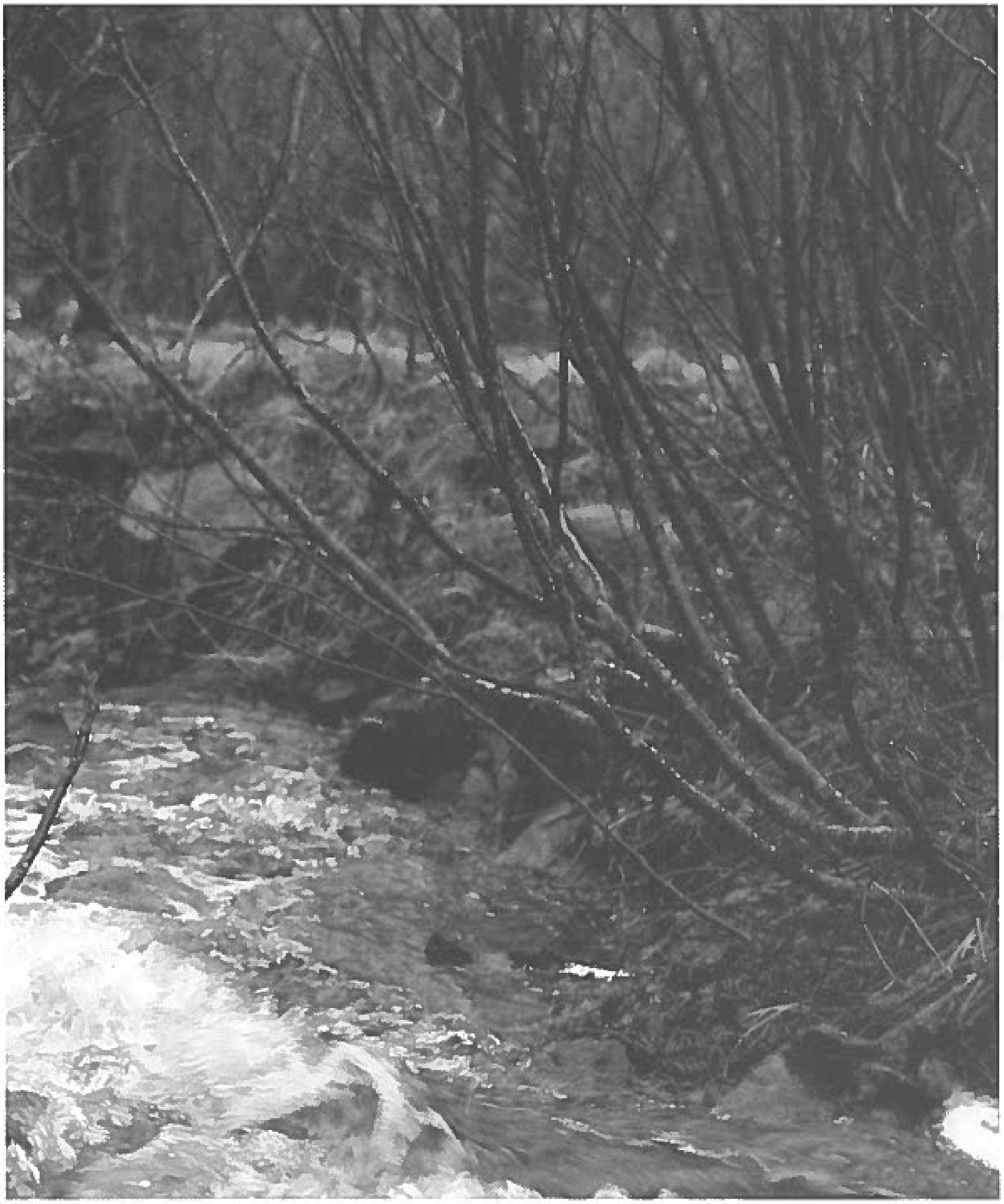
COOPERATION

COOPERATION AGREEMENT FOR FORESTRY DEVELOPMENT 1991-1995

woodlot roads stream crossings



Canada

NOVA SCOTIA

woodlot roads
stream crossings

Glen C. Brathwaite, P. Eng.
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Canada

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Introduction

Road construction has a major impact on soils, drainage and the forest ecosystem. The construction of roads, not wood harvesting, has proven to be the major cause of soil erosion and stream siltation in forest operations. Research has shown that much of the siltation in streams is the result of poorly selected and installed stream crossings. Siltation can ruin fish habitat and water quality, and measures must be taken to prevent it.

Forest Management programs are being used to guarantee an adequate supply of wood fibre in future years. These programs have resulted in the increase of road construction activities on woodlots. Good construction practices must be followed to reduce the negative impact associated with stream crossing installations on these roads.

This booklet will assist woodlot owners and operators by addressing the problems that may be encountered with stream crossings and recommending solutions. It describes selecting, locating and constructing stream crossings to help eliminate siltation. This will help ensure the protection of fish habitat and water quality in forest streams.

1.0 Selecting A Site

A stream crossing may be a culvert or a bridge. A culvert is an enclosed channel serving as a continuation of, and a substitute for, an open channel where that channel meets an artificial barrier (e.g., road embankment). In contrast, a bridge serves as a part of the road and is a definite link in a roadway surface. (Fig. 1)

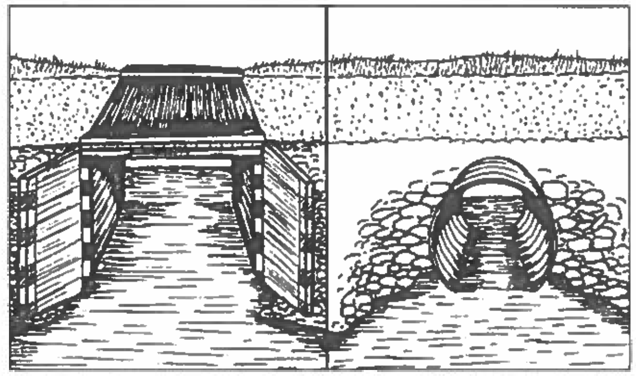

Fig. 1 Bridge Culvert

A stream is continually changing its channel, straightening or bending, scouring itself deeper, or depositing silt.

Because the crossing is a fixed link in a stream which can and often will change its location, good engineering is needed. In Nova Scotia, approval is required from the Department of the Environment before a stream crossing can be built. Engineering input at the planning stage will help in obtaining this approval.

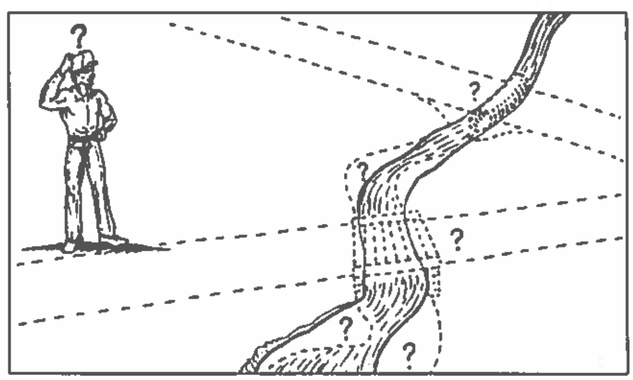

Fig. 2 Selecting a streram crossing requires good engineering.

1.1 Principles of Location

The first principle of locating a stream crossing is to provide a direct entrance and exit for water flow. Any abrupt change in the direction of water flow before or after the crossing may cause damage and create an opportunity for future washout and siltation.

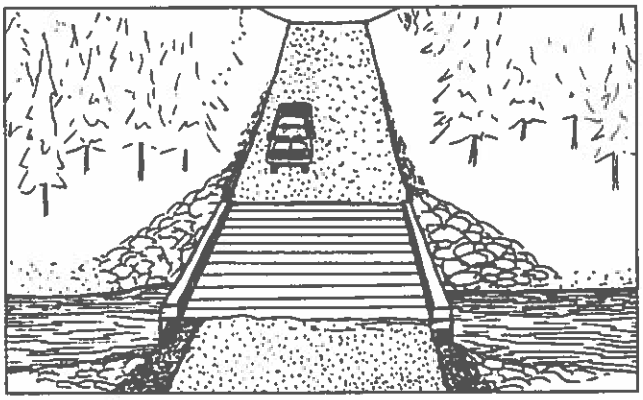

Fig. 3 Stream should enter and exit in a straight line.

The second principle is to prevent the stream from changing course immediately before it enters or immediately after it exits the structure. Otherwise, the structure may become inadequate, causing excessive scouring or ponding which can result in damage to, or washout of the structure. Such damage means expensive maintenance or replacement costs, not to mention the accompanying siltation.

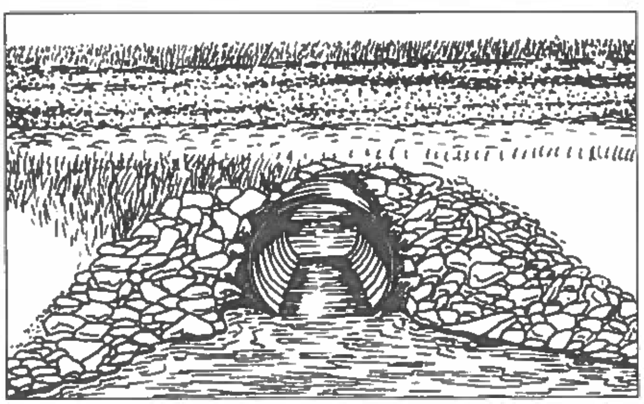

Fig. 4 Entrance and exit must be protected against erosion.

Other factors to consider when selecting a stream crossing are: type of structure, area and shape of stream, grade of stream channel, and treatment of inlet and outlet of the structure.

1.2 Characteristics of a Good Crossing

The factors that make a good crossing should be considered when selecting a possible site:

1. The crossing causes no unnecessary or excessive flooding or erosion damage;
2. The structure allows debris to flow through without any drastic change in water flow pattern above or below the structure;
3. The structure should be designed to handle storm runoff increases that could result from land clearing, land development or other change in land use;
4. The structure should be built economically, but large enough to handle peak runoff, structurally sound, and easy to maintain;
5. The outlet should be protected to prevent undermining or washout;
6. Connecting structures at the inlet and outlet should properly handle water, bed load, and floating debris at all stages of flow;
7. The structure must be positioned to allow easy entrance and a fast get-away of water flow;
8. The structure should be installed to function properly after the embankment has settled;
9. Where necessary, entrance structures should be used to screen out materials which will cause blockage and reduce water handling capacity of the structure.

The preferred type of stream crossing structures are bridges and box culverts. They allow stream velocity to remain undisturbed and reduce the risk of obstruction caused by beavers. Round culverts result in increased water velocity that restrict fish passage through the structure and cause scouring at the outlet.

1.3 Using Aerial Photographs & Maps

Various types of aerial photography and maps can be used to investigate sites for stream crossings. The most popular aerial photography available in Nova Scotia is the Vertical Colour Forest Resource Photography, flown at a scale of 1:10,000 and used primarily for forest inventory purposes.

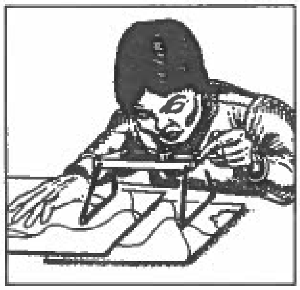

Fig. 5 Stereo-pairs viewed with the aid of a stereoscope.

The photography is flown along planned flight lines to give a 60 per cent overlap of successive photographs and a 15 per cent overlap between adjacent flight lines. When two adjoining photographs are viewed with the aid of a stereoscope, a three dimensional model of the area can be seen.

The Photo Model allows the viewer to study large land areas. Topography, drainage pattern, vegetation, soil types and terrain can be examined and tentative stream crossing sites selected for more detailed studies and final selection in the field.

A number of maps are available for preliminary selection of stream crossings. For determining and calculating drainage areas the 1:50,000 National Topographic Series (NTS) maps are useful. Another very useful map is the Orthophoto Series Maps at a scale of 1:10,000 (Fig. 6). The Orthophoto Maps are made from aerial photographs corrected for distortion and scale.

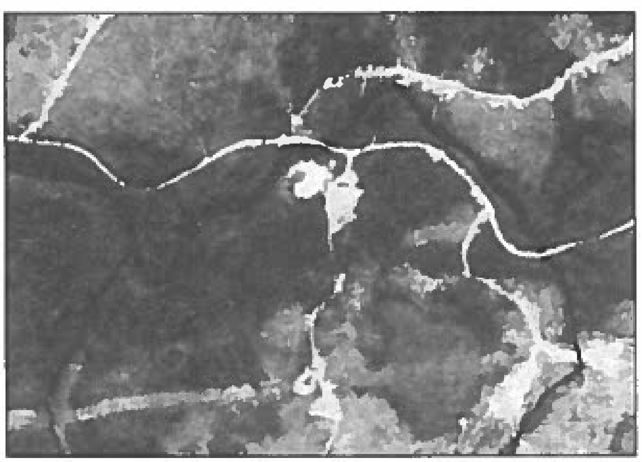

Fig. 6 Orthophoto Map.

1.4 Alignment

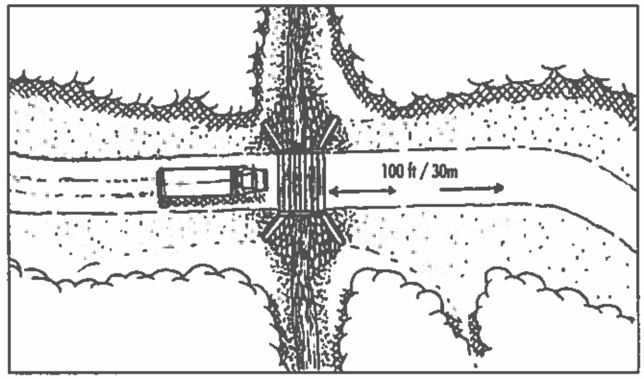

Fig. 7 Stream alignment.

Choose a site where the stream bed is straight and narrow. Such sites indicate the stream is stable and will offer the best chances of a solid base. Avoid selecting a site on or near a meander. Meanders indicate the stream bed is shifting and possibly soft based.

A recommended 100 feet (30 m) straight road approach should be provided on either side of a bridge. This makes it easier for tractor trailers to navigate the structure.

1.5 Grade

When locating and installing pipe culverts, the natural grade or slope of the stream must be maintained.

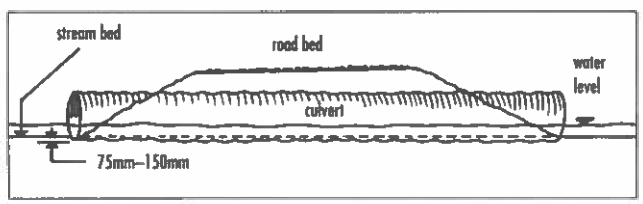

Fig. 8 Install Culvert 75 mm to 150 mm below the stream bed.

Setting the pipe 3 to 6 inches (75 mm to 150 mm) into the stream bed (Fig. 8) will maintain enough water in the bottom of the pipe at low flow to allow fish movement. Setting the pipe too low can cause it to become partially blocked with sediment. Setting too high can cause ponding. Avoid using pipes larger than 48 inches (1200 mm) in diameter. They are more difficult to install, and stream bed scouring and bank erosion is more likely. When using pipes greater than 48 inches (1200 mm), install them properly protecting against erosion and scouring. (Section 5.0)

2.0 Rainfall Runoff

Precipitation in its various forms – rain, snow, sleet or hail, is recorded as rainfall. Very intense rainfall usually occurs during storms and can result in property damage.

