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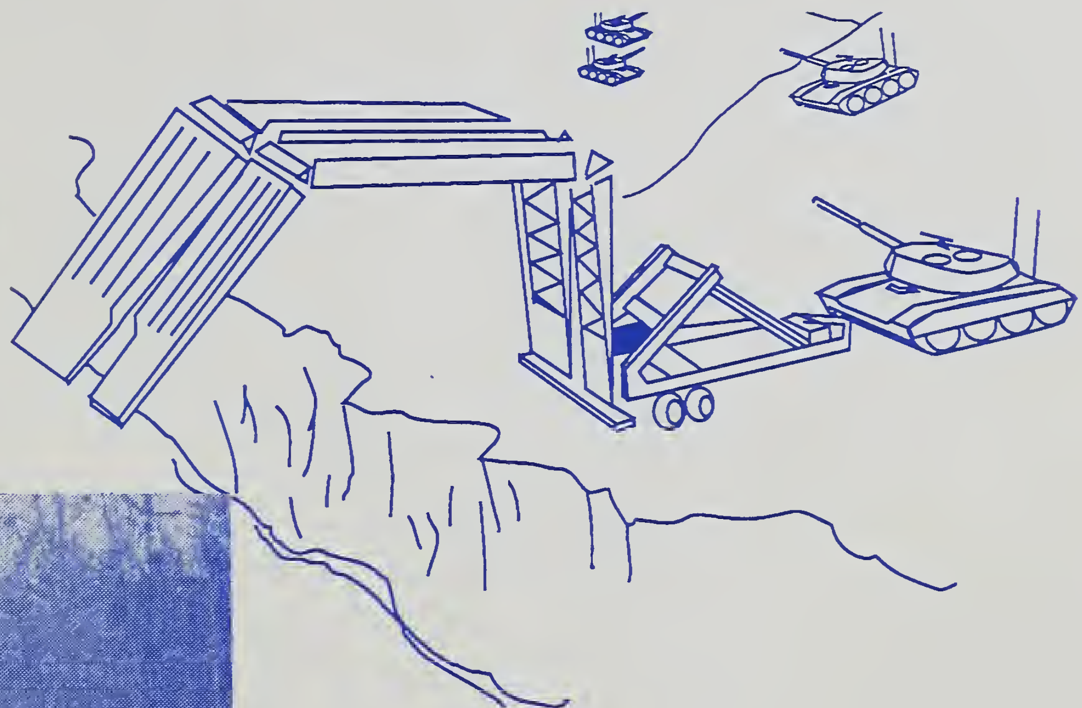
Portable Wetland Area and Stream Crossings



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We would like to know what you think of the new Portable Wetland Area and Stream Crossings report.

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- How did they perform?

- Are there other products that should be investigated?

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Portable Wetland Area and Stream Crossings

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INTRODUCTION

Each year, the Forest Service constructs thousands of miles of roads. These roads are primarily used for timber sales. In some areas, the roads are constructed over sensitive wetland areas. In other cases, the roads are built in areas that already have a high open road density. In both cases, constructing permanent roads can be detrimental to the environment.

Wetland areas consist of soil with poor load-bearing capacity and high moisture content or standing water. (See figure 1.) When the soil is dry, it can withstand the vehicular loads. Once the moisture content increases, the soil can no longer carry the load. In wetland areas, roads are needed through highly sensitive portions of the area in order to effectively harvest timber.

Currently, the typical construction design is a built-up road. A built-up road consists of placing layers of imported soil to a total depth, typically several feet, that will carry the traffic. (See figure 2.) The roads are considered permanent due to the high cost of removing the large amount of soil. Open road density increases in the area and the permanent roads become an environmental disturbance.

Open road density in itself can become an environmental concern. In the past, many of the roads constructed for timber sales were never closed nor maintained. The occasional public traffic caused continual erosion problems and the roads were not safe to drive on. The Forest Service has been trying to decrease the open road density by closing roads after the sale. An easy solution used on some roads is to remove culverts at the stream crossings. However, removing culverts can create problems. The fill soil placed over the removed culvert area can pollute the stream and a continuous erosion problem can result.

For both wetland areas and stream crossings, the possible solution could be portable crossing products that are temporary and reusable. For the wetland areas, the product needs to be able to distribute the load of a loaded timber truck. There is also a need for such a product to be used as a loading platform for the trucks and as a surface for skidder traffic. A very rudimentary loading platform in use currently is shown in figure 3. The product will need a surface with good traction if emerged in water and for the expected muddy conditions. For the stream crossings, a substructure is needed that can be used on steep

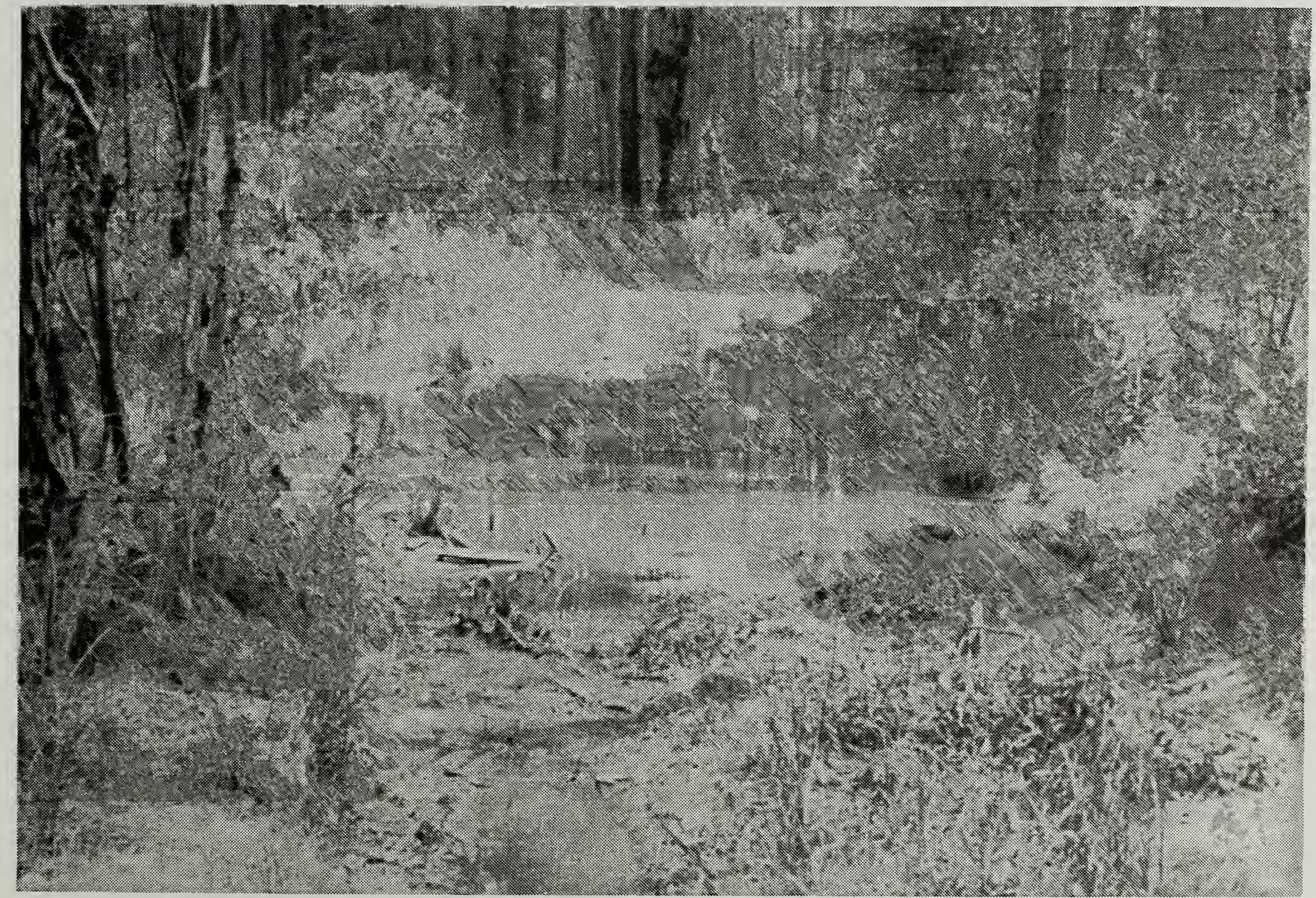

Figure 1. Typical wetland area.

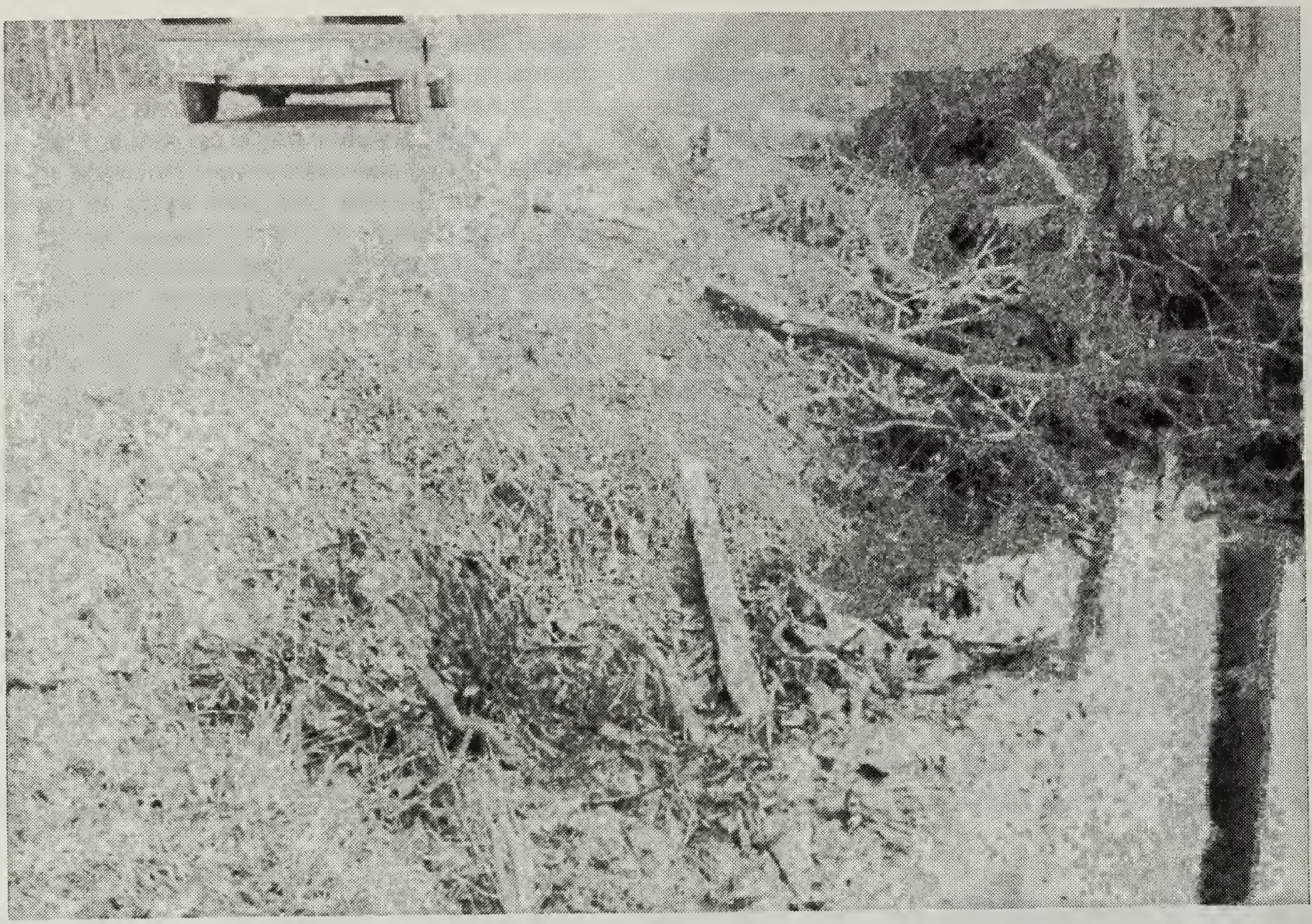

Figure 2. Built-up road.

