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Temporary Stream and Wetland Crossing Options for Forest Management

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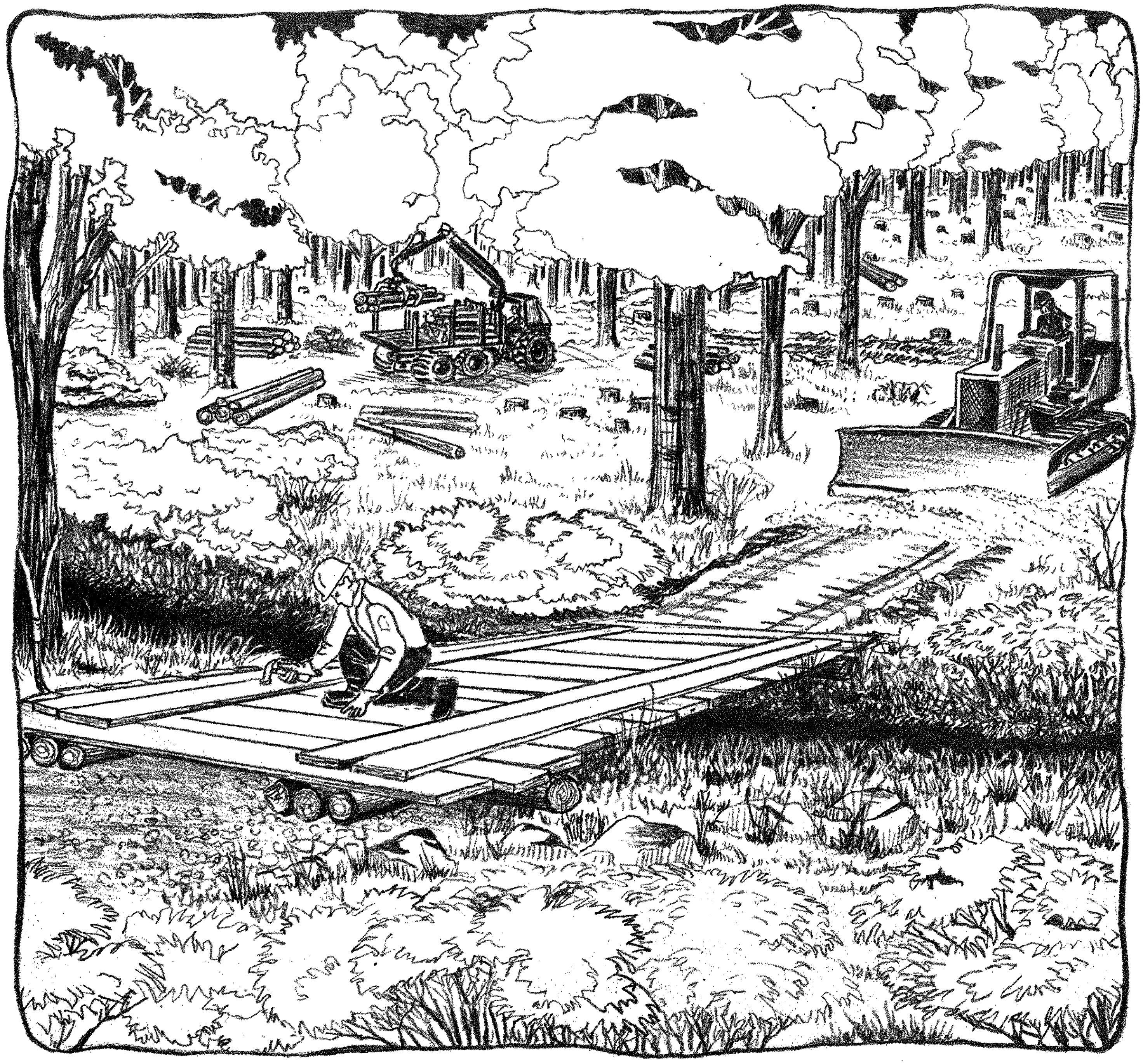

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INTRODUCTION

Expansion of economies and populations worldwide has increased the demand for forest products and other uses of forests. Removing wood products from the forest requires access systems, such as truck roads and skid trails. Roads and trails must often cross streams (fig. 1) and wetlands[1] (fig. 2). The construction and use of these access roads and trails has the potential to negatively impact streams and wetlands directly by soil compaction, rutting, or the placement of fill (fig. 3). Streams and wetlands can also be impacted indirectly by funneling the movement of sediment, debris, and nutrients into the water body or by causing changes in hydrologic flows across the area.

The best way to protect streams and wetlands is to avoid crossing them. If this is not feasible, it is important to minimize and mitigate impacts while using the crossing. For any particular application, selecting a crossing option that is cost-effective for the contractor and/or landowner, that adequately addresses the environmental concerns of society, and that satisfies the wide range of regulatory constraints is becoming increasingly difficult.

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In many areas, fords, culverts, and ice bridges are the types of stream crossings most commonly used, although use of portable bridges is rapidly increasing. Corduroy, permanent fill, and frozen soil are the most common choices for crossing wetlands. While there are numerous other options, lack of information has been an obstacle to expanding the range of options that landowners, land managers, contractors, and regulatory agencies are willing to consider.

The purpose of this paper is to help reduce this obstacle by providing detailed information about a broad range of reusable temporary[2] stream and wetland crossing options. To accomplish this, we have:

- Summarized information about many of the temporary stream and wetland crossing options,
- Reviewed some of the reported environmental impacts associated with using these options,
- Highlighted some of the key points from statutes that regulate stream and wetland crossings in Michigan, Minnesota, New York, Pennsylvania, Wisconsin, Ontario, and Quebec, and
- Identified some research and education needs.

[1] For the purpose of this report, wetlands are areas that contain soil with poor load-bearing capacity and high moisture content or standing water that are often affected by seasonal fluctuations in water level. Examples include peat, muck, wet mineral soils, or unstable sections of access roads and trails.

[2] For the purpose of this report, a temporary crossing is one that is used for a maximum of 3 years before it is removed or rendered unusable.

Figure 1.—*Stream that may need to be crossed by an access road or trail.*

Figure 2.—*Wetland area that may need to be crossed by an access road or trail.*

Information was compiled through contacts with individual loggers, staff in several forest products companies and land management and regulatory agencies, and through a review of published literature.

The options discussed in this report include both commercial and homemade devices that are either transported to the site or built on-site. Increased use of these options can help minimize the cost of protecting water resources. While the initial price of a reusable temporary option may exceed the cost of a currently used alternative (e.g., a culvert for a stream crossing or fill for a wetland crossing), the fact that it is reusable and that it may be easier to install may make it the lowest cost option in the long-term. Also, some of the temporary options reduce environmental

Figure 3.—*Rutting that can occur when crossing soft, wet soils.*

impacts and can be installed and removed more rapidly than the options most frequently used today.

It is likely there are additional excellent crossing options not identified in this paper. It was not possible to identify all available options, and new ideas for crossings and new applications of existing technologies are constantly being developed. We recommend that you contact vendors, contractors, and other sources for more detailed information on local experience regarding costs, installation and removal, the availability of specific options in your area, and additional options not covered in this report.

We also recommend that you compare each vendor's recommendations and specifications to your long-term needs and applications. Seek the advice of a licensed engineer when purchasing a stream crossing product that lacks engineering specifications, when using a product in an application for which it was not designed, or when constructing a crossing yourself. Inspect all products before each installation. Some criteria to consider when evaluating which option(s) to select for your particular application are noted in table 1. Before deciding to install a crossing, be sure to weigh the potential value(s) of the resource within the accessed area against the costs and potential negative environmental impacts.

Additional details and quick reference tables are provided in the Appendices. Appendix 1 contains a list of commercial vendors. Tables summarizing specifications, approximate cost, installation and removal time, and equipment needs are provided in Appendices 2 (stream crossings) and 3 (wetland crossings). All costs and prices presented in this report are in $US unless specified. Arnold (1994) and Mason (1990) also provide excellent overviews of many products, including design specifications, drawings, and photographs. Copstead *et al.* (1997) have also prepared an extensive annotated bibliography of published literature on water/road interaction technologies and associated environmental effects. Appendices 4 (stream crossings) and 5 (wetland crossings) contain additional information for each option according to the categories listed in table 2. Although we recognize that there is some redundancy built into this report, we chose to do this to make it more useful for a number of different applications and users.

Table 1.—*Criteria to consider when selecting a stream or wetland crossing option. Unless otherwise noted, all criteria are appropriate for both stream and wetland crossing options.*

Effectiveness for reducing potential impacts	Local availability
Relative safety of the option	Installation and removal time and costs
Compliance with safety regulations	Number of reuses possible
Compliance with other applicable non-safety regulations, including permitting requirements	Anticipated future need for a particular option
Potential conflicts with insurance coverage	Maintenance requirements
Season(s) of use	Driving surface traction under anticipated operating conditions
Length of time the crossing will be needed	Potential costs avoided, such as the purchase and placement of fill or the need to divert stream flow during a culvert installation or removal
Ability to handle anticipated traffic loads and speeds	Anticipated fluctuation in water level during use
Purchase price or construction cost	Site conditions (e.g., soil type, hydrology, amount of rock present, stream width and depth, volume of water in the stream, types of aquatic life in the stream, permitting requirements, etc.)
Maximum distance of crossing	Potential value(s) of the resource within the area to be accessed
Bridge abutment requirements (stream crossing options only)	Landowner’s management objectives
Availability of engineering specifications, especially for bridging options (stream crossing options only)	Rehabilitation requirements following removal
Ease of transport, installation, and removal with available labor and equipment	

Table 2.—*Informational categories summarized in Appendices 4 and 5 for each stream and wetland crossing option.*

Description of option	Approximate price of materials (March 1998)
Area of application	Construction directions and/or diagram and time required
Advantages	Equipment needed for construction, installation, and/or removal
Disadvantages	Installation approach and time required
Source(s)	Patent protection of product design
Recommended supplemental material	

STREAM AND WETLAND CROSSING CONSIDERATIONS

There are several considerations that apply to nearly all stream and wetland crossings. Do not cross unless absolutely necessary. If it is necessary to cross a stream or wetland, the number of crossings should be limited to as few as possible and the location(s) should be carefully selected. Existing crossings should be used whenever possible, unless their rehabilitation and use would be more damaging than establishing a new one.

The crossing should be as short as possible. Stream crossings should be perpendicular to the direction of water flow to the degree practical. Wetland crossings should be parallel to the direction of water flow to the degree practical. Approaches to crossings should be direct and have a low grade. Water diversion structures, such as a broad-based dip or water bars, should be constructed to direct water flowing down the road or skid trail into a vegetated area before it reaches the crossing. This will help minimize the movement of sediment into the water body.

Stream crossings should be located on a straight segment of the stream channel that has low banks (except for bridge crossings where higher banks are preferred to support the abutments). This will minimize the need to disturb the bank or to alter the natural shape of the channel. It will also reduce the impact of turbulent water action against the crossing structure itself or against any portions of the bank that need to be disturbed to permit installation of the structure. Where there is a risk of flooding, structures should be anchored at one end to allow them to swing out of the main channel without washing downstream or obstructing water flow (fig. 4).

Proper installation, maintenance, and site rehabilitation are essential for any crossing option to be fully effective. All necessary permits should be obtained in advance and terms communicated clearly to the employees or contractors working on the crossing. The crossing structure should be carefully inspected before each installation and appropriate repairs made. If the crossing structure becomes damaged, a licensed engineer should be consulted to certify that it is still safe for the anticipated loads. Structures that are installed either in or over open water should be cleaned (away from the water body) before each installation to remove accumulated debris, such as mud and branches. Stream crossing options that are placed in the water (e.g., culverts, pipe bundles) need to be frequently checked for blockage to avoid damming the stream.

Abutments and Geotextiles

Many of the structures are most effective when a proper foundation is provided. Bridges need a log, railroad tie, or similar abutment to rest on to help level the structure, to minimize disturbance to the stream bank, and to make removal easier (fig. 5).

Some stream crossing options and most wetland crossing options function best with a geotextile under them. Geotextile, also called

Figure 4.—*Anchoring of a bridge to a nearby tree.*

Figure 5.—*Abutment logs below a log stringer bridge (approach yet to be constructed).*

filter fabric, is a fabric mat used to prevent a new layer of material from mixing with the material below (usually native soil when used with crossing structures). Geotextiles allow water to drain through them, provide additional support for a crossing, and make removal of the crossing easier. A non-woven fabric is recommended for use with temporary installations because it is less slippery than woven fabrics, reducing movement of the structure during use (fig. 6). Also, non-woven geotextiles exclude fine particles while allowing water to flow through from above and below. A needle-punched non-woven polypropylene or high-density polyethylene (HDPE) geotextile of low (3 oz/yd^2 [100 g/m^2]) to medium (6 oz/yd^2 [200 g/m^2]) weight has been used in most trials of temporary crossings.

Another type of geotextile is a woven geotextile (fig. 7). It is mainly used in applications that require high tensile strength and low elongation of the fabric, such as permanent road building. The woven fabrics tend to allow more fine particles to flow through. Some properties of a few representative non-woven and woven geotextiles are compared in table 3.

A non-woven fabric will not continue to tear as a woven fabric may if it becomes punctured. Despite this, it is important to limit the number of high spots (e.g., rocks, stumps) to reduce the potential of punctures during use of the crossing. At the same time, care should be taken to avoid damaging the root or slash mat

Figure 6.—*Non-woven geotextile.*

Figure 7.—*Woven geotextile.*

Table 3.—*Properties of some geotextiles used in stabilization and separation applications*[a] *(metric units are reported in brackets).*

Property	Non-woven geotextiles 4546	Non-woven geotextiles 4551	Non-woven geotextiles 4553	Typical woven geotextile 2002
Physical				
Weight (oz/yd^2) [g/m^2]	4.6 [156]	7.0 [237]	9.2 [312]	5.0 [170]
Grab tensile strength (lbs) [kN]	100 [0.44]	150 [0.67]	203 [0.90]	200 [0.89]
Grab tensile elongation (%)	50	50	50	15
Packaging and price				
Roll width(s) (ft) [m]	15 [4.6]	15 [4.6]	15 [4.6]	12.5 [3.8] or 18 [5.5]
Roll length(s) (ft) [m]	300 [91]	300 [91]	240 [73]	504 [154] or 351 [107]
Gross weight/roll (lbs) [kg]	145 [66]	220 [98]	229 [104]	220 [100]
Area/roll (yd^2) [m^2]	500 [418]	500 [418]	400 [334]	700 [585]
Price[b] (\$/yd^2) [\$/m^2]	0.56 [0.47]	0.84 [0.70]	0.95 [0.82]	0.60 [0.50]

[a]The geotextiles shown here are produced by Amoco Fabrics and Fibers Company[3].
[b]The reported 1998 price (FOB) assumes the purchase of one roll of geotextile. Prices may vary between vendors and according to the amount of fabric purchased.

to the degree possible. This mat will provide additional support during use, lessen the movement of sediment, and can speed revegetation of the site after the structure is removed.

The geotextile should be removed at the same time as the crossing option. Sometimes, the geotextile may be too heavy with soil and water to be easily recovered in a reusable condition. For this reason, it may be beneficial to use shorter lengths with the ends overlapped (e.g., 25-ft [7.6-m] lengths with 2 ft [0.6 m] of overlap) or sewn (e.g., leave about 3 in. [7.5 cm] of overlap in the sewn seam). On very soft soil where the geotextile sinks when it is stepped on, it is best to sew the overlapped area together. If it is not possible to remove the geotextile, a biodegradable fabric should be used. Fiber options for biobased geotextiles include coir, jute, kenaf, flax, sisal, hemp, cotton, and wood fiber (English 1994).

Paper machine felt may be a low-cost alternative to geotextile (Bridge 1989). Used carpet and other materials may also be viable alternatives to geotextile. However, some materials may contain toxic substances that could leach into the water. Therefore, the appropriate regulatory agencies should be contacted before any substitute materials are used.

Erosion Control Measures

The installation, use, and removal of stream and wetland crossing structures frequently results in movement and exposure of soil. Use of temporary erosion control measures is strongly recommended to prevent movement of sediment into water bodies while these soils are being adequately stabilized by vegetation or armoring. Adamson and Harris (1992) recommend development of a sediment control plan to reduce sediment concerns at water crossings. The four broad categories they recommend that need to be considered in formulating a plan for a particular water crossing are noted below. Not all measures will apply for all crossings.

- Administrative measures (e.g., purchase of adequate pipe length, training and instruction of workers, timing of the construction to avoid fish spawning periods, inspection frequency, contingency plan to follow in case of change).

- Protection (e.g., protecting the existing ground cover, limiting the area of disturbance to reduce the area requiring stabilization).

[3] *The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the University of Minnesota, the Minnesota Department of Natural Resources, or the USDA Forest Service to the exclusion of others that may be suitable.*

- Strategic planning of the sequence of operations to manage the factors affecting sediment entering the water body (e.g., storm water flowing toward the water body, flowage within the water body during construction).

- Structural controls that will be used individually or in combination for reducing sediment (e.g., silt fencing, hay or straw bales, mulch, erosion blankets, diversion ditches, water bars).

Options that may be used for reducing sediment include silt fencing, hay or straw bales, mulch, and erosion blankets. Silt fencing and hay bales are installed as barriers across the slope of exposed soils to intercept and slow the movement of water down the slope. They trap the sediment the water is carrying and release the water slowly. To be most effective, they should be placed at spacings similar to that recommended for water bars on long slopes (refer to the Best Management Practices [BMP] guidelines in your State or Province). The barrier closest to the water or wetland is most critical. Proper installation and maintenance is essential for these barriers to work effectively.

To properly install hay or straw bale barriers (fig. 8):

- Set the bales in a shallow trench to prevent water from flowing under the barrier. If digging is impractical due to frost, pack snow against the uphill side of the bales.

- Overlap the bales to avoid leaving gaps between them.

- Drive stakes or lath through the bales so that the stakes are buried 6 to 10 in. (15 to 25 cm) into the soil to firmly anchor them in place.

To properly install silt fencing (fig. 9):

- Drive wooden stakes or lath spaced 4 to 6 ft (1.2 to 1.8 m) apart into the ground to hold the geotextile or other permeable fabric silt fencing in place.

- Cut the fabric in long strips that are 2 to 3 ft (0.6 to 0.9 m) wide.

Figure 8.—*Installation of hay or straw bale barriers.*

Figure 9.—*Installation of silt fencing.*

- Attach a continuous length of the fabric to the uphill side of the stakes so that pressure from water and sediment will not pull the fabric loose. The lower 6 in. (15 cm) of the fabric should form an "L" facing uphill. This should be buried, preferably in a shallow trench, or covered with soil to prevent water from running under the barrier. Pack the soil firmly over this part of the fabric.

Silt fence and hay bale barriers should be inspected periodically and maintained as necessary to make sure they remain functional. They may fill with sediment or become damaged, rendering them ineffective. Once the site is effectively stabilized by revegetation, the barriers should be removed.

In some situations, additional erosion protection may be needed. The force of raindrops on exposed surfaces can loosen and wash away substantial amounts of soil. In most cases, a layer of mulch or an erosion blanket over the exposed soil will provide good protection. Mulch or erosion blankets shield the soil and help disperse and slow the surface flow of water. Mulching with loose straw or hay (fig. 10) on level or moderate slopes can work well. On steeper slopes, it may be necessary to lightly disk the mulch into the soil to keep it in place. Where the risk of erosion is high or where concentrated flows of water are anticipated, such as the bottom of a ditch, an erosion blanket may be needed. These blankets (fig. 11) are mats made of shredded wood or other fibers. They are commercially marketed by several manufacturers and should be available through suppliers that sell culverts and geotextiles.

Steep excavated cuts, particularly on the bank of a stream, may require permanent protection, such as heavy rock riprap (fig. 12). Information on this and several other possible treatments for slope failure prone areas can be found in Moll (1996) and Mohoney (1994). Moll (1996) also discusses techniques used to close and obliterate access routes after use. The level of restoration required for a particular access corridor will depend on many site, management, and political factors.

In any case, speeding the revegetation of disturbed soil surfaces is always a good idea. Vegetation provides a root mass that holds soil in place and soaks up water, reducing runoff. Fertilizing and seeding disturbed soil facilitates and speeds revegetation, minimizing erosion potential (fig. 13). Care should be taken to use native seed sources to avoid introducing non-native species to the ecosystem unless they have been proven to be innocuous. Fertilizer and seed mixture recommendations for exposed soil are generally available from most local land management organizations.

Figure 11.—*Erosion blanket samples.*

Figure 10.—*Mulched surface.*

Figure 12.—*Riprap slope.*

Figure 13.—*Seeding an area with a hand seeder.*

TEMPORARY STREAM CROSSING OPTIONS

Crossing streams is often perceived to be one of the most controversial, time consuming, and expensive parts of any forest management operation. Properly designed, installed, and maintained temporary stream crossing structures can greatly reduce costs and help meet the concerns of regulatory agencies. The types of temporary stream crossing options discussed below include fords, culverts, polyvinyl chloride (PVC) and high-density polyethylene (HDPE) pipe bundles, and portable or on-site constructed bridges.

It is important to follow the proper permitting process when installing and using a stream crossing. A local hydrologist should be contacted to determine whether a permit is required. The permit may specify what type of crossing as well as when it can be installed and/or used.

As noted previously, engineering input from a licensed engineer into the design of many stream crossing options is recommended. However, engineering design information for some of the alternatives is limited, and the additional costs for an engineered design may be considered exorbitant for a temporary crossing. Caution is necessary when using any crossing that has not been engineered and/or that has not been inspected during and between uses.

The condition of any crossing should be monitored as long as it exists. Regular maintenance may be needed to keep the crossing functional. Maintenance is especially important for culvert and pipe bundle crossings to make sure that they are clear and free of debris. Weak soils on the approach to a crossing can be stabilized by placing one or more of the temporary wetland crossing options (e.g., corduroy, wood mats, wood panels, expanded metal grating, tire mats, etc.) on top of a non-woven geotextile.

Appendix 1 contains a list of commercial vendors for several stream crossing options. Appendix 2 presents a summary of product specifications and approximate costs for some of the options discussed. Additional information can be found on the Internet. The *Logging and Sawmilling Journal* has a World Wide Web page (http://www.forestnet.com/log&saw/stream/introstr.htm) that includes information on a variety of stream crossing options, planning tips, and suggestions for protecting aquatic resources and rehabilitating the site.

Fords

A ford or low-water crossing uses the stream bed as part of the road or access trail (fig. 14). They are best suited for short-term, limited traffic. Use should be limited to periods of low flow when the water is less than 2 ft (0.6 m) deep. Because the spawning beds of many fish species occur within the same areas that make a good ford crossing, fords should not be constructed or used during periods of fish spawning. Also, construction should not occur during fish migration periods. Fords should maintain the natural shape and elevation of the stream channel to avoid creating obstructions to the movement of fish and other aquatic organisms.

Figure 14.—*Ford crossing.*

Because equipment will be directly in the stream channel when using a ford, it is especially important to keep vehicles clean and well-maintained. Mud and debris dragged in on skid loads or on tracks and tires, as well as oil and fuel leaks, contribute to polluting the water. Protecting the approaches to a ford with clean gravel, corduroy, wood mats, wood panels, expanded metal grating, or other temporary surfacing material is recommended for this reason. (See the section on wetland crossing options for a description of corduroy, wood mats, wood panels, expanded metal grating, tire mats, etc.)

Existing crossings should be used whenever practical unless rehabilitating and using the crossing would be more damaging than establishing a new one. New fords should be located where the banks are low, less than 4 ft (1.2 m) high, and gently sloping; where the grade of the approach to the stream does not exceed 5:1 (horizontal to vertical); and where the stream bed is firm rock or gravel. Such locations require little or no modification to accommodate traffic. More often some grading, excavating, and placement of road base material is needed.

To facilitate construction of a ford where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement and compaction of fill much easier and minimizes sediment movement in the stream. It may also be desirable to place large rocks or logs or to construct a sediment trap below a ford to catch sediment introduced by use of the ford. However, excavation of material within the stream bed should only be done with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities.

A mucky or weak stream bed is not acceptable as a base for a ford unless it is frozen. When the soil within the stream bed is weak, it will be necessary to cover or to replace it with materials that will support traffic. There are several alternative materials for creating a firm base for a ford. Those applicable to normal forestry operations include:

- Permanently constructed fords using clean gravel or rock with or without geotextile or a plastic cell webbing known as a cellular confinement system.[4] A ford constructed with the cellular confinement system is sometimes known as a plastic ford.

- Temporarily constructed fords using mats made of wood, tires, expanded metal grating, logs or poles, or a floating rubber mat.

Use of a geotextile below any material (e.g., clean gravel, rock, wood, or tire mats) in either a permanently or temporarily constructed ford can provide additional support to the crossing while separating the material from weak native soil. However, use of the geotextile should be approved by the appropriate regulatory authorities because of concerns about impacts if any downstream movement of the geotextile occurs.

Permanently constructed fords

Constructing a firm crossing using gravel or rock is common when the existing bed of an intermittent or perennial stream is too weak to support traffic. When using clean gravel or rock fill to construct a ford, the existing weak material in the stream bed should be excavated first. This allows the natural shape of the stream channel to be maintained and reduces the problem of the gravel mixing with the mud, making the fill ineffective. A minimum of 6 in. of gravel or rock fill should be used unless it is not possible to excavate deep enough to accommodate this much fill. The gravel or rock fill should not raise the crossing higher than the original stream bed level.

We recommend that a geotextile be laid down before placing gravel or rock fill (fig. 15), as long as it is approved by the appropriate regulatory authorities. This keeps the fill separated from the weak native materials and provides added support to the crossing. Although fords that are constructed with gravel or rock fill are intended as temporary crossings, the gravel or rock fill is not removed when the crossing becomes inactive.

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[4] *A cellular confinement system is an expandable honeycomb plastic panel into which different types of fill material can be added. The panels confine the fill into small compartments, holding them in place.*

Figure 15.—*A geotextile used in a ford.*

Pence (1987) and Tufts *et al.* (1994) describe plastic fords that were constructed to help keep the gravel or rock fill in place. Without the cellular confinement system, the fill can be pushed aside by heavy vehicles or frequent traffic over a crossing. Also, the cellular confinement system reduces the chance that fast currents will wash the gravel downstream.

A vented ford or emergency spillway can be formed by providing culverts to handle the day-to-day flow and by partially lowering the road grades for passing floods (Adamson and Racey 1989). This type of ford is suitable where the normal flow may exceed a fordable depth either seasonally or following storm events. A wall must be provided along the downstream edge of the spillway to keep the gravel fill from eroding under the action of the flowing water. Various wall types include gabions and precast concrete sections. Riprap erosion protection is required downstream of the wall. Coarse granular fill is required to make the vented ford erosion resistant.

Temporarily constructed fords

A firm base for a ford can be temporarily established by using materials such as mats made of wood or tires, or by using expanded metal grating, logs, or floating rubber mats. (See the section on wetland crossing options for a description of wood mats, tire mats, and expanded metal grating.) Wood or tire mats or expanded metal grating, in combination with a non-woven geotextile, can be placed directly across a stream to create a firm base for the ford (fig. 16). Installation is quick and easy. Removal is also simple, but may require re-turning at a later date if the site is frozen when the operation is finished. In some instances,

Figure 16.—*A tire mat used to provide support in a temporary ford.*

the stream bed or bank may be too weak for the geotextile and mats or expanded metal grating to provide sufficient support for traffic. Supplemental corduroy, gravel, or rock fill may be needed in the weakest portions of the crossing to create a firm base for the ford.

In some jurisdictions, a pole or log ford may be established for crossing small streams. For this type of ford, the stream channel is filled with logs laid parallel to the direction of stream flow. This works well for crossings that will be used only a few times and where the logs can be easily removed as soon as the work is completed. It is best suited for dry ditches and intermittent stream channels because of the risk of blocking stream flow, particularly during spring breakup or following a heavy rain. Placement of two or more steel cables laid bank-to-bank below the pole ford will facilitate removal of the logs. To minimize the risk of blocking stream flow, polyvinyl chloride (PVC) pipe bundles can be used in place of logs. (See the section on PVC pipe bundles below for a description of this option.)

A “dam bridge” or “rubber mat bridge” can also be used to provide a temporary ford (Arnold 1994, Looney 1981). It is constructed from strips of rubber conveyor belting joined side-by-side. Looney (1981) describes a dam bridge constructed of 0.5-in.- (1.3-cm)-thick strips of rubber conveyor belt that was cemented and bolted together. Support cables hold the sides upright so the mat floats on the water when no vehicles are in the crossing. When a vehicle enters the dam bridge the mat is pushed down to the stream bottom, momentarily damming the stream. Once the vehicle is across the stream, the mat floats up again, allowing the stream to flow normally. Looney (1981) recommends placing rock on the approaches to the dam bridge to assist vehicles in climbing out, particularly for skidders with chains.