2.1 Hydrologic Cycle

Water is evaporated into the atmosphere and is transported over land where it condenses and falls as rain. Some of this rain is absorbed into the soil, some is intercepted by plants and animals, and some evaporates into the atmosphere. The remainder collects and flows along the earth's surface as runoff. Runoff flows into streams and rivers and will eventually find its way to lakes and oceans where it again evaporates into the atmosphere. This cycle (Fig. 9) known as the "Hydrologic Cycle" is repeated time after time.

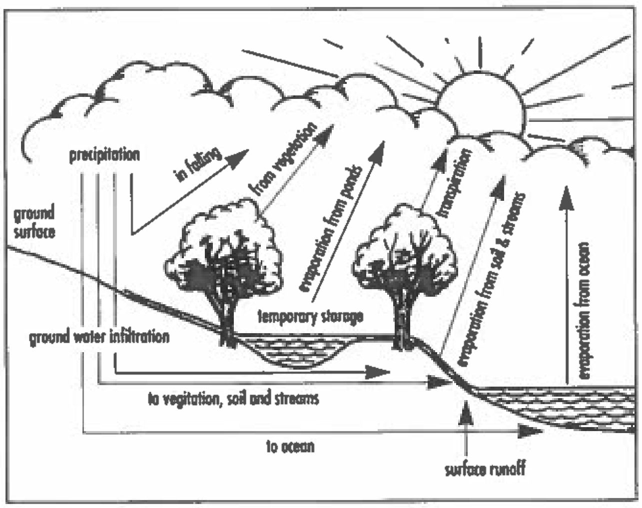

Fig. 9 The Hydrologic Cycle.

The quantity of water in the hydrologic cycle is nearly constant. Abnormally low precipitation in one area of the world is offset somewhere else by above normal precipitation. Rainfall is influenced by climate, soil and topography in an infinite variety of ways.

2.2 Peak Flow

Runoff occurs when water saturates the ground surface and exceeds the rate of evaporation.

Peak flow or maximum runoff usually occurs during the spring when melting snow creates saturated soil conditions and some runoff prior to a heavy rainfall. Records also show peak flow occurring in other seasons, the result of large rainfalls.

Peak flow can be increased by activities such as clearcutting, soil compaction by heavy equipment, land development and the creation of impermeable areas such as parking lots and buildings, and by filling depressions when land is cleared and levelled for development or agricultural purposes.

2.3 Estimating Peak Flow

A number of factors must be considered before an estimate of real storm runoff can be made.

(a) size of watershed
(b) slope of watershed
(c) type of vegetation
(d) type of soils
(e) intensity of rainfall
(f) number & size of natural reservoirs (lakes, swamps, etc.)

(a) Size of Watershed: The affective area contributing to the flood peak is the watershed area. This will be the land area draining to the crossing structure, and can be determined from a contour map. The area may be outlined by drawing a line along the height of land upstream from the crossing, and ending at the crossing, as shown in Fig. 10.

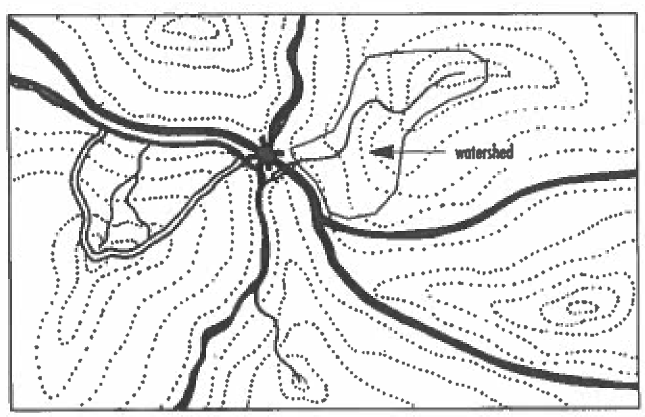

Fig. 10 Watershed Area

(b) Slope of Watershed: The average slope of the land within the watershed and the slope of the stream may be determined from a topographical map of the watershed. Storm runoff along steep slopes contributes a larger volume more quickly to the peak flow.

(c) Vegetation: Vegetation will intercept rainfall and increase evaporation. The roots of plants increase the porosity of the soil and obstruct the flow of runoff. Vegetation or ground cover will reduce the amount of runoff and in turn reduce the peak flow.

(d) Type of Soils: Some rainfall flows along the surface of the earth and some soaks into the soil. Impermeable soils will allow little or no infiltration. Runoff will therefore be higher on silts and clays and in soils where bedrock is exposed or covered with a thin layer of soil.

(e) Intensity of Rainfall: A long continuous storm of moderately heavy intensity over a large area may cause greater runoff than a more intense storm for a short period over only a portion of the drainage area. Intensity defines the quantity of the rainfall over time. *See Appendix "A"*.

(f) Number & Size of Natural Reservoirs: Lakes, swamps and depressions in the watershed act as buffers and control the peak storm runoff. Some depressions don't allow drainage away from them and will reduce the quantity of runoff reaching the stream channel. Large lakes and swamps provide a large surface area for evaporation and runoff entering them can be evaporated before flowing into the stream and river system.

There are generally three methods of determining peak runoff for watershed areas:

1. Inspecting the high water mark in existing structures and along stream banks.

2. Runoff calculations relating drainage, area and the size of stream crossing.

3. Making and collecting actual flow measurements over a period of years.

Contact the local Department of Natural Resources office for help in sizing the crossing.

3.0 Bridge or Culvert

In most cases, the size of the stream will dictate the selection of the structure. Some other factors which influence the selection are environmental considerations, the passage of fish through the structure, beaver damage, and possible property damage caused by upstream flooding.

Environmental factors and fish passage encourages the choice of a bridge or box culvert installation. These structures cause less environmental damage both during and after construction.

In some situations the physical characteristics of a crossing make it more economical to install a pipe culvert. In these cases, precautions should be taken to reduce environmental damage and provide good fish passage. (Fig. 11)

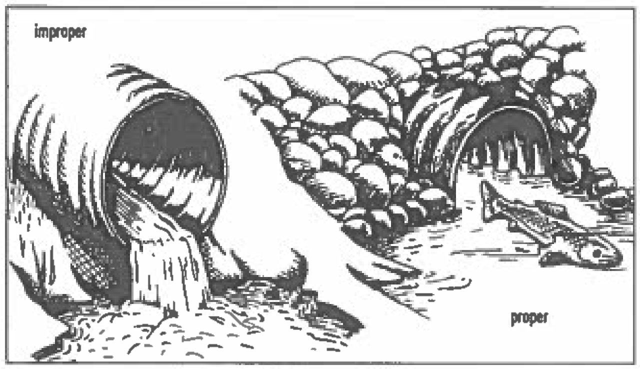

Fig. 11 Proper installation provides fish passage and reduces environmental damage.

3.1 Size of Opening

When sizing a stream crossing structure, factors such as ponding, sedimentation, debris and variable stream conditions must be considered if the structure is expected to function properly.

For woodland management roads, design of culverts should be based on a 25-year flood, where the flood water will rise a full culvert diameter at the entrance, and a 50-year flood using available head above the entrance (Fig. 12). This design would give a risk of two per cent for a storm exceeding the culvert capacity in any one year.

Size will be established by the volume of water to be passed through the culvert. The required opening can be calculated using hydraulic formulae. A good rule of thumb is to allow a one square foot opening for every 10 cubic feet per second (CFS) (0.3 m^3/sec) of runoff.

Culverts for woodlot roads may be designed to discharge:

(a) A 25-year flood without static head at the entrance.

(b) A 50-year flood utilizing the available head at the entrance; the head is a maximum of 1.5 diameters of the culvert used.

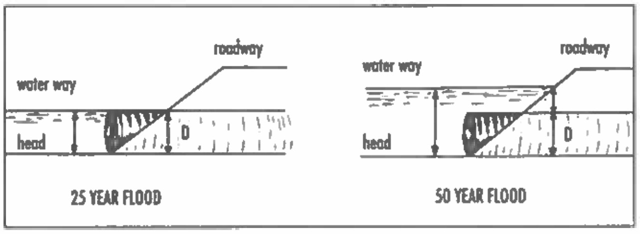

Fig. 12 Criteria for Balanced Design

3.2 Choice of Structure

The choice of stream crossing structures should be based on the size of the stream (Quantity of Flow) and site conditions.

Normally, pipe culverts may be used for stream crossings requiring a pipe diameter of 48 inches (1200 cm) or less. For larger sizes, it is usually more economical to use a box culvert or timber bridge. Bridges are normally used for streams that are wider than 8 feet (2.4 m).

Special site conditions can make it more feasible to use large pipes. Technical assistance should be obtained for installing these, otherwise serious damage may occur.

Flood damage may result if water is forced to pond behind a culvert. This problem is critical in areas where the upstream elevation changes very little over a long distance. Forcing water to pond 2 or 3 feet (0.6 or 1 m) above the normal flood height can cause extensive flooding and property damage over a large area. In such cases a multiple pipe installation could be used to provide the required cross-section area or a bridge may be necessary. Figure 13 shows how pipe arches or multiple pipes may be used to reduce flood height.

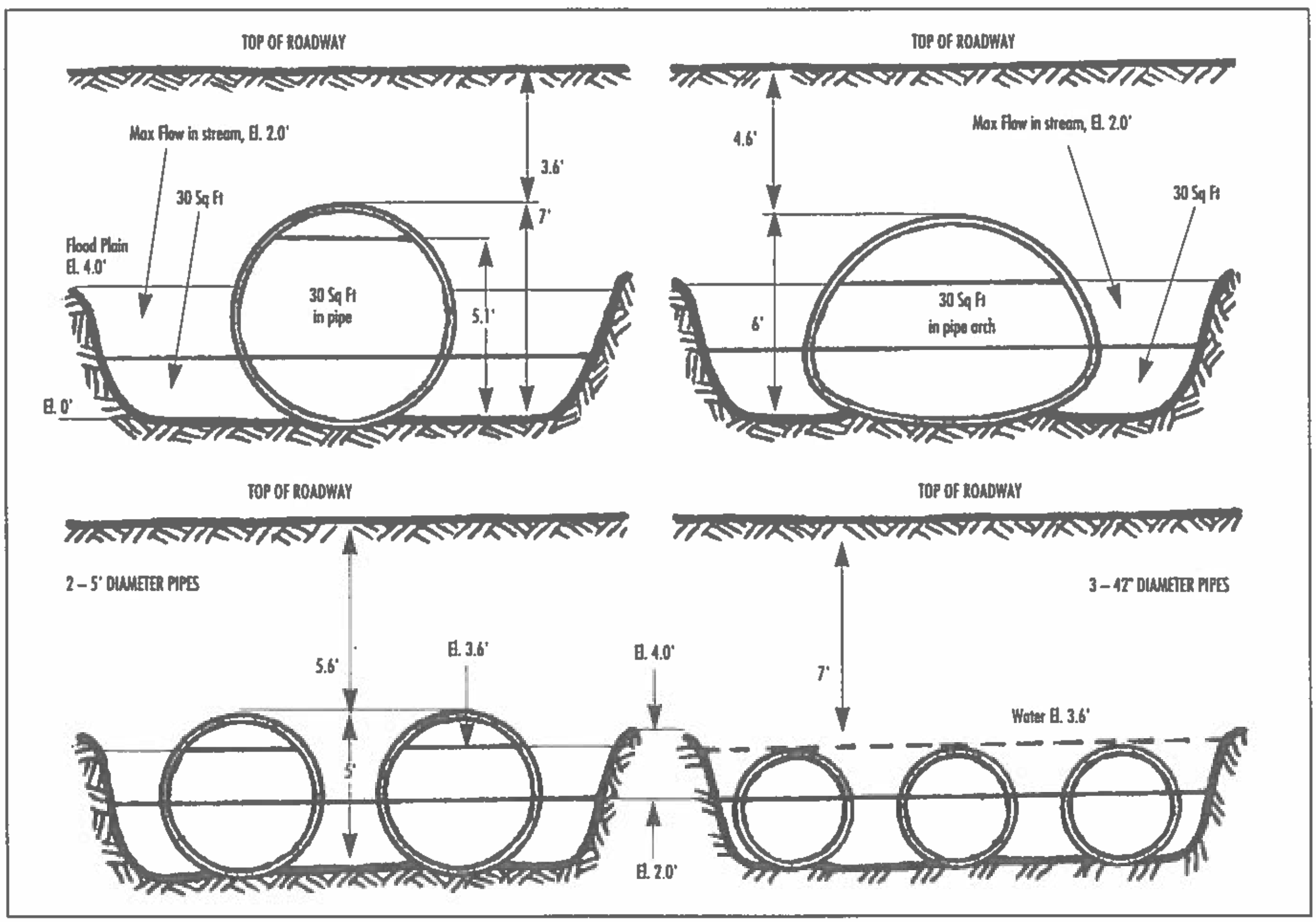

Fig. 13 Pipe arch or multiple pipes used to reduce flood height.

4.0 Flexible Pipe Culverts

Culverts are made from a variety of materials and are available in many shapes and sizes. Since the culvert is an engineering structure, choose a design of the correct thickness and strength so the pipe will function properly under normal use.

There are basically two types of pipe culverts in use: solid and flexible. The flexible pipe is corrugated and used extensively.

4.1 Soil Arch

Corrugated pipes are a flexible design and when placed in an embankment, are able to transfer a portion of their loading to the surrounding soil embankment (Fig. 14). The soil will carry as much as 40 per cent of the pipe loading. **Soil around a pipe culvert should be well graded, pit-run granular soil and should be compacted around the pipe.** ***See Appendix "B".***

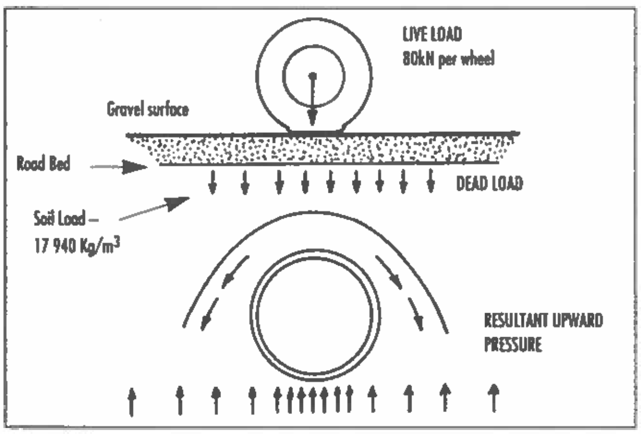

Fig. 14 Soil-Arch, load partially carried by surrounding soil.

5.0 Culvert Installation (Flexible Pipe)

The pipe culvert is designed to flex under load, and to build up side support in the surrounding soil backfill. The pipe culvert depends on the selection, placement and compaction of soil backfill and will determine how evenly load pressures are distributed. Section 8.0 explains the environmental protection required when installing a culvert.

5.1 Foundation

For best performance and service life, the culvert must be installed on foundation material that will evenly distribute the load to the sub-soil. The foundation must maintain grade and elevation of the culvert and prevent excessive stresses in the pipe structure due to localized concentration of pressures. Avoid having large rocks or boulders placed next to or under the pipe culvert.

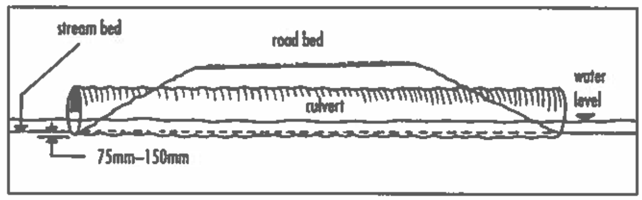

Fig. 15 Match culvert to stream grade.