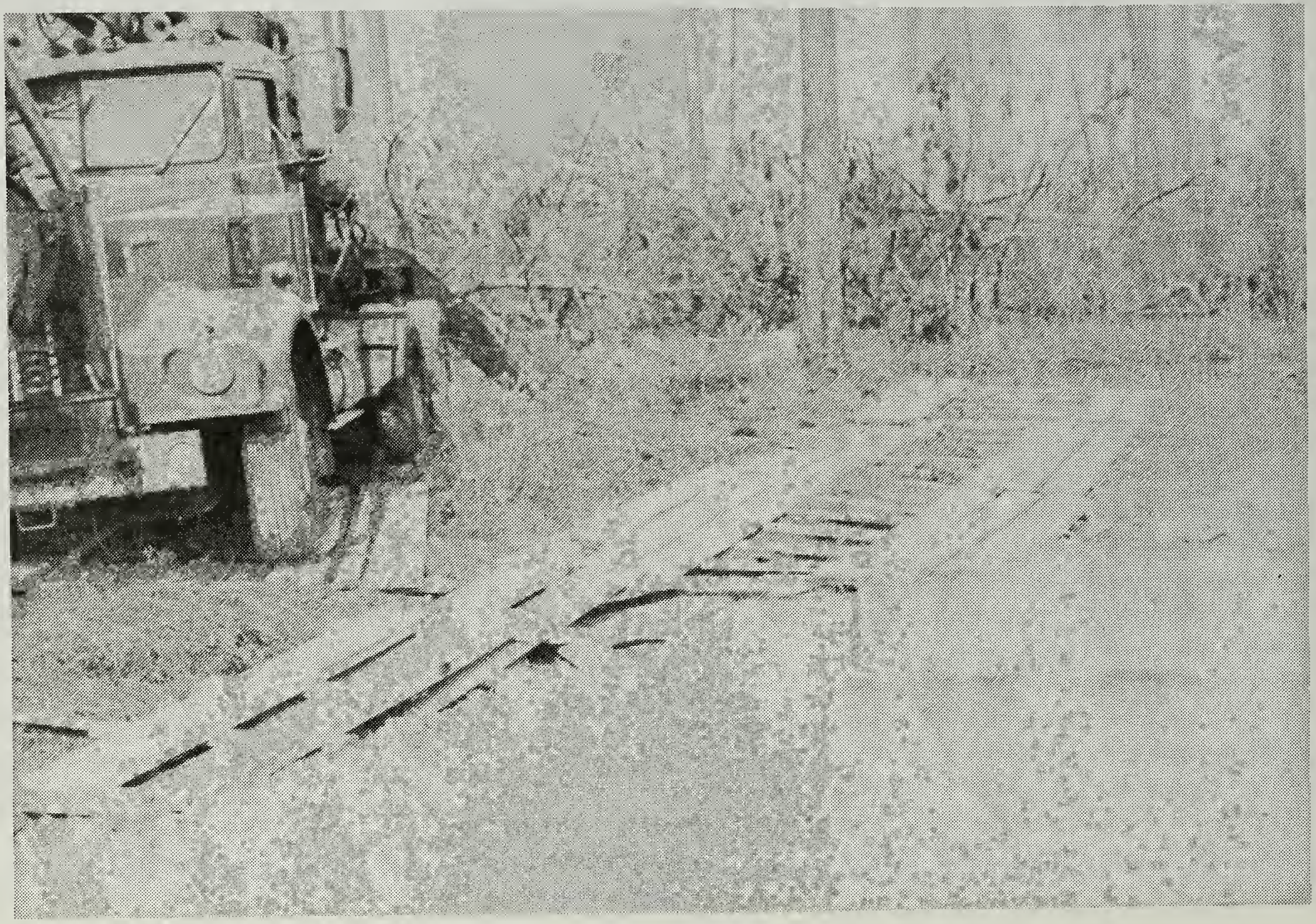

Figure 3. Rudimentary loading platform.

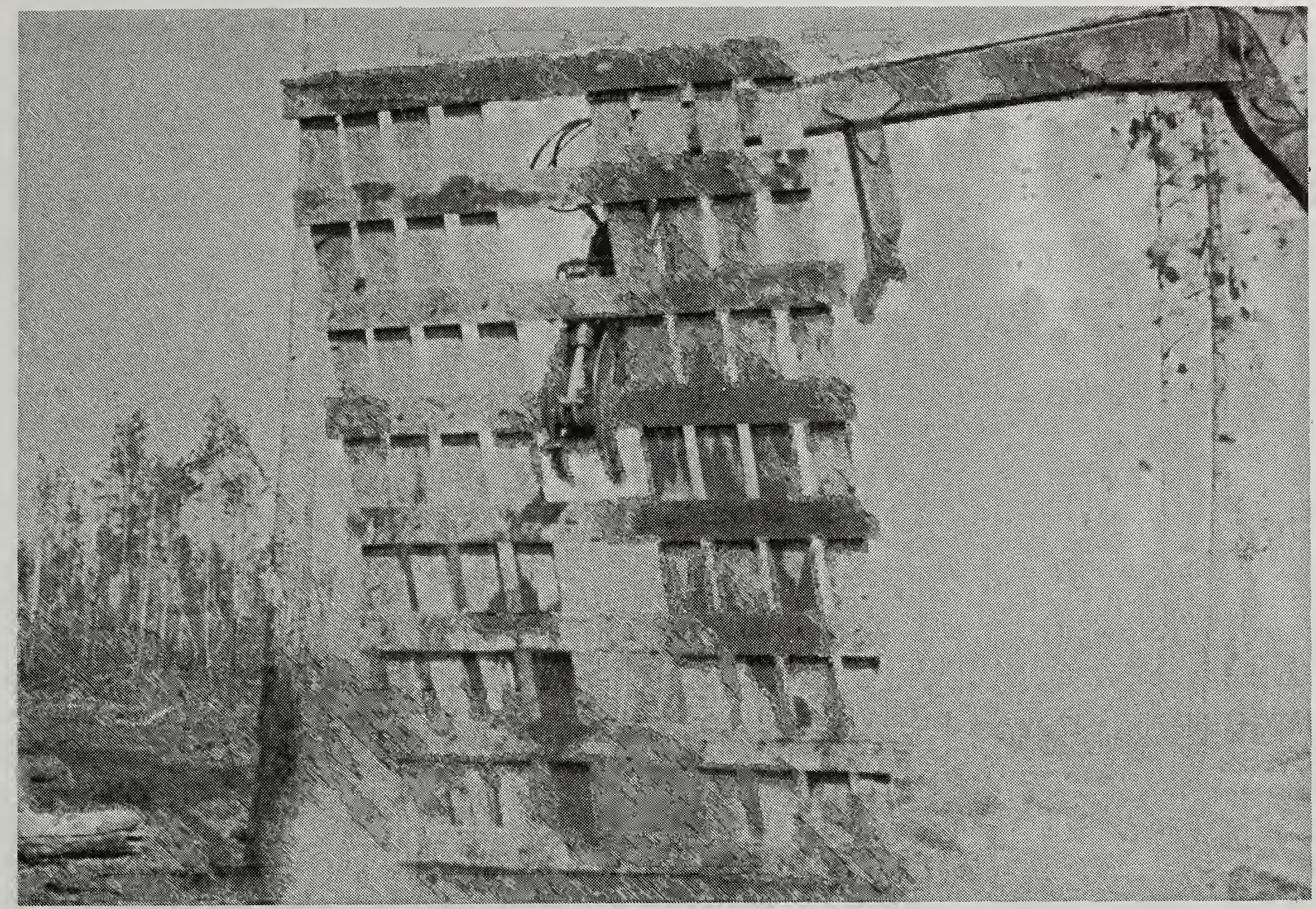

Figure 4. Logging equipment transporting crossing.

side slopes. It would be left in place and reused whenever the road is needed. Thus, it needs to be durable enough to last. The superstructure needs the capability to be increased or decreased in length for its next use. It will need to be durable enough to withstand being moved each time the road is opened or closed. This could be as often as every 6 months. In both cases, the crossing needs to be transportable by logging equipment. (See figure 4.) Any construction should require no special equipment, outside of timber equipment, and no specialized labor skills. The cost needs to be minimal.

There are no records of what has been tried in the past. This report covers a market search of what may be available commercially and through the military. Also included are possibilities that still need research and design. Field testing still needs to be performed on all of the products. Life expectancy versus costs are unknown and will be determined as the products are tested. This report includes a description of each product, including photos and sketches. Situations where the product can be used, the testing and use that has been performed, and the possible problems that will need to be addressed are identified.

WETLAND CROSSINGS

Crossing Wetland Areas

There are a few products and construction techniques that could be useful in conjunction with the other products described in this report. The use of geotextiles could be appropriate for separation of the product and soil or for stabilization purposes. Use of material in the immediate area, such as stumps, limbs, logs, etc., to protect the product or be used as fill material, could be effective. The use of construction techniques that limit the type of equipment used according to weight and the Central Tire Inflation (CTI) concept, designed to help with traction and load distribution, can both provide positive results.

Geotextiles are fabrics made in diverse ways with different materials for various purposes. They can be used to separate materials so that the material integrity is not lost. They can be used for reinforcement although this takes special design considerations. They are also used for drainage, filtration, and erosion purposes. The main reason for using them in conjunction with other products in wetland applications is for separation. The geotextile would reduce the amount of soil infiltrating the product.

