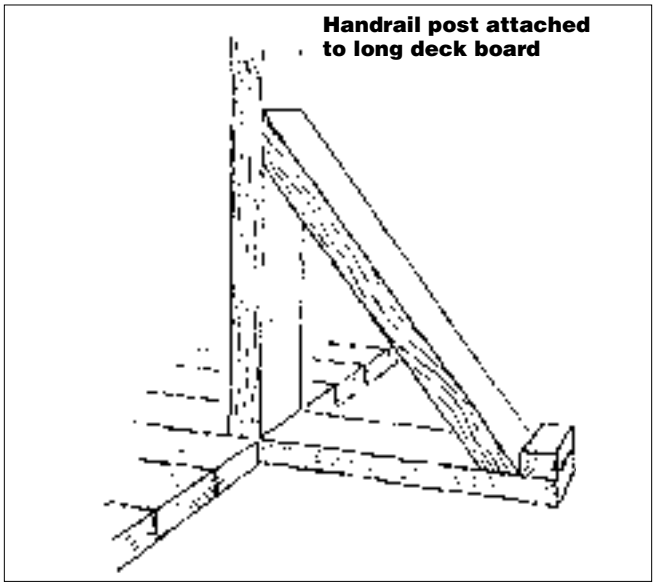


Figure 57—Attaching the handrail post directly to the decking requires long deck pieces to support an angle brace.

The second method is to attach the posts to the outside of the stringers. It is much easier to bolt the post in place before attaching the adjacent deck plank. To provide solid support, 12 inches of post should contact the stringer. The posts can be accurately cut and drilled in a shop and brought to the site. To avoid the awkward and time-consuming work of notching the planks, the width of the post should match the width of the deck planking (figure 58).

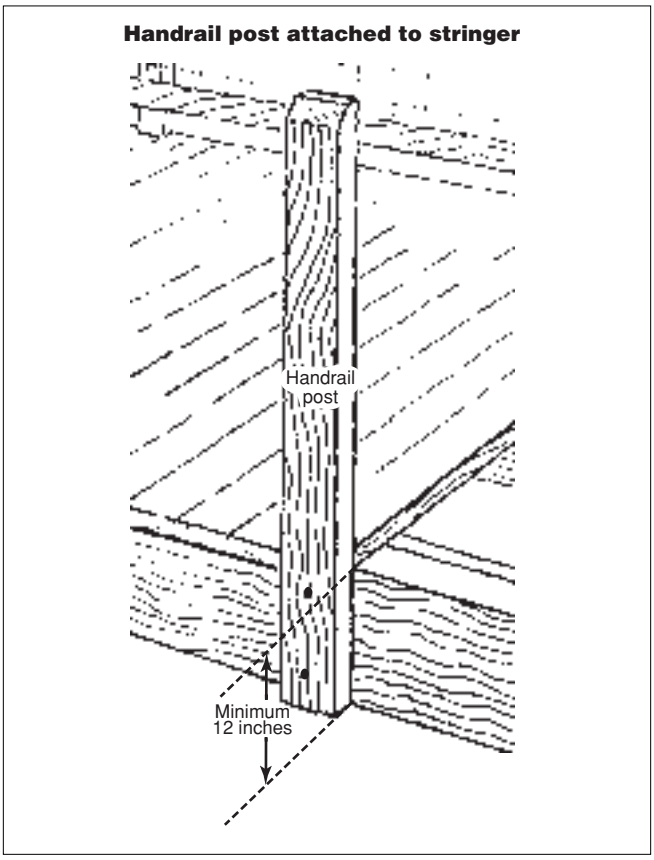
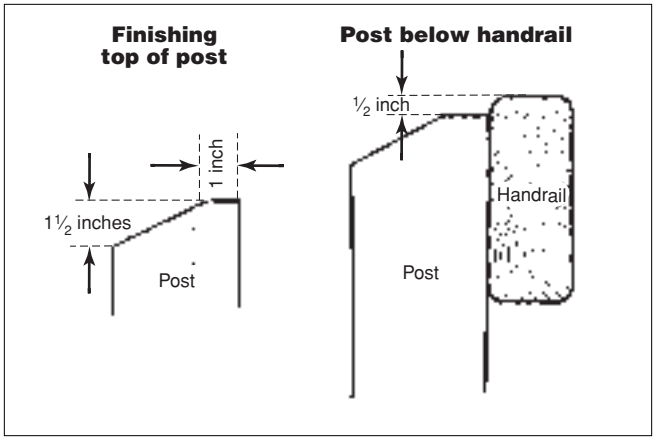
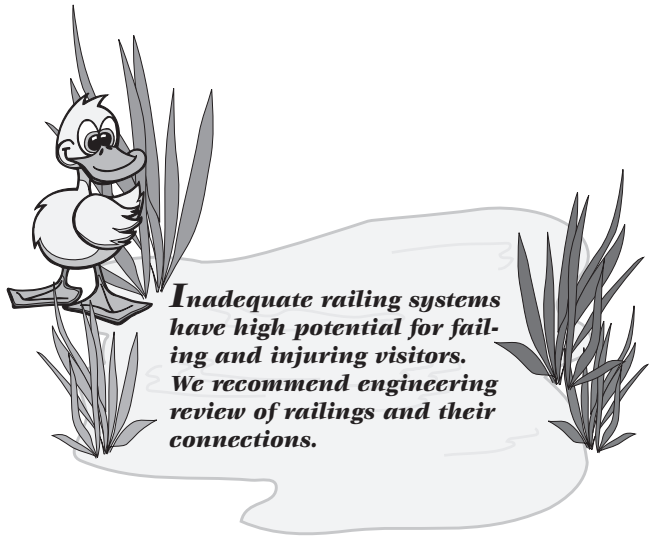


Figure 58—To provide proper support, at least 12 inches of the post needs to be in contact with the stringer.

The top of each post or pile should be cut at an angle to shed water and to help prevent decay. To avoid a sharp corner at the top of the post, a narrow 1-inch area closest to the handrail should be cut level, and the sloping portion should be pitched away from the boardwalk (figure 59). For esthetic and safety reasons, the posts should not extend above the top of the handrail (figure 60).



Figures 59 and 60—Cut the top of the post at an angle, but leave 1-inch flat on the inside edge. The post should not extend above the top of the handrail.



Pedestrian Railing Types

Safety must be the first consideration in selecting a railing system. Safety requirements are primarily determined by the relative accessibility of the trail. Railing types must fit the appropriate Recreational Opportunity Spectrum class. Railings are of three basic types:

➥ Railings attached to buildings (visitor centers, for example), must meet building code requirements such as those listed in the International Building Code (IBC). This code requires a railing at least 42 inches high that a 4-inch sphere will not pass through.

➥ Handrails on bridges need to meet the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges. Although most of the structures described in this book are not bridges, we offer these specifications for information. AASHTO requires 42-inch-high guardrails on all pedestrian highway bridges. Bridges on fully accessible trails usually need this type of railing. This code requires handrail at least 42 inches high for pedestrian traffic and at least 54 inches high for bicycle or equestrian traffic. A 6-inch sphere must not pass through the railing in the bottom 27 inches, and an 8-inch sphere must not pass through the area above 27 inches.

➥ Handrails for more remote trail bridges must be at least 42 inches high for pedestrian traffic and at least 54 inches high for bicycle or equestrian traffic. These handrail systems must also have at least one intermediate rail so that vertical distances between rails do not exceed 15 inches. Three-fourths of all Forest Service trail bridges fall in this category.

Not all wetland trail structures need railings. If the trail itself has more hazardous drops than the trail bridge would have without a handrail, a handrail is probably not required. Other considerations, such as convenience, may justify installing a handrail. Although IBC requirements and AASHTO specifications do not govern trail construction, they can serve as guidelines. As a general rule, any fully accessible trail with a drop of 3 feet or more, or a more remote trail with a drop of 8 feet or more, should have a pedestrian railing system. All accessible trails require a curb. A wheelchair handrail is required for any accessible trail bridge on a grade of 5 percent or steeper. Document your decisions with a design warrant retained in your files.

Railing Installation

Install the railings after the posts and deck are complete. Most railings consist of a top and bottom rail, usually 2 by 6s, although 3 by 6s make a better splice and a stronger rail. The stronger rail permits posts to be spaced more widely than if 2 by 6s were used for rails. The rail can also be cut and drilled in a shop where the splices can be cut accurately and more efficiently.

Often there is no clear direction regarding splicing the railings if the span exceeds 16 feet, the longest lumber that is readily available. It is difficult to butt splice a railing to the surface of a post that is less than 6 inches wide without an awkward splice or a maintenance problem (figure 61).

Walking on the top rail is a potential problem. Round logs or poles have been used to discourage visitors from walking on them, as well as 4 by 4s and 6 by 6s laid diagonally with one corner up. Another technique is to cut the tops of all posts at an angle and place a 2 by 6, or 2 by 8, on the cut surface. This helps to shed water and prevent decay.

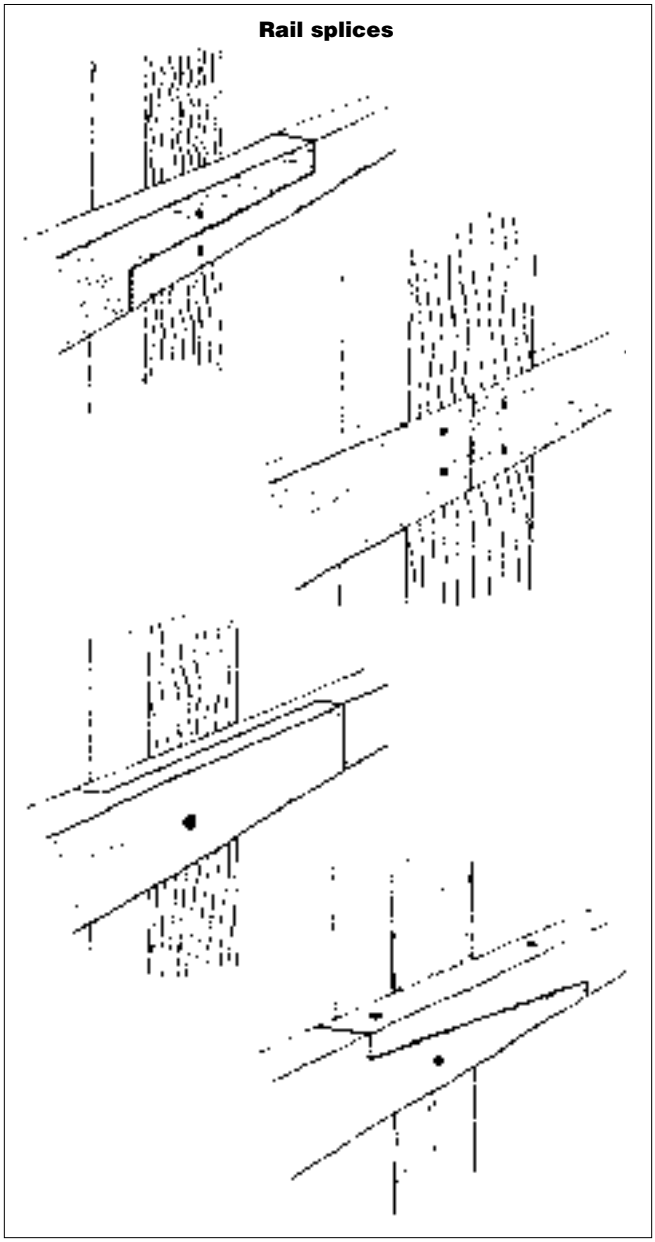


Figure 61—Four methods of splicing rails. It is best to cut the rails in the shop. Use carriage bolts with the round end on the inside of the railing to prevent users from snagging themselves.

The edges of all rails should be "edges eased." Edges eased is a trade term indicating that the corners along the edges of the piece of wood are rounded. To reduce splinters, the radius of the handrail edge should be ½ inch or more.

Installing a handrail on a curved bog bridge or angled boardwalk can be a challenge. One way to do this is to use steel angles. Measure the distance between posts and cut the rail to that length. Nail or screw the angles at the ends and to the outside of a 2- by 4-inch or 2- by 6-inch rail. The angles will have to be bent slightly to conform to the different alignment of the posts. Hold the rail in place and nail or screw the angle to the side of the post with the inside face of the board flush with the inside face of the post. Measure the distance between the centerline of the two posts and cut a 2 by 6 to that length. Round the ends slightly and bolt the 2 by 6 to the 2 by 4. The result will be a stronger rail than a single piece of material. This technique may also be used for straight sections of railing to avoid nailing or screwing into the face of the post (figure 62).

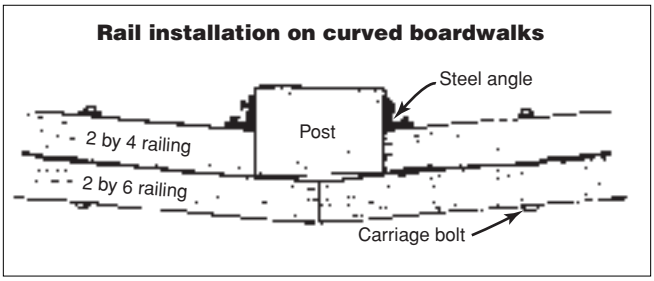


Figure 62—One method of installing rails on curving boardwalks using steel angles bent to accommodate the curvature of the structure.

For rails on curved trails, short wedge-shaped pieces of lumber can be used as shims between the posts and the rails. The wedges should be oak or cedar. Wedges are difficult to cut in the field. You could notch posts to the correct angle to accept the rails, but this is also difficult.

Cable or wire rope can be used as a railing system in some specialized applications (figure 63). Often the posts are close, 4 to 6 feet, and the cable is strung through holes drilled in the posts or through screw eyes. A single piece of cable may be strung through all the holes in the upper part of the posts, down the last post to the next lower hole and continuing this process back to the beginning through the lower holes, reducing the need for many splices. Use cable tensioners as needed.

Figure 63—Wire rope is used here as part of the railing system.

Curbs (Bull Rails)

Curb and bull rail are two names for the same thing. If the drop from a boardwalk is about 36 inches or less, a curb is usually installed. A curb is required for accessible trails. Curbs help to delineate the trail tread (figure 64).

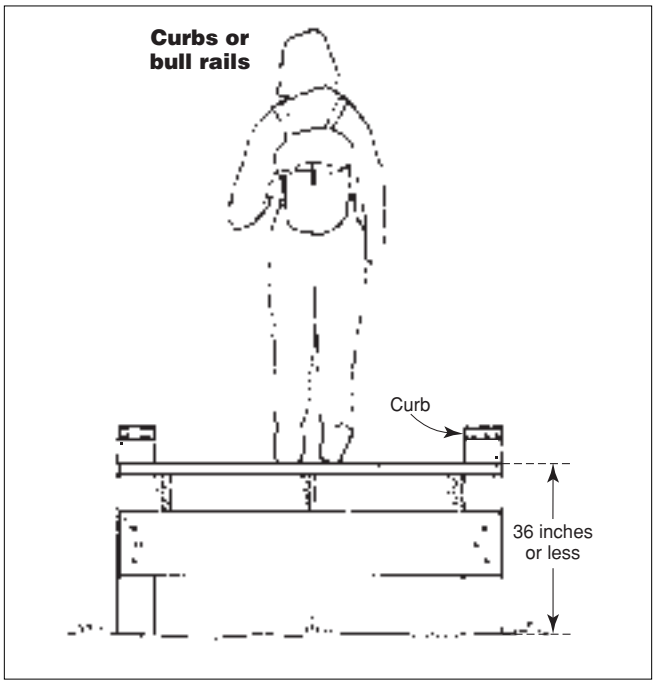


Figure 64—Typically, curbs (bull rails) are used when the deck is no more than 36 inches off the ground.

Curbs placed directly on the surface of a wood deck can cause the deck planking to decay. Leaves, needles, and dirt accumulate against the curb, absorb water, and cause additional decay. During the winter, ice and snow will build up on the deck, causing a hazardous condition.

To keep the deck from decaying, place the curbs on blocks. A finished block of 2 by 4 lumber is only 1½ inches thick. Leaves and dirt can still build up against the curb and under it. With just 1½ inches of space between the curb and the deck, it is difficult to get a shovel under the curb, making this area almost impossible to clean. A better solution is to use two blocks of 2 by 4 lumber, one on top of the other, or one block of 4 by 4 lumber (figure 65) to eliminate the opening under the curb. Litter will not be trapped, and melting ice and snow will run off more quickly. These openings underneath the curbs sometimes are called scuppers, an old nautical term.

Bulkheads (Backwalls, End Dams, Faceplates)

Bulkheads must be installed where wood construction meets the earth trail at each end of a puncheon, bog bridge, or boardwalk. They function as retaining walls to support the earth. They also protect the end grain of the stringers from decay and insect damage (figure 66). Bulkheads should always be treated timber.

Install the top of the bulkhead level with the top of the stringers, covering the gap with a piece of deck plank. This is the best way to keep moisture away from the stringer.

Extend the backwall 1 to 2 feet on each side of the structure to keep wet soil away from the sides of the stringers.

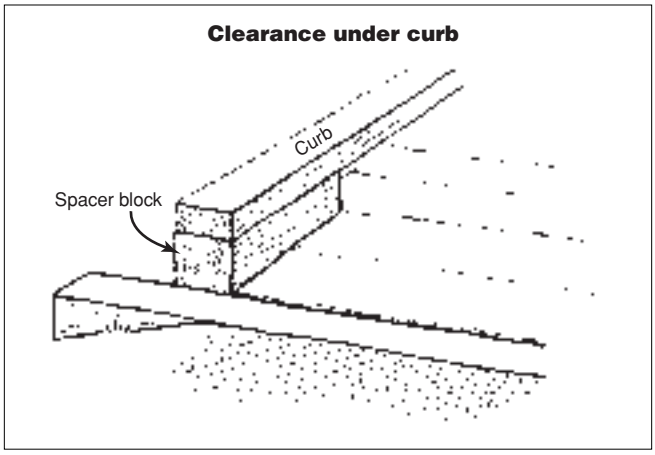


Figure 65—Having at least 4 inches of clearance under the curb is best.

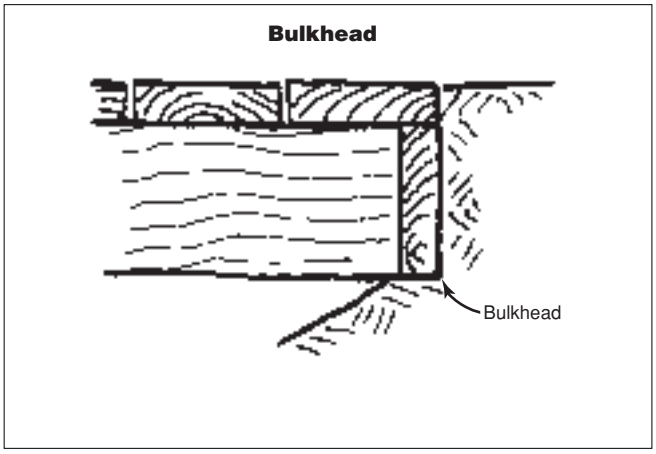


Figure 66—Bulkheads serve as retaining walls to support the earth, and they protect the stringers from decay and insect damage.

Floating Trails

Trails that float on the surface of the water are quite rare. They are covered briefly here. For more detailed information, refer to *Floating Trail Bridges and Docks* (Neese and others 2002).

Most floating trails are engineered structures, like docks, that float on watertight drums, polystyrene-filled corrugated plastic pipe, or other specialized floating systems. Rely on your engineering and landscape architectural staff to help you design a functional, attractive system.

A floating trail needs solid anchors at each end. Depending on the length of the floating trail and the expected water condition, the anchors may be timber deadmen (buried anchors), helical piles, concrete deadmen, or long wooden piles. Two cables, connected to these anchors and the opposite ends of each float, hold the floats in place. The trail must be straight between anchor points. Bends in the route require intermediate anchor points for the cables. If there is any current, an additional cable brace should be attached to the floats toward the middle of the span to hold them in place against the current. This cable brace must also be anchored on both ends. You may need to install cable braces on both sides of the floating trail to hold it in place (figure 67).

A floating trail tends to bob around, creating an unsteady tread surface. Such trails may not be suitable for all users. During periods of rough water, the floating trail may have to be closed. Sometimes, outriggers extending to the sides of the deck can provide additional floatation and stability.

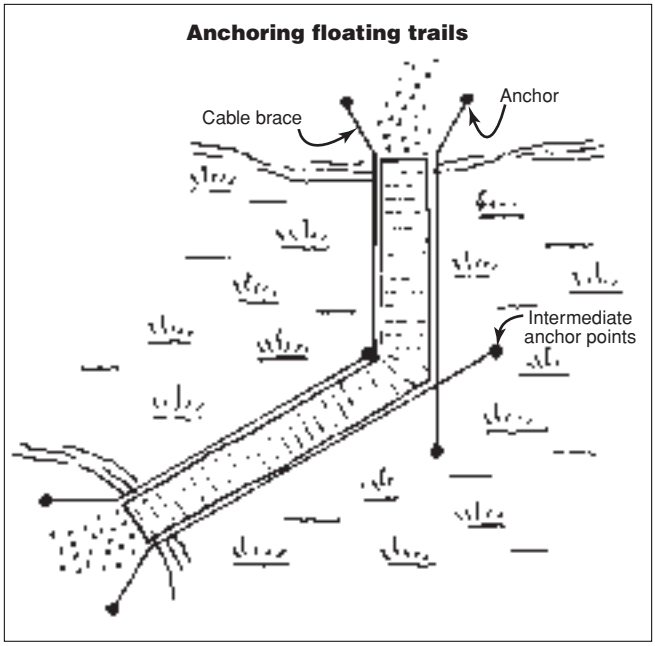


Figure 67—True floating trails need solid anchorages. Often they are secured with wire rope.

Construction Materials

Choosing Materials

Materials used in trail design should be appropriate for the setting. Steel, plastic, concrete, and asphalt may be appropriate in an urban greenbelt, but out of place in the backcountry. Log construction, stone masonry, and dirt trails are appropriate in a primitive, backcountry setting, but out of place in a city.

The Forest Service recognized this problem in the late 1970s and developed a system called the Recreational Opportunity Spectrum (ROS).

The ROS system establishes seven types of recreational land uses and describes the level of development, management, and construction materials suitable for each of them. The ROS principles may appear overly structured, but their application should result in construction and management that is compatible with the environment surrounding a wetland trail whether that trail is in a remote area, an urban greenbelt, or another setting. The ROS concepts are too detailed to include here, but they should be understood by anyone planning to design and construct wetland trails.

Logs

Wood from logs cut onsite is commonly used in trail construction, but wood is susceptible to attack by insects and fungi. Bark separates from the wood. The gap collects water and provides shade and protection for insects and fungi. Peeling off the bark reduces the likelihood of these attacks. Depending on local conditions, removing the bark may double the life of a log.

The bark can be removed by hand or machine. Using a draw knife or bark spud is the traditional way of peeling logs. The random scrape marks left on the peeled logs gives them a rustic appearance. Machine peeling “chews” the bark and some of the wood in a spiral pattern. The finished pieces are almost uniform in size, with a machined appearance that lacks the rustic character of peeled logs.

Wood that is exposed to the weather or is in contact with the ground will eventually require replacement. In wetlands, a flood, a heavy snow, a buildup of ice, fallen trees, or animal damage may shorten the life of wooden materials. Trees growing near a wetland site are unlikely to provide a sustainable source of logs for replacement structures. Even in remote areas, logs cut from trees growing in the vicinity may not be the best choice of materials.

Using logs cut onsite for trail construction is an inefficient use of wood and does not represent sustainable design. Tearing up areas near a site and destroying the character of the wetland makes no sense. Today, responsible trail crews are taking commercially obtained logs and other wood materials to remote wetland sites by boat, horse, mule, off-highway vehicle, by hand, or by helicopter, even when adequate material is growing a few feet from where it could be used. Sometimes materials can be hauled in more easily over snow during the winter for use the following summer.

Lumber and Timber

For the purposes of this text, lumber is wood that has been sawed and planed into uniform pieces with a minimum dimension of 2 inches or less. For instance, a 2 by 6 is a piece of lumber. Timber is wood that has been sawed into more or less uniform pieces, with a minimum dimension of at least 3 inches. Usually, timbers have not been planed smooth.

It helps to understand how logs are processed into lumber and timbers. Logs run through a sawmill are typically sawed into standard-size pieces, usually 1-inch thick or in increments of 2 inches. Common sizes are: 1 by 4, 1 by 6, 2 by 4, 2 by 6, 2 by 8, and 4 by 4. The pieces can also be cut into 3-inch stock. However, such nonstandard timbers would not be readily available at the local lumberyard. Most 4-by-4, 6-by-6, and larger timbers are cut from the center of the log. Generally 1- and 2-inch materials are cut from the outside of the log.

After the pieces of wood are cut from the log, they are referred to as rough sawn. The first step produces a piece that is sawn on its two widest faces. The bark remains on the narrow edges. At this point the piece is described as rough sawn and waney edged. The edges are not parallel or square. Waney-edged wood is used for rustic siding. Waney-edged lumber can be special ordered (figure 68).

Next, the piece of wood is run through another saw, the edger, that trims the edges square and to a standard 2-inch dimension. The piece of wood is now rough sawn on all four sides and is full size—a 2 by 4 is 2 inches thick, 4 inches wide, and as long as the log.

The pieces are cut to standard lengths. Normally, the shortest pieces are 8 feet long. Longer pieces are cut in multiples of 2 feet, up to 16 feet. Rough-sawn lumber or timbers can be ordered. A piece of rough-sawn, 2-inch lumber is considerably heavier than the finished lumber normally carried at a lumberyard. Rough-sawn pieces are not completely uniform.

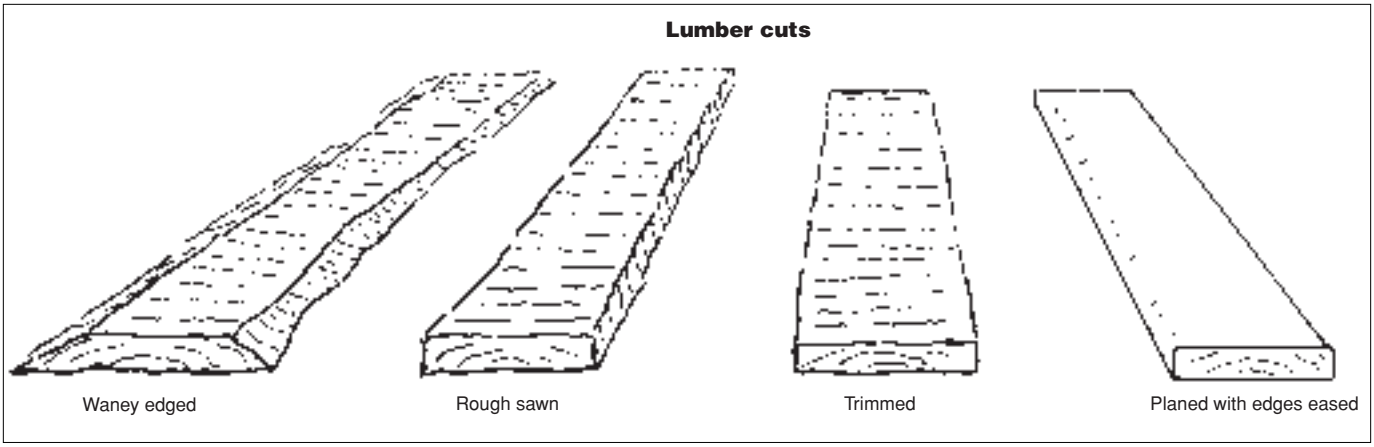


Figure 68—Lumber terminology.

Depending on the capability of the sawmill, similar pieces may vary ⅛ to ⅜ inch from each other. The pieces will not have a smooth surface, and the edges will be sharp and splintery.

Finally, the rough-sawn pieces are run through a planer. The planer removes enough wood to smooth the surface on all sides and to produce standard-size pieces. After planing, a 2 by 4 is 1½ inches by 3½ inches and is described as S4S (surfaced four sides). The size after the lumber has been surfaced on all four sides is referred to as nominal size.

Most 2-by-4 material is usually run through a special planer to round off the corners. This process is called edges eased and reduces the chances of splinters when handling the wood. Edges eased can also be specified for other dimensions of lumber and the smallest dimension timbers, but must be special ordered.

Waney-edged material should be less expensive than rough-sawn because it requires less processing. Rough-sawn material should also be less expensive than nominal-size material because it has not been through a planer or had the edges eased. If the imperfections of waney-edged or rough-sawn material are acceptable, there is no point in specifying the nominal size material for a project. Why pay for someone to turn wood into sawdust and shavings that you can't use? Besides, the additional work results in a weaker piece of wood.

Wholesalers sell wood by the thousand board feet. A board foot is 12 inches by 12 inches and 1 inch thick, or 144 cubic inches. The board footage of lumber and timber is determined at the time the piece of wood is rough sawn. See appendix E for a table of board feet contained in most standard sizes of lumber and timber, and for various standard lengths.

Decay-Resistant Wood

Using decay-resistant wood will greatly increase the life of the material and reduce maintenance. Some species of trees are naturally decay resistant. Wood from other species can be treated with preservatives to extend its life. Depending on the climate and the location of the piece of wood in the finished work, construction without decay-resistant wood may last only 7 to 10 years, while installations of naturally decay-resistant woods may last 70 years or more.

Naturally Decay-Resistant Wood

The most common decay-resistant species include the various cedars, redwood, baldcypress, black locust, honeylocust, and some white oaks. A tannin found in the wood of these trees colors the heartwood and makes it decay and insect resistant. The sapwood of the same tree is almost white and is not resistant. The wood of Douglas-fir and the white oaks does not contain a toxin, but it is dense enough to repel some fungus and insect attacks.

Preservative-Treated Wood

Using chemically-treated wood in wet environments may mean the structure lasts 30 years instead of 7 to 10 years. It is important to know which chemical treatments are appropriate, and whether or not they cause adverse health or environmental effects.

The subject of chemically-treated wood is complex, and is an area of continuing research and product development. Follow the recommendations in the *Best Management Practices for the Use of Treated Wood in Aquatic Environments* (Western Wood Preservers Institute 2006). Another comprehensive source of information is *Preservative-Treated Wood and Alternative Products in the Forest Service* (Groenier and LeBow 2006).

In a nutshell, there are several good reasons to use preservative-treated wood in wet areas and few reasons not to use them. All of the treatments effective in wet areas must be applied under pressure in a factory to exacting standards. The exception is copper naphthenate, which can be applied carefully and sparingly with a brush and is good for spot treatment. Both oil-type and waterborne preservatives are suitable for wet environments from a standpoint of preserving wood, but the person specifying materials needs to know the characteristics and effects of each type of preservative before deciding which to use. Water-soluble preservatives, such as borates, are not suited for wet environments. The borates do not permanently "fix" to the wood.

Workers need to take safety precautions when handling or disposing of treated wood. Treated wood should not be burned. Some States and other jurisdictions may also impose disposal restrictions. Best management practices call for proper collection and disposal of treated wood debris and sawdust.

Each of the preservatives containing copper imparts a color that disappears in time. Normally, the color disappears within 2 years, but depending on site conditions and exposure, the process may take several months to 3 or 4 years. One of the most popular preservative treatments, chromated copper arsenate (CCA), is no longer used if anyone is likely to contact the preservative-treated wood. Replacement treatments are more corrosive than CCA, so hot-dipped galvanized hardware and fasteners are recommended to prevent corrosion.

Recycled Plastic

Many manufacturers of recycled plastic are producing this material in the shapes and dimensions of standard wood lumber and timber products. Some of these products are being marketed as premium deck coverings. Recycled plastic can be worked like wood. It can be sawed, drilled, nailed, screwed, bolted, and painted. Although the surface is smooth, it is not slippery.

The properties of some recycled plastic may present unexpected challenges and disappointments. The material can be up to three times heavier than wood. By itself, 100-percent recycled plastic has little strength. It must be reinforced with a steel backing or core to have any structural value, increasing its weight and introducing another material.

Plastic is decay resistant. The thermodynamic properties of plastic—how much it expands and contracts in the heat or cold—are quite different from those of concrete, steel, or wood, the materials that would normally be used with recycled plastic. The surfaces of some recycled plastic severely degrade in sunlight. The problems of strength, thermodynamics, and ultraviolet degradation are being studied. These problems have resulted in new, improved formulations of recycled plastic. These products have not yet withstood the test of time.

Some recycled plastics contain sawdust or another form of wood fiber or fiberglass. These composites are usually stronger and do not have the same thermodynamic problems as most 100-percent plastics. When sawed or drilled, the exposed sawdust and wood fiber may be just as subject to fungus and insect attack as untreated wood. However, wood fibers completely encased in plastic will be decay resistant.

A problem is created when any of the recycled plastics are drilled or sawed in the field. Unlike wood, the shavings and sawdust will not decompose. This problem can be resolved by drilling and sawing over a large plastic sheet and carrying the shavings out, the same process that is recommended for disposing of treated wood residues.

Recycled plastic is not a traditional construction material. It may be inappropriate where a rustic appearance is important. Recycled plastic costs 50 to 300 percent more than treated wood. The increased weight of plastic will be reflected in higher shipping and onsite construction costs. One advantage of this plastic is that it does not support combustion.

Hardware

Connectors

The nails, bolts, washers, nuts, and other connectors used for outdoor construction should be made of corrosion-resistant steel. Hot-dipped galvanizing provides more durable protection than electroplating. Products commonly available at most building supply stores are electroplated. It is especially important to use galvanized or stainless steel connectors on wood that has been treated with waterborne preservatives containing copper.