The foundation material should be investigated prior to culvert installation. Muck, muskeg, peat, bedrock and rock ledge provide poor support for a culvert, and must be removed and replaced with suitable material. Avoid excessive excavation in these soil conditions whenever possible.

The type of foundation soil can be determined by inserting a metal rod or bar into the foundation (Fig. 16). The resistance to penetration will provide a good basis for assessing the soil conditions. A more accurate method will involve soil testing.

Fig. 16 Use a rod to assess foundation conditions.

5.2 Bedding

A bedding blanket of loose gravel should be used to provide uniform and continuous support for a culvert. A relatively thin mat, 6 to 12 inches (15 - 30 cm) thick, of well graded loose granular material will provide satisfactory support. In soft foundation material it may be necessary to use 24 inches (60 cm) or more of bedding to provide uniform support. **In-stream work should be done in the dry with the aid of a coffer dam and a diversion ditch. Refer to Section 8.0 before installing.**

In non-uniform or poor bearing foundation material, remove the foundation material and replace it with granular fill. The excavation should be at least three times the diameter (3xD) of the culvert in width. The depth of the excavation will depend on the bearing capacity of the soil in the foundation. The excavation can vary from a depth of 12 inches (30 cm) minimum, to 0.75xD in rocks or unyielding foundation, and 24 inches (61 cm) in soft foundation. In soft foundations, the excavation should be deep enough to equalize the upward pressure in the soil and the downward pressure of the backfill, culvert and road embankment above. A separation material such as a brush mat or geotextile fabric should be used over the foundation material before the granular bedding is placed on soft foundation, especially where high ground water is present. Fig. 17 shows how various foundation conditions are handled.

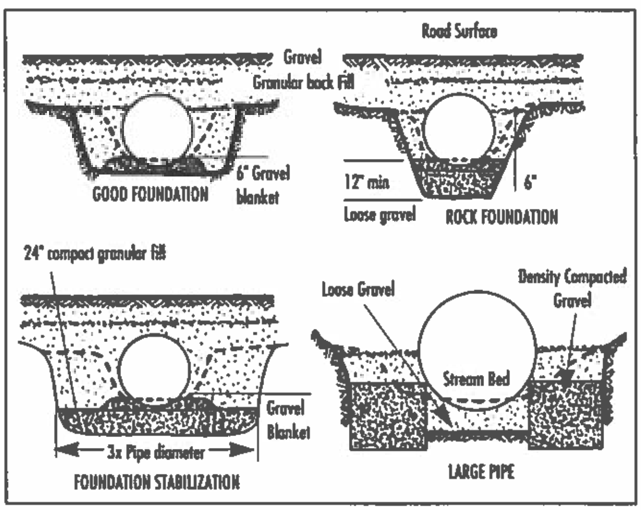

Fig. 17 Bedding on foundation material.

5.3 Camber

After construction, a roadbed will go through a period of settlement. Pipe culverts installed in the embankment will settle along with the embankment material. Because of the larger volume of fill near the center line of the embankment, settlement will be greater at the center of the roadbed.

Culverts installed improperly along a flat grade will sag at the middle. The sag will often collect sediment or retain water reducing the flow capacity of the pipe. **All culverts, especially those at stream crossings, should be cambered slightly during installation.** Cambering (Fig. 19) raises the pipe slightly at the middle without restricting flow. This is achieved by placing the bedding blanket for the upstream half of the pipe on a flat grade, and the downstream half on a slightly steeper than normal grade. The pipe will settle to the desired slope after the embankment has consolidated.

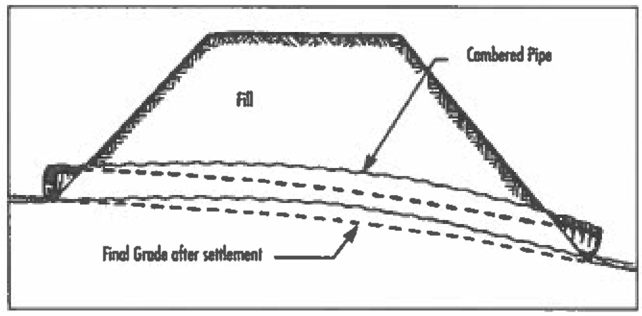

Fig. 18 Camber pipe under fill.

The amount of camber is based on soil conditions of the fill and foundation material. Some materials will settle more than others. The amount of camber should be determined for each site. A good rule-of-thumb is to provide a camber equivalent to 1 per cent of the pipe length. This estimate will usually be adequate in fair to good mineral soil.

For example, if a pipe culvert is 30 feet (9 m) long, the camber should be 30 x (1/100) = 0.3 feet or about 4 inches (10 cm). This applies to installations in good road building material.

5.4 Pipe Length

Length of the pipe for a culvert depends on roadbed width, height of road embankment and skew angle, the angle between the road and stream alignment. See Fig. 19.

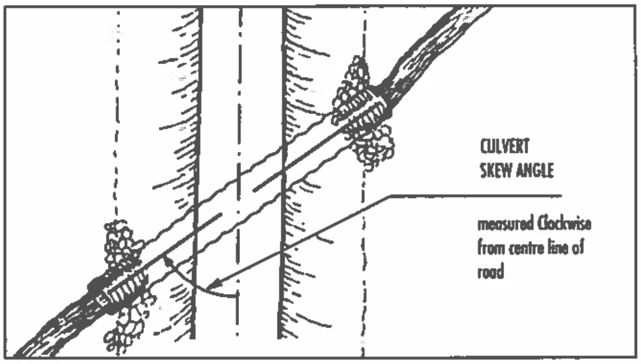

Fig. 19 Skew angle of culvert.

To ensure the end of the culvert protrudes from the embankment, 12 inches (30 cm) should be added to the calculated length. This is included in the following formula.

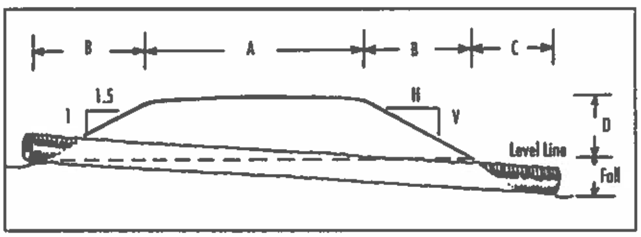

Fig. 20 Determining length of culvert.

The length of culvert, L required as shown in Figure 21, is

L = A + 2B + C + 1 (feet)

where L = Length of Culvert (feet)
A = Road Width, feet
B = (Side slope ratio) x (fill depth, D)
C = (Side slope ratio) x (fall, E)
D = Depth of fill in embankment at centerline of roadway
E = Fall or (Stream Gradient x (A + 2B))

Example: Find length of culvert required for stream crossing where road width is 15 feet, fill depth is 4 feet, side slope is 1 1/2:1 and stream grade is 4 per cent.

A=15 ft.; B=1.5 x 4 = 6 ft.; C=1.5 x 0.04 x (15+12)=1.62 ft.

then, L = A + 2B + C + 1
= 15 + (2x6) + 1.62+1 = 29.62 ft.
The culvert should be 30 feet in length.

The length of the culvert can first be determined as for installation normal to road. The skew angle is then applied to the normal length to determine the skew length.

A correction must also be made to adjust the length of the pipe, depending on size of the diameter. In this case the length is:

$$Ls = Ln \times (1/\cos ø) + D \tan ø$$

Where Ls = Skewed Length
Ln = Normal Length (perpendicular to center line)
ø = Skew Angle
D = Culvert Diameter

The length of the culvert can be reduced if the ends are rip-rapped or if headwalls are used to protect the ends. (Section 8.5)

5.5 Structural Backfill

Backfill should be well graded material (Appendix "B") capable of supporting load. A well graded pit-run gravel with a diameter less than 2 inches (5 cm) is excellent backfill material. Cohesive type materials such as clays can also be used if careful attention is given to compaction. Very fine granular materials, such as sand and silts should be avoided. Fine material may filter into the pipe, especially where ground water is high. Also, water can filter through these fine materials and flow along the length of the pipe causing the movement of these materials, resulting in washouts.

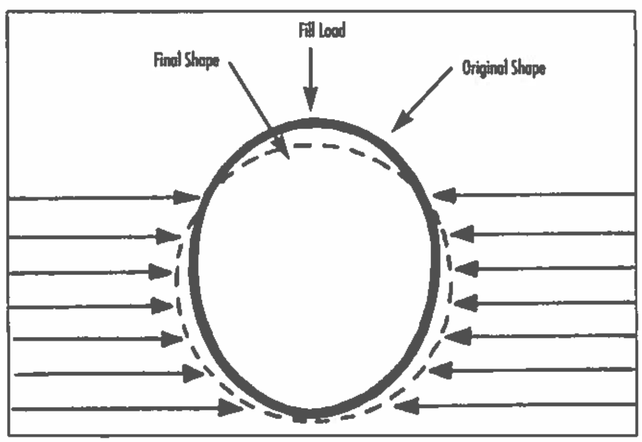

Fig. 21 Proper side support enables pipe culvert to carry load.

5.5.1 Placing Backfill

Place backfill equally on either side of the culvert. The fill should also extend at least one diameter from the face of the culvert. Material should be spread evenly in layers, 6 to 9 inches (15-23 cm) in thickness and compacted lightly, as shown in Fig. 22. Uniform compaction is essential to ensure equal distribution of pressures between culvert and soil. Place backfill in this manner until the culvert is covered. Continue placing backfill in layers and compact to road grade. Never push material under the pipe and raise it above the stream grade when starting placement of the backfill.

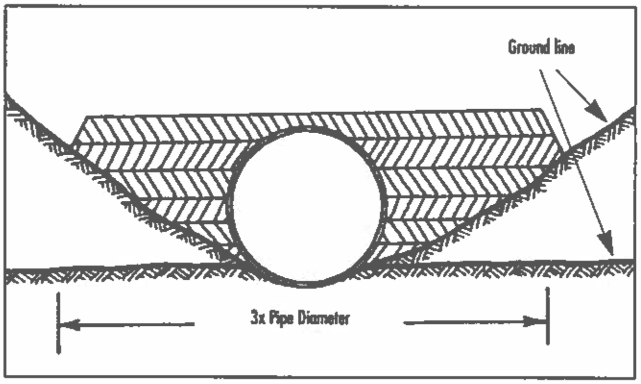

Fig. 22 Uniformly placed backfill around culvert.

Take special care to tamp backfill along the haunches (Fig. 23), the crevices formed where the pipe meets the bedding. The greatest stresses in a pipe arch are set up along the haunches.

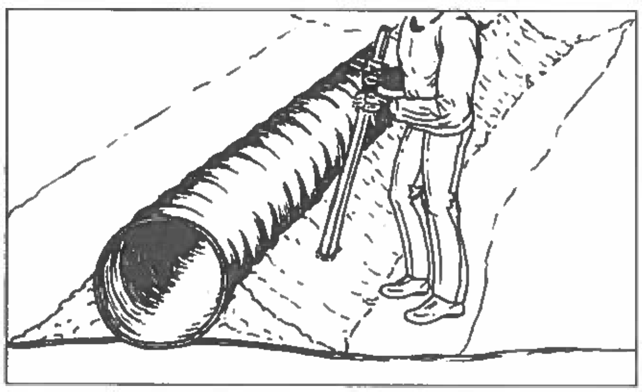

Fig. 23 Tamping under pipe haunches.

For Pipe Arches, first cover entirely with an envelope of backfill at the middle of the pipe. Placed and compacted in layers, this material will maintain the shape of the Pipe Arch and will prevent the tendency of the arch to "peak up", see Fig. 24.

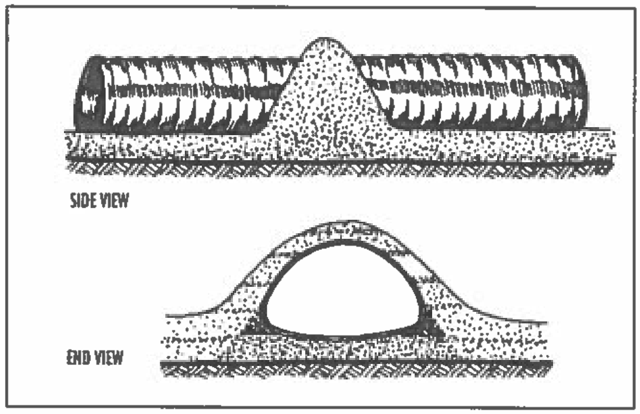

Fig. 24 Backfilling Pipe Arch.

Then place fill from the top of the arch and extend it towards each end of the culvert. Place fill evenly to ensure equal distribution on both sides of the pipe. Spread fill in layers and compact as before. The fill will help the pipe to retain its shape.

5.6 Compaction

Purchasing mechanical tamping equipment is very costly and although rental is possible, mechanical tampers may be inconvenient for site conditions. In most cases, you can do the tamping required around a culvert with easily made hand tampers. A typical hand tamper can be a simple length of 2x4 inches (38 x 89 cm); which is ideal for tamping the haunches of culverts. Hand tampers for horizontal layers should have a tamping face no greater than 6 x 6 inches (15 x 15 cm) and should weigh about 20 lbs. (9 kg).

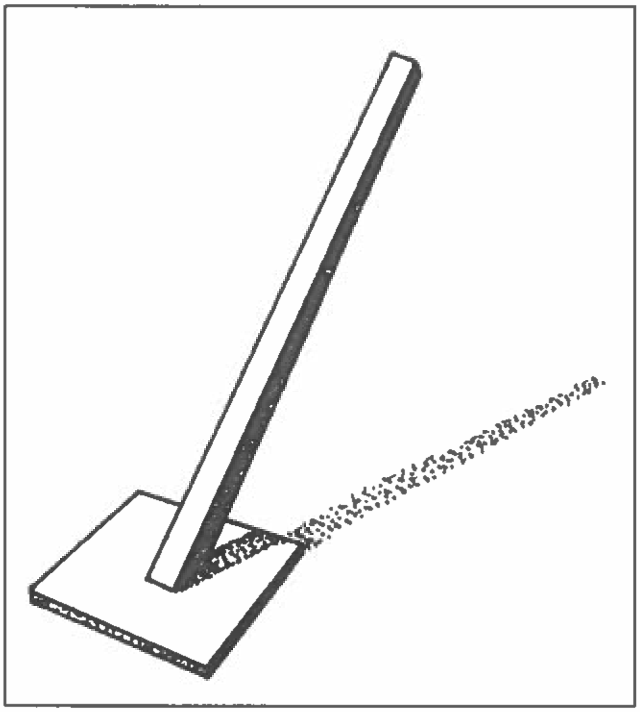

Fig. 25 Hand Tamper for compacting horizontal layers.

When mechanical tampers are used, ensure there is even compaction over the entire area. Working too near the structure should be avoided, since the tamper could damage the structure or cause the pipe to shift, lift or peak up.

When using rollers, compact the fill adjacent to the structure with a hand tamper and operate the rollers parallel to the pipe. A vibrating roller should be kept well away from the pipe.

5.7 Structural Protection

Construction equipment moving over a newly installed culvert of a new road can easily damage the culvert. The road embankment is not well compacted and settlement may not be complete enough to prevent equipment from punching through the road bed.

To prevent damage, add at least 2 feet (61 cm) of fill over culverts before construction equipment is allowed to travel over them. Failure to take this precaution will result in culverts being crushed or partially damaged. Replacement will be required after only a few years use.