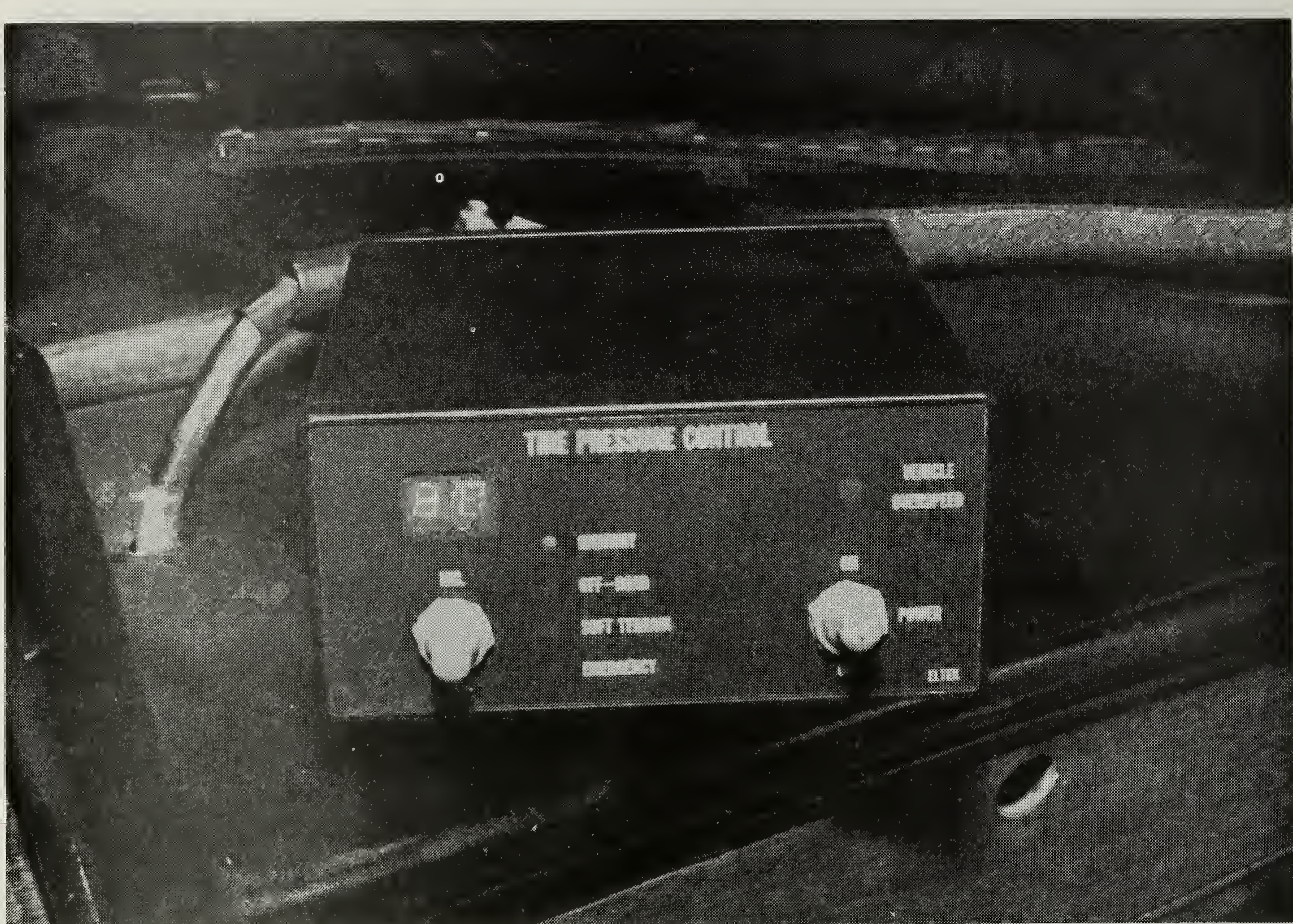

Figure 5. Central Tire Inflation Control Panel (in cab).

This would help reduce any possible traction problems by limiting the amount of mud on the surface. This material may also help during retrieval of the crossing product. The product would be easier to remove by not being "stuck in the mud" which would save time and may also help to prolong the life of the product. The geotextile itself would probably not be easy to remove nor be reused. If the geotextile is nonbiodegradable, it would have to be retrieved so it will not pollute the area. Once it has been retrieved, it would have to be properly disposed of if it cannot be reused.

Because there is such a wide variety of fabrics on the market, there may be biodegradable types available. If the product is biodegradable, it will have less effect on the area if left in place. After some inquiry, the few that are available do not seem to be rugged enough to last and still take time to degrade. The best alternative is to buy a high tensile strength, woven fabric. (See appendix C.) It may be strong enough to be reused. Whether or not the possible benefits of using a geotextile fabric is worth the extra cost is unknown. Only field tests that are conducted both with and without fabric will show its worth. The 600X, produced by Mirafi Inc., has been requested for field testing this fall in Florida. Cost is in appendix B.

During the market search, some of the Regions that deal with low-strength soil in wet areas were contacted. Several methods utilized to reduce costs reported by these Regions included varying the type of fill material and the type of equipment used. Instead of using imported soil for the entire amount of fill material, forest debris is used. The initial layer of the road would be made up of stumps, limbs, logs, or any debris material available in the vicinity. This material would help stabilize and add strength to the soil. Above this material, imported soil could then be added. The forest debris would cut costs by decreasing the amount of imported soil needed. This design in itself is still a permanent road, but there may be other areas where this material alone could be used as fill with a portable running surface. For the roads that do need to be permanent, it is an option for decreasing costs. It could also be used to separate the soil and products instead of using a geotextile. The material would not be portable but it is biodegradable and attainable at any site.

Another alternative is to vary the type of equipment used. Both the type and size of equipment utilized during construction could be modified. Heavy equipment should be kept off the area before, during, and after construction. This would decrease the amount of disturbance in the area. The road would be designed for lighter equipment thus reducing the needed strength, the amount of fill, and the construction costs.

Central Tire Inflation (CTI) is a method for varying tire pressure. A control panel in the cab of the vehicle allows the driver to decrease tire pressure on low speed, off-highway roads and increase tire pressure to normal for high speed, paved roads. (See figure 5.) One of the main purposes of the system is to decrease road maintenance on soil roads. By decreasing tire pressure, soil roads are not damaged as quickly nor to as great an extent. This is due to an increase in the tire contact area which increases the load distribution area as well as increasing traction. This is very valuable in wetland areas where load distribution and traction are critical. CTI would help during short distances, maybe during loading. The concept is being researched and field tested through San Dimas Technology and Development Center. Field tests in the various areas could help to prove the applicability in wetland areas. The limits on just how soft the soil can be before the concept is no longer useful is unknown. The cost of the CTI system is high but other alternatives for varying tire pressure such as airing stations may not be less expensive. The amount of cost savings in road construction and maintenance compared to the cost of the system is still being determined through field tests.

Chunkwood

The entire concept of using chunkwood as fill material for forest roads is relatively new. Region 9 was one of the first to experiment with chunkwood. They researched several different road designs ranging from varying the depth of chunkwood to using geotextiles and gravel with the chunkwood. (See appendix C.) The designs depend on the type of soil being crossed and the type of traffic that will be using the road. Some of the roads constructed by Region 9 were for logging traffic over wetland areas and were very successful as permanent roads. Because it is lightweight, the dead load of the road may not have as much of an impact on the soil. For wetland crossing applications, when a permanent road is not wanted, chunkwood could be used as a separator between the soil and other crossing products instead of a geotextile. It could then be left in place to degrade. Recently, Missoula Technology

Figure 6. Chunkwood chunker machine in operation.

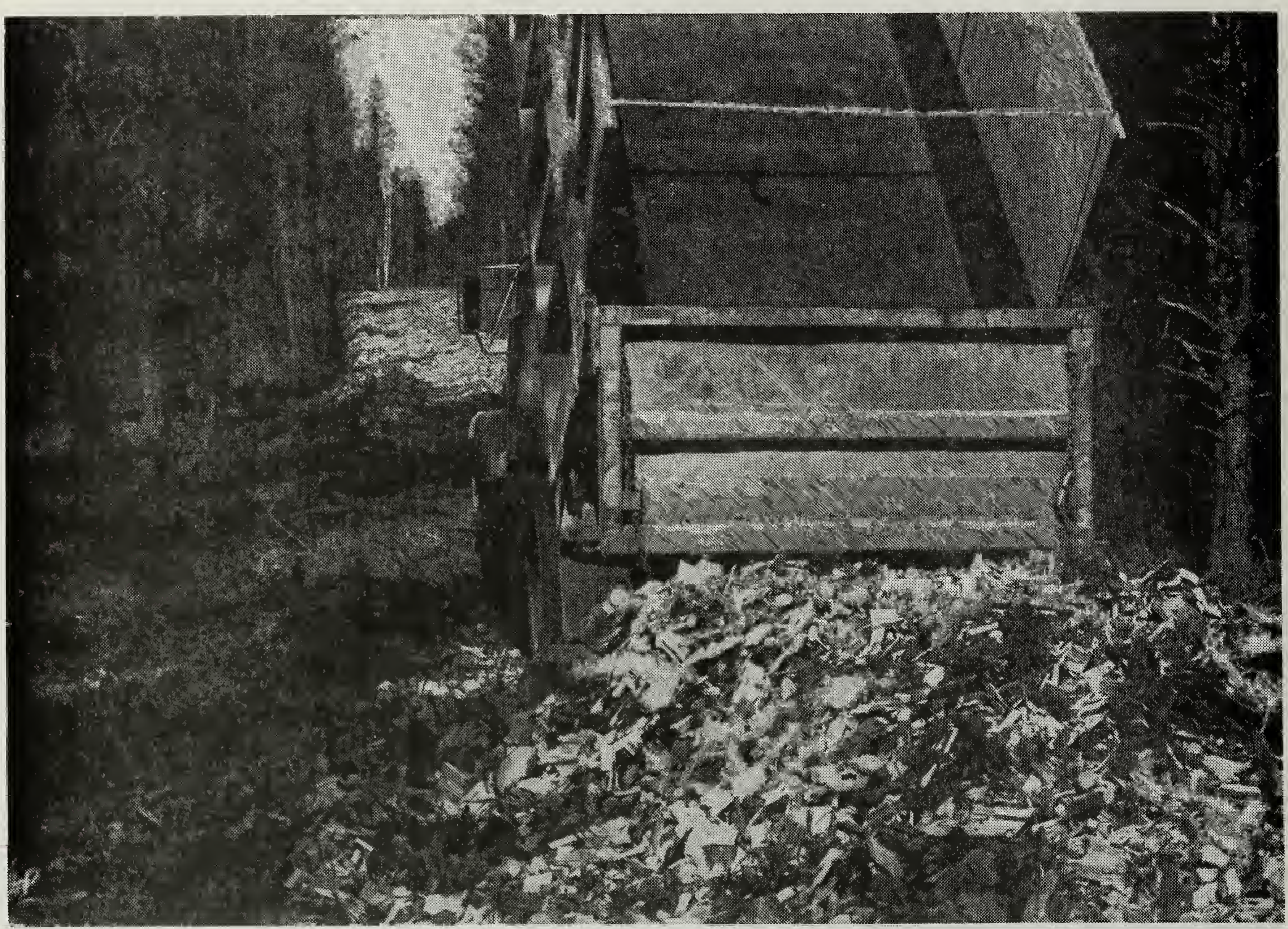

Figure 7. Spreading chunkwood as fill material.

and Development Center (MTDC) has taken on chunkwood research with the possibility of demonstration projects in wetland areas.

Chunkwood is comprised of fist-sized chunks of wood that are made by running logs through a chunker machine. The size varies from 2 to 6 inches with a maximum size of 8 inches. (See figure 6.) Chunkwood was originally developed to be used as a biomass fuel or as material for structural flakeboard. The chunker machine was originally developed by the Forest Service in Houghton, Michigan, and handles logs up to 8 inches in diameter.

Another experimental prototype was developed by MTDC which handles logs up to 12 inches. (See figure 7.) Typically, 1.75 cubic yards of chunkwood is produced from 1 ton of raw logs. Because chunkwood is made from a low-cost (unmerchantable timber) renewable resource, it became an alternative to nonrenewable rock sources to reduce the costs of forest road construction. This was the main reason for the initial chunkwood research. The material can be used as the base coarse and/or as the surfacing coarse. It can be used as is or mixed with the existing soil. The chunkwood contributes to dust abatement because it holds moisture for an extended amount of time. It may be possible to enhance the designs and reduce the amount of chunkwood and soil. This could be done through laboratory determination of engineering and behavioral characteristics of chunkwood for road design. Geomatrices, discussed later, could add stabilization and keep the chunkwood in place. Tires, discussed later, could also offer these benefits.