Culverts

A culvert is a structure that conveys water under a road or access trail (fig. 17). It is one of the most common methods of crossing intermittent and perennial streams. Manufactured culverts come in many shapes (round, oblong, or arched), lengths, and diameters, and may be made of corrugated steel, concrete, or polyethylene. An arch culvert is an open-bottom arch with appropriate footings into which the arch is fitted. New culverts are available from a variety of suppliers. Used culverts suitable for temporary installations may be available from state, provincial, or local road authorities or from construction, pipeline, or drilling companies.

Although corrugated steel culverts are used most frequently, the use of polyethylene pipes is increasing for temporary installations and low standard roads. Polyethylene pipes have several limitations that should be considered (Stjernberg 1987); however, proper installation can overcome most problems. Other materials are often used as substitutes for manufactured culverts on temporary forest roads and skid trails. Some examples are hollow steel piling, well casings, gas pipeline, wooden box culverts, and hollow logs. Small culverts can be installed and removed with a bulldozer or backhoe. An excavator may be needed to install and remove larger culverts. Low-cost culvert transportation systems have been developed (Ewing 1992).

Figure 17.—*Culvert.*

Proper sizing and installation of culverts are critical to constructing a successful crossing. Both culvert diameter and length need to be considered when determining culvert size requirements. The recommended minimum diameter for any culvert is generally 12 in. (30 cm). Smaller sizes are difficult or impossible to clean out if they become clogged. Temporary installations that are removed seasonally may only need to accommodate estimated peak flow for the season of use. Year-round installations need to consider peak flows of longer term events (e.g., 10-, 25-, 50-, or 100-year floods). In all cases, it is important to confirm sizing requirements with a hydrologist or licensed engineer and the appropriate permitting authority.

A single large-diameter culvert is better than two or more smaller culverts. A common mistake is to assume that two 12-in. (30-cm) culverts equal the capacity of a single 24-in. (60-cm) culvert. However, it takes at least three 12-in. (30-cm) culverts to equal the capacity of one 24-in. (60-cm) culvert. The greater surface area of the three smaller culverts will also cause more turbulence, reducing the flow rate through each culvert. The pipe must also be long enough to extend to at least the toe of the fill slope. Placement of the culvert should follow the same grade as the existing stream channel and should be placed deep enough to avoid washing out from below. If the upstream end of the culvert becomes too elevated, the water may move through the culvert too fast and impede the migration of aquatic organisms. Culverts should not be installed during fish spawning and migration.

The pipe should be placed in line with the direction of stream flow. Attempting to use the culvert to redirect the stream may violate the terms of a permit and can result in the culvert being washed out. The side slope of the fill should be no steeper than 2 to 1 (horizontal to vertical) to ensure it is stable. The culvert should be covered with fill to a depth of 12 in. (30 cm), or one-half the diameter of the pipe, whichever is greater. This protects the pipe from being crushed and avoids damage to the pipe during grading of the road surface. When earth fill is used, it should be compacted in layers (fig. 18). This is especially important for the bottom half of the culvert, which may be washed out if the earth fill is not properly compacted. Compaction of the road surface over the culvert will help ensure that the driving surface sheds water rather than turning to mud.

Figure 18.—*Packing earth around a culvert during installation.*

Some jurisdictions may permit logs or brush to be used as fill around a temporary culvert to avoid placement of soil that would need to be disturbed when the pipe is removed. A hydrologist or the appropriate permitting authority should be consulted before using logs or brush. There may be concerns about the logs or brush washing away during use of the crossing, or that the fill material will not be removed from the stream when the culvert is removed. In either case, downstream movement of the logs and/or brush may dam the stream.

To facilitate installation and/or removal of a culvert where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement, compaction, and/or removal of fill much easier and minimizes sediment movement in the stream. It may also be desirable to place large rocks or logs or to construct a sediment trap below a culvert to catch sediment introduced by use of the crossing. However, this should only be done with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities.

Periodic maintenance of culverts is important to ensure proper function. Both ends of the culvert should be checked and cleared of debris to allow an unimpeded flow of water. This is especially important in areas subject to beaver activity. Problems with unnatural erosion around the culvert should be corrected to minimize the chance of washout of the culvert and sedimentation of the stream.

PVC and HDPE Pipe Bundles

A pipe bundle crossing is constructed using 4-in.- (10-cm)-diameter Schedule 40 PVC or SDR11 HDPE pipes that are cabled together forming loose mats that can be formed into bundles. The bundle provides mechanical support for the vehicle while allowing water to pass through the pipes unimpeded (fig. 19). Streams with a U-shaped channel to contain the pipes are most appropriate for this option.

Because standard PVC pipe is light-sensitive and will lose strength when exposed to sunlight, using PVC pipe that has been exposed to the sun should be avoided. Strength of the crossing can be maintained by covering or

Figure 19.—*PVC or HDPE pipe bundle.*

painting PVC pipe or by using an ultraviolet-resistant type of pipe, such as HDPE. HDPE pipe also tolerates temperature extremes of -40° F (-40° C) better than PVC without becoming brittle or losing shock resistance and will return to its original shape after being deformed (Légère 1997). No published studies have evaluated the use of PVC or HDPE pipe bundles for stream crossings during winter in an environment where temperatures are consistently below freezing.

HDPE pipes may be more expensive than standard PVC and may need to be purchased through a vendor that specializes in plastic pipe. The thickness of many alternative plastic pipes is often specified using the term “standard dimension ratio” (SDR), which is calculated by dividing the average outside diameter of the pipe by its minimum wall thickness. For any given outside diameter, SDR will increase as wall thickness decreases.

It is important to make the crossing wide enough for the widest vehicle that will use it. Plastic pipe is generally sold in multiples of 10-ft (3-m) lengths; therefore, it may be necessary to purchase 20-ft (6.1-m) sections that can be cut to the desired length. Mason and Greenfield (1995) proposed using shorter pipe sections, end-to-end, between full-length pipes making a 14-ft- (4.2-m)-wide crossing.

Constructing pipe bundles consists of drilling 1/4-in.- (6.4-mm)-diameter holes at 1 ft (0.3 m) and 4 ft (1.2 m) from each end of each pipe. Four 3/16-in.- (4.8-mm)-diameter galvanized steel cables are threaded through the holes to connect the individual pieces. It is important to drill round holes to avoid creating potential stress points that could later facilitate pipe shattering. It may be necessary to control cable end fray before stringing the cable through the sections. Loops should be made at the end of each cable, extending beyond the last pipe, and then secured using 3/16-in.- (4.8-mm)-diameter cable clamps to prevent individual pipes from rolling or moving in other directions.

Our experience has shown that it takes about 1 hr for two people using two hand drills and one saw to cut, drill, and cable 4-in.- (10-cm)-diameter and 20-ft- (6.1-m)-long PVC into a 10-ft x 12-ft (3-m x 3.7-m) section. The initial construction cost of this size section, including materials and labor, is about $500. Two 10-ft x 12-ft (3-m x 3.7-m) sections are necessary to build a crossing for a 6-ft (1.8-m) wide x 2-ft (0.6-m) deep channel. Each cabled section should be loose so the pipes can conform to the stream channel. A tight connection is used for a single layer crossing.

The crossing is created by first laying down a geotextile fabric (fig. 20) to ensure separation from the stream bottom and to facilitate removal (Mason and Greenfield 1995). A layer of connected pipes is then placed on top of the geotextile along the stream bottom, parallel to the stream flow. If necessary, loose or connected pipes are then layered to the desired height (fig. 21). A layer of connected pipes should be placed as the top mat. Loops at the end of connecting cables should be covered so that they don’t hook onto the underside of a passing vehicle. The top and bottom layers of pipe should be long enough to go beyond the stream edge to protect the stream banks.

Figure 20.—*Installation of a geotextile under a pipe bundle.*

Figure 21.—*Pipe bundle crossing layered to the desired height.*

Typically, a stiff surface such as expanded metal grating, tire mats, or wood panels are laid over the top mat to limit pipe movement (wave action) and to provide traction. The crossing surface needs to be sufficiently connected to the pipe to avoid flipping up under a crossing vehicle (Mason and Greenfield 1995). Wood mats or expanded metal grating can be placed on top of a non-woven geotextile to stabilize the approaches to the crossing if they are weak.

The time required to install the crossing depends on the crossing length, stream depth, water volume, equipment available, and the amount of room needed for the equipment to maneuver. It took about 1.5 hr to place a PVC pipe bundle crossing with a wood pallet running surface within a stream channel that was 35 ft (11 m) wide (the bundles covered 25 ft [7.5 m] of that span). It took about 20 minutes to remove a PVC pipe bundle crossing consisting of a non-woven geotextile placed below two 10-ft x 12-ft (3-m x 3.7-m) bundle sections, a wood plank running surface, and one 10-ft x 12-ft (3-m x 3.7-m) wood mat that was used on each side of the stream to protect the banks.

Transportation equipment needed to bring the pipe or bundles to the crossing site depends on the length and amount of pipe (Mason and Greenfield 1995). In some cases, the drilled individual pipes may be transported by pickup truck and constructed on-site. Preconstructed mats may be too heavy for a pickup truck, requiring a dump truck or lowboy. Front-end loaders or skidders are typically used to place the mats.

Bridges

By spanning the stream, bridges keep fill and equipment out of the water body to the greatest degree of any stream crossing option (fig. 22). For this reason, they have the least impact on streams. Designs are available for a wide range of span lengths and load capacities (e.g., pickup trucks, skidders and forwarders, or loaded semi-tractor trailers). Temporary bridges can be made from ice, timber, used railroad cars (flatcars and boxcars), used flatbed truck trailers, steel, or pre-stressed concrete.

Little site preparation is normally required when installing a temporary bridge. To provide stable, level support for the structure, it is recommended that bridges be installed on abutments on both sides of a stream. This will also facilitate removal if the ground is frozen. Logs or large wooden beams are often used for abutments. Crossing permit requirements, local statutes, or specific site conditions may require more extensive abutments. Also, crossing permit requirements or local statutes may specify the minimum clearance between the bridge and the stream to accommodate peak flows and/or recreational use.

Figure 22.—*Temporary bridge spanning a stream.*

Ramps from the approaches up to the bridge traffic surface often need to be created on-site. Soil, snow, and corduroy are usually adequate, but permit requirements and/or site conditions, such as weak soil, may require use of other materials. Also, if the soils within the approaches to the bridge are weak, or if they will be significantly disturbed during installation and use of the bridge, we recommend using corduroy, wood mats, wood panels, expanded metal grating, or other temporary surfacing material to strengthen the approaches. (See the section on wetland crossing options for a description of corduroy, wood mats, wood panels, and expanded metal grating.) This will reduce rutting or other damage that may inhibit use of the crossing. It will also minimize the potential for sediment reaching the stream.

Bridges are generally designed to be a fixed length. Unfortunately, a fixed-length bridge is not applicable to all streams. Engineered bridges have been evaluated and a load (weight) rating established for a maximum span distance. If that maximum span distance is lengthened and/or the maximum load is exceeded, the bridge may fail. It may be feasible to span longer distances; however, the maximum load will need to be decreased and should be determined only by a licensed engineer.

Some bridge designs are open in the middle, or have holes or gaps in the traffic surface. These designs may be less expensive or easier to install, but also allow dirt and debris to fall into the stream. As a result, some jurisdictions may not permit use of these designs. Also, movement of individual bridge panels may occur during use if they are not adequately connected. For structures with a gap in the traffic surface, it is recommended that a decking material (e.g., plywood, lumber) be added to close this space. Installation of curbs or guardrails is an important safety consideration for bridges designed for truck traffic. They help the driver position the vehicle safely on the structure. The curbs or guardrails may need to be removed for skidder traffic if the skid loads will damage them.

Most temporary bridges can be installed and removed with a knuckleboom loader, front-end loader, bulldozer, or skidder. Long spans for wide streams may require special equipment, such as a crane or excavator. Keliher *et al.* (1995) recommend that individual bridge sections weigh less than 5,000 lb (2,300 kg) and be under 30 ft (10 m) long if a grapple skidder is to lift the structure. Sections could weigh as much as 11,000 lb (5,000 kg) if the skidder drags, winches, or pushes them. The size and weight of the bridge or its individual components is also an important consideration for loading, unloading, and transport from one location to another. In some circumstances, the machine installing the bridge may need to cross through or work in the stream channel to get the structure in place. This should be avoided whenever possible and may require prior approval from the local permitting authority.

Prefabricated, portable bridges made of steel, treated or untreated lumber, and pre-stressed concrete can be purchased from commercial manufacturers. When they are retrofitted, used railroad cars and flatbed truck trailers can also serve as a prefabricated crossing. Although they are generally more expensive than a structure built of locally available materials, prefabricated options offer two important advantages. First, commercially manufactured bridges generally incorporate engineering input into their design. This will help reduce concerns about safety and liability. Second, they can be used many times over several years, considerably reducing the cost per crossing. Prefabricated designs include single, rigid structures, and hinged or modular panels. The hinged or modular panels facilitate transport, installation, removal, and handling. Prefabricated bridges can usually be installed or removed in less than 2 hr.

Bridges fabricated from locally available materials also come in a wide variety of shapes and sizes. Some are built on-site for a single use; others are portable and can be used several times. Examples of on-site constructed bridges include ice and log stringer bridges. Portable bridges may be constructed from solid sawn timbers and planking, flatbed truck trailers, steel beams, pre-stressed concrete panels, or other materials. Because the initial cost of a bridge fabricated from locally available materials is often much lower than that of commercially manufactured bridges, they are a viable alternative for many stream crossings. The installation and removal time may be longer for a bridge fabricated from locally available materials than for a prefabricated bridge.

We recommend that a licensed engineer review the design of any bridge that is fabricated from locally available materials to ensure that the structure will be safe and is adequate for the intended use. However, this review may be difficult to obtain and the cost may be considered too exorbitant in some cases. Construction specifications have not been established for some materials (i.e., hardwood lumber), and others may be converted to a use for which they were not originally designed (e.g., flatbed truck trailers). Many materials or structures have had substantial wear and tear before their use as a bridge structure (i.e., railroad flat cars, flatbed truck trailers, concrete panels), which may have significantly reduced their strength or limited their remaining service life.

Ice bridges

Ice bridges are a common type of winter crossing over streams, lakes, and rivers in areas where there are extended periods of temperatures below freezing (fig. 23). In some areas, the ice may be thick enough that no construction is needed. Where construction is necessary, ice bridges are made by packing snow and/or pumping water onto the existing ice. Some jurisdictions permit slash or brush to be placed in the stream channel when there is no ice to build on, but this is generally undesirable because it is often difficult to remove the brush. Because an ice bridge will take longer to melt than the stream, a new channel may be cut around the blockage on streams with large or high velocity spring flows. Therefore, ice bridges may not be appropriate on those streams.

Figure 23.—*Ice bridge.*

Creating an ice bridge requires cold weather. Night temperatures below 0° F (-18° C) are best, with several days required to build up ice thick enough to safely support traffic. Once an ice bridge is in use, the thickness and condition of the ice should be checked frequently to be sure it remains adequate. This may need to be done as often as once or twice a day, or more, on fast moving streams or large rivers and lakes and as temperatures warm up.

On lakes, ice bridges are sometimes created by plowing snow off the path chosen for the road. Removing the snow enables the ice to grow thicker faster, thereby increasing the load bearing capacity. Because the plowed snowbanks represent concentrated loads on the ice, they should be spread over as large an area as possible. When a vehicle crosses floating ice, a deflection bowl moves with it, generating waves in the water (Haynes and Carey 1996). If the speed of these waves is the same as the vehicle speed, the deflection of the ice sheet is increased and will likely lead to failure of the ice. The problem is more serious for thin ice and shallow water depths. When in doubt, operators should drive less than 15 miles (24 km) per hr.

The following formula was developed to estimate the minimum ice thickness required to support a given load above a flowing river or stream or on a lake (Haynes and Carey 1996).

$$h=4(P)^{1/2}$$

Where: h = ice thickness in inches
P = the load or gross weight of the vehicle plus its contents, in tons.

This equation can also be expressed in tabular format, where the vehicle class equals the total weight of the vehicle plus its load (table 4).

Timber bridges

Donnelly (1997) provides a good overview of timber bridges. Engineering design guidelines are available for many different types of timber bridges. Two popular designs for temporary structures are log stringer bridges and solid sawn stringer bridges with or without a plank deck. Log stringer bridges (fig. 24) are built by cabling logs together from trees felled in the area of construction. It is especially important to bundle stringers together with cable (fig. 25) when building a log stringer bridge to improve performance. A narrow stream can sometimes be crossed by bundling stringers together with chains or cable and placing them only in the wheel path. Several log stringer bridge options are discussed in Peterson (1987). Solid sawn stringer bridges (fig. 26) are built with new lumber, railroad ties, or demolition materials. Kittredge and Woodall (1997) describe a solid sawn stringer bridge made with 6-in. x 6-in. (15-cm x 15-cm) and 6-in. x 8-in. (15-cm x 20-cm) cants. This design provides an uneven driving surface for better traction.

Table 4.—*Minimum ice thickness required to support a given load above a flowing river or stream or on a lake (Haynes and Carey 1996)*[a]

Vehicle class[b] (tons) [tonnes]	Minimum ice thickness (in.) [cm]	Minimum distance between vehicles[c] (ft) [m]
0.1 [0.1]	2 [5.1]	17 [5.2]
1 [1.1]	4 [10]	34 [10]
2 [2.2]	6 [15]	48 [15]
3 [3.3]	7 [18]	58 [18]
4 [4.4]	8 [20]	67 [20]
5 [5.5]	9 [23]	75 [23]
10 [11]	13 [33]	106 [32]
20 [22]	18 [46]	149 [45]
30 [33]	22 [56]	183 [56]
40 [44]	26 [66]	211 [64]

[a] Information in this table assumes clear, sound ice. If white, bubble-filled ice makes up part of the ice thickness, count it only half as much as clear ice. If the air temperature has been above freezing for at least 6 of the previous 24 hr, multiply the vehicle class by 1.3 to obtain a larger minimum thickness. If the air temperature stays above freezing for 24 hr or more, the ice begins to lose strength and the table no longer represents safe conditions. Maximum recommended speed is 15 mi (24 km) per hr.
[b] Vehicle class equals the gross weight of the vehicle plus the weight of its contents in tons.
[c] At ice thicknesses greater than the minimum, the spacing between vehicles can be reduced on sound ice.

Figure 24.—*Log stringer bridge.*

Figure 25.—*Cabled logs in a log stringer bridge.*

Figure 26.—*Solid sawn stringer bridge.*

Plank decks provide a smooth running surface, decrease lateral movement of the structure during use, and reduce the amount of dirt and debris that may fall into the stream. If a plank deck is to be installed on either of these bridge types, annularly threaded (ring-shank) or helically threaded (spiral) spikes should be used to attach the surface deck. The spikes should be at least 9 in. (23 cm) long to reduce withdrawal during use of the crossing. If care is used during installation, removal, and transport, stringer bridges can be reused several times.

The main concern with log stringer and solid sawn stringer designs is that there is limited information on the engineering properties of logs, railroad ties, and demolition materials. Thus, designs using these materials typically include little, if any, engineering input. Care should be exercised when using these materials if they have not been evaluated to determine their structural strength and engineers are not involved in the design or in accurately estimating their load ratings. Rot, decay, knots, and grain can greatly affect their strength properties. Some of these factors become more important the longer a bridge is in use, especially if the species does not have a high decay resistance.

Muchmore (1976) presents basic design criteria to determine whether single lane log stringer bridges are designed and constructed to safely support specific loadings and to meet minimum safety criteria. Bradley and Krag (1990) present span designs for seven tree species (white spruce [*Picea glauca*], eastern white pine [*Pinus strobus*], jack pine [*Pinus banksiana*], red pine [*Pinus resinosa*], eastern hemlock [*Tsuga canadensis*], quaking aspen [*Populus tremuloides*], and balsam poplar [*Populus balsamifera*]) and two types of bridges (with and without needle beams[5]). Guidelines are also available for evaluating the capacity of sawn timber and log stringers in existing bridges (Ontario Ministry of Natural Resources 1989). The USDA Forest Service is currently developing guidelines for different types of portable timber bridges.

Other timber bridges have been constructed using treated panels of stress-laminated, glued-laminated (glulam), dowel-laminated, or nail-laminated materials. Stress-laminated panels consist of lumber placed edgewise and held together with high-strength steel rods (fig. 27) that are stressed in tension, up to 100 lb/in.^{2} [PSI] (7,000 g/cm^2). There is a need to retension the steel rods periodically. Russell (1997) presents a review of stress-laminated technology. Glulam panels consist of dimension lumber glued together on the wide face. Dowel- and nail-laminated panels are similar to stress-laminated panels, except that dowels or nails are used to connect each successive piece of lumber. In all cases, the panels are placed side-by-side across a stream.

One advantage of these designs, as well as a solid sawn stringer design using new lumber, is that the lumber is a known species and grade. Thus, structural properties are known and an engineer can properly design a safe structure. Also, because they are panelized, transportation to the site may be easier than for some other bridging options. Field performance for some of these engineered bridges

Figure 27.—*Stress-laminated timber bridge panel.*

[5] *A needle beam distributes a live load to all stringers and is positioned across the stringers at midspan.*

installed for permanent use indicates that their performance is generally satisfactory (Ritter *et al.* 1995).

Behr *et al.* (1990) compared the initial costs of timber, steel/concrete, and prestressed concrete bridges. Five New England general contractors performed cost estimates on bridge designs spanning 20, 40, and 60 ft. Also, three timber bridge suppliers provided cost estimates for nine bridge designs, three at each span length. Results from general contractors indicated that timber was cost competitive with steel/concrete and was less expensive than prestressed concrete. Results from timber bridge suppliers showed a distinct initial cost advantage for timber over both steel/concrete and prestressed concrete.

The USDA Forest Service Wood in Transportation Program has established the Wood in Transport National Information Center. The Center maintains a website at http://wit.fsl.wvnet.edu that describes the program and provides an on-line order form to obtain free publications, design plans, cost information, etc. The Center can also be contacted directly at 304-285-1591 (voice) or 304-285-1505 (FAX). The Forest Products Lab also has a website at http://www.fpl.fs.fed.us/wit/ containing some of their publications on wood-in-transportation technology. The Forest Service has also published an excellent reference on timber bridge design, construction, inspection, and maintenance (Ritter 1992).

Used railroad cars and flatbed truck trailers

Railroad cars (flatcars and boxcars) and flatbed truck trailers can be retrofitted for use as stream crossings (fig. 28). The retrofitting provides additional reinforcing to the main support beams so they will support vehicle traffic. Bradley and Pronker (1994) present a standard design for using railcars as temporary bridges. Carraway (1997) indicated that railroad boxcars are much lighter than flatcars, allowing a 50-ft- (15-m)-long x 10-ft- (3-m)-wide bridge to be transported on a lowboy trailer. A railroad boxcar bridge can be unloaded with a knuckleboom loader and placed across the stream with a skidder. A crane may be needed to lift and install a railroad flatcar bridge. Individual railroad cars and flatbed truck trailers tend to be narrow which may be a limitation for hauling applications.

Figure 28.—*Bridge made from a used railroad car.*

Used railroad cars may be purchased from third-party vendors who purchase old railroad cars from railroad companies. Contact your local railroad company or railroad car repair facility to find out how to obtain one. Used flatbed truck trailers are lighter and are more readily available locally through trailer repair and salvage operations. While it is possible to purchase retrofitted used railroad cars for use as bridges, most used flatbed truck trailer vendors do not provide the additional reinforcement needed.

Steel bridges

Steel bridges include hinged portable bridges and modular bridges (fig. 29). Where permitted, two or more bridge spans or bridge panels (multi-spans) may be connected across a pier to span wide crossings. Hinged bridges fold up for transport. Modular steel bridges are designed as a series of individual panels that interlock, forming a bridge of variable length.

Figure 29.—*Steel bridge.*

We are aware of a locally fabricated, non-engineered, steel bridge that is about 50 ft (15 m) long and was constructed using I-beams. Also, catwalks with wood decking have been used.

Pre-stressed concrete bridges

Precast, pre-stressed concrete panels can be locally fabricated. Generally, two or more panels are placed side-by-side to form the bridge (fig. 30). Although the initial cost of this bridge may be low, they are usually heavy and require larger equipment to install and remove. It is important to make sure that the panels are engineered to handle the anticipated loads. Highway departments or local road authorities may be a source for used panels.

Figure 30.—*Pre-stressed concrete bridge.*

TEMPORARY WETLAND CROSSING OPTIONS

This overview of temporary wetland crossing options focuses on alternatives that can be applied to the surface of a wetland soil, including a wet spot on a haul road, to stabilize it for short crossing distances (fig. 31). While we define "short" as being less than 200 ft (61 m), the distance may depend on the initial cost to purchase or construct the selected option, the value of whatever is to be accessed, and the costs associated with other travel routes. Although a very long distance could be crossed when the option is matched to site needs, the cost may be prohibitive. The ability to reuse options makes them more viable, especially those with a higher initial cost.

Temporary wetland crossing options include wood mats, wood panels, wood pallets, bridge decking, expanded metal grating, PVC and HDPE pipe mats or plastic road, tire mats,

Figure 31.—*Wet area in a haul road.*

corduroy, pole rails, wood aggregate, and low ground pressure equipment. Low ground pressure equipment includes machines with wide tires, duals, tire tracks, bogies, tracks, light weight, and/or central tire inflation (CTI). We have chosen not to discuss road construction activities or wetland dredging and filling operations that are associated with constructing a new road or crossing over long distances. We have also not included cable yarding systems, helicopters, or balloons. Although use of frozen ground may be the most viable crossing option in many areas, that option is also not discussed.

Many of the options should not be placed on areas that have firm high spots (e.g., stumps, large rocks) to reduce bending stress and breakage during use. Hislop and Moll (1996) recommend blading the surface as flat as possible before installation. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with the vegetation. The performance of any wetland crossing option is enhanced if there is a root or slash mat to provide additional support to the equipment.

Maintaining the root mat can also speed revegetation of the site following removal of the crossing. The performance of the crossing is also enhanced by use of a geotextile (fig. 32), which helps segregate the crossing from the underlying soil and provides additional flotation. Most of the options are best suited to be used in conjunction with hauling and forwarding, but not during skidding. If used during skidding operations, the options will wear faster and may move out of position when trees are dragged over them. Also, if a geotextile is used, it may become torn and displaced by skidding.

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Figure 32.—*Applying a geotextile under a temporary wetland crossing.*

The length and width of a crossing option needed to achieve a particular wetland crossing will vary according to the site characteristics, soil strength, anticipated loads, and installation equipment available. The crossing option used should cover the entire length of area to be crossed so that ruts do not develop beyond the end of the option. Ruts may cause drivers to steer the vehicle out of a wheel path on the crossing option and to rut outside the edge of the crossing. On very weak soils that have a low bearing strength (e.g., muck, peat), the options may need to be wider than what is required on other soils. The additional width is needed to spread the weight over a larger area. Additional width may also be needed at road intersections and curves to provide necessary maneuvering room for vehicles.

Most of the options are best applied on road sections with straight alignments, grades up to 4 percent, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or lateral movement of the option outside of the planned travel area. Traction loss may occur between the tires and the surface of the option, especially when the surface is wet. Slippage can occur between the crossing option and the geotextile below it. Because most wetland crossing options have a rough surface, they require a reduction of vehicle speed. They should be placed in areas where the speed is low or where there is good visibility and plenty of distance to slow the vehicle.

For the options constructed from wood (e.g., wood mats, wood panels, wood pallets), the ground surface should be fairly level before installation to reduce breakage of the wood members. Use of a dense hardwood species and treated timbers may extend the life of the crossing. However, use of treated timbers may not be cost-effective if the anticipated life and use of the panels do not require that application (e.g., only a short-term use is anticipated, skidding material over the option). Also, best management practices for the use of treated wood in aquatic environments should be used (WWPI 1996).

Each temporary wetland crossing option is briefly described below. Rummer and Stokes (1994) also discuss some of these options. As with stream crossings, there are several ways to accomplish each of the various options. Appendix 3 includes further information about many of the temporary wetland crossing options, including information about dimensions, product weight, and approximate purchase price. A list of some vendors of temporary wetland crossing options is presented in Appendix 1.

Wood Mats

Wood mats are individual cants or logs cabled together to make a single-layer crossing (fig. 33). A 10-ft- (3-m)-long, 4-in. x 4-in. (10-cm x 10-cm) cant or log is the recommended minimum size. Longer cants or logs may be needed to distribute the weight better on very weak soils or under heavy loads. Mason and Greenfield (1995) tested both 4-in.- (10-cm)- and 6-in.- (15-cm)-square cants on a silty sand soil within the Osceola National Forest in Florida. They found that while both mats worked well, the smaller mats cost less and were lighter weight, facilitating on-site installation.