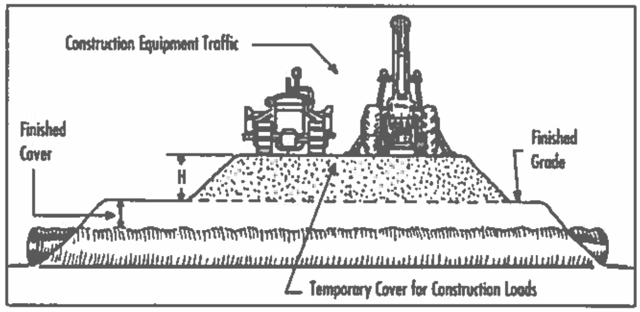

Fig. 26 Culvert Protection

5.8 Multiple Culverts

You may need to install more than one culvert in parallel at a stream crossing. Upstream flooding may limit the height of ponding water behind the culvert. The selection and installation of multiple pipes should be made carefully as there is greater risk of washouts. (If possible install a bridge or box culvert.)

Set the culverts at least 3 feet (1 m) apart to allow for good compaction between the pipes. Compaction is important in preventing washout. Set one culvert with its grade lower than the others to allow flow to concentrate in that pipe at low water flow. (Fig. 27) This will ensure ease of fish passage through the pipe. The embankment should be well protected with rip-rap to prevent erosion and possible washout. Rip-rap should also be used to protect the stream bed from scouring. (Table 8.1)

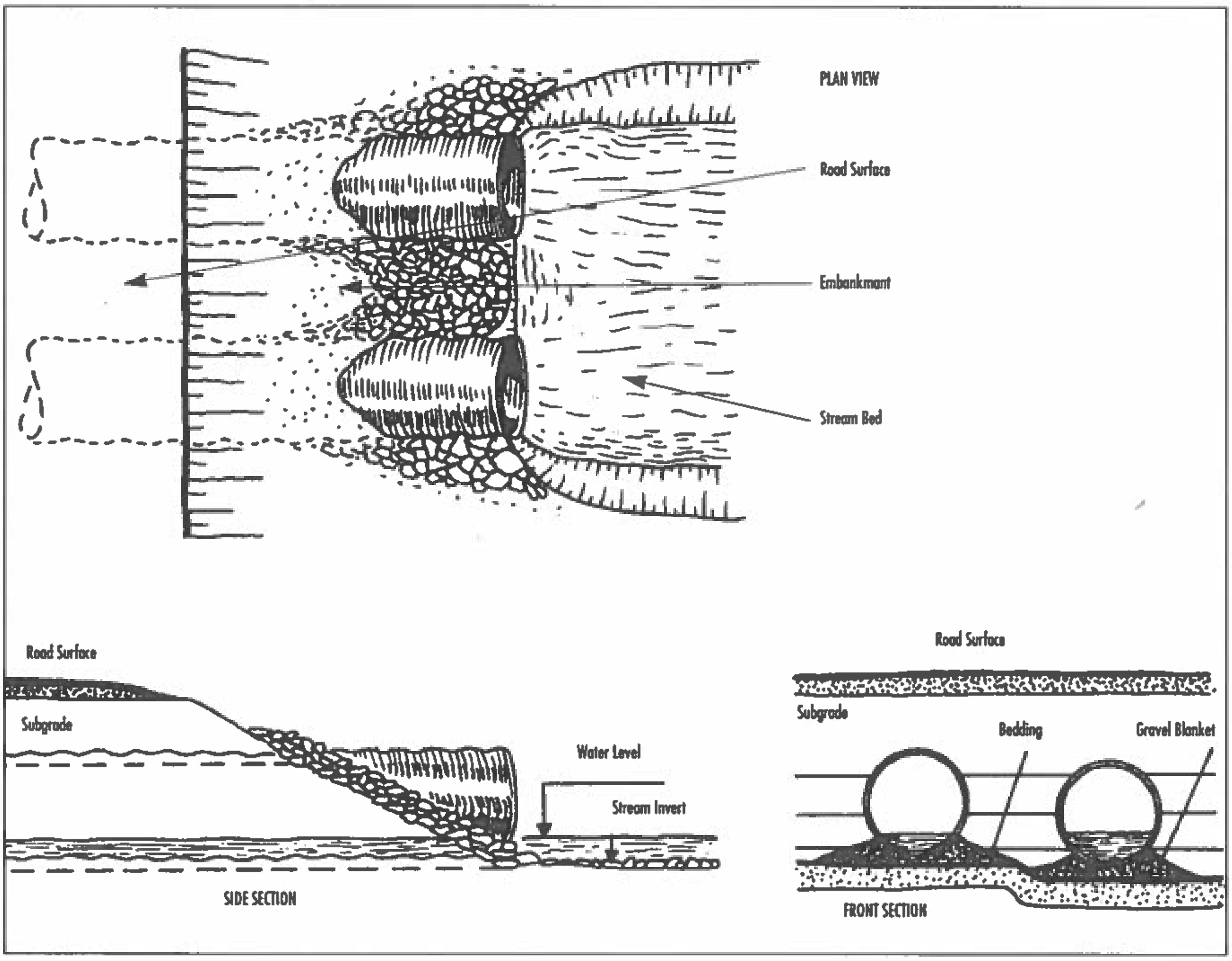

Fig. 28 Multiple Culvert Installation

6.0 Bridges and Box Culverts

Materials frequently used in the construction of bridges and box culverts are timber, steel, concrete or a combination thereof.

The design of bridges and box culverts is governed by codes which are meant to protect the public. The design must provide for a safe, reliable structure which is practical and economical to construct and maintain over its anticipated life span.

6.1 Design Code

The code in use by the Department of Natural Resources in Nova Scotia is the National Standards of Canada Code CAN/CSA-S6-88, Design of Highway Bridges. This code, prepared by the Canadian Standards Association, provides structural engineering guidelines for the design of bridges and other similar structures in timber, concrete and steel.

6.2 Loading

Bridge structures must be designed for all loads and load effects that they may be expected to carry. These loads and load effects may include:
(a) Dead Loads
(b) Live Loads
(c) Other Loads and Load Effects

(a) Dead loads refer to the permanent loading caused by the weight of the structure itself and all permanent attachments, such as the deck, stringers, and other parts.

(b) Live loads consist of the applied moving load due to vehicles and pedestrians. In the case of forest road bridges, the live load will be a tractor-trailer loaded with wood fibre.

(c) Other loads and load effects result from wind, ice, snow, earthquakes, temperature change, and settlement. The Design Code specifies how loads and load effects are to be considered in the design of the bridge structure.

6.3 Stringer Size

The size of bridge stringers varies with the length of span. The dead load of the bridge deck and stringers and all applied loads and load effects cause stresses in the stringers. The stringer must be strong enough to resist these stresses which are expressed as:
(a) Bending
(b) Shear
(c) Bearing and
(d) Buckling

6.3.1 Bending

When the deck of a bridge is loaded, the stringers will bend under the load causing stress in the stringer material. If the unit stress exceeds the unit stress resistance of the material, the stringers will break, resulting in the collapse of the bridge.

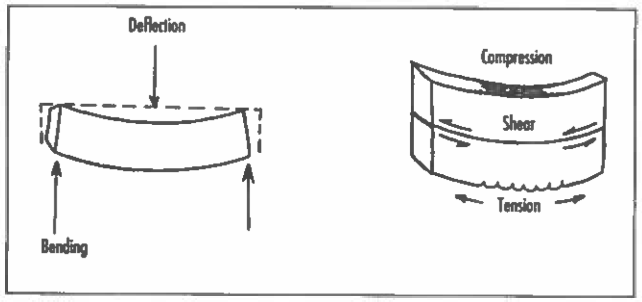

Fig. 28 Load causes stringers to bend.

Timber is often used in bridge construction for woodlot roads. All timber used in bridge construction must be visually stress graded in conformation with the National Lumber Grading Association (NLGA) Standard Grading Rules for Canadian Lumber. The allowable stresses will change with species or species group and with the specific grade of lumber. Substitution of species, species group or grade must be done only at the instruction of the design engineer.

6.3.2 Shear

A farmer when mowing hay is often stopped when a rock caught in the mower causes the shear-pin to break. On inspection, the pin appears to be sliced through by a knife. This happens when the shaft driving the mower is suddenly stopped, and the fly-wheel providing the power continues to move. The external forces acting on the pin at the plane of failure is called shear.

Similar forces are set up in the bridge stringers when a load is moved across its deck (see Fig. 29). The stringer must be strong enough to resist the shear at its supports.

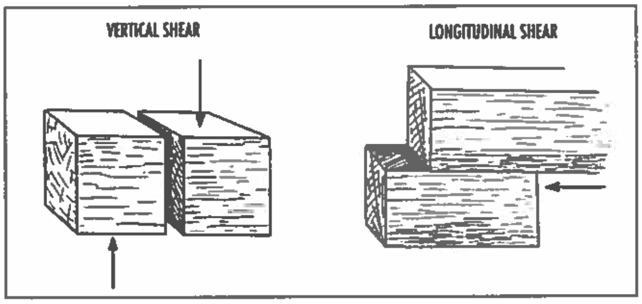

Fig. 29 Shear at plane segment.

6.3.3 Bearing

The contact area between the stringer and the abutment is called the loaded or bearing area. There is also a bearing area between the abutment and the soil. A stringer must not be crushable under the applied load.

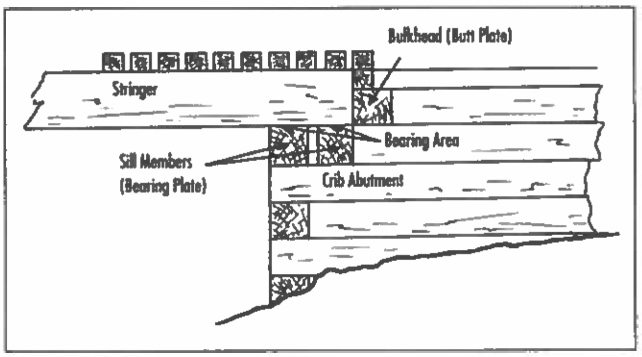

Fig. 30 Bearing area of stringer.

6.3.4 Buckling

When the depth of a beam exceeds its breadth, lateral supports are required at the points of bearing to prevent torsional rotation. If a stringer is very long, it may require lateral support at a number of points along its length to prevent rotation.

6.4 Abutment & Wing Walls

The abutments are designed to support the load of the structure plus all superimposed loads, including live load. The design must also consider resistance to overturning and sliding, and forces caused by ice floes, earthquake and hydrostatic pressure.

6.5 Deck

The deck must be rigid enough to distribute the weight of the vehicle and its load to all stringers. Each deck timber must be able to carry the total weight of a loaded truck wheel.

Woodlot road bridge decks are usually one lane width, 14 to 16 feet (4.3-4.8 m). Under normal conditions, deck timbers are 4 inches (100 mm) thick. Wheel runs are placed on the deck to protect the deck timbers from wear. Wheel runs also help distribute the truck load over the entire deck.

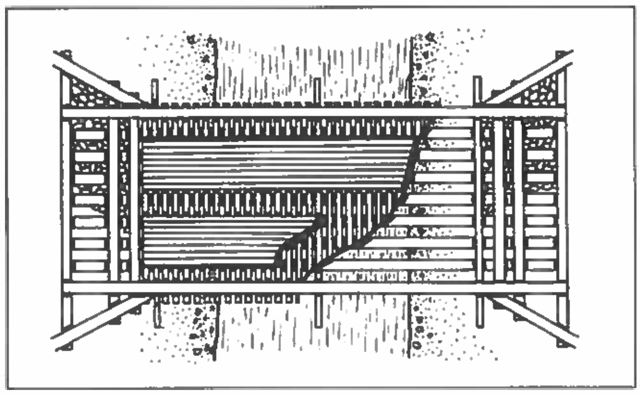

Fig. 31 Bridge Deck., Plan view

7.0 Bridge And Box Culvert Installation

Bridges and box culverts require careful installation according to the designer's specifications. Failure to adhere to guidelines can nullify the safety and versatility of the design.

Box culverts are generally used on streams that would require round culverts with diameter over 48 inches (1200 mm). The equivalent timber structure is often cheaper to install than large diameter round culverts.

Timber bridges are the popular choice for woodlot roads, and are used for spans 10 feet (3 m) and larger. Timber has been used for spans of 45 feet (14 m), but the cost of installation rises with span length because of increased stringer cost. Refer to Section 8.0 before starting installation.

7.1 Alignment and Grade

Since a bridge deck is part of the roadway, proper alignment and grade between the bridge and road approaches is necessary. Although it is best to have a road alignment intersect a stream at right angles, the roadway may intersect the stream at a skew angle. In either case, the bridge abutments must be aligned parallel to the stream banks. This may result in the abutments being staggered to match the road alignment.

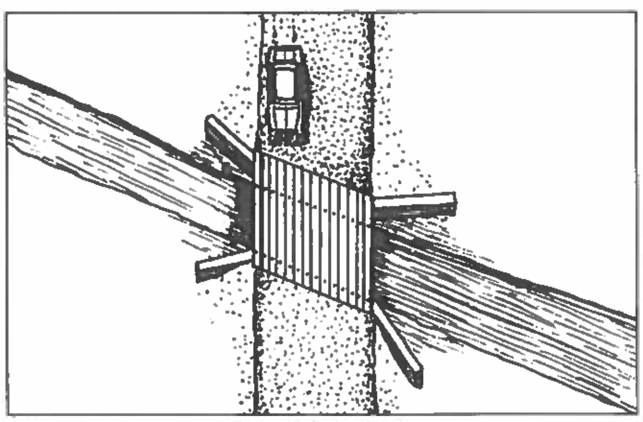

Fig. 32 Bridge aligned with roadway and stream.

A straight approach of 100 feet (30 m) minimum on either side of the bridge is recommended. This will allow vehicles, especially tractor trailers, to approach the bridge in a straight line.

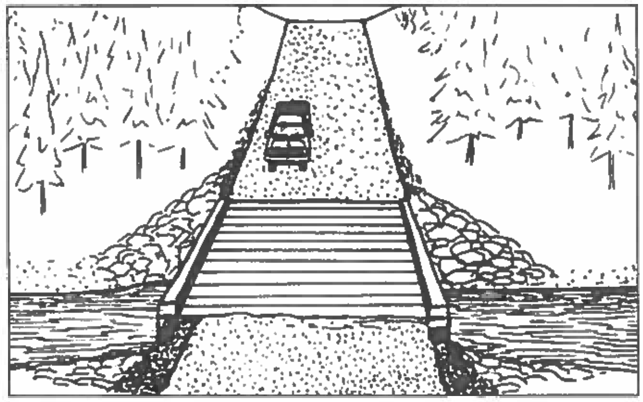

Fig. 33 Provide a straight approach.

Where possible, the grade of the bridge should be higher than the road grade. This allows flood water to cross the road under extreme flood conditions, rather than cause damage to the bridge.

7.2 Foundation

Foundation material must provide good support for the bridge abutments. In poor soil conditions, it may be necessary to increase the base area of the abutments to reduce the unit load on the foundation material. In very soft conditions, especially in areas where the ground water is high, poor foundation material can be excavated to a depth of 24 to 36 inches (60 - 90 cm) and be replaced with well graded pit run gravel or rock. Use a separation layer such as geotextile fabric before placing the gravel. Gabion mats can also be used as a base for timber abutments or for the total construction of abutments.