Nails

Most nails used in trail construction are ringshank nails, barn spikes, or occasionally, roofing nails. Ringshank nails have closely spaced circular rings around the shank of the nail. These nails rarely work loose and are very difficult to remove if driven incorrectly. The steel is quite brittle. It will usually break off if it is bent or hit on the side. Nails are sized by the penny, an old form of measurement. See appendix D for gauge (thickness), lengths, and number of nails per pound for each size. Barn spikes are from 8 to 12 inches long, with a wide thread making a complete revolution around the shank every 4 to 6 inches.

Bolts

Bolts are used for constructing bents. Bolted connections are better than screwed connections because the bolt passes completely through at least two timbers or a timber and a steel plate or angle. Both ends of the bolt are visible and can be tightened if the wood shrinks. Three different types of bolts can be used: carriage bolts, machine bolts, and long bolts that are custom cut from threaded rod (called *all thread*).

Carriage bolts were used to construct wooden wagons and carriages. A square portion of the head of a carriage bolt penetrates into the wood, preventing the bolt from turning when it is tightened. Carriage bolts were originally used with oak, a hardwood that did not allow the bolt head to turn. Carriage bolts are effective with most woods, except for softwoods such as redwood and western redcedar. Carriage bolts do not require washers between the head of the bolt and the wood, but a washer is needed between the nut and the wood. Carriage bolts may be up to 12 inches long.

Machine bolts have a hexagonal head that is flat on the top and bottom. Machine bolts require steel between the head and the wood and between the nut and the wood. The steel can be either a washer or a steel angle or plate. Machine bolts may be up to 12 inches long.

All-thread rods are available in lengths of 2, 3, 6, and 12 feet and diameters of ¼ to 1 inch. The rod, threaded for its entire length, is useful where long bolts are needed. The appropriate length is cut from the long rod with a hacksaw, and a nut and washer are attached to each end. Bolt cutters should not be used to cut the rod. They will mash the threads, making it impossible to attach the nut (figure 69).

Figure 69—Fasteners (from left): carriage bolt, machine bolt, all-thread rod, and lag screw.

Lag Screws (Lag Bolts)

Most people working with these connectors refer to them as lag bolts. Manufacturers call them lag screws. Regardless of their name, they usually have a square or hexagonal head, a threaded tapered shank, and a sharp point. They must be tightened with a wrench. They are made in lengths from 1 to 8 inches and diameters from ¼ to ⅝ inch.

Washers

Four types of washers are suitable for working with wood in a wetland trail: flat washers, fender washers, lockwashers, and malleable iron washers. Flat washers are the most commonly

used. They are placed between the wood and nuts and between the wood and the head of machine and lag bolts. The washer prevents the bolt head or nut from being drawn into the wood. Fender washers are wider than flat washers, but they have the same purpose. Fender washers are used if the wood or other material is soft. Lockwashers are not a closed circle; they are cut once and the ends are offset on one side or the other. They are used with the other washers and against the nut to prevent the nut from loosening.

Malleable iron washers are much larger and thicker than other washers. These washers were used when large-diameter bolts joined logs and heavy timbers in traditional rustic construction. Malleable iron washers can be used with ⅜- to 1-inch-diameter bolts.

Nuts

Nuts fit over the threaded ends of carriage and machine bolts and all-thread rods. They must be used against a washer or a piece of structural metal. Nuts are either square or hexagonal, with a round, threaded hole in the center to fit over the bolt or rod. Locknuts fit more snugly on the bolt than common nuts. They are used when vibration may loosen a common nut. Locknuts function better than lockwashers, but they are not as readily available.

Wood Screws (Deck Screws)

A screw is threaded and tapers to a point. The use of a screw determines the desired shape of the screw's head and point, and the material from which it is made. There are perhaps 100 kinds of screws, but wood screws are the ones most likely to be used in wetland trail construction. Wood screws are used to attach tread plank to a nailer, or an interpretive sign to a post. The head of a wood screw is wedge shaped to penetrate into the wood without protruding above the surface. Most screw heads will either have a recessed slot or cross to accommodate a standard screwdriver or a Phillips-head screwdriver. Hot-dipped galvanized steel, stainless steel, and brass screws should be used for trail work.

Most stainless steel deck screws are produced with a hexagonal recess in the head to accommodate an Allen wrench, which makes them somewhat vandal resistant. Other vandal-resistant screws require special screwdrivers for removal. These screws are best for installing signs.

Steel Reinforcing Bars

Steel reinforcing bars used for driftpins must be protected from the weather and the copper in wood treated with preservatives. Epoxy-coated steel reinforcing bars are available from suppliers of heavy construction materials. Usually these suppliers sell only to contractors. Epoxy can be purchased from some mail-order companies. The crew building the trail can cut the uncoated bars to size and dip the ends and paint the bars with the epoxy compound. The epoxy coating will resist saltwater corrosion. Before epoxy compounds were available, steel driftpins were protected with a thin layer of heavy automobile grease. The grease also made driving the driftpins easier.

Staples

Heavy steel fence staples, ¼ to ½ inch in size, are useful for attaching hardware cloth to wooden piles used for bog bridge and boardwalk in areas frequented by beavers. Staples can also be used to attach geotextile fabric to wood.

Hardware Cloth

Hardware cloth consists of two sets of steel wires placed per-pendicular to each other and welded together. The result is a pattern of equal squares. The squares are either ¼ or ½ inch. After welding, the hardware cloth is hot-dipped galvanized. It is available in 20- and 50-yard rolls, and in 2-, 3-, and 4-foot widths (figure 70). Hardware cloth is sometimes stapled around piles to discourage beavers from chewing on them.

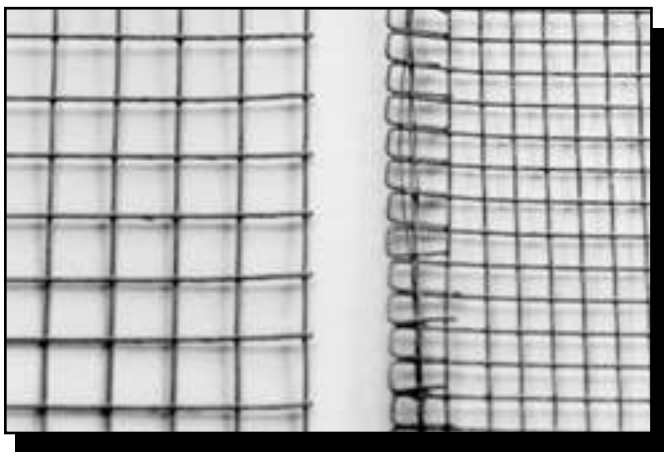


Figure 70—Two sizes of hardware cloth.

Geosynthetics

Geosynthetics are synthetic materials used with soil or rock in many types of construction. Geosynthetics can improve construction methods and offer some alternatives to traditional trail construction practices.

The Missoula Technology and Development Center produced a detailed report, *Geosynthetics for Trails in Wet Areas: 2000 Edition* (Monlux and Vachowski 2000), about these versatile products. The following information is summarized from that report. MTDC plans to update the report in 2007.

Geosynthetics perform three major functions: separation, reinforcement, and drainage. Geosynthetic materials include geotextiles (construction fabrics), geonets, sheet drains, geogrids, and geocells. All these materials become a permanent part of the trail, but they must be covered with soil or rock to prevent ultraviolet light or trail users from damaging them.

Geotextiles, sometimes called construction fabrics, are the most widely used geosynthetic material. They are made from long-lasting synthetic fibers bonded to form a fabric. They are primarily used to separate trail construction materials from wet, mucky soil and to reinforce the trail. They have the tensile strength needed to support loads and can allow water, but not soil, to seep through. Nonporous geotextiles can be used in drainage applications to intercept and divert groundwater. Felt-like geotextiles are easier to work with than heat-bonded, slit-film, or woven products that have a slick texture.

Geotextiles are often used in trail turnpike or causeway construction. They serve as a barrier between the silty, mucky soil beneath the fabric and the mineral, coarse-grained, or granular soil placed as tread material on top of the geotextile. The importance of separation cannot be overemphasized. Once mineral soil contains about 20 percent of silt or clay, it takes on the characteristics of mud—and mud is certainly not what you want for your tread surface. Most geotextiles commonly used in road construction work for trail turnpikes. The fabric should allow water to pass through it, but have openings of 0.3 millimeters or smaller to prevent silt from passing through.

Geotextile is sensitive to ultraviolet light. It readily decomposes when exposed to sunlight. When geotextile is not exposed to sunlight, it lasts indefinitely. Always store unused geotextile in its original wrapper.

Geonets or geonet composites (figure 71) have a thin polyethylene drainage core that is covered on both sides with geotextile. They are used for all three functions—separation, reinforcement, and drainage. Since geonets have a core plus two layers of geotextile, they provide more reinforcement for the trail than would a single layer of geotextile.

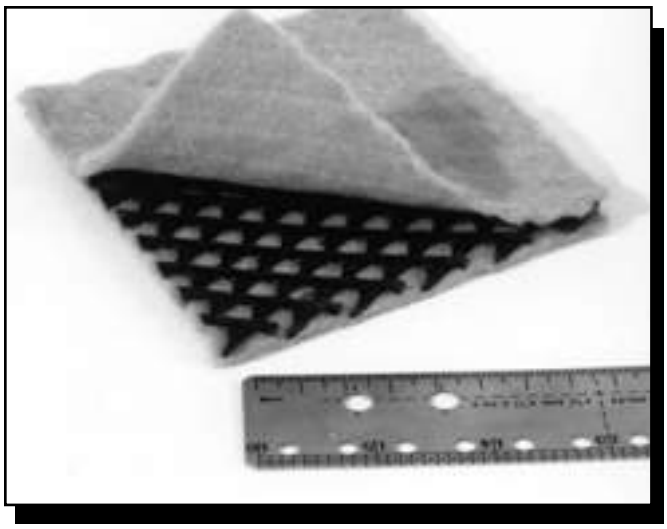


Figure 71—The net-like core of geonet allows drainage.

Sheet drains are a form of composite made with a drainage core and one or two layers of geotextile. The core is usually made of a polyethylene sheet shaped like a thin egg crate. The core provides separation, reinforcement, and drainage. Since sheet drains have greater bending strength than geotextiles or geonets, less tread fill is often needed above them.

Geogrids are made from polyethylene sheeting that is formed into very open grid-like configurations. Geogrids are good for reinforcement because they have high tensile strengths, and because coarse aggregate can interlock in the grid structure. Geogrids are normally placed on top of a layer of geotextile for separation from saturated soil.

Geocells (figure 72) are usually made from polyethylene strips bonded to form a honeycomb structure. Each of the cells is filled with backfill and compacted. Geocells are good for reinforcement, reduce the amount of fill material required, and help hold the fill in place. Geocell usually has geotextile under it to provide separation from saturated soils. The grids need to be covered with soil so they will never be exposed. Exposed geocells present a substantial hazard to vehicles due to loss of traction, and can cause hikers or packstock to trip.

Figure 72—Geocell being laid in courses for a bridge approach. When the approach is completed, the geocell will not be visible.

Nonslip Gratings and Grit-Treated Mats

Gratings are normally used for walking surfaces at industrial sites and boat docks. They may be useful where a slippery tread in a wetland trail has become a problem, or where this problem can be anticipated because of deep shade, heavy rainfall, or icy conditions.

Gratings are made in a variety of sizes from steel, stainless steel, aluminum, and fiberglass. Some manufacturers use fine serrated teeth on the surface of the grating to prevent users from slipping; others use small, round, raised knobs on the surface; still others embed silica grit. The gratings can be attached to an existing deck or used by themselves in the original construction.

Other options to reduce the likelihood of users slipping on the trail include the use of strips of rubber-like material with a non-skid surface. The strips adhere to clean decking. When wood is painted, stained, or sealed, a nonskid additive (sold at paint stores) can be mixed with the paint, stain, or clear sealer before they are applied.

Silica-treated fiberglass mats are available from some of the grating manufacturers. They come in thicknesses of ⅛ to ¾ inch and in panel sizes of 5 to 12 feet. Fiberglass can be sawed to size. Holes can be drilled for nailing or screwing fiberglass to wood planks.

Most gratings are extremely expensive, well beyond the budgets of most trail projects. The exceptions would be for wetland trails at very heavily used sites such as visitor centers or for short interpretive trails.

In Alaska, slippery surfaces are a reality on miles and miles of boardwalk. The Forest Service Alaska Region's *Trails Construction and Maintenance Guide* (1991) offers several ways of dealing with this problem. These methods are described next.

Roughened Wood Surface

Use a saw or adz to cut grooves perpendicular to the line of travel. Make the cuts deep enough to be effective, but not so deep that they hold enough water to cause decay.

Mineral Paper

Mineral paper is available in a 9-inch width in 50-foot rolls. This tar-fiberglass material is tacked down every 3 to 4 inches along each edge with galvanized roofing nails. Mineral paper should be used on pressure-treated wood because it will hasten the decay of untreated wood. If properly installed, it has given good service for up to 10 years. Mineral paper is inexpensive and easy to replace.

Fishing Net

Nylon fishing net (No. 96 Bunt Web) has been used successfully in the Alaska Region and has been found to be durable and effective. Make sure the net is properly stapled to each pressure-treated plank before delivering and installing the planks. Use an air-driven pneumatic stapler (that can be rented with an air compressor) to drive galvanized staples. Staple at 4-inch intervals to keep the net from bunching and creating a tripping hazard. The netting can be applied in the field using hand-driven galvanized fencing staples.

Neatly hide all edges underneath the walking surface of the plank or logs. Black 1- to 2-inch mesh netting has been used successfully on trails in Alaska. The color blends into the landscape. Used net material can usually be obtained free from net hangers in most Alaska fishing towns.

Cleats

Cleats, narrow boards screwed or bolted perpendicular to the tread at step-sized intervals, are an effective way to reduce slipping, especially on slopes. Metal cleats are common on steep gangways leading to docks subject to tidal fluctuations.

Construction Tools

The standard tools used for trail construction are also needed for building a trail in a wetland. Standard trail tools are not described here. Instead, this report focuses on tools specifically needed for wetland trail construction. Find out more about handtools in MTDC's *Handtools for Trail Work* report (Hallman 2005) and two-part video (98–04–MTDC).

Measuring Tapes

Measuring tapes are a necessity for estimating and constructing a wetland trail. Construction measurements for wetland trails are often taken from the trail centerline. It is frequently necessary to divide by two. Metric measurements offer an advantage over English measurements in such cases. In addition, there is a move from the English system of measurement to the metric system (appendix F). Buy new tapes that are graduated in both systems.

Tapes 50 feet and longer are made of fiberglass, cloth, or steel. Fiberglass is best for the wet, brushy environment of wetlands. Cloth is not recommended because it will wear and rip easily. Long steel tapes may rust, kink, and break when used in wetlands. Short steel tapes, 6 to 30 feet long, are essential.

The longer tapes are best for estimating quantities of materials and hours needed for construction and for laying out centerlines of sleepers, bents, and other structures. The shorter steel tapes are handy for the actual construction.

Framing Squares

Framing squares (figure 73) are thin, L-shaped pieces of steel with a 90-degree angle at the corner. Each leg of the L is 1 to 2 inches wide and graduated in inches (or centimeters) from both the inside and outside corners of the L. The legs may be 8 inches to 2 feet long. Framing squares are used to mark hole centers and timbers to be cut at a 90-degree angle and to provide a straight, firm edge for marking angled cuts.

Plumb Bob

A plumb bob is a solid steel or brass cone, 3 inches long by 1½ inches in diameter. The plumb bob accurately transfers measured points above the ground to comparable points on the ground. It is useful for locating the centers of holes to be dug.

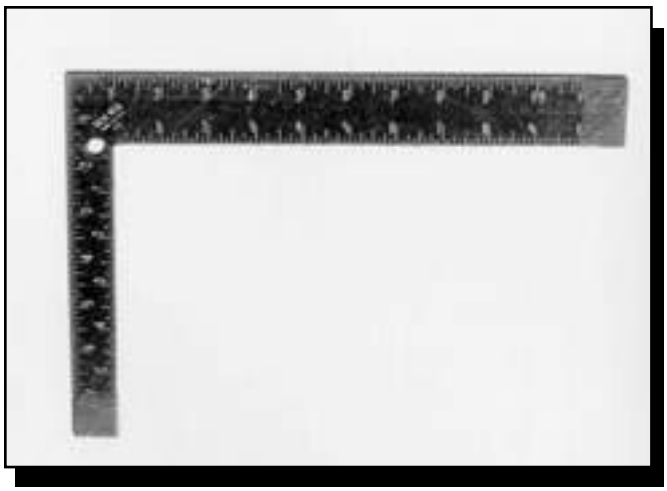


Figure 73—Framing square.

Levels

Specialized levels are useful for wetland trail work. An Abney hand level or a clinometer is accurate enough to be used for setting grades during the preliminary layout of most wetland trails (figure 74). String or line levels and carpenter's and mason's levels are needed during construction.

Figure 74—Use a clinometer to set grades for preliminary trail layout.

String or Line Levels

There are two types of string or line levels: one establishes percent of grade easily, the other does not. Each level is about 3 inches long by ½ inch in diameter and has a hook at each end to hang the level on a string. The string is pulled tight between two points in an almost horizontal line. One of the points must be at a known elevation. The string level will be used to establish the elevation of the other point.

The most common type of string level has two marks on the level tube. These marks are equidistant from the high point of the level tube. Center the level bubble between the two marks on the tube by raising or lowering the string at the second point. When the bubble is centered, the string is level. If the tread is to be level, this is the elevation to be met. If the tread is to be sloped, the difference between the two points must be calculated; the elevation to be met is established by measuring the difference needed, up or down, from the level line.

In the second type of string level, the high point of the level bubble is off center. The level tube has five graduations. The first two are widely spaced. The rest are closer together, but evenly spaced. When the bubble is centered between the two widely spaced marks, the string is level. When the edge of the bubble touches the third mark, the string is at a 1-percent grade, the fourth mark is at a 2-percent grade, and so forth. A string level is accurate enough to begin to establish relative elevations and slopes for small wetland trail projects (figure 75).

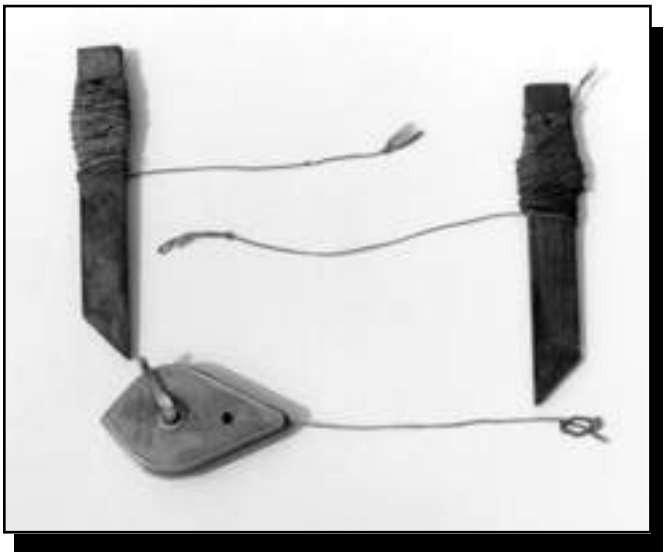


Figure 75—String levels and a chalkline.

Stringlines

Almost any type of string can be used for a stringline, but for repeated use a professional stringline is best. This type of stringline is a tightly braided string wound around a short, narrow piece of wood, plastic, or metal. Usually there is a metal clip, or a loop, tied on the end.

The stringline extends a straight line to reference the location of the next section of construction. The stringline can also be used with string levels to establish relative elevations and slopes.

Chalklines

A chalkline is another type of stringline used to mark a straight line between two points on a flat surface. The marked line is commonly a guide for sawing.

Professional chalklines come in a metal case that holds the coil of string and the chalk dust. One end of the chalkline is held tightly at a fixed point on the surface of the object to be marked. The chalkline is stretched to the mark at the opposite end and held tightly at that point. Hold the chalkline at about midpoint, pull the chalkline straight up from the surface and release it. The chalkline will snap back into place, leaving a sharp, straight line of chalk between the two points.

A chalkline is useful for marking the centers of sleepers and bents for a deck that needs to be in a straight line, or the edges of a deck to be trimmed uniformly, or the edges of a log to be cut with a flat face.

Carpenter's and Mason's Levels

There used to be a distinction between carpenter's levels and mason's levels. Carpenter's levels were wood or wood with steel strips to protect the edges. The mason's level was all or mostly steel. Today, wood, steel, aluminum, and plastic are used in either type of level.

These levels are available in lengths of from 2 to 6 feet. Given the abuse trail tools take, steel or aluminum levels are best. A 3- to 4-foot-long level is more accurate than a shorter level. These levels are easier to pack than 5- to 6-foot-long levels. Plastic levels are also available and cost less.

The levels have three tubes mounted in the body of the level. One level tube is parallel with the length of the level, one is perpendicular to it, and one is at 45 degrees to the other two. When a level bubble is centered, the edge of the level is either level, vertical, or at 45 degrees.

Torpedo Levels

A torpedo level is steel or aluminum and plastic and only 8 to 12 inches long and 1 to 2 inches wide. It is used to determine if a surface within a confined area is level, for example the surface of a notch. Although the torpedo level is not as accurate as the longer levels, it can be used to check whether an item is out of level, or out of plumb. If so, a more accurate level can be used to make the corrections.

Post Levels

Post levels save time when setting posts and piles. They are basically plastic right angles that are 4 inches long in three dimensions. Two level tubes are mounted in the two faces of the level. Set the level along the side of the post or pile, and use a crowbar or shovel to adjust the post or pile until it is plumb (figure 76).

Figure 76—Post level.

Surveyor's Transits and Electronic Instruments

Hand-held tapes and levels are adequate for short destination or loop trails in a wetland, or for low, poorly drained sections of existing trails. However, for trails longer than a quarter mile or over undulating terrain, more precise measurements might avoid future problems. Control points for elevation and slope can be established using surveyor's transits or a variety of electronic instruments.

Surveyor's Levels or Transits

Old surveyor's levels or transits may be hiding in a closet or storage area at some agency offices. Blow the dust off and try to find someone who knows how to run the instrument. A builder's level or transit may be less accurate, but should work. A surveyor's level rod will be needed to obtain distances and elevations. Distances can be quickly measured optically using stadia.

Electronic Distance Measuring Instruments

Two types of electronic distance-measuring instruments (EDMs) are available. The least expensive type is hand held and can measure distances across a flat surface to a point from 2 to 250 feet away. This type of instrument does not provide elevations of points or information needed to determine slopes and relative elevations. It will not provide accurate distance measurements if vegetation impedes the line of sight.

More expensive instruments can measure distances up to 12,000 feet with an accuracy of 0.02 to 0.03 feet. A direct, clear line of sight is required.

Global positioning systems (GPS) provide horizontal positioning through the use of coordinates and can provide elevations. This equipment may cost from a hundred dollars to several thousand dollars depending on the quality. The skills needed to operate GPS equipment vary depending on the equipment's sophistication and accuracy.

The accuracy of small hand-held instruments can be close to 1 meter (3.28 feet), in open, relatively level terrain, sufficient accuracy for trail work if frequent points are taken along the route.

Survey-grade GPS instruments also are available for more precise work. These instruments require extensive training and experience in their use. They are also very expensive.

GPS technology changes quickly. Technological advances, reduced costs, and increased accuracy have resulted in many practical and affordable GPS trails applications.

Saws

Handsaws

Most timbers and logs used in wetland trail construction are of relatively small diameter. Usually the largest are the piles, 6 to 10 inches in diameter.

If only a few pieces must be cut, or if wilderness regulations require, a one-person crosscut saw can do the job. This is an old-fashioned large handsaw. The blade is 3 to 4 feet long and heavier than a carpenter's handsaw, with much larger teeth (figure 77).

Chain Saws

If many pieces of wood need to be cut, and if regulations permit them, chain saws do faster work for cutting the small sleepers, piles, and planks used for some wetland trails. A small, lightweight saw designed for tree pruning is better for cutting horizontally on vertical piles, posts, and other items. Pruning saws are available weighing 8 pounds, with a 12- to 14-inch bar.

The sawyer should be adequately trained and experienced in the use of the chain saw and the safety equipment. Most government agencies, the Forest Service included, require workers to receive special training and certification before they are allowed to use a chain saw.

Figure 77—A one-person crosscut saw is a good choice for backcountry settings.

Hand-Held Pruning Saws

Small hand-held pruning saws are used on most projects. Most types have a curved blade 12 to 26 inches long. For wetland work, the shorter saws are adequate. Some saws have a wood or plastic handle that the blade folds into when it is not being used. Small pruning saws with a straight blade 6 to 8 inches long are available. The short saws with the straight blade work well for cutting shallow notches in log sleepers. When the saws are folded, they can be carried in a pocket (figure 78).

Figure 78—Pruning saws.

Axes

Three kinds of axes are commonly used in trail work: single-bit, double-bit, and broad axes. The hatchet is not included in this tool list. A Maine guide once wrote that the hatchet is the most dangerous tool in the woods. He may have been right. It takes only one hand to use a hatchet. The other hand is often used to hold the piece of wood to be cut—not the safest thing to do. Few trail crews include a hatchet in their toolbox.

Proper ax selection, care, and use is described in MTDC's videos and reports: *An Ax to Grind: A Practical Ax Manual* (Weisgerber and Vachowski 1999) and *Handtools for Trail Work* (Hallman 2005).

Adzes

If the hatchet is the most dangerous handtool in the woods, the carpenter's adz is the second most dangerous. A person getting hurt with a hatchet has usually been careless. It is not necessary to be careless to get hurt using an adz. The carpenter's adz is used for cutting a level surface on a log for some types of puncheon and gadbury and for removing knots and bulges on log surfaces.

The blade of a carpenter's adz is 5 inches wide and similar to an ax except that it is mounted perpendicular to the line of the handle, similar to a hoe. The edge must be sharp. The handle is curved, similar to a fawn's-foot handle on a single-bit ax.

Workers using an adz normally stand on a wide log (16 inches or more in diameter) and swing the adz toward their feet, almost like hoeing a garden. An adz can be used on smaller-diameter logs by a worker standing next to the log and chopping sideways along the length of the log. When one face of the log is cut to a level plane, the log can be turned and another face can be cut. It is extremely difficult to use a long-handled adz to cut anything but the upper surface of a log.

Two other types of carpenter's adzes have short handles. They are not suitable for shaping large logs, but work well for removing knots and bulges and for cutting notches. Short-handled adzes are made with a straight or concave blade, about 3 inches wide. Striking the back of the adz head with a hammer will eventually crack the head (figure 79).

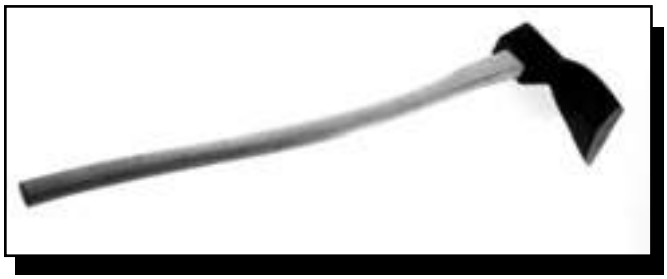


Figure 79—Using an adz safely requires that the adz has a razor-sharp edge and that the worker use the utmost control and concentration when making the swing.

Planes

Small block planes can be used for shaping bevels and chamfers, for removing unevenness where two pieces of wood butt together, and for smoothing splintery edges that visitors might touch. Block planes are small, about 2 inches wide and 4 inches long, and easily packed to the worksite (figure 80).

Draw Knives

Draw knives are often used to peel the bark off logs. Logs will last longer without the bark. Draw knives work best on logs with thin bark.

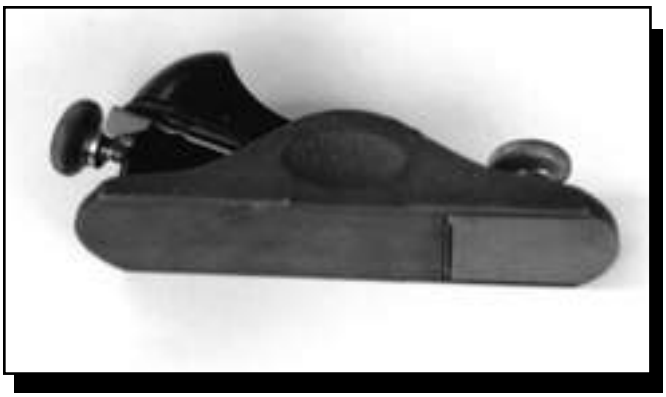


Figure 80—A small block plane is useful for finish work on wood structures.

Draw knives have either straight or concave steel blades that are 12 to 15 inches long with a wooden handle at each end. The draw knife is pulled toward the worker. The straight draw knife does not put as much of the edge against the wood as the concave knife, making the concave knife more efficient and more popular (figure 81).

Figure 81—Straight and concave draw knives.

Bark Spuds

Bark spuds are better suited for removing the bark from thick-barked or deeply furrowed logs and logs with many knots or large knots. Normally, logs are most easily peeled when the tree is still green, but this characteristic varies by tree species. Bark spuds are from 18 inches to 6 feet long. All have a steel head that is 2 to 3 inches wide and 3 to 5 inches long, sharpened on the end and both sides. The wooden handle is 15 inches to 5½ feet long (figure 82).

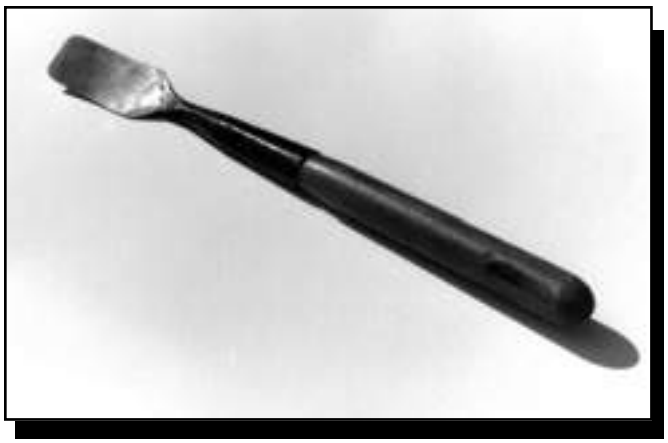


Figure 82—A bark spud works well when peeling green logs.

Tools For Drilling Holes in Wood

Bits

Bits are used to drill holes in wood for bolts and for pilot holes for nails and screws. Some of the types of bits available are twist bits, chisel bits, augers, and ship augers.

Twist bits are intended for use on steel, but the smaller bits can be used for drilling pilot holes in wood for nails and screws (see appendix D for appropriate pilot hole sizes). Chisel bits resemble a chisel with a point in the center. Chisel bits tend to tear up the wood around the hole on the top and bottom surfaces of the wood, but they are readily available in diameters of $\frac{1}{16}$-inch increments. Augers resemble a widely threaded screw with a sharp end and sharp edges. Augers do not tear up the wood like chisel bits do. A normal auger bit is 6 inches long and readily available in ¼- to 1½-inch diameters, in ⅛-inch increments, less readily in $\frac{1}{16}$-inch increments. With a 6-inch-long auger, it is difficult to get the holes to line up when two 3-inch ledgers are on each side of a 6 by 6 pile. Ship augers help in this situation because they are longer. Ship augers are 15, 17, 18, 23, and 29 inches long and are indispensable when working with timbers and logs.

Old auger bits were made with a four-sided shaft to fit into a manually powered brace or drill. A six-sided shaft is designed for use in a power drill and will spin uselessly when used in a manually powered brace or drill. Today, most bits are made for power drills. When selecting a bit from a maintenance shop, check to see that the shaft of the bit matches the brace or drill to be used at the worksite (figure 83).

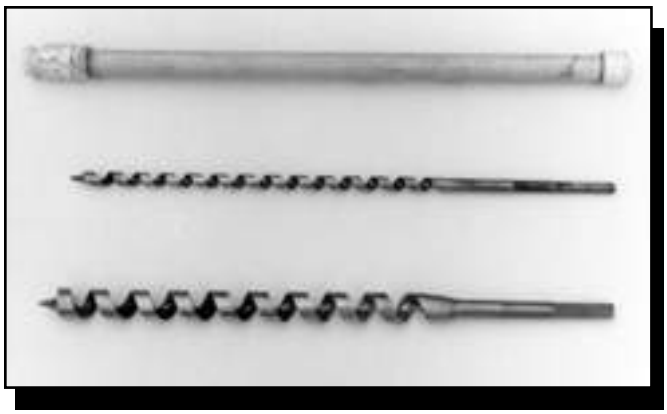


Figure 83—Ship augers are longer than normal 6-inch augers.

Braces

Braces and bits are the traditional tools for drilling holes in wood. The brace, a handtool suitable for wilderness use, is extremely slow. Old braces require an auger bit with a four-sided shaft (figure 84).

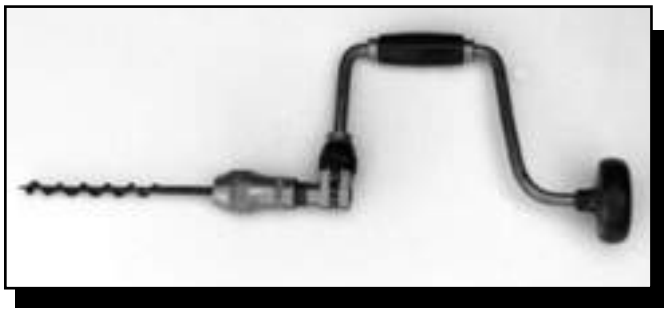


Figure 84—A traditional brace and bit.

Some braces are made with a ratchet, which is helpful when working in close situations where the brace cannot be turned a full circle. People have a tendency to lean on the brace to speed up drilling. This practice bends inexpensive braces. Buy a good brace or don't lean on it. Keep the bits sharp.