There are a few problems with using chunkwood. First, the chunker is only a prototype model with many imperfections. It breaks down often under some circumstances and can only handle certain sizes of logs. Problems with the blades occur if dry wood is used due to the excessive amount of heat. There is only one machine available at this time.

There is a private company that is interested in manufacturing the machines, so these mechanical problems may not exist in the near future.

Another possible problem is that chunkwood could not be considered easily portable or reusable. The costs to recover and transport the material are unknown

Figure 8. Difficulty in recovering and transporting chunkwood.

but they are assumed to be high. (See figure 8.) The best road design appears to consist of using both geotextile, to completely surround the chunkwood, and a layer of fill material as the running surface. This type of road would become very time consuming if it is only to be temporary. By using the geotextile, the soil and chunkwood would be separated so that retrival may be a little easier, but it would still be time consuming compared to other portable crossings. The geotextile would not be easily removed and could be considered an environmental concern.

Research will continue on various roadbed designs and material characteristics in order to understand and predict chunkwood performance. As part of that research, possible solutions to the problems with the chunker and possible environmental effects will be worked on. Chunkwood has the potential of being a viable, low-cost alternative for wetland crossings. It is especially useful when permanent roads are needed or when a layer to separate the soil and the product is required. Chunkwood has been used in road design in some areas for over 4 years with very few problems, making it an ideal choice for some wetland crossing situations.

Logs

One of the desired characteristics of a portable crossing product is that the material used in the product be readily available to the timber contractor. Logs could be a viable alternative because of this characteristic. They are a renewable resource that is readily available to all timber contractors. Individual logs are seen as a way to distribute the traffic load over a greater area of soil. By binding logs together, some of the load is distributed between the logs, making an even larger load distribution area. The larger the distribution area, the larger the safe vehicular load.

The design would consist of panels made up of logs bound together. These panels could then be set side by side with the logs running in either a transverse or longitudinal direction. The panels should only be as large as a loader could handle. Steel cables, which are used for log stringer bridges or metal bands, could be used to bind the logs. (See figure 9.) The panels may need to be interconnected and, depending on the length, the whole system may need to be anchored. Logs are typically not treated so there would be no harmful environmental effects from preservatives.

Figure 9. Logs, bound together, used as a crossing.

There are some very rudimentary examples of log panel use in Alaska, the deserts of California, and other areas. However, there is no written history of the concept and its design or performance. The use of logs is still considered experimental due to many foreseeable and unforeseeable problems. The main problem is design. The size of the logs needs to be determined based on the soil and log species strength. The soil strength would help determine the necessary distribution area. For determining the necessary log species strength, initial designs could be based on log stringer bridge guidelines. See the log stringer bridge section in this report.

The size of the panels needs to be determined based on what the loader can handle. The number, size, and type of metal bands need to be determined based on distributing the load between the logs. The band would also need to keep individual logs from moving relative to each other. The panels may need to be interconnected depending on panel movement. A way to easily connect and disconnect the panels may need to be designed.

Depending on movement, the entire system may need to be anchored. A way to effectively anchor the system without specialized equipment needs to be determined. Weights might be an option. A running surface may be needed depending on driving roughness and length of time in place. The most efficient type of running surface (soil, planks, etc.,) needs to be determined. Basically, design work and field testing need to be carried out.

Using logs could be very beneficial. The material is low cost and readily available. The panels would probably be easy to construct, portable, and reusable. The life expectancy is unknown but once the logs begin to deteriorate they can be left in place. All the hardware could then be reused to make new panels. No special care nor any specialized equipment would be needed. With research and planning, logs can be a viable, low cost alternative.

Bridge Decks

One of the original ideas for a portable wetland crossing was the use of the stress-laminated deck design. The idea included using the timber deck as a wetland crossing and as a bridge deck for stream crossings. The stress-laminated panels could be designed to fit a variety of lengths or widths. Because they are constructed of wood, the basic materials are readily available to the contractor. There are other bridge decks that could possibly be used as wetland crossings. Some are the commercially available portable bridges. The superstructure, which is typically a stringer and deck configuration, would need to be built as individual components. Entire superstructures would probably be unnecessary and very difficult to work with. (See figure 10.) Glue-laminated wood panels typically used as bridge decks could be used. The panel dimensions can be varied so that they are practical as a wetland crossing and structurally safe as a deck on a stringer bridge. All of these types of crossings may be more costly initially than other types. But, they may have longer life expectancies and may be more versatile when used as both a wetland crossing and a bridge deck. In these installations, a geotextile may be needed to separate the deck and soil to assist deck retrieval. Photos, sketches, and design characteristics can be found in the bridge section later in this report.

The stress-laminated timber deck is still considered experimental as a bridge superstructure. The superstructure consists of 2-or 4-inch laminae with holes drilled along centerline through each laminae. Posttensioning steel bars are placed through the holes the length of the deck width. Steel plates and bolts are placed on either side of the deck over each bar. The bars are put in tension to a predesigned stress using a jack. The bolts are tightened down and the stress is transferred through the bolts and plates to literally squeeze the individual wood laminae together. In wetland areas, this would make for a solid plate of wood to disperse the load over the low strength soil.

Other bridges that could be used are commercially available. Acrow Corporation of America sends out individual deck components. The panels that make up the deck could then be used as a road or landing surface in wetland areas. The panels are either steel or wood. The other three types of bridges, EZ Bridge, Big R, and Skip Gibbs, are all prefabricated and would probably not be applicable as wetland crossings.

Figure 10. Installing a prefabricated bridge.

Skip Gibbs is very rugged and would probably hold up better than the other two.

There are also the glue-laminated panels used for bridge decks. The glue-laminated panels consist of lumber laminae that are glued together. The laminae are typically 1 and 1/2 inches and, because of the way they are glued together, the panels are much stronger then the original wood. There are design guides available stating strength characteristics. The panels are typically 4 feet wide by any specified length and depth. They make for a solid panel of wood that could effectively disperse the load over the soil.

There are some problems with using the stress-laminated decks. In the stress-laminated design, the wood needs to be graded. Grading determines the strength characteristics of the wood, thus the strength of the deck and the amount of stress that needs to be in the bars. Therefore, a contractor cannot use just any available lumber. This design has not been used in this manner and although 2 by 4's may be the largest size necessary, 2 by 6's may need to be used. In previous decks, there has been a problem with bowing when using 2 by 4's. A large enough stress to carry the load may be too great for a shallow deck. The wider the panel, the more prevalent the problem.

Also, if this is wanted as a bridge deck, it would probably have to be placed over stringers in order to carry the load. A 6-inch deep deck is not strong enough to carry heavy loads over an open span.

Another problem is that a solid deck would be difficult for timber equipment to pick up, so the deck would need to be made up of panels. The rods could be coupled together and stressed in order to make the entire deck. A jack, used to stress the bars, needs to be available. If the bar stress becomes too low, the lumber acts as individual laminae and the bars could become bent. The life expectancy is unknown. But, once the wood does begin to deteriorate, the wood could be left in place as biodegradable and all the hardware could be reused.

The biggest problem with the other types of decks is cost. If the contractor has the components of a portable bridge and it is not being used, then using the deck components could be feasible. The portable bridge companies would probably handle only complete orders for entire bridge superstructures which would be costly if only the deck will be used. Also, if damage is done to the deck components, they will need to be replaced. The glue-laminated panels are strong and durable if the wood is protected. The panels are expensive and will not have a long life if treated roughly. A design for transporting any of these deck panels may need to be developed. It depends on the size and weight of the panel.

The stress-laminated deck seems the most viable option. The material is readily available, low cost, and renewable. It is easy to construct and the hardware can be reused although some maintenance would be needed to maintain bar stress. The decks from some portable bridge companies would be very rugged and have a long life expectancy yet could be expensive. Glue-laminated material would cost too much for a probable short life expectancy due to rough treatment. Only field experimentation will help determine the feasibility of using a bridge deck as a wetland crossing.

Foam Inflated Fabric/Inflatable Rubber

Due to military needs to cross difficult areas including wetlands, Construction Engineering Research Laboratory (CERL) of the U.S. Army was one of the initial contacts made to obtain crossing information. Originally, material was requested for both wetland crossings and portable bridges. The only research they had been involved in was pedestrian bridging over slow moving streams using foam inflated fabric. This proved to be a lightweight, portable bridge. Designs for floating vehicles across streams instead of using a continuous bridge were tested. This did not sound promising as a bridge over streams or gullies for timber equipment. But, because wetlands are made up of low strength soil, the idea of "floating" a road on top of the soil using the foam inflated fabric sounded like a possibility. Another possible way to "float" a road incorporates air and water inflated rubber. The idea of inflatable rubber came from a magazine article discussing high strength, long lasting, inflatable rubber dams. The fabric or rubber panels could be connected together to make the base of the road with a running surface placed on top. A simpler design could consist of interconnected tire inner tubes. They would be much more readily available than the other materials. The foam inflated fabric, air and water inflated rubber, or tire inner tubes could make for a lightweight, portable, reusable, wetland crossing.

The foam inflated fabric crossings are made from common materials. The foam is a rigid polyurethane foam which is mixed and poured into the fabric form. (See appendix C.) The foamed plastic can be mixed in the field by manual, mechanical, static, or autofroth methods. It takes 20 minutes for the foam to cure. Once it is cured, it will hold its shape and be serviceable even if the fabric is torn. The compressive, tensile, and shear properties can be changed by adjusting the mix density. The fabric form is made up of water-resistant canvas fabric. The fabric needs to have a high-tensile strength. The sewing pattern is very important because of the foam properties. There were several different fabric forms tested by CERL. For personnel crossings, the product was a foot bridge floating on the water surface. There was also a 3-man raft designed. For vehicle crossings, tubes were designed and attached along the sides of the vehicle.

The other two designs would be more applicable for wetland crossings. One consisted of aluminum running planks attached to foam-filled pontoons. This was called the MLC 5 rafting/bridging system. (See figure 11.) It is 23 feet long and weighs a total of 2,935 pounds. Each pontoon is 240 pounds with the aluminum made up of pieces of 88 pounds or less. It takes 4 men 45 minutes to construct the system. The other is a flat foam platform with plywood ramps called the utility truck raft/boat. (See figure 12.) It is 4 to 6 inches thick and weighs 140 pounds. There are two 3/4-inch plywood ramps. The entire platform is 200 inches long and 131 inches wide. (See figure 13.) In this manner, the foam inflated fabric acted more like a raft to disperse the load. All of the products were constructed by CERL.

Today, rubber walls inflated with water and air are used as dams. Improvements in rubber have made it a very durable, long lasting material. The material is a synthetic, rubber-coated nylon fabric that can be purchased from rubber manufacturers. If dams can be commercially manufactured, then panels to be used as a road base could also be manufactured. The water being used in the fill would make the panels heavier yet would probably help to stabilize the panels. Stabilization would be needed due to vibrational movement.

Figure 11. Rafting/bridging system.