Figure 33.—*Wood mat.*

Constructing wood mats consists of drilling holes 1/4-in. (6.4-mm) in diameter through each cant or log about 1 to 2 ft (0.3 to 0.6 m) from each end. Two 3/16-in. (4.8-mm) galvanized steel cables are then threaded through these holes to form the mat. Loops should be made at the end of each cable, extending beyond the last cant, and then secured with 3/16-in.- (4.8-mm)-diameter cable clamps (fig. 34). These loops are used to handle the mat during installation and removal. The connection between the cants should be tight to reduce any rippling or "wave" movement that might occur when vehicles pass. Improperly tightened cable clamps can lead to slip and loss of connectivity within the mat. We noted that a 10-ft x 12-ft (3-m x 3.7-m) mat constructed from 4-in. x 4-in. (10-cm x 10-cm) material over deep, organic, muck soil developed a rippling motion in front of the tires of a moving flatbed truck. This was caused by the mat sinking into the soil in the area immediately below the tire. We speculated that a wider mat with the cants more tightly connected may have avoided this problem.

Figure 34.—*Cable loop at the end of a wood mat.*

Hislop (1996a) reported that it took three people up to 3 hr to cut, drill, and cable together a 20-ft- (6.1-m)-long x 10-ft- (3-m)-wide mat. To reduce drilling time and errors in marking, she recommends making one set of drilling marks on the ground and ensuring that several hand drills are available. A welding torch or some other means of controlling cable end fraying will increase threading speed. The cost to initially construct a 10-ft x 12-ft (3-m x 3.7-m) mat using 4-in. x 4-in. (10.2-cm x 10.2-cm) cants is about $200 (including about $40 for labor) and the mat can be expected to last several years under normal use.

Individual mats can be connected to one another on-site to form the complete crossing. Limiting mat length to about 10 ft (3 m) reduces weight and facilitates installation. Shorter lengths may be needed if the mats are wider than about 12 ft (3.7 m). During installation, it is important to tuck the ends of all cable loops under the mats to avoid their being caught by a passing vehicle. If the surface of the crossing becomes slick during use, expanded metal grating (as described later in this report) can be added as a running surface to provide traction.

Wood Panels

Two-layer wood panels can be constructed by nailing parallel wood planks to several perpendicular wood planks where the vehicle's tires will pass (fig. 35). The actual running surface may be on either side of the panel, unless the nails have gone all the way through it. The individual panels can be either preconstructed or constructed on-site. We constructed panels using 3-in.- (7.6-cm)-thick x 8-in.- (20-cm)-wide planks. A gap of about 1 in. (2.5 cm) was left between each plank during assembly. Each finished panel was 8 ft x 12 ft (2.4 m x 3.7 m).

Figure 35.—*Wood panel.*

Annularly threaded (ring-shank) or helically threaded (spiral) spikes can be used to attach the planks. For ease of construction, starter holes should be pre-drilled into the top board. To reduce withdrawal, spikes should be placed at slight angles from vertical with one spike angled toward the traffic and one away from it. To facilitate picking up the panels during installation and removal, loops can be created by attaching 3/16-in.- (4.8-mm)-diameter galvanized steel cables to each section using 3/16-in.- (9.5-mm)-diameter cable clamps. The initial construction cost of an 8-ft x 12-ft (2.4-m x 3.7-m) wood panel is about $150 (including about $40 for labor). Connectors and non-woven geotextile are extra.

Interconnecting adjacent panels in a crossing will help minimize the rocking that occurs when vehicles drive over the panels and will improve the overall flotation provided by the crossing. However, interconnecting panels will also increase the time required for installation and removal of the crossing. Adjacent panels can be interconnected using eye hooks screwed into the end of each panel with quick links or other heavy duty connectors through the hooks. If the panels won't be interconnected when installed, about 6 in. (15 cm) should be left between the individual panels to facilitate installation and removal.

Wood Pallets

Wood pallets for crossings are sturdy, three-layered pallets similar to those used for shipping and storage but specifically designed to support traffic (fig. 36). They are a commercially available product generally made from dense hardwood planks that are nailed together. They are specially designed so that they can interconnect, so that they are reversible, so that broken planks can be easily replaced, and so that nail points won't surface. Some pallets are designed so that the top and bottom pieces are already interconnected similar to a traditional pallet, while others are designed so that the top and bottom pieces are separate and interlock during installation to prevent longitudinal movement.

Figure 36.—*Wood pallet.*

Hislop and Moll (1996) indicated that the width of some commercial wood pallets is a disadvantage. Interconnection along their 8-ft (2.4-m) edge is too narrow for hauling roads. It may be necessary to cut commercial pallets in half to make two 4-ft- (1.2-m)-wide x 14-ft- (4.3-m)-long pallets. Each half-pallet would then be placed in a wheel path. Because the half-pallets weigh less, they are also less cumbersome to install. However, the smaller pallets may become too narrow to support equipment on undisturbed peat or very weak mineral soils. Pallets can be custom-made so that the interconnection is along the 12-ft- (3.7-m)- or 14-ft- (4.3-m)-wide edge.

Most commercial pallets are designed to be moved with a forklift, which is not a common piece of equipment in the woods. A thin choker cable can be run between the planks and hooked to lifting chains to facilitate installation with a front-end loader or backhoe (Hislop and Moll 1996). Before installation, the ground surface should be fairly level to reduce breakage.

Bridge Decking

The decking of a timber bridge can be used to cross a small wetland area. Bridge panel options that do not have steel or wood stringers, such as prefabricated stress-laminated, glulam, dowel-laminated, and nail-laminated bridges, may be most appropriate and available. Individual panels would be placed across the area with soft soil and approach ramps to the decking built.

Expanded Metal Grating

Machine weight can be distributed over a broader area by placing a rock crusher screen or a commercially available metal grating on top of a geotextile, parallel to the direction of travel (fig. 37). The two types of commercial grating that have been tested are expanded metal and deck span safety grating (Mason 1992). Of the two commercial products tested, only the expanded metal grating is recommended. It is made of regular (not flattened), non-galvanized (carbon) steel and comes in a variety of thicknesses with different opening sizes. The grating is relatively light, inexpensive, and the surface is rough enough to provide some traction.

Figure 37.—*Expanded metal grating over a geotextile.*

Expanded metal grating can be installed by hand once it is moved to the crossing area. Various amounts of steel are used in expanded metal grating, and it is sold on the basis of weight/square unit of area. Although the lighter weight steel can be placed by one person, it is more susceptible to movement as vehicles drive over it. The heavier weight steel can be placed by two people. Gloves are recommended during installation and removal. It takes about 1 hr for four people to install 100 ft (30 m) of geotextile and grating. During removal, a winch may be needed to remove sections if they become covered by tracked soil.

The grating sections will move during use if they are not interconnected. Adjacent sections can be connected using heavy duty connectors, such as quick links that are 3/8 in. (9.5 mm) in diameter or larger. Because the grating sections are likely to bend into the shape of a large shallow rut during use, they may need to be flipped periodically or when placed at a new site. This deformation of the grating does not harm it. A connector that is larger than 3/8 in. (9.5 mm) will be easier to install and remove if the grating becomes deformed. A crescent wrench may be needed during installation or removal of the quick links because soil will make it more difficult to close and open the link. Hislop (1996a) indicated that theft of the metal grating was a problem during tests in Florida.

PVC and HDPE Pipe Mats or Plastic Road

A portable, reusable, lightweight corduroy-type crossing can be created with PVC or HDPE pipe mats (fig. 38). An important advantage of

Figure 38.—*PVC or HDPE pipe mat in a road.*

using pipes is they provide a conduit for water to move through the crossing without further wetting the area. A pipe mat is constructed using 4-in.- (10.2-cm)-diameter Schedule 40 PVC or SDR11 HDPE pipes that are tightly connected using 3/16-in.- (4.8-mm)-diameter galvanized steel cables to form panels (fig. 39). A plastic road (fig. 40) is similar to pipe mats, except that pipe transition mats/panels are built into the design to ease the transition of tires ramping up and then back down again on the approach between the firm soil and the mat. Also, the various pipes in a plastic road are connected using 1-in.- (2.5-cm)-diameter Schedule 80 PVC. Complete instructions for constructing a plastic road mat are presented in Moll and Hiramoto (1996). It is important to drill round holes to avoid creating potential stress points that could facilitate pipe shattering.

Because standard PVC pipe is light-sensitive and will lose strength when exposed to sunlight, using PVC pipe that has been exposed to

Figure 39.—*PVC or HDPE pipe mat.*

Figure 40.—*Plastic road mat.*

the sun should be avoided. Strength of the crossing can be maintained by covering or painting PVC pipe or by using an ultraviolet-resistant type of pipe, such as HDPE. HDPE pipe also tolerates temperature extremes of -40° F (-40° C) better than PVC without becoming brittle or losing shock resistance and will return to its original shape after being deformed (Légère 1997). No published studies have evaluated the use of PVC or HDPE pipe mats or the plastic road option for wetland crossings during the winter in an environment where temperatures are consistently below freezing.

HDPE pipes may be more expensive than standard PVC and may need to be purchased through a vendor that specializes in plastic pipe sales. The thickness of many alternative plastic pipes is often specified using the term "standard dimension ratio" (SDR), which is calculated by dividing the average outside diameter of the pipe by its minimum wall thickness. For any given outside diameter, SDR will increase as wall thickness decreases.

Moll and Hiramoto (1996) reported that PVC plastic road panels and transition mats for an 8-ft- (2.4-m)-wide x 40-ft- (12-m)-long crossing were transported in a 3/4-ton pickup truck and assembled by two people in about 1 hr. Material costs for that crossing, including the non-woven geotextile, were about $2,000. The various panels in either the pipe mat or the plastic road crossing can be quickly hand-placed by two people. A tractive surface, such as expanded metal grating or wood panels, may be necessary depending on the length of the crossing and the grade. Once installed, the plastic road can be moved from site to site by attaching a chain to one end of the transition mats and then towing it with a pickup truck or logging equipment. The distance and surface over which the plastic road is dragged should be evaluated to avoid excessive wear and breakage. A prototype plastic road installation supported over 400 loaded 18-wheel log truck passes at two sites.

Tire Mats

A mat or panel of tires can be created by interconnecting tire sidewalls and/or treads with corrosion resistant fasteners (figs. 41 and 42). Mats of varying length and width can be developed. Consideration of the weight that can be handled by on-site equipment during installation and removal is important when deciding on mat length and width. Some designs include double layers of sidewalls, while others use a layer of treads topped by sidewalls. The mats conform to the area after placement. Anchoring may be needed to prevent lateral movement during use, especially in areas with a grade over about 5 percent. The mats can be dragged into place with a skidder or installed using a knuckleboom loader. Tire mats can be placed on top of geotextile or corduroy to provide additional flotation. However, if a skidder will be used to drag the tire mat into place, geotextile is not recommended due to the likelihood of bunching and tearing of the fabric. No running surface is needed over the mat, although gravel can be added to improve traction (MacGregor and Provencher 1993).

Mason and Greenfield (1995) reported that because the mats are heavy, large, and very flexible, on-site installation time can take

Figure 41.—*Tire mat.*

Figure 42.—*Another tire mat design.*

about 15 minutes to more than 1 hr per mat. Maneuvering room and the type of equipment used are critical to the amount of time required for placement. Placement is easier without the geotextile because the mats can be dragged instead of lifted into place. However, this will result in the loss of the separation and support provided by the geotextile. When installing the mats with a clam loader, it is important that the clam not close on any of the fasteners (e.g., bolts) used to connect the individual sections within a mat. Once the bolts are bent, the mat is more susceptible to coming apart, life expectancy is reduced, and/or its strength characteristics are diminished.

Overall site impacts will be reduced during installation and removal by having the proper equipment on-site to handle the mats and through the use of lighter mats. To the extent possible, installation machinery should work parallel to the direction of the crossing instead of perpendicular to it so that disturbance is minimized. However, depending on the configuration of the mats and the particular area where they are to be installed, they can be either positioned in front of the installation equipment, laid from a perpendicular position, or dragged into place.

Corduroy

Corduroy is a crossing made of brush, small logs cut from low-value and noncommercial trees on-site, or mill slabs that are laid perpendicular (most often) or parallel to the direction of travel (fig. 43). The effect of corduroy is to spread the load over the whole length of the log or slab, effectively increasing the load-bearing area. Flotation increases with increasing surface area, especially length, of the individual pieces of corduroy. Multiple layers of corduroy may be required in some crossings. Brush corduroy will provide less flotation than small logs or mill slabs (Arnold and Gaddum 1995).

Figure 43.—*Corduroy.*

Corduroy is not normally covered with fill. During installation, application of a non-woven geotextile is recommended to separate the brush, logs, or mill slabs from the underlying soil. The use of geotextile should result in less corduroy being required to accomplish the crossing. To facilitate removal of temporary corduroy, two cables can be laid below and perpendicular to the corduroy before installing the crossing. The ends of each cable would then be joined with a cable clamp or similar device forming two large cable loops. The loops are then pulled out after use of the crossing with available on-site machinery. Corduroy is usually not removed or reused, however.

Pole Rails

When attempting to support skidding or forwarding machinery equipped with high flotation or dual tires, one or more straight hardwood poles cut from on-site trees can be laid parallel to the direction of travel below each wheel (fig. 44). The poles can either be with or without limbs. If the poles are not delimbed, more flotation will be provided at the top of the tree where the diameter is smallest. The diameter of the poles should not exceed about 10 in. (25 cm) on the large end so that they penetrate the wet area to a sufficient depth that the tires come in contact with the soil. Two or more poles may need to be laid parallel to each other if only small diameter material is available or if sufficient flotation is not provided. If dense hardwood poles are used, large limbs facing upward may need to be removed to minimize the chance of punctures and other tire damage.

For a crossing that is longer than the length of one pole, additional poles may need to be laid in a linear manner. The larger end of the pole, or the top of the tree for full-tree material, should be placed in the end of the crossing with the weakest soil to maximize flotation. After placing the poles, it is important to drive across them a few times without carrying a load to get them properly seated in the soil. Remove the poles when there is no further need to cross the wet area. This option will not work well if the machinery is equipped with conventional width tires because they are too narrow and are operated at too high a pressure to stay on top of the poles. It takes about 15 minutes to build a 40-ft- (12-m)-long pole rail crossing using two precut 40-ft- (12-m)-long poles.

Figure 44.—*Pole rails.*

Wood Aggregate

Wood particles ranging in size from chips to chunks (fist-size and larger) can be used as a fill material for crossing soft soils (fig. 45). There are several advantages to using wood aggregate in wetland crossings. Wood is relatively light, giving it better natural flotation than other materials, such as gravel. Low grade, unmerchantable wood that is normally left in the woods can be used. Low grade wood can be easier and cheaper to obtain in areas where no gravel deposits exist. Also, wood will naturally biodegrade over time, eliminating the need to remove it from the crossing following use (wood aggregate is not considered reusable). Finally, chunk-size wood aggregate allows water to flow freely through it, causing no changes to natural hydrologic flows. Although chunk-size particles are better for fill material than chips, chips are more readily available as chunking machines have not yet been commercialized.

Figure 45.—*Wood aggregate.*

The depth of aggregate needed will depend on soil conditions at the site. Saturated organic and mineral soils generally require at least 12 in. (30 cm) of aggregate. Less is generally needed to stabilize soft sand. Wetzel (1997) describes the use of green wood fuel chips to stabilize haul roads on deep sand soils in northwest Florida. The chips were spread to a depth of 6 in. (15 cm). The cost of stabilizing this road with wood chips was about half the cost of using gravel.

Wood aggregate can be used with or without geotextiles underneath (fig. 46). A layer of geotextile will improve performance on any soft soil, reducing the depth of aggregate needed. Provencher (1991) recommends the use of geotextile over organic soils. The use of geotextile is more critical over deep, saturated, organic soils where the root mat supplies much of the support. In this case, a heavy geotextile with at least 24 in. (61 cm) of aggregate is recommended (Arola *et al*. 1991). This keeps the aggregate from being forced down through the root mat. Another layer of geotextile should be placed over the aggregate (MN DNR 1995), creating a floating subgrade, with additional surfacing placed on top. Surfacing may also need to be added during use to maintain acceptable performance. If use of the road is meant to be short-term, biodegradable geotextile should be used.

Mullis and Bowman (1995) evaluated several sawmill-generated wood aggregate materials for rutting potential and road stiffness. A woodwaste material depth of 18 in. (46 cm) was able to carry construction traffic in the muskeg areas but did not seem to provide a significantly stable base for extended use. Depths of woodwaste material greater than 24 in. (61 cm) performed well. It was noted that sawdust tended to break down under traffic loading. When sawdust was predominant in the section, deeper rutting tended to occur. Planer chips did not compact very well. Bark fibers tended to form a well-compacted layer. The woodwaste seemed to perform the best when placed in a good mixture of sawdust, planer chips, and bark fibers. Mullis and Bowman (1995) recommend frequent maintenance to repair the rutting and low-frequency washboarding that developed on the test sections.

Figure 46.—*Use of a geotextile under wood aggregate.*

Low Ground Pressure Equipment

The pressure exerted by a machine on the ground surface will affect trafficking ability and site impacts. Low ground pressure equipment reduces this pressure by reducing overall machine weight, or by increasing the contact area between the equipment and soil, spreading the weight over a larger surface area. By reducing ground pressure at each contact point, equipment flotation is enhanced, traction is usually improved, and road maintenance requirements, such as grading, can be reduced. Low ground pressure equipment can also reduce rut depth and compaction, and can result in reduced fuel consumption.

Ground pressures of less than 5 or 6 PSI (34 or 41 kPa) are often considered high flotation. For reference, a typical adult applies about 3 PSI (28 kPa) to the ground when standing. Ground pressures lower than 4 PSI (28 kPa) may be needed to operate on wetland soils without significant impacts. The principal options for achieving low ground pressure on in-woods equipment include use of machines with wide tires, duals, tire tracks, bogies, tracks, light weight, and/or central tire inflation (CTI). CTI is an option for use on hauling trucks and may become available for in-woods equipment in the future.

Clambunk skidders and tree-length forwarders can move large loads while exerting a low ground pressure. A conventional cable skidder can operate like low ground pressure equipment on ground with intermittent soft spots by releasing its load, crossing to better ground, and winching the load back to the machine. Aerial systems that can either partially or fully lift logs off the ground, such as skyline cable systems, helicopters, and balloons, may also be an option.

While reducing load size when skidding, forwarding, or hauling is an option that doesn't require additional equipment or the retrofitting of existing machinery, many operators are reluctant to do this because of the loss in production and the resulting higher production costs. Forwarders may be able to maintain acceptable productivity and costs under situations where a reduced load is needed. Because a specific volume of material may need to be moved when skidding, forwarding, or hauling, more trips will be required to transport that volume under the reduced load scenario. Therefore, the net reduction in site impacts may be minimal.

A potential problem with low ground pressure equipment is that operators may build larger loads, given their increased traction and flotation. In weak soil conditions, this could result in impacts similar to traditional equipment. Therefore, the net positive environmental effect could be minimal unless operators keep their load size properly adjusted for soil conditions. Also, as machinery becomes bigger and heavier additional ground contact area is required to maintain the same ground pressure as smaller equipment with narrow tires. Therefore, as equipment gets bigger, the minimum size of high flotation tires will need to be increased to compensate for the added weight.

Equipment with wide tires, duals, bogies, and/or tire tracks

Wide tires, duals, bogies, and tire tracks improve flotation and mobility in soft ground by spreading the machine and load weight over a larger surface area. Wide (or high flotation) tires are wider than conventional tires (fig. 47). They are usually considered wide tires at about 34 in. (0.9 m) and are available up to about 72 in. (1.8 m) wide. Dual tires consist of two conventional width tires mounted on each end of an axle (fig. 48). Dual tires may be used on one machine axle (e.g., front or back axle, usually the back) or on all axles. It is also possible to add wrap-around tracks to existing, individual, conventional width rubber tires to make them wider (fig. 49). As an example, tracks can extend the width of a 30-in. (0.76-m) tire to either 42 in. (1.1 m) or 53 in. (1.3 m) and extend a 44-in. (1.1-m) tire to 65 in. (1.6 m).

Figure 47.—*Wide tires.*

Figure 48.—*Dual tires.*

Figure 49.—*Tire tracks.*

Although flotation is improved with wide tires and duals, these options have several disadvantages. The cost of purchasing and using wide tires and duals can be significantly greater than the cost of conventional tires. A good portion of this cost can be attributed to the heavy duty axles and transmissions that are usually required to carry the extra load from these tires. Because these options take time to install and remove, operators may keep them on the machines longer than necessary, reducing useful life and increasing costs. It is more difficult to transport machinery with wide tires and duals over some roads because oversize permits may be required. It may also be difficult to move equipment with wide tires down narrow roads or roads that have gates on them, unless the gate posts are wide enough apart or unless the machinery can go off the road around the gate. The turning radius of equipment outfitted with wide tires or duals is normally greater than that of conventionally equipped machinery.

A bogie is an axle system in which two tandem wheels with independent axles are mounted on a rocker frame and axle (fig. 50). If the wheels are driven, the bogie frame contains the appropriate devices to drive each wheel on the assembly. The bogie functions in two ways to reduce impacts to the site. First, the extra wheel adds contact area, reducing static ground pressure. Second, the rocking action of the bogie frame allows better contact with the broken ground surface, improving traction and lowering impacts. Further improvements in traction can be made by installing tire tracks around the adjacent tires on the bogie (fig. 51). These tracks are usually made of rubber with steel reinforcement. They are fairly easy to install and remove, especially

Figure 51.—*Tire tracks on a bogie.*

relative to wide tires and duals. Also, tire tracks can be used on bald, worn-out tires to improve traction and extend their useful life.

Equipment with tracks

Tracked machines distribute the weight of the machine and load over steel or rubber tracks (fig. 52). These tracks are usually between 18 and 36 in. (46 and 91 cm) wide and 8 to 14 ft (2.4 to 4.3 m) long on each side of the machine. This provides a large area over which to distribute the weight of the machine and load, normally resulting in lower ground pressures than conventional equipment and better flotation. A disadvantage of these machines in skidding is they often travel at slower speeds than rubber-tired machines, which reduces productivity, especially for long skidding distances. Tracks are more commonly found on felling equipment where speed of movement is not as important, especially for designs that reach out to the tree. These designs also lower impact by not having to traverse as much of the site to access the area.

Figure 50.—*Bogie system.*

Figure 52.—*Tracked machine.*

Lightweight equipment

Lightweight equipment reduces ground pressure by reducing the weight of the machinery. In many cases, there is little change in contact area with the soil surface as compared to traditional-size equipment. An added benefit of smaller equipment is better maneuverability, which results in less damage to the remaining vegetation. This is especially important in thinning and partial cutting, which is becoming more prevalent across the country due to public concerns. By reducing the weight of the machinery, the machinery's ability to move large loads is also reduced. As a result, smaller, lightweight equipment has not been popular with producers in the past because the smaller loads have resulted in lower productivity and profitability. This will probably change in the future as land managers and landowners begin specifying the use of lightweight equipment to lessen impacts on their forests.

Equipment with central tire inflation

Central tire inflation (CTI) technology is a low ground pressure option for use on hauling vehicles equipped with radial tires (fig. 53). Most log trucks operate with very high tire pressure (around 100 PSI [690 kPa]) to allow heavy loads to be transported at highway speeds. However, problems such as damage to the road surface (Bradley 1993 and Hodges *et al.* 1987) can develop on unpaved roads during use of these high pressure tires. CTI allows a driver to automatically and uniformly vary the inflation pressure of a truck's tires while the vehicle is moving. With a CTI system, the tire pressure can be lowered to yield a tire with a larger footprint area (fig. 54), which reduces the vehicle pressures applied to the ground. As an example, the typical footprint length of a tire with 100 PSI (689 kPa) is 8 in. (20.3 cm), whereas the footprint of a tire inflated to 43 PSI (296 kPa) is 13 in. (33 cm) (Anonymous 1993, Greenfield 1992). That larger footprint translates into better flotation, increased traction, and reduced rutting in wet areas (Bradley 1997). The cost to retrofit a vehicle depends on the number of axles that are to be retrofitted. For an 18-wheel log truck with a three-zone system, the cost will probably exceed $16,000.

Figure 53.—*Central Tire Inflation (CTI) system.*

ECONOMIC CONSIDERATIONS FOR CROSSING OPTIONS

The temporary and portable crossing options identified in this paper differ greatly in cost. Some can be assembled on-site using native materials, while others require more sophisticated design and assembly, available primarily from commercial vendors. Each option has a limited range of conditions and applications

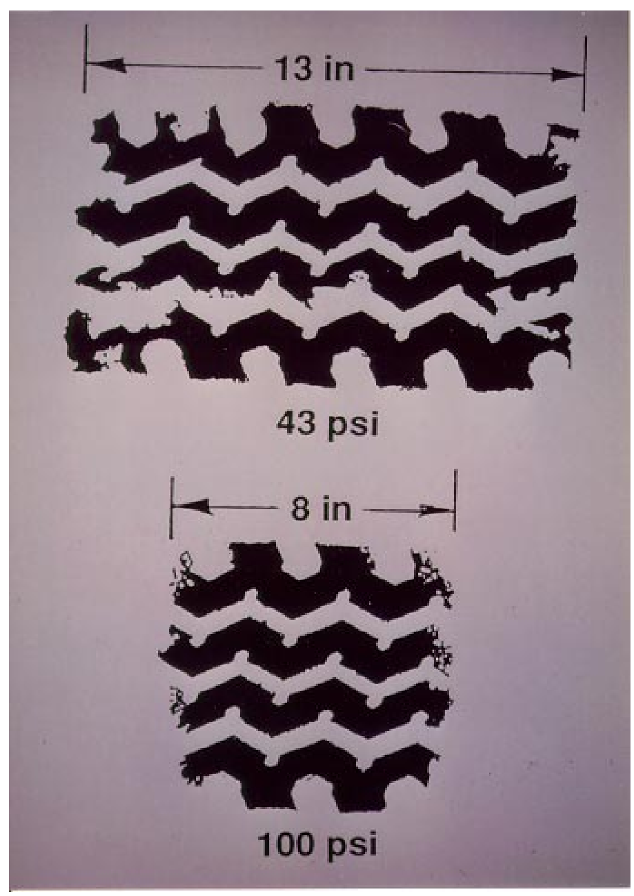

Figure 54.—*Tire footprint at two pressures.*

under which it is most effective. Several options may be considered effective for any particular application. Selecting the option(s) that best fit the normal applications and operating conditions for your company or agency requires careful consideration of many short-term and long-term factors. Investing in crossing options can control or reduce overall operating costs.

For example, a log stringer bridge constructed on-site may have the lowest initial cost, but a stress-laminated panel bridge that can be used and reused for several years may be the cheapest option over the long term. Internal factors affecting overall cost include initial cost; reusability; average time to replacement; time, labor, and equipment required for construction, installation, and removal; safety; and operational efficiency and effectiveness. External factors driving these decisions include product availability, public policy, regulatory agency acceptance, market conditions, and other site specific conditions or considerations. All these factors must be weighed carefully against actual out-of-pocket costs to determine the best long-term choices.

Most organizations invest in the options they anticipate using most often or that best meet their immediate need. Some options are too expensive for many companies or agencies to invest in, even though they may be the safest and most effective option for their needs. This may be because the initial cost is beyond their financial resources, or because the frequency of use is too limited to justify the major investment. Investment in a portable steel bridge may be one example. In these situations, it may be desirable for larger forest products companies and land management agencies to purchase these items and make them available for loan or rent to smaller organizations.

ENVIRONMENTAL IMPACTS ASSOCIATED WITH CROSSINGS

Environmental impacts associated with a broad range of forest management practices in areas near streams, and to a much lesser extent wetlands, have been extensively studied. These impacts can affect the aesthetics, biology (e.g., presence of plant and animal species, biomass), physical characteristics (width, depth, and shape of the stream or wetland, stream channel stability), temperature, and chemical composition (e.g., pH, turbidity,[6] conductivity[7]) of water bodies. Some of the reports that have summarized impacts from many studies include Brown and Binkley (1994), Campbell and Doeg (1989), Kahl (1996), Marcus *et al.* (1990), Meehan (1991), Salo and Cundy (1987), and Ward (1992).

Unfortunately, little information exists that focuses specifically on the environmental impacts associated with stream or wetland crossings. Most of the literature relates to the use of round culverts. Few studies have addressed the effect of stream crossings on stream quality other than from the standpoint of sedimentation. Few studies have examined impacts associated with the removal of the temporary crossings or have compared the long-term impacts associated with using a ford versus a temporary bridge. Questions still remain about what type of and how much impact is acceptable. The information that follows summarizes some of the studies that have reported environmental impacts resulting from these crossings.

Background

Where a stream bank becomes destabilized as a part of constructing or removing a crossing, sedimentation can become a problem, especially in lower gradient systems that respond to increased flow by increasing stream width. Such problems will likely be more persistent than those associated with just the road crossing itself (Everest *et al.* 1987, Sullivan *et al.* 1987). Sedimentation is a concern in streams because of the change in habitat for fisheries and benthic fauna, and because of phosphorus input associated with soils and sediment. Establishing the crossing at an area with a stable stream bank and providing adequate bank protection are critical.

When a culvert crossing fails, extensive local scouring occurs with deposition and additional erosion downstream (Furniss *et al.* 1991). Culvert crossing failures that divert streamflow into nonstream areas are particularly damaging (Weaver *et al.* 1987).