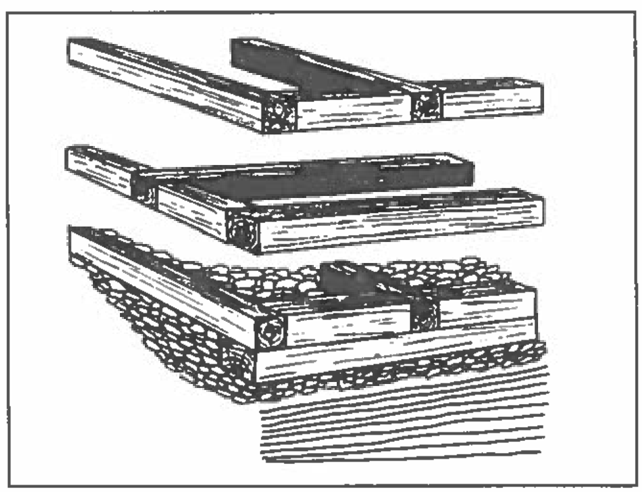

Fig. 34 Foundation

Scour damage or undercutting caused by flood water is the most common damage occurring at a bridge abutment. Where scouring may occur, the abutment should be extended at least 12 inches (30 cm) below the stream bed to provide protection. Wing walls should also start below the stream bed.

Abutments are man-made restrictions, or a bottle neck in a stream bed, that may cause flow velocity to increase and cause soil erosion. Care must, therefore, be taken to protect the stream banks near the structure. The structure will produce eddies next to the embankment which can cause soil erosion. Constructing the abutment behind the natural stream bank will negate this problem.

7.3 Bedding

At most abutments excavation will be needed to imbed the abutment in the foundation material below the bottom of the stream bed. To prevent siltation in the stream a coffer dam (Fig. 36 & 42), should be used during excavation. The excavated area should be levelled and a gravel blanket used to provide a level working surface for starting the crib work.

In bedrock, a bed can be made with concrete or timbers to provide a level footing for the crib. A sloping surface can be levelled by cutting and keying the footing into the rock to resist movement.

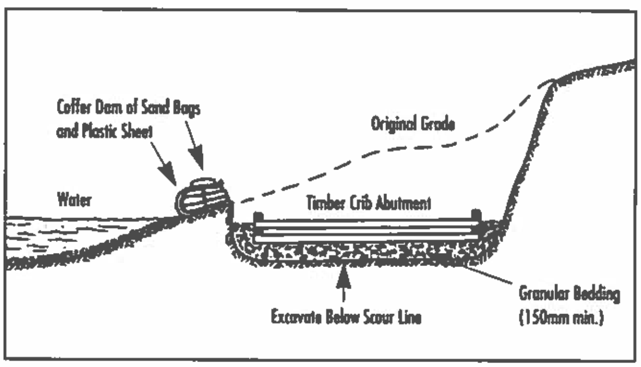

Fig. 35 Bedding and Timber Crib Abutment

7.4 Abutments

Abutments support their own weight, their share of the dead load and live load of the bridge, and the horizontal pressure of the earth backfill behind them.

The combined loads on the abutments can cause uplift at the face of the abutments, which will result in instability and possible collapse of the bridge.

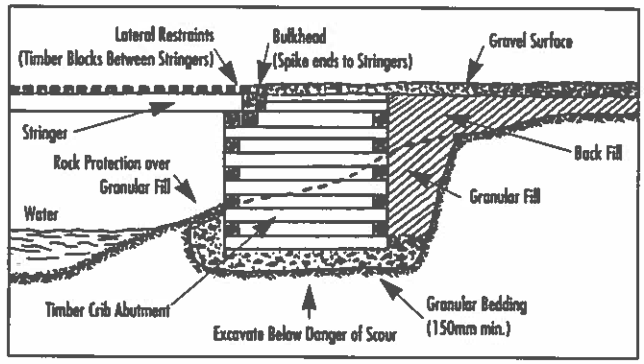

Fig. 36 Typical Timber Crib Abutment

A level footing will provide a good base for the cribs. The cribs are fastened together with drift-pins. After about 3 feet (1 m) of construction the rock backfill is started. This will help to maintain even packing of backfill throughout the construction of the cribs. See Appendix "C".

A sill is constructed at the top of the cribs to support the stringers. A butt plate should also be used to prevent the stringers from sliding over the sills. Sills are normally 18 inches (460 mm) wide, but should be constructed according to the bridge plan.

The crib can either have an open or closed face construction. When an open face is used, the rock backfill should be larger than the open space between the crib timbers. A close face construction should be used where ice floes may damage the abutments.

7.5 Stringers

For spans over 30 feet (9 m), the cost of timber stringers increase dramatically so they are used only in special cases. Hemlock, tamarack, and Douglas fir are the preferred species for stringers, but other species such as eastern fir, spruce, Jack pine, lodgepole pine and ponderosa pine can be used.

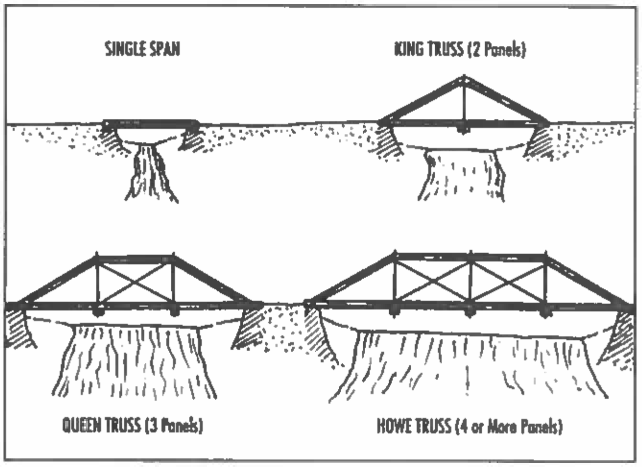

Fig. 37 Various types of bridge construction on woodlot roads.

Stringers should be placed parallel to the center line of the roadway and should extend 18 inches (45 cm) on to the sill plates. The span will be measured along the stringer from abutment face to abutment face, and should not be longer than the specified design length of span. Place diaphragms at the ends of the stringers to prevent rotation about their longitudinal axes. Stringers are equally spaced across the width of the bridge, normally with eight stringers to a 16 foot (5 m) wide timber bridge.

7.6 Deck

The deck timbers are equally spaced along the stringers, with equal overhang beyond the outside stringers as shown in Fig. 38. Rough sawn lumber can be used, but should be pressure treated. Deck timbers should be attached to each stringer with galvanized spikes which should extend into the stringers by at least 3 inches (76 mm). Sawn decking less than 4 inches (100 mm) thick is not recommended.

Use wheel runs over the deck timbers to protect the deck from wear and also to assist in distributing the load over the entire deck. Material 3 inches (75 mm) thick is recommended for wheel runs.

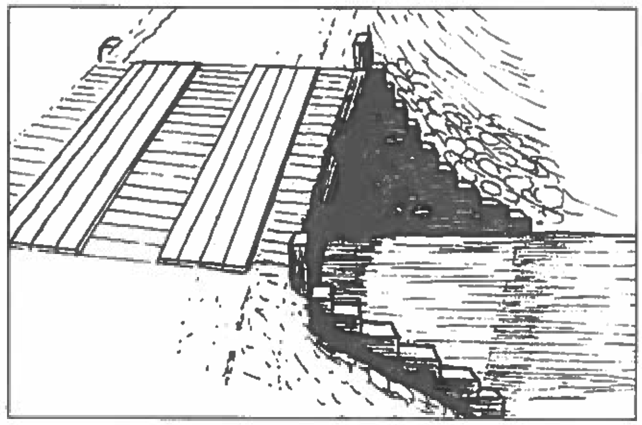

Fig. 38 Bridge Deck Showing Timber Spacing.

7.7 Backfill

Abutments should be backfilled with rock. The rock should be larger than the opening between the crib members where an open faced crib is used. For a closed face abutment, smaller rock can be included to fill the spaces between the larger rocks.

Sand or silt should not be used for backfilling bridge abutments. Even with a closed face arrangement, water can cause the backfill to be washed out from under the abutment during flood conditions, and cause bridge damage.

7.8 Box Culverts

The basic structure of a box culvert is very similar to that of a bridge (see Fig. 39). The sidewalls can be considered abutment faces without the wing walls.

This design provides for tie-backs into the embankment from the side walls, similar to a bridge abutment. The approach to construction should be similar to that for a bridge. Backfill used around the tie-backs should be granular and well packed to provide a counter-balance for the side walls.

In soft foundation conditions, a footing should be provided for the sidewall. In places where scouring is likely, the use of wing-walls is preferred.

Provisions are made for covering the deck with granular backfill. The length of the culvert will depend on the amount of fill cover over the deck. Cautions should be taken against scouring and siltation at the toe of the embankment.

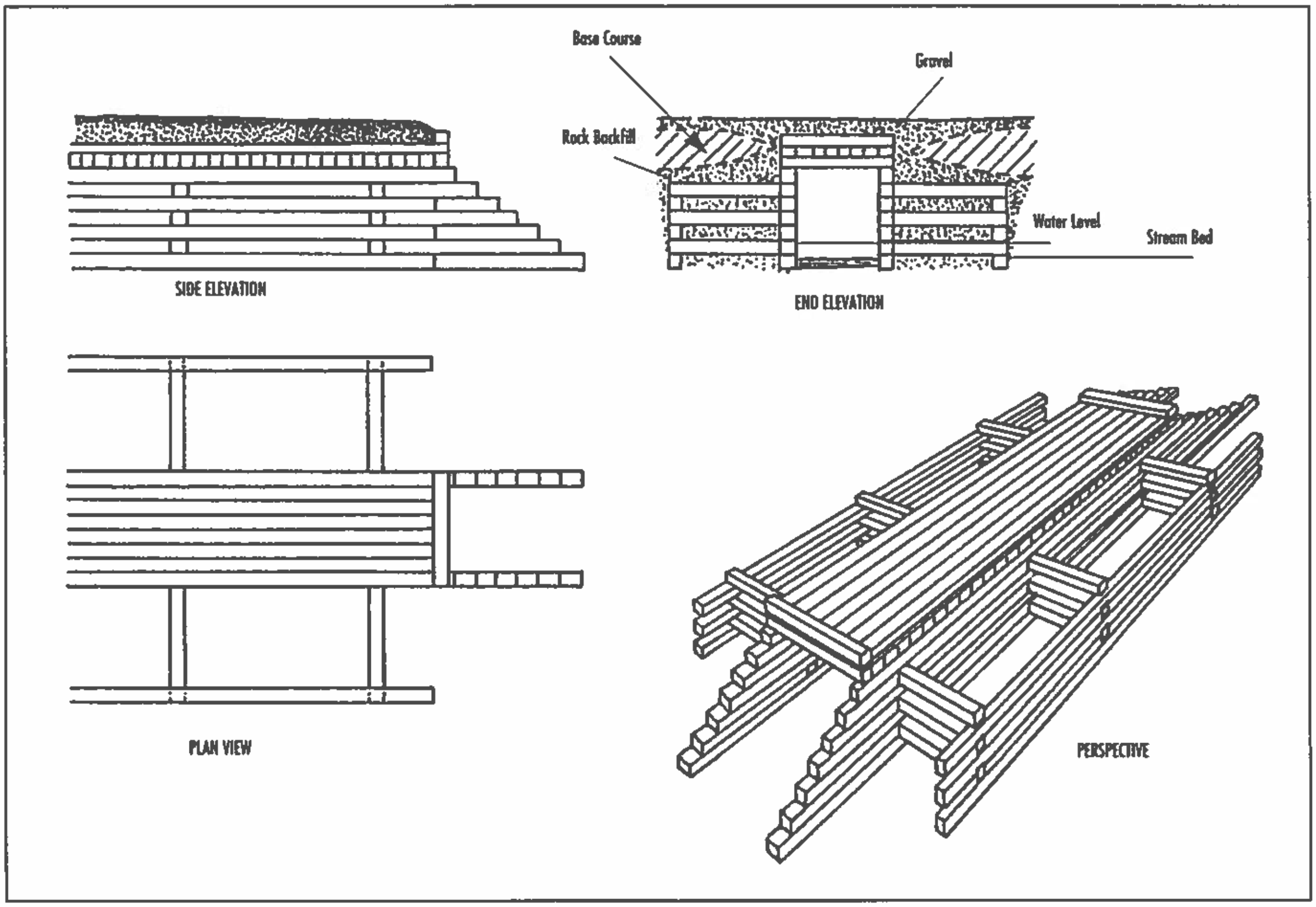

Fig. 39 Box Culvert - Typical.

7.9 Temporary Crossings

Fording streams should be avoided because of the damage that can be caused to the stream bed and banks.

In cases where it is necessary to cross a stream, but the construction of a permanent road is not feasible, a portable bridge or temporary structure may be used.

A permit may be required, therefore, the Department of the Environment should be contacted.

The temporary structure can be made of logs fastened together and placed on a mud sill constructed behind the stream banks. (See Fig. 40). Manufactured reusable structures are also available.

The approaches to the structure should be protected with gravel or a brush mat. Precautions should be taken to prevent erosion and siltation.

Temporary crossings should be used during low stream flow and should be removed immediately after access is no longer required. When the structure is removed, repair wheel ruts and any other damage that may cause siltation in the stream.

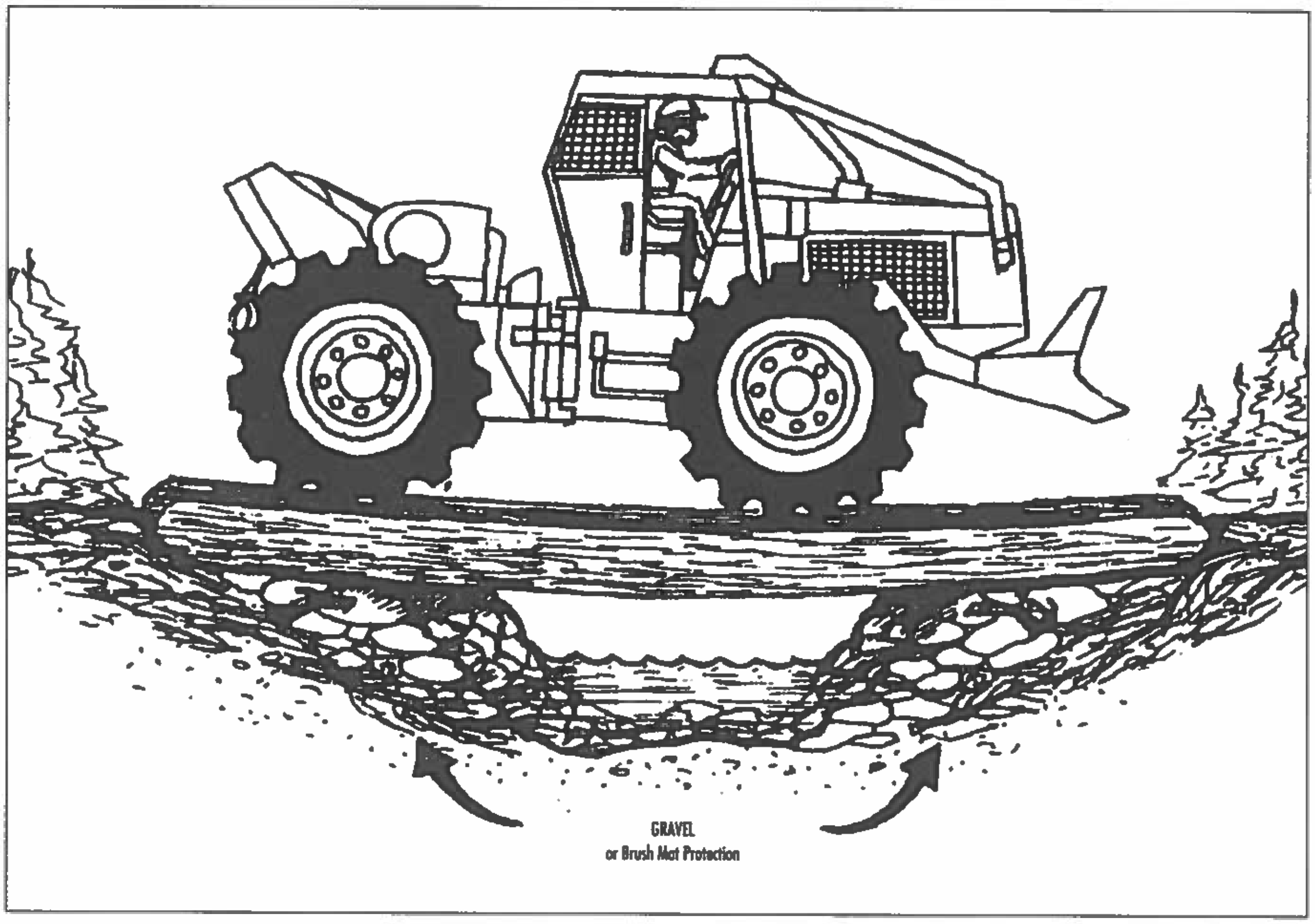

Fig. 40 Temporary Log Bridges

8.0 Environmental Protection

Contractors should be aware of the effects road construction has on the forest environment. Steps should be taken to minimize the impact of woodlot roads construction on streams. The effect of erosion and siltation is two-fold. Firstly, it causes stream pollution, destroying fish habitat and reducing water quality. Secondly, it causes road damage which results in high maintenance costs. **The booklet "Environmental Standards for the Construction of Forest Roads and Fire Ponds in Nova Scotia" published by the Department of the Environment should be read and carefully followed.**

8.1 No-Grub Zone

All grubbing activity should be stopped a minimum of 100 feet (30 m) from the banks of a stream. On smaller watercourses, grubbing should be stopped far enough back to allow silt to settle out of run-off water before it can enter the watercourse.