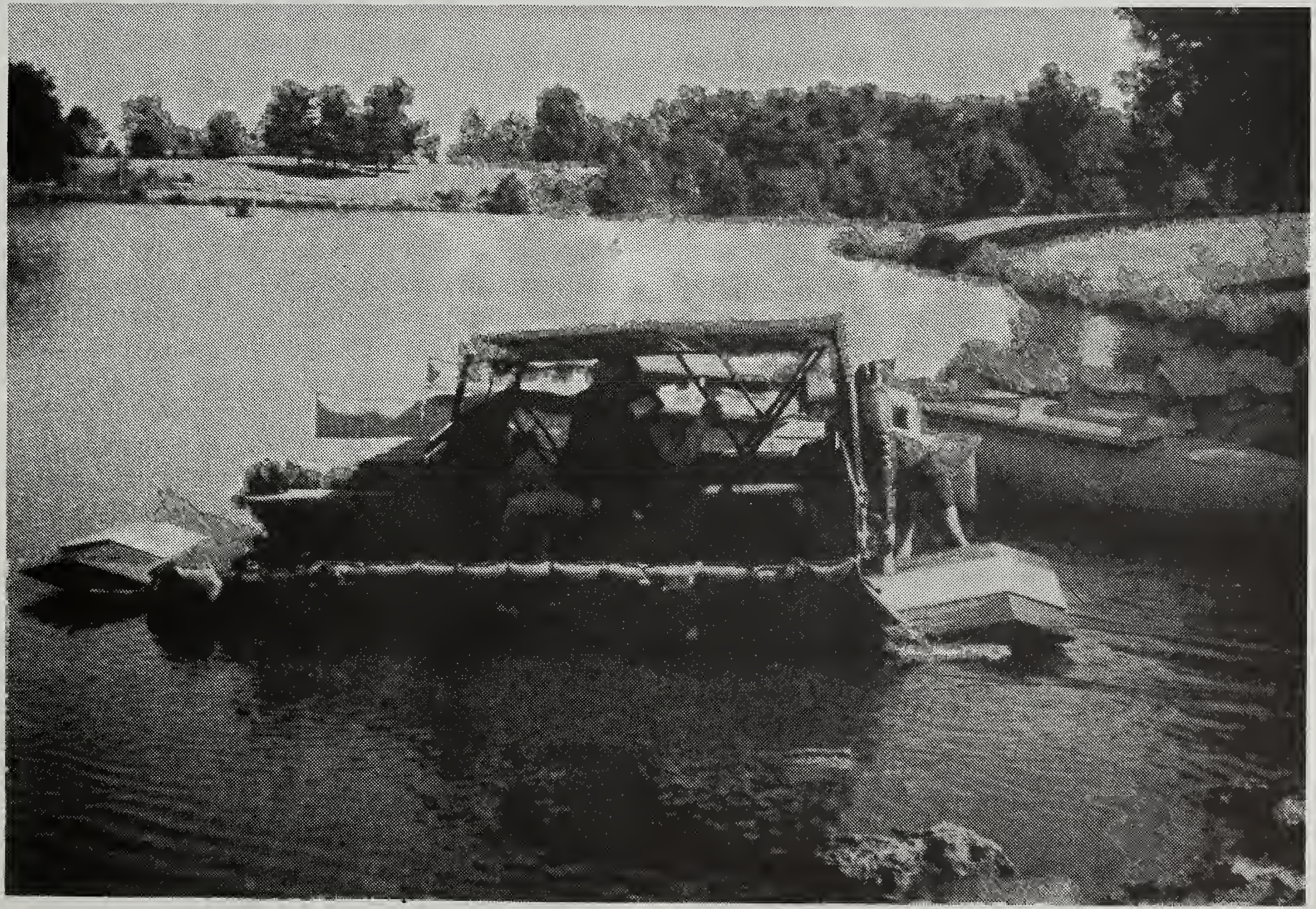

Figure 12. Utility truck raft/boat.

Figure 13. Fabric form filled with foam.

Movement would be caused by variations in the load, uneven pressure, and by the panels spreading over the soil surface to disperse the load instead of sinking into the soil and then contracting. This may cause a rocking movement or a wave type movement in which case the panels would have to be anchored. The rubber panels would probably experience more movement than the foam inflated fabric due to the rigid foam holding its shape.

There are stories told about the military using rubber tire inner tubes, filled and tied together to cross wetland areas during wars. Unfortunately, there is no known written history describing the design or performance. Vehicles would drive directly over them to successfully cross the wet, low strength soil. The tubes could be interconnected using metal bands and it may also be possible to fill them with the foam or water to help stabilize them. A running surface could then be placed on the tubes, if necessary.

There are a number of problems with using the foam inflated fabric. The product was hand-made by the military. So, the fabric would have to be purchased and sewn together. This could become expensive and time consuming. It could be made commercially but the cost is unknown, especially for a small quantity. The polyurethane foam chemicals would need to be purchased and thoroughly mixed together. This is not difficult, but special equipment is needed. Some of the problems the military had with the chemicals were accurate measurement, temperature dependance of the foaming reaction, and accumulation and disposal of waste mixing materials. A mixing system called the autofroth foaming system was tested. It alleviated the mixing problems but it costs $8,000. The panels need to be handled carefully enough to resist puncture. If punctured, they would still be useful but their life would greatly decrease. The system depends on the fabric for its tensile strength.

The entire system should be designed to “float” on land instead of water. Too much weight can permanently damage the foam. A means of moving the panels with a loader is required. A way to anchor down the entire system may need to be established. A design for interconnecting the panels needs to be determined. Although, if the running surface is interconnected and attached to the fabric, there would be no connection problem. The entire project would be very experimental, as this idea has never been used before as a wetland crossing.

The inflatable rubber would have many of the same problems as the inflatable fabric. The advantages of rubber would include the possible commercial availability of the product and the use of air and water as the fill material instead of chemicals. Unfortunately, a commercial source has not yet been found. When one is, the research and design will be new, so the cost to produce the rubber form would probably be high, especially for a small quantity. Other problems include the actual design of the form including how to attach a running surface. Initially, experimenting with inner tubes may help answer some questions at a lower cost. When it comes to life expectancy and cost, the difference between using fabric or rubber is another unknown.

A combination using rubber, for durability, availability and cost, and filling the rubber with chemicals for greater stability, could possibly be the best product as a wetland crossing. In both cases, the life expectancy and stability over a long distance is unknown.

The idea of floating a road has many problems, yet is a definite possibility. The research phase of this concept should begin with design and move through construction and testing. This could make for an interesting and successful project. The end product would be lightweight, reusable and the least likely to sink compared to the other options. Cost and stability are unknowns that would need to be determined.

Aluminum Access/Egress Modules

Waterways Experiment Station (WES) is a research center connected with the U. S. Army. CERL had recommended contacting WES about wetland crossing possibilities. WES is located in Mississippi and has intensely researched products that could be used as an egress from rivers as well as access over low strength soils. Many times, vehicles cross rivers but cannot exit due to steep, slippery, river banks on the opposite side.

One item tested that was designed by a private consulting firm under contract with WES is the Aluminum Access/Egress Modules. The system is made to distribute the load over the width of the mat. It is very durable, and very quick and easy to lay/recover. The system is costly but should have a long life expectancy. This system and many others were tested under specific criteria at WES. (See appendix D.) This system proved very successful.

The modules are made up of 16-feet by 2-feet by 2-inch aluminum panels. A cross section along the width of a panel shows 13 tunnel-like openings separated by aluminum walls. The individual panels are hinge connected together so that the length can vary from two panels up to any desired length. Because of the hinged connections, the panels can be easily folded into an accordion-like bundle. Each panel weighs 244 pounds. (See figure 14.) The bundle can then be easily lifted and transported by a loader to another site. The panels have a rough surface made up of 1/4-inch protrusions for increased traction. Vehicles showed no visible signs of having problems climbing a slope with water and mud on the modules surface. Maintenance should be minimal. Any damaged panels could be easily replaced.

The module was tested as both a river egress for tanks and as a crossing over wet, low-strength soil. Several passes with several different types of vehicles were run over the modules with very successful results. (See figure 15 and appendix D.) It would probably be advantageous to place a geotextile material before laying the modules. The material would separate the module from the soil making it easier to retrieve. In case the panels need to be anchored, the military initially tried a 2-foot long 3/4-inch reinforcing bar with an 8-inch diameter plate welded to one end. Belvoir Research Development and Engineering Center later developed an anchorage system for the modules consisting of two anchor attachments with a 22-inch long piece of hinge material per attachment, four 6-inch arrowhead anchors with 4-foot long, 1/4-inch diameter anchor cables and a set of anchor driving equipment. Either type may suit our needs.

There are a few problems. One is that the module was specially made for the WES experiments, so it is not readily available. Due to this fact, the module is expensive and it may be difficult to find a manufacturer willing to produce the modules. (See appendix B.) The life expectancy is unknown, so it is difficult to determine if it is worth the cost. The module needs to be field tested to help determine its life expectancy and if it is applicable for our circumstances. For retrieving and placing the module, the military designed some specialized equipment. This equipment may not be necessary but it did make retrieval much faster and easier during the military testing. Although a geotextile will help during retrieval, it may cause problems with movement.

During testing, WES noticed the panels moving vertically at the joints. This movement decreased as the panels became seated in the soil. A geotextile may limit the amount the panels can seat which would increase movement. Also, for timber application, the panels may be damaged if placed over large rocks or stumps. So, some clearing may be required before laying the panels.

Although the Aluminum Access/Egress Module is expensive, it has proven to be highly durable. It successfully passed very stringent military requirements as a river egress and wetland crossing. Because of its high cost, it may be most useful for repetitive moves as landings and for very difficult, short distance crossings.