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[6] *Volume of suspended solids.*

[7] *Electrical resistance due to dissolved solids.*

Sediment can have lethal impacts on fish in several ways (Ward 1992):

- Increased suspended sediment limits photosynthesis of algae and rooted aquatic plants by reducing sunlight penetration into the water. This limits production of food for aquatic life.

- Spawning beds for many species (e.g., walleye, whitefish, brook trout) consist of cobble or gravel substrate where the eggs fall into the interstitial spaces between stone particles. In these spaces, the eggs are protected from predators while water flow ensures the exchange of gases needed for survival. Sediment from construction sites can change the substrate by blocking the spaces and reducing or destroying productivity.

- Suspended sediment can cause changes in fish feeding behavior because prey is less visible.

- Suspended sediment can harm incubating fish eggs or fry and reduce the abundance of insect larvae, a food source for fish. Many fish eggs have an adhesive surface to which suspended sediment can attach and block gas exchange, causing the egg to suffocate.

- High levels of suspended sediment lasting for many days can cause direct fish mortality.

In addition, all fish species do not spawn at the same time. While some species spawn in the spring, others spawn in the fall and the eggs then hatch during the following spring. Because fish spawn at different times and areas with cobble or gravel are a preferred spawning area for some species, any in-stream activity can impact fish habitat and populations.

Fish are particularly sensitive to changes in water quality, temperature, and oxygen. Suspended sediments can abrade or clog gill filaments and reduce visibility of insects, thus reducing feeding success. A comparative post-logging study of 10 moderate gradient (0.3 to 3 percent) streams in New Brunswick and Nova Scotia found a significant reduction in the biomass of Atlantic salmon, brook trout, and brown trout at stream crossings (Grant *et al.* 1986). It has been reported that a 17 parts per million (ppm) increase in sand bedload results in a 10 lb per acre decline in trout populations (Alexander and Hansen 1983).

The immediate effects of in-stream disturbance frequently cause fish populations to decline. Generally, these effects last less than 10 years and often only a year or two (Gregory *et al.* 1987). Within a watershed, the cumulative effects of multiple crossings or other disturbances may be more persistent. In contrast to most authors, Everest *et al.* (1987) suggest that some fine sediment may be beneficial to trout and salmon (salmonids) by contributing to increased invertebrate productivity, and that the adverse consequences of fine sediment introduction to trout streams have been overstated.

Crossings can cause loss of fish habitat within, above, or below the crossing (Marcus *et al.* 1990). Improperly designed and installed culvert crossings can block fish migration routes. Common problems include outfall drops that are too great, lack of resting pools below culverts, excessive water velocities, or insufficient water depth within culverts. Anderson and Bryant (1980) published an annotated bibliography of fish passage at road crossings. A number of considerations necessary to minimize potential effects of culvert crossings on salmonids have been suggested (Yee and Roelofs 1980). Culvert and bridge installers also need to consider whether they are creating an obstruction of a navigable waterway.

A stream adjusts its geometry to accommodate the water and sediment it carries. When the amount of water or sediment a stream must carry increases, channel geometry must change to accommodate the increase. When channel geometry is artificially changed, such as by an incorrect stream crossing, the stream will adjust by altering its geometry upstream or downstream of the change (Furniss *et al.* 1991). Road crossings that modify and restrict stream geometry least, such as bridges or low-water fords, are likely to have the least adverse effects on channel geometry.

Using treated wood products in and around water bodies can cause toxic substances to leach into the water. Best Management Practices for the use of treated wood near water have been developed (WWPI 1996). These practices should be followed when using treated wood in temporary crossings.

Studies of Stream Crossings

Thompson *et al.* (1996) evaluated sediment production from two gravel-bottom fords located on third-order streams in the Talladega National Forest in Alabama. Both permanent fords were being used for occasional administrative traffic before being cleaned out and gravel added in preparation for a timber harvest. Results from background samples taken before the sites were disturbed indicated that the old existing fords produced little sediment at base flow rates. The base flow rate during winter months ranged from 0.0038 m^3/sec to 0.051 m^3/sec for Ford 1 and from 0.0018 m^3/sec to 0.049 m^3/sec for Ford 2. During the renovation of the fords, the peak sediment concentration increases were 2,810 mg/l and 1,355 mg/l for Fords 1 and 2, respectively. Mean sediment concentration increases were 359 mg/l and 353 mg/l for Fords 1 and 2, respectively. The total sediment produced was 116.8 lb (53 kg) for Ford 1 versus 35.3 lb (16 kg) for Ford 2. The difference in sediment load was due to differences in stream flow rates.

Thompson *et al.* (1996) reported that the first storm after renovation of the two fords produced higher sediment loads than during construction. The rainfall, which measured 12.78 cm over a 50-hr period, resulted in peak sediment concentration increases of 585 mg/l and 745 mg/l for Fords 1 and 2, respectively. Total sediment produced at Fords 1 and 2 during the storm event was 2,107 lb (956 kg) and 374.7 lb (170 kg), respectively.

Tests showed that when a pickup truck drove through Ford 1 at base flow rate conditions, sediment concentrations increased by as much as 255 mg/l (10 minutes after the vehicles passed through the ford) and 110 mg/l (25 minutes after the vehicles passed through the ford) at sampling points that were 148 ft (45 m) and 302 ft (92 m) downstream, respectively, from the lower edge of the ford (Thompson *et al.* 1996). Sediment concentration levels returned to normal within 1 hr after the vehicles passed through the fords. It was projected that heavier vehicles with more wheels, such as log trucks, might generate more sediment load than the light vehicles used in the tests.

Water quality was monitored while installing a ford with a bulldozer in a stream with a moderate current (2.3 ft/s) [0.7 m/s] and a hard bottom (limestone bedrock, limestone cobble, and gravel) in Michigan (White Water Associates, Inc. 1996). Sampling stations were set up 66 ft (20 m) upstream of the ford (control) and 33 ft (10 m), 82 ft (25 m), and 164 ft (50 m) downstream. A total of 33 samples were collected at each station. The control station had significantly lower sediment load than the other stations ($p<0.001$). The total sediment loads produced by the ford installation at the stations 33 ft (10 m) and 82 ft (25 m) downstream were about 1,570 lb (710 kg) and 1,030 lb (470 kg), respectively. The total suspended sediments returned to near zero soon after discrete disturbance events occurred. The interval between disturbance and return to near background level took about 18 minutes for the two disturbances that had sufficient time between them and the next disturbance.

Water quality was monitored while installing a culvert on a stream that was 7.2 ft (2.2 m) wide, 9.3 in. (24 cm) deep, flowing 0.63 ft/s (0.19 m/s), and discharging 3.5 ft^3 (0.1 m^3) of water per second (White Water Associates, Inc. 1997). Monitoring stations were established at points 66 ft (20 m) upstream of the culvert (control) and at 33 ft (10 m), 82 ft (25 m), 144 ft (45 m), 331 ft (100 m), and 427 ft (130 m) downstream. Highly significant increases in sediment load were noted for each station except the one that was 427 ft (130 m) downstream, which had sediment loads that were equivalent to the upstream control. It was estimated that 482 lb (220 kg) of sediment were deposited between the stations 33 ft (10 m) and 427 ft (130 m) downstream of the culvert installation.

In a study conducted on Horse Creek in Idaho, 12.3 lb (5.6 kg) of sediment were contributed to a stream when right-of-way timber and debris were cleared from the stream channel and a temporary culvert was installed (USDA Forest Service 1981). When a permanent culvert was installed after the stream was diverted around the construction site, 0.2 lb (0.1 kg) of sediment were contributed to the stream as compared to 46 lb (20.9 kg) for a similar culvert installation where the water was not diverted.

Hornbeck *et al*. (1986) reported turbidity levels of 2,200 and 3,300 Jackson Turbidimeter Units (JTU) for a skid road culvert crossing in New Hampshire. A value of 10 JTU or less usually is considered desirable for drinking water. The high values, which occurred during summer harvesting activities, resulted from failure of the culvert.

Mason and Greenfield (1995) provide observational information about potential impacts due to PVC pipe bundle crossings. They indicate that soil may be picked up and later deposited into the stream if the crossing materials were stored on the ground before installation. Also, small fragments of pipe from cutting and drilling may remain inside the pipes and be deposited in the stream. During removal of a PVC pipe bundle crossing, sediment that had settled on the surface of the pipes can enter the stream. Removal of the geotextile caused disturbance. Indentations of about 0.5 in. (12 mm) were noticeable at the stream edges upon removal of a 25-ft- (7.5-m)-wide PVC pipe bundle crossing that was crossed once with a loaded 80,000 lb (36,230 kg) lowboy.

During two demonstrations that we conducted, depressions of about 0.5 in. (12 mm) were caused by a PVC pipe bundle crossing after about 20 passes with a loaded forwarder. When we used wood mats on the approaches, maximum rutting was about 0.5 in. (12 mm) as compared to areas beyond the approaches where maximum rut depth was about 8 in. (20 cm). No sediment was observed being stirred up while the pipes were being removed. However, removal of the geotextile did stir up a small amount of deposited sediment. Fisheries and waters biologists were impressed by the minimal impact caused by the crossing. Légère (1997) reported similar findings for two crossings where HDPE pipe bundles were installed. In one test, 70 passes were made by a forwarder. In the second test, 40 passes were made with a cable skidder.

Hassler *et al*. (1990) reported that there were no statistically significant differences between turbidity, pH, and conductivity samples taken above and below a stress-laminated timber bridge crossing. Thompson *et al*. (1994, 1995) reported that culverts contributed more sediment to the stream during installation and removal than the bridge crossings, which did not contribute any sediment. Pierce *et al*. (1993) noted that bridges usually are preferred because culvert installation and removal causes channel disturbance and produces sediment and turbidity.

Taylor *et al*. (1996) reported that the installation and removal of several glulam bridges was accomplished without operating any equipment in the stream or disturbing the stream channel or banks. Based on a visual appraisal, the authors reported no adverse impacts on water quality. Keliher *et al*. (1995) reported that some debris fell into the stream during skidding over a glulam bridge that consisted of two separate longitudinal panels. The 2-ft (0.6-m) gap between the bridge panels was partially filled with logs to reduce the amount of soil and vegetation dragged into the stream during skidding.

Without specifying the type of crossing that was constructed, Swift (1988) reported that road crossings over streams are the most critical points on a road because fills are larger, the road drains directly into the stream system, and opportunities for mitigating practices are limited. As an example, the author refers to three roads built in one watershed within the Coweeta Hydrologic Laboratory in western North Carolina during 1976 at a density of 1.26 mi/100 ac (5 km/100 ha). During the first year, all sediment collected in a stream weir originated from the roads, most of it from eight stream crossings during the first 2 months after construction began. Sediment measurements immediately below one crossing showed a cumulative total of 267.7 tons of soil entering the stream from each acre (600 metric tons of soil from each hectare) of roadway during those 2 months and 357 tons from each acre (800 metric tons from each hectare) of roadway in the first 2.5 years following construction of the crossing. About 80 percent of the soil washed into the stream remained in the channel and had not reached the weir located 2,362 ft (720 m) downstream after 2.5 years. However, portions of those deposits were still being transported out of the stream system 8 years later.

A series of 1-day post-harvest assessments of 78 recently completed timber harvesting sites was conducted in Vermont to evaluate Acceptable Management Practice compliance, soil erosion extent, and water quality impacts (Brynn and Clausen 1991). The crossings were accomplished with either a metal or wooden culvert, ford, bridge, or brush. Some of the crossings were permanent. Comparisons of impacts between crossing types were not conducted. Over 60 percent of the crossings were made by a ford. Stream crossing sedimentation and debris were above background levels on 57 and 55 percent of the sites, respectively. The impacts of increased woody debris were judged not to be major.

Brynn and Clausen (1991) reported that stream crossings for trucks on perennial streams had adequately sized bridges or culverts 60 percent of the time. Also, 60 percent of the fords had stable approaches and stream beds. Stream crossings were made at right angles 81 percent of the time. Temporary stream crossing structures were removed and the channel restored 77 percent of the time. The study recommended that stream crossings over brush or pole fords[8] should not be allowed because the brush was infrequently removed and restoration may result in increased sedimentation. The seeding and mulching of the stream crossing approaches was completed on only 2 percent of the sites. Newton *et al.* (1990) recommended that fords of perennial streams should not be allowed except under unusual circumstances (e.g., the crossing is too wide for any other option).

Suspended solids and turbidity were evaluated for several stream crossing options on haul roads and skid trails at two locations in Pennsylvania (Tornatore 1995, Tornatore *et al.* 1996). At one site, four skidder crossings were installed: a culvert with shale fill, a culvert with log fill,[9] a portable hinged steel bridge, and a plastic ford that was constructed using a GEOWEB® cellular confinement system with shale fill underlain by geotextile fabric. An unmitigated crossing was also evaluated at that site by having a bulldozer pass directly through the stream at an area with a rocky bottom and a gradual approach. At the second site, three hauling crossings were installed: a culvert with gravel fill, a bedrock-based gravel ford, and a wooden cross-tie bridge that used rejected railroad ties as the cross supports and oak lumber spaced 2 in. (5 cm) apart for the decking. Stream samples were taken at sites above and below each crossing before, during, and after installation, during the use of the crossings, and during high flows due to snow melt.

Tornatore (1995) and Tornatore *et al.* (1996) reported that installation of all skidder crossings at the first site caused significant increases in suspended solids and turbidity. The level of impact to the stream was less severe during installation of the portable bridge versus the culvert. Installation impacts were reduced to insignificant levels within 24 hr following bridge installation versus 96 hr following installation of the culvert with the log fill.

Increases in suspended solids occurred downstream from all skidder crossings at the first site (Tornatore 1995, Tornatore *et al.* 1996). Increases below the portable bridge appeared to be a result of debris (leaves, twigs, and bark) falling through gaps in the bridge planking. Despite this, the portable steel bridge showed lower increases in suspended solids than either the culvert with shale fill or the culvert with log fill. To reduce debris, it was recommended that the bridge deck be kept reasonably clean. The culvert with shale fill performed better than the culvert with log fill. Suspended solids below the culvert with log fill resulted primarily from increased inorganic sediment that may be related to the stability of the approach area and stream bank. Two skidder passes made within 15 minutes of each other at the unmitigated ford crossing increased sediment solids by 350 times.

The ford with the GEOWEB® cellular confinement system protected and supported what otherwise would have been a wet, muddy depression in the haul road (Tornatore 1995, Tornatore *et al.* 1996). Use of the gravel-based ford resulted in greater increases in suspended solids and turbidity on haul roads than the

[8] *The poled ford (also known as corduroy) was installed by filling the stream with logs or poles that were longer than the width of the equipment using the crossing. The poles were laid parallel to the flow of the stream with sufficient space between logs to allow the stream to pass through. To improve stream flow through the ford, two 10-ft- (3-m)-long sections of 16-in.- (41-cm)-wide ductile iron pipe (a high-carbon pipe designed to withstand pressurized gas) were placed in the poled ford without backfill.*

[9] *The culvert with log fill was "filled" with 4 to 5 in. (10 to 13 cm) diameter pole-size timber taken from the immediate vicinity of the crossing. The poles were laid parallel to the culvert until both the culvert and the area 2 to 3 ft (0.6 to 0.9 m) on either side were covered by a 8 to 12 in.- (20 to 30 cm)-deep log fill buffer.*

culvert with shale fill and the cross-tie bridge crossings. Approach stability was important for all skidder and haul road crossings.

Tornatore (1995) recommended constructing crossings during dry or low flow periods to reduce downstream impacts. Also, the study concluded that culvert use for both skid trails and haul roads is a viable means of crossing streams if care is taken to minimize installation time, if approaches and stream bank areas are adequately protected, and if the culverts are properly maintained. The study also suggested that if sufficient care is taken to prevent the accumulation of mud and debris on top of portable bridges and wooden cross-tie bridges, those crossing options would outperform culverts in protecting streams.

Miller *et al*. (1997) evaluated environmental conditions above and below 70 forest road crossings (40 culvert, 21 bridge, and 9 ford) in Pennsylvania. Only crossings 2 years old or older were evaluated. The study reported that only 35 of the 814 comparisons of mean environmental conditions above and below the crossings were found to be significantly different ($p<0.05$). Significant differences found were related to increased levels of fine sediment, reduced basal area, and increased herbaceous vegetation in the immediate vicinity of the road crossings. Successional- and disturbance-related factors seemed to be responsible for the vegetation changes typically found in the crossing area. Based on the measurements made in their study, the authors suggested that severe long-term impacts due to crossings are not common.

Thompson and Kyker-Snowman (1989) evaluated both short- and long-term impacts at an unmitigated stream crossing as well as mitigated crossings constructed with a portable bridge, a poled ford with a ductile iron culvert, and concrete slabs with hay bales. The unmitigated crossings provided no protection from disturbance of the stream or its banks. No clear effect of season (flow level) or equipment type (rubber-tire cable skidder vs. dual rear axle forwarder) on turbidity levels was documented. The effect of mitigation was dramatic. Unmitigated crossings generally caused large increases in turbidity at 15 and 100 ft (4.6 and 30.5 m) downstream of the crossing. No significant differences between before- and after-crossing values were found for pH, specific conductivity, or nitrate levels. Nitrate levels were negligible and in no case did they come near the allowable drinking water limit. For both unmitigated and mitigated crossings, there were no significant differences between turbidity values measured at 1,000, 2,200, 2,640, or 5,280 ft (305, 671, 805, or 1,609 m) below the crossings from samples taken at upstream locations.

Of the mitigated crossings, Thompson and Kyker-Snowman (1989) reported that the bridge was the most effective and the concrete slabs with hay bales the least effective at reducing crossing impacts. Measurable impacts with a portable bridge extended less than 100 ft (30.5 m) downstream. Measurable effects with other crossing options rarely extended as far as 1,000 ft (305 m) downstream. Although a natural ford was not included as a mitigated crossing in the study, the authors concluded that this option would be an acceptable mitigation from observational evidence of active and inactive harvesting sites. The study concluded that the largest impacts occurred as a result of unmitigated crossings, crossings that did not meet Best Management Practices (BMP) standards, and unstable approach areas adjacent to some of the crossings.

Thompson and Kyker-Snowman (1989) noted that poled fords used in winter can become a problem if they freeze into the stream and become difficult to remove. The temporarily abandoned ford can act as a dam during spring runoff, possibly causing the stream to overflow its banks and increase erosion. They suggested that ductile iron pipes might carry the spring floods through the ford and facilitate earlier removal.

Looney (1981) compared the use of a rubber mat dam bridge to a ford and a culvert crossing. While whole-tree skidding, the rubber mat dam bridge yielded a significant reduction in the amount of suspended solids being carried downstream, as compared to a ford crossing. During 1.33 hr of use at one site (5 one-way crossings with the first, third, and fifth crossings being loaded), the ford crossing resulted in 155 lb (52.7 kg) of sediment as compared to 92 lb (31.2 kg) of sediment for the dam bridge. During 2 hr of use at a second site (8 one-way crossings, every other one being loaded), the ford crossing resulted in 613 lb (208 kg) of sediment as compared to 242 lb (82.3 kg) for the dam bridge. The author also noted that the dam bridge provided considerable flotation to the skidder as compared to the ford crossing. Installation and removal of a culvert crossing added 583 lb (198 kg) of sediment to the stream. Water quality protection was given paramount importance during the culvert installation. To accomplish that goal, sandbags were used to divert the water flow into the culvert during backfilling around the culvert and the fill material was of superior quality. The author indicated that a dam bridge falls somewhere between a ford and a culvert in terms of stream protection.

Studies of Wetland Crossings

Mason and Greenfield (1995) compared the impacts associated with using or not using wood pallets over a silty sand soil in the Osceola National Forest in Florida. The soil moisture content in the area that did not have wood pallets was typically 5 to 10 percent less than in the area that contained the pallets. After 150 passes with a loaded log truck that had a gross vehicle weight of 80,000 lb (36,300 kg), the rutting that occurred at the non-pallet crossing was 6 to 10 in. (15.3 to 25.4 cm) deep. The wood pallets had settled about 0.5 in. (12 mm). The authors reported that the use of wood pallets left no specific areas to hold and channelize water or specific areas of high compaction or rutting.

Hislop (1996b) tested wood pallets, wood mats, and an expanded metal grating on a silty sand soil within the Osceola National Forest in Florida. A non-woven, needle-punched geotextile was placed beneath each option. After 240 passes with a loaded log truck that had a gross vehicle weight of 80,000 lb (36,300 kg), the maximum rut depth was 8 in. (20 cm) on a control section and 1.5 in. (3.8 cm) on the wood pallet and wood mat section. After 75 passes, the maximum depth was 15 in. (38 cm) on a control section versus 5 in. (13 cm) for the expanded metal grating.

On a silty sand soil within the Osceola National Forest, areas with geotextile under expanded metal and deck-span safety grating showed less soil rutting as compared to areas with no grating (Mason and Greenfield 1995). After about 130 round trips with loaded log trucks that had a gross vehicle weight of 80,000 lb (36,300 kg), rutting in the area with grating was about 0.5 to 1 in. (1.3 to 2.5 cm) as compared with up to 1 ft (0.3 m) in areas without grating.

After about 20 passes with an unloaded flatbed truck with a loader on a deep black muck soil in Michigan, we noted the following maximum rutting depths: wood mat—12.5 in. (32 cm), expanded metal grating—8 in. (20 cm), tire mat—6.5 in. (17 cm), and wood plank—4.5 in. (11 cm). A single pass in a control area produced ruts 11.5 in. (29 cm) deep. On an upland area at that site, the flatbed truck became stuck and had to be pushed with a bulldozer. Once it was pushed onto the first test section of expanded metal grating that led from the upland area to the wetland, traction was regained and the vehicle was able to drive up and back down the slope without any trouble.

After about 20 passes with a loaded forwarder on a ponded histosol soil in Minnesota, we noted the following maximum rutting depths: tire mat—21 in. (53 cm), wood plank—6.8 in. (17 cm), wood mat—5.1 in. (13 cm), expanded metal grating—4.8 in. (12 cm), and PVC pipe mat—1.3 in. (3.3 cm). A non-woven geotextile was placed below all options. Soil penetrometer readings at both sites did not show any differences in soil strength.

Wolanek (1995) monitored downslope water quality for 25 months after constructing a road using mill-generated bark and wood fiber as primary fill material on the Tongass National Forest in Alaska. Overall, the study found minimal effects on stream water quality. The parameter most effected was pH, increasing significantly by 0.2 to 1.5 pH units in the naturally acidic streams. Dissolved oxygen in the streams remained unaffected. All observed effects were within the limits of Alaska water quality standards.

Goudey and Taylor (1992) and Taylor (1994) examined the toxicity of aspen wood leachate to aquatic organisms. They reported that leachate from aspen wood chips and wood piles was very toxic to aquatic life. Aspen wood leachate can be produced in any season when the wood is exposed to water and the temperature is above freezing. Karsky (1993) reported that the short-term potential leaching of tannic acid from cedar and some other species must be considered when constructing a chunkwood road close to a stream. No studies have reported leachate toxicity in wetland roadbuilding using chunkwood.

Bradley (1995) and Foltz (1994) reported that central tire inflation can reduce sediment runoff from unpaved roads. In a 3-year study that evaluated CTI on test loops, sediment runoff was reduced by as much as 80 percent on road sections that were used by CTI-equipped vehicles (70 PSI [480 kPa] on the steering axle and 30 PSI [210 kPa] on the other axles), as compared to vehicles using 90 PSI (620 kPa) in all tires. Little rut development occurred after 1,205 passes with a CTI-equipped loaded log truck.

SUMMARY OF SOME STREAM AND WETLAND CROSSING STATUTES

Each State and Province has enacted statutes to reduce nonpoint source pollution and to protect wetlands. As a result, there is no uniformity in regulations across the Great Lakes basin. In addition, many local jurisdictions (e.g., county, shoreland zoning ordinances) within a State or Province have implemented additional statutes to further regulate nonpoint pollution sources. A summary of some of the key State/Provincial statutory regulations on stream and wetland crossings in Michigan, Minnesota, New York, Pennsylvania, Wisconsin, Ontario, and Quebec is presented below. This information was gleaned from a review of the statutes as well as from contact with individuals in the appropriate regulatory organization in each State or Province. Regulators from each State or Province reviewed draft copies of the summary for their jurisdiction, and their revisions were then incorporated. If you are interested in additional information, contact the appropriate regulating body in that State or Province. Contact information for each State and Province is provided in table 5.

Michigan

Stream quality, cost, and season of use are evaluated when deciding what type of crossing to allow. Bridges are the preferred crossing method for streams, especially designated trout streams and their tributaries. During winter, it is acceptable to place native material or an ice/snow bridge across the stream when a frozen water crossing is not practical. When determining culvert size and the minimum clearance height for bridges, the height of the 100-year flooding frequency is considered.

A permit is required anytime a stream is to be crossed. The minimum permit fee is $50 and the maximum $2,000. Most permits cost $50. Permits may be granted or denied within 60 days after an acceptable application has been received. No permits are required for wetland crossings. However, the operator should follow voluntary BMP's.

Areas that have high-quality fish spawning beds or that contain threatened and endangered species should be avoided for crossings. Waterbars may be required on the approaches of stream crossings to divert water off the road before it reaches the stream.

Minnesota

The type of crossing is determined based on site-specific needs. Crossings of protected waterbasins or wetlands are allowed only where there is no feasible and practical alternative. It is more difficult to obtain a permit to cross a designated wild and scenic river, a designated trout stream or one of its tributaries, or a protected wetland. Ice bridges do not require a permit. Other crossings that do not require a permit are described below.

Provided that all conditions are met, a permit is not required for a low water ford crossing on a stream when the site is not an officially designated trout stream, wild, scenic, or recreational river, or officially designated canoe or boating route; no special site preparation is necessary; normal summer flow does not exceed 2 ft (0.6 m) in depth; normal low flow is not restricted or reduced; the crossing conforms to the shape of the natural stream channel; the original stream bank is no higher than 4 ft (1.2 m); the ford is constructed of gravel, natural rock, concrete, steel matting or other durable, inorganic material not more than 1 ft (0.3 m) thick; the graded finished slope is not steeper than 5:1 (horizontal to vertical); and graded banks are re-seeded or mulched.

A permit is not required for a temporary bridge on a stream when the crossing is consistent with floodplain, shoreland, and wild, scenic, or recreational river ordinances; the stream bank

Table 5.—*Central office contact information for water regulatory authorities in Michigan, Minnesota, New York, Pennsylvania, Wisconsin, Ontario, and Quebec*

State or Province	Organization and address	Telephone number
Michigan	Department of Environmental Quality Land and Water Management Division P.O. Box 30458 Lansing, MI 48909-7958	(517) 373-1170
Minnesota	Department of Natural Resources Division of Waters 500 Lafayette Rd. St. Paul, MN 55155-4032	(651) 296-4800
New York	Department of Environmental Conservation Division of Regulatory Services 50 Wolf Road Albany, NY 12233-1750	(518) 457-2224
	Adirondack Park Agency P.O. Box 99 Ray Brook, NY 12977	(518) 891-4050
Pennsylvania	Department of Environmental Resources Bureau of Dams, Waterways and Wetlands P.O. Box 8554 Harrisburg, PA 17105-8554	(717) 783-1384
Wisconsin	Department of Natural Resources Bureau of Water Regulation and Zoning Box 7921 Madison, WI 53707-7921	(608) 266-8034
Ontario	Director, Forest Management Branch Ministry of Natural Resources Suite 400, Roberta Bonda Place 70 Foster Drive Sault Ste. Marie, ON Canada P6A 6V5	(705) 945-6660
Quebec	Ministere des Ressources Naturelles Direction de l'environnement forestier 880 Chemin Sainte-Foy, 5^{e} étage PQ Canada G1S 4X4	(418) 643-2922

can support the bridge without pilings, foundations, culverts, excavation, or other special site preparation; nothing is placed in the bed of the stream; the bridge can be removed for maintenance and flood prevention, the bridge is firmly anchored at one end and can swing away during flooding; and there is a minimum 3 ft (0.9 m) of clearance between the lowest portion of the bridge and normal summer stream flow.

All other crossings require permits. The application fee for a permit ranges from $75 to $500, depending on the size or cost of the project. Once an application is declared to be complete, the average turnaround time before a decision is made concerning a permit is 45 to 60 calendar days.

New York

The New York Department of Environmental Conservation (DEC) has jurisdiction over stream crossings throughout the State. Within the Adirondack Park, wetlands are regulated by the Adirondack Park Agency. Outside of the Park, the DEC regulates wetlands. Crossings are determined on a case-by-case basis by evaluating factors such as season, cost, and local conditions. The Talbot formula (Merritt 1983) is used to size culvert and bridge openings for temporary stream crossings that will be in place during periods other than low summer flow. A 2 in./hr (5 cm/hr) rainfall is assumed, unless conditions warrant consideration of a larger rainfall. Multi-span bridges may be acceptable. Skidding or winching of logs or trees in or along the axis of tributary channels or across wild rivers is prohibited.