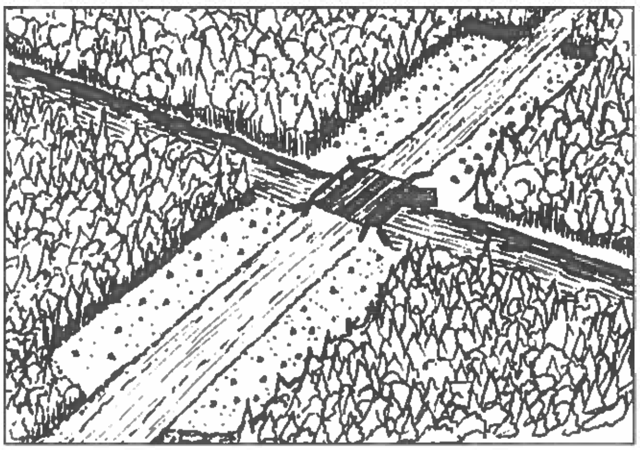

Fig. 41 No-Grub Zone with Take Off Ditches.
30m (100ft) should be clear on each side of the stream crossing.

Take-off ditches must be constructed at the beginning of the no-grub zone. Take-off ditches move storm water away from the road and deposit it onto the forest floor where silt may be filtered out before the water reaches a stream.

8.2 Coffer Dams & Stream Diversions

A coffer dam is a watertight temporary structure used in a waterway to separate the water from a work area. Coffer dams should be used to prevent silting in waterways when construction work such as building bridge abutments and culvert installation must be done in the stream bed when water is present.

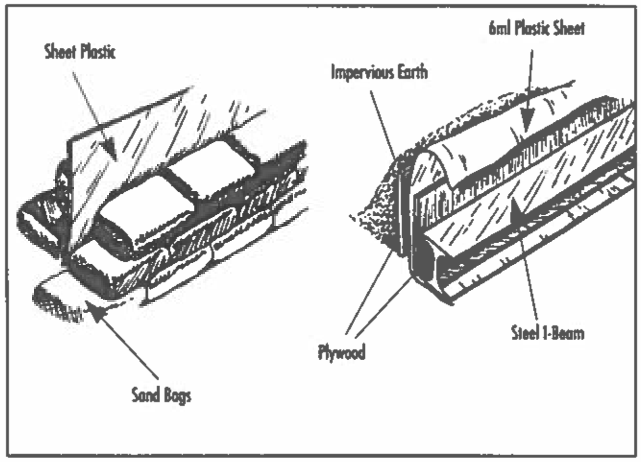

Fig. 42 Coffer Dam.

Coffer dams are to be constructed of erosion resistant material. Generally, a combination of plastic and sandbags or plastic and plywood is used. Streambed material is not to be used for constructing coffer dams.

When the coffer dam is in place, the work area is pumped dry. Any water pumped from the work area should be directed into a sediment basin or over the forest floor so the water does not re-enter the stream unfiltered.

Coffer dams should be constructed so that no more than two-thirds of the normal stream flow is cut off. In cases where it is necessary to restrict a larger area, a stream diversion should be considered.

A permit must be obtained from the Nova Scotia Department of the Environment before a stream diversion is made.

Start excavation for the diversion ditch downstream. Continue upstream leaving an earth plug between the stream and the head of the diversion ditch. The ditch must then be lined with a plastic sheet to prevent erosion. The plastic sheet should be pegged along the edge of the diversion ditch, and stones and gravel placed on the plastic along the ditch to reduce the speed of the water. Enough plastic should be left at the head of the ditch to cover the exposed earth after the earth-plug is removed. The ditch should be large enough to carry at least one-third of the water flow in the stream, but should normally match the natural channel width and depth.

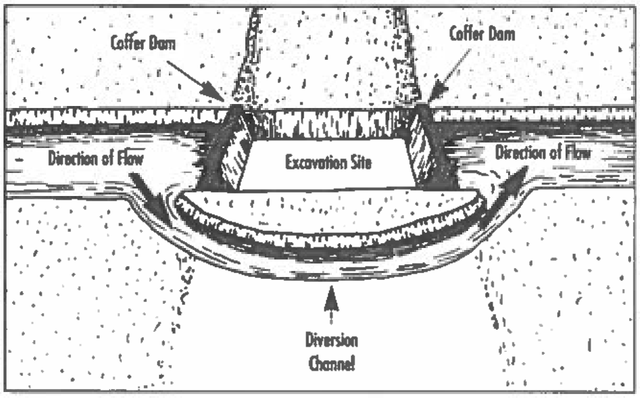

Fig. 43 Temporary Diversion Ditch.

Coffer dams are used with a temporary diversion ditch to restrict water movement into the work area. After the work is completed and measures have been taken to prevent soil erosion, the water is diverted back to the stream by removing the coffer dam and plugging the diversion ditch. All material imported for the construction of the coffer dam must be removed from the stream after the work is complete.

8.3 Fish Passage

Fish depend on streams for spawning and rearing as well as for food and nutrients. Research has shown that fish use small streams and intermittent streams more than larger streams for spawning. If their movement from larger streams to smaller streams is restricted by poorly installed culverts, debris and dams, the most productive fish spawning areas will be lost.

It is important to ensure that a large enough volume of water is present in culverts at low water flow to allow fish to move through these structures and upstream to spawning areas. Also, all debris and other material that will block water flow should be removed after a construction job is completed. All streams should be left in good condition, and disturbance caused by construction should be kept to a minimum.

8.4 Stream Bed and Bank

Sudden increases in velocity in the water flow result in eddie currents which can cause erosion. The increase in speed of water through pipe culverts causes scouring along the stream bed. This is noticeable at the outlet end of a pipe culvert if no stream bed protection is provided. (Fig. 44)

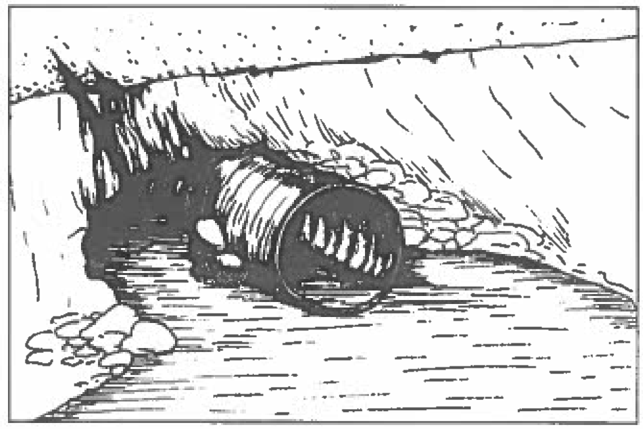

Fig. 44 Scour at Culvert

A rock apron should be placed, at the outlet end of the culvert structure, along the stream bed. The rock should be at least 6 inches (15 cm) in diameter and should extend downstream relative to the diameter of the culvert as shown in Table 8.1. The length of rock protection should be 4.5 to 6 times the diameter of a pipe culvert, or about the same as the width of a box culvert.

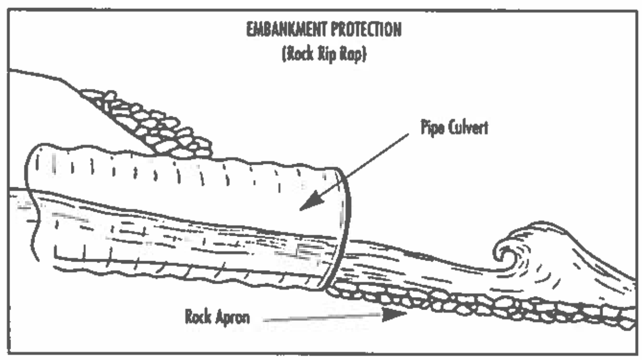

Fig. 45 Stream bed and bank protection using rip-rap.

Table 8.1 Culvert Outlet Protection

Culvert Diameter	Length of Rock Apron	Apron Thickness
18 ins. (450 mm)	7 ft. (2.1 m)	12 ins. (300 mm)
24 600	9 2.7	12 ins. (300 mm)
30 760	11 3.3	12 ins. (300 mm)
36 900	13 4.0	12 ins. (300 mm)
48 1200	18 5.5	12 ins. (300 mm)

To protect stream banks, the rock should extend up their sides. For bridge structures, it is more important to protect the fill embankment. Rock can be placed along the fill embankment from the toe of the slope to above the expected flood water level for protection. Where the soil is sandy or highly erodible, use geotextile fabric to provide a protective blanket and separation layer over the bank and bed before the rock is placed. Large boulders used for rip-rap provide little or no protection if the spaces between them are not filled with smaller rocks. **Grass seed can be planted along the slopes of the fill embankment to reduce erosion.**

8.5 End Treatment of Culverts

Culverts can be made to work better by the treatment utilized at their ends. In most cases, culverts are installed with their ends projecting from the fill. Greatly improved water handling capacity can be made by constructing headwalls around the ends of the culvert. A headwall is a vertical wall around the end of the culvert and extending back into the slopes of the road embankment. Headwalls are similar to wingwalls, but extend parallel to the road alignment. Headwalls also allow for the use of shorter culverts.

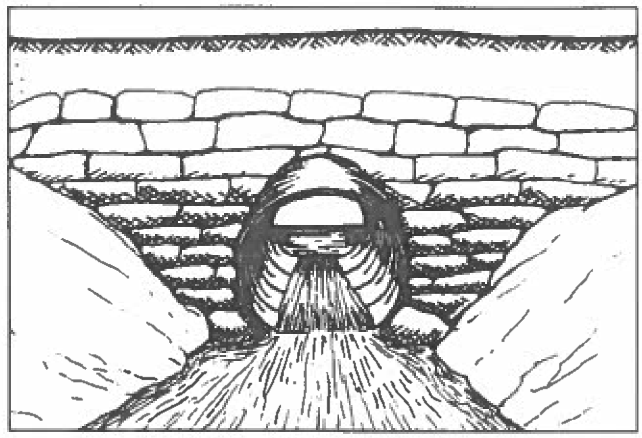

Fig. 46 Culvert with headwalls.

Wingwalls can also be constructed around the ends of culverts, and are considered a better method of end treatments than headwalls, since they facilitate better flow through the culvert.

The culvert ends can also be bevelled to conform to the fill slope. This type of treatment is often used on highway pipe culverts. Headwalls are used more often for concrete box culverts on highway roads.

8.6 Debris Control

One major problem with any culvert is the possibility of debris blocking the entrance during floods. If this occurs, water will flow over the embankment and can cause road damage or wash out the structure.

Larger culverts and more expensive installations can be protected by screens built at or near the culvert entrance. These screens should be easy to clear and be reasonably self-cleaning during periods of easy flow.

8.7 Beaver Damage

Many a forest road maintenance foreman is faced with the endless task of cleaning culverts and stream crossings plugged with a maze of sticks, leaves, and mud placed by one of the most tenacious animals known to man, the beaver. The plugged crossing will often cause water to flow over the embankment. This results in road damage and often the loss of the structure itself. Mere cleaning is not the answer, since the material is often replaced overnight.

Many methods have been used to dissuade the beaver without much success. One method that often works is the construction of an upstream barrier around the entrance of the culvert against which the beaver can build a dam far enough upstream not to cause blockage. (Fig. 47)

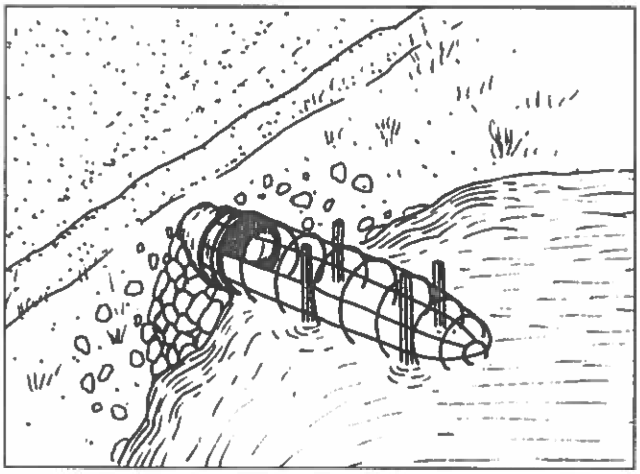

Fig. 47 Typical Beaver Barrier

Another interesting method is the use of a battery operated electric fencer and vertical control wires placed across the entrance of the culvert to discourage the beaver. This method usually takes about a week before the beaver leaves, but the wires should be left in place after the fencer is disconnected. (Fig. 48).

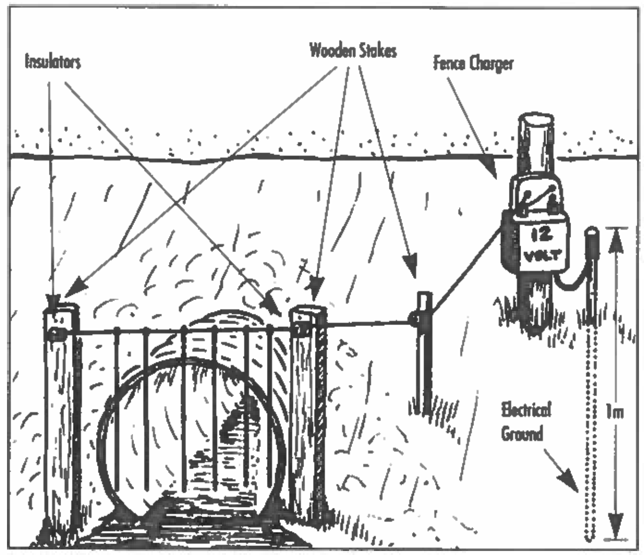

Fig. 48 Electric Beaver Repelling Device for Protecting Culvert Entrance.

Make sure the fencer is well grounded. A grounding rod or metal pipe at least 3 feet (1 m) long is recommended.

Glossary

Axis ....A real or imaginary line about which a body rotates; the line around which the parts of a thing or system are symmetrical or evenly arranged.