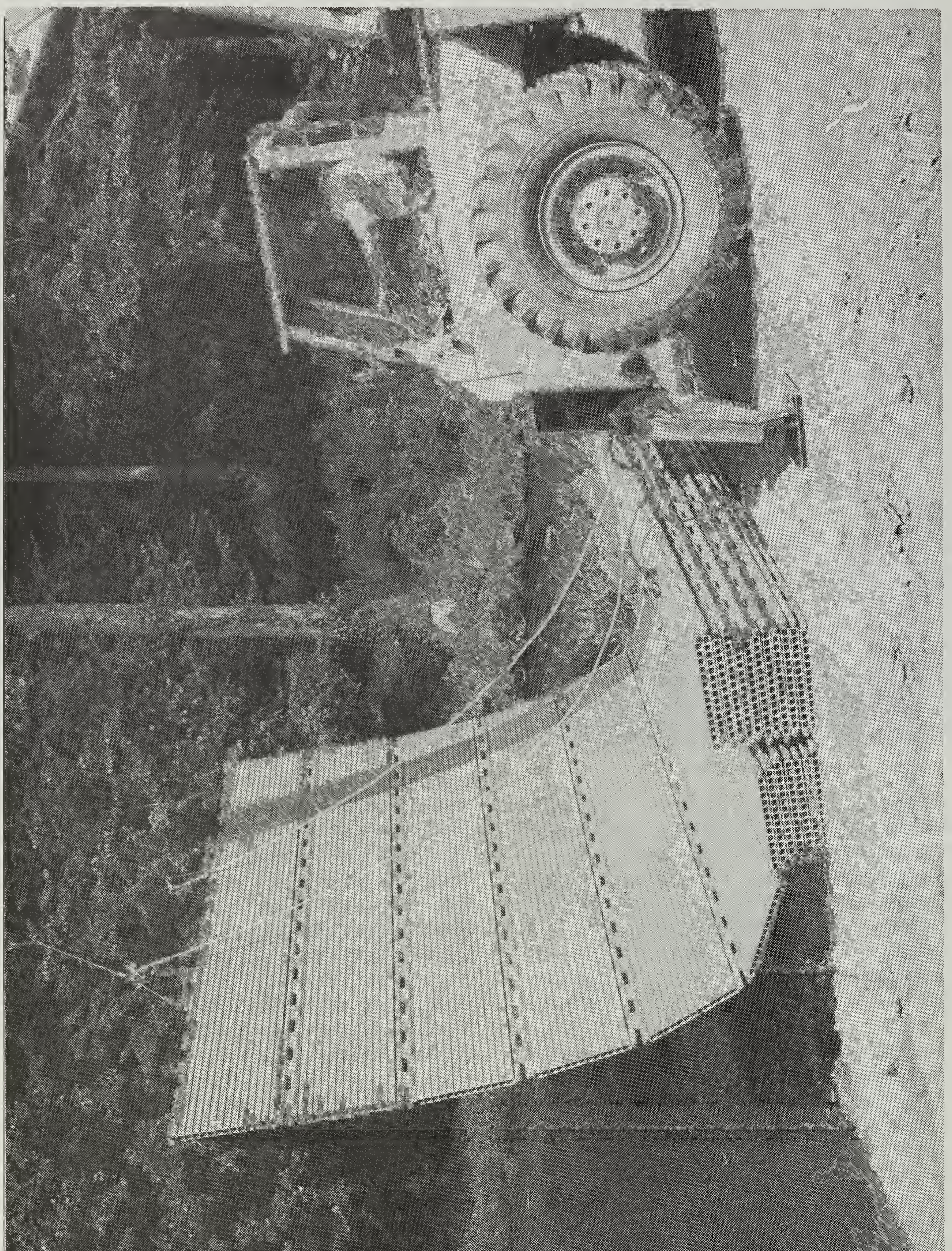

Figure 14. Installing modular aluminum panels.

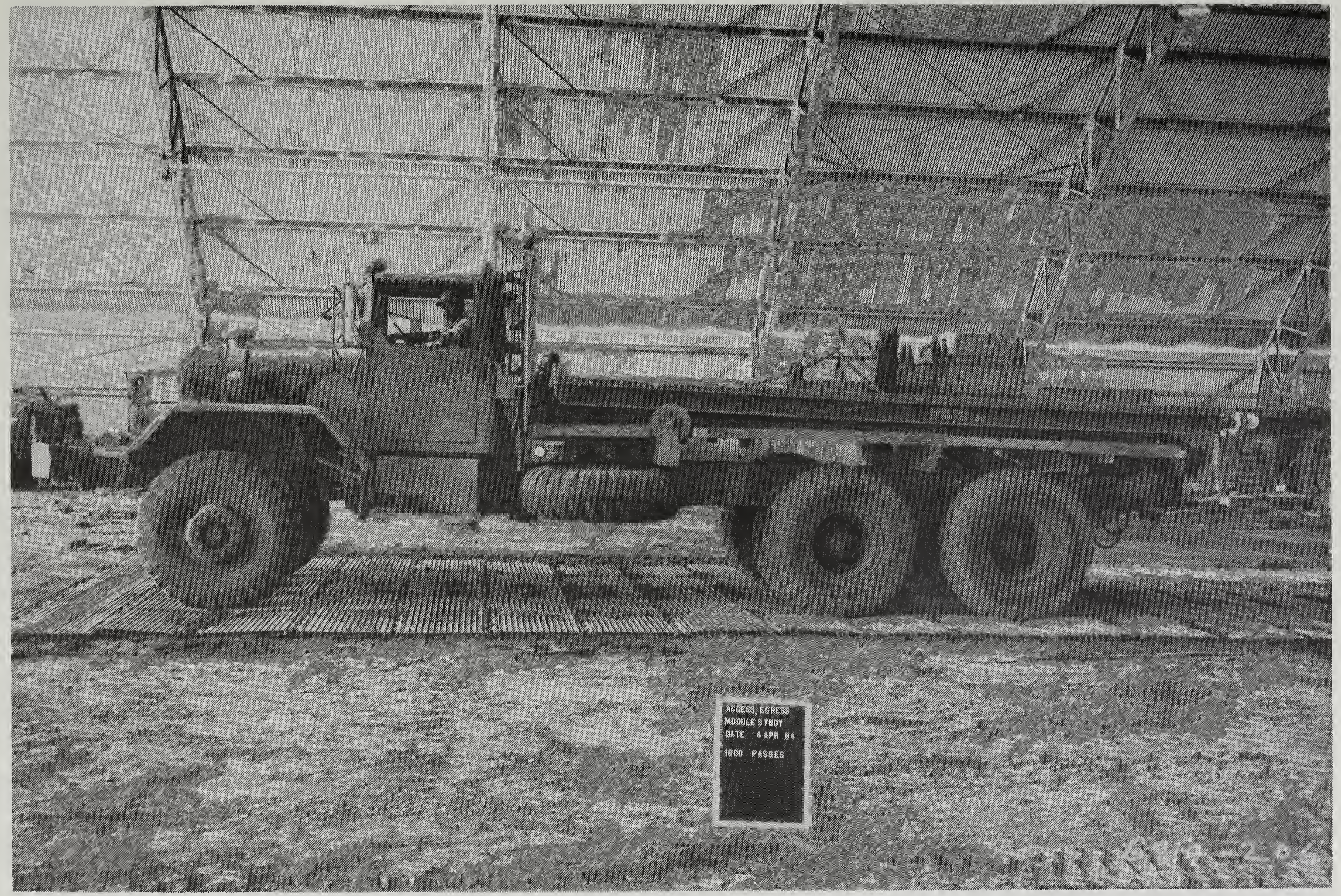

Figure 15. Aluminum Access/Egress Modules study.

This way, not many would have to be purchased and yet they might be used extensively. The modules would make for a very good, specialized situation product.

Flexmat

Before WES had the Aluminum Access/Egress Modules developed, a system called the Flexmat was developed and tested. The system was tested as a river egress and running surface over low-strength soil. The tests were similar to those used on the Aluminum Access/Egress Modules. (See appendix D.) After each test, the original design was altered using various types of material to improve strength and anchoring. The entire system was constructed by the WES carpenter shop using skilled labor. Some of the materials are readily available (screws and aluminum channels). The system is rolled up for transport and unrolled, using no special equipment, on site. (See figure 16.) A geotextile to separate the soil from the mat may help during removal. Compared to the Aluminum Access/Egress Modules, the system is not as rugged and will probably have a lower life expectancy but it is easy to construct and lower in cost.

The original Flexmat design consisted of a neoprene coated nylon fabric (T16 membrane) with 1-by 4-inch oak planks connected along the underside at 12-inch centers. A woven 9-gauge wire fabric was placed on the surface connected with 1-inch staples. The final design of the Flexmat was determined by testing four designs. The variations in these designs include: using a stronger, double thickness fabric (T17 membrane); using 2-by 5-inch aluminum rectangular tubes, 4-by 1.65-inch aluminum channels, 4-by 1.75-inch aluminum channels; using adhesive and adjustable stainless steel hose clamps, aluminum clips with hex head screws, aluminum clips with phillips pan head screws; using 6-gauge wire. (See appendix C.)

The best result came from a combination of T17 membrane, 4-by 1.75-inch aluminum channels at 3-foot centers, aluminum clips 2-by 3/4-inch with 1/4-by 1-inch phillips pan head screws. (See figure 17.) The system is 16.4 feet wide and 48.3 feet long and lightweight at 2.21 pounds per square foot. If failure does occur, it is easily repaired. The cost of the system is considerably less than the Aluminum Access/Egress Modules. (See appendix B.)

There are a few problems with this system. The system is not commercially manufactured nor readily available. However, all the material can be purchased and the system constructed. Construction could prove to be manually intensive due to all the connectors and may require skilled labor. (See figure 18.) The woven wire, T17 membrane and clips are not off-the-shelf items. WES now uses a membrane similar to the T17. It would be easier to procure the sections based on a data package describing the system. This way the system is delivered to the site completely assembled and rolled into bundles.

WES is in the process of obtaining a patent on the government designed Flexmat. The data package for the product could then be used for procurement purposes. The life expectancy is unknown but will be much shorter than the modules. The system would be easy to place but retrieval may be difficult. Using a geotextile or chunkwood to help separate the system from the soil may help. The problem could be that the channels are needed to help anchor the system and anything that separates the system from the soil may cause problems in anchoring. If a failure occurs, pieces may be left on site, creating an environmental concern.

The Flexmat system may prove to be worthwhile due to its lower cost. It would still be considered an experimental system, especially in the areas of life expectancy and maintenance. The system may prove to hold up well if used as a landing or if used for a short distance. Flexmat was designed mainly for traction rather than distribution characteristics. It may be more useful as a running surface for one of the other systems.

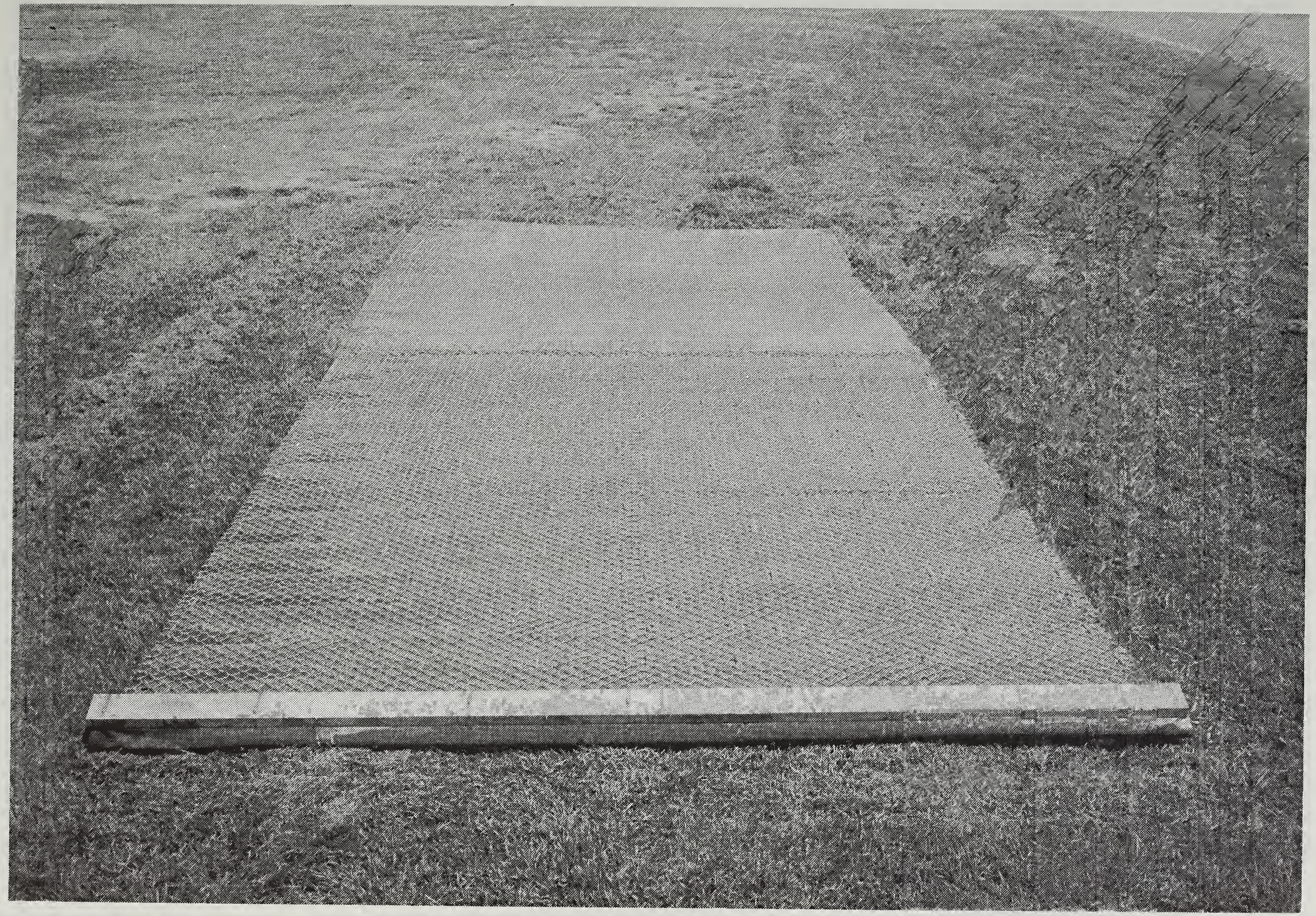

Figure 16. Flexmat section.