Outside of the Adirondack Park, permits are required for all protected stream crossings where disturbance will occur to the stream bank or stream bed or within 100 ft (30 m) of wetland crossings in regulated wetlands that are 12.4 acres (5 ha) or larger in size. A wetland smaller than 12.4 acres (5 ha) in area may be regulated if it is determined to have unusual local importance. For some small stream crossings, permits may be issued on-site. There is no cost for filing any permit application.

Stream and wetland crossing applications are classified as either minor or major using review criteria contained in the Freshwater Wetlands Permit Requirements Regulations. Review time frames, procedures, and requirements for public notice of applications differ for minor and major projects. For stream crossings, a minor permit application is one where the length of the stream bed or bank to be impacted does not exceed 50 ft (15.2 m). There are many other criteria in these regulations that are used to assess whether a wetland crossing is minor or major.

Minor permit applications require up to 45 calendar days for a decision on the permit after the application is declared to be complete. A decision on a major crossing permit application can take up to 90 calendar days if no public hearing is held. Major permit applications require publication in the New York Department of Environmental Conservation's Environmental Notice Bulletin and a designated local newspaper to solicit public review and comments.

Within the Adirondack Park, the DEC rules specified above apply to stream crossings. Any wetland within the Park that is 1 acre (0.4 ha) in size or larger, or any size wetland adjoining an open water body that has a free interchange of water at the surface, falls under the jurisdiction of the Adirondack Park Agency. Skid trails and other roads may be constructed without a permit within a wetland if they do not involve a material disturbance to the wetland (e.g., cut and fill). Permits are required for all other activities within a wetland. Before a permit is denied, a public hearing must be held.

Pennsylvania

Two different types of crossings, minor road crossings (GP-7) and temporary road crossings (GP-8), are recognized. A minor road crossing is a road constructed across a wetland where the length of the crossing is less than 100 ft (30 m) and the total wetland area disturbed is less than 0.1 acre (0.04 ha), or a road constructed across a stream and an adjacent wetland using a bridge, culvert, or ford crossing where the watershed drainage area is 1.0 mi^2 (259 ha) or less and the total wetland area disturbed is less than 0.1 acre (0.04 ha). A temporary road crossing would consist of a road installed for a period of time not to exceed 1 year across a wetland or along a stream that uses a pipe culvert or a series of culverts, a bridge, a causeway, or a ford.

If the crossing of a wetland cannot be avoided under a minor road crossing, the crossing must be undertaken at the narrowest point of the wetland and shall not exceed 100 ft (30 m) in length and 0.1 acre (0.04 ha) in disturbance. The total wetland impact for all minor road crossings installed on an individual property or project, including phased projects, cannot exceed 0.25 acre (0.10 ha).

For a temporary road crossing, skidding across fords and multiple-span bridges is prohibited. Also, temporary fords are prohibited within 2,000 ft (610 m) upstream of all high quality and exceptional value watersheds and watersheds tributary to drinking water intakes or public water supply reservoirs. Within a temporary road crossing, culverts must be installed with a depressed roadway embankment so that overtopping of the roadway will occur within the stream channel. If a temporary road crossing across a wetland cannot be avoided, the crossing is permissible if it is located at the narrowest practicable point of the wetland and the length of the crossing within the wetland does not exceed 200 ft (61 m). Temporary road wetland crossing surfaces must be stabilized by appropriate means, such as removable, temporary mats, pads, or other similar devices.

Instead of using a specified flooding frequency when sizing culverts, knowledge of local conditions and season(s) of operation are considered. A permit is required for all minor road and temporary road crossings, unless the drainage area is less than 100 acres (40 ha). Within wetlands, the regulations specified above apply. There are two different types of permits: a general permit and a joint permit. For forest management activities, an application for a joint permit would be filed only when the general permit is not applicable. While joint permits may offer an alternative to a denied general permit, the detailed environmental assessment requirements make them unattractive for most forest management practices. If neither a general permit for a minor road (GP-7) nor a temporary road crossing (GP-8) is applicable to a certain location, the only option is to apply for the joint permit application.

For both minor road and temporary road crossings, a general permit would not be granted under a number of situations. As an example, for both crossing types, a general permit would not be usable where any of the following conditions were present: historic, cultural, or archaeological sites were identified; stocked trout streams from March 1 to June 15, wild trout streams from October 1 to December 31, and Lake Erie tributaries from September 1 to December 1 unless written approval is obtained from the Fish Commission's Division of Environmental Services. During these periods, the general permits for minor road and temporary road crossings and a joint permit can be used. However, no in-stream work can occur during those dates.

Minor road crossings of wetlands both under the general permit (GP-7) and the joint permit application require a wetland delineation and a replacement plan. If the permanent impact to the wetland is less than 0.05 acre (0.02 ha), no replacement is required under the State's deminimus policy. There is no application fee for a general permit, unless the crossing is to be established across submerged water lands of the Commonwealth. In that case, the license fee for occupying submerged lands is $50/0.10 acre ($50/0.04 ha) of disturbance with a minimum charge of $250/year.

Wisconsin

Culvert crossings on navigable waterways[10] must be designed to pass a 100-year flood frequency without causing an increase of 0.01 ft (1 cm) or greater in the regional flood elevation if flooding easements are not obtained from affected upstream property owners before a permit will be issued. Gravel or concrete plank fords and clearspan bridges are preferred over culverts. For multi-span bridges, bridge piers may be permitted, as long as they don't create upstream flooding on property where an easement cannot be obtained. Ice bridges can be used on a case-by-case basis. A clearance of 5 ft (1.5 m) or more may be required for bridge and culvert clearance on waterways that may be used by other than lightweight craft (e.g., powerboats). Clearance on other navigable waterways is evaluated on a case-by-case basis.

[10] *A waterway is navigable if it has beds and banks, and if it is possible to float a canoe or other small craft in the waterway on a regular recurring basis, even if only during spring runoff.*

Permits are required whenever crossing a navigable waterway or grading and/or removing top soil from the bank of any navigable waterway where the area exposed will exceed 10,000 ft^2. The minimum cost for a permit, \$30, is applicable to ford crossings. Culvert and bridge crossings and grading or removal of top soil from the bank of a waterway for an area more than 10,000 ft^2 require an application fee of \$100. The permit cost for crossing a stream wider than 35 ft (10.7 m) is \$300. A permit is required to remove or dredge material from navigable and non-navigable streams. The permit costs \$100 if less than 3,000 yd^3 are removed and \$300 for larger removals.

After receiving a complete application, the DNR Water Regulation and Zoning staff will provide the applicant with language for a public notice of intent that the applicant must have published in local newspapers. After a 30-calendar day comment period, the crossing could be approved if objections were not filed against it. If objections are filed, it may take 6 months or longer before the permit might be approved through a hearing process.

Ontario

Every 5 years, a forest management plan must be prepared or renewed for approval by the provincial government. This plan identifies activities (e.g., access, harvest, renewal, and maintenance) that will take place over the next 20 years, although specific plans are required only for the upcoming 5-year period. As a part of the planning process, public input is solicited at three different times. Once a plan is approved by the government, a company must annually submit a work schedule showing specific locations and a time frame for activities that will occur within the next 12 months. All of those activities must fall within the scope of the 5-year plan. An approval to begin operations is issued when the annual work schedule is approved. As part of the approval, specific stream and wetland crossings are authorized. There is not a separate application process or cost associated with securing permission to make a crossing.

In lieu of developing statutes, Ontario has produced several different sets of guidelines that must be followed as a part of timber management. Each set of guidelines is designed to establish standards and to provide practical advice for ensuring minimum disturbance to the natural environment. Most of the decisions about what to apply in a specific instance are left for the professionals and operators to make on-site. Operators must stay within the guidelines, unless an exception is granted. Areas where the approach deviates from the guidelines are to be clearly noted on the plan. If the variances are approved, they must be closely monitored by the contractor. The Ministry of Natural Resources also monitors variances on-site and/or through an extensive reporting process.

No crossing options are excluded by the guidelines. All water crossings must be sized using hydrological analysis techniques approved by Ministry of Natural Resources engineers. Design flows on access roads are typically for a 10- to 50-year flooding frequency, with the lower frequency for culverts and the higher for major bridges. All bridges must be designed by a qualified professional engineer to meet bridge design codes and Ministry standards. Bridge proposals must be reviewed and approved by the Ministry engineer. The Ministry provides design aids and training for in-house staff and the forest industry.

Quebec

Before harvesting within a publicly owned forest, a company must submit a 25- and 5-year plan to the provincial government for approval. Public consultation is also mandatory during the development of these plans. Annual plans delineating areas to be harvested within the upcoming year must also be submitted. The 25-year, 5-year, and annual plans must be approved by a forest engineer. Roads must be indicated on the plan (only access roads are usually shown). Except for crossings, any road that is to come within 197 ft (60 m) of a stream or lake must be clearly indicated, justified, and protection measures identified. The location of bridges, along with their size, must appear on the annual plan. All bridge designs must be approved by a civil engineer, although they can be constructed by a forest engineer.

Logs can be used on each side of the stream to stabilize the approach. If logs are used for this purpose, they must remain in place after use. A goal is to achieve zero particles deposited into streams. Therefore, the use of geotextile is mandatory for permanent stream crossings and strongly suggested for temporary stream crossings.

Fording a stream is not allowed, even in winter. Bridging or ice bridges are acceptable on winter roads. Logs can be incorporated into the ice bridge, as long as they are securely cabled to a tree or other nearby secure structure. Both types of structures must be removed at the end of the work, except for the log mats used to stabilize the banks on either side of the stream.

Culverts are sized on a 10-year flood frequency, if the watershed is less than 14,830 acres (6,000 ha). On larger watersheds, culverts are sized on a 20-year flood frequency. The smallest culvert that can be used in a stream is 18 in. (45 cm) diameter. Prescribed or equivalent stabilization techniques must be used during the installation and removal of the culvert. Wooden culverts are acceptable only if their span does not exceed 3.3 ft (1 m) wide. Stream enlargement is prohibited. When constructing either a culvert or bridge crossing, the width of the stream can be reduced by up to 20 percent or, if calculations based on flood frequency allow it, by up to 50 percent. Only bridges are acceptable when crossing a lake or bay within a lake.

A stream crossing (bridge or culvert) cannot be constructed in or within 164 ft (50 m) upstream from a spawning ground indicated on the annual plan. When designing a crossing in a stream where fish migrate, installation of a structural plate culvert or construction or improvement of a bridge cannot be conducted during the upstream migration of fish, as determined by the Ministry of Environment.

RESEARCH AND EDUCATION NEEDS

The growing worldwide demand for forest products will increase the probability of harvesting in areas that are adjacent to or that contain streams and wetlands. Appropriate crossing options are needed to avoid negative impacts to these water bodies. Unfortunately, little research is currently available that has evaluated and compared the various crossing options. Also, little information has been compiled to make people aware of how to best use each option so that it meets their operational requirements and provides adequate environmental protection. As a result, we have identified the following research and education needs:

- Relatively few studies have evaluated the impacts of different stream and wetland crossing options. Further examination of the impacts associated with stream and wetland crossings, especially those that result from the removal of a temporary crossing, is needed.

- The various studies that have evaluated impacts to streams and wetlands from use of different crossings have applied different methodologies and evaluated different parameters to derive their results. There is a need to develop and apply a standard approach so that results can be more easily compared.

- Maintaining the hydrologic function of a wetland is key to sustaining its integrity. Severe rutting may impede subsurface flow of water across a wetland. There is a need to evaluate the impacts to subsurface water movement across a wetland that result from application of different crossing options.

- From the operator's perspective, there are costs and benefits associated with using any crossing option. Costs can include the installation, maintenance, and removal of an option. Benefits may include improved access, shorter roads and skid trails, extended time of operability, increased productivity, reuse, and reduced maintenance. The limited available research is largely focused on quantifying the installation and removal costs associated with use of culverts in streams without considering any benefits that may be derived. There is a need to quantify the net costs (total costs minus total benefits) to the operator associated with the variety of different options that are available for use in streams and wetlands. That analysis needs to consider the life cycle costs and benefits.

- While each crossing option may accomplish its intent, different options may perform better in some instances and worse in others. There is a need to identify the optimal range of site and operating conditions for each option. As a part of that process, the temporal dimension of "temporary" needs to be addressed.

- There are costs and benefits to the operator, to the landowner, and to society associated with using the various options. Individuals who make on-the-ground decisions about what crossing option(s) to allow need better information about these costs and benefits to make sure that their prescription is appropriate to each particular crossing.

- An economic analysis (that includes pay-back analysis) comparing non-reusable options with reusable options needs to be done. The analysis should consider all costs associated with each option, including labor and materials, over the expected life of the crossing option.

- Several options are available to cross streams and wetlands. Most operators are either unaware of the variety of options available or lack sufficient information to correctly install, maintain, and remove the options or rehabilitate the site following removal. Training materials are needed to help them properly accomplish these tasks.

- Appropriate institutional arrangements between organizations need to be identified to assist with the purchase of some options. Many large landowners may have a continual need for reusable options on their land, but many operators may not be able to afford the initial investment for some of these. If these larger landowners obtained the options outright, they could then make them available to operators through a variety of mechanisms, to be reimbursed for the investment. Owners could also share their crossing options through other arrangements.

SUMMARY

Streams and wetlands are broadly recognized as valuable ecosystems. Timber harvest and forest management activities have the potential to adversely impact these systems. A variety of reusable temporary stream and wetland crossing options are available that can reduce impacts to water bodies while providing long-term cost advantages and day-to-day operational benefits. Before implementing any of the options, be sure to compare their capabilities and costs to actual needs. We highly recommend using a non-woven geotextile fabric below most temporary wetland crossing options. We also recommend using a geotextile fabric with some stream crossing options placed within the stream as well as beneath any temporary materials used to protect the approaches on the stream banks. However, the use of geotextile with a stream crossing option should be approved by the appropriate regulatory authorities because there may be concerns about impacts if the geotextile moves downstream. Various studies have reported that bridge crossings contribute less sediment to the stream than culvert crossings during installation. Various studies have reported that the options were effective in improving trafficability and reducing rut depth. Contact us for additional information about any of the options or to inform us of others that are not identified in this publication. The e-mail address for the first author is cblinn@forestry.umn.edu.

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APPENDIX 1

PARTIAL LIST OF COMMERCIAL VENDORS FOR TEMPORARY CROSSING OPTIONS

This is not a complete list and some information provided may be inaccurate or out-of-date. Many vendors provide a variety of products but are listed under only one category. Although the listing for a company may not be from your area, there may be a local distributor who can supply information and materials.

Geotextiles

Amoco Fabrics and Fibers Company
900 Circle 75 Parkway, Suite 550
Atlanta, GA 30339
Voice: (800) 445-7732
(770) 984-4444
Fax: (770) 956-2430

Cascade Distribution Ltd.
15620 - 121A Ave.
Edmonton, AB Canada T5V 1B5
Voice: (800) 565-6130
(403) 454-2400
Fax: (403) 451-0911

Layfield Plastic
14604-115A Ave.
Edmonton, AB Canada T5M 3C5
Voice: (403) 453-6731
Fax: (403) 455-5218

Synthetic Industries, Inc.
4019 Industry Dr.
Chattanooga, TN 37416
Voice: (800) 621-0444
(423) 899-0444
Fax: (423) 899-7619

Belton Industries
8613 Roswell Rd.
Atlanta, GA 30350
Voice: (800) 225-4099
(770) 587-0257
Fax: (770) 992-6361

Fireflex Division, SEI Industries
7400 Wilson Ave.
Delta, BC Canada V4G 1E5
Voice: (604) 946-3131
Fax: (604) 940-9566

Linq Industrial Fabrics, Inc.
Geotextile Division
2550 West 5th North St.
Summerville, SC 29843-9669
Voice: (800) 543-9966
(803) 875-8277
Fax: (803) 875-8276

TC Mirafi
365 S. Holland Dr.
Pendergrass, GA 30567
Voice: (800) 234-0484
Fax: (800) 333-6205

Cellular confinement systems

A. G. H. Industries, Inc.
4600 Post Oak Place
Suite 111
Houston, TX 77027
Voice: (713) 552-1749
Fax: (713) 552-1147

Nilex Corporation
6810 South Jordan Rd.
Englewood, CO 80112
Voice: (800) 537-4241
(303) 766-2000
Fax: (303) 766-1110

GeoCHEM, Inc.
106 Lake Ave. S.
Seattle, WA 98055
Voice: (425) 227-9312

Presto ProductsCompany
P.O. Box 2399
Appleton, WI 54913-2399
Voice: (800) 548-3424
(920) 738-1118
Fax: (920) 738-1432

Tenax Corporation
4800 East Monument St.
Baltimore, MD 21205
Voice: (410) 522-7000
Fax: (410) 522-7015

Erosion control products

American Excelsior Company
P.O. Box 5067, 850 Ave. H East
Arlington, TX 76005-5067
Voice: (800) 777-SOIL
(817) 640-1555
Fax: (817) 649-7816

BonTerra America, Inc.
355 West Chestnut St.
Genesee, ID 83832
Voice: (800) 882-9489
Fax: (208) 285-0201

Canadian Forest Products, Ltd.
Panel and Fibre Division
430 Canfor Ave.
New Westminister, BC Canada V3L 5G2
Voice: (800) 363-8873

Conwed Fibers
219 Simpson St.
Conover, NC 28613
Voice: (800) 366 1180
Fax: (704) 328-9826

Erosion Control Systems, Inc.
1800 McFarland Blvd., Suite 180
Tuscaloosa, AL 35406
Voice: (800) 943-1986

Finn Corporation
9281 LeSaint Dr.
Fairfield, OH 45014
Voice: (800) 543-7166
(513) 874-2818
Fax: (513)874-2914

Greenfix America
P.O. Box 62, 604 E. Mead Rd.
Brawley, CA 92227
Voice: (800) GREENFX
(800) 929-2184
(760) 344-6700
Fax: (760) 344-4305

Nedia Enterprises
89-66 217th St.
Jamaica, NY 11427
Voice: (888) 725-6999
(718) 740-5171
Fax: (718) 740-1049

North American Green, Inc.
14649 Highway 41 North
Evansville, IN 47711
Voice: (800) 772-2040
(812) 867-6632
Fax: (812) 867-0247

RoLanka International, Inc.
365 Toccoa Place
Jonesboro, GA 30236
Voice: (800) 760-3215
(770) 506-8211
Fax: (770) 506-0391

PPS Packaging Company
204 N. Seventh St.
P.O. Box 56
Fowler, CA 93625
Voice: (209) 834-2011

Verydol Alabama, Inc.
P.O. Box 605
Pell City, AL 35125
Voice: (205) 338-4411

Steel/aluminum culverts

Atlantic Industries Limited
Dorchester, NB, Canada
Voice: (506) 379-2455
Fax: (506) 379-2290

Contech Construction Products, Inc.
1001 Grove St.
Middletown, OH 45044
Voice: (800) 338-1122
(800) 363-3873

Culverts and Industrial Supply Co.
7242 W. Yellowstone
Casper, WY 82644
Voice: (307) 472-7121
Fax: (307) 577-4914

Johnston Fargo Culverts, Inc.
3575 85th. Ave. NE
St. Paul, MN 55126-1186
Voice: (651) 780-1760
Fax: (651) 780-1763

Polyethylene culverts

Advanced Drainage Systems
3300 Riverside Dr.
Columbus, OH 43221
Voice: (800) 733-7473
(614) 457-3051
Fax: (614) 459-0169

Crumpler Plastic Pipe
P.O. Box 2068, Highway 24 West
Roseboro, NC 28382
Voice: (800) 334-5071
Fax: (800) CPP-PIPE

Hancor, Inc.
401 Olive St.
Findlay, OH 45839
Voice: (800) 537-9520
(419) 423-6913
Fax: (419) 424-8337

Soleno SPD, Inc.
1160 Rt. 133, C.P. 147
Iberville, PQ, Canada J2X 4J5
Voice: (800) 363-1471
(514) 347-8315
Fax: (514) 347-3372

High density polyethylene pipe

CSR Polypipe
P.O. Box 390
Gainesville, TX 76241-0390
Voice: (800) 433-5632
(817) 665-1721
Fax: (817) 668-8612

Fluid Controls
3435 Stanwood Blvd. NE
Huntsville, AL 35811
Voice: (800) 462-0860
(205) 851-6000
Fax: (205) 852-6005

Forrer Supply
P.O. Box 220
Germantown, WI 53022-0220
Voice: (800) 255-1030
(414) 255-3030
Fax: (414) 255-4064

Harvel Plastics
P.O. Box 757
Easton, PA 18044-0757
Voice: (610) 252-7355
Fax: (610) 253-4436

Plastic Pipe and Supply
100 Glen Rd.
P.O. Box 8066
Cranston, RI 02920
Voice: (401) 467-9370
Fax: (401) 461-9520

Plexco Performance Pipe Division
Chevron Chemical Company
1050 IL Route 83 - Suite 200
Bensenville, IL 60106-1048
Voice: (630) 350-3700
Fax: (630) 350-2704

Stress-laminated bridges

Forestry and Wildlife Consult. Serv., Inc.
Rt. 1, Box 531
Gretna, VA 24557
Voice: (804) 656-6684

Hughes Brothers
210 N. 13th St.
Seward, NE 68434
Voice: (402) 643-2991
Fax: (402) 643-2149

Dowel-laminated bridges

Wheeler Lumber, LLC.
P.O. Box 26100
St. Louis Park, MN 55426
Voice: (800) 328-3986
(612) 929-7854
Fax: (612) 929-2909

Glued-laminated bridges

Structural Wood Systems, Inc.
P.O. Box 250
Greenville, AL 36037
Voice: (334) 382-6534
Fax: (334) 382-9860

Modular steel bridges

Acrow Corporation of America
P.O. Box 812
Carlstadt, NJ 07072-0812
Voice: (800) 524-1363
(201) 933-0450
Fax: (201) 933-3961

Hamilton Construction Company
P.O. Box 659
Springfield, OR 97477-0121
Voice: (541) 746-2426
Fax: (541) 746-7635

Van Straten and Sons Manufacturing
RFD #1, US 41 North
Baraga, MI 49908
Voice: (906) 353-8177
(906) 353-6490
Fax: (906) 353-7115

Big R Manufacturing
P.O. Box 1290
Greeley, CO 80632
Voice: (800) 234-0734
(970) 356-9600
Fax: (970) 356-9621

Modular Bridge Systems
8035 Alexander Rd.
Delta, BC Canada V4G 1C6
Voice: (604) 946-1524
Fax: (604) 946-1514

Hinged bridges

ADM Welding and Fabrication
Pennsylvania Ave. West Ext., Rear
Warren, PA 16365
Voice: (814) 723-7227
Fax: (814) 723-7227

Concrete decked steel bridges

SureSpan Bridge
Suite 216
545 Clyde Ave.
West Vancouver, BC Canada V7T 1C5
Voice: (604) 925-3377
Fax: (604) 925-3394

Railroad flatcar bridges

Rick Franklin Corporation
101 Industrial Way
P. O. Box 365
Lebanon, OR 97355
Voice: (800) 428-1516
(541) 451-1275
Fax: (541) 258-6444

Expanded metal grating

Alabama Metal Industries, Inc.
P.O. Box 3928
Birmingham, AL 35208
Voice: (800) 366-2642
Fax: (205) 780-7838

Brown-Campbell Steel Co.
14290 Goddard St.
Detroit, MI 48212
Voice: (800) 521-4512
(313) 891-2390
Fax: (313) 891-2903

McNichols Co.
1951 Lively Blvd.
Elk Grove, IL 60007
Voice: (800) 237-3820
Fax: (847) 640-8388

Wood mats/panels

Carolina Mat Company
P.O. Box 339
Plymouth, NC 27962
Voice: (800) 624-6027
(919) 793-4045
Fax: (919) 793-5187

Clemons Forest Products
P.O. Box 982
Amite, LA 70422
Voice: (504) 748-9079
Fax: (504) 748-9719

Wood pallets

Uni-Mat International
503 Martin St.
Houston, TX 77018
Voice: (800) 445-7850
(713) 697-3585
Fax: (713) 697-1227

Tire mats

Terra Mat Corporation
462 Arbor Circle
Youngstown, OH 44505
Voice: (330) 759-9412
Fax: (330) 759-7679

Unique Tire Recycling, Inc.
155 LaFarge Rd.
Kamloops, BC Canada V2C 6T5
Voice: (800) 446-5955
Fax: (604) 573-3492

High flotation tires

Ardco-Traverse Lift, LLC.
322 Riley Rd.
Houston, TX 77047
Voice: (713) 433-6751
Fax: (713) 433-5655

Continental General Tire Co.
1800 Continental Blvd.
Charlotte, NC 28273
Voice: (704) 583-3900
Fax: (704) 583-8540

Firestone Agricultural Tire Co.
730 E. Second St.
Des Moines, IA 50309
Voice: (515) 242-2306
Fax: (515) 242-2329

OTR Wheel Engineering
Box 5811
Rome, GA 30162-5811
Voice: (706) 235-9781
Fax: (706) 234-8137

Rolligon Corporation
10635 Brighton Lane
Stafford, TX 77477
Voice: (281) 495-1140
Fax: (281) 495-1145

Toyo Tire USA Corporation
300 W. Artesia Blvd.
Compton, CA 90220
Voice: (310) 537-2820
Fax: (310) 604-1519

United Tire & Rubber Company
275 Belfield Rd.
Rexdale, ON Canada M9W 5C6
Voice: (416) 675-3077
Fax: (416) 675-4337

Single and bogie tire tracks

Hultdins, Inc.
22 Morton Ave. East
Brantford, ON Canada N3T 5T3
Voice: (519) 754-0044
Fax: (519) 754-1569

Pedno Tracks, Inc.
3641 rue des Forges
Laterriere, PQ Canada G0V 1K0
Voice: (418) 678-1506
Fax: (418) 678-9748

Central tire inflation equipment

Eaton Air Control Products
1303 Durham Rd.
P.O. Box 241
Roxboro, NC 27573-0241
Voice: (910) 503-6411
Fax: (910) 503-6425

APPENDIX 1

PARTIAL LIST OF COMMERCIAL VENDORS FOR TEMPORARY CROSSING OPTIONS

This is not a complete list and some information provided may be inaccurate or out-of-date. Many vendors provide a variety of products but are listed under only one category. Although the listing for a company may not be from your area, there may be a local distributor who can supply information and materials.