Battery-Powered Drills

Small battery-powered drills are useful for drilling holes 1/16 inch to 3/8 inch in diameter. Some heavy-duty drills can drill holes up to 1 inch in diameter. Battery-powered drills may be practical for backcountry use where only a few holes are to be drilled, where the crew returns to the shop after work, or where a generator or photovoltaic power source is available.

Gasoline-Powered Drills

Many trail crews use gasoline-powered drills. These tools can drill holes up to 1 inch in diameter and weigh from 10 to 12 pounds, plus fuel (figure 85).

Figure 85—Gasoline-powered drills are great for backcountry work if regulations allow their use.

Only the more expensive heavy-duty drills, whether battery or gasoline powered, have a reverse gear. A bit can become stuck if it does not go all the way through the wood. To avoid getting a bit stuck, lift the drill up a few times while drilling each hole. If the bit does get stuck, disconnect the bit from the brace or drill and use a wrench to twist the bit backward.

If you have a generator at the worksite, another alternative is to use a 1/2-inch-diameter electric drill. Most of these drills have a reverse. An annoying drawback is stepping over a long extension cord and getting it tangled in brush and timbers. If the operator is standing in water, electric shock is a possibility. Generators are heavy and require fuel. Although some generators have wheels, most are awkward to transport to wetland sites.

Clamps

A pair of large jaw clamps can speed the installation of two ledger bents. The clamps should have at least a 12-inch opening. These clamps are used for making furniture and may be all steel or part steel and part plastic. Both ledgers are placed roughly in position and clamped loosely to each pile. The height of each ledger is adjusted, the clamps are tightened, and the bolt holes are drilled (figure 86).

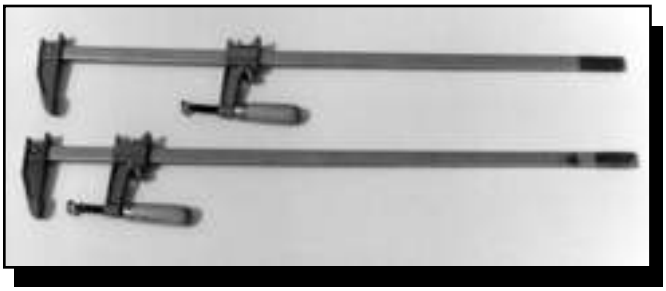


Figure 86—Large jaw clamps.

Wrenches

At least one wrench is needed to securely fasten carriage bolts and lag screws. Two wrenches are needed to fasten machine bolts and all-thread rod. Specialty wrenches or screwdrivers are needed to install vandal-proof screws. Closed-end and open-end wrenches, and a set of socket wrenches, may all be needed. Tying one end of a cord to the wrench and the other end to your belt may help keep the wrench from getting lost in the water or mud.

Chisels

Wood chisels are needed for wetland trail structures. The blade may be ¼ to 2½ inches wide. Wood chisels are typically made with short handles, which often contribute to scraped knuckles. It is worthwhile to repair or replace the handles of old, long-handled chisels.

For a small amount of close work, the wood chisel can be hit or pushed with the palm of the hand. If this technique is impractical, use a wooden mallet. Hitting a wood chisel with a steel hammer will damage the chisel's handle. A good wood chisel should not be used close to nails, screws, or bolts. The cutting edge should be kept sharp.

The socket slick, an oversized chisel, is a difficult tool to find. However, if considerable notching or other accurate work is required, obtaining a slick will be worth the extra effort and expense. The blade is 3⅜ inches wide with an 18-inch wooden handle. The slick weighs 3 pounds. A 2-inch-wide chisel weighs just 10 ounces. The advantages of the slick are its wide blade and long handle. The slick can remove wood twice as quickly as a wide chisel. The long handle keeps the hands farther from the wood being cut (figure 87).

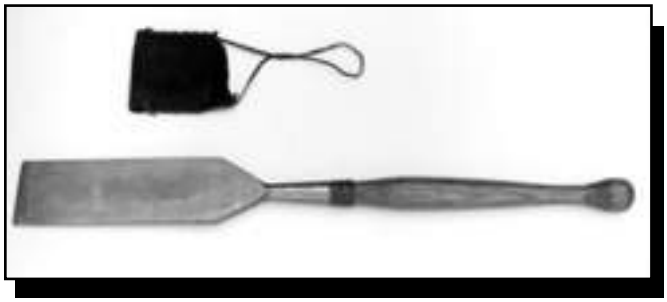


Figure 87—Socket slicks can be hard to find.

Mallets

Mallets are made with plastic, wooden, leather, or rubber heads. Mallets with plastic or wooden heads should be used for hitting wood chisels.

Hammers

Claw Hammers

A carpenter's claw hammer is helpful for nailing log culverts, bog bridges, boardwalks, and geotextile fabric. A 28-ounce framing hammer is better than the lighter models, although the heavy hammer may be awkward for workers who are unaccustomed to it.

Sledge Hammers

A variety of different weight sledge hammers should be available at the worksite. A 4-pound sledge is good for starting driftpins and spikes. A 6- or 8-pound hammer is better for driving them. The 8-pound hammer is better suited for moving heavy timbers and logs fractions of an inch when they are almost in place. Surveyor's sledge hammers have shorter handles. They are better for driving long pieces of steel because they provide better control.

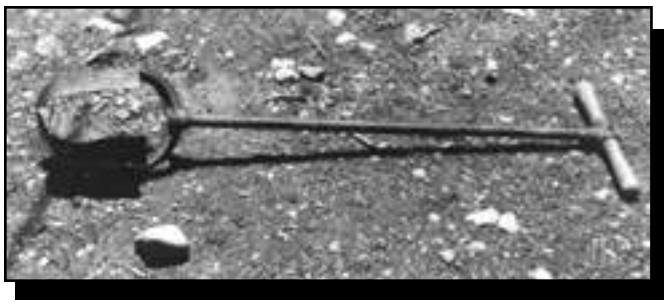


Figure 88—A hand auger.

Crowbars

A crowbar is indispensable for building trails in rocky terrain. For most wetland trail work, the crowbar is used to move fallen trees and logs out of the way and to align piles, logs, and timbers. A crowbar, also called a rock bar or pry bar, is much stronger than a hollow-pipe tamping bar. The two are often confused.

Tools for Digging Holes

Shovels and Posthole Diggers

The sharp-pointed shovel can be used for digging a narrow deep hole, but a posthole digger or manual auger is more efficient. The posthole digger with its clamshell-like blades is most common, but it is slow and awkward to use. The auger is more expensive, but more efficient.

Augers

The auger blade consists of two pieces of immovable curved steel set at opposing angles to each other. The wooden handle is turned in a horizontal plane while the blades drill a hole in the ground. In most soils an auger is more efficient than a posthole digger (figure 88).

Gasoline-Powered Augers

Gasoline-powered augers are available. These can usually be rented from local equipment rental companies. A one-person auger weighs 18 to 140 pounds. A two-person auger weighs 35 to 75 pounds. These augers are easily moved to a site. The heavier one-person augers have an engine mounted on wheels that is separate from the auger. Power augers usually make fast work of drilling holes in almost any soil. Problems occur when the auger runs into a boulder, a large root, or soil containing 4- to 6-inch pieces of gravel. The bit will stop, and the torque of the engine may cause back injury.

Wheelbarrows

Wheelbarrows are an underrated and often forgotten piece of equipment for trail work. A wheelbarrow is a necessity for moving fill for most turnpike construction and can be helpful for moving tools, materials, and supplies. For big jobs, two wheelbarrows are handy. One can be loaded while the other is being dumped.

Steel and fiberglass are the most common materials for the body. Steel is heavier and stronger, but fiberglass is cheaper and more easily repaired.

Wheelbarrows commonly available at most local building supply stores do not withstand the rigors of trail work. Contractor's wheelbarrows are made with stronger steel, and the handles are made of heavier, better quality wood. Although more expensive, a contractor's wheelbarrow will far outlast the flimsy backyard variety. Contractor's wheelbarrows can also be rented.

The solid-body wheelbarrow is the type that comes to mind when we think of wheelbarrows, but the gardener's wheelbarrow also has a place in trail construction. This wheelbarrow, without sides, is easier to use when loading large stones, short timbers and logs, and bags and boxes of materials. Gardener's wheelbarrows are more expensive than contractor's wheelbarrows and are difficult to find. Most have steel wheels. Pneumatic rubber tires are better for trail work. The frame of a standard wheelbarrow can easily be converted to a gardener's wheelbarrow. Temporary flat-tire repair sealants, sold in aerosol cans, help prevent pneumatic tires from going flat. Motorized carriers could greatly ease the burden of moving materials, where their use is allowed.

Compactors

Compactors should be used when placing fill for turnpike and for backfill around end-bearing piles. Several companies make a vibratory tamper type of compactor that is suitable for compacting small areas of fill. These companies also make vibratory plates, which are better suited for larger areas, such as turnpike and accessible surfaces. Vibratory tampers have an area 8 inches square that contacts the ground. Vibratory plates have an area 15 inches square that contacts the ground (figures 89 and 90).

A third type of compactor is an attachment to the Pionjar rock drill. It can be used for compacting backfill in narrow spaces around end-bearing piles, fenceposts, and signposts.

Figure 89—A vibratory tamper.

Figure 90—Vibratory plate compactor.

Practicing the Craft

Working With Logs

You learn some time- and labor-saving procedures after working with logs a few times. Here are some tricks that can make your work easier.

Felling

Trees needed for log construction should be felled during the growing season, mid-April to early September in most regions. The bark is easier to remove from trees cut during this season.

Ideally, fell trees uphill from the construction site, and out of sight of trail users. Select straight trees free of obvious defects. Often defects are not noticeable until the tree is down, but outward signs of decay, fungus growth, and insect attack indicate a tree to be avoided. Special training and agency certification are required for fallers, a very hazardous occupation.

Bucking and Seasoning

After felling, the tree is bucked, or cut, into log lengths. The logs can be peeled, which will reduce their weight and permit them to dry out, or *season.* Leaving the bark on the logs will protect the surfaces when the logs are moved, especially if the logs are dragged. Whether the logs are peeled or not, they should be stacked off the ground on two or three stringers of low-quality logs. Stickers should be used between layers of usable logs to allow uniform seasoning. Stickers can be 2 by 4s or small-diameter logs placed across a layer of logs at the ends and midpoints of a layer (figure 91).

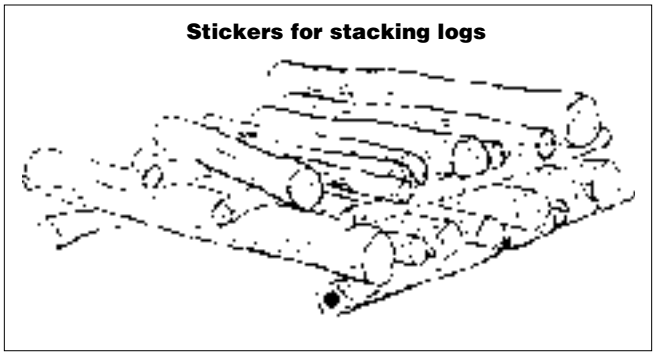


Figure 91—Stickers placed between layers of logs help the logs dry faster and reduce decay.

Moving Logs

Logs are heavy. Footing is uneven and often slippery. Accidents can happen easily, and the emergency room is far away. When logs are carried by hand, the tendency is to pick up the logs and carry them on the shoulder or at the waist. If workers holding the log slip, the log will come down on them. The result can be a serious injury to the ribs, hip, ankle, or foot.

To avoid or reduce the severity of this type of injury, use two or more log carriers. Log carriers are large steel tongs mounted in the center of a 2- to 3-inch-diameter wooden handle that is 4 feet long. Two workers can use one log carrier to drag a log. At least two carriers are needed to lift a log, one carrier at each end. Each carrier requires one worker on each side of the log.

Log carriers are awkward to pack, heavy, and serve only one purpose. The teeth of log carriers indent the wood half an inch or so on each side of the log. The indentations mar the appearance of the log and provide a place for decay to begin.

A cheaper and lighter method for moving a log is to use rope slings and the removable handles of mattocks or adzes (or small-diameter logs that are 3 to 4 feet long). The slings are made by taking 6 feet of 1,000-pound-test nylon rope and tying a fisherman's knot, double fisherman's knot, or a grapevine knot at the ends, forming a loop.

Roll the log onto the slings and slip the handles over the log and through the loops of the slings. With one worker on each end of the handles (four workers total), lift the log off the ground. The log should be about ankle high. If anyone slips and drops the log, the most serious injury will be to the ankle or foot, and the log will not have fallen far enough to develop much force (figure 92).

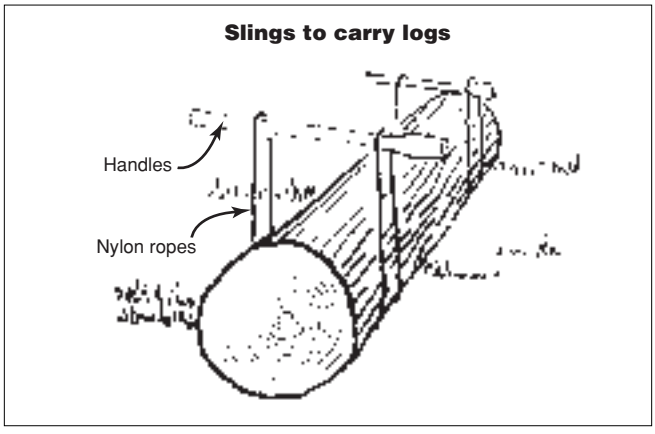


Figure 92—Slings are a good way to move logs and timbers, bundles of steel bars, wheelbarrows that must be carried over soft ground, or bags of cement carried on plywood.

Peeling

Peeling is a tedious process. There is little reason to peel the bark off a log if you plan to hew or plane it, unless the bark is dirty and likely to dull your cutting tools. Pine, fir, and other evergreen trees may develop pitch pockets just under the bark. On freshly cut trees, pitch may be runny rather than thick or sticky. The cutting edge of a drawknife is never more than an arm's length from a worker's face, and the drawknife is pulled toward the worker's body. Cutting into a pitch pocket splatters pitch on the worker. A drop of pitch in an eye results in the same burning effect as a drop of turpentine. Wear safety glasses or goggles when peeling logs of most evergreen species.

Squaring a Log

It is not easy to cut a uniform plane surface on a log. That difficulty plus the desirability of using treated timbers for longevity is the reason less work is being done with native logs on site. However, if you are determined to use logs because of their availability and their rustic appearance, here is how to do so. The first step is to place the log on nearly level ground and roll it over to determine which face is easiest to work with. Avoid areas with many knots or large knots. The crook of the log, if any, should be in the direction that will cause the least problem when the construction is completed. Roll the log until the best face is up and in a roughly horizontal position (figure 93).

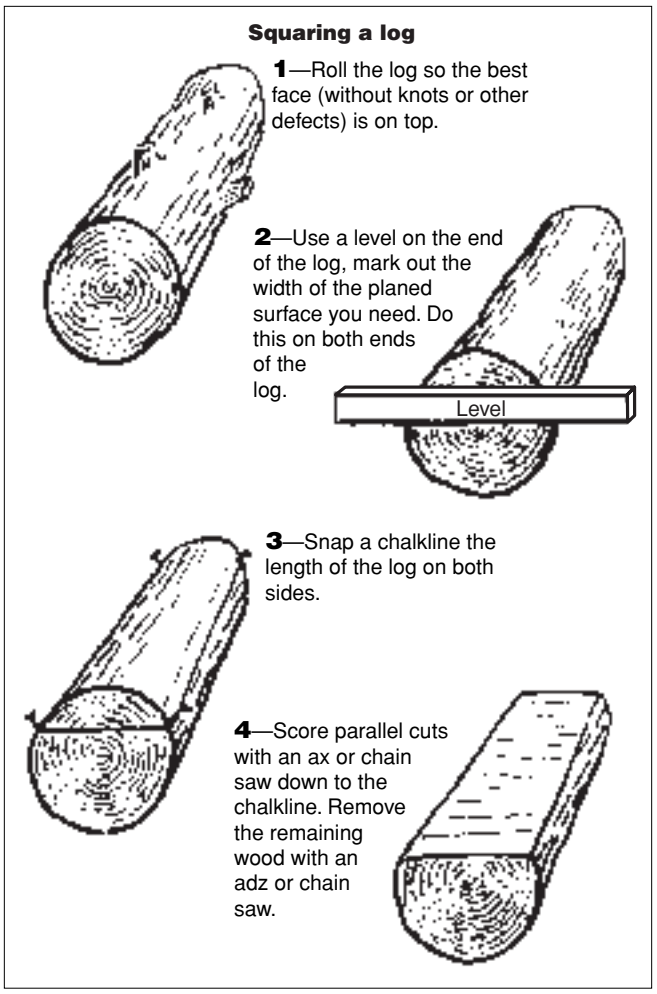


Figure 93—Steps to square a log.

Determine the width of the plane surface that is needed. Put a carpenter's or mason's level in a horizontal position against the end of the log. Use a measuring tape or framing square to measure the distance between the solid wood and the inside of the bark at the edge of the level. By trial and error, move the level up or down until its upper edge is level and on a line that measures the dimension needed. Draw a line across the end of the log on the edge of the level. Without moving the log, use the same process to draw a line across the other end.

Drive a nail into the bark where each horizontal line meets the bark. Stretch a chalkline or stringline between the two nails on one side of the log. If the bark is thin or has been removed, a chalkline can be used and snapped, leaving a chalk mark to work to. A chalkline will not leave an accurate or discernible mark on thick, deeply furrowed bark or on a log with an inch or more of crook. In this situation, drive nails to hold the string every 2 feet or so along the line of the string. Repeat the process on the other side of the log.

After scoring parallel cuts down to the chalkline with a chain saw or ax, use an adz to remove the wood from the top of the log down to the chalklines. Use small-diameter logs, 2 by 4s, or log dogs to hold small logs in place while doing the adz work. To control how much wood is removed, cut with the grain of the wood. This technique reduces the likelihood of breaking out deep chips of wood. The direction of the grain will be obvious after the first few cuts.

A chain saw will do the work much faster. A helper is needed to make sure the sawyer doesn't cut below the chalkline on the far side of the log (which the sawyer cannot see). Otherwise, you will end up with a wavy surface. If the wavy surface is used as a tread, it will cause hikers to slip and fall when the tread is wet or frosty.

If you are not using a chain saw, the technique described above is practical only on small logs. The adz is considered a finishing tool for surfaces that have already been hewed to size. If a lot of wood must be removed and power equipment is not available, hewing with a broad ax is more common and

more efficient. The process starts out much like that described for adz work, but instead of horizontal cuts, broad ax cuts are made vertically, for the length of the log along the chalkline. This technique is spelled out in more detail in *An Ax to Grind: A Practical Ax Manual* (Weisgerber and Vachowski 1999).

Check the surface with a straightedge, a framing square, or a long level. Check across the log and also along its length. Mark any high spots and remove them. It is easier to detect high spots by kneeling on the side of the straightedge in shadow and looking between the straightedge and the wood (figure 94).

Smoothing the surface of a log

Figure 94—Use a long level to find high spots that need to be removed.

After the first surface is complete, a second surface can be marked and cut. If the second surface is perpendicular to the first, a framing square can be used to mark the ends of the log. Repeat the marking procedure with the chalkline or stringline and nails. The log can be rolled over so that the second surface is horizontal and can be adzed, or the log can be left in place so the second surface can be shaped with a broad ax. This method is suitable for making log puncheon that must be two logs wide (figure 95).

If the second surface needs to be parallel to the first, place the log with its ends resting on two other logs with the first surface facing up and the log level (figure 96). Determine either the thickness of the log needed, or the width of the second surface needed. Using the level, mark a line along the log's edge parallel with the first surface. Roll the log until the first surface is facing down and repeat the chalkline or stringline procedure for the second surface. Use an adz or saw to level the second surface. This technique is suitable for situations where one surface must be level for a tread and the bottom at each end must rest on log or stone piers.

Perpendicular cuts

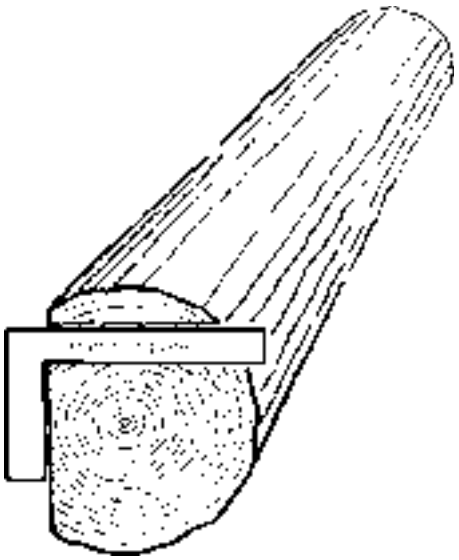


Figure 95—Use a framing square to mark a perpendicular cut.

Parallel surfaces

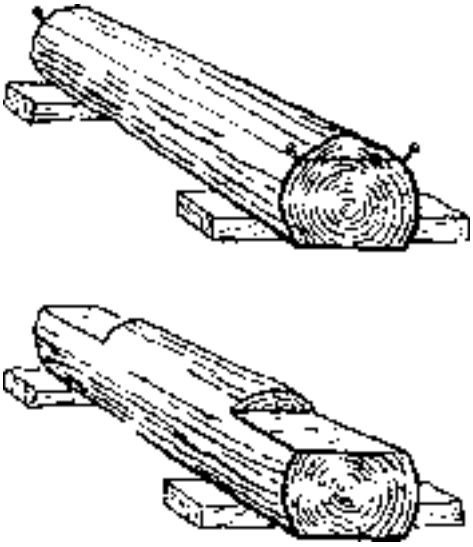


Figure 96—Use this procedure when a second flat surface must be parallel to the first.

Cutting Planks With Chain Saw Mills

Where chain saws are allowed, native logs are available, and distance or other factors preclude hauling in treated timbers, consider using an Alaskan sawmill (figure 97). This is about the only way to effectively channel the power of the saw to create uniform, square planks. Several sizes of mills are available. A basic mill costs less than $200. You also need a powerful chain saw, one equipped with ripper teeth.

Working With Timbers

Rough-sawn timbers are splintery, and some species of wood are more prone to splinter than others. To avoid a handful of splinters, wear good-quality, heavy work gloves.

Timbers to be used in a horizontal plane, (ledgers, stringers, and culvert inverts) should be checked for camber, a slight bend in the length of a piece of wood. Although camber usually is slight—less than ½ inch per 10-foot length—it should be used to your advantage.

Camber can usually be determined by sighting along all the surfaces of the timber from one end. Sometimes a stringline held to each end of the timber helps to identify camber. Many timbers will not have any camber.

If camber is present, the convex face should be placed up and the concave face placed down, even if this contradicts the “green-side up” general rule of placing growth rings down to reduce cupping. Weight on a timber will cause the timber to deflect or sag. With the convex surface up, deflection will act to straighten the timber. If camber is ignored and the timber is installed with the concave surface up, it is already sagging. Additional weight will cause the timber to sag even more.

Figure 97—An Alaskan sawmill works great for creating planks from native logs. The mill requires a powerful chain saw (at least 3.8 cubic inches of displacement, more is better) and a special ripping chain.

Working With Treated Wood

At a preservative treatment plant, freshly treated wood is stacked on areas of concrete where excess preservative drips from the stack and is collected and recycled. The treated wood is air dried, which works well in a dry climate. However, the wood is sometimes dry at the surface but wet below the surface when it is shipped. This wood will weigh more because of the moisture. You need to consider this factor when transporting the wood to remote locations. The high moisture content of newly treated wood will also cause tools to bind and tear the wood. This is not intended to deter you from using treated wood, but it is something you need to be aware of.

Treated wood may be kiln dried if that process is specified. Kiln drying to 19-percent humidity can be required. However, the minimum order for large plants may be a truckload. Most small local plants probably cannot do this at all. Kiln drying does cost more.

Pinning Logs and Timbers

Driftpins (usually ½-inch-diameter steel reinforcing bars, also called #4 deformed rebar) are used to pin logs and timbers. Some trail crews prefer to use driftpins cut from ½-inch-inside-diameter galvanized steel pipe. The length of the driftpins will vary. When driftpins are used to anchor a log or timber to the ground, about 12 to 18 inches of the driftpin should be in the ground. If rock or boulders are encountered before the driftpin is driven its full length, it will have to be cut off with a hacksaw. When pinning one log or timber to another, the driftpins should be long enough to go through the upper piece and all the way through the lower piece, or at least 12 inches into it.

First, drill holes in the wood 1/16 inch smaller than the diameter of the rebar. Before driving the driftpins, dip the end of the driftpin in heavy automobile grease. The lubricant will make it easier to drive the driftpins, will protect the driftpin from the weather, and will provide a thin, protective film between the steel and the copper in treated wood. Driving the driftpins is much easier if you make a striking plate out of a short piece of pipe with a 2- to 3-inch round plate welded to one end.

The top of the driftpin should be countersunk (figure 98). Countersinking can be done neatly by placing a 4- to 6-inch piece of steel pipe around the driftpin and a 12-inch piece of a smaller diameter rebar inside the pipe. With the pipe resting on the log or timber and the smaller diameter rebar resting on the driftpin, hit the rebar with a sledge hammer until the top of the driftpin is below the surface of the wood. This depression can be filled with grease to protect the steel from rusting. Wipe any surplus lubricant off of the wood.

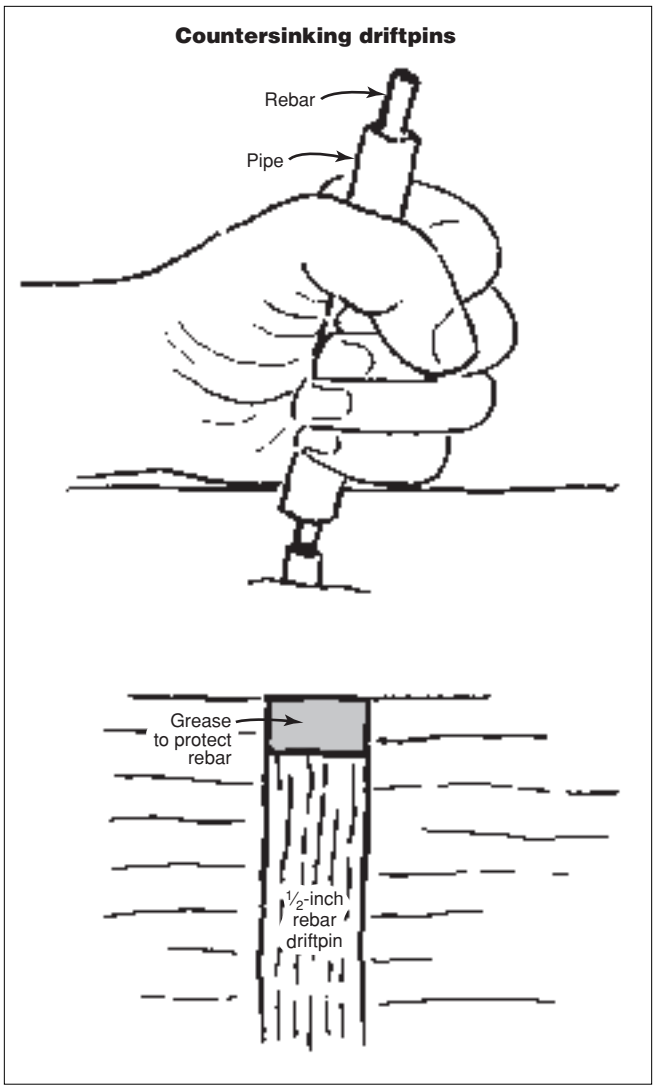


Figure 98—Countersinking the driftpin is a good practice easily accomplished by striking a short piece of rebar inside an even shorter piece of pipe.

Tread Surface

Slippery Wooden Treads

We are frequently asked how to correct a slippery wooden tread. Often, the surface is not the source of the problem. The slippery surface usually is the result of overlooking factors such as trail grade, cross slope, or soil conditions.

Trail Grade

If the grade of the trail surface is too steep, there is little that can be put on the tread to eliminate slipperiness. A wooden surface that has been installed at an 8-percent grade will be slippery with only a heavy dew. Pedestrians will find a wooden surface built at 5-percent grade slippery with frost or light rain. Shaded and north-facing sites aggravate the problem. The maximum grade for a trail with a wooden surface should be 2 percent (¼ inch per foot).

Cross Slope

Another cause of a slippery tread is a cross slope that is too steep. To prevent excessive cross slope on a trail, use a simple carpenter's, mason's, or torpedo level to identify any difference in elevation between parallel stringers, the notch in sleepers, and ledgers attached to the piles. To eliminate or reduce cross slope, shim up the stringers or ledgers, excavate the high end of the sleepers, redrill the bolt holes, or replace the ledgers (figure 99).

It is much cheaper to build the foundation correctly than to try to correct problems later through maintenance.

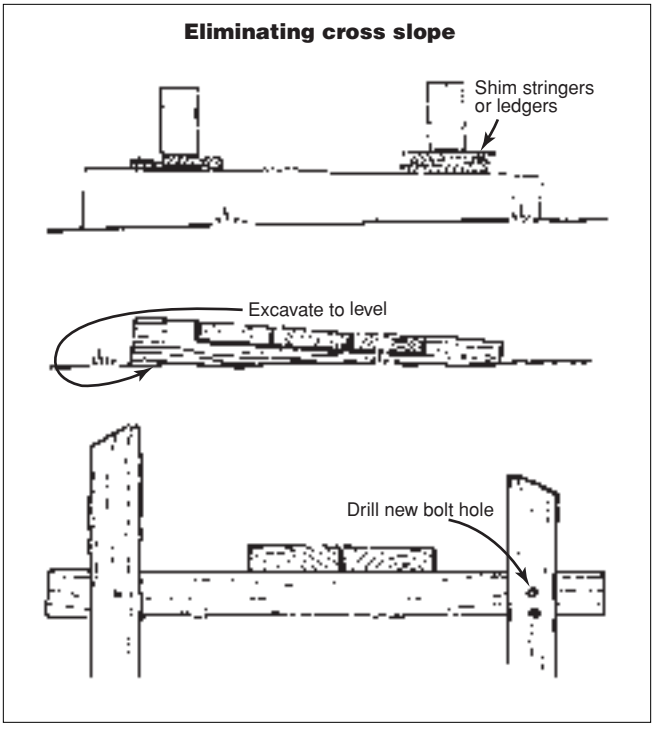


Figure 99—Eliminate cross slope with shims, by excavating the high side of sleepers, or by drilling new bolt holes on the ledgers.

Soil Conditions

Another factor that can create a slippery tread is settlement, a problem that occurs when soil settles after a trail has been constructed. The trail may have been built properly, but all or part of the trail may have settled over time. Perhaps sleepers or a bent on end-bearing piles were used instead of a bent on friction piles. That part of the foundation settled over time, causing the trail to sag. The result is that one or both sections of trail on each side of the sag are steeper than intended.

One part of a trail support may settle. For example, one end of a sleeper may settle and the other end may not, or one pile in a bent may settle and the other may not. Both piles may settle, but one may settle more than the other. This type of settling will affect cross slope.

Cross slope of ¼ inch per foot (2 percent) is common for concrete and asphalt surfaces, but is excessive for wood. The cross slope should be level or ⅛ inch or less per foot (0 to 1 percent). Settlement can be corrected by shimming the low side, notching the high side, or a little of each. This is extremely difficult to do after construction and can be avoided to a degree by taking ample rod soundings and digging a number of test holes during the design phase. During construction, the crew should be alert for changes in soil conditions and should take remedial actions when necessary.

Surface Treatments

If the hazard of a slippery tread cannot be corrected by shimming, notching, or adding steps, a few surface treatments can be applied. These treatments will require maintenance.

Latex Paint

A nonskid latex paint is made for boat decks. This paint is opaque, unlike a clear wood stain, but it can be tinted. As with all painted surfaces, peeling, scraping, and periodic repainting must be expected.

Walnut Chips

Walnut chips are a hard, angular material produced in various sizes. The number 4 size is suitable for nonslip surfaces. Walnut chips can be applied to a wooden surface by sand painting (using chips and paint mixed at the factory), using chips mixed into the paint at the site, or by painting the wood and sprinkling on chips while the paint is wet.

Mineral Products

Nonslip products are also made from pumice and aluminum oxide. Some are premixed. Others are sold as a gritty powder that is mixed with paint.

Nonslip Gratings and Grit-Treated Mats

Another method for correcting a slippery trail tread is to replace a wooden plank tread with nonslip gratings or to apply grit-treated fiberglass mats to the planks.

Working With Rock, Stone, and Gravel

The construction industry recognizes differences between rock, stone, and gravel. It helps to understand the differences in the materials so you will know what to specify or order.

Rock

Rock is the parent material in and under the ground. Sometimes it is called bedrock or ledgerock. Moving rock usually requires drilling and the use of explosives.

Stone

When rock is broken or crushed, the pieces are referred to as stone. Stone, when used in construction, describes usable pieces of what once had been rock. Stone may be large enough to use for walls, or it may be small pieces that have been through a rock crusher for use as aggregate in concrete or as a base course in a road. Stone is angular on all sides.

Among the byproducts of rock-crushing operations are "crusher fines," screened material smaller than ¼ inch that is not suitable for most crushed stone contracts. This material is often sold at a discount at crusher operations and makes a fine trail surface when it is wetted and compacted.

Gravel

Small pieces of rock that have broken naturally and have been subject to glacial action or tumbled in a river or creek are called gravel. The glacial action or the effect of water has rounded and removed all the corners of the original piece of rock.

Uses of Stone and Gravel

Rock is rarely found in a wetland. Stone can be brought to the site for use as riprap. Crushed stone can be used for walking surfaces. Because crushed stone is angular, when it is compacted it will knit together to form a solid mass. Gravel cannot be compacted to produce a solid mass. Gravel's rounded shape is useful because water can move through the spaces between the gravel particles. Crushed stone should not be used for drainage (around perforated pipe or to carry water from one point to another). Use gravel for drainage (figure 100).