Backfill ....Earth or other material used to replace material removed during construction or material placed between an old structure and a new lining.

Bearing Capacity ....The ability to support a certain load or pressure without failure or deformation.

Bed Load ....Sediment in the flow that moves by rolling, sliding or skipping along the stream bed, and is essentially in contact with the stream bed.

Brush mat............A mat made of brush and tree branches used under a road embankment, a separation layer made of brush and branches.

Dead Load...........The weight of the materials and attachments such as the embankment and pavement over a culvert or the stringers and deck material of a bridge.

Density.................The mass per unit volume of a substance; the quality or condition of being packed tightly together.

Diaphragm ....A separating member used between bridge stringers to prevent them from twisting or rotating around their length.

Embankment......A bank of earth used to hold up a road.

Erosion.................The detachment of soil particles by the action of water, wind or temperature.

Flex ....To bend without breaking.

Foundation..........The base or lowest part of a structure.

Frequency............The number of times an event, or activity is repeated in a given period of time.

Gabion mat ....A basket made of steel wire mesh and filled with rock to form a mat.

Geotextile............A woven or nonwoven engineering fabric used as a separation layer between soils or as a filter for removing sediment from flowing water.

Grade ....The degree of rise or fall of a slope, as of a road or stream.

Intensity..............The relative strength or magnitude, as the amount of rainfall over a period of time.

In the dry.............Separated from water as on dry land, free from water.

Lateral support...Support along the sides.

Live Load............The weight of any moving load or impact, as traffic moving over a bridge or road.

Longitudinal ....Running or placed lengthwise, end to end.

Meander ....To take a winding course, as a winding stream.

Normal.................At right-angle to a given line or perpendicular to a given line or surface.

Peak Flow............Maximum flow, as a river at flood.

Ponding ....Water setting in small bodies or pools along the ditch of a road.

Rip-Rap................Large rocks, cobble or boulders placed in or around a watercourse to prevent moving water from eroding soil.

Run-off.................The portion of precipitation on a drainage area that runs along the surface of the ground and is discharged in streams and waterways.

Saturation............When water is thoroughly soaked into the soil.

Scouring...............The erosion of soil caused by running water, as the banks and bed of a stream channel at the outlet end of a culvert.

Tie-Backs............Anchor timbers for securing the sidewalls of a culvert to the embankment.

Torsional Rotation...............Twisting or rotation about the longitudinal axis or length, as in a stringer twisting about its length.

Unit load.............The load per unit area such as pounds per square foot.

Vertical Photographs........Photographs usually taken from a plane, where the camera is held in a vertical or nearly vertical position.

Washout..............The failure of a culvert, bridge, embankment or other structure resulting from the action of flowing water.

Wing-Wall...........A protective wall constructed at a bridge abutment and extending into and supporting the embankment.

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Appendix A

Rainfall Intensity

The Atmospheric Environment Services (AES) of Environment Canada is the principal source of meteorological data in Canada. Information collected from a network of observation stations throughout Canada is used to compile rainfall intensity - duration - frequency data which is used in calculating design discharge.

Typical Rainfall Intensity - Duration - Frequency Curves

The period of return simply defines the peak discharge that will occur, on the average, once in say 10 or 25 years. To be more meaningful, the probability of a storm occurring in any one year may be expressed as reciprocal of the return period. For example, a 25 year storm has a probability of 1/25 or 4 per cent chance of occurring in any one year.

Appendix B

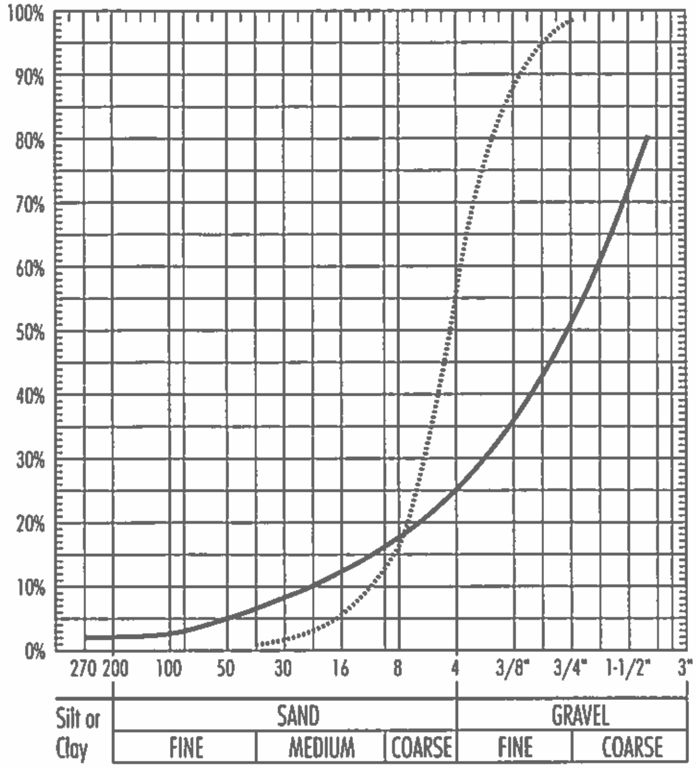
Well Graded Gravel

Gradation refers to the various sizes a soil may be separated into by the use of a series of sieves. In the Unified Soil Classification System, four soil fractions are recognized to distinguish the size range of soils. These are cobbles, gravel, sand and fines.

Component	Size Range
COBBLES	Larger than 75mm (3 in.)
GRAVEL	75mm (3 in.) to 4.75mm (No. 4 Seive)
Coarse Gravel	75mm (3 in.) to 19mm (3/4 in.)
Fine Gravel	19mm (3/4 in.) to 4.75mm (No. 4 Seive)
SAND	4.75mm (No. 4) to 75um (No. 200)
Coarse Sand	4.75mm (No. 4) to 2.0mm (No. 10)
Fine Sand	2.0um (No. 4) to 425um (No. 200)
FINES (Silt or Clay)	Smaller than 75um (No. 200)

Gravel may be defined as well graded or poorly graded. This refers to the relative gradation of the gravel. Well graded, defines a gravel that has various grain sizes in an amount that will fit together with the least amount of air voids between particles, and have little or no non-plastic fines (less than 5 per cent passing the No. 200 sieve). The present fines must not noticeably change the strength properties of the gravel.

Typical Example of Well Graded Gravel (GW)
in Percent Finer by Weight



Curve 1:
Pit Run Gravel; Nonplastic; Well-Graded; Small Percentage of Fines.

Curve 2:
Sandy Gravel; Nonplastic; No Fines. (Curve is about the steepest one that will meet the criteria for GW Group.)

The above curves can be expressed as percentage by weight passing a particular size sieve as follows:

Sieve Size	Percentage Finer By Weight
3 inches	100 %
1 1/2 inches	67 to 100 %
3/4 inch	50 to 95 %
3/8 inch	35 to 82 %
No. 4	25 to 55 %
No. 10	12 to 16 %
No. 100	0 to 4 %
No. 200	0 to 3 %

Appendix C

Assembly of Timber Bridges by Terry Amirault, P.Eng.

Before starting:

1. Has an environmental permit been issued by the Department of the Environment?
2. Are there stipulations, restrictions outlined on the permit?
3 Is the contractor aware of Environmental Guidelines?
4. What equipment, tools will be needed?
5. Is the site readily accessible by truck, porter, skidder, backhoe?
6. Have the materials been ordered? Are they available locally? Immediately?
7. How will the construction be completed? In what order? Both abutments at same time? How will machinery, materials, reach far side?
8. Where will backfill material (rock) come from?

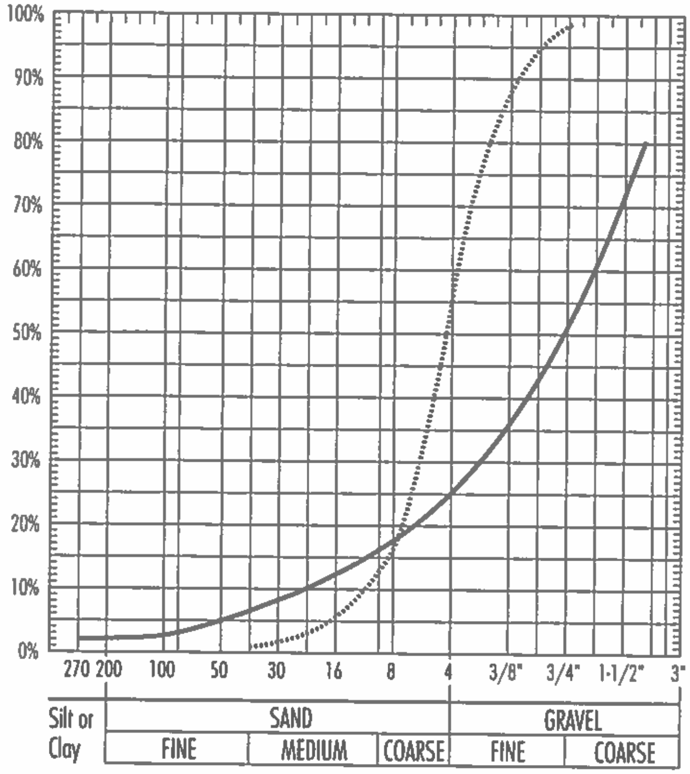
On-Site Planning:

1. Materials should be loaded and/or stockpiled on-site in order of use, e.g., crib material before decking.
2. Exact bridge location should be determined and abutment locations staked.
3. Decide on appropriate erosion control measures if needed. (Section 8.0)
4. Plan on building far side abutment first — this will give you additional flexibility.

Preparing Base for Abutments:

1. Use a backhoe/excavator to remove all organic and/or unsuitable material such as low bearing capacity soils from the area where abutment will be constructed.
2. If site is swampy, some coarse rock may be required to fill hole created by removal of the unsuitable material. (Section 7.3)
3. If part of excavation will be in the streambed area, provisions should be made to control damage to fish habitat, i.e., cofferdam, straw bales, silt curtain. (Section 8.2)
4. Allow for working space around crib abutment (excavate an area larger than the abutment).
5. Make sure base is as even and level as possible. Abutments built on solid rocks will probably need shims to level first layer. (Section 7.3)

Typical Example of Well Graded Gravel (GW)
in Percent Finer by Weight



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Crib Construction:

STEP 1.

Place bottom face stretcher (key timber) and bottom back stretchers (1, 2 or 3 pieces depending on length available) parallel, at desired spacing and such that back stretchers extend past both ends of stretcher in equal amounts (Fig. C1). If pieces are not level, shim or excavate base to adjust the timbers.

STEP 2.

On top of initial pieces place the first two wingwall pieces and the two headers and pin these with 14" x 5/8" diameter pins (for 8" x 8" timber). One pin is to be placed at each connection. Holes, 9/16" in diameter, shall be drilled through the top layer and 6" into the second layer to accept the pins (Fig. C1).

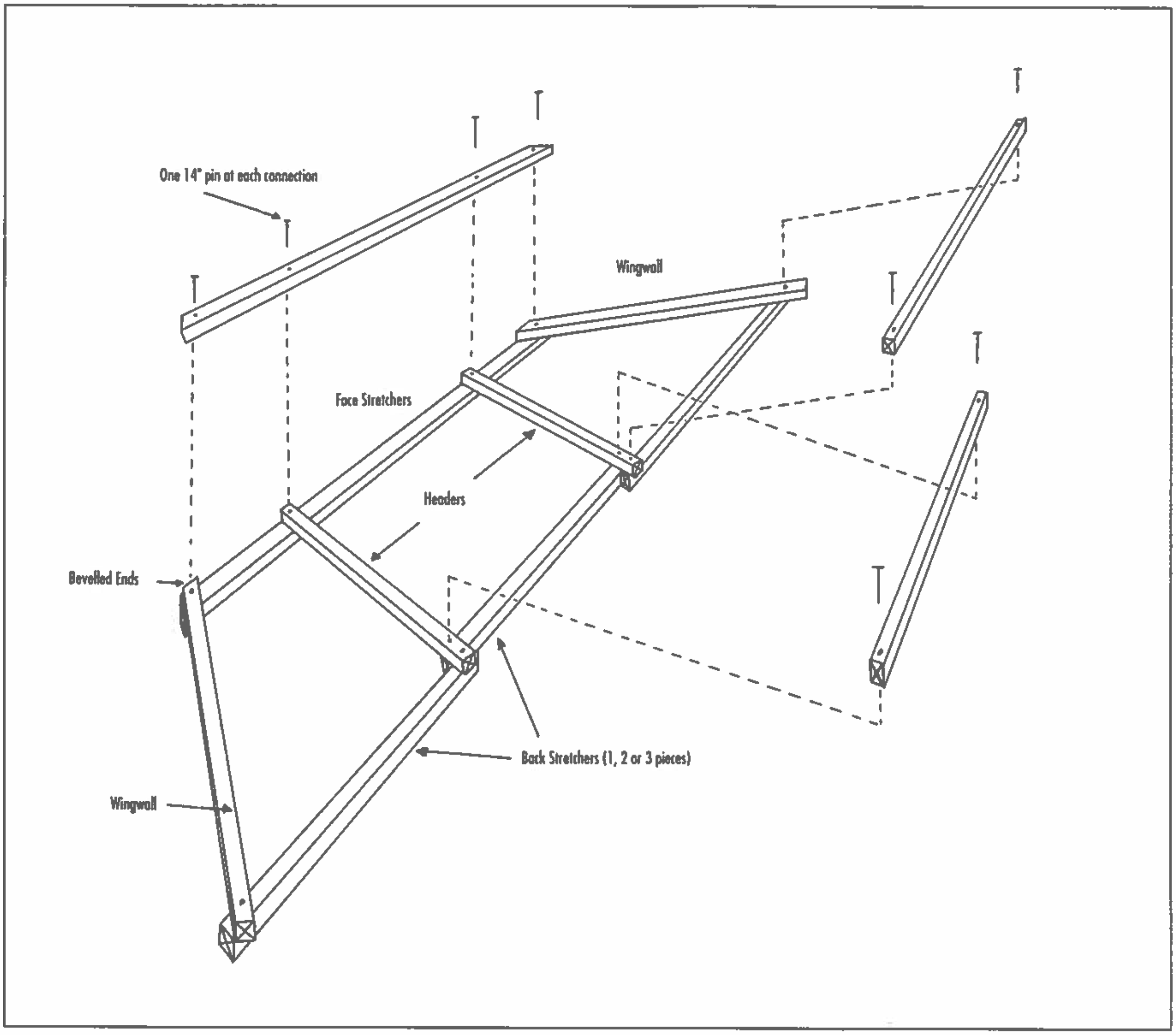

Fig. C1 First layers of Crib

STEP 3.
Steps 1 & 2 are repeated until desired height is reached (Fig. C2). Corners between face stretches and wingwalls should be bevelled. Other junctions may be left with square butts. All field sawn ends are to be treated with suitable preservative.

STEP 4.
Two bearing plates 8" x 8" are pinned to the top layer of the wingwalls and headers. Second bearing plate is longer than first to account for angle between wingwall and crib face (Fig. C2).

STEP 5.
Blocking pieces are added to top of headers and wingwalls, immediately behind rear bearing plate (Fig. C2). Each blocking piece is pinned with two fasteners and will be used to support the butt plates and the final layers of wingwall.