Geotextiles

Amoco Fabrics and Fibers Company
900 Circle 75 Parkway, Suite 550
Atlanta, GA 30339
Voice: (800) 445-7732
(770) 984-4444
Fax: (770) 956-2430

Cascade Distribution Ltd.
15620 - 121A Ave.
Edmonton, AB Canada T5V 1B5
Voice: (800) 565-6130
(403) 454-2400
Fax: (403) 451-0911

Layfield Plastic
14604-115A Ave.
Edmonton, AB Canada T5M 3C5
Voice: (403) 453-6731
Fax: (403) 455-5218

Synthetic Industries, Inc.
4019 Industry Dr.
Chattanooga, TN 37416
Voice: (800) 621-0444
(423) 899-0444
Fax: (423) 899-7619

Belton Industries
8613 Roswell Rd.
Atlanta, GA 30350
Voice: (800) 225-4099
(770) 587-0257
Fax: (770) 992-6361

Fireflex Division, SEI Industries
7400 Wilson Ave.
Delta, BC Canada V4G 1E5
Voice: (604) 946-3131
Fax: (604) 940-9566

Linq Industrial Fabrics, Inc.
Geotextile Division
2550 West 5th North St.
Summerville, SC 29843-9669
Voice: (800) 543-9966
(803) 875-8277
Fax: (803) 875-8276

TC Mirafi
365 S. Holland Dr.
Pendergrass, GA 30567
Voice: (800) 234-0484
Fax: (800) 333-6205

Cellular confinement systems

A. G. H. Industries, Inc.
4600 Post Oak Place
Suite 111
Houston, TX 77027
Voice: (713) 552-1749
Fax: (713) 552-1147

Nilex Corporation
6810 South Jordan Rd.
Englewood, CO 80112
Voice: (800) 537-4241
(303) 766-2000
Fax: (303) 766-1110

GeoCHEM, Inc.
106 Lake Ave. S.
Seattle, WA 98055
Voice: (425) 227-9312

Presto ProductsCompany
P.O. Box 2399
Appleton, WI 54913-2399
Voice: (800) 548-3424
(920) 738-1118
Fax: (920) 738-1432

Tenax Corporation
4800 East Monument St.
Baltimore, MD 21205
Voice: (410) 522-7000
Fax: (410) 522-7015

Erosion control products

American Excelsior Company
P.O. Box 5067, 850 Ave. H East
Arlington, TX 76005-5067
Voice: (800) 777-SOIL
(817) 640-1555
Fax: (817) 649-7816

BonTerra America, Inc.
355 West Chestnut St.
Genesee, ID 83832
Voice: (800) 882-9489
Fax: (208) 285-0201

Canadian Forest Products, Ltd.
Panel and Fibre Division
430 Canfor Ave.
New Westminister, BC Canada V3L 5G2
Voice: (800) 363-8873

Conwed Fibers
219 Simpson St.
Conover, NC 28613
Voice: (800) 366 1180
Fax: (704) 328-9826

Erosion Control Systems, Inc.
1800 McFarland Blvd., Suite 180
Tuscaloosa, AL 35406
Voice: (800) 943-1986

Finn Corporation
9281 LeSaint Dr.
Fairfield, OH 45014
Voice: (800) 543-7166
(513) 874-2818
Fax: (513)874-2914

Greenfix America
P.O. Box 62, 604 E. Mead Rd.
Brawley, CA 92227
Voice: (800) GREENFX
(800) 929-2184
(760) 344-6700
Fax: (760) 344-4305

Nedia Enterprises
89-66 217th St.
Jamaica, NY 11427
Voice: (888) 725-6999
(718) 740-5171
Fax: (718) 740-1049

North American Green, Inc.
14649 Highway 41 North
Evansville, IN 47711
Voice: (800) 772-2040
(812) 867-6632
Fax: (812) 867-0247

RoLanka International, Inc.
365 Toccoa Place
Jonesboro, GA 30236
Voice: (800) 760-3215
(770) 506-8211
Fax: (770) 506-0391

PPS Packaging Company
204 N. Seventh St.
P.O. Box 56
Fowler, CA 93625
Voice: (209) 834-2011

Verydol Alabama, Inc.
P.O. Box 605
Pell City, AL 35125
Voice: (205) 338-4411

Steel/aluminum culverts

Atlantic Industries Limited
Dorchester, NB, Canada
Voice: (506) 379-2455
Fax: (506) 379-2290

Contech Construction Products, Inc.
1001 Grove St.
Middletown, OH 45044
Voice: (800) 338-1122
(800) 363-3873

Culverts and Industrial Supply Co.
7242 W. Yellowstone
Casper, WY 82644
Voice: (307) 472-7121
Fax: (307) 577-4914

Johnston Fargo Culverts, Inc.
3575 85th. Ave. NE
St. Paul, MN 55126-1186
Voice: (651) 780-1760
Fax: (651) 780-1763

Polyethylene culverts

Advanced Drainage Systems
3300 Riverside Dr.
Columbus, OH 43221
Voice: (800) 733-7473
(614) 457-3051
Fax: (614) 459-0169

Crumpler Plastic Pipe
P.O. Box 2068, Highway 24 West
Roseboro, NC 28382
Voice: (800) 334-5071
Fax: (800) CPP-PIPE

Hancor, Inc.
401 Olive St.
Findlay, OH 45839
Voice: (800) 537-9520
(419) 423-6913
Fax: (419) 424-8337

Soleno SPD, Inc.
1160 Rt. 133, C.P. 147
Iberville, PQ, Canada J2X 4J5
Voice: (800) 363-1471
(514) 347-8315
Fax: (514) 347-3372

High density polyethylene pipe

CSR Polypipe
P.O. Box 390
Gainesville, TX 76241-0390
Voice: (800) 433-5632
(817) 665-1721
Fax: (817) 668-8612

Fluid Controls
3435 Stanwood Blvd. NE
Huntsville, AL 35811
Voice: (800) 462-0860
(205) 851-6000
Fax: (205) 852-6005

Forrer Supply
P.O. Box 220
Germantown, WI 53022-0220
Voice: (800) 255-1030
(414) 255-3030
Fax: (414) 255-4064

Harvel Plastics
P.O. Box 757
Easton, PA 18044-0757
Voice: (610) 252-7355
Fax: (610) 253-4436

Plastic Pipe and Supply
100 Glen Rd.
P.O. Box 8066
Cranston, RI 02920
Voice: (401) 467-9370
Fax: (401) 461-9520

Plexco Performance Pipe Division
Chevron Chemical Company
1050 IL Route 83 - Suite 200
Bensenville, IL 60106-1048
Voice: (630) 350-3700
Fax: (630) 350-2704

Stress-laminated bridges

Forestry and Wildlife Consult. Serv., Inc.
Rt. 1, Box 531
Gretna, VA 24557
Voice: (804) 656-6684

Hughes Brothers
210 N. 13th St.
Seward, NE 68434
Voice: (402) 643-2991
Fax: (402) 643-2149

Dowel-laminated bridges

Wheeler Lumber, LLC.
P.O. Box 26100
St. Louis Park, MN 55426
Voice: (800) 328-3986
(612) 929-7854
Fax: (612) 929-2909

Glued-laminated bridges

Structural Wood Systems, Inc.
P.O. Box 250
Greenville, AL 36037
Voice: (334) 382-6534
Fax: (334) 382-9860

Modular steel bridges

Acrow Corporation of America
P.O. Box 812
Carlstadt, NJ 07072-0812
Voice: (800) 524-1363
(201) 933-0450
Fax: (201) 933-3961

Hamilton Construction Company
P.O. Box 659
Springfield, OR 97477-0121
Voice: (541) 746-2426
Fax: (541) 746-7635

Van Straten and Sons Manufacturing
RFD #1, US 41 North
Baraga, MI 49908
Voice: (906) 353-8177
(906) 353-6490
Fax: (906) 353-7115

Big R Manufacturing
P.O. Box 1290
Greeley, CO 80632
Voice: (800) 234-0734
(970) 356-9600
Fax: (970) 356-9621

Modular Bridge Systems
8035 Alexander Rd.
Delta, BC Canada V4G 1C6
Voice: (604) 946-1524
Fax: (604) 946-1514

Hinged bridges

ADM Welding and Fabrication
Pennsylvania Ave. West Ext., Rear
Warren, PA 16365
Voice: (814) 723-7227
Fax: (814) 723-7227

Concrete decked steel bridges

SureSpan Bridge
Suite 216
545 Clyde Ave.
West Vancouver, BC Canada V7T 1C5
Voice: (604) 925-3377
Fax: (604) 925-3394

Railroad flatcar bridges

Rick Franklin Corporation
101 Industrial Way
P. O. Box 365
Lebanon, OR 97355
Voice: (800) 428-1516
(541) 451-1275
Fax: (541) 258-6444

Expanded metal grating

Alabama Metal Industries, Inc.
P.O. Box 3928
Birmingham, AL 35208
Voice: (800) 366-2642
Fax: (205) 780-7838

McNichols Co.
1951 Lively Blvd.
Elk Grove, IL 60007
Voice: (800) 237-3820
Fax: (847) 640-8388

Brown-Campbell Steel Co.
14290 Goddard St.
Detroit, MI 48212
Voice: (800) 521-4512
(313) 891-2390
Fax: (313) 891-2903

Wood mats/panels

Carolina Mat Company
P.O. Box 339
Plymouth, NC 27962
Voice: (800) 624-6027
(919) 793-4045
Fax: (919) 793-5187

Clemons Forest Products
P.O. Box 982
Amite, LA 70422
Voice: (504) 748-9079
Fax: (504) 748-9719

Wood pallets

Uni-Mat International
503 Martin St.
Houston, TX 77018
Voice: (800) 445-7850
(713) 697-3585
Fax: (713) 697-1227

Tire mats

Terra Mat Corporation
462 Arbor Circle
Youngstown, OH 44505
Voice: (330) 759-9412
Fax: (330) 759-7679

Unique Tire Recycling, Inc.
155 LaFarge Rd.
Kamloops, BC Canada V2C 6T5
Voice: (800) 446-5955
Fax: (604) 573-3492

High flotation tires

Ardco-Traverse Lift, LLC.
322 Riley Rd.
Houston, TX 77047
Voice: (713) 433-6751
Fax: (713) 433-5655

Continental General Tire Co.
1800 Continental Blvd.
Charlotte, NC 28273
Voice: (704) 583-3900
Fax: (704) 583-8540

Firestone Agricultural Tire Co.
730 E. Second St.
Des Moines, IA 50309
Voice: (515) 242-2306
Fax: (515) 242-2329

OTR Wheel Engineering
Box 5811
Rome, GA 30162-5811
Voice: (706) 235-9781
Fax: (706) 234-8137

Rolligon Corporation
10635 Brighton Lane
Stafford, TX 77477
Voice: (281) 495-1140
Fax: (281) 495-1145

Toyo Tire USA Corporation
300 W. Artesia Blvd.
Compton, CA 90220
Voice: (310) 537-2820
Fax: (310) 604-1519

United Tire & Rubber Company
275 Belfield Rd.
Rexdale, ON Canada M9W 5C6
Voice: (416) 675-3077
Fax: (416) 675-4337

Single and bogie tire tracks

Hultdins, Inc.
22 Morton Ave. East
Brantford, ON Canada N3T 5T3
Voice: (519) 754-0044
Fax: (519) 754-1569

Pedno Tracks, Inc.
3641 rue des Forges
Laterriere, PQ Canada G0V 1K0
Voice: (418) 678-1506
Fax: (418) 678-9748

Central tire inflation equipment

Eaton Air Control Products
1303 Durham Rd.
P.O. Box 241
Roxboro, NC 27573-0241
Voice: (910) 503-6411
Fax: (910) 503-6425

APPENDIX 2

SPECIFICATIONS FOR SOME TEMPORARY STREAM CROSSING OPTIONS

Appendix 2. Specifications for some temporary stream crossing options.[1,2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Ford								
Plastic ford	28 ft [8.5 m] long by 16 ft [4.9 m] wide	---	114 lbs [52 kg] per panel	---	4 people for 6 hrs each $2,400	Bulldozer	---	Milauskas (1988)
Plastic ford	40 ft [12.2 m] long by 16 ft [4.9 m] wide	---	---	$860	3 people for 1.5 hrs each	Bulldozer	---	Pence (1987)
Plastic ford	80 ft [24.4 m] long by 16 ft [4.9 m] wide	---	---	$1,325	3 people for 8 hrs each	Backhoe, small crawler tractor	---	Tufts et al. (1994)
Concrete plank ford	Each plank is 16 in [41 cm] long by 14 ft [4.3 m] wide by 5.5 in [14 cm] thick	---	1,300 lbs [590 kg] per panel	---	---	---	---	McNemar (1983), Milauskas (1988)
Rubber mat	0.5 in [1.3 cm] thick	---	1,600 lbs [725 kg]	Used material	2 people for 2 hrs each	Skidder or pulley block	---	Looney (1981)
Culverts								
Steel arch culvert	---	---	---	---	---	No special equipment is needed for small culverts, an excavator is needed for large culverts.	---	Provencher (1992)

Appendix 2. Specifications for some temporary stream crossing options.[1, 2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Steel arch culvert	39 ft [12 m] long by 26 ft [8 m] wide by 9.2 ft [2.8 m] tall	---	---	$36,207 (Canadian)	$23,000 (Canadian)	Crane	---	MacGregor and Provencher (1995)
PVC pipe bundle								
Schedule 40 PVC pipe bundle	9 ft [2.7 m] long by 20 ft [6.1 m] wide	---	---	$602	3 people for 3 hours each	Front-end loader or skidder	---	Mason (1993a), Mason (1993b), Mason and Moll (1995)
Bridges (timber, used railroad cars, steel, or pre-stressed concrete)								
Log stringer bridge	30 ft [9.1 m] long	118,000 lbs [53,500 kg]	---	$6,500 (includes fabrication, transport, installation, removal, and storage)	2 days needed to install the bridge and build approaches	Excavator and front-end loader	---	Grabinski (1993)
Log stringer truck bridge	30 ft [9.1 m] long	50,000 lbs [22,600 kg]	---	---	½ day	Skidder	---	Hancock (1987)
Solid sawn stringer skidder bridge	26 ft [7.9 m] long by 12 ft [3.7 m] wide	---	---	$500	3 people for 30 min each	Skidder	---	Thompson (1988)
Solid sawn stringer skidder bridge	12 ft [3.7 m] long by 12 ft [3.7 m] wide	16,200 lbs [7,300 kg]	---	$342	2 people for 1 day to purchase, deliver, and assemble	Skidder	---	Bihun (1991)

Appendix 2. Specifications for some temporary stream crossing options.[1,2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Solid sawn stringer skidder bridge	21 ft [6.4 m] long by 12 ft [3.7 m] wide	---	---	$1,600	1 hr	Loader or skidder	---	Bates (1995)
Oak solid sawn stringer skidder bridge panels	24 ft [7.3 m] long by 6 ft [1.8 m] wide	---	---	$45 per panel	---	---	---	Beasley (1991)
Stress-laminated panel skidder bridge	Each panel is 19 to 24 ft [5.8 to 7.3 m] long by 4.5 ft [1.4 m] wide	---	---	between $200 and $1,200 for two panels	About 8 hrs to assemble two panels	Loader or skidder	---	Kittredge and Woodall (1997)
Stress-laminated panel truck bridge	63 ft [19.2 m] long by 23 ft [7 m] wide	---	---	$79,500	$10,500 130 hrs of labor; cranes were on-site for 30 hrs and used for 15 hrs	Two cranes	---	Dickson (1995)
Stress-laminated panel truck bridge	33 ft [10 m] long by 21 ft [6.4 m] wide	---	---	$45,200	$9,900	---	---	Dickson (1995)
Stress-laminated panel truck bridge	40 ft [12.2 m] long by 16 ft [4.9 m] wide	---	---	$7,000	2-3 hrs	Bulldozer equipped with a winch and knuckleboom loader	---	Hassler (1990)
Glulam panel truck bridge	50 ft [15.2 m] long	---	---	$44,000	$11,100	---	---	Groenier (1995)

Appendix 2. Specifications for some temporary stream crossing options.[1, 2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Glulam panel truck bridge	32 ft [9.8 m] long by 9 ft [2.7 m] wide	---	Each 4.5 ft wide panel weighs 6,500 lbs [2,950 kg]	$16,100	---	Loader or small truck-mounted crane	---	Taylor et al. (1995)
Glulam panel truck bridge	30 ft [9.1 m] long by 16 ft [4.9 m] wide by 10.5 in [27 cm] thick	80,000 lbs [36,300 kg]	Four panels, each 4 ft [1.2 m] wide, totaling 5,500 lbs [2,500 kg]	$15,500	$375 (3 people for about 4.5 hrs each)	Loader or small truck-mounted crane	$375 (3 people for about 4.5 hrs)	Taylor (1994), Taylor et al. (1995)
Glulam panel skidder bridge	Two panels, each one is 26 ft [7.9 m] long by 4 ft [1.2 m] wide by 8.5 in [21.5 cm] thick	34,000 lbs [15,400 kg]	---	$9,300 (this was a prototype; the estimated cost was less than $8,000 for a commercial bridge)	---	Loader with a grapple skidder	---	Keliher and Taylor (1994), Keliher et al. (1995)
Glulam panel truck bridge	Two panels, each one is 40 ft [12 m] long by 6 ft [1.8 m] wide	---	---	$17,000	$1,680 (less than 3 hrs)	Tracked backhoe	---	Taylor and Ritter (1996)
Dowel-laminated panel skidder or truck bridge (Wheeler Lumber, LLC.)	Two panels, each one is 26 ft [7.9 m] long by 5 ft [1.5 m] wide by 7.8 in [20 cm] thick	---	About 4,200 lbs [1,900 kg] per panel	$3,300 per panel, 2 panels required for a skidder crossing and 4 panels for a truck crossing	1 hr	Loader or small truck-mounted crane	30 min	Wheeler Lumber, LLC.

Appendix 2. Specifications for some temporary stream crossing options.[1, 2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Railroad flatcars (Rick Franklin Corporation)	41 ft [12.5 m] long by 8.5 ft [2.6 m] wide	80,000 lbs [36,300 kg]	18,000 lbs [8,100 kg]	$5,000	---	Excavator for the smaller units and a crane for larger railcars	---	Rick Franklin Corporation
	53 ft [16.1 m] long by 10.5 ft [3.2 m] wide	80,000 lbs [36,300 kg]	45,000 lbs [20,400 kg]	$9,000				
	60 ft [18.3 m] long by 10.5 ft [3.2 m] wide	80,000 lbs [36,300 kg]	60,000 lbs [27,200 kg]	$9,000				
	89 ft [27.1 m] long by 9 ft [2.7 m] wide	80,000 lbs [36,300 kg]	130,000 lbs [59,000 kg]	$12,000				
Railroad flatcar subframes	20 ft [6.1 m] long by 18.7 ft [5.7 m] wide	---	---	$17,100 (Canadian)	---	Excavator with front-end loader	---	Bradley and Pronker (1994)
	40 ft [12.2 m] long by 18.7 ft [5.7 m] wide	---	---	$20,700 (Canadian)				
	52.5 ft [16 m] long by 18.7 ft [5.7 m] wide	---	---	---				

Appendix 2. Specifications for some temporary stream crossing options.[1, 2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Railroad boxcar for log trucks	50 ft [15.2 m] long by 10 ft [3 m] wide	---	---	$3,000	---	Transported on lowboy trailer. One end of bridge lifted with Prentice 210 D knuckleboom loader	---	Carraway (1997)
Hamilton EZ steel truck or skidder bridge	50 ft [15.2 m] long	---	---	$37,800	$7,260	---	---	Groenier (1995), Muchmore (1978)
Steel panel skidder bridge	26 ft [7.9 m] long by 4 ft [1.2 m] wide	34,000 lbs [15,422 kg]	4 ft [1.2 m] wide panels each about 5,000 lbs [2,267 kg].	$3,600 per panel	10 - 15 min	Grapple or cable skidder	---	Weatherford (1996)
Steel plank skidder bridge	Two panels, each one is 24 ft [7.3 m] long by 4 ft [1.2 m] wide	99,000 lbs [45,000 kg]	2,200 lbs [1,000 kg] per panel	$8,000 (Canadian)	---	Excavator	---	Plamondon and Maranda (1996)
Steel panel forwarder bridge	16 ft [3.3 m] long	---	Two panels, each about 3,000 lbs [680 kg]	$2,500 (Canadian) total for the two panels	---	Trailer and loader	---	Makkonen (1991)
Steel small-vehicle bridge	20 ft [6.1 m] long	19,800 lbs [9,000 kg]	6,280 lbs [2,850 kg]	$11,200 (Canadian)	16 hrs for frame assembly; 1 hr to install	Dual-axle flatbed truck and a loader	45 min	Hamilton (1990b)

Appendix 2. Specifications for some temporary stream crossing options.[1, 2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Van Straten and Sons steel truck bridge	32 ft [9.8 m] long by 12 ft [3.7 m] wide 40 ft [12.2 m] long by 12 ft [3.7 m] wide 50 ft [15.2 m] long by 12 ft [3.7 m] wide	100,000 lbs [45,350 kg]	The bridge comes in two 6 ft [1.8 m] wide panels that are bolted together. Each panel weighs about 5,000 - 6,000 lbs [2,270 - 2,720 kg]	$6,500 $6,800 $8,500	---	Front-end loader, crane, or a skidder	---	Van Straten and Sons
Hinged steel small-vehicle bridge	16 ft [4.8 m] long	2,000 lbs [907 kg]	---	$12,500	---	Half-ton pickup truck	---	Moller (1989)
Hinged steel small-vehicle bridge	18 ft [5.5 m] long	6,600 lbs [3,000 kg]	---	$10,600 (Canadian)	2 people for 1 hr each	Half-ton pickup truck	2 people for 1 hr each	Hamilton (1989, 1992)
Modular steel truck bridge	30 ft [9.1 m] long 80 ft [24.4 m] long 110 ft [33.5 m] long	---	---	---	---	---	---	Groenier (1995)

Appendix 2. Specifications for some temporary stream crossing options.[1,2]

Option	Dimensions	Maximum weight supported	Product weight	Approximate purchase price[3]	Installation cost or time[4]	Installation equipment	Removal cost or time	Reference[5]
Modular steel skidder and truck bridge[8] (Acrow Corp. of America)	80 ft [24.4 m] long by 15.7 ft [4.8 m] wide 120 ft [37 m] long by 15.7 ft [4.8 m] wide	204,000 lbs [92,500 kg] 204,000 lbs [92,500 kg]	50,000 lbs [22,700 kg]	$60 per ft^2 of deck space $85 per ft^2 of deck space	100 ft [30 m] bridge would require three 10-hr days with a crew of 5 or 6 people (No more than 16% of the purchase price)	Small loader	100 ft [30 m] bridge would require three 10 hr days with a crew of 5 or 6 people (No more than 16% of the purchase price)	Acrow Corporation of America, Muchmore (1978)
Truck bridge	30 ft [9.1 m] long by 14 ft [4.3 m] wide 40 ft [12.2 m] long by 14 ft [4.3 m] wide	150,000 lbs [68,000 kg]	---	$18,000 (Canadian) $24,000 (Canadian)	---	Excavator	---	Ross (1997)
Precast pre-stressed concrete truck bridge	50 ft [15.2 m] long	---	---	$43,300	$4,400	---	---	Groenier (1995)
Precast pre-stressed concrete truck bridge	35 ft [10.6 m] long by 12 ft [3.7 m] wide	100,000 lbs [45,350 kg]	---	$7,100	$950	Crane	---	Jerkins (1991)

[1]All data represent information obtained from published sources, promotional materials, or from personal contacts with vendors. No attempt was made by the authors to validate the accuracy of the information. This is not a complete listing; other vendors and options are available. It is important to consider your needs and applications before making a purchase or rental decision. Evaluate and compare vendor recommendations and specifications. Where appropriate, consider factors such as travel speed, maximum span distance, and abutment requirements. Verify that bridging products have been certified by a licensed engineer. Inspect all products before each installation. Conform to all appropriate regulations.

[2]For some criteria, metric equivalent measurements are shown in brackets immediately following the English units. Unless otherwise specified, all costs and prices are given in $US.

[3]For commercial products, the approximate purchase price does not include shipping. Where two or more references are noted for an option, all cost information reflects information obtained from the most current source or the manufacturer.

[4]Bridge installations assume that all required stream bank abutments are in-place and that the crossing is already on-site.

[5]A list of commercial product vendors is presented in Appendix 1. Other references are noted in the listing of references.

[6]Wider bridges can be fabricated, if needed, for high flotation equipment. Rental units are available.

[7]Bridges 16 ft (4.9 m) wide and up to 156 ft (47.6 m) long are also available. Each bridge is divided longitudinally into either a 7- or 8-ft (2.1-m or 2.4-m) panel. Add about 6 to 8 percent to purchase the 16-ft- (4.9-m)-wide bridge.

[8]Longer bridges to almost any length are available in increments of 10 ft (3 m).

APPENDIX 3

SPECIFICATIONS FOR SOME TEMPORARY WETLAND CROSSING OPTIONS

Appendix 3. Specifications for some temporary wetland crossing options.[1,2]

Option	Dimensions	Product weight	Approximate purchase price[3]	Installation cost or time	Installation equipment	Removal cost or time	Reference[4]
Wood mats/panels							
Oak wood mats (Carolina Mat Company)	14 ft [4.3 m] long by 10 ft [3 m] wide 16 ft [4.9 m] long by 10 ft [3 m] wide	15,500 lbs [7,000 kg] per mat 17,500 lbs [7,900 kg] per mat	$130 per mat $150 per mat	---	Knuckleboom loader	---	Carolina Mat Company
Random-length hardwood planks	Lumber: 125 ft [38 m] long by 12 ft [3.7 m] wide by 2.5 in [6.4 cm] thick	---	Lumber and nails: $620	---	---	---	Bridge (1989)
Oak dragline mats (Clemons Forest Products)	Many lengths, from 16 ft [4.9 m] to 36 ft [9.1 m]; either 4 or 5 ft [1.2 or 1.5 m] wide and 8, 10, or 12 in [20, 25, or 30 cm] thick	---	$210 for a 16 ft [4.9 m] long by 4 ft [1.2 m] wide by 8 in [20 cm] thick mat $980 for a 36 ft [11 m] long by 5 ft [1.5 m] wide by 12 in [30 cm] thick mat	---	---	Knuckleboom loader	Clemons Forest Products

Appendix 3. **Specifications for some temporary wetland crossing options.**[1, 2]

Option	Dimensions	Product weight	Approximate purchase price[3]	Installation cost or time	Installation equipment	Removal cost or time	Reference[4]
Wood pallets							
Oak interlocking wood pallets (Uni-Mat International)	12 ft [3.7 m] long by 8 ft [2.4 m] wide	1,200 lbs [544 kg]	$188 per mat (As pallets interlock, two pallets are needed)	1,200 lineal ft [366 m] per day	Front-end loader	---	Uni-Mat International
Expanded metal grating							
Expanded metal grating	200 ft [60 m] long	---	Metal safety grating: $238 per 3-ft x 10-ft [0.9 x 3.0-m] section Non-woven geotextile: $380 per 12.5-ft x 360-ft [3.8 x 110-m] roll	4 people for 2 hrs each	Front-end loader	---	Mason (1992), Mason (1993a), Mason (1993b), Mason and Greenfield (1995)
Tire mats							
Terra Mat	10 ft [3 m] long by 5 ft [1.5 m] wide	1,200 lbs [550 kg]	$300 for 2 mats each 10 ft [3 m] x 5 ft [1.5 m]	80 ft [24.4 m] per hr with a loader, 50 ft [15.2 m] per hr with a skidder; estimated to be $1.43 per lineal ft [$4.69 per lineal m]	Knuckleboom loader or skidder	Estimated to be $1.91 per lineal ft [$6.27 per lineal m]	Terra Mat Corporation, Goldberg (1993), Howe (1990), Wilson (1990)

Appendix 3. Specifications for some temporary wetland crossing options.[1, 2]

Option	Dimensions	Product weight	Approximate purchase price[3]	Installation cost or time	Installation equipment	Removal cost or time	Reference[1]
Low ground pressure equipment							
Tracks for a single tire (Pedno Tracks, Inc.)	23.1 x 26 with 42 in [1.1 m] pad width	4,762 lbs [2,160 kg] (set of two tracks)	$6,950 for a set of two tracks	---	---	---	Pedno Tracks, Inc.
	30.5 x 32 with 50 in [1.3 m] pad width A variety of pad widths are available from 42 in [1.1 m] to 65 in [1.6 m] for different tire dimensions	5,118 lbs [2,320 kg] (set of two tracks)	$7,250 for a set of two tracks	---	---	---	
Tracks for a single tire (Hultdins, Inc.)	23.1 x 26 with 32 in [0.88 m] pad width	2,132 lbs [967 kg] (set of two tracks)	$4,240 for a set of two tracks	---	---	---	Hultdins, Inc.
	30.5 x 32 with 37 in [0.95 m] pad width A variety of sizes are available - consult the manufacturer for further information	2,838 lbs [1287 kg] (set of two tracks)	$6,320 for a set of two tracks				

Appendix 3. Specifications for some temporary wetland crossing options.[1, 2]

Option	Dimensions	Product weight	Approximate purchase price[3]	Installation cost or time	Installation equipment	Removal cost or time	Reference[4]
Tracks for adjacent bogie tires (Hultdins, Inc.)	Many sizes available in four different designs - consult the manufacturer for further information	Ranges from about 3000 lb [1360 kg] to about 5000 lbs [2268 kg]	Ranges from about $8,000 to about $12,000 for a set of two tracks	---	---	---	Hultdins, Inc.

[1]All data represent information obtained from published sources, promotional materials, or from personal contacts with vendors. No attempt was made by the authors to validate the accuracy of the information. This is not a complete listing; other vendors and options are available. It is important to consider your needs and applications before making a purchase or rental decision. Evaluate and compare vendor recommendations and specifications. Conform to all appropriate regulations.

[2]For some criteria, metric equivalent measurements are shown in brackets immediately following the English units. Unless otherwise specified, all costs and prices are given in $US.

[3]For commercial products, the approximate purchase price does not include shipping. Where two or more references are noted for an option, all cost information reflects information obtained from the most current source or the manufacturer.

[4]A list of commercial product vendors is presented in Appendix 1. Other references are noted in the listing of references.

APPENDIX 4

INFORMATIONAL SUMMARIES FOR TEMPORARY STREAM CROSSING OPTIONS

Fords

Description of option:

A low-water crossing that uses the streambed as part of the road or skid trail.

Area of application:

A ford is appropriate for stream crossings in which the use will be short-term and traffic levels low. A ford crossing can be used: (1) in an area where a ford crossing was previously in existence, resulting in less soil disturbance during installation, (2) in an area where the stream is straight and conforms to the shape of the natural stream channel, (3) in streams with low water where the normal summer flow does not exceed about 2 feet (0.6 m) in depth, (4) in streams with banks that are no higher than about 4 feet (1.2 m) and are not steep, (5) in an area with a natural gentle grade leading to the stream, providing a graded finished slope less than about 5:1 (horizontal to vertical), (6) in an area where firm banks and a natural rock or coarse gravel streambed capable of supporting equipment are present or where a mat (e.g., wood mat, tire mat, rubber mat) or expanded metal grating can be temporarily placed to provide that stability, and (7) if allowed by pertinent regulations. Construction and use of fords should not occur during fish spawning and migration.

Advantages:

Quick installation and removal.
Low maintenance.
Low cost.