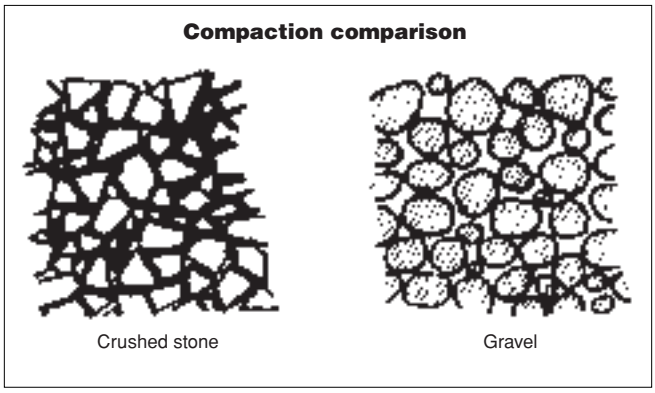
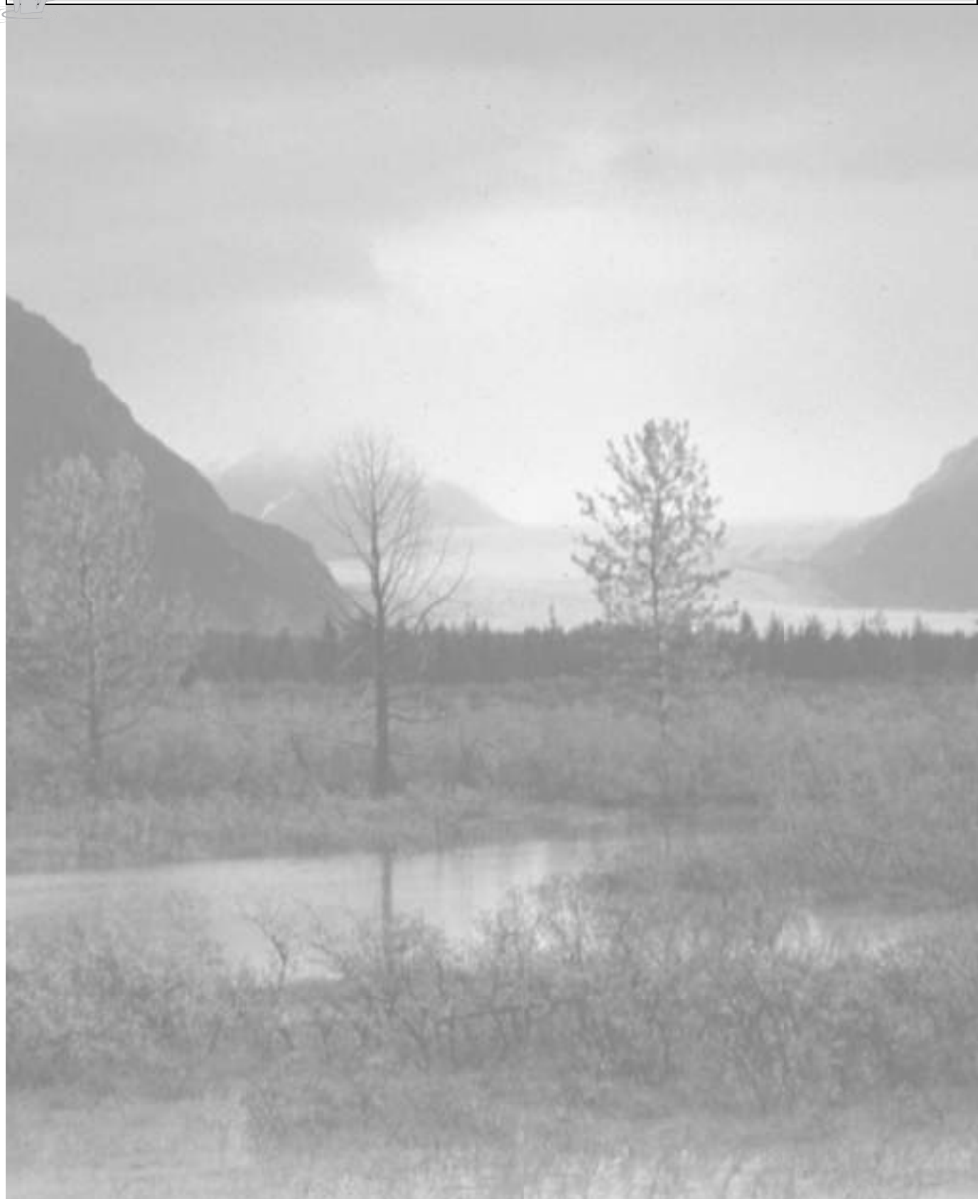


Figure 100—Crushed stone has angular edges and compacts well. It is good for tread surfacing. Gravel does not make good surfacing because it has rounded edges. Gravel is good for subsurface drainage because water flows freely through it.

Appendix A—Field Note Sheets



Station & distance	Tread width	Sideslope (percent)	Gradient (percent)	Notes

Station & distance	Tread width	Sideslope (percent)	Gradient (percent)	Notes

Appendix B—Slope Conversion Table

Slope Conversion Table		
Percent grade	**[1]Slope**	**[2]Pitch**
0.5	1 ft per 200 ft	1/16 in per 1 ft
1	1 ft per 100 ft	1/8 in per 1 ft
2	1 ft per 50 ft	1/4 in per 1 ft
2.5	1 ft per 40 ft	5/16 in per 1 ft
3	1 ft per 33 ft	3/8 in per 1 ft
3.3	1 ft per 30 ft	7/16 in per 1 ft
4	1 ft per 25 ft	1/2 in per 1 ft
5	1 ft per 20 ft	5/8 in per 1 ft
6	1 ft per 16.5 ft	3/4 in per 1 ft
7	1 ft per 14.3 ft	7/8 in per 1 ft
8	1 ft per 12.5 ft	1 in per 1 ft
8.33	1 ft per 12 ft	1 in per 1 ft

[1] One unit of climb or descent per 100 units of horizontal distance.

[2] Number of vertical inches per horizontal foot. Vertical inches shown are rounded off to the nearest 1/16 of an inch.

Maximum grade recommended for wood surface trails = 2 percent.

Appendix C—Comparison of Round and Rectangular Culverts

These tables show the open-end area of round culvert pipe and the open-end area of rectangular timber culverts.

Round Pipe Culverts								
Diameter (inches)	8	10	12	15	18	24	30	36
End area (sq. ft)	0.4	0.6	0.8	1.2	1.8	3.1	5.0	7.1

Rectangular Timber Culverts								
	Clear width (inches)							
Height (inches)	20	24	30	36	48	60	72	84
	End area (sq. ft)							
5	0.7	0.8	1.1	1.3	1.7	2.1	2.5	2.9
11	1.4	1.8	2.3	2.8	3.7	4.5	5.5	6.4
17	2.1	2.9	3.6	4.3	5.0	7.1	8.5	9.9
23	2.9	3.8	4.8	5.8	7.7	9.6	11.5	13.4

Appendix D—Sizes of Hot-Dipped Galvanized Nails

[1]Penny (d)	Length (inches)	[2]Penetration required (inches)	Nails per pound	Gauge (inches)	Bit size for pilot holes (inches)
10	3	2	75	10	NA
12	3¼	2⅛	69	10	NA
16	3½	2¼	54	9	3/32
20	4	2⅝	33	7	⅛
30	4½	3	29	7	⅛
40	5	3¼	22	5½	⅛
50	5½	3⅝	20	5½	⅛
60	6	4	18	5½	3/16

[1] Nails are sold by the old English system of pennyweight. The value of the penny has changed since the system was devised, and today there seems to be no relation to the size and weight of the nail to the penny. The standard symbol for penny is "d."

[2] The "penetration required" column shows the minimum depth the nail must penetrate into the second piece of wood to make a sound connection. The penetration must be increased by one-third when nailing into the end of the piece of wood (end nailing).

Appendix E— Table of Board Feet

The most common sizes of boards used for boardwalk and bog bridge construction.

Size of board	Length of board (ft)						Finished size (inches)
	6	8	10	12	14	16	
	Yield (board ft)						
1 x 6	3	4	5	6	7	8	¾ x 5½
2 x 4	4	5.33	6.67	8	97	11	1½ x 3½
2 x 6	6	8	10	12	14	16	1½ x 5½
2 x 8	8	10.67	13.33	16	19	21	Normally rough sawn
2 x 10	10	13.33	16.67	20	23	27	Normally rough sawn
2 x 12	12	16	20	24	28	32	Normally rough sawn
3 x 4	6	8	10	12	14	16	Normally rough sawn
3 x 6	9	12	15	18	21	24	Normally rough sawn
3 x 8	12	16	20	24	28	32	Normally rough sawn
3 x 10	15	20	25	30	35	40	Normally rough sawn
3 x 12	18	24	30	36	42	48	Normally rough sawn
4 x 4	8	10.67	13.33	16	19	21	3½ x 3½
4 x 6	12	16	20	24	28	32	Normally rough sawn
6 x 6	18	24	30	36	42	48	Normally rough sawn

Appendix F—Metric Conversions

METRIC CONVERSIONS

To convert from this unit	To this unit	Multiply by
inch	millimeter	25.4*
inch	centimeter	2.54*
foot	meter	0.3048*
yard	meter	0.9144*
mile	kilometer	1.6
millimeter	inch	0.039
centimeter	inch	0.394
centimeter	foot	0.0328
meter	foot	3.28
meter	yard	1.09
kilometer	mile	0.62
acre	hectare (square hectometer)	0.405
square kilometer	square mile	0.386*
hectare (square hectometer)	acre	2.47
ounce (avoirdupois)	gram	28.35
pound (avoirdupois)	kilogram	0.45
ton (2,000 pounds)	kilogram	907.18
ton (2,000 pounds)	megagram (metric ton)	0.9
gram	ounce (avoirdupois)	0.035
kilogram	pound (avoirdupois)	2.2
megagram	ton (2,000 pounds)	1.102
ounce (U.S. liquid)	milliliter	30
cup (inch-pound system)	milliliter	247
cup (inch-pound system)	liter	0.24
gallon (inch-pound system)	liter	3.8
quart (inch-pound system)	liter	0.95
pint (inch-pound system)	liter	0.47
milliliter	ounce (U.S. liquid)	0.034
liter	gallon	0.264
liter	quart	1.057
degrees Fahrenheit	degrees Celsius	(°F – 32) ÷ 1.8
degrees Celsius	degrees Fahrenheit	(°C x 1.8) + 32

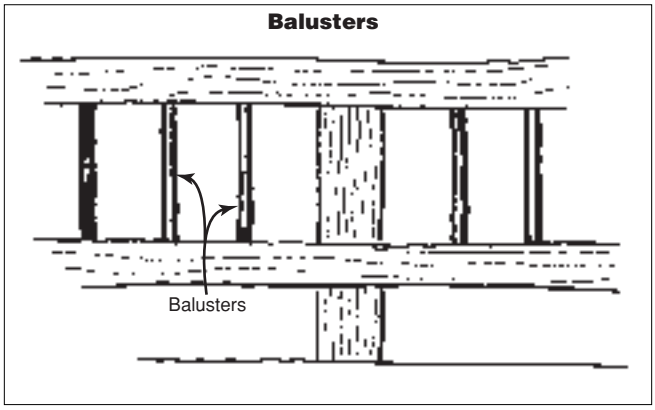
*These items are exact conversion factors for the units—the others give approximate conversions.

Glossary

Aggregate—Crushed stone or gravel used as a base course for riprap, asphalt, or concrete pavement. Aggregate is also used in asphalt and concrete mixes.

Asphalt—A mixture of aggregate and asphalt cement, correctly called asphaltic concrete.

Baluster—One of many vertical pieces between the top and bottom rails of a guardrail.



Batter, battering—Sloping the exposed face of a wall back either at a uniform angle, or stepping it back uniformly, the structurally sound way to build a timber wall.

Bevel—Finishing the corner of a piece of lumber by removing a narrow portion of wood at a uniform angle to the edge and face. A bevel follows the grain of the wood (see chamfer).

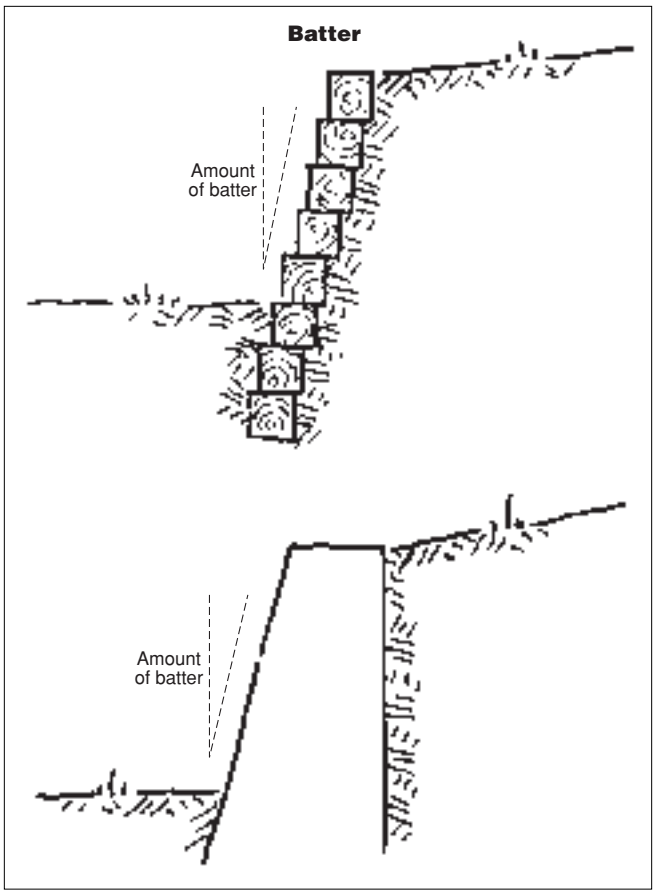
Borrow pit—An excavation used to obtain fill for a construction site.

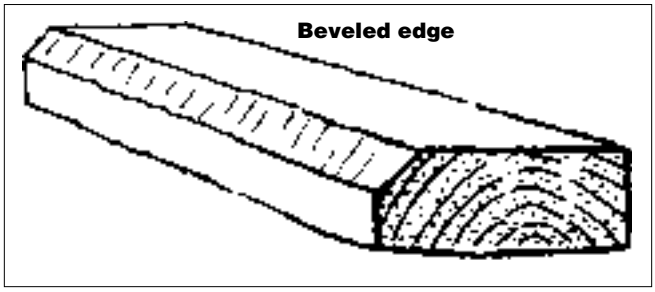
Braided trails—Parallel trails around a low, wet spot. These trails are not constructed, but are worn in the ground by trail users who do not want to get their feet wet or walk in mud. Each new trail funnels water to a low point. Users repeat the process, producing a series of trails.

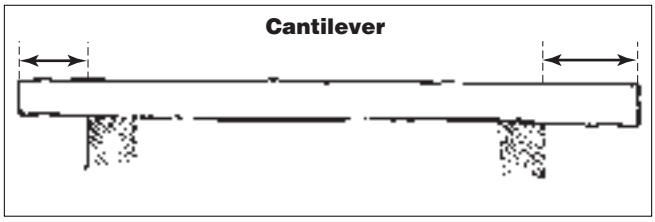
Camber—A slight bend in a timber.

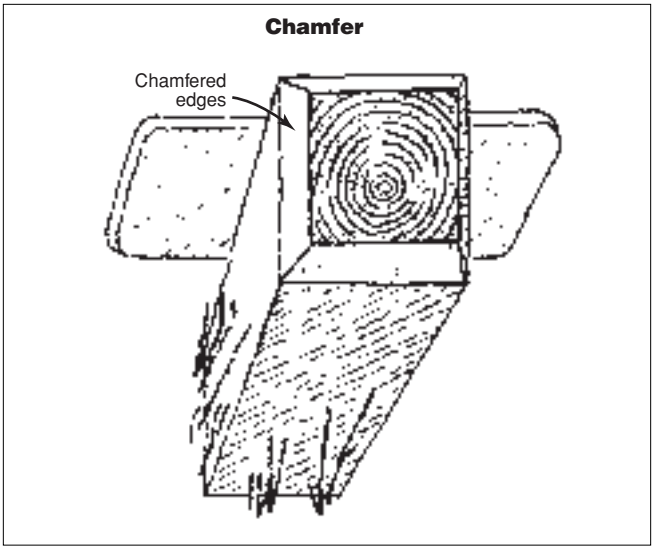
Cantilever—The portion of a beam or plank extending beyond one or both of its supports.

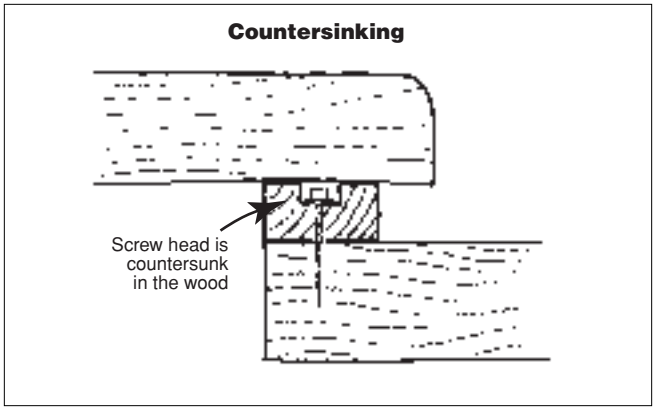
Chamfer—Similar to a bevel but done at the end of the piece of wood and across the grain.

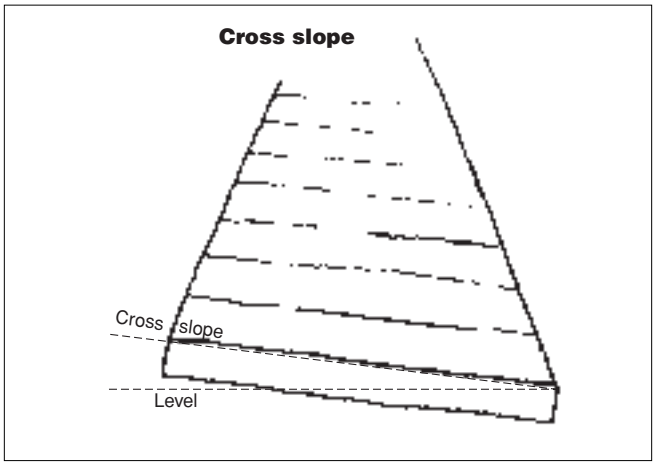


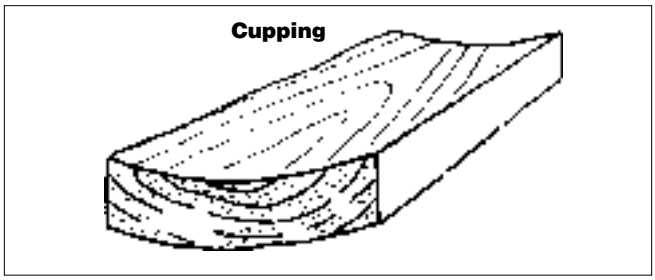












Concrete—A mixture of sand, coarse aggregate (crushed gravel or crushed stone), portland cement, and water correctly called Portland cement concrete. The wet mixture is placed in a form or trench and dries to a hard material.

Control points—Natural, recognizable features on the site or a series of survey stakes used to establish distances and elevations during trail construction.

Countersinking—Drilling a wide, shallow hole in a piece of wood for a washer and nut or for the head of a bolt or screw. Countersinking allows the hardware to be recessed below the surface of the wood. Countersinking reduces the amount of treated wood and will accelerate decay if the hole is exposed to moisture.

Course—A single layer of building material of a uniform height. The material is placed one layer (or course) at a time on top of another layer (or course). Materials laid in courses include bricks, concrete blocks, timbers, and logs.

Crook—A defect in a log caused by a crooked tree.

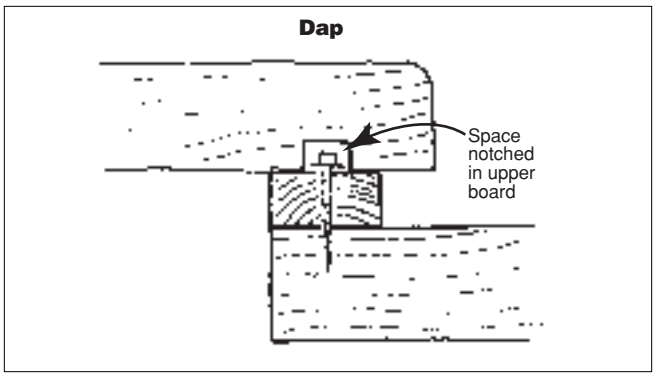
Cross slope or cross pitch—The amount a surface slopes, measured perpendicular to the centerline of a road or trail.

Crown—The branches, twigs, and leaves of a tree. Also a paved surface that is higher in the center than at the edges.

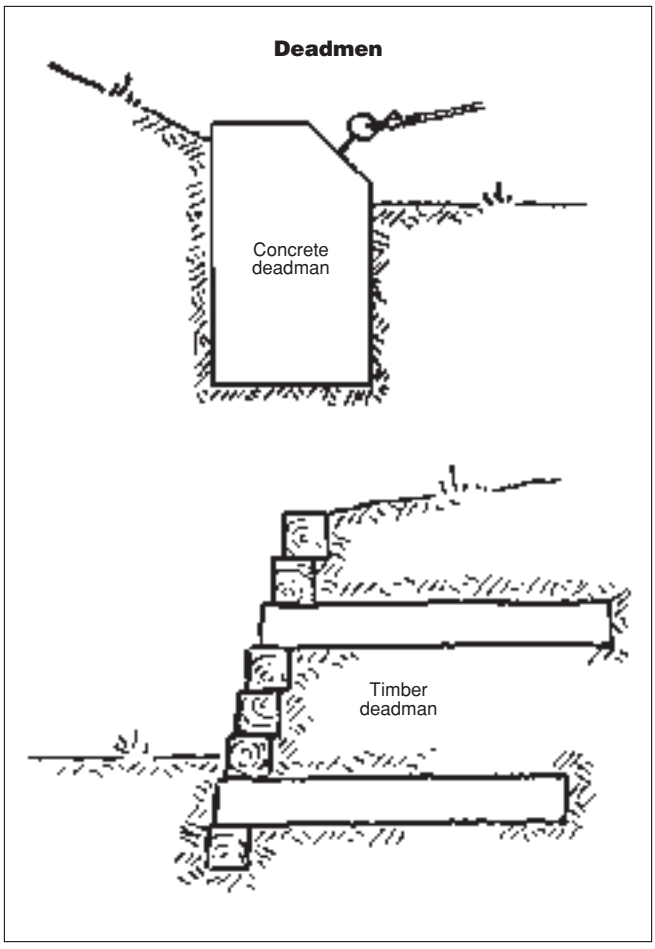
Cupped, cupping—A board or plank whose edges are higher or lower than the center. Cupping is often found in decks, where the board edges are higher than the middle. Water, trapped in the cupped area, accelerates decay.

Curb—A wood, concrete, or stone trail component that rests on the ground or on the trail tread, rising 2 to 8 inches above the trail tread.

Dap—A shallow hole or slot drilled or routed in a piece of wood. A dap is usually drilled to fit over a piece of hardware (a nut, the head of a bolt, or a portion of a steel plate or angle) that is connected to an adjacent piece of wood.



Deadman—A log or logs, heavy timber or timbers, a large block of concrete, a large boulder, or combination of the above that is partially or completely buried. Eyebolts placed in deadmen are used to anchor cables. Log or timber deadmen (without eyebolts) are used in log or timber retaining walls. They are placed perpendicular to the face of the wall, extending into the earth behind it to prevent the wall from falling over.

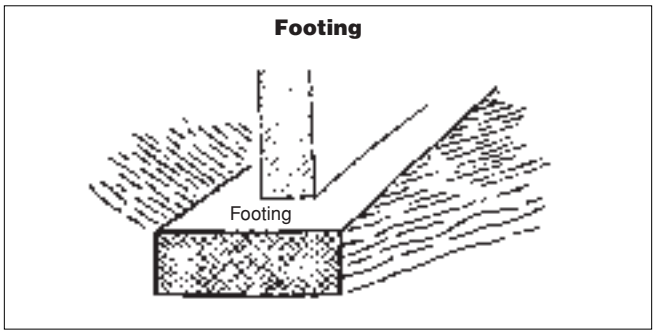


Destination trail—A trail route that starts at a trailhead and ends at a point of interest, the destination. The trail user returns by the same route.

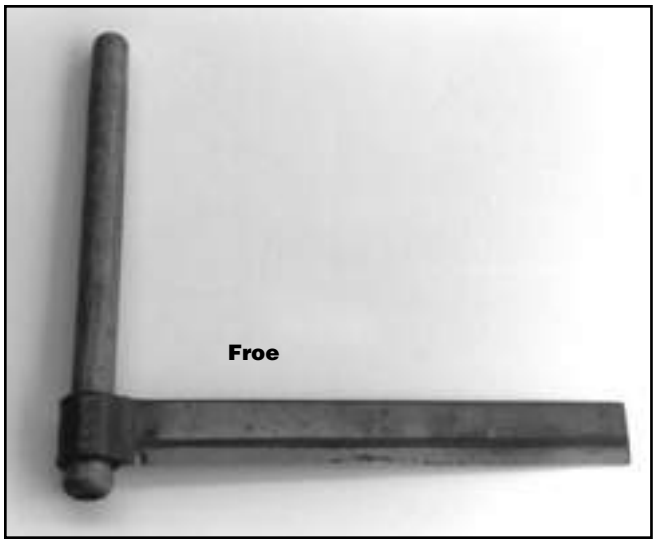
Driftpin—A piece of 12- to 30-inch rebar or steel pipe used to keep logs and timbers in place.

Fisherman's knot—A knot used to tie a rope sling for moving logs and timbers. A single length of rope is tied into a loop using two overhand knots tied in each end of the rope and around the opposite end.

Footing—The part of a structural foundation that rests on the ground, spreading the weight of the structure and supporting the structure above. Footings are usually concrete. At remote sites the footings may also be mortared stone masonry.



Froe—An old handtool used originally for splitting shingles and shakes. The froe consists of a heavy, 12-inch-long, straight steel blade with a wooden handle. The cutting edge of the blade is placed against the wood to be cut and a club or mallet is used to hit the face.



Frostline—The maximum depth that frost can be expected to penetrate into the ground.

Glulaminated—A process used to fabricate long beams from short lengths of 2 by 4, or 2 by 6, or 2 by 10 lumber. The pieces are placed flat on top of each other with glue spread between them. Lengths are varied so that transverse joints in each layer are not opposite one another. Pressure binds the pieces together. The assembly may be two to four times longer than the longest individual piece of lumber within it.

Grade—The rate of climb or descent along the centerline of a trail. It is described as a percentage and expressed as the number of units of climb or descent per 100 units of horizontal distance. A +5-percent grade rises 5 feet in 100 feet, or 5 meters in 100 meters. A -2-percent grade descends 2 feet per 100 feet (or 2 meters per 100 meters). The plus symbol indicates climb. The minus symbol indicates descent.

Groundwater—Water contained in the soil a few inches to several feet below the surface of the ground. In wetlands, the depth to groundwater is often higher in winter and spring and lower in summer and fall.

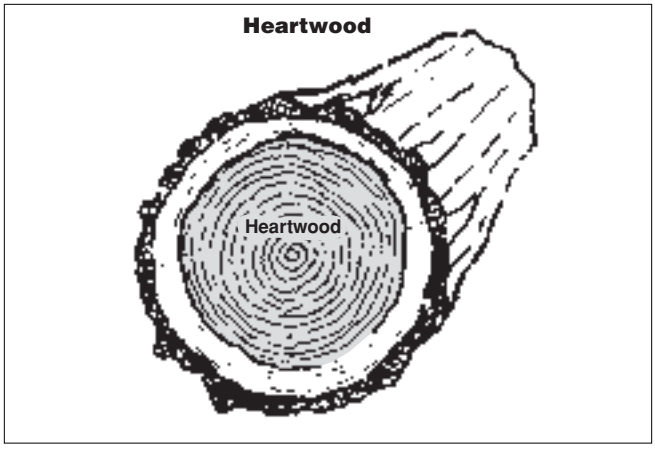
Guardrail—A railing at the edge of a deck to prevent people from falling. A guardrail should be 36 to 42 inches above the deck.

Handrail—A railing along a stairway to help people avoid falling down the stairs. A handrail should be 32 to 35 inches above the stairs.

Hardwood/softwood—Inaccurate logger's terms that have nothing to do with how hard or soft the wood is. By the logger's definition, hardwoods are deciduous trees with broad leaves and softwoods are conifers with needles. Aspen and red maple are "hardwoods," but their wood is soft; Douglas-fir and Atlantic white cedar are "softwoods," but their wood is hard. Some hardwoods, such as live oak and southern magnolia, keep their leaves through the winter. Some "softwoods," such as larch and baldcypress in the northern portion of its range, lose their needles in the fall.

Heartwood—The oldest wood of a tree, extending from the center of a log to the sapwood. The heartwood is the densest, strongest, and darkest wood in a log.

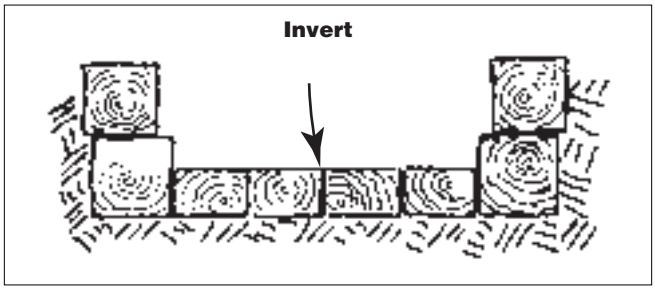
Helical pile—A solid steel shaft 1½ to 2½ inches square with a series of steel helixes welded to the shaft. The helixes are similar to threads on a bolt or the threads on a powered earth auger. The smallest helical piles or screw piles are 6 inches in diameter and 30 inches long. A machine screws them into the ground.



Hewing—Using an ax or adz to cut a log so that its cross section is a square or rectangular.

Hummocky—Wetland terrain containing hummocks, ridges, and small mounds of earth 2 to 4 feet higher than the surrounding area.

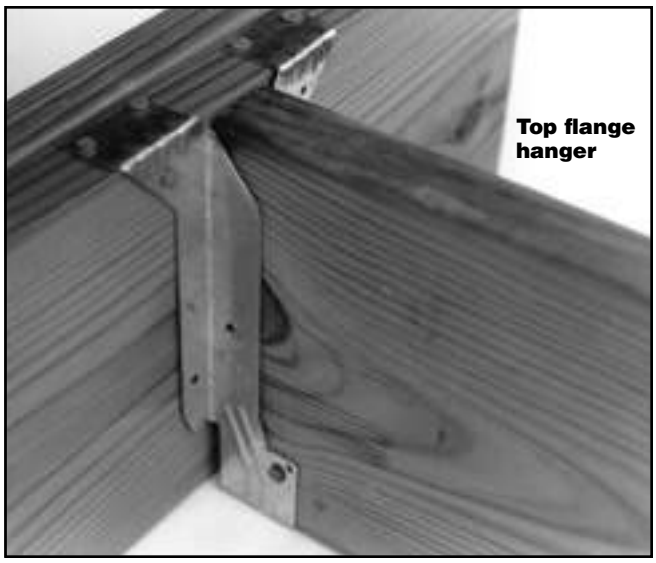
Invert—The bottom surface of a pipe, ditch, or culvert over which water flows.



Joist—Usually a wooden 2 by 6, 2 by 8, 2 by 10, or 2 by 12, with the 2-inch dimension resting on a sleeper (sill) or ledger, toenailed into place, supporting a floor or deck.

Joist hanger—A steel angle or strap nailed to the side of a ledger and shaped to hold a joist. If a top flange hanger or face mount hanger is installed, the joist is placed within the hanger and the two are nailed together.

Ledger—A horizontal piece of wood attached to, and supported by, piles or concrete or stone masonry piers. The ledgers support stringers or tread timbers.



Log dogs—The first type of log dog is a broad U-shaped steel bar 18 to 30 inches wide, with pointed ends, which is used to temporarily hold two logs at right angles to each other.

The second type of log dog is smaller and easier to pack. It consists of a 6-inch to 12-inch-long steel plate that is 2 to 3 inches wide and pointed at each end. A second steel plate (3 to 6 inches long, identical width, pointed at one end and straight on the other) is welded across the center of the first to form a T.

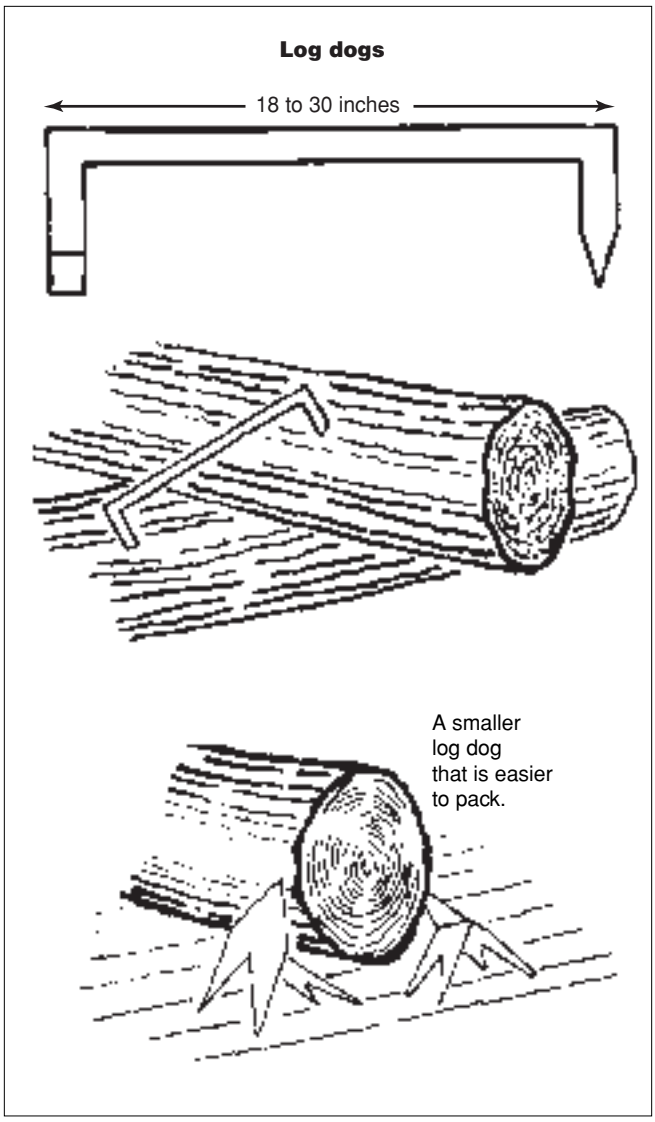
Loop trail—A trail route that forms a closed circuit connecting a number of points of interest. The trail returns to the trailhead where it began but the trail user does not cover the same route twice.

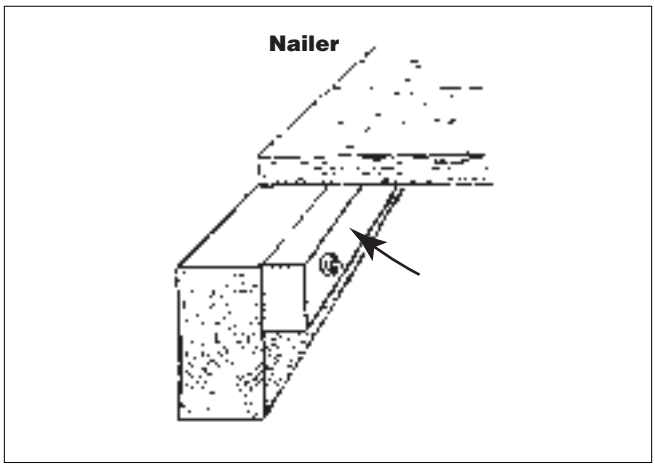
Lumber—As used in this text, wood that has been sawed into a square or rectangular cross section that is 2 inches thick or less.

Moraine—Moraines are made of debris deposited by glaciers. The most common moraines are end (or terminal) moraines and lateral (or slide) moraines. Rock that the glacier has broken out of the valley is deposited in the moraines. Rock in moraines has been broken up and ground into boulders and various sizes of gravel and sand.

Mortar—A mixture of sand, lime, Portland cement, and water. Mortar is used in masonry construction to bind bricks, concrete blocks, or stone to form structural elements such as retaining walls and piers. Mortar may also be used when constructing riprap.

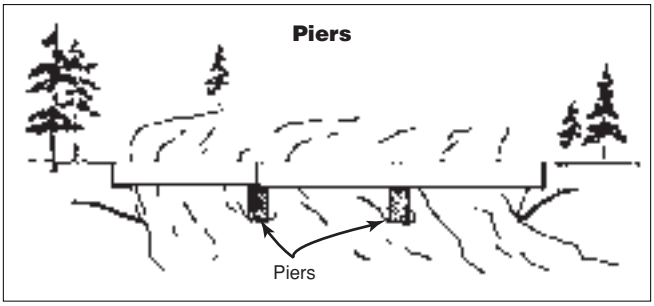
Nailer—A strip of wood attached to a stringer that tread planks are nailed or screwed to.





Peen—To strike a piece of metal with a hammer, denting the surface, or mashing the threads of a bolt after installing a nut, to prevent the nut from being removed.

Pier—Piers are used to support one or both ends of a beam or stringer. Piers may be timber or log cribbing or piles, helical piles, stone masonry, or concrete.



Pile—For wetland construction piles may be wooden logs, poles, or timbers, steel helixes, or concrete that is cast in place. A pile is usually no more than 12 inches in diameter. The pile is either placed in a hole dug to the depth required (end bearing pile), driven with a heavy weight (friction pile), or screwed into the ground by a machine (helical pile).

Pilot hole—A small hole drilled in wood or steel to guide a nail, screw, or drill bit.

Pinning—Driving driftpins through a log or timber into a log or timber, or into the ground.

Plank—A 2 by 4, 2 by 6, 2 by 8, 3 by 6, or wider board or timber. In wetland construction, planks are usually used as a walking surface or tread.

Plumb—A line or plane perpendicular to the Earth's surface.

Ponding—Water that has accumulated in a low area.

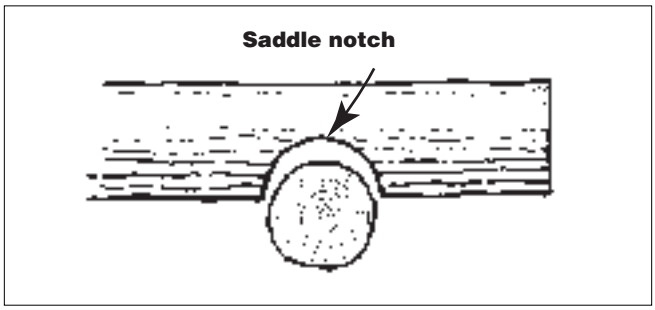
Portland cement—A gray powder made from limestone that is mixed with sand and water to make mortar, or mixed with sand, small stones or gravel, and water to make Portland cement concrete. In this text Portland cement concrete is referred to as concrete.

Puncheon—Short-span footbridges or a series of short-span footbridges supported by sleepers.

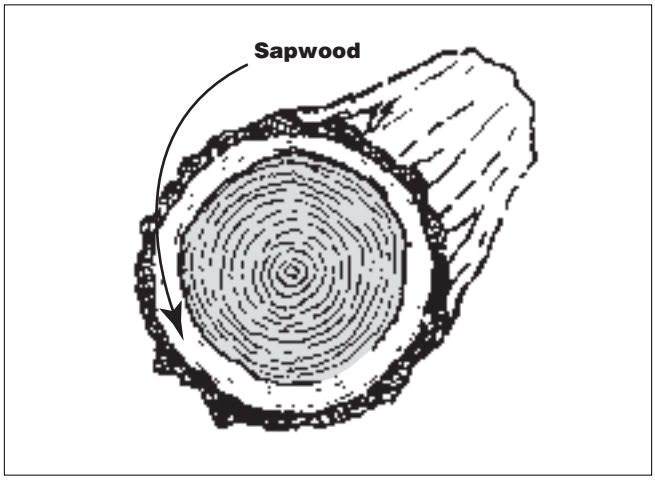
Riprap—Stones placed to prevent fast water from scouring and eroding a surface. Large stones (12 by 12 by 6 inches or larger) are hand placed on a setting bed of either aggregate or mortar. With an aggregate setting bed, adjacent stones are butted tightly together. Because of the irregularity of the stones, spalls are used to prevent them from moving. If the stones are placed on a mortared setting bed, the stones may be ½ to 3 inches apart.

Rod sounding—Driving a steel rod or pipe into the ground to determine the location of firm soil or rock.

Saddle notch—A half-circle notch cut in the bottom of a log to fit over a log in the course below.

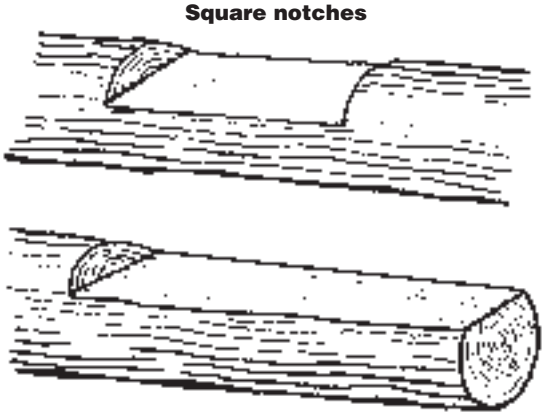


Sapwood—Wood just under the bark of a tree. Sapwood is only a few years old. This wood is usually a light color and not as strong or as dense as the heartwood.



Square notch—A notch cut in a log to fit snugly against a square notch cut in another log, the square cut end of another log, or a plank. The portion of the notch in contact with the other log is cut as a flat, uniform plane. The end or ends of the square notch are perpendicular to the flat plane.

Square notches



Setting bed—A layer of aggregate (either crushed stone or crushed gravel), or mason's sand, mortar placed on solid rock, or a compacted subgrade of existing ground or fill. Depending on the setting bed, material, and subsurface conditions, the setting bed may be from 4 to 12 inches deep.

Shim—A short, thin piece of wood, usually oak or redcedar, used between two pieces of wood or between a piece of wood and steel, earth, or rock. The shim is used to bring a ledger, stringer, or tread to level.

Slackwater—Floodwater with little or no velocity. Slackwater is formed when water in creeks, streams, and rivers backs up into low terrain, creating a temporary ponding condition.

Sleeper ß—A horizontal log or timber laid in a shallow trench to support a plank or logs.

Slope measurements—Measurements taken on the ground or parallel with the slope of the ground. Slope measurements provide a true indication of the quantities of materials needed for construction. Maps and construction drawings for roads and utility lines are measured horizontally. Measurements taken electronically are also measured horizontally. Slope measurements can sometimes be as much as 10 percent greater than horizontal measurements.

Sonotubes—Hollow cardboard cylinders used for forming round concrete columns. The sonotube is removed after the concrete sets.

Spalls—Small angular pieces of hard, durable stone. Spalls are wedged between stones that have been placed without mortar. Spalls have a function similar to that of shims used in wood construction.

Stringer—One of two or more beams placed parallel with the centerline of the tread that supports the tread plank.

Tamping—Using a narrow machine compactor, a tamping bar, the handle of a shovel, or other tool to compact earth backfill around a post, pole, or pile.

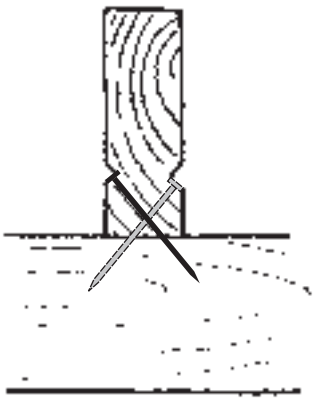
Test boring—A deep, narrow hole drilled into the ground with a power auger. A record is kept of the types of soils encountered and their depth. Test borings are usually done by geotechnical engineers (see test holes).

Test holes—Frequently, soil information does not require the sophistication and accuracy of test borings. A test hole can be dug by hand, or it can be dug with a backhoe. Test holes are wider than test borings, allowing the soil strata on the sides of the hole to be easily seen. Test holes can be no deeper than the equipment can easily and safely dig. The information provided by test holes is usually sufficient to determine construction techniques needed for wetland trails in areas where there is no previous wetland construction experience. It is simpler and cheaper to dig test holes than it is to drill test borings.

Timber—As used in this text, wood that has been sawed or hewed into a square or rectangular cross section that is at least 3 inches thick.

Toenail—Joining two pieces of wood by driving nails at an angle to the surface of one piece and into the second piece.

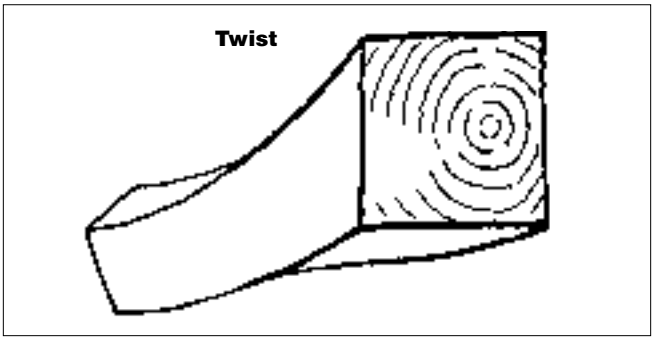
Toenailing



Tread—The walking surface of a trail. Applied to wetland trails constructed of wood, tread refers to the portion of the timber, log, or plank that the user steps on.

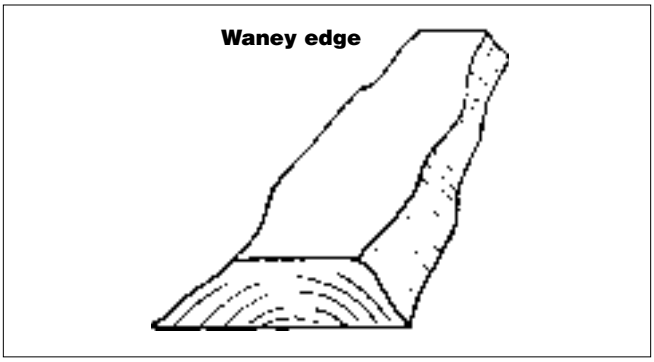
Twist—A defect in lumber and timber caused by a tree growing with a twisted grain. The result is a piece of lumber or timber with surfaces at one end that are not in the same plane as the surfaces at the other end. Occasionally, usable short

lengths with little twist can be cut from the original piece. More commonly, the original piece is useless.

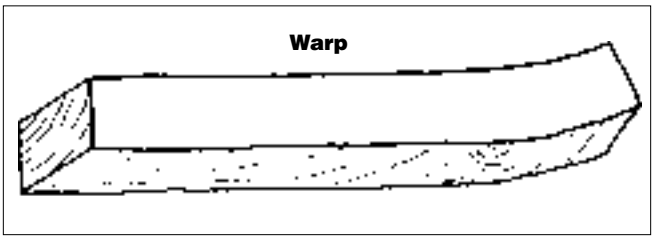


Wane—A defect in a piece of lumber or timber, caused by bark that was not removed or a beveled edge.

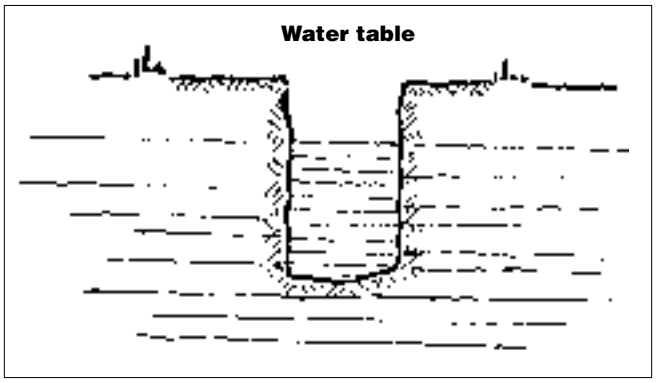
Waney edge—A term used at the sawmill to describe a board, plank, or timber of nonuniform width when one or two edges contain bark or irregular sapwood just below the bark. A waney edge is considered a defect, but the board or plank may be suitable for rustic construction.



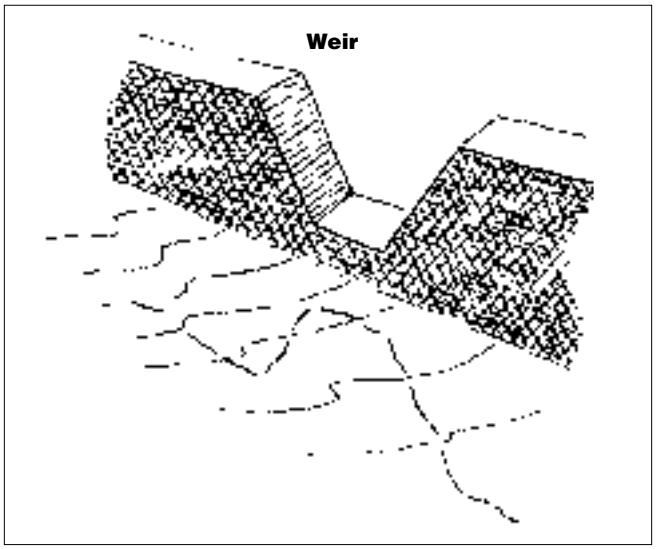
Warp—Severe bend in a piece of lumber or timber making it unusable in its original length. Sometimes the warp occurs mostly at one point, usually a knot, and short usable pieces can be cut on either side of that point.



Water table—The level below the ground surface where groundwater will fill a test hole.



Weir—A depressed channel in a dam providing an outlet for the overflow water in a pond when the water level exceeds a desired height. Weirs are usually concrete or timber, or a combination of the two.



Wetland indicator plants—Various species of plants that are tolerant of wet soils. When many specimens of these species are present at a site, they indicate a wetland environment.

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Brian Vachowski has been a project and program leader at the Missoula Technology and Development Center since 1993. He received a bachelor's degree in forestry from the University of Massachusetts and a master's degree in outdoor recreation from Utah State University. He has worked for the Nez Perce, Bighorn, Winema, and Routt National Forests in recreation, wilderness, lands, planning, rural community assistance, special uses, fire, and timber positions.

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Steinholtz, Robert T.; Vachowski, Brian. 2007. Wetland trail design and construction: 2007 edition. Tech. Rep. 0723–2804–MTDC. Missoula, MT: U.S. Department of Agriculture Forest Service, Missoula Technology and Development Center. 82 p.

Describes materials and techniques used to construct trails in wetlands. This manual is written primarily for workers who are inexperienced in wetland trail construction, but it also may be helpful for experienced workers. Techniques suitable for wilderness settings and for more developed settings are included. Drawings by the author illustrate all important points. A glossary is included, as are appendixes with material specifications.

Keywords: boardwalks, bogs, carrs, corduroy, drainage, maintenance, marshes, muskeg, piles, puncheon, recreation, swamps, tools, trail crews, trail planning, turnpikes

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You can order a copy of this document using the order form on the FHWA's Recreational Trails Program Web site at:
http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm

Fill out the order form and fax it to the distributor listed on the form. If you do not have Internet access, you can send a fax request to 301–577–1421 or a mail request to:
FHWA R&T Report Center
9701 Philadelphia Ct., Unit Q
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Forest Service and Bureau of Land Management employees may obtain additional copies from:
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5785 Hwy. 10 West
Missoula, MT 59808
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Fax: 406–329–3719
E-mail: *wo_mtdc_pubs@fs.fed.us*

Electronic copies of MTDC's documents are available on the Internet at:
http://www.fs. fed.us/eng/t-d.php

For further technical information, contact Brian Vachowski at MTDC or Bob Steinholtz.

Brian Vachowski:
Phone: 406–329–3935
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Bob Steinholtz:
Bristlecone Trails
10350 W. 14th Ave.
Lakewood, CO 80215
Phone: 303–233–4522
E-mail: *brstlcn@aol.com*

Appendix E

Floating Wetland Information

Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Island

De-nitrification for Nitrate removal

Total Suspended Solids (TSS) reduction

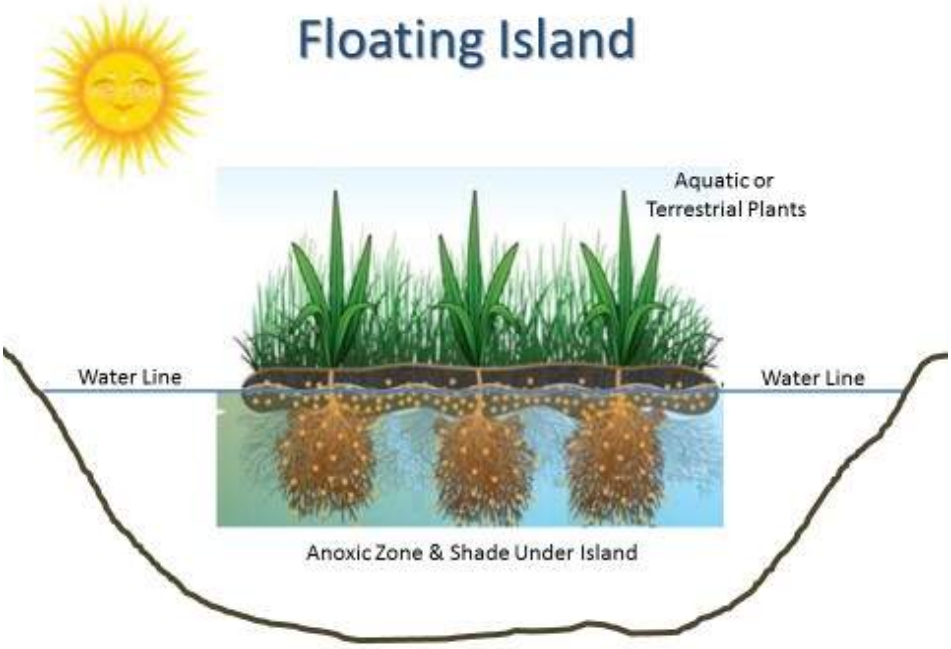
Phosphorus reduction and sequestration

Fish & Wildlife habitat, food, shade and protection

Shoreline protection & Erosion Control

Platform for plants: Terrestrial & Aquatic Plants

FWS-Floating Islands incorporate the very best features based on years of experience. Floating Islands are widely accepted as a highly versatile water quality stewardship tool and Best Management Practice (BMP). Floating Islands bio-mimic nature's scientific mechanisms for improving water quality by providing a platform for plants and surface area for micro-organisms. At the same time they also provide other ecological benefits such as habitat for fish and wildlife, as well as beautification. With versatile design and engineering features, Floating Islands can be used for erosion control, wave breaking and structural platforms.



Phone: (888) 660-3473 **Website: FloatingWetlandSolutions.com** **Email: Info@FloatingWetlandSolutions.com**

Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Island

FWS-Floating Island enhancements:

- Increased tear strength **2 to 4 times** that of other leading brands
- **UV degradation reduced by 90%** to nearly zero
- **Modular design** and new connector straps simplify field assembly
- **New edge** design looks better, eliminates exposed cuts where the material bond is weakest, provides a wetland planting edge and makes for easier wildlife access

More durable

Greater UV stabilization

Modular design easier to install

Aesthetically pleasing edge

Easier access for wildlife

Engineered Materials: All of our products are based on the use of specially engineered materials that provide a substratum with significant mass transfer features and large surface area to support diverse, robust periphyton biofilm communities. We design, engineer and manufacture our own materials.

Pricing & Design: We can custom design and build any size of Floating Island. For best value, we provide eight standard designs. Prices are for the island only and do not include plants, anchoring, shipping, or labor to assemble and launch.

Standard Sizes & Prices

8ft by 5ft	$795	8ft by 20ft	$3,181
8ft by 10ft	$1,590	10ft by 16ft	$3,181
5ft by 16ft	$1,590	10ft by 24ft	$4,772
8ft by 15ft	$2,386	15ft by 16ft	$4,772

Please contact us for custom designs and pricing

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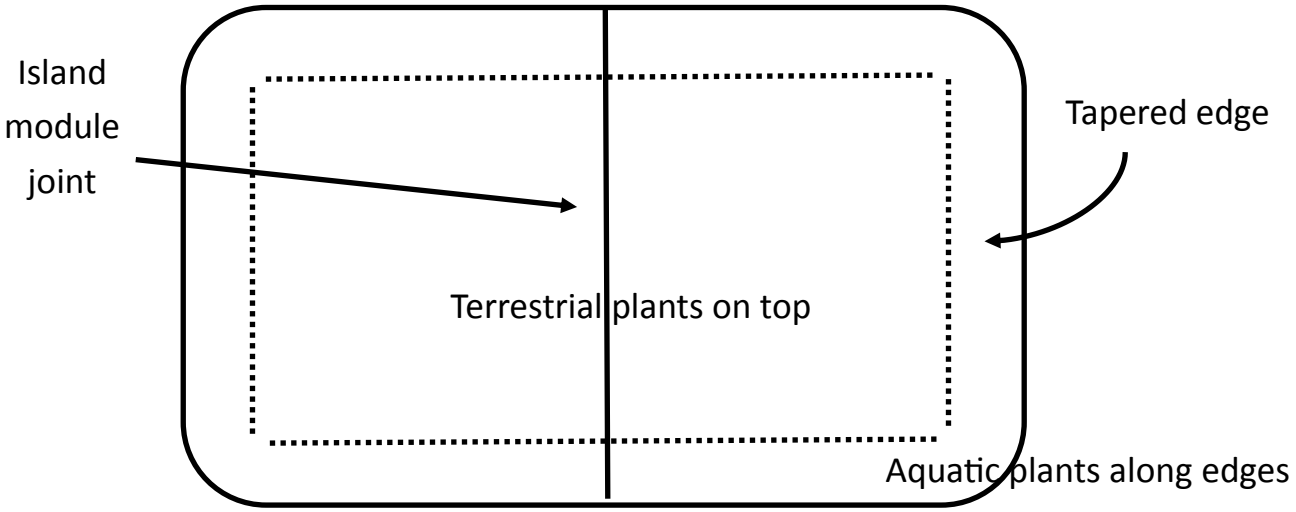
Floating Wetland Solutions

Cleaning Water Nature's Way

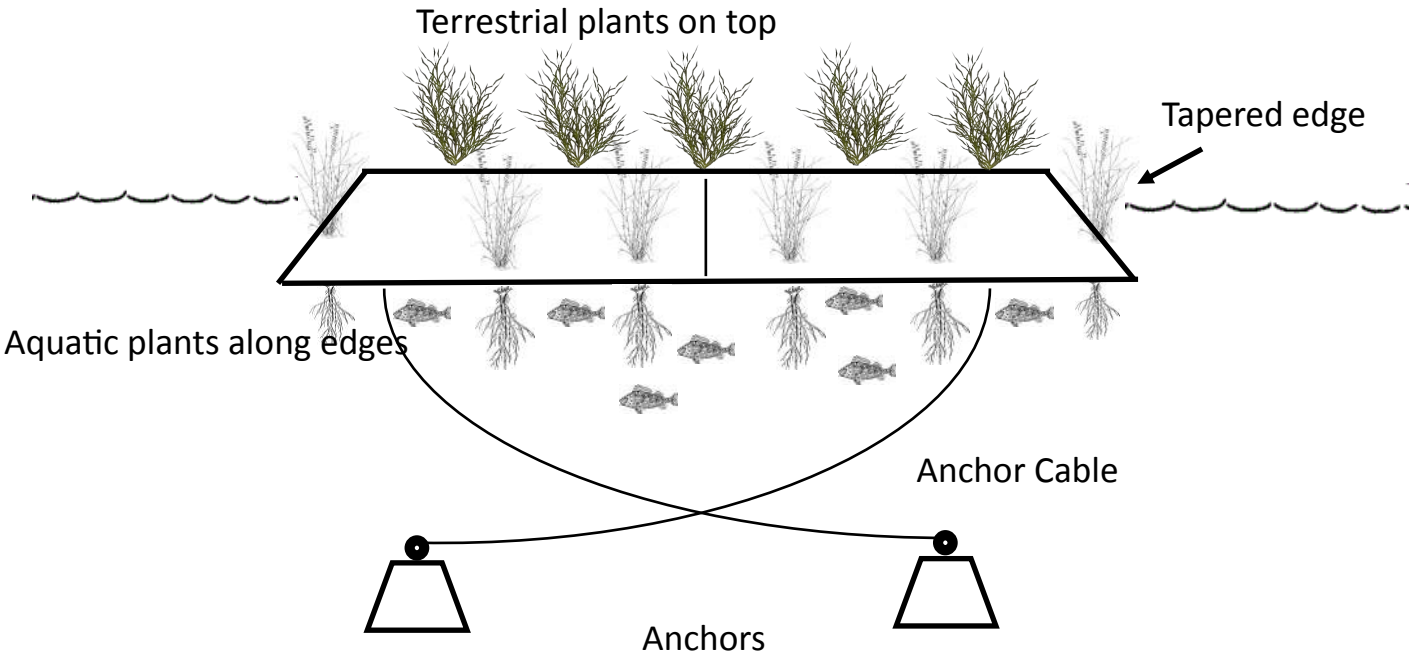
FWS - Floating Island

Top View



2 modules forming 10 ft by 8 ft island

Side View



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Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Island

Services: We provide a complete set of support services:

- **Project Assessment**
- **Design, Sales & Marketing Support**
- **Manufacturing**
- **Delivery**
- **Field Supervision**
- **Field Installation**
- **Maintenance Contracts**
- **Training**

Combined Sewer Overflow (CSO)

Rural Waste Water Treatment

Wave breaking in Jamaica Bay near LaGuardia Airport

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Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Wetland

"a true floating wetland"

Nitrification for Ammonia removal

De-nitrification for Nitrate removal

Total Suspended Solids (TSS) reduction

Phosphorus reduction and sequestration

Fish & Wildlife habitat, food, shade and protection

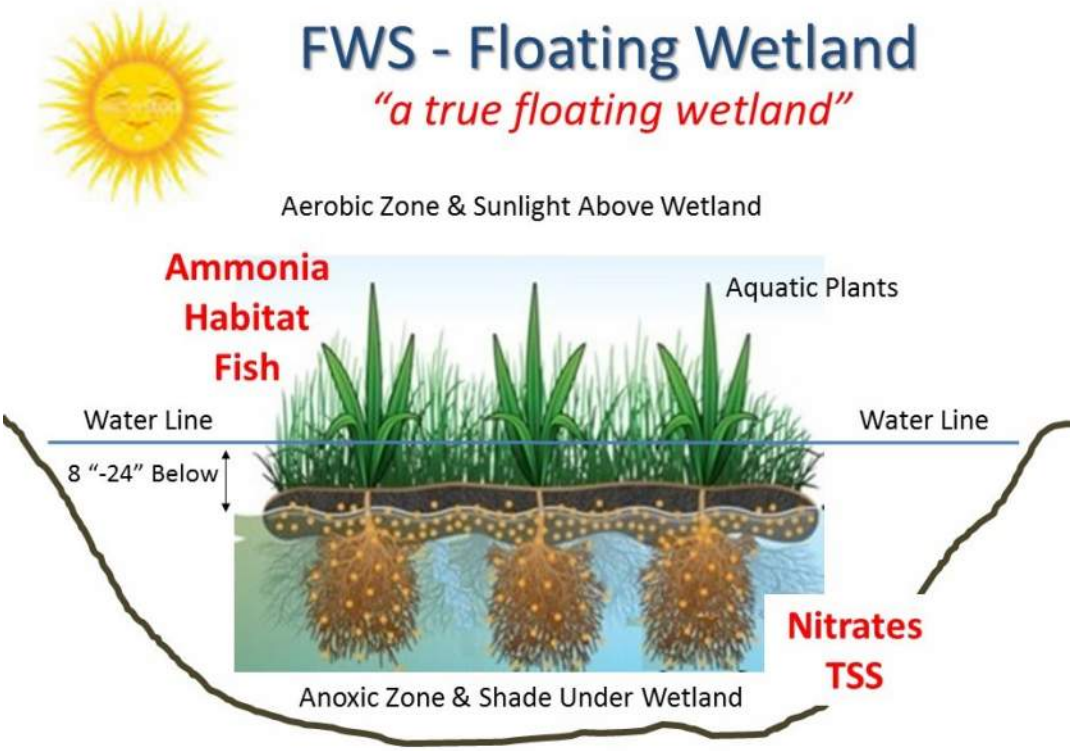
Platform for plants: Aquatic Plants

2 Distinct O_2 Zones

Aerobic above

Anoxic below

FWS-Floating Wetlands mimic nature as **"a true floating wetland"** for better performance in most water quality and fishery applications. **FWS-Floating Wetlands** floats 8" to 24" below the water's surface and is planted with aquatic plants. Unlike Floating Islands, the area under the water's surface and above the wetland is in the photic zone which is ideal for healthy periphyton development and is highly aerobic for superior microbial processing for mechanisms such as nitrification for the removal of ammonia. Rich with oxygen and robust with periphyton, **FWS-Floating Wetlands** are ideal for fish and other wetland habitat, while still adding beauty to the environment. Since **FWS-Floating Wetlands** floats just under the surface, there are other advantages such as goose protection, plant maintenance and better aesthetics during winter plant die off.



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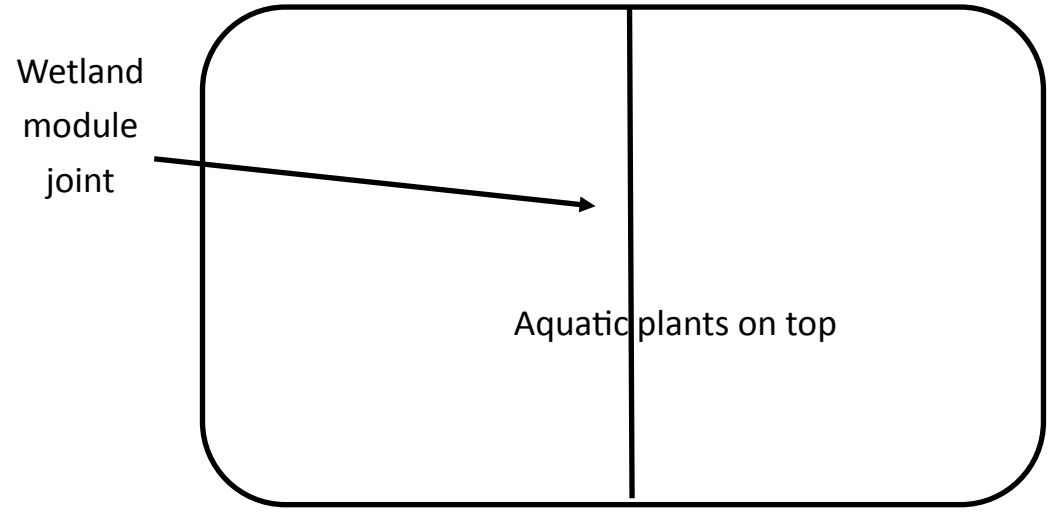
Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Wetland

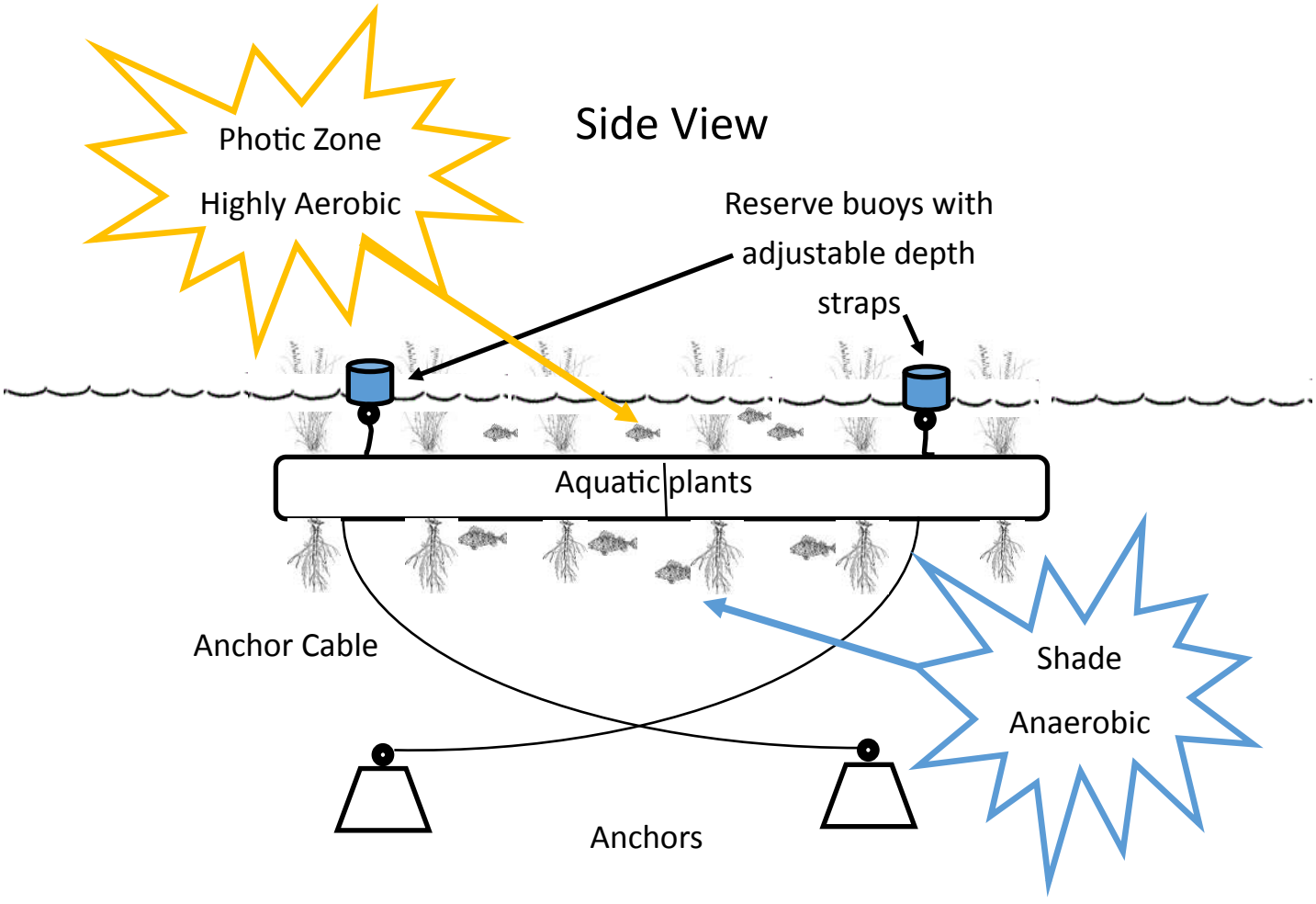
"a true floating wetland"

Top View



2 modules form 10 ft by 8 ft FWS-Floating Wetland

Side View



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Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Wetland

"a true floating wetland"

Small FWS-Floating Wetland

Larger FWS-Floating Wetland

- **Better nitrification**
- **More food and oxygen for fish**
- **Aquatic plant conditions are more stable as a wetland**
- **Winter "plant die off" does NOT expose barren island**
- **Solves "geese issue" without netting**

FWS-Floating Wetland underwater views

Highly aerobic with healthy periphyton

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Floating Wetland Solutions

Cleaning Water Nature's Way

FWS - Floating Wetland

"a true floating wetland"

Simplicity of Design: **FWS-Floating Wetlands** are manufactured and sold as "modules" that are nominally 5ft by 8ft in size. Each module has floatation, anchoring and tethering connections so that multiple modules can be configured to create any size of floating wetland as required for the project. Each module has internal buoyancy but it also uses external buoyancy to maintain and adjust the depth of subsurface floatation.

- **5ft by 8ft modular design**
- **Modules easily assemble to make any size or shape**
- **Wetland depth is adjustable to 24"**

Simplicity of Price: **FWS-Floating Wetland** modules are sold for $695 each plus freight. This does NOT include plants, anchor, tethers or labor to plant and launch. These services can be priced and provided as needed for a specific project.

Price Per Module $695

Engineered Materials: All of our products are based on the use of specially engineered materials that provide a substratum with significant mass transfer features and large surface area to support diverse, robust periphyton biofilm communities. We design, engineer and manufacture our own materials.

FWS-Floating Wetland near the water's surface

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2007 Final Report
to
Montana Board of Research and Commercialization Technology

Principal Investigator:
Frank Stewart
406.586.0790
fstewart@wildblue.net

Grant Agreement Number: 06-20

Title: Biomimetic floating islands that maximize plant and microbial synergistic relationships to revitalize degraded fisheries, wildlife habitats, and human water resources.

Agreement Dates: August 1, 2005 – October 30, 2007

Funding for Year 1: $144,757
Funding for Year 2: $165,535

Floating Island International

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Project Summary

The purpose of this project was to produce and test biomimetic, self-sustaining floating treatment wetlands ("floating islands") that are designed to remove excess nutrients and other contaminants from lakes, streams, and wastewater lagoons. The goal of the research was to produce a family of new products with proven efficacy which are cost effective and environmentally friendly compared to other commercial products that are currently available to treat water and wastewater.

The research focused on the design, construction, testing and optimization of floating islands for removal of selected contaminants that are common problems in municipal wastewater, urban stormwater, and agricultural runoff. The primary contaminants tested in this project include ammonium, nitrate, phosphate, organic carbon, and suspended solids. The research involved initial laboratory-scale experiments followed by outdoor test-pond experiments. Since market research (conducted with cash-match funds) during the project indicated that key potential markets are likely to include municipal and agricultural sewage treatment, the majority of the experiments were run with relatively high-level concentrations of contaminants in order to simulate municipal and livestock wastewaters.

Major Research Results

- The islands demonstrated rapid removal of ammonium, nitrate, phosphate, organic carbon and suspended solids, compared to controls and to previous data by other researchers. Removals were calculated on a unit basis (milligrams of nutrient removed per day per square foot of island surface). The best removal rates obtained by BioHaven® floating islands in outdoor test ponds during this project were as follows: ammonium 759 mg d^{-1} ft^{-2}; nitrate 759 mg d^{-1} ft^{-2}; phosphate 106 mg d^{-1} ft^{-2}; BOD 547 mg d^{-1} ft^{-2}. The best removal rates obtained by BioHaven® floating islands in test tanks under laboratory conditions during this project were as follows: ammonium 338 mg d^{-1} ft^{-2}; nitrate 10,600 mg d^{-1} ft^{-2}; phosphate 428 mg d^{-1} ft^{-2}.

- The BioHaven® floating islands achieved simultaneous aerobic and anoxic removal of ammonium, nitrate, phosphate, and organic carbon within a single island in a single impoundment.

- The BioHaven® floating islands removed phosphate via bacterial processes at approximately the same rate as suspended algae removed phosphate via plant growth. After the phosphate had been removed, water in ponds with BioHaven® floating islands was much clearer than algae-choked water in ponds without BioHaven® floating islands. Turbidity values were 26 NTUs versus 388 NTUs for the island pond and the control, respectively.

- The performance of BioHaven® floating islands can be optimized by providing proper conditions for the bacterial processes. These conditions are dependent upon the nutrient of concern: for ammonium removal, alkalinity and aeration control are critical; for nitrate removal, adequate organic carbon is required. In order to maximize the efficacy of the islands, critical parameters must be measured prior to and during the treatment process; auxiliary aeration, alkalinity and carbon should be supplied if necessary.

Achievement of Objectives

The originally proposed objectives were met: Nutrients concentrations were reduced to target levels; long-term efficacy was demonstrated; commercial and naturally occurring microbes were compared, required micronutrients and other auxiliary requirements were identified, scale-up criteria were developed; wildlife habitat benefits were documented; products were successfully introduced into the marketplace.

Assessment of Commercial Potential

The measurable results from this research have been presented to public and private entities throughout Montana, across the U.S. and worldwide. The strongest and most immediate commercial potential comes in the form of licensing to a Montana firm for a new U.S. production facility in Montana. That facility would create new jobs, enhance many existing related businesses, and positively impact economic development in Montana. Additional strong prospects include the specialized production and placement of islands in California for treatment of the Salton Sea, in Singapore to remediate the Lower Seletar Reservoir, and in New Zealand to treat millions of acres of degraded waterways throughout the country.

6

A. Objectives, Work, & Results

Objective I: Reduction to target levels of phosphorus, nitrogen, algae and other suspended particles in water

Over the course of the project, we conducted approximately 35 experimental runs to measure nutrient removal rates by bacteria and plants. During the first phase of the project, we conducted 30 tank-scale tests under controlled laboratory conditions with various combinations of nutrient concentrations, aeration, and water temperature. In general, we obtained progressively better removal rates as we learned how to optimize growing conditions for the various types of aerobic and anoxic bacteria that remove the studied nutrients (phosphorus, ammonium, and nitrate). We documented the conditions that produced the best laboratory results, then conducted four outdoor experiments in test ponds in which we duplicated the conditions that produced the best laboratory results.

Our experiments demonstrated that the BioHaven® floating islands can reduce nutrient, organic carbon and suspended solids concentrations to target levels for both stormwater and wastewater applications. Our results indicate that the laboratory-scale and test-pond scale BioHaven® floating islands remove nutrients significantly faster than floating planters or constructed wetlands that have been studied by others. Table 1 is a comparison table of those results.

Significantly, we also demonstrated that BioHaven® floating islands can remove all of the constituents of concern (ammonium, nitrate, phosphorus, organic carbon and suspended solids) within a single island body. This finding has important ramifications for the treatment of wastewaters, in which simultaneous removal of these constituents can result in lower construction and operating costs.

Table 1 - Representative Nutrient Removal Rates (updated 9/22/07)

Nutrient	Removal Rate mg d^{-1} ft^{-2}		Source	Notes
NO3-N	10,600		Floating Island Intl - tank test Run 23	microbes only - carbon source added
NO3-N	1880		Floating Island Intl - test pond Run 33	September 2007
NO3-N	520		U.S. BoR - tank test	macrophytes, microbes, and algae
NO3-N	56		Floating Island Intl - tank test	macrophytes only - early results
TN-N (see note 1)	540		motel septic effluent - Hart (Australia)	Vetiver grass on floating platforms (microbes and macrophytes)
TN-N	270		Tanner 1995	total removal (plants, microbes, absorption); tank scale;wastewater
TN-N	255		U.S. Ag Research Service- tank test	macrophytes only; wastewater
TN-N	68		Swine effluent - constructed wetland	macrophytes, microbes, and algae
NH_4-N	759		Floating Island Intl - test pond Run 34	microbes only
NH_4-N	338		Floating Island Intl - tank test Run 16	microbes only
PO_4-P	428		Floating Island Intl - tank test Run 27	microbes only - controlled ORP conditions
PO_4-P	106		Floating Island Intl – test pond Run 34	microbes only
PO_4-P	52		motel septic effluent - Hart (Australia)	Vetiver grass on floating platforms (microbes and macrophytes)
PO_4-P	40		Tanner 1995	total removal (plants, microbes, absorption); tank scale wastewater
PO_4-P	38		U.S. Ag Research Service- tank test	macrophyte uptake only - assumes 180-day annual growth period
PO_4-P	28		Floating Island Intl - test pond Run 33	September 2007
PO_4-P	12		Floating Island Intl - tank test	macrophytes only - early results

Notes:

1) total nitrogen (TN) in wastewater is typically composed primarily of ammonium

Objectives, Work, & Results *cont.*

We conducted literature reviews to determine typical nutrient influent concentrations and target effluent levels in stormwater detention ponds, municipal sewage, and concentrated animal feedlot operation (CAFO) lagoons; then we performed chemical analyses at selected wastewater sites to confirm nutrient concentrations in untreated lagoons. Starting nutrient concentrations for the experiments were based on the influent data we obtained. We established nutrient removal rates in the experiments by measuring the time required for approximately 90% removal of each nutrient. We compared turbidity and total suspended solids (TSS) levels in island ponds to control ponds to determine the effectiveness of islands for reducing algae and other suspended solids. The experiments showed that the islands could produce target-level concentrations of nutrients, organic carbon, and total suspended solids. A large percentage of the project effort involved optimizing the rates of nutrient removal by floating islands, then comparing the removal rates of the island to the removal rates produced by algae and bacteria in the control ponds.

In order to test the effect of floating islands on improving water clarity, turbidity was monitored in two test pond experiments (Run 33 and 34), and TSS were monitored in one. In these tests, water clarity in the island pond was about 16 times better than the controls; TSS was below detection level in the island pond, but was significant in the non-island ponds. These results indicate that the floating islands provide significant water clarification benefits.

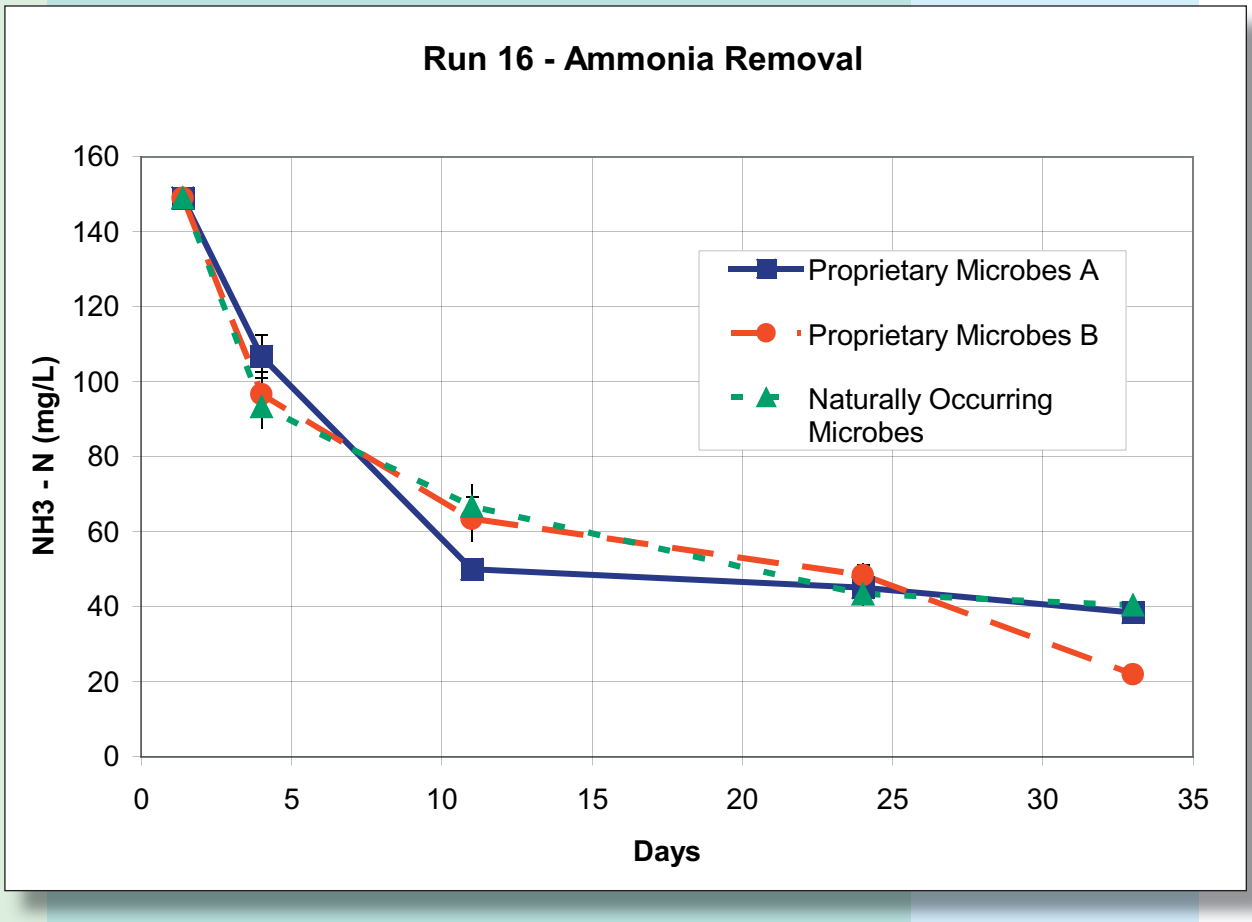
Details of the individual runs are presented in the eight quarterly reports that were produced during the project. A summary of selected experiments that yielded the most significant results is presented below.

Run 16 – best ammonium removal in a test tank

Experiment I.D.		Run 16
run dates		6/27/06 – 7/29/06
island surface area		2.0 square feet
island thickness		8 inches
Results	**value**	**units**
ammonium removal	338	mg d^{-1} ft^{-2}
Test conditions		
ammonium starting concentration	149	mg/l
unit aeration rate	>0.5	(cfm air / sf of island)
unit water circulation rate	none	no circulation pump, but bubbler provided circulation
water temperature	20.0	degrees Celsius

Notes: This run demonstrated that naturally occurring bacteria were as effective as commercially purchased bacteria when proper growth conditions were met.

Objectives, Work, & Results *cont.*



Run 23 – best nitrate removal in a test tank

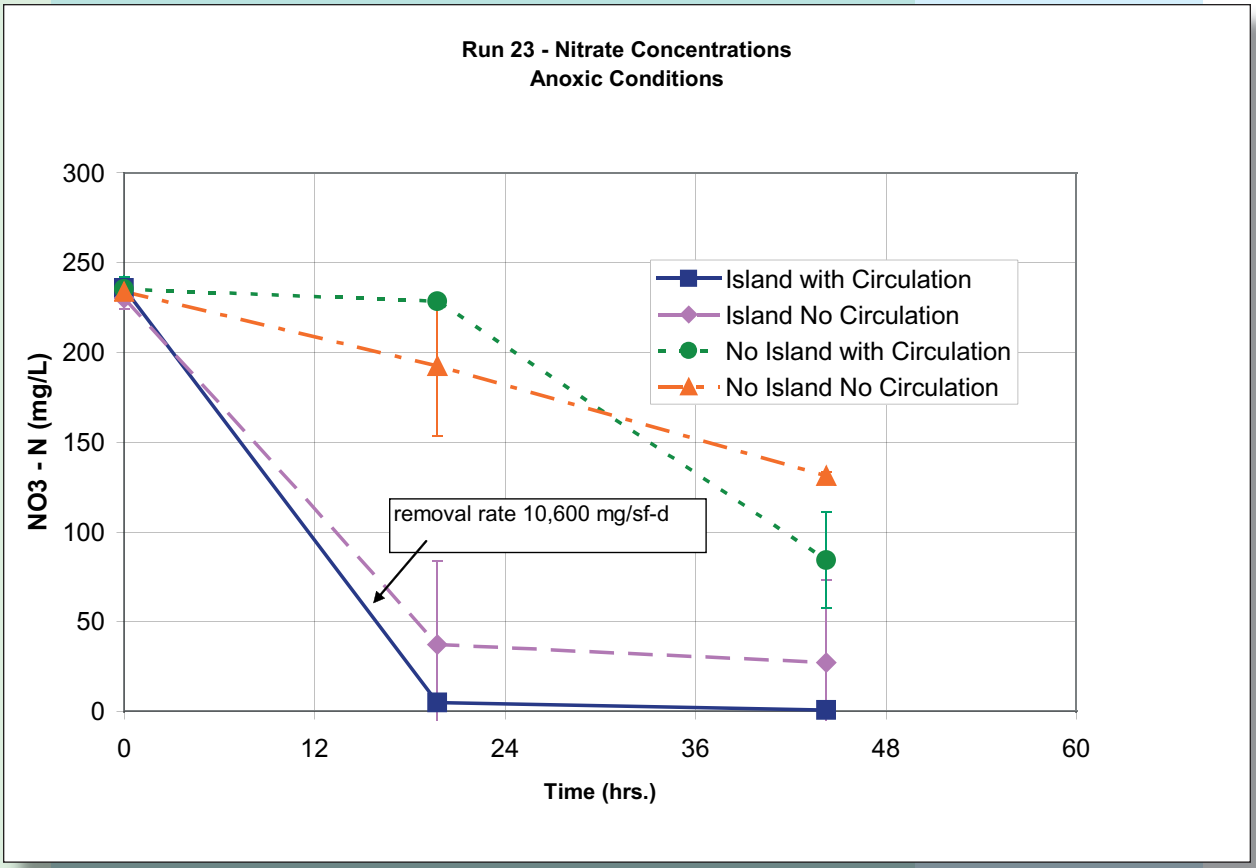
Experiment I.D.		Run 23
run dates		1/09/07 – 1/10/07
island surface area		2.0 square feet
island thickness		8 inches
Results	**value**	**units**
nitrate removal	10,600	mg d^{-1} ft^{-2}
Test conditions		
nitrate starting concentration	236	mg/l
unit aeration rate	0	no aeration
unit water circulation rate	0.4	gal min^{-1} ft^{-2}
water temperature	26	degrees Celsius

Notes:

1) 1.6 g/l molasses added at start of experiment as organic carbon source for denitrification.

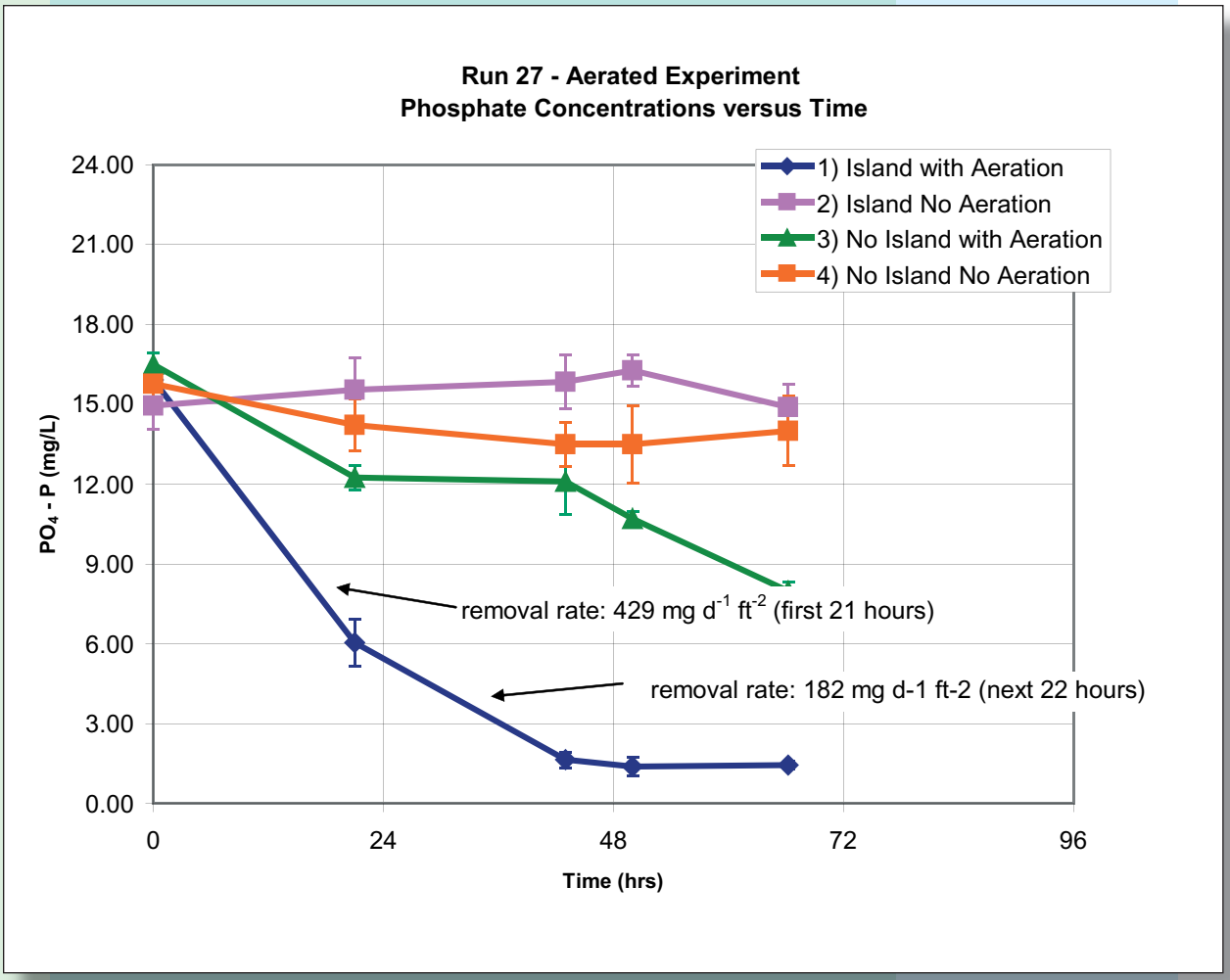
2) nitrate 100% removed by second sample – actual nitrate removal rate may be greater than calculated rate

Objectives, Work, & Results *cont.*



Run 27 – best phosphate removal in a test tank

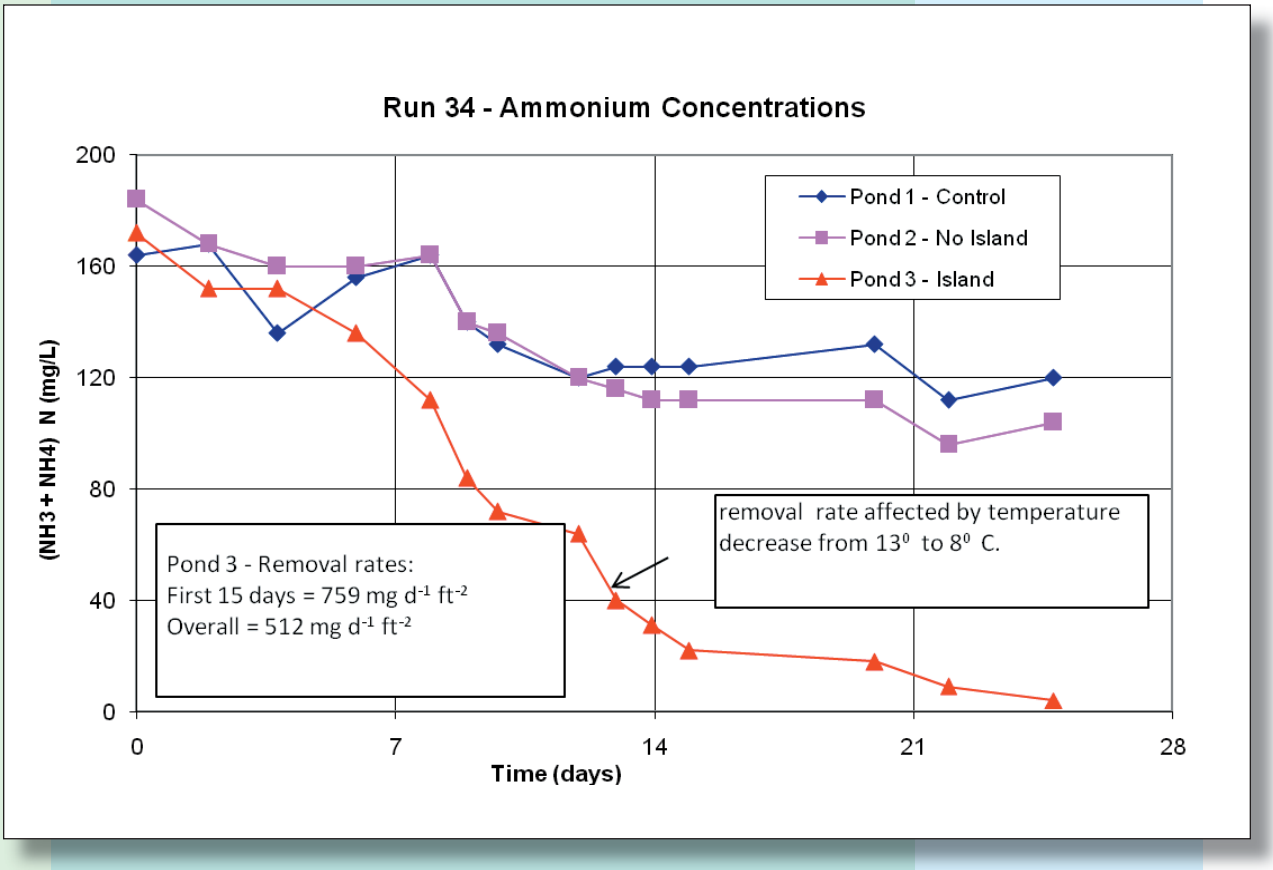
Experiment I.D.		Run 27
run dates		4/10/07 – 4/11/07
island surface area		2.0 square feet
island thickness		8 inches
Results	**value**	**units**
phosphate removal	428	mg d^{-1} ft^{-2}
Test conditions		
phosphate starting concentration	15.9	mg/l
unit aeration rate	0.05	cfm air /square foot island
unit water circulation rate	0.4	gal min^{-1} ft^{-2}
water temperature	26	degrees Celsius

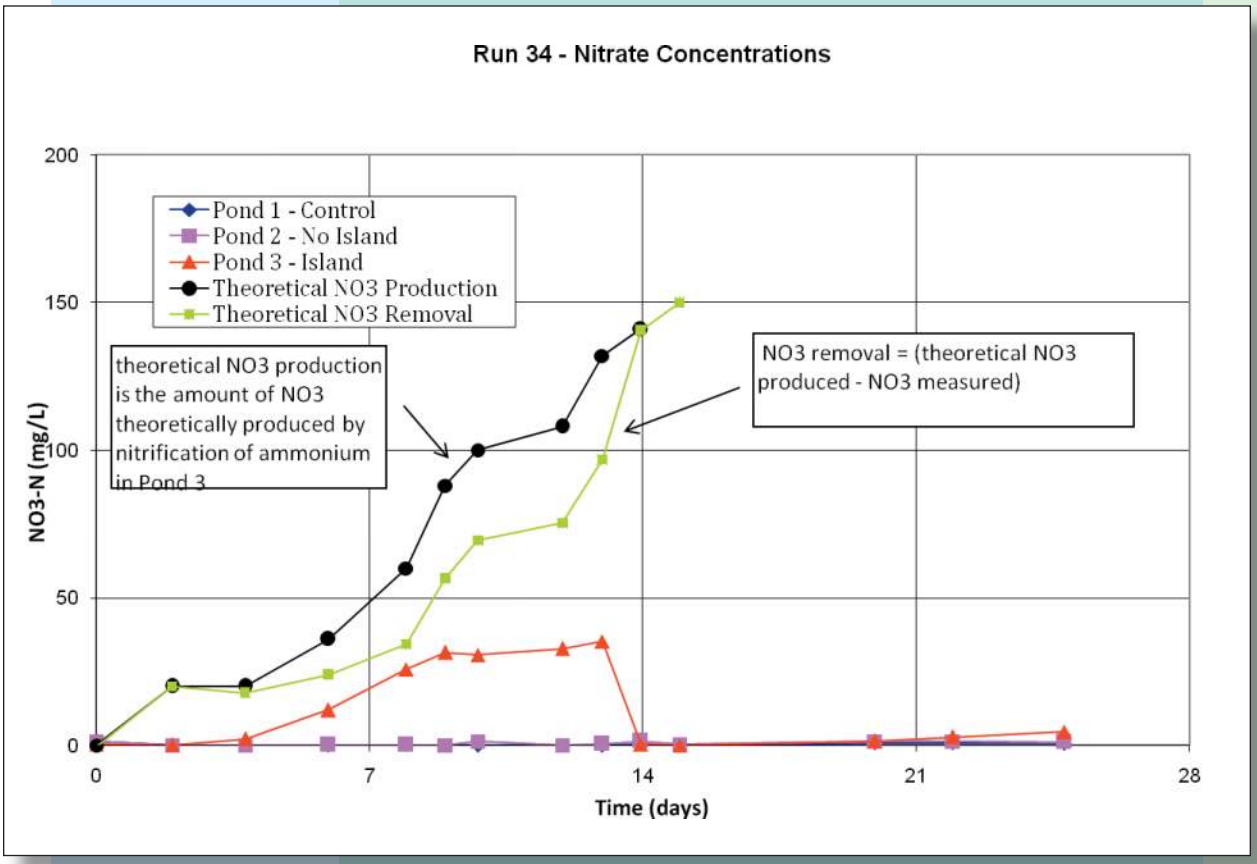

Run 27 - Aerated Experiment
Phosphate Concentrations versus Time
1) Island with Aeration
2) Island No Aeration
3) No Island with Aeration
4) No Island No Aeration
PO4 - P (mg/L)
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
0
24
48
72
96
Time (hrs)
removal rate: 429 mg d-1 ft-2 (first 21 hours)
removal rate: 182 mg d-1 ft-2 (next 22 hours)

Run 34 – best removal of ammonium, nitrate, phosphate, turbidity, and suspended solids in a test pond