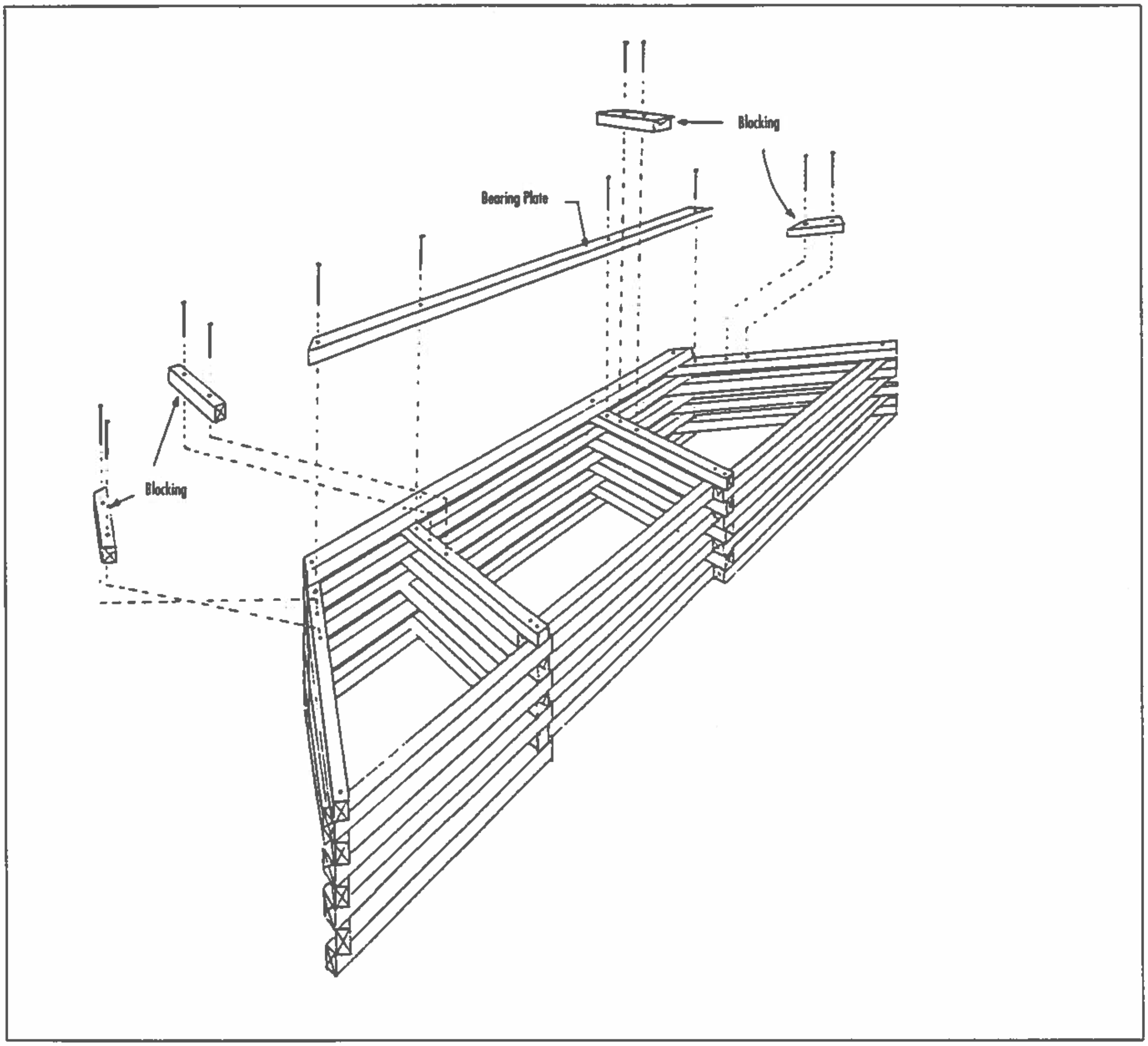

Fig. C2 Installation of Blocking Plates

STEP 6.
Stringers are placed with ends on the two bearing plates, at the specified spacing (Fig. C3). (See table for stringer sizes, species, and spacing.) Large stringers will require mechanical equipment, boom-truck, grapple loader, backhoe) to lift them in place.

STEP 7.
Each stringer is pinned to the bearing plates through predrilled holes and with fastener extending through the stringer and the plates.

STEP 8.
Attach two 4" x 8" butt plates to ends of the stringers. Nail both butt plates to each stringer with 10" spikes (Fig. C3). These butt plates serve two purposes. They restrain the stringers and they prevent the roadway backfill from falling into the stream.

STEP 9.
Remaining wingwall pieces are fastened to the blocking pieces (Fig. C3).

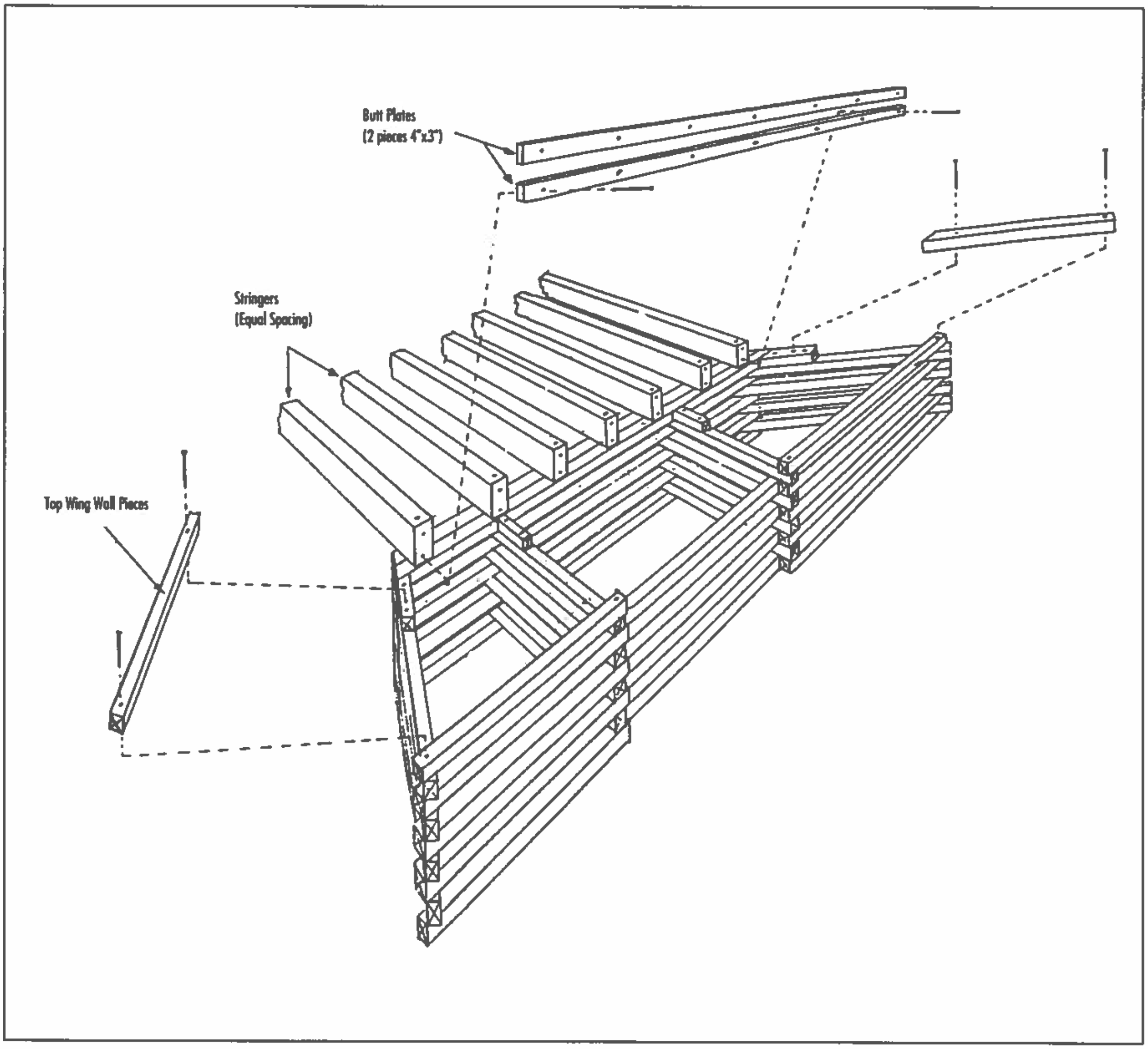

Fig. C3 Placing Stringers and Butt Plates

STEP 10. (Optional)
If crib is to be filled with fine backfill material instead of rock, crib should be lined on front face and wingwalls with 2" x 6" planks placed in an upright position on the inside of the crib. These will block all openings between crib layers, preventing the backfill from being washed away. Note: When fine material is used for backfill, crib abutment should be set far enough below surrounding grade to prevent stream flows from washing backfill from the underside of the crib.

STEP 11.
Abutment(s) may be backfilled either before or after bridge deck is placed. If backfill material is to be trucked in, near side abutment should be filled first, then deck put in place, then truck slowly backed over bridge and fill dumped into far abutment. Abutment can also be filled as the abutments are built. If front of crib is to be protected with rip rap stone, these should be put in place before bridge deck is installed.

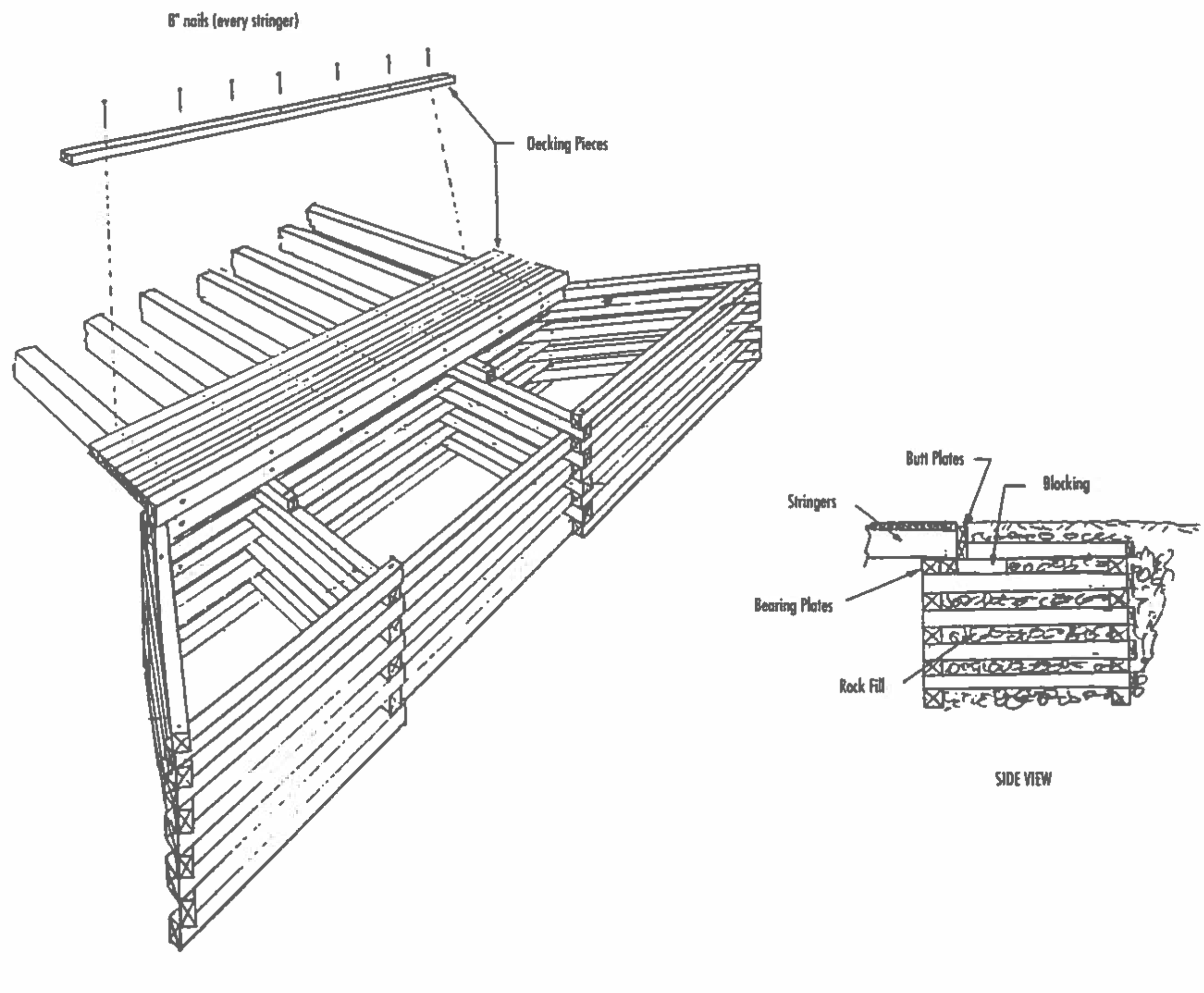

Fig. C4 Decking

STEP 12.
Nail decking pieces to each stringer with 8" nails. Decking pieces should be one piece, if possible.

STEP 13.
Install tire guard and blocking and guard rails if required.

STEP 14.
Nail running surface to bridge deck.

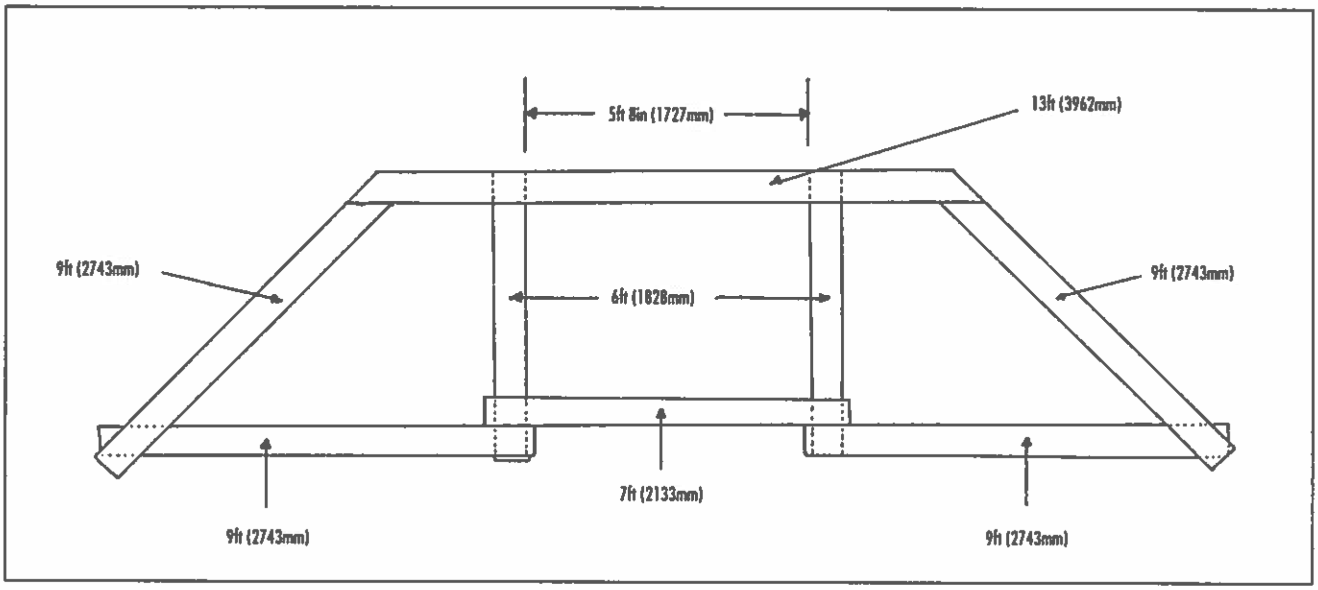

Fig. C5 Crib Dimensions

Further Reading

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Forest Access Road Planning and Construction Manual - Steve D. Talbot, P.Eng., N. S. Dept. of Lands and Forests, 1982, Revised 1991.

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