Disadvantages:

Site criteria (e.g., low firm banks, firm streambed, straight portion of stream, low flow rates) restrict application.
Limited to use during times of low water flow.
Cannot be constructed or used during fish spawning, incubation, or migration periods.
Equipment crossing the ford should be clean and well-maintained with no oil or gas leaks. Mud and debris dragged in on skid loads, or on tracks and tires, and oil and fuel leaks contribute to polluting the water.

Source(s):

On-site materials, unless supplemental materials are required.

Recommended supplemental material:

Clean, dirt-free rock, if a firm base needs to be created on the streambed or banks.
Non-woven geotextile or woven geotextile below any imported rock, coarse gravel, or gabions that are placed on the streambed or banks.
Wood mats, tire mats, rubber mat, or expanded metal grating on the streambed and banks if the soil is weak and needs to be stabilized (see wetland crossing options).
Protecting the approaches to a ford with gravel, corduroy, wood mats, or other materials is recommended.
Non-woven geotextile if a wood mat or expanded metal grating is used.
Cable attached to an upstream tree or other fixed object to anchor wood mats or expanded metal grating.

Fords (continued)

Approximate purchase price of materials:

None. Moderate if supplemental materials are required.

Construction directions and/or diagram and time required:

Before constructing a ford crossing, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and construction. Do not construct the crossing during the time of fish spawning or migration. To facilitate construction of a ford where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement and compaction of fill much easier and avoids significant sediment movement in the stream. Create gradual approaches to the stream so that the graded finished slope does not exceed about 5:1 (horizontal to vertical). Minimize disturbance to the stream banks and bed, including minimizing the amount of vegetation removed adjacent to the water crossing. Add clean, dirt-free, rock, coarse gravel, or gabions to the stream bed as necessary. Place the clean rock, coarse gravel, or gabion on top of either a woven or non-woven geotextile. Maintain the natural shape and elevation of the stream channel to avoid obstructing the movement of fish and other aquatic organisms. During construction and use of the ford, keep out of the stream any machinery that has soil on the tires, the body, or the undercarriage of the vehicle or where oil, fuel, or lubricant is leaking. Protecting the approaches to a ford with clean gravel, corduroy, wood mats, or other materials is recommended. Before applying that surfacing material, place a woven geotextile fabric down on top of the soil to reduce sinking of the fill material. At least 12 inches (30 cm) of fill are needed on top of the geotextile. Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. Wood mats, tire mats, a rubber mat, or expanded metal grating can be used to stabilize the stream bed. It may also be desirable to place large rocks or logs or to construct a sediment trap below a ford to catch sediment introduced by use of the ford. However, this should be done only with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities. A water bar or broad-based dip should be constructed to divert water off of the road and into a vegetated area so that the road does not become a source of sediment to the stream. Revegetate all bank cuts immediately following construction to reduce erosion.

Construction time is generally less than 1 hour, as long as rock does not need to be added. One or two days may be required if extensive rock armoring is necessary. It took about 3 hours to construct a ford that was 14 feet wide x 40 feet long (4.3 m x 12.2 m) using about 30 cubic yards (22.9 m^3) of gravel on top of a woven geotextile fabric.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

If wood mats are used, the equipment must have at least a 12-foot (3.7-m) lift span.

Installation approach and time:

Not applicable.

Patent protection of product design:

No.

Culverts

Description of option:

A culvert conveys water through it under the access road. Manufactured culverts come in several shapes (round, oblong, or arched) and many sizes (lengths and diameters). They are typically made of corrugated steel, concrete, or polyethylene. An arch culvert has concrete footing walls along each side into which the steel arch is fitted.

Area of application:

Streams that have a well-defined, deep channel and that are narrow enough to require no more than three culverts for the crossing. A single large diameter culvert is better than two or more smaller culverts. Culverts should not be used in streams with a lot of woody debris because this material can get lodged in the inlet of the culvert.

Advantages:

Quick installation and removal.
Very portable and usually readily available locally.

Disadvantages:

Appropriate technical assistance from a hydrologist or engineer is required to properly size a culvert.
Requires the addition of fill (e.g., soil) around the culvert, often causing sedimentation of the stream during installation and removal of the culvert.
Frequently installed incorrectly (e.g., culvert is too short, not wide enough to carry peak loads, not buried deep enough below the road surface to support vehicular traffic and/or road maintenance, not buried deep enough into the stream channel to allow fish migration).
Cannot be installed during fish spawning, incubation, or migration periods.
Requires frequent maintenance to keep it from becoming plugged with debris.

Source(s):

Local suppliers for new culverts.
Highway departments or local road authorities may be a source for used culverts.
Local pipeline, drilling, or construction company may have used casings, pilings, and gas pipelines.

Recommended supplemental material:

Pump, if water is to be lifted over the crossing during installation.
Rock or gabions to armor the culvert inlet and outlet.
Wooden poles or lumber to facilitate proper packing immediately adjacent to the culvert.

Approximate purchase price of materials:

Moderate.

Construction directions and/or diagram and time required:

Does not apply.

Equipment needed for construction, installation, and/or removal:

Backhoe or excavator.

Installation approach and time:

Before installing a culvert, contact the appropriate regulatory agency to determine whether a permit is required and to solicit advice on sizing, placement, and installation. Culverts should not be installed during fish spawning, incubation, or migration periods. Obtain technical assistance from a hydrologist or other specialist to appropriately size a culvert. Size the culvert so that its diameter is large enough to handle anticipated flows and so that it is long enough to extend to at least the toe of the fill slope. To facilitate installation and/or removal of a culvert where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement, compaction, and/or removal of fill much easier and minimizes sediment movement in the stream. It may also be desirable to construct a sediment trap or place large rocks or logs below a culvert to catch sediment introduced by use of the crossing. This, however, should be done only with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities. Excavate a channel that is at least twice the width of the culvert to accommodate the culvert and people working around it. Both the slope and direction of the excavated channel need to follow the natural drainage. Culvert depth below the stream bed needs to meet local regulations. Pack the base of the excavated ditch before placing the culvert. Place the culvert in the ditch and then deposit fill partially around it. Pack the fill around the culvert, paying special attention to the sides and lower portion. Wooden poles or lumber may be required to facilitate proper packing immediately adjacent to the culvert. Cover the top of the culvert with fill through a series of lifts, packing each layer. The culvert should be covered with fill to a depth of 12 inches (30 cm), or one-half the diameter of the pipe, whichever is greater. Pack the side slopes of the fill. Armor culvert inlets and outlets with rock to reduce bank and channel erosion and sedimentation. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

Installation time is generally less than 2 hours, unless extensive diversion of the stream is needed.

Patent protection of product design:

No.

PVC Pipe Bundles

Description of option:

Four-inch (10.2-cm) diameter Schedule 40 polyvinyl chloride (PVC) or SDR11 high-density polyethylene (HDPE) pipes are cabled together using 3/16-inch- (4.8-mm)-diameter galvanized steel cable to form mats of varying length. A non-woven geotextile is used under the mats to provide added support to the crossing and separate it from the underlying soil.

Area of application:

Small streams or stream channels with confining banks (U-shaped channel) that are less than 10 feet (3 m) wide, 4 feet (1.2 m) deep, slow moving water, straight channel, and little, if any, cross slope of the stream bottom. Pipe bundles should not be used in a stream that has a lot of woody debris because this material can get lodged at the inlet of the pipes. Durability of the pipes during periods of extended frozen conditions is unknown.

Advantages:

Material is lightweight and readily available.
Easy to construct, install, remove, and repair.
Can be constructed by the operator.
No fill required.
Can be easily adapted to different stream channel shapes and sizes.
Low cost
Reasonably durable

Disadvantages:

Requires maintenance to keep pipes from becoming plugged.
Surface moves and is slick during use without stiff surfacing (e.g., frozen ice/snow or non-woven geotextile with wood plank, wood mat, expanded metal grating) to provide traction.
May inhibit migration of aquatic organisms.
Requires cleaning between uses to remove soil.
Standard pipe is sensitive to ultraviolet (UV) light and will degrade. Need to cover the pipe or use an ultraviolet-resistant type of pipe. Pipe should be stored out of the sun.
Use during extended frozen conditions has not been evaluated.

Source(s):

Local hardware or plumbing supply store.

Recommended supplemental material:

Non-woven geotextile placed both below to protect stream bed and facilitate removal, and above to prevent soil from dropping into the stream and reduce UV exposure of the pipes.
Running surface material (e.g., wood planking, wood mat, expanded metal grating) to provide traction.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Material to protect the approaches to the crossing if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).
A welding torch or some other means of controlling cable end fraying will increase threading speed when constructing the pipe bundle.

Approximate purchase price:

Initial construction cost of a 10-foot x 12-foot (3-m x 3.7-m) section is about $450. Two sections are needed to build a crossing for a 6-foot-wide x 2-foot-deep (1.8-m x 0.6-m) channel. Non-woven geotextile, approach stabilization material, and surfacing are extra.

Construction directions and/or diagram and time required:

Use 20-foot (6.1-m) lengths of Schedule 40 PVC or SDR11 HDPE; black for UV protection may be needed. Maximum pipe diameter should be 4 inches (10.2 cm). Saw pipes into 12-foot (3.7-m) lengths and the remaining 8-foot (2.4-m) sections in half. Drill four 1/4-inch (6.4-mm) diameter holes through the 12-foot- (3.7-m)-long pipes at locations that are 2 feet (0.6 m) and 4 feet (1.2 m) from both ends. Drill two holes through each 4-foot (1.2-m) section 1 foot (0.3 m) from each end. When constructing a 12-foot- (3.7-m)-wide bundle, alternate between two 12-foot- (3.7-m)-wide sections and two rows of 4-foot- (1.2-m)-wide sections. The two 4-foot- (1.2-m)-wide sections should be placed within each short row, 2 feet (0.6 m) from each other. String 3/16-inch (4.8-mm) galvanized steel cable through all sections. It may be necessary to control cable end fray before stringing the cable through the sections. Loops should be made at the end of each cable, extending beyond the last pipe, and secured using 3/16-inch- (4.8-mm)-diameter cable clamps. Each cabled section should be loose so that pipes can conform to the stream channel. Use tightened cable connections for a single layer crossing.

Add surfacing and approach materials as necessary.

For two people using two hand drills and one saw, about 1 hour is needed to cut, drill, and cable PVC that is 4 inches (10.2 cm) in diameter and 20 feet (6.1 m) long to build a 10-foot x 12-foot (3-m x 3.7-m) section.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

Before installing a pipe bundle crossing, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Wash off the pipes on the outside and inside at an upland location away from the crossing to remove sediment. Place non-woven geotextile on the stream bottom and layer in the bundles. Before installing the geotextile fabric on the stream banks, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. While the top and bottom layers should be cabled together into separate bundles, intermediate layers can be created using loose pipe. Place non-woven geotextile (if needed) and then surfacing material on the top. During installation, it is important to tuck the ends of all cable loops under the bundles to avoid their being caught by a vehicle or a skidded load of material. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

About 20 minutes were needed to install a PVC pipe bundle crossing using a backhoe in a 6-foot- (1.8-m)-wide, 2-foot- (0.6-m)-deep channel. The crossing consisted of non-woven geotextile along the stream bottom, two 10-foot x 12-foot (3-m x 3.7-m) sections layered above, and a wood plank on top. Each approach was protected with a wood mat.

Patent protection of product design:

No.

Ice Bridges

Description of option:

Ice bridges are a common type of winter stream crossing in areas where there are extended periods of temperatures below freezing. They are constructed by packing snow and/or pumping water onto the existing ice. Some jurisdictions permit slash or brush to be placed in the stream channel when there is no ice to build on, but this is generally undesirable because it is often difficult to remove the brush.

Area of application:

A winter crossing over open water (e.g., lake, pond, wetland), streams, and rivers with low flow rates or dry channels and existing ice. Approaches need to be low to minimize the gradient. Snow and a source of water for freezing down the packed snow are required. Because an ice bridge will take longer to melt than the stream, it may not be appropriate on streams with large or high velocity spring flows.

Advantages:

No need to remove the structure.
Can be constructed by the operator.
Low cost.

Disadvantages:

Safety concerns due to weather, water flow, and fish impacts on ice strength and thickness.
Need a source of water to apply to the snow to create sufficient ice thickness.
Need to periodically check ice condition for safety, especially toward the end of winter.
May require more than a day to build the bridge, depending on temperature.
Local jurisdictions may not allow brush or other vegetation to be incorporated into the bridge.
Soil may be pushed into the stream with the snow during construction.

Source(s):

On-site.

Recommended supplemental material:

None.

Approximate purchase price of materials:

None.

Construction directions and/or diagram and time required:

Before constructing an ice bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. For a stream crossing, select an area where the flow velocity is slow or the channel is dry or frozen, where some ice already exists on top of flowing water, and where approaches are low to minimize the gradient. Push snow into stream channel, pack it down, and then apply water. Repeat the process once the surface has hardened until the crossing reaches the desired height and width. Keep soil, brush, and other vegetation out of the crossing because the material will end up in the stream after the bridge thaws. Pack snow on the approaches to avoid disturbing the banks.

Depending on the outside temperature and the size of the desired crossing, an ice bridge can be constructed in 1 or more days.

<u>Equipment needed for construction, installation, and/or removal:</u>
Equipment to pile snow.
Pump or other means of applying water.

<u>Installation approach and time:</u>
Not applicable.

<u>Patent protection of product design:</u>
No.

Timber Bridges — Log Stringer

Description of option:

Log stringer bridges are built from trees felled in the area of construction. After abutments are set on both banks, the log stringers are placed on top of the abutments in the areas where vehicle traffic will pass. Lumber is frequently nailed to the top of the log stringers. Because engineering specifications for logs are limited, special care needs to be exercised when constructing this type of bridge.

Area of application:

Small streams or stream channels where the maximum span distance is less than 16 feet (4.9 m). A firm, stable stream bank is required.

Advantages:

Materials available on-site.
Little site preparation is usually needed.
Materials may be reusable, as long as they are still sound.
Low cost.

Disadvantages:

Need sound timbers that are at least 10 inches (25.4 cm) in diameter on the small end and are at least 8 feet (2.4 m) longer than the maximum span distance.
The stringers and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
Engineering specifications are limited for logs. Rot, decay, knots, and grain can greatly affect their strength properties. Some of these factors become more important the longer a bridge is in use, especially if the species does not have a high decay resistance.
May not support fully loaded truck, except for situations where the span distance is short.
The surface may wear quickly during skidding.
Bridge should be inspected between uses to make sure that it is still structurally sound.
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

On-site.

Recommended supplemental material:

Lumber that is 8/4 inches (2 inches or 5.1 cm) or thicker to serve as a surface deck for the bridge.
Annularly threaded (ring-shank) or helically threaded (spiral) spikes that are at least 9 inches long to attach the surface deck to the log stringers.
Galvanized steel cable that is 3/16 inch (4.8 mm) in diameter and 3/8-inch (9.5-mm) cable clamps to bind together stringers below each wheel track.
Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Abutments (e.g., logs) for both sides of the stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).
Guardrails or curbs on the bridge, if it is to be used during truck hauling.

Approximate purchase price:
Low.

Construction directions and/or diagram and time required:
Before installing a log stringer timber bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Cut six logs that are at least 10 inches (25.4 cm) in diameter on the small end to a length at least 8 feet (2.4 m) longer than the maximum distance to be spanned. More logs may be required if the tree species selected has relatively low strength (e.g., basswood, aspen), if heavier equipment (e.g., fully-loaded trucks) must be supported, and/or if the span is longer than normal. Place abutment material (e.g., two logs) on each bank parallel to the stream flow. For each wheel path, place three logs on the abutments and tie them together with three cables and clamps. Connect the two sets of log stringers together with lumber, to provide stability and to prevent debris from falling into the stream during use.
A log stringer bridge can be constructed in about 2 hours.

Equipment needed for construction, installation, and/or removal:
Standard logging equipment.

Installation approach and time:
Build the approach ramps. Stabilize to the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.
It takes about 1 hour to install a 13-foot wide x 16-foot long (4-m x 4.9-m) plank bridge.

Patent protection of product design:
No.

Timber Bridges — Solid Sawn Stringer

Description of option:

Solid sawn stringer bridges are built from new lumber, railroad ties, or demolition material. After setting abutments on both banks, the stringers are placed on top of the abutments in the areas where vehicle traffic will pass. Lumber is frequently nailed to the top of the stringers.

Area of application:

Streams or stream channels where the maximum span distance is limited by the dimensions of the available timbers, providing at least 2 feet (0.6 m) of overlap on each bank. A firm, stable stream bank is required.

Advantages:

Materials generally available locally.
Little site preparation is usually needed.
Materials may be reusable, as long as they are still sound.
For new lumber, the material is a known species and grade so structural properties are known (engineering specifications may be available).

Disadvantages:

The stringers and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
Engineering specifications are limited for railroad ties and demolition materials. Rot, decay, knots, and grain can greatly affect their strength properties. Some of these factors become more important the longer a bridge is in use, especially if the species does not have a high decay resistance.
The surface may wear quickly during skidding.
Bridge should be inspected between uses to make sure that it is still structurally sound.
Length limits its application in some instances (too short or too long).
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

Local lumber yard or demolition company.

Recommended supplemental material:

Lumber that is 8/4 inches (2 inches or 5.1 cm) or thicker to serve as a surface deck for the bridge.
Annularly threaded (ring-shank) or helically threaded (spiral) spikes that are at least 9 inches (22.9 cm) long to attach the surface deck to the solid sawn stringers.
Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Abutments (e.g., logs) for both sides of the stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).
Guardrails or curbs on the bridge, if it is to be used during truck hauling.

Approximate purchase price:

Low to moderate. About $800 to purchase hemlock lumber to construct a 13-foot-wide x 16-foot-long (4-m x 4.9-m) bridge.

Construction directions and/or diagram and time required:

Before installing a solid sawn stringer timber bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Place abutments (e.g., two or more sill logs) on each bank parallel to the stream flow. For each wheel path, place sawn timbers on the abutments. Nail lumber to the top of the bridge, tying together the two wheel paths, to provide stability and to prevent debris from falling into the stream during use.

A solid sawn stringer bridge can be constructed in about 1 hour.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

Build the approach ramps. Provide stabilization to the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

It takes about 1 hour to install a 13-foot-wide x 16-foot-long (4-m x 4.9-m) solid sawn timber bridge.

Patent protection of product design:

No.

Timber Bridges — Laminated Panel

Description of option:

Bridge panels are constructed using stress-laminated, glued-laminated (glulam), dowel-laminated, or nail-laminated materials. Generally, two panels are placed side-by-side to form the bridge. The panels are treated in some cases. After setting abutments on both banks, the panels are placed on top of the abutments in the areas where vehicle traffic will pass. If there is a space between the panels, lumber should be used to tie them together.

Area of application:

Streams or stream channels where the maximum span distance is limited by the dimensions of the panels, providing at least 2 feet (0.6 m) of overlap on each bank. A firm, stable stream bank is required.

Advantages:

Commercially available.
Little site preparation is usually needed.
Materials are generally reusable, as long as they are still sound.
For new bridges, the material is a known species and grade so structural properties are known.
Engineering specifications may be available.

Disadvantages:

Need to periodically retension steel rods in stress-laminated bridge.
Lamination may become damaged during installation, removal, and transport.
The stringers and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
The surface may wear quickly during skidding.
Panels should be inspected between uses to make sure they are still structurally sound.
Length limits its application in some instances (too short or too long).
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

Commercial vendors.

Recommended supplemental material:

Lumber that is 8/4 inches (2 inches or 5.1 cm) or thicker to connect multiple bridge panels so that debris does not fall between them.
Annularly threaded (ring-shank) or helically threaded (spiral) spikes that are at least 9 inches (22.9 cm) long to attach the surface deck.
Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Abutments (e.g., logs) for both sides of the stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).
Guardrails or curbs on the bridge if it is to be used during truck hauling.

<u>Approximate purchase price:</u>

High. Prices exceed $6,000 for a 30-foot long x 12-foot wide (9.1-m x 3.7-m) bridge.

<u>Construction directions and/or diagram and time required:</u>

Not applicable.

<u>Equipment needed for construction, installation, and/or removal:</u>

Standard logging equipment.

<u>Installation approach and time:</u>

Commercially available products generally include installation instructions.

Before installing a timber panel bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Place abutments (e.g., two or more sill logs) on each bank parallel to the stream flow. Place the bridge panels on top of the abutments. If the panels are not placed side-by-side, nail lumber to connect them together so that debris does not fall into the stream during use. Build the approach ramps. Stabilize the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge, if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

It takes about 1 hour to install a timber panel bridge.

<u>Patent protection of product design:</u>

Commercial designs are likely patented.

Used Railroad Cars and Truck Flatbeds

Description of option:

Used railroad cars (flatcars and boxcars) and truck flatbeds can be retrofitted for use as temporary bridges. The retrofitting provides additional reinforcing support in the wheel paths.

Area of application:

Wide streams or stream channels with a firm, stable bank.

Advantages:

Commercially available.
Truck trailer frames are generally locally available.
Can span wider streams, especially railroad cars.
Engineering specifications may be available.

Disadvantages:

Railroad cars, especially flatcars, are heavy.
Used railroad cars and truck flatbeds are available in a limited number of lengths, generally about 85 feet (25.9 m) long for railroad cars and about 60 feet (18.3 m) long for truck flatbeds. This limits their usefulness at narrow stream crossings.
The railroad cars, truck flatbeds, and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
Used railroad cars and truck flatbeds that are sold "as is" should be inspected before use.
Requires retrofitting of main support beams to ensure adequate strength.
The width is generally narrow (less than 12 feet [3.7 m]). Two used railroad cars or truck flatbeds may be needed.
Bridge should be inspected between uses to make sure that it is still structurally sound.
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

Commercial vendors.

Recommended supplemental material:

Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Logs or timber sills/abutments for both sides of stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).
Guardrails or curbs on the bridge if it is to be used during truck hauling.

Approximate purchase price:

High. It costs about $9,000 (FOB) to purchase a 60-foot-long x 10.5-foot-wide (18.3-m x 3.2-m) railroad flatcar and about $3,000 (FOB) to purchase a 50-foot-long x 10-foot-wide (15.2-m x 3-m) railroad boxcar.

Construction directions and/or diagram and time required:
Not applicable.

Equipment needed for construction, installation, and/or removal:
Knuckleboom loader or excavator for smaller railroad cars and truck flatbeds. A crane may be required for larger units.

Installation approach and time:
Commercially available products generally include installation instructions.
Before installing a used railroad car or truck flatbed bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Place abutments (e.g., two or more sill logs) on each bank parallel to the stream flow. Place bridge panels on top of abutments. If the bridge panels are not placed side-by-side, nail lumber to connect the panels together so that debris does not fall into the stream during use. Build the approach ramps. Stabilize the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge, if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.
It takes about 1 hour to install a used railroad car or truck flatbed bridge.

Patent protection of product design:
No.

Steel Bridges

Description of option:

Steel bridges include hinged portable bridges and modular bridges. Hinged bridges fold up for transport. Modular steel bridges are designed as a series of individual panels that interlock, forming a bridge of variable length.

Area of application:

Streams or stream channels where the maximum span distance is limited by the dimensions of the available materials. A firm, stable stream bank is required.

Advantages:

Protects the streambed
Commercially available.
Engineering specifications should be available.
Low maintenance.

Disadvantages:

High initial cost
Bulky and heavy.
The panels and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
Bridge should be inspected between uses to make sure that it is still structurally sound.
Length limits its application in some instances (too short or too long).
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

Commercial vendors.

Recommended supplemental material:

Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Logs or timber sills/abutments for both sides of stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).

Approximate purchase price:

High. About $12,600 (FOB) for a 30-foot x 13-foot (9.1-m x 4-m) hinged bridge.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Dozer, skidder, snatch block. Large bridges may require special equipment (e.g., crane).

Steel Bridges (continued)

Installation approach and time:

Commercially available products generally include installation instructions.

Before installing a steel bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Place abutments (e.g., two or more sill logs) on each bank parallel to the stream flow. Place bridge on top of abutments. Build the approach ramps. Stabilize the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

It takes about 1 hour to install a steel bridge.

Patent protection of product design:

Commercial designs are likely patented.

Pre-Stressed Concrete Bridges

Description of option:

Bridge panels are made of precast, pre-stressed concrete. Generally, two panels are placed side-by-side to form the bridge. It is important to make sure that the panels are engineered to handle the anticipated loads.

Area of application:

Streams or stream channels where the maximum span distance is limited by the dimensions of the available materials. A firm, stable stream bank is required.

Advantages:

Commercially available.
Engineering specifications should be available.
Low maintenance.

Disadvantages:

Bulky and heavy.
The panels and/or abutments may become frozen to the ground in cold weather, making them difficult to remove.
Concrete may break during handling.
Panels should be inspected between uses to make sure that it is still structurally sound.
Length limits its application in some instances (too short or too long).
Exposed steel may corrode and decrease structural strength.
They may be installed improperly (e.g., not enough overhang on stream banks, inadequate abutments), which will decrease load capacity and compromise safety.

Source(s):

Commercial vendors.
Highway departments or local road authorities may be a source for used panels.

Recommended supplemental material:

Material (e.g., logs, poles, ice, soil) to build a ramp approach on both banks.
Cable attached to upstream tree or other fixed object to anchor one end of the structure.
Logs or timber sills/abutments for both sides of stream to set the bridge on.
Material to protect the approaches to the bridge if the soil is weak (e.g., wood mats, wood planks, corduroy, or expanded metal grating with non-woven geotextile).

Approximate purchase price:

Moderate.

Construction directions and/or diagram and time required:

Not appropriate.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment. Large bridge panels may require special equipment (e.g., crane).

Installation approach and time:

Before installing a pre-stressed concrete bridge, contact the appropriate regulatory organization(s) to determine whether a permit is required and to solicit advice on placement and installation. Place abutments (e.g., two or more sill logs) on each bank parallel to the stream flow. Place bridge panels on top of abutments. Build the approach ramps. Stabilize the approaches as necessary. Attach one end of a cable to the bridge and the other end to an upstream tree or other fixed object to anchor the structure. Add guardrails or curbs to the bridge if it is to be used during truck hauling. Revegetate all bank cuts or disturbed areas near the stream immediately following construction of the crossing to reduce erosion.

It takes about 1 hour to install a pre-stressed concrete bridge.

Patent protection of product design:

No.

APPENDIX 5

INFORMATIONAL SUMMARIES FOR TEMPORARY WETLAND CROSSING OPTIONS

Wood Mats

Description of option:

Wood mats are individual cants that are strung together using two 3/16-inch (4.8-mm) galvanized steel cables to make a single-layer crossing. Four 3/16-inch (4.8-mm) cable clamps are used to tie off the ends of each cable with a loop after they have been threaded through the cants. The loops facilitate installation and removal of the mats. The length and dimension of the cants may vary according to anticipated loads and soil strength. A 10-foot- (3-m)-long, 4-inch x 4-inch (10.2-cm x 10.2-cm) cant is the recommended minimum size. Longer cants may be needed on weaker soils (e.g., soft clay or organic soils).

Area of application:

Wet mineral or sandy soils or existing road beds. Wood mats are not recommended for undisturbed peat or very weak clay soils. They require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or lateral movement of the option outside of the planned travel area. They are most appropriate for use during hauling or forwarding operations. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Materials are readily available.
Can be constructed on-site by the operator.
Conforms to uneven ground.
Easy to install and remove.
Easy to remove broken pieces by disconnecting the cable clamps and sliding off the broken section(s).

Disadvantages:

Breakage may occur if applied on top of high stumps, rocks, or uneven ground.
Log skidding and tire chains will damage the mat.
The surface can be slick, resulting in loss of traction.
A rippling or wave movement may occur on very weak soils.

Source(s):

Wood: Local sawmill or lumber supply store.
Components: Local supply store.

Recommended supplemental material:

Non-woven geotextile to place below the mats.
Expanded metal grating if the running surface becomes slick and traction is lost.
Quick links or other heavy duty connectors to link together adjacent wood mats.

Approximate purchase price:

Low. About $170 (US) to initially construct a 10-foot-long x 12-foot-wide (3-m x 3.7-m) mat using 4-inch x 4-inch (10.2-cm x 10.2-cm) cants.

Construction directions and/or diagram and time required:

Drill holes 1/4-inch (6.4-mm) in diameter through each cant about 1 to 2 feet (0.3 to 0.6 m) from each end. To reduce errors in marking and drilling time, establish one set of drilling marks on the ground and make sure that several hand drills are available. Thread a 3/16-inch (4.8-mm) galvanized steel cable through each set of holes to connect the cants. A welding torch or some other means of controlling cable end fraying will increase threading speed. Loops should be made at the end of each cable, extending beyond the last cant, and then secured with 3/16-inch (4.8-mm) diameter cable clamps. The loops are used to pick up the mat during installation and removal. The connection between the cants should be tight to reduce any rippling or wave movement when vehicles pass. Improperly tightened cable clamps can lead to slip and loss of connectivity within the mat.

Limiting mat length to about 10 feet (3 m) reduces weight and facilitates construction, installation, and removal.