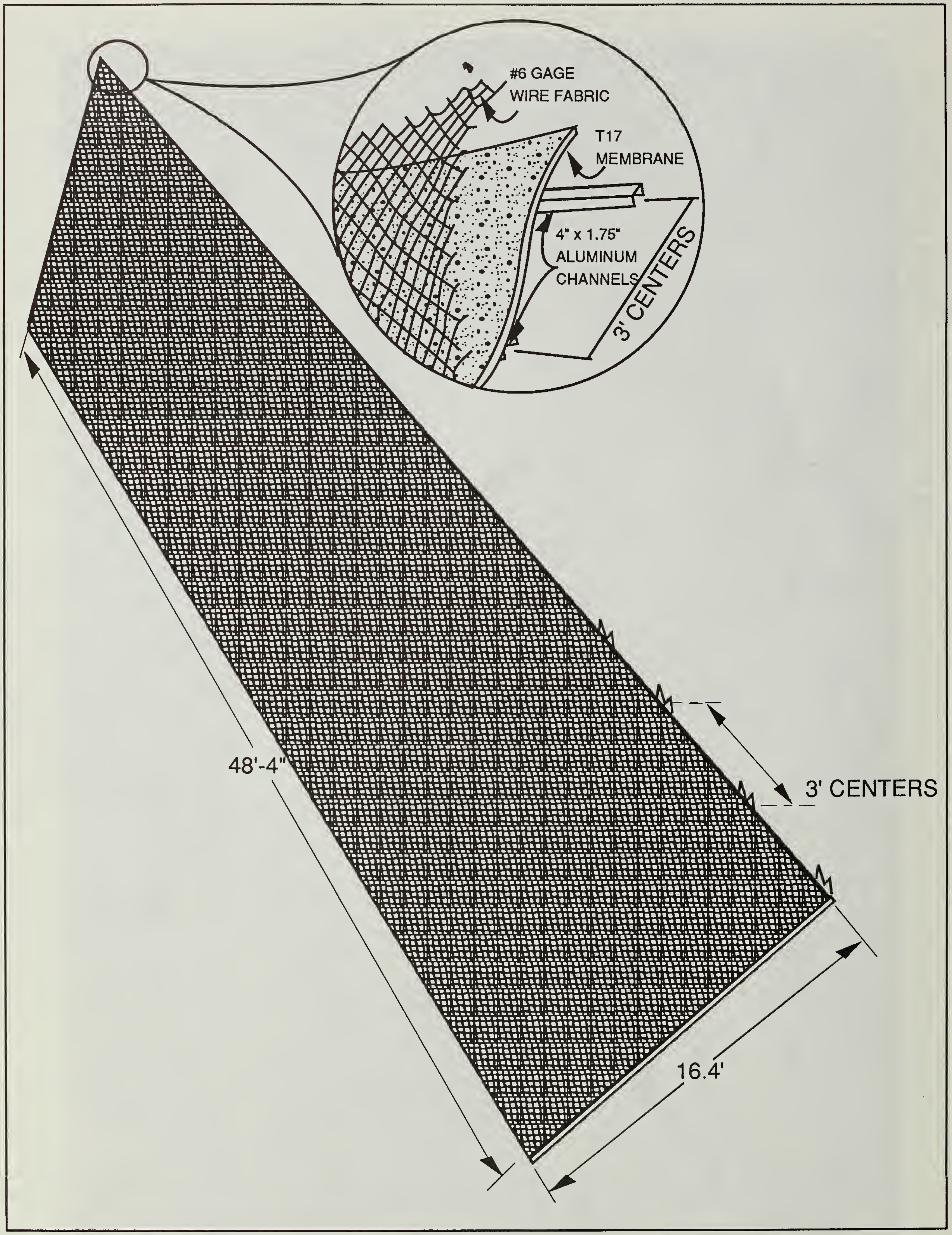

Figure 17. Graphic representation, Flexmat IV system.

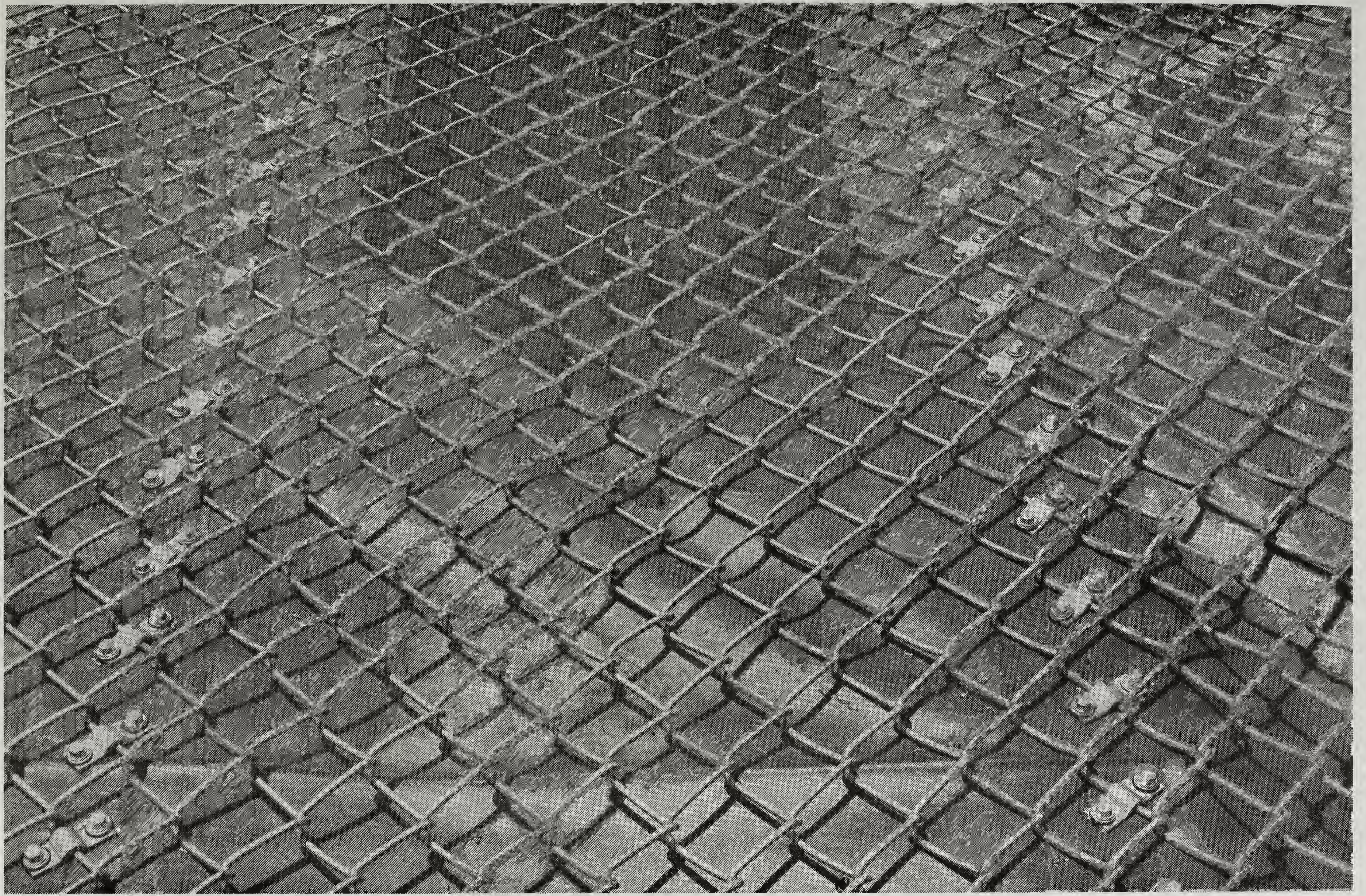

Figure 18. Close up, Flexmat details (woven wire, membrane, and clips).

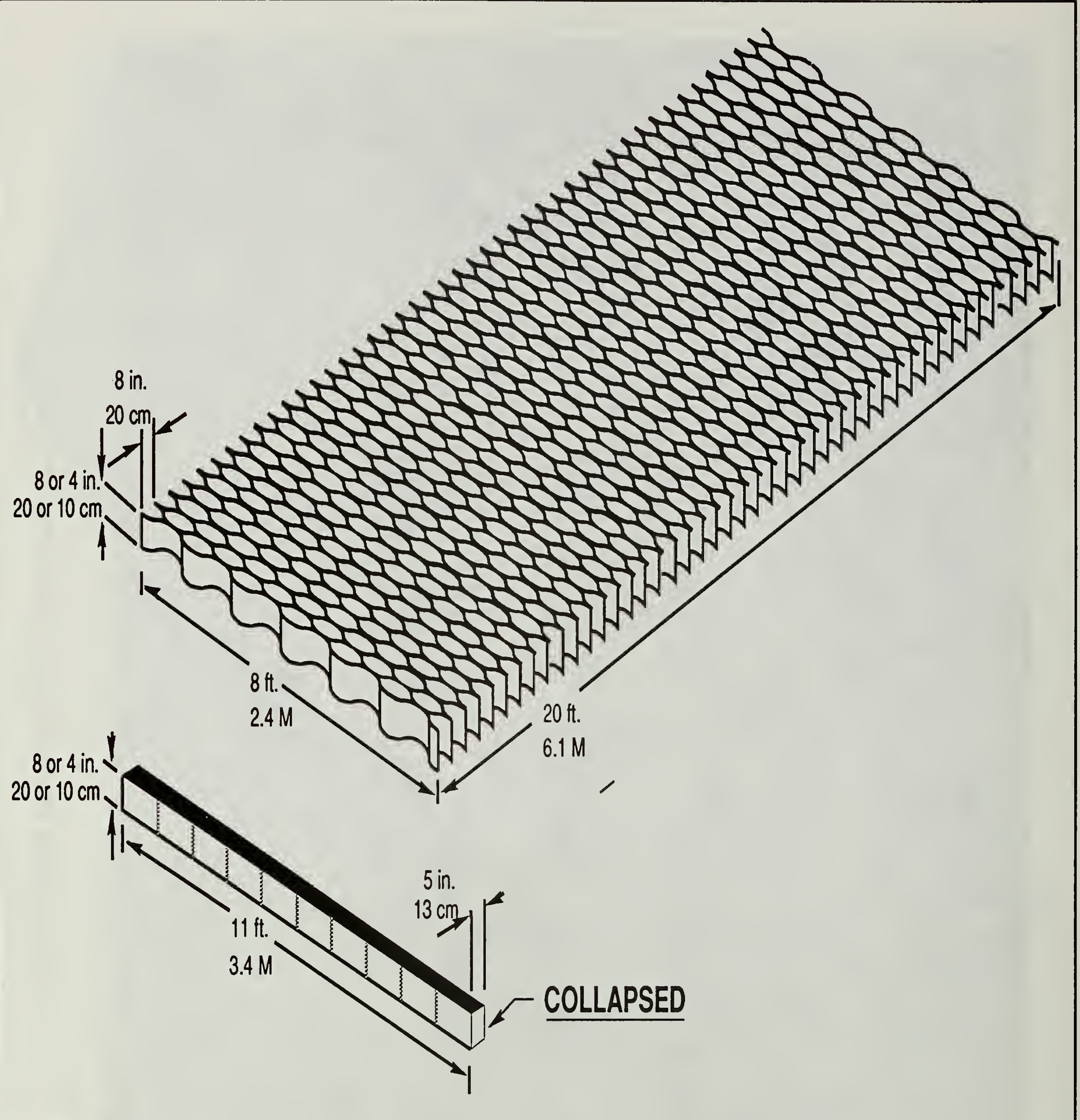

Figure 19. Graphic representation, cellular confinement system.

Geomatrices

During the search for items that could be used as river egress and crossing low-strength soils, Waterways Experiment Station (WES) looked into some possible commercial items. Geomatrices were one of the commercial items tested by WES. The geomatrices underwent testing as a soil strengthening system for access/egress bridging applications. (See appendix D.) The testing performed was on a single layer of geomatrix and sand crossing over low-strength soils. Several different types of geomatrices were tested with some performing well. The matrices are very easy to transport and install but are made for only one installation. No special skills are required for installation and the entire matrix is very lightweight. Only equipment to fill the matrix is necessary. The matrices are inexpensive compared to other alternatives.

Geomatrices are an expandable honeycomb that are used to confine and reinforce existing cohesionless or unstable soil. The type tested by the military were interconnected sheets of aluminum or paper produced by Hexcell Structural Products. They are flexible so they can conform to the existing contour. (See figure 19.) There are also catwalk-type fiberglass panels (grating) that can be used as a geomatrix. These products, produced by IKG Industries and Borden Metal Products Company, are discussed in the grating section.

The geomatrices are used to contain fill material which gives added support strength to the fill. This in turn can reduce the amount of fill necessary. The dimensions of the matrices are: paper - 24 feet by 8 feet by 6 inches; aluminum - 20 feet by 8 feet by 4 inches, 6 or 8 inches; fiberglass - 3 feet by 13 by 1 inch or 4 feet by 12 feet by 1 inch. The most common type of fill material used in geomatrices is sand. The WES experiments were performed with sand fill on a sand base. (See figure 20.)

The possibility of using chunkwood or other materials as fill could be tested. The geomatrices can be stacked to make any depth of fill. A geomatrix would be placed, the fill material compacted into the matrix, then another layer would begin. The fiberglass panels were connected together to form the required length. High density, polyethylene geomatrices called Geoweb, produced by Presto Products Co., have been used by the Forest Service as boat ramps and stream crossings and have proved successful in both applications. (See figure 21 and appendix C.)

For the WES tests, the 6-and 8-inch aluminum matrices held up well with the fiberglass panels performing the best. The tests were performed with and without a membrane underlay produced by Reeves Bros., Inc. The membrane is a kevlar material covered on both sides with neoprene. It is 0.013 of an inch thick and weighs 1.8 ounces per square foot. (The results of the WES tests are shown in appendix D.)

The problem with the test results is that the fill material was not compacted in the matrices. There is an increase in strength when the fill is compacted and is surfaced with 2 to 3 inches of crushed stone or a 1-inch sand-asphalt mix. Using lower tire pressure may also help increase strength. WES was looking at speed and available equipment in the field when performing these tests. The installation rate at which an 8-inch by 14-feet by 40-feet aluminum geomatrix including the membrane and aggregate, was 1 and 1/2 hours without any compaction.

The biggest problem with geomatrices is that they are not easily reusable. The paper and aluminum would probably fall apart during removal. A way to remove the matrices would have to be developed. It may be possible to attach the system to a metal frame. This way, the frame and geomatrix could be lifted out as one unit. This would lead to the extra cost of removing the fill material that would be left.

Figure 20. Using sand fill in cellular confinement system.

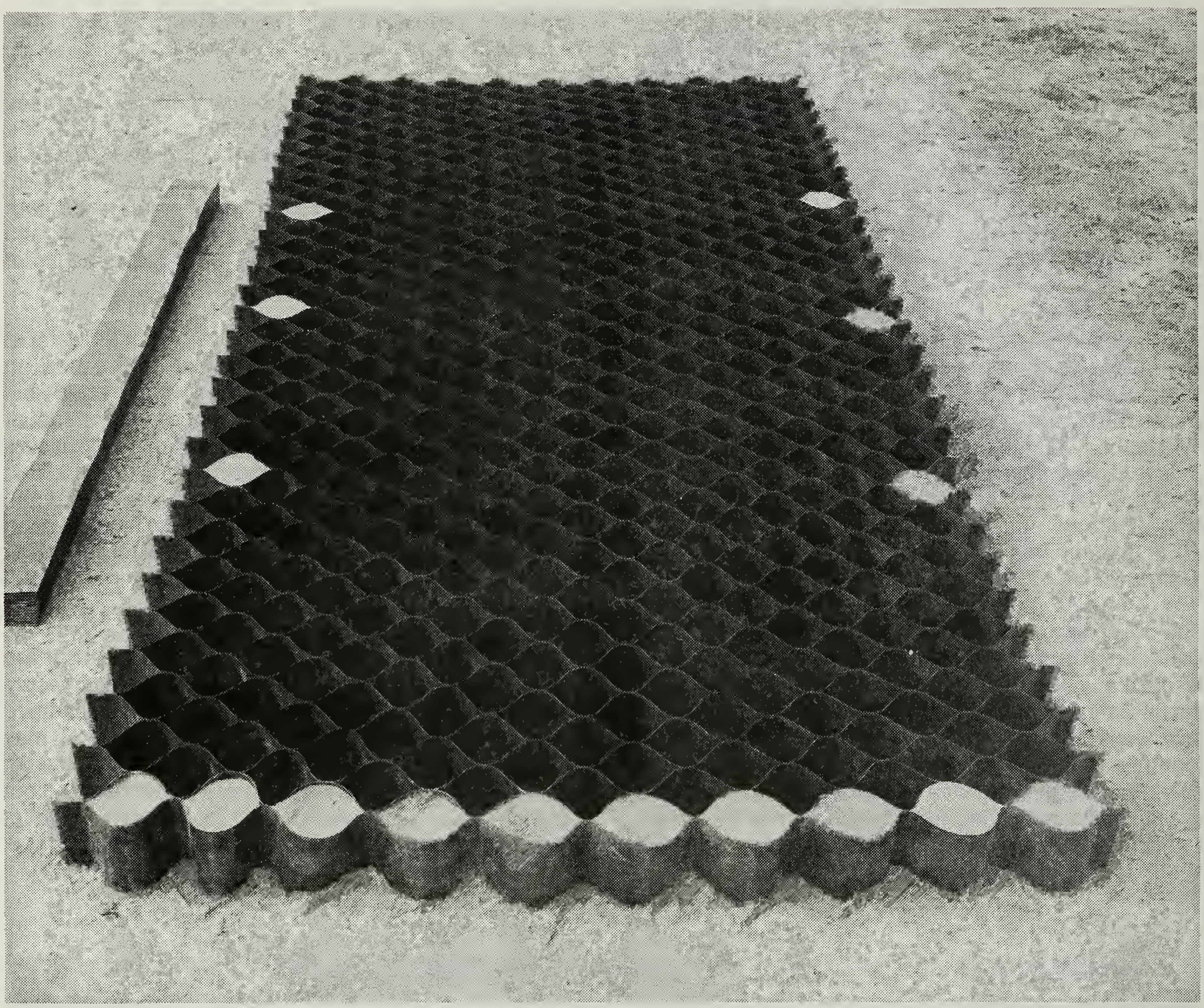

Figure 21. Polyethylene geomatrices used for ramps and crossings.

The best alternative would be to use them in an area with soil that could be used as fill and needs to be strengthened using a geomatrix. A geotextile may help the entire system and make removal easier. This could only be determined through experimentation.

The fiberglass panels would be easier to remove but a way to bundle them for transport would need to be designed. Also, discussions with the manufacturer indicate that fiberglass is very weak under rolling loads. So, the panels would need to be continuously filled with sand in order to withstand traffic. A possibility might be a system using the paper geomatrices and chunkwood. The materials could then be left in place to naturally deteriorate. This could only be used in areas without standing water due to the chunkwood floating and the paper weakening. There may also be a problem with rutting. Because the geomatrices are flexible, if the underlying soil moves (compresses) due to an applied load, the geomatrix will conform to that deformation and cause rutting. This will decrease with an increase in layers. A better design would have to be determined concerning single or multiple layers. Availability and type of fill material would need to be determined. The life expectancy compared to cost is unknown and would be determined through more experimentation.

The geomatrices would probably only be used in more permanent situations due to the difficulty in removal. There may be situations where a more permanent road is needed and the geomatrices could be used to help reduce fill material costs. Only the fiberglass panels could possibly be portable and reusable but the life expectancy is unknown. In sandy areas, where a more permanent road is needed, the matrices may prove very useful.

Grating

As part of the research into geomatrices, IKG Industries was contacted in reference to the fiberglass panels. IKG and Borden were two separate companies during the military testing but have since merged. The company showed some interest in using fiberglass in a wetland crossing situation. Although it performed well during the WES testing, it is not recommended for use under direct rolling loads. The main benefits of fiberglass are its light weight and resistance to corrosive environments.

Inquiry was made into using other types of grating. Aluminum is less expensive and lightweight. Yet, it is a softer metal and would probably do poorly under harsh conditions. Steel is the least expensive, very durable, but can be very heavy. Gratings have not been used as wetland crossings in any known experiments. There are so many variations that only through field experimentation can it be determined which type would best suit our purpose.

Because the manufacturer did not recommend using fiberglass, no certain type for testing was discussed. They did feel that the molded type would hold up well. The molded type is a solid panel of fiberglass molded into a grating form. (See appendix C.) The other type is the pultruded grating. The pultruded product consists of individual grating components made of fiberglass that are glued together to form the panel. (See figure 22.) There are several types of pultruded fiberglass grating including a heavy-duty type. (See appendix C.)

From the photos in the report, WES tested both types of gratings. The results for the Borden panels represent molded fiberglass and the results for the IKG panels represent the pultruded type. They both performed about the same with a sand fill on sand soil. The molded type did better with direct traffic (no fill) on low-strength soil. Fiberglass gratings could hold up very well if used on sand roads. (See figure 23.) This way the gratings could be kept filled with sand for support for rolling loads.