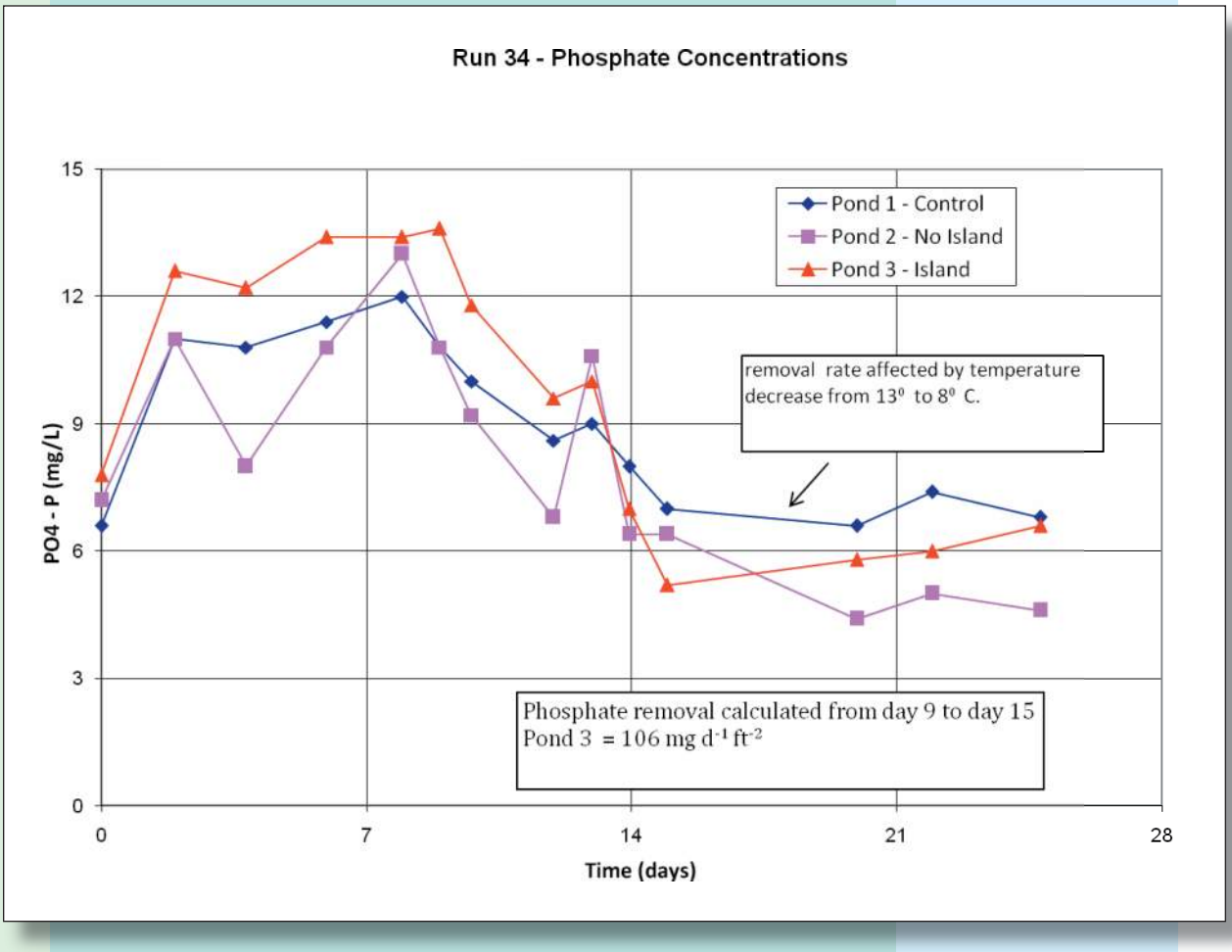
Experiment I.D.		Run 34
run dates		9/26/07 – 10/24/07
island surface area		250 square feet
island thickness		8 inches
Results	**value**	**units**
ammonium removal	759	mg d^{-1} ft^{-2}
phosphate removal	106	mg d^{-1} ft^{-2}
nitrate removal	759	mg d^{-1} ft^{-2}
turbidity ratio	0.06	(NTU island / NTU control)
DOC removal	1177	mg d^{-1} ft^{-2}
BOD removal	547	mg d^{-1} ft^{-2}
CaCO3 required	3.6	kg CaCO3 required per kg NH4 removed
Organic carbon required	10	liters molasses required per kg NO3 removed
Test conditions		
ammonium starting concentration	172	mg/l
phosphate starting concentration	13.6	mg/l
unit aeration rate	0.03	(cfm air / sf of island) for half of island aerated
unit water circulation rate	0.12	gal min^{-1} ft^{-2}
water turnover time (volume pond / flowrate)	167	(gal / (gal/min)) = minutes
water temperature range	8.5 – 15.0	degrees Celsius
percent of pond surface covered by island	55	%

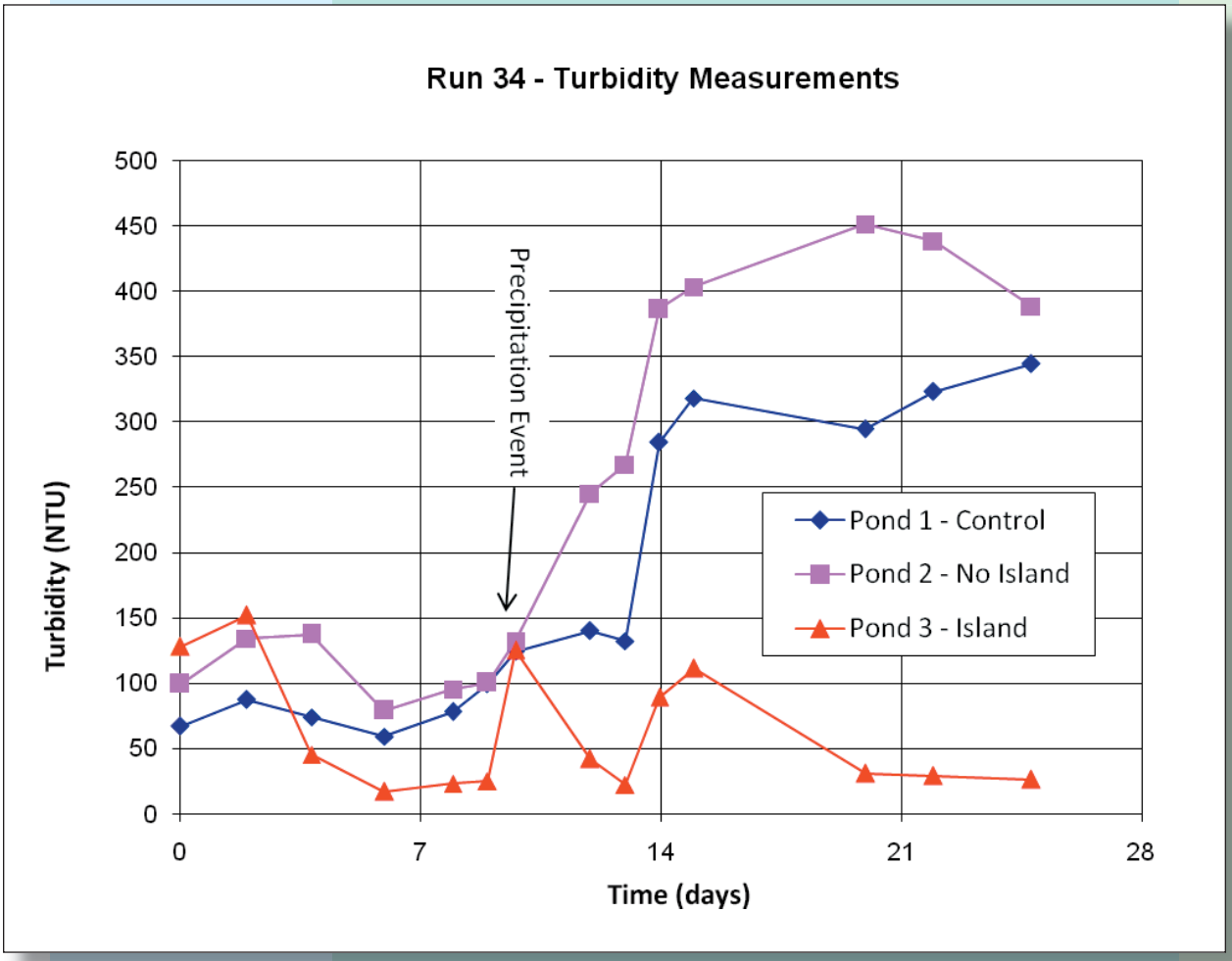
Objectives, Work, & Results *cont.*

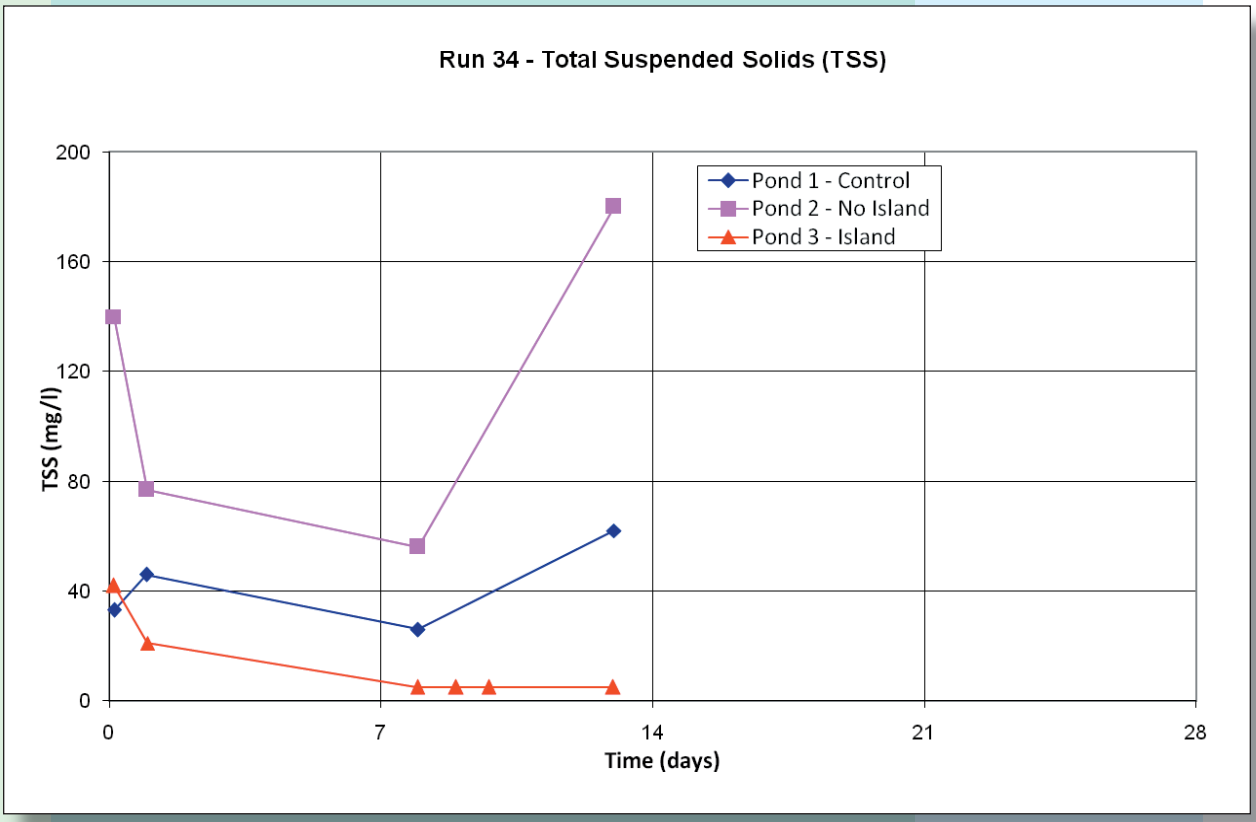



Run 34 - Nitrate Concentrations
200
150
100
50
0
NO3-N (mg/L)
0
7
14
21
28
Time (days)
Pond 1 - Control
Pond 2 - No Island
Pond 3 - Island
Theoretical NO3 Production
Theoretical NO3 Removal
theoretical NO3 production is the amount of NO3 theoretically produced by nitrification of ammonium in Pond 3
NO3 removal = (theoretical NO3 produced - NO3 measured)

Objectives, Work, & Results *cont.*




Run 34 - Turbidity Measurements
Turbidity (NTU)
500
450
400
350
300
250
200
150
100
50
0
0
7
14
21
28
Time (days)
Precipitation Event
Pond 1 - Control
Pond 2 - No Island
Pond 3 - Island


Run 34 - Total Suspended Solids (TSS)
TSS (mg/l)
200
160
120
80
40
0
0
7
14
21
28
Time (days)
Pond 1 - Control
Pond 2 - No Island
Pond 3 - Island

Objective II: Data proving that a proprietary blend of nitrogen- and phosphorus-removing microbes with natural root-enhancing additives improve islands' performance in favorable and adverse weather conditions

We compared several commercial formulations of microbes to naturally occurring microbes found in nutrient-rich waters for five experimental runs under various nutrient loading conditions and temperatures, and we found that the naturally occurring microbes that had adapted to the specific local conditions performed as well or better than the relatively expensive commercial microbes. Communications with microbial researchers at MSU-Bozeman confirmed that commercial microbes typically do not outperform native microbes that have adapted to local conditions. Subsequent experiments focused on using natural bacteria, providing them with proper growth conditions, and allowing them to adapt to the particular experimental conditions that were present. (Proper growth conditions varied depending upon the nutrient that was being treated – for example, ammonium-removing bacteria require oxygen and alkalinity, but are inhibited by excess carbon; nitrate-removing bacteria require carbon but are inhibited by oxygen.) We used published literature in the field of biological wastewater treatment for reference guidelines. In general, the performance of the microbes continued to improve when the same islands were reused in follow-up experiments indicating that the ability of an island to remove nutrients will improve as the island microbial colonies mature.

We developed a proprietary plant-growth medium for use in sprouting seeds and starting young plants on the islands. This product is a combination of hydrophilic polymers and organic materials, and may be applied as a top coating on the islands or placed in pockets that are preformed into the island matrix. The material, named BioMix™, provides wicking, moisture retention, and starting nutrients for young plants, and also serves as a colonizing surface

for beneficial microbes. Seeds and plants started in BioMix™ exhibit higher survival and faster growth rates than those started on bare island matrix.

In summary, the best combination of microbial and plant performance was achieved by using locally-adapted microbes well established on island matrix, in combination with plants that were grown in proprietary BioMix™.

Defined parameters for microbial dosing frequency

As described in the previous section, we used native microbes that were present in nutrient-rich shallow groundwater to seed the islands, and we found that additional microbial redosing was not required during the experiments. For the ammonium removal experiments, alkalinity was required by the nitrifying bacteria to convert ammonium to nitrate, and we dosed the experiments as required to maintain sufficient alkalinity and to keep pH in a favorable range for the nitrifying bacteria. The water used in the experiments contained a natural starting concentration of about 150 mg/l of carbonate alkalinity and had a pH of about 7.8. The pH was monitored daily throughout the experiments, and powdered calcium carbonate was added as required to maintain the pH between about 6.5 and 8.0. The additional mass of calcium carbonate required for unit removal of ammonium is shown in Run 34 on page 16.

Dissolved organic carbon (DOC) in the form of molasses was added to promote conversion of nitrate to nitrogen gas by denitrifying bacteria. The mass of DOC required for unit removal of nitrate was determined experimentally, as is shown in the Run 34 table on page 16. (Organic carbon is present in most wastewaters, and one of the primary goals of wastewater treatment is to remove this carbon. When excess carbon is added to promote nitrate removal, the additional carbon mass required should be calculated so that the effluent is depleted of both nitrate and carbon.)

Objective III: Data proving that islands work long-term after macrophytes have reached maturity

Nutrient removal in wetlands has been shown to decrease over time as wetland vegetation matures and plant growth rate decreases. We evaluated this potential effect with floating islands in order to determine if floating islands have a longer predicted operational lifetime than conventional treatment wetlands.

Comparing the nutrient removal rates for microbes and plants from data produced during this project and from other researchers (see table on page 8), it has been shown that microbes (when supplied with ideal growth conditions) can remove nutrients 10 to 20 times faster than plants. Based on these data, nutrient uptake associated with plant growth is not a significant source of nutrient removal compared to microbial removal on floating islands; therefore, the bacterial component of floating islands will continue to uptake nutrients at a relatively high rate after the plant component has matured and experienced a slowdown in nutrient uptake. (Submerged plant roots can provide a significant growth area for colonizing bacteria and therefore can be beneficial for nutrient removal; however, in this case mature plants are more beneficial than young plants.)

Although we did not experience significant plugging of the island matrix or sludge buildup in the island ponds or tanks during this project, we do expect an eventual buildup of biomass associated with conversion of phosphate to organic phosphorus. For some applications with high phosphate loading, it may be beneficial to replace the islands periodically in order to remove accumulated phosphorus. In some cases, the old phosphorus-rich islands may be redeployed for other applications such as streambank stabilization.

Objective IV: Established ratio of island mass to water volume that is required to reach target levels of phosphorus, nitrogen, and algae in the water

Experimental results were documented in terms of "unit removal rates" (i.e., mass of nutrient removed per day per square foot of island, abbreviated as mg d^{-1} ft^{-2}); auxiliary parameters found to be of significance (e.g., unit aeration rate, pH control, and through-island water circulation) were also recorded. Using this approach, it is possible to use the experimentally-derived data to predict the performance of a given island system for removal of nutrients in any wastewater having known nutrient concentrations and target effluent levels, if the volume, temperature, alkalinity, and other field parameters of the wastewater can be determined. Examples of the experimental results and operating parameters are shown in the data tables beginning on page 8.

Objective V: Creation of habitat for native species of fish and wildlife—documenting for commercialization that combined benefits of water quality improvement and wildlife enhancement add market value

The objective in the proposal stated that we would select and track wildlife progress on five islands within the state of Montana. During the course of the Grant timeline, we expanded our tracking to include islands installed at several sites in other states and countries. These projects were funded by a combination of commercial sales and cash-match funding. Selected projects are summarized below. All of these projects are providing data and photographs that are documenting the combined benefits of BioHaven® floating islands.

- Delta Waterfowl Duck Nesting Project – We provided islands for duck nesting projects in South Dakota for the 2005 and 2006 nesting

seasons. Brush covered islands provided successful nesting habitat; sod-covered islands provided loafing and grazing habitat.

- Michigan Loon Nesting Project – FII provided four nesting islands for a test in U.P. Michigan that was conducted by White Water Associates. Two of the islands were used in the first season, and three of the islands were used in the second season.

- Chicago River Project – FII installed 22 floating islands in the Chicago River in the city of Chicago during July 2006. The purpose of the project was to provide aesthetic enhancement, wildlife habitat, and water quality improvement. The islands have been heavily used by wildlife and may require modification to protect plants from excessive grazing by waterfowl.

- Citizens for Conservation Project – A series of islands were installed by a volunteer group in Barrington, IL, for the purpose of wetland restoration. Plant growth and wildlife use are being photographed.

- Singapore – A group of islands was launched during 2007 in a brackish water lagoon in Singapore as part of the city's "ABC" program for water (Active, Beautiful, Clean).

- ZooMontana – Floating islands have been installed in several locations in the Billings zoo, including the otter habitat. The underwater viewing window in this display allows monitoring and photography of root growth and the use of the underwater portions of the island by captive wildlife as well as wild birds with access to the site. Islands at other sites within the zoo are being used for aesthetic value, water quality improvement and wildlife habitat.

- Shepherd Research Facility – Numerous floating islands in various sizes and configurations have been launched in wetlands and ponds at FII's Montana site. The oldest island is currently six years old. This island has been monitored and photographed to track its use by frogs, garter snakes, shore birds, waterfowl, fish and other wildlife. Plant species succession has also been photographed and documented. An underwater viewing chamber has been constructed in a 20-foot deep pond to allow monitoring and photography of underwater island use by fish, insects, and other forms of wildlife. Root palatability of various plant species by native fish has been investigated to either encourage or discourage fish grazing depending on the intended use of the island. There are currently about 200 islands under study at the site, ranging in size from 1 square foot to over 1700 square feet. These islands grow trees, flowers and vegetables as well as native wetland plants.

Objective VI: Application and expansion of current commercialization efforts—building and capitalizing on brand recognition—to connect successfully with target markets in the areas of water quality improvement

- Launch introductory product—aquarium-size island—into the commercial market Aquarium-scale islands were manufactured in Shepherd and test marketed through a retail store in Bozeman during 2006-2007. At this time, an existing license-holder is considering picking up the license for the aquarium-size market. The Shepherd facility is currently taking telephone orders and manufacturing custom and stock islands in a wide range of sizes. These products are being sold nationally and internationally.

- Conduct market research to identify specific targets in mine reclamation, municipal and private water treatment, feedlot waste management, dairy operation, manufacturing, water treatment and stormwater management, and fisheries; and expand current marketing plan to these markets Over the period of the Grant, FII has conducted extensive market research in the fields of mine waste remediation, wastewater treatment, livestock effluent management and stormwater management. We have done limited market research in the areas of manufacturing process treatment and aquaculture.

  We have made wastewater presentations to representatives from the city of Helena, the Montana DEQ, the MSU Water Center, and several other authorities. We presented to Montana Department of Environmental Quality (MDEQ) on behalf of the Hebgen Lake Subdivision Water and Sewer Board. The Board is interested in using FII technology in wastewater lagoons that receive sewage from approximately 50 homes. Project team members from FII are continuing to work with engineering consultants and subdivision water and sewer board member to win a pilot project. We also presented to the City of Kalispell, Montana, and to the developer of a new subdivision to incorporate FII technology into stormwater management wetlands. The presentation received a very favorable response which resulted in the developer requesting a proposal for FII technology. In addition, we have conducted seminars on various topics including water quality remediation and waterfowl nesting habitat.

  FII is currently in negotiations with a national marketing firm to promote brand recognition. In addition, we are working with the Montana university system to run annual conferences, beginning in 2008, that will bring together water quality professionals (researchers,

government agencies, foundations, and other public and private entities) together in dialog to inform, educate, and problem-solve, as well as to promote floating islands as a bio-remediation tool.

- Expand photographic and videographic materials Over the period of the Grant, we have assembled a portfolio of over one thousand photographs that show a diverse range of island-based subjects, including plant growth, wildlife use, test setups, and launching techniques. FII has produced a DVD of a general concepts presentation by Mark Osterlund that is coordinated with a promotional PowerPoint. Another DVD is in the works that demonstrates how to launch a floating island.

- Prepare marketing materials, media buys, website updates, tradeshow attendance/presentations We have used data and photographs collected during the Grant to produce several marketing documents that are being distributed to potential customers, and we have also distributed copies of the quarterly reports to numerous potential partners and customers.

  We have developed and keep current an extensive website www.floatingislandinternational.com with the latest results of research, product development, and new locations of island deployment. In addition, we are compiling a list of tradeshows and working with our growing international network to recommend and attend key shows on our behalf.

- Success will be measured by tracking return on investments—cost-benefit analysis FII is tracking expenditures, incomes and profit margins as part of our normal business operation.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B. Performance Benchmarks

1. **Secure greenhouse facility, equipment, and supplies for *Stage 1*. Target Date August 2005**

   Benchmark accomplished. Greenhouse space was rented from Aquatic Design and Construction (ADC) in Livingston, Montana, starting July 2005. Analytic instruments were purchased, including a Hach 890 Colorimeter (used for measuring ammonium, nitrate, phosphorus, and other parameters); a pH meter, an alkalinity meter, and a conductivity meter. Tanks, aerator pumps, circulation pumps, chemical supplies, nursery plants, etc., were purchased during August 2005.

2. **Construct controlled testing facilities, run tests to establish baseline statistics. Target Date Sept 2005.**

   Benchmark accomplished. A bank of 24 aerated tanks was installed; 2 technicians (employed by ADC) were trained to operate the measuring instruments and other equipment; baseline tests (screening runs) were conducted using reference standards to confirm proficiency for measuring concentrations of phosphate, nitrate, ammonium, dissolved oxygen, pH and temperature.

3. **Start *Stage 1* cool weather laboratory experiments. Target date Oct 2005.**

   Benchmark accomplished. Experimental Runs 1, 2, and 3 were started. Run 2 was completed; Runs 1 and 3 were continued into Q2.

4. **Submit first Quarterly Progress Report. Target date Oct 2005.**

   Benchmark accomplished. The Q1 report was submitted on time and accepted by the MBRCT.

5. **Submit second Quarterly Progress Report. Target date Jan 2006.**

   Benchmark accomplished. The Q2 report was submitted on time and accepted by the MBRCT. By the end of Q2, we had completed six experimental runs, including tests with plants and microbes.

6. **Secure equipment and supplies for *Stage 2*. Target date March 2006.**

   Benchmark accomplished. Tanks, plants, and expendable supplies were obtained for the outdoor tank experiments at the Livingston facility.

7. **Complete *Stage 1* cool weather laboratory experiments. Target date March 2006.**

   Benchmark accomplished. Twelve laboratory runs were completed during the first six months of the project.

8. **Start *Stage 2* warm weather laboratory experiments. Target date April 2006**

   Benchmark accomplished. Run 13 (first warm weather plant experiment) was started April 25, 2006.

9. **Submit third Quarterly Progress Report. Target date April 2006.**

   Benchmark accomplished. The Q3 report was submitted on time and accepted by the MBRCT.

10. **Summarize Bruce Kania's international research trip(s) for Year 1. Target date July 2006.**

Performance Benchmarks *cont.*

Benchmark accomplished. This information was originally presented in the Q4 report as follows:

"Research and Commercialization Trips by Bruce Kania and other Floating Island International Associates (cash match funding)"

Jan 2006

- Bruce Kania and Anne Lamont-Low (International Liaison) – Visit to Americo (Acworth, GA), the manufacturers of the matrix used in island fabrication. Met with Richard Rones (President) and Kris Panattiere (Sales Manager); viewed the production lines; discussed product development to meet current and projected needs; discussed investment potential.

- Bruce Kania – Meeting with D2 Corporation (Indianapolis, IN) to advance distributorship possibilities.

- Bruce Kania – Held talks with patent attorneys (Columbus, OH), which have subsequently resulted in an arrangement to secure patent enforcement representation.

February 2006

- Bruce Kania and Anne Lamont-Low – Visited two companies in Germany and one in Switzerland to begin market development in Europe; crossed to UK and held talks with five companies: one importer, a consulting engineer specializing in erosion control, and retailers; in addition, met with the Duke of Buccleugh's estate manager and prepared the ground for a license deal in Scotland. We are holding ongoing talks with the importer.

May 2006

- Bruce Kania – Trip to Raleigh, NC, to visit Nomaco (part of the multi-billion dollar Noel Group) to present FII as a license/investment prospect.

July 2006

- Bruce Kania and Anne Lamont-Low – Drove to Chicago to install 22 floating islands for the city on the Chicago River in downtown Chicago. The islands will be monitored carefully with respect to plant species / growth success rates, tolerance by (and to) waterfowl and overall improvement in the river health and aesthetics.

11. Submit fourth Quarterly Progress Report. Target date July 2006.

Benchmark accomplished. The Q4 report was submitted on time and accepted by the MBRCT.

12. Complete *Stage 2* warm weather laboratory experiments. Target date Sept 2006.

Benchmark accomplished. Final runs for this stage were Run 14B and Run 20 comprised of both microbes and macrophytes. Details were presented in the Q5 report.

13. Submit fifth Quarterly Progress Report. Final report for Stages 1 and 2 will be completed. Target date Oct 2006.

Benchmark accomplished. The Q5 report was submitted on time and accepted by the MBRCT.

Performance Benchmarks *cont.*

14. Technical Articles for Year 1 results will be generated and submitted to a minimum of 3 major technical/commercial publications. Target date Nov 2006.

Benchmark accomplished. The following documents were published or submitted for publication during year 1.

a. "Implementation of an Effective Floating Island and Water Quality Treatment Technology," presented to the National Association of Lake Management Society, 26th International Symposium, November 8-10, 2006, Indianapolis, IN. (printed copies available for distribution)

b. "Island Life," Watershapes Magazine, Volume 7, Number 4, April 2005.

c. "Treasure Islands," Billings Gazette, June 17, 2006. Front page article with color photographs of islands, picked up by AP and reprinted nationally in numerous newspapers.

d. "Floating Islands as an Alternative to Constructed Wetlands for Treatment of Excess Nutrients from Agricultural and Municipal Wastes – Results of Laboratory-Scale Tests," Land Contamination and Reclamation Magazine, submitted for peer-reviewed publication, January 2007. Accepted with major revisions required 2/16/07. Revised article submitted 7/16/07. Accepted by editor 7/23/07. Accepted by publisher with minor revisions required 9/13/07. Expected submittal date for revised version is end of November, 2007.

15. Submit sixth Quarterly Progress Report. Target date Jan 2007.

Benchmark accomplished. The Q6 report was submitted on time and accepted by the MBRCT.

16. Secure facilities, equipment, and supplies for *Stage 3*. Target date March 2007.

Benchmark accomplished. A site for construction of the test ponds was selected at the Shepherd Research Facility. Pond liner, piping, valves, and other required parts were purchased.

17. Build full scale islands, design and build outdoor test facility. Target date April 2007.

Benchmark accomplished. The *Stage 3* facilities comprised three identical 5000-gallon test ponds with grid power, solar power, and wind power options for aeration and water circulation. The ponds could be filled either by gravity flow from a connected irrigation ditch or from an existing pond by pumping. Dry and liquid nutrients were purchased for the purpose of dosing the ponds with simulated wastewater containing ammonium, phosphate and organic carbon. Powdered calcium carbonate was purchased to provide alkalinity dosing for the nitrifying bacterial process. The three ponds were set up as follows: Pond 1 – no aeration or circulation (to simulate a stagnant wastewater lagoon); Pond 2 – aeration and water circulation supplied, but no floating island; Pond 3 – one 250-square foot floating island equipped with both aeration and water circulation. Initial screening runs were conducted to develop efficient methods for mixing chemicals, distributing the circulated water, collecting samples, etc.

Performance Benchmarks *cont.*

18. Submit seventh Quarterly Progress Report. Target date April 2007.

Benchmark accomplished. The Q6 report was submitted on time and accepted by the MBRCT.

19. Start *Stage 3* - Full Scale verification tests. Target date May 2007.

Benchmark accomplished. We started and completed screening Run 30 in the outdoor test ponds, then modified the equipment setup as required. We started Run 31 which tested the uptake of high concentrations of ammonium by a 250-sf floating island and compared the island performance against two different control conditions.

20. Summarize Bruce Kania's international research trips for Year 2. Target date July 2007.

Benchmark accomplished. The U.S. and international research trips taken by FII personnel were originally presented in the Q8 Report as follows:

<u>January 2007</u>

- Presented to NACO – National Association of County Commissioners – ag caucus (Bozeman).

- Licensing Visit to Arizona and California – Bruce Kania and Anne Lamont-Low (27 Jan – 11 Feb 2007)

    a. Meeting with Dr. Bruce Rittmann ASU and Andrew Wooten AZTE – Presented FII and learned about BR's hydrogen membrane technology for nutrient and selenium removal; assessed the potential fit between the two technologies as high:

compatibility excellent and moving toward a potential FII technology license deal with Andrew's company.

b. Jerry Miller, Coyote Wash Golf Course and condominiums, Wellton, AZ – Jerry owns two old-style floating islands which have developed buoyancy problems. We left him with two new islands and need to work with him further to review how they're doing and replace them with larger ones. Jerry's family owns a construction company and is involved in major property development. He could be an ideal license candidate for FII.

c. Polycoat Plastics, Santa Fe Springs – Met with Ashish and Mike Volesky, reviewed their operation and presented FII technology; came away with greater understanding of their coatings and how they can be used by FII. Good relationship-building exercise, especially with Mike, with whom we have already had excellent dealings.

d. Meeting with senior members of the Departments of Conservation and Water Resources in Sacramento – Presented FII technology to senior members of the California state government - Karen Scarborough, Undersecretary, Dept. of Resources; Bridgett Luther, Head, Dept. of Conservation, and Dale Hoffman-Floerke, head of the Salton Sea office. The use of recycled plastics is a prime concern in CA, and the use of floating islands in the remediation of the Salton Sea was explored. Our presentation was very well received. It was considered more practical to treat the tributaries flowing into the Sea, especially the New and Alamo Rivers. Concerns still expressed by the Salton Sea office about floating islands' ability to withstand the environment's harsh conditions.

Performance Benchmarks *cont.*

e. Meeting with Zenny Yagen, Division Head, Dept. of Recycling – We were talked through the grants available for keeping recycled plastics in California and shown sample successful applications. Enthusiasm was strong for our potential application.

f. Meeting with Water Resources Board (California EPA) – Tom Howard, acting Director; Charlie Hoppin and others. Presented to a more technical, scientific audience who were supportive of permitting floating islands in TMDL and stormwater applications. They were more conservative about waste-water applications.

g. Travelled South to meet with Bruce Milne and George Aguilar – Were taken to visit Pinnacle Plastics and Jacobsen Plastics, but there did not seem to be much prospect of a license deal or partnership with either company.

h. Introduced to the management team of the new company George and Bruce have set up, Bio Remedial Services – Were presented with their business plan. This company is very serious about moving forward with a license covering the State of California, and plans to send Arn Lahde, CEO, to Shepherd the week of February 18, and conclude the license deal on March 8–10.

i. Visited Inca Plastics – Met with Bill Odell, the owner, who has been ear-marked as the production manager for Bio Remedial Services.

j. Lake Elsinore – Ray and Sandra Stinnett, Pat Kilroy, Jeff and Rick (from SAWPA). Visited the Lake and discussed the implications of using floating islands in a pilot project in two one-acre areas.

Presented the benefits of floating islands to Pat and the two SAWPA engineers. Their main concerns centered around how to measure these benefits (Frank Stewart has already been in touch to offer assistance). Pat indicated there were no funds yet allocated for this project. Ray and Sandra Stinnett are very enthusiastic supporters of FII and are shaping up as dealers.

k. Back in Sacramento – Breakfasted with George Tchobanoglous and made him aware of the benefits of floating island technology. George offered to set up a meeting between FII and the city manager(s) of San Francisco.

Saturday, March 24

- Pond Boss Conf. & Expo. Texas – Break-out session with Dr. Richard Anderson
- Left Texas for Florida

Monday, March 26

- 1:30 pm – Bruce presented for Peter Seyffert's group in Sarasota, FL
- Met with Wendy Swindell, Biological Research Associates

Wednesday, March 28

- Met with Larry Dyck in Lake Sinclair Business
- Bruce met with reps from Georgia DNR at Lake Sinclair, GA

Friday, March 30

- Breakfast meeting with Ted Martin, Ted Falgout & CC Lockwood in Baton Rouge, LA

Performance Benchmarks *cont.*

Report of International Research Trip April 2007
Bruce Kania, Anne Lamont-Low

New Zealand

- We visited with John Preece of NZ Wetland Nursery, a wetlands plant specialist and wetland construction consultant, and his wife Elspeth, a businesswoman. We presented them with the floating island concept and research data with a view to their participation as a distributor or license holder. John decided to be part of the Delphi system as his current circumstances do not permit a more committed business involvement.

- Anne visited with Ken Johns of Astron Plastics, a possible supplier of recycled plastic "re-grind." Ken suggested an alternative option would be chopped laminate for filling the low-cost modules. Ken then put us in touch with RDR Foam, a manufacturer of a brand new polyethylene foam. Discussions have commenced. Both manufacturers represent suppliers to whatever entity eventually becomes the NZ manufacturer of floating islands.

Singapore

- Bruce, Anne, and initially Bernie Masters held extensive meetings over four days with engineering firm CPG Consultants, the Public Utilities Board (PUB) of Singapore, academics representing research projects, and other engineering firms and individuals.

- CPG Consultants have a contract with PUB to construct a floating amenity of approximately 2,000 sq. meters in the Sungei Punggol, a waterway which flows inland from the sea, which is soon going to be blocked off to form, over time, a freshwater reservoir. FII has

been approached by CPG to supply islands as part of the overall project solution. We are working with Coco Wang. We needed to demonstrate that floating islands were suitable for the job, and nutrient removal was a significant factor. We were able to draw on the excellent results of Q5 to support our case. We presented to a large number of representatives from CPG and PUB (including the Director of the Catchment and Waterways Department) and were well received. We spent the remainder of our day with CPG helping to modify their design and generating more ideas about how our islands can be used most effectively.

- The credibility that our involvement with the MBRCT grant gave us, along with FII's matching contributions, led to an invitation the following Monday to present to a group of academics and researchers who administer grant funding for water-related projects in Singapore. They seemed very willing to identify suitable projects and assist us to apply for funding.

- Further meetings with CPG led to two demonstration projects being finalized, to be undertaken immediately: on May13, the Prime Minister of Singapore will open a sports facility on the Lower Seletar reservoir right by the water's edge. FII will air-freight demonstration islands to take advantage of this public occasion. Bernie Masters will be on hand to manage the launch. The second pilot, slated to begin the end of May, will test what vegetation grows best on floating islands in the target waterway, in both freshwater and brackish conditions, in the tropical climate of Singapore.

- There are two other similar projects being undertaken by other engineering firms elsewhere on the island. We met with two

Performance Benchmarks *cont.*

representatives from Black and Veatch to establish our credentials and make initial contact.

- And finally, a private contact – a relative of one of the engineers approached us interested in being involved in FII at some level. He, Isaac, toured us around the islands' waterways and gave us extensive insight into the water issues and resources that the PUB is seeking to steward. "ABC – Active, Beautiful, Clean" is their slogan, and they are serious about enacting it.

Seoul, South Korea

- Our purpose was to meet with a potential license candidate, Magicone21, a firm involved in zoo construction and live animal importation which has business connections with a relative of Bruce's. They appeared to be very keen to distribute or license floating islands.

- Over two and a half days, we presented our technology in detail, and indeed the research results were one of the keys to establishing the credibility of FII and the islands themselves. Korea is especially interesting as there is at least one other firm manufacturing and launching a version of a floating island, so Magicone21 were particularly interested in the points of difference. We were able to establish that the efficacy of BioHavens® exceeded the efficacy of the Korean islands by a huge factor, if their figures are accurate (Their firgures - P : 1.4mg/square feet per day. N : 21mg/square feet per day. Our figures - N:10,600 mg/sf/day; P 140 (at the time) mg/sf/day). This was very persuasive.

- The outcome was we shook hands on a license agreement, to be worked out in detail and contracts to be signed over the next 45 days.

This will give Magicone21 the rights to manufacture and sell floating islands in Korea, and in the short term into any territory not yet covered by a license. In return they will pay a lump sum, and royalties on all sales, to FII.

Report of U.S. Research Trip July 2007
Bruce Kania, Anne Lamont-Low

Harrisburg, PA.

- Brinjac Engineering – Met with Steve Zeller and Dr. Vikram Pattarkine to review wastewater treatment using floating islands, in particular, the pilot project at Wiconsico, which is starting to show preliminary results.

- Presented to section directors at DCNR and Wildlife and Parks.

- Land Science – Bill Achor and Jim Baney. Very strong interest in taking a distributorship or license.

Columbus, OH.

- Met with business development manager and scientists at Battelle with a view to entering into a partnership involving research and/or investment.

Wisconsin

- Various sites in Wisconsin to research natural floating islands. Engaged Charles Sandstrom (Guide on Lake Chippewa Flowage) for diving services.

Performance Benchmarks *cont.*

- Dave Knapp and Lisa Reas – based in Green Lake, WI. Potential distributor / WI licensee. Bank restoration specialists.

21. Submit eighth Quarterly Progress Report. Target date July 2007.

Benchmark accomplished. The Q8 report was submitted on time and accepted by the MBRCT.

22. Complete *Stage 3* - Full Scale Verification Tests. Target date Sept 2007.

Benchmark accomplished. We completed Runs 31 and 33 by the end of September. Based on continued favorable outdoor weather conditions, we made one additional run (Run 34), which was completed October 21, 2007. This final run provided our best nutrient removal rates for the project in an outdoor test pond environment.

23. Complete Final Report for *Stage 3* results. Target date October 2007.

Benchmark accomplished. This report fulfills the requirement for Benchmark 23. The details of the *Stage 3* experiments are presented in our Year 2 Annual Report which will be submitted shortly following this Final Report.

24. Submit technical articles for Year 2 results to a minimum of six major technical/commercial publications. Target date Nov 2007.

Benchmark accomplished. The following articles were published or submitted during Year 2.

a. "Microbes Rule!" WaterShapes Magazine, May 2007, by Bruce Kania.

b. "Microbes Rule", Landscape Architecture, July 2007 (P. 92 – 99 Copyright WaterShapes. Reprinted with permission from May 2007 issue)

c. "Floating Islands – New Dimensions in Pond Management," cover story, Pond Boss Magazine, Nov/Dec 2006, VXV, No. 3.

d. "The Future of the Environment – Mega Engineering Projects – Build Wetlands from Scratch," Popular Science Magazine, August 2007. An article about BioHaven® Floating Islands, by Rena Marie Pacella with technical support by Bruce Kania and Frank Stewart; May 2007.

e. "Floating Islands Dress Up Farm Ponds," Farm Show Magazine, 2007, Vol 31, No. 4.

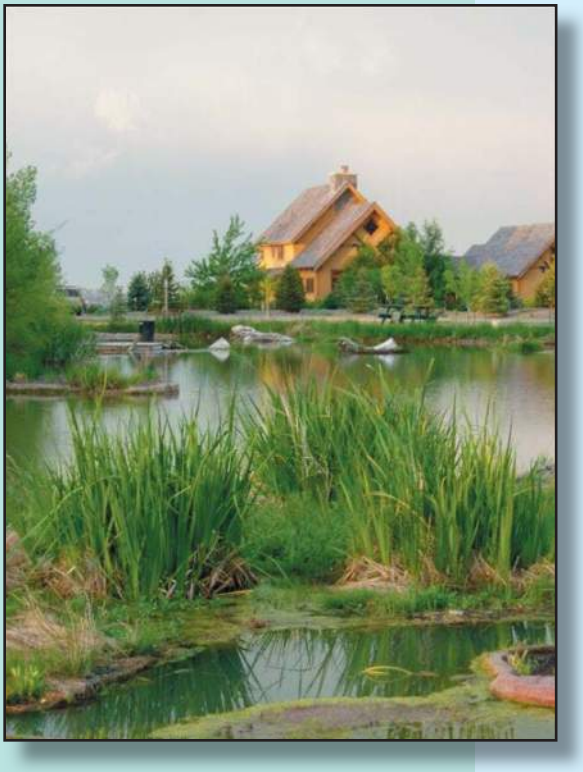
f. "Biomimicry…Nature Knows Best - Pathways to Healthier Water," Pond Boss Magazine, submitted for publication Sept 2007, By Bruce Kania, Frank Stewart & Mark Osterlund

g. "Floating Wetlands may help sink algae," "Water and Atmosphere," Vol. 15, No. 2, July 2007, by Tom Headley, NIWA. An article describing the planting and deployment of a BioHaven® floating island by volunteers in New Zealand.

h. "Stacking Functions: Floating island technology for water purification, habitat creation, environmental research and community mobilization," Municipal World Magazine, November 2007. An article about the multiple benefits of BioHaven® floating islands.

Performance Benchmarks *cont.*

i. "Results of Floating Island Experiments to Improve Water Quality in Test Ponds," Land Contamination and Reclamation Magazine. by Frank Stewart, Al Cunningham, Tim Mulholland, Mark Osterlund. This article is currently being completed and will be submitted after the report of the first year's research has been published.



FII's Shepherd, Montana, Research Facility

C. Financial Report

Montana Board of Research and Commercialization Technology

FINAL FINANCIAL REPORT

Grant Agreement: #06-20 Biomimetic Floating Islands that Maximize Plant and Microbial Synergistic Relationships to Revitalize Degraded Fisheries, Wildlife Habitats, and Human Water Resources

Principal Investigator: Frank Stewart **Phone: 406-586-0790** **Email: fstewart@wildblue.net**

Date Submitted: November 30, 2007

I. FINANCIAL STATUS

Budget Item	Original Amount Budgeted – Total Years 1 & 2				R&C Funds	Matching Funds	Other Funds	
	R&C Funds	Matching Funds	Other Funds	Total	Expended	Expended	Expended	Total
Salaries	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Payroll Benefits	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Repair and Maintenance	$ 8,700.00	$ - 0 -	$ - 0 -	$ 8,700.00	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Travel	$ 15,600.00	$ 14,000.00	$ - 0 -	$ 29,600.00	$ 11,627.81	$ 15,342.44	$ - 0 -	$ 26,970.25
Communications	$ 4,000.00	$ - 0 -	$ - 0 -	$ 4,000.00	$ 5,804.21	$ - 0 -	$ - 0 -	$ 5,804.21
Contracted Services	$ 204,810.00	$ 102,600.00	$ - 0 -	$307,410.00	$ 228,242.66	$ 118,195.78	$ - 0 -	$346,438.44
Supplies and Materials	$ 62,462.00	$ - 0 -	$ - 0 -	$ 62,462.00	$ 53,447.19	$ 4,691.82	$ - 0 -	$ 58,139.01
Rent	$ 5,400.00	$ - 0 -	$ - 0 -	$ 5,400.00	$ 9,406.85	$ - 0 -	$ - 0 -	$ 9,406.85
Equipment	$ 9,320.00	$ - 0 -	$ - 0 -	$ 9,320.00	$ 1,763.28	$ - 0 -	$ - 0 -	$ 1,763.28
Subcontracts	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Awards	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Participant Support Costs	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
Facilities and Administrative Costs	$ - 0 -	$ 7,500.00	$ - 0 -	$ 7,500.00	$ - 0 -	$ 1,727.78	$ - 0 -	$ 1,727.78
Total	$ 310,292.00	$ 124,100.00	$ - 0 -	$434,392.00	$310,292.00	$ 139,957.82	$ - 0 -	$450,249.82

Description of Variations between Budgeted and Actual Expenditures

1) Repair and Maintenance (actual R & C expenditures was lower than budgeted): There was a significant amount of effort expended on equipment repair, maintenance and replacement during the project. Since this work was a normal part of the work routine for technicians and engineer, the labor costs were credited to Contracted Services, and the parts costs were credited to Supplies and Materials.

2) Contracted Services (actual expenditures were higher than budgeted for both R & C Funds and Matching Funds): a) we modified the work plan to run our own chemical analyses of water samples rather than sending them to an outside lab, which lowered the overall cost of testing but raised labor costs for technicians and engineer; b) we performed more laboratory work than originally planned, which raised labor costs but produced a better result; c) maintenance and repair labor was included in this category; d) matching fund expenditures were greater than budgeted due to extra R & D work that was performed during the project.

3) Supplies and Materials (R & C Funds actual were lower than budgeted and Matching Funds were higher): a) expenses for outside laboratory analyses were lower than budgeted due to work being done in-house; b) materials for aquarium tests and distribution of research results to prospective customers were contributed with Matching Funds but not originally budgeted.

4) Rent (actual were higher than budgeted): We required more indoor laboratory space for wintertime work than originally budgeted, which resulted in higher rental and utility costs.

5) Equipment (actual expenditures were lower than budgeted): a) items such as pumps and mixing equipment that had individual costs of less than $500 each were originally listed as Equipment but were shifted to Supplies and Materials; b) costs for diversion structures were originally listed under Equipment but were shifted to Contracted Services.

D. Commercialization Plan

This grant project has provided empirical data that establishes the ability of BioHaven® Floating Islands to improve water quality. Armed with this data, Floating Island International can aggressively market BioHavens® to the Environmental Remediation market.

BioHavens® have many applications, and have already been successfully introduced into markets that do not depend upon water quality improvement data. The ornamental pond market is one example. Floating islands as wildlife habitat, particularly for fish and waterfowl, is another. But the most significant market, commercially and environmentally, is the "regulatory market," where contaminated water is required to be cleansed to a specific standard to avoid heavy penalties for non-compliance. BioHaven® Floating Islands, backed by solid data and capable of providing compliance to these standards, are now able to enter this market.

Product Description

BioHavens® are artificial floating wetlands offering a concentrated surface area for the growth of microbes and plants, which together offer a natural means to cleanse water of troublesome pollutants such as nutrients and heavy metals. A non-woven matrix made of 100% recycled plastic is fabricated into floating mats which are planted with a variety of vegetation and launched onto a water body. It is a very simple concept, based on naturally occurring floating peat bogs, which allows a complex process of microbial and chemical interrelationships to be optimized for the removal of pollutants.

These island wetlands are beautiful as well as natural, versatile and functional, and now they are effective problem-solvers. The problems they solve are among the most significant to the ultimate survival of our planet.

The Target Market

As a result of the success of this project, the commercialization focus of BioHaven® Floating Islands will be on Environmental Remediation Specialists – government entities and private companies who offer diverse environmental services that include watershed management and land use planning; wetland determination and mitigation; and environmental education.

Projects where floating islands can substantially contribute to cleaner water are common to virtually any community and generally fall into three main areas:

- Tertiary treatment of wastewater that has been through a wastewater treatment facility but still contains high levels of phosphate which enter the water column
- Primary treatment of wastewater in communities that do not have a wastewater treatment plant but rely instead on the evaporation process to deal with their effluent in lagoons
- Stormwater ponds which contain pollutants of all kinds, including toxic metals such as copper and zinc

In the first area, floating islands can supplement the engineered solution; in the second, they are a very competitive option to the engineered solution, especially in communities which cannot afford a wastewater plant; and for the third scenario, treatment of stormwater ponds, BioHavens® provide an additional stewardship tool—a concentrated floating treatment wetland that can provide one acre's worth of wetland surface in a 250 sq. ft. island.

Data generated by this study and applied in a real life setting promise to save municipalities like our own capital city of Helena as much as 90% of the

Commercialization Plan *cont.*

conventional cost of an expanded sewage treatment system. In Helena, based on numbers provided by that city's sewage treatment manager, our island technology could save the city in excess of $50,000,000 in installation costs compared to other options under consideration—a significant impact to a city of 28,000 people. Beyond Montana, virtually every community in the U.S. and around the world can benefit from floating islands in at least one of these three major areas. Other common municipal applications where efficacy data will be required include acid mine drainage, golf courses, zoos, and farm effluent ponds.

Size of the Market

The size of this market is immeasurable. Environmental Remediation entities are located in every state and most cities in the United States. Major headquarters offices for government land agencies tend to cluster in Washington D.C. and Colorado, but all have regional and area offices in other states—two of significance in Montana are the Bureau of Land Management and the Bureau of Reclamation. The pressure to clean up our water and restore our wetlands is increasing every year. In California, for example, if the Salton Sea restoration project proceeds as planned, costs are estimated at $6 billion. In many countries outside the US, environmental remediation is an even greater focus than it is here.

Marketing Strategy

Our current marketing strategy has several facets:

- Distributor-led marketing
- Publications – articles in journals, magazines, newspapers, press releases
- Web site positioning – www.floatingislandinternational.com
- Delphi System – where our contacts use their contacts to

introduce potential licensees to us

- Licensing in Montana – FII is in the final stages of assigning the US license to a Montana organization who will become the production facility for the whole of the U.S.
- Licensing world-wide - FII plans to license island production to appropriate entities around the world while retaining R&D in Montana. We cemented our first license almost a year ago, and have three others in advanced stages of negotiation.
- Pilot Projects – We are planning large-scale pilot projects in China and Singapore which we believe will lead to licenses in those countries.
- Contracting with a world-class marketing firm for a complete go-to-market campaign

Production/Manufacturing Plan

Currently, island production is occurring in the plant located adjacent to FII's Shepherd Research Facility. Production at that facility is limited to islands that are 25 sf or larger. In the last year, 3000 islands have been shipped from FII's production facility, and in 2008 we expect island production to increase 10-fold with the anticipated licensing of Floating Island America (FIA), a Montana-based group planning to build a larger production facility in Shepherd.

The growth of FII and the licensing of island production/sales outside Montana and the US, may lead to additional production facilities outside of Montana. These potentials are discussed in various places in this report; an abbreviated bullet list can be found under Economic Impacts. Regardless of the licensing locations, the FII Research Center will remain stable in Shepherd, Montana, and FII expects the premier product to be produced here.

Commercialization Plan *cont.*

Business Risk Assessment

Patent Protection

1. Piracy – FII has surrounded its technology with extensive patent protection, in 42 countries around the world. However there remains the risk of piracy, particularly in economies not noted for IP compliance. The risk of pirated floating islands hitting retail stores in the U.S. is perhaps higher in the "general" market. The municipal market is relatively protected from this given the large scale of most municipal projects, the custom-built nature of solutions and the relatively high integrity of public servants (on the whole). FII is protecting itself from piracy within a suspect licensed territory by charging a much higher downstroke and lower royalty than it would elsewhere.

2. Cost of IP Enforcement – Probably the greatest risk associated with FII's position is the company's ability to cash flow through an IP enforcement action. Regarding this risk factor, the company has partnered with an IP enforcement specialist law firm. In addition, we will not advance aggressively in countries that do not honor intellectual property.

Large-scale Island Failure

To combat this, as well as other risks such as incomplete projects, FII is negotiating an insurance bonding arrangement with a Montana insurance firm. At this point, FII has no long-term debt so the risks associated with outright failure are reduced.

Projected Sales Revenues

2008 – $650,000 2009 – $625,000 2010 – $250,000
2011 – $250,000 2012 – $400,000

E. Economic Impacts

The economic impacts resulting from this project are expanding almost daily—in Montana, throughout the U.S., and around the world.

New Production Facility in Montana – FII is in the final stages of assigning the license to a Montana-based group who will become the production entity for the entire US market. Their operation, Floating Island America (FIA), will be based in Shepherd, Montana, and is expected to contribute significantly to the state's economy. The production facility will be designed and built by Montanans, and when complete, will initially create 16 new jobs—3 production staff, 1 production manager, 3 sales and marketing staff , 2 administrative staff, and 2 senior managers to oversee the operation. We also expect the need for 5 science and engineering professionals to provide specification support and island launching expertise to support and train franchise holders across the U.S.

Impact on Related Montana Businesses – In addition to the direct creation of new jobs, the ripple effect will touch other Montana businesses—transport providers like Roadway, plant nurseries, and a network of potential distributors. As FIA franchise holders increasingly place islands into the state's waterways, numerous related businesses will begin to feel the positive impact.

The Montana Invention Company – FII, based in Shepherd, Montana, will continue as an invention company, developing prototypes and Intellectual Property, and contracting with Montana firms for patent work, engineering, and ongoing scientific research. Royalties generated by FIA's sales will come back to Montana and be used to further develop environmental solutions to benefit the planet.

Returns from Beyond Montana – The results of the MBRCT study are set to have a profound affect on FII's business. Though it is early, and municipal authorities are slow to act, some projects have been initiated as a direct result of the data achieved through the Grant study:

- Lower Seletar Reservoir, Singapore – 2000 sq. m floating island for water remediation, via PUB. FII will install and supervise a pilot project in February 2008 which is likely to lead to an order generating revenue for the Montana-based scientists and engineers who spec and supervise the study.

- Wiconisco – a successful pilot study would open the doors to floating islands being used to treat wastewater in communities all over the United States, each installation being worth from $1 – 5 million and upwards.

- New River, California – floating islands are being proposed to treat this heavily polluted waterway which flows into the environmentally sensitive Salton Sea. FII's solution is one of the few cost-effective options that will actually work, as nutrient loading, wave action, and habitat decimation are three of the major issues we can remediate. Conventional solutions are estimated to cost billions of dollars, and authorities have understandably baulked at this cost. We are committed to providing an affordable solution to the extent that we are planning to build a facility in California to facilitate this project. FII has received initial support from the State government which will enable us to fulfill their goals to increase plastics recycling and to restore the Salton Sea. This project will utilize Montana expertise in science, engineering, and manufacturing, and will create a revenue flow from sales back to this state.

Economic Impacts *cont.*

- New Zealand – The grant's research data with concurring data generated by the National Institute of Water & Atmospheric Research (NIWA) has been influential in Kauri Park Nurseries' decision to purchase a license from FII for New Zealand and Australia. NZ has millions of acres of degraded waterways and the will to remediate. Floating islands have been well-received and promise to generate royalty revenue for FII, new patents as R&D continues in a new environment, and partnerships between US and NZ scientists.

- Seven other major projects are in progress with similar benefits to the state of Montana, FII, and its associates.

In the last two years, and over the course of the grant project, FII or Bruce Kania has appeared in 15 magazine articles, 3 books and numerous newspapers across the US and Canada, and on Canadian TV. Many of the news articles are available on our website: www.floatingislandinternational.com and most will be included in the more comprehensive Annual Report. We believe that as a result of the empirical data made possible through research funded by this grant, we have made significant strides toward our goal to provide a natural biomimetic solution to revitalize degraded fisheries, wildlife habitats, and human water resources. We are grateful to the Montana Board of Research & Commercialization Technology for their support.

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Red wing blackbird nest on floating island in the pond at FII's Shepherd Research Facility.

Appendix F

User Group Meeting Notes

Wingfield Pines Research Stakeholder's Meeting Notes
April 13, 2018

Attendance
Brady Porter (Duquesne University)
Scott Schuette (Western Pennsylvania Conservancy)
Tim Nuttle (CEC)
David Quatchak (CEC)
Matthew Opdyke (Point Park University) provided input in an email on April 16

Species Data

- There is historic (prior to construction of treatment wetlands and Hurricane Ivan) and more recent aquatic species and water-quality data from work Ed Schroth and Brady completed. This data was once on ALT's website. Since we're very light on aquatic data, we should make an effort to track down this data.
- Dr Nancy Trun (Duquesne) may have data on microbes at Wingfield.
- Brady has historical data including before treatment ponds and before Hurricane Ivan.
- Scott may have more complete species info through his account access with iNaturalist.
- We are currently very weak on amphibian, reptile, and crustacean species data. Above sources would help to rectify this.
- Scott may be able to share additional species information from David Yeany.
- Matthew Opdyke may also have additional data but was unable to attend today's meeting.

Biological Strengths and Threats
Notable species for good or ill

- The *Gambusia* established in the treatment ponds and likely golf course ponds are not native and potentially invasive. There are advantages to them but we should explore eradication (draw down) and possible replacement with native killifish, which would provide a similar function (mosquito control).
- Historical data from Ed Schroth/Brady may provide further insights to inform these discussions.
- Scott believes teasel needs to be controlled.
- Agreement on need to control tree of heaven (*Ailanthus altissima*)(hack and squirt), buttercup (*Ranunculus ficaria*), flowering rush (*Butomus umbellatus*), purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*), and Callery pear (*Pyrus calleryana*) (hack and squirt) as high priorities. Control of reed canarygrass and loosestrife will require reseeding/replanting to fill voids.

- Painted turtle is unusual and should be encouraged. It is frequently out-competed by red-eared slider.

General habitat concerns

- Explore options for floodplain forest and expanding it to provide better bank protection during high flows.
- Lynches ponds may be oxbows or remnants from original Chartiers channel before relocation and appear to be un-impacted by AMD. May provide a glimpse into historic conditions at Wingfield. Since Wingfield is providing default access to Lynches, this could be a liability for ALT. ALT should explore purchasing a conservation easement for this property, as property is unlikely to be for sale. Appears to be a good-quality property with ponds in better condition than existing non-treatment ponds at Wingfield. Would provide strong protection of riparian habitat through the Mayview/Wingfield/Lynch Ponds corridor.
- Scott may be able to share a preliminary habitat report on Wingfield Pines currently in the works for ALT, with ALT's permission.
- Need to carefully consider balance of habitats currently present and evaluate options/risks/ opportunities of/for changes.
- Be mindful of sandy soil areas necessary for painted turtle reproduction.
- Reach out to Powder Mill staff for input on bird habitat.

Park user threats

No one was immediately aware of any biological threats caused by park users, except potentially dogs in the treatment wetland, but that issue is now being addressed. Some remaining concern about dogs in off-leash area.

Other ideas

- Bluegill/sunfish in ponds are stunted, encourage fishing through an annual children's fishing event.
- Increase access to natural wetlands to contrast natural wetlands and treatment wetland, emphasize flood control function, and consider a second boardwalk to access these wetlands.
- There is potential for signage to make public more aware of research taking place, need to coordinate/discuss +/- with researchers.

Wingfield Pines Conservation Area
Focus Group Meeting
Monday August 27th, 2018 @ 6:30 PM – 8:00 PM

Introduction

Matt Opdyke: Point Park University
George Watzlaf: Hedin Environmental
Jen Dalke: Citizens for Land Stewardship
Alison Thomas: Property User
Dave Wade: Volunteer for ALT Planning Commission
Dave Yeany: Western PA Conservancy

Discussion Notes

- Hedin Environmental
  - George talked about how the AMD system works to process and clean the water
  - ALT is responsible for maintaining the system Continued and annual maintenance plan would be helpful.
  - Beaver issues (tried to live trap – did not work with dogs)
  - Beavers left as muskrats moved in
  - Worked with PA trappers association and caught ~70 muskrats in just a few days
  - Can burry chain link fence on berms to attempt to control the muskrat situation
- **Jesse at ALT is a key stakeholder** to interview for the project. Jesse coordinates with the local schools, and will have more information on how the students use the site. CEC to meet with Jessie to understand current and future needs.
- Group liked the idea of Use Zones. Use Zones could have maintenance plans that respond to the various use zone. Additional bioblitz with scientist and volunteers could be one way of categorizing use zones.
- ADM System is a district. Mine blow out discussion – Construction to start Sept 18th 2018 and be completed by May 2019
- ALT will be putting 2 rocks in each of the AMD system pond for access (educational purposes).
- ALT received a $30,000 grant for a yurt (Colorado Yurt Company) potential diameter ~24-30 ft. and would be ideal to hold between ~60 – 80 people. Those people are most likely school aged children (6th – High school. Jesse for more details). Mt Lebanon comes ~16 times a year in May. Bus access issue/consideration. Grant has been received for approx. $30,000 for a Yurt. Location to be determined – ideas included the pool area on a platform. Could have a 10 year temporary lifecycle.
  - Other educational structures were discussed – "A teaching shelter" - nestled into the hillside to create a teaching shelter under with a green roof / deck access to provide an overlook of conservation areas. This viewshed could be an outdoor classroom. The Teaching Shelter to have Restrooms.
  - Pool area is open flat area for various educational and gathering events. Should be built into the overall mowing plan.

    - The need for a structure in the site presents a great opportunity for sustainable building that blends with and compliments the landscape. Solar panels, green roof, passive solar heating and daylighting. Use the building as not only a place for education but also a topic of discussion.
- **Bathrooms** – township may have an issue with a portable toilet.
    - Bathrooms are necessary for school students – they can only be in a place without a bathroom for 2 hours (depends on the age of children). Verify the specifics with Mt. Lebanon contact.
    - Possible pavilion for education with lockers and bathroom.
- Need a mowing plan with frequencies – David Q.
- Want Bats, Not Lights. Species inventory and action plan.
- Invasive species plan.
- Volunteer that wants to help mulch the trails
    - Could the bat boxes be volunteer made?
- Dave Yeany is concerned with maintaining the ecological integrity of the site as the space becomes more accommodating to a wider range of users.
- Alison mentioned a connection to Chartiers Park that used to exist before the mine blow out, and asked the design team if we would re-establish that connection. ALT tried to buy the property (Lynch Ponds), but were unsuccessful. Fishermen use Lynch Ponds.
- Boy Scout Bridge (see map)
- Point Park University conducts botanic research in the space. **LICHEN ON TELEPHONE POLE apparently** the specific type of lichen on this pole is very large which is amazing because it is extremely slow growing.
    - Existing telephone poles laying on the ground have Fungi – suggestion to leave it as is educational infrastructure.
- Trails - connecting to the Upper St. Clair Community Center? (Community Center has not expressed interest in the connection).
    - Walking trails – Chartiers Creek Park connection through Lynch Ponds to Wingfield Pines. The bridge connecting Wingfield to Lynch Ponds is no longer in place. Discussion of a formal trail easement through the Lynch property or even purchase (although purchased has not been acceptable to the Owner in the past)
- Security – Gate recommendations to provide safe secure but accessible conservation experience.
- Access – General feel to minimize parking (restrictive parking). Like the idea to keep the naturalist feel of the park. Generally do not want Wingfield Pines to become Boyce Mayfield. Jessie could provide input on buses and vehicular needs along with educational.
    - Access to the ponds for maintenance, low frequency maintenance schedule for ponds.
- Dog was bit by a copperhead snake.
- David Yeany mentioned organizing the space based on ecological zones.
    - How are we fertilizing?
    - The ecological importance of this site is the focus of the project
    - The marsh birds' habitat

- Dave Wade made the point about improving the site and attracting more visitors. Can the site sustain that possible increase while still maximizing the ecological importance? That question should be considered as the Master Plan recommendations are developed.
- Available parking has a direct impact on the use of the site.
    - Parking limits the number of people using the site. Must take into account that people use Chartiers Park for parking as well and that connection was washed away in the blow out but was an asset.

Alison says that park usage has gone down by ~50% this year because of the new 'dogs must be on a leash' in certain portions of the area. Dave Wade posed the question, "Are people respecting the rules?" Alison believes ~90% of dog walkers obey the rules.
Dave Wade commented on the entrance, make it better maybe a different type of fence to accommodate people walking through without allowing vehicles through. Takes the younger students 20 minutes to walk down when they only have 2 hours maximum to spend on the site was a concern.

- Signage – broom bristles with different colors stuck in the ground every 8 ft or so (Boyce Mayview Park) apparently this was not a permanent way of wayfinding in Boyce Mayview Park
    - Trail names to highlight the particular habitat and/or the ecological component in that portion of the site
    - No current signage inventory. Kiosk, signage that exists due to volunteer and friends. Would be nice to have an overall wayfinding and signage plan.
    - Trail identification through naming the trails. Trails could be marked through whiskers or other low impact and environmental sensitive blaze / marker system.
    - Chartiers Creek access is currently through one canoe access. Rename to water access. Provide additional access points, possible southern access with a bench
    - Signage with bird ID, Plant ID, fungi and lichen ID per ecozone
    - Signage explaining how the AMD system works, how acid mine drainage happens.
    - A simple map is needed with all the information on it, trails, ecological zones, dog areas, etc.
    - What are the pros and cons to signage? Easy to navigate site attracts more people, while this might be good can the ecological integrity of the site be maintained with more visitors
- Create termination points and make people choose a different way or go elsewhere
- Canoe Launch is not used as a canoe launch, it is mainly used as just water access. Maybe re name canoe launch to water access. Perhaps another access point in the northern half of the site, the off leash half.
- Vandalism is not a concerning, people go to Lynch Ponds to drink beer. Littering
- Safe recommendations for access – cost and details.
- South area – Botanical research includes herbaceous and tree growth/flooding
- Dave Wade asks who the audience is, and this question should drive a lot of the recommendations
- USC treats for mosquitos and rabies every year

    - Current picnic table in the south should be relocated to higher ground due to mosquitos.
- David Yeany talked about water fowl migration in conjunction with the water returning to the ponds.
- **Wingfield Pines Primary Uses**
    - Fishing
    - Walking/Dog walking
    - Educational
    - Birdwatching

Potential Case Studies

Spruce Knob Mountain Institute

Civil & Environmental Consultants, Inc.