About 30 minutes are needed for two people with two hand drills to drill and cable together one 10-foot x 12-foot (3-m x 3.6-m) mat from 4-inch x 4-inch (10.2-cm x 10.2-cm) material. It took three people up to 3 hours to cut, drill, and cable together a 20-foot-long x 10-foot-wide (6.1-m x 3-m) wood mat.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment that has at least a 12-foot (3.7-m) lift span.

Installation approach and time:

Wood mats should not be installed on areas with firm, high spots (e.g., stumps), large rocks, or ruts to reduce the chance that they will break during use. Before installing the non-woven geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the non-woven geotextile fabric across the area where the crossing is to be placed. Install preconstructed wood mats in front of the installation equipment. The mats can be connected to each other on-site using quick links or other heavy duty connectors to increase overall crossing strength. During installation, it is important to tuck the ends of all cable loops under the mats to avoid their being caught by a passing vehicle.

Installation takes about 15 minutes for a 10-foot x 12-foot (3-m x 3.7-m) mat, including laying down the non-woven geotextile.

Patent protection of product design:

No.

Wood Planks/Panels

Description of option:

Wood planks or panels are constructed using lumber planking to create a two-layer crossing. Parallel runners are laid down on each side where the vehicle's tires will pass and then lumber is nailed perpendicular to these runners. Annularly threaded (ring-shank) or helically threaded (spiral) spikes can be used to attach the planks. The actual running surface may be on either side of the panel, unless the nails have gone all the way through it. A panel 8-feet x 12-feet (2.4-m x 3.7-m) constructed with 3-inch x 8-inch (7.6-cm x 20.3-cm) lumber is the recommended minimum size. Lumber longer than 12 feet (3.7 m) may be needed on weaker soils (e.g., soft clay or organic soils). The number of reuses possible for planks will increase if the wood used is dense and strong. The individual planks can be either preconstructed or constructed on-site.

Area of application:

Most wetland soils, if sized appropriately. The surface width needed depends on the soil strength. Wood plank crossings require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or lateral movement of the planks outside of the planned travel area. Wood planks/panels are most appropriate for use during hauling or forwarding operations. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Can be constructed on-site by the operator.
Little lateral movement under a load.
Easy to install and remove.
Easy to replace broken pieces.

Disadvantages:

Heavy if preconstructed.
Breakage may occur if applied on top of high stumps, rocks, or uneven ground.
Log skidding and tire chains will damage the planks.
Surface may become slick when wet or when operating in fine-textured soils, resulting in loss of traction.
No space between planks to facilitate chains being placed for installation and removal.

Source(s):

Components: Local supply store.
Lumber: Local supply store or sawmill.

Recommended supplemental material:

Non-woven geotextile to place below the planks.
Four 3/16-inch (4.8-mm) galvanized steel cables formed into loops for attaching to the corners to facilitate installation and removal of the crossing.
Four 3/8-inch (9.5-mm) cable clamps to tie off the ends of each cable loop.
Eye hooks with quick links or other heavy duty connectors to link together adjacent wood planks.
Expanded metal grating, if the running surface becomes slick and traction is lost.

Approximate purchase price:

Low. Initial construction cost of an 8-foot-long x 12-foot-wide (2.4-m x 3.7-m) wood plank is about $150. Connectors and non-woven geotextile are extra.

Construction directions and/or diagram and time required:

For the planks, use 3-inch-thick x 10-inch-wide x 12-foot-long (7.5-cm x 25.4-cm x 3.7-m) lumber. Longer lumber is needed on weak soils. To create an 8-foot- (2.4-m)-long plank, the lumber runners should be 3 inches thick x 10 inches wide x 8 feet long (7.5 cm x 25.4 cm x 2.4 m). Create two parallel rows of runners on the ground, each containing three pieces that are next to each other. Place the two rows of runners 6 feet (1.8 m) apart on center or whatever width is required to support vehicle tires. Place the planks on top of the runners in a perpendicular direction, leaving a 1-inch (2.5-cm) gap between planks. Use annular or ring shank nails annularly threaded (ring-shank) or helically threaded (spiral) spikes to attach the planks to the runners. For ease of construction, starter holes should be pre-drilled into the top board. To reduce withdrawal, spikes should be placed at slight angles from vertical with one spike angled toward the traffic and one away from it. To facilitate installation and removal, attach four 3/16-inch (4.8-mm) galvanized steel cables, one to each corner. Create a loop on the exterior portion of each cable using a 3/8-inch (9.5-mm) cable clamp.

About 1 hour is needed for two people to nail together an 8-foot x 12-foot (2.4-m x 3.7-m) plank mat.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

Wood planks should not be installed on areas with firm high spots (e.g., stumps), large rocks, or ruts to reduce the chance that they will break during use. Before installing the non-woven geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the non-woven geotextile fabric across the area where the crossing is to be placed. Install the preconstructed wood plank mats in front of the installation equipment. The spacing between adjacent wood plank mats should be minimized. They can be connected to each other on-site through the use of quick links or other heavy duty connectors that are attached to the loops. During installation, it is important to tuck the ends of all cable loops under the planks to avoid their being caught by a passing vehicle.

It takes about 15 minutes to install a non-woven geotextile and a preconstructed 8-foot x 12-foot (2.4-m x 3.7-m) plank crossing.

Patent protection of product design:

No.

Wood Pallets

Description of option:

Wood pallet crossing mats are a sturdy, commercially available, multi-layered variation of a three-layer wood pallet (used for shipping or storage) that has been specially designed to support traffic. They are generally made from hardwood planks that are nailed together. They are specially designed to be interconnecting with adjacent mats, to be reversible, to allow for broken planks to be easily replaced, and to ensure that nail points won't surface. Some pallet mats are designed with the top and bottom pieces already interconnected like a traditional pallet, while others are designed with the top and bottom pieces separate, interconnecting during installation. The driving surface of a pallet should be fairly smooth and even to reduce stress to the pallets.

Area of application:

Most wetland soils, if sized appropriately. They require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the pallets outside of the planned travel area. They are most appropriate for use during hauling or forwarding operations. While large pallets may need to be cut in half, they may become too small to support equipment on undisturbed peat or very weak clay soils. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Preconstructed.
Easy to install and remove.
Some designs make it easy to replace broken pieces.

Disadvantages:

Heavy.
Breakage may occur if applied on top of high stumps, rocks, or uneven ground.
Log skidding and tire chains will damage the pallets.
Commercial products traditionally overlap along an 8-foot (2.4-m) edge which is not a wide enough surface for vehicle traffic. Need to cut the pallets in half and place the smaller sections in the wheel path. Pallets can be custom-made so that the interconnection is along the 12-foot- (3.7-m)- or 14-foot- (4.3-m)-wide edge.
A forklift may be needed to install and remove the crossing if standard logging equipment is not sufficient.

Source(s):

Commercial vendors.

Recommended supplemental material:

Non-woven geotextile to place below the pallets.
Materials to facilitate handling (e.g., cable with clamps).
Connectors to link together adjacent pallets.

Approximate purchase price:

Moderate. About $350 (FOB) for a commercial 8-foot x 16-foot (2.4-m x 4.9-m) pallet.

Construction directions and/or diagram and time required:

Not applicable. To cut a commercial product in half requires about 30 minutes or more for a 12-foot (3.7-m) length.

Equipment needed for construction, installation, and/or removal:

A forklift may be required if standard logging equipment is not sufficient.

Installation approach and time:

Wood pallets should not be installed on areas with firm high spots (e.g., stumps), large rocks, or ruts to reduce the chance that they will break during use. Before installing the non-woven geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the non-woven geotextile fabric across the area where the crossing is to be placed. If the soil in the surrounding area is of adequate strength, place the loader equipment perpendicular to the area with weak soil or use a skidder to drag the pallets into place. Otherwise, install the pallets in front of the installation equipment. Interconnect the panels as appropriate. Where the top and bottom panels of the pallets are already nailed together, installation will not require that the two panels be interconnected on-site.

Patent protection of product design:

Commercial designs are likely patented.

Bridge Decking

Description of option:

The decking of a timber bridge can be used to cross a small wetland area. Bridge panel options that do not have steel or wood stringers, such as prefabricated stress-laminated, glulam, stress-laminated, and dowel-laminated bridges, may be most appropriate and available.

Area of application:

Most wetland soils, if sized appropriately. Bridge decking requires a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades and cross slope may result in loss of traction. Support may be inadequate if the road is not fairly straight. They are most appropriate for use during hauling or forwarding operations. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Easy to install and remove.

Disadvantages:

Breakage may occur if applied on top of high stumps or rocks.
Log skidding and tire chains will damage the bridge deck.
Length limits its application in some instances (too short).

Source(s):

Commercial vendors.

Recommended supplemental material:

Non-woven geotextile to place below the bridge deck.
Lumber that is 8/4 inches (2 inches or 5.1 cm) or thicker to connect the bridge panels, if they are not placed side-by-side.
Annularly threaded (ring-shank) or helically threaded (spiral) spikes that are at least 9 inches (22.9 cm) long to attach the surface deck.

Approximate purchase price:

High. Prices exceed $6,000 for a 30-foot-long x 12-foot-wide (9.1-m x 3.7-m) bridge.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the geotextile fabric across the area where the crossing is to be placed. If the soil in the surrounding area is of adequate strength, place the installation equipment perpendicular to the area with weak soil to lift the bridge deck panels into place. Otherwise, install the bridge deck panels in front of the installation equipment.

Installation time is generally about 1 hour.

Patent protection of product design:

Commercial designs are likely patented.

Expanded Metal Grating

Description of option:

Expanded metal grating is made of nongalvanized (regular carbon) steel that is 4 feet x 10 feet by 0.618 inch (1.2 m x 3 m x 15.7 mm), with a diamond-shaped opening that is 1.33 x 5.33 inches (34 mm x 13.5 cm). This grating is relatively light and inexpensive, and the surface is rough enough to provide some traction. The crossing is built by hand-placing the grating sections in the wheel paths.

Area of application:

Most shallow wetland soils, sandy soils, or on existing roads. Expanded metal grating is not recommended for undisturbed peat or very weak clay soils. It requires a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the option outside of the planned travel area. This option is most appropriate for use during hauling or forwarding operations. Heavy duty connectors are needed to keep the grating panels from moving laterally during use of the crossing. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Lightweight.
Readily available material.
No initial construction required.
Easy to install and remove by hand.
Can be installed without equipment.
Difficult to destroy or break.
Has multiple uses (can be used alone as a crossing option or in combination with other options to provide stiffness and traction).

Disadvantages:

Bends to conform to ruts, although the grating can still be reused.
Moves if it is not interconnected.
May be difficult to connect grating if it is already bent and connectors aren't large enough.
Easily stolen.
Not recommended for use during skidding.

Source(s):

Local building supply store.
National distributors.

Recommended supplemental material:

Non-woven geotextile to place below the grating.
Quick links that are at least 3 inches x 3/8 inches (7.5 cm x 9.5 mm) in size, reinforcing rod (rebar) "staples" (in a sandy soil, staples were 0.5 inches (12.7 mm) thick, 4 feet (1.2 m) long, bent into U shape with a 6-inch (15.2-cm) center and 21-inch- (53.3-cm)-long legs), or other heavy duty connectors.

Approximate purchase price:

Low to moderate (about $100 for a 4-foot x 8-foot [1.2-m x 2.4-m] grate).

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Gloves for use during handling.

Crescent wrench to tighten or disconnect the quick links when installing or removing the crossing.

A winch may be needed during removal to lift sections if they become anchored in the soil.

Installation approach and time:

Smooth any existing ruts to reduce grating deformation or lay the grating directly over the existing vegetation on top of a non-woven geotextile. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the non-woven geotextile across surface. Lay the grating in the wheel paths, parallel to the direction of travel. Connect adjoining pieces of grating with heavy duty connectors (e.g., quick links, reinforcing rod (rebar) "staples").

About 30 minutes were needed to lay a 32-foot- (9.8-m)-long crossing, including placement of a non-woven geotextile and the grating, and installation of connectors between grating sections.

Patent protection of product design:

None for this application.

PVC and HDPE Pipe Mats and Plastic Road

Description of option:

A PVC or HDPE pipe mat is constructed using 4-inch (10.2-cm) diameter Schedule 40 PVC or HDPE SDR11 pipes that are tightly connected using 3/16-inch (4.8-mm) diameter galvanized steel cables to form panels. A plastic road is similar to the pipe mat, except that PVC or HDPE transition mats/panels are built into the design to ease the transition of tires ramping up and then back down on the approaches between the firm soil and the mat. Also, the pipes in a plastic road are interconnected using 1-inch- (2.5-cm)-diameter Schedule 80 PVC or similar-size HDPE pipe.

Area of application:

Most wetland soils, if sized appropriately. Mat width needed depends on soil strength. These options require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the mat outside of the planned travel area. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Lightweight.
Readily available materials.
Easy to install, remove, and repair by hand.
Can be constructed by the operator.

Disadvantages:

Extended use has not been evaluated.
Surface is slick and loss of traction can occur, especially on grades.
Standard pipe is sensitive to ultraviolet (UV) light and will degrade. Need to cover the pipe or use an ultraviolet-resistant type of pipe. Pipe should be stored out of the sun.
Log skidding and tire chains will damage the mats.

Source(s):

Local hardware or plumbing supply store.

Recommended supplemental material:

Non-woven geotextile below the mat and above it if a surfacing material is applied.
Running surface material (e.g., wood planking, expanded metal grating) to provide traction and to reduce the wave action on a pipe mat.
A welding torch or some other means of controlling cable end fraying.

Approximate purchase price:

Initial construction cost of a 4-foot x 12-foot (1.2-m x 3.7-m) pipe mat is about $200. Materials for an 8-foot-wide x 40-foot-long (2.4-m x 12-m) plastic road cost about $2,000. Nonwoven geotextile is extra.

Construction directions and/or diagram and time required:

The pipe mat is constructed using 20-foot (6.1-m) lengths of 4-inch (10.2-cm) diameter Schedule 40 PVC or SDR11 HDPE pipe. Black PVC for UV protection may be needed. Saw pipes into 12 foot (3.7 m) lengths and saw the remaining 8-foot (2.4-m) sections in half. Drill four 1/4-inch (6.4-mm) diameter holes through the 12-foot- (3.7-m)-long pipes at locations that are 2 feet (0.6 m) and 4 feet (1.2 m) from each end. Drill two holes through each 4-foot (1.2-m) section 1 foot (0.3 m) from each end. When constructing a 12-foot- (3.7-m)-wide pipe mat, alternate between two 12-foot- (3.7-m)-wide sections and two rows of 4-foot- (1.2-m)-wide sections. The two 4-foot- (1.2-m)-wide sections should be placed within each short row, 2 feet (0.6 m) from each other. String 3/16-inch (4.8-mm) galvanized steel cable through all sections. A welding torch or some other means of controlling cable end fraying will increase threading speed when constructing a pipe mat. Loops should be made at the end of each cable, extending beyond the last pipe, and then secured using 3/16-inch (4.8-mm) diameter cable clamps. Each cabled section should be tight.

The plastic road is constructed using 2-inch- (5.1-cm)-, 3-inch- (7.6-cm)-, and 4-inch- (10.2-cm)-diameter Schedule 40 PVC or SDR11 HDPE pipe of varying lengths, 1-inch- (2.5-cm)-diameter Schedule 80 PVC or similar-size HDPE pipes, 3/8-inch (9.5-mm) diameter galvanized steel cable, and 3/8-inch- (9.5-mm)-diameter cable clamps.

Add surfacing materials as necessary.

For two people using one drill press, about 1 hour is needed to construct a pipe mat 4 feet x 12 feet (1.2 m x 3.7 m).

Equipment needed for construction, installation, and/or removal:

Pickup truck to haul materials and two people to place the pipe mat or plastic road.

Installation approach and time:

Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the geotextile fabric across the area where the crossing is to be placed. Hand carry and place the individual mats on the geotextile.

About 30 minutes were needed to install a 30-foot x 12-foot (9.1-m x 3.7-m) pipe mat crossing, including a non-woven geotextile below the mats.

An 8-foot-wide x 40-foot-long (2.4-m x 12-m) plastic road crossing was installed by two people in about 1 hour.

Patent protection of product design:

No.

Tire Mats

Description of option:

A tire mat is a mat or panel of tires created by interconnecting tire sidewalls with corrosion-resistant fasteners. Tire treads are also used in some designs. Mats of varying length and width can be developed.

Area of application:

Most wet mineral soils with different designs for distinct soils and situations. Tire mats require a relatively level surface with grades up to 5 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the mats outside of the planned travel area. Tire mats are most appropriate for use during hauling or forwarding operations. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Relatively low maintenance.
Some designs may not require non-woven geotextile.
With appropriate care, tire mats may have a long life.

Disadvantages:

Product is very heavy and flexible, making it difficult to install and remove.
Not recommended for use when skidding material.
If the individual mats are dragged into place, it is difficult to use a non-woven geotextile below the mats.
Use of a clam loader to install or remove the mats may damage the fasteners (e.g., bolts) that hold the mats together.
Operators may not install product correctly.

Source(s):

Commercial vendor.
Homemade from waste tires and fasteners (e.g., cables, bolts).

Recommended supplemental material:

Non-woven geotextile to place below the mats, unless they are dragged into place.

Approximate purchase price:

Moderate. About $300 for a 5-foot x 10-foot (1.5-m x 3-m) mat.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Skidder (if mats are dragged), forwarder, or a truck with a loader.

Installation approach and time:

Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the geotextile fabric across the area where the crossing is to be placed. Depending on the configuration of the mats and the strength of the soil where the mats are to be installed, they can be either positioned in front of the installation equipment, laid from a perpendicular position, or dragged into place.

About 30 minutes are needed to install two 5-foot x 10-foot (1.5-m x 3-m) sections, including a non-woven geotextile.

Patent protection of product design:

Commercial designs are patented.

Corduroy

Description of option:

Corduroy is a crossing made of brush, small logs cut from low-value and noncommercial trees on-site, or mill slabs that are laid perpendicular (most often) or parallel to the direction of travel. The effect of corduroy is to spread the load over the whole length of the log or slab, effectively increasing the load-bearing area. Flotation increases with increasing surface area, especially length, of the individual pieces of corduroy. Brush corduroy will provide less flotation than small logs or mill slabs. Temporary corduroy normally is not covered with fill. During installation, application of a geotextile is recommended to separate the logs or mill slabs from the underlying soil. The geotextile should result in less corduroy being required.

Area of application:

Most wetland soils. Corduroy crossings require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the corduroy outside of the planned travel area. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Material is generally available on-site or from a local sawmill.
Easy to adjust crossing width to accommodate different soil strengths.

Disadvantages:

Installation is slow.
Difficult to remove the corduroy.
Corduroy may be dirty when removed from the crossing, making it difficult to process or sell to a forest products company.

Source(s):

On-site materials.
Slabwood, which is available from a sawmill, may be substituted for logs on some wet mineral soils.

Recommended supplemental material:

Non-woven geotextile to place below the corduroy.
Wood plank wheel path for truck hauling across corduroy.

Approximate purchase price:

Low.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the geotextile fabric across the area where the crossing is to be placed. Place bucked pieces of roundwood or mill slabwood into the wet area perpendicular to the direction of travel. The roundwood should be as wide as the weak area of soil or at least as wide as the equipment that will be using the crossing. Multiple layers of roundwood may be required.

About 45 minutes are needed to build a 12-foot-wide x 20-foot-long (3.7-m x 6.1-m) crossing using precut roundwood.

Patent protection of product design:

No.

Pole Rails

Description of option:

When attempting to support skidding or forwarding machinery equipped with high flotation or dual tires, one or more straight hardwood poles cut from on-site trees can be laid parallel to the direction of travel below each wheel. The poles can either be with or without limbs. If the poles are not delimbed, more flotation will be provided at the top of the tree where the diameter is smallest.

Area of application:

Skidding and felling machinery equipped with wide, high flotation tires and used across small mineral soil wetlands. They require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Steeper grades, cross slope, or curves may result in loss of traction or the lateral movement of the pole rails or the equipment outside of the planned travel area. This option will not work well if the machinery is equipped with conventional width tires because they are too narrow and are operated at too high a pressure to stay on top of the poles. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Easy to install.
Material is available on-site.

Disadvantages:

Only applicable if machinery has wide or dual tires.
Not advisable as an option on crossings that are much longer than one tree length.
Poles may sink in crossings that have deep wet spots, making it difficult to remove them.
Dirty poles may be difficult to process or sell to a forest products company after being removed.

Source(s):

On-site materials.

Recommended supplemental material:

Cable or chain to bind together logs, if needed.

Approximate purchase price:

Low.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Standard logging equipment.

Installation approach and time:

For each wheel path, place tree-length or full-tree sections into the wet area parallel to the direction of travel at the required distance apart for the equipments' tires. If possible, the pieces should be as long as the crossing. Individual poles should be no more than about 10 inches (25.4 cm) in diameter on the large end so that they penetrate the wet area to a sufficient depth that the tires come in contact with the soil. Two or more poles may need to be laid parallel to each other if only small diameter material is available or if sufficient flotation is not provided. For a crossing that is longer than the length of one pole, additional poles may need to be laid in a linear manner. Place the end of the pole that has the most flotation (the end of the log with the largest diameter for tree-length sections or the top of the tree for full-tree material) in the end of the crossing with the weakest soil. After placing the poles, it is important to drive across them a few times without carrying a load to get them properly seated in the soil. Remove the poles when there is no additional need to cross the wet area.

About 15 minutes are needed to build a 40-foot- (12.2-m)-long crossing using two precut 40-foot- (12.2-m)-long poles.

Patent protection of product design:

No.

Wood Aggregate

Description of option:

Wood particles ranging in size from chips to chunks (fist-size and larger) can provide cohesion and support to soft soils. Wood aggregate is used in the same way gravel might be, except that it is lighter weight and temporary because of natural deterioration.

Area of application:

The trafficability of most wet soils can be improved substantially with the application of wood aggregate. Although the wood is not removed after use of the crossing, it will naturally biodegrade over time. Wood aggregate can be used on a variety of grades, alignments, and cross slopes. It can also be used during skidding operations. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support.

Advantages:

Easy to install, lightweight, and naturally biodegrades over time.
Allows low flow drainage through the subgrade.

Disadvantages:

Cannot be easily removed, but will biodegrade over time.
Chips, sawdust, and hog fuel particles are available, but chunk-size material is not.

Source(s):

Whole-tree chipping and grinding operations, sawmills, and other wood processing plants.

Recommended supplemental material:

Non-woven geotextile to place below the wood aggregate, if warranted by conditions.

Approximate purchase price:

Competitive with local sources of gravel fill.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Standard road construction equipment (e.g., dump truck and dozer).

Installation approach and time:

A biodegradable geotextile should be used with wood aggregate that will be left in place. Before installing the geotextile fabric, smooth out any high spots and fill in any ruts to reduce the potential of the geotextile tearing during use. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with that vegetation. Roll out the geotextile fabric across the area where the crossing is to be placed. Layer the wood aggregate over the geotextile to the desired depth, which will depend on the underlying soil conditions. Between 6 and 16 inches (15 and 41 m) of wood aggregate is usually adequate.
Installation time for a 15-foot x 40-foot (4.6-m x 12.1-m) section is about 1 hour.

Patent protection of product design:

No.

Equipment with Wide Tires, Duals, Bogies, or Tire Tracks

Description of option:

These mobility options provide a method for increasing the contact area between the equipment and the soil so that the machine's weight is spread over a larger surface area. Wide or high flotation tires are wider than conventional tires, normally between about 34 and 72 inches (0.9 and 1.8 m). Dual tires consist of four conventional width tires on a single axle. Dual tires can be used on one machine axle (usually the back) or on more than one axle. A bogie system has two tires mounted in series on each end of a rocking axle assembly. It is possible to add wrap-around tracks to existing, individual, conventional width rubber tires to make them wider. For example, tracks can extend the width of a 30-inch (0.76-m) tire up to either 42 inches (1.1 m) or 53 inches (1.3 m) and extend a 44-inch (1.1-m) tire up to 65 inches (1.6 m). Similar tracks have been designed for use on the adjacent wheels of a bogie.

Area of application:

Many wetland soils. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support to the equipment.

Advantages:

Reduces the need to construct temporary crossings.
Allows movement off of designated trails.
Extends seasonal access into wet areas.
Can increase travel speed, load size, and productivity and decrease fuel consumption on wet sites.
Can decrease operational site impacts on most sites.
Tire tracks can be installed on bald, worn-out tires to improve traction and extend life.

Disadvantages:

May not be needed on every site, necessitating tire or track changes.
Loss of maneuverability and turning radius.
Extended machine width may reduce ability to move through standing timber, gates, or bridges.
Special oversize permits may be needed when transporting machinery equipped with wide tires.
Extended and/or heavy-duty axles and a heavy-duty transmission required, increasing costs.
Increased machine wear.
Operators may build bigger, heavier loads, negating the environmental benefits.
Operators may traverse soils they normally wouldn't, negating the environmental benefits.

Source(s):

Commercial vendors only.

Recommended supplemental material:

None.

Approximate purchase price:

High. Wide tires may cost more than $4,000 each. Tire tracks may cost about $7,000 for a set of two tracks.

Construction directions and/or diagram and time required:
Not applicable.

Equipment needed for construction, installation, and/or removal:
Not applicable.

Installation approach and time:
Not applicable.

Patent protection of product design:
Yes.

Equipment with Tracks

Description of option:

Tracked machines travel on steel or rubber tracks instead of tires, providing a larger area of contact between the equipment and the soil. This spreads the machine and load weight over this larger surface area, lowering static ground pressure and increasing flotation.

Area of application:

Many wetland soils. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support to the equipment.

Advantages:

Reduces the need to construct temporary crossings.
Allows movement off of designated trails.
Extends seasonal access into wet areas.
Can decrease operational site impacts on most sites.

Disadvantages:

Tracks may require frequent cleaning and maintenance.
Tracked machines are generally slower than those with wheels.
Operators may build bigger, heavier loads, negating the environmental benefits.
Operators may traverse soils they normally wouldn't, negating the environmental benefits.

Source(s):

Commercial vendors only.

Recommended supplemental material:

None.

Approximate purchase price:

Normally higher than rubber-tired equipment.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Not applicable.

Installation approach and time:

Not applicable.

Patent protection of product design:

Yes.

Lightweight Equipment

Description of option:

Lightweight equipment achieves lower ground pressure by reducing the weight of the machinery. In many cases, there is little change in contact area with the soil surface as compared to traditional-sized equipment.

Area of application:

Many wetland soils. Performance is enhanced in areas where there is an adequate root or slash mat to provide additional support to the equipment.

Advantages:

Reduces need to construct temporary crossings.
Allows movement off of designated trails.
Extends seasonal access into wet areas.
Can decrease operational site impacts on most sites.
Smaller size (width) increases the machine's ability to maneuver in thinnings without damaging residual trees.

Disadvantages:

Reduced load capacity and overall productivity.

Source(s):

Commercial vendors only.

Recommended supplemental material:

None.

Approximate purchase price:

High.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Not applicable.

Installation approach and time:

Not applicable.

Patent protection of product design:

Yes.

Equipment with Central Tire Inflation

Description of option:

Central tire inflation technology is a low ground pressure option currently for use on hauling vehicles only, but will likely be available on other equipment in the future. It allows an operator to automatically and uniformly vary the inflation pressure of the tires while the vehicle is moving. The reduced tire pressure, when used with radial ply tires, results in a longer tire "footprint," which reduces the vehicle pressures applied to the ground.

Area of application:

Trucks used for hauling across many wet mineral soils.

Advantages:

Can adjust vehicle flotation when road surface strength changes.
Reduces quality of road needed for hauling, thereby reducing road construction costs.
Increased tire traction, making it possible to operate on steeper grades without assistance.
Reduced tire wear (as much as 90 percent) and increased tire life.
Reduced truck maintenance (fewer vibration-related and frame repairs).
Reduced amount of road maintenance required.
Reduced sediment runoff from unpaved roads, due to reduced rutting and surface damage.

Disadvantages:

Cannot be installed by operator.
Change in inflation pressure is not immediate.
Potential for additional tire wear if operator fails to adjust tire pressure for existing road conditions.

Source(s):

Commercial vendors only.

Recommended supplemental material:

None.

Approximate purchase price:

The cost to retrofit a vehicle depends on the number of axles that are to be retrofitted. For an 18-wheel log truck with a three-zone system, the cost will probably exceed $16,000.

Construction directions and/or diagram and time required:

Not applicable.

Equipment needed for construction, installation, and/or removal:

Not applicable.

Installation approach and time:

Not applicable.

Patent protection of product design:

Yes.

Blinn, Charles R.; Dahlman, Rick; Hislop, Lola; Thompson, Michael A.
1998. **Temporary stream and wetland crossing options for forest management**. Gen. Tech. Rep. NC-202. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 125 p.

Discusses temporary options for crossing streams and wetland soils with forest harvesting and transportation equipment. Reviews the available literature on the environmental effects of temporary crossings. Provides an overview of regulations pertaining to temporary crossings for several jurisdictions in the Great Lakes Region.

KEY WORDS: Forest access structures, harvesting, transportation, environmental effects, regulations.

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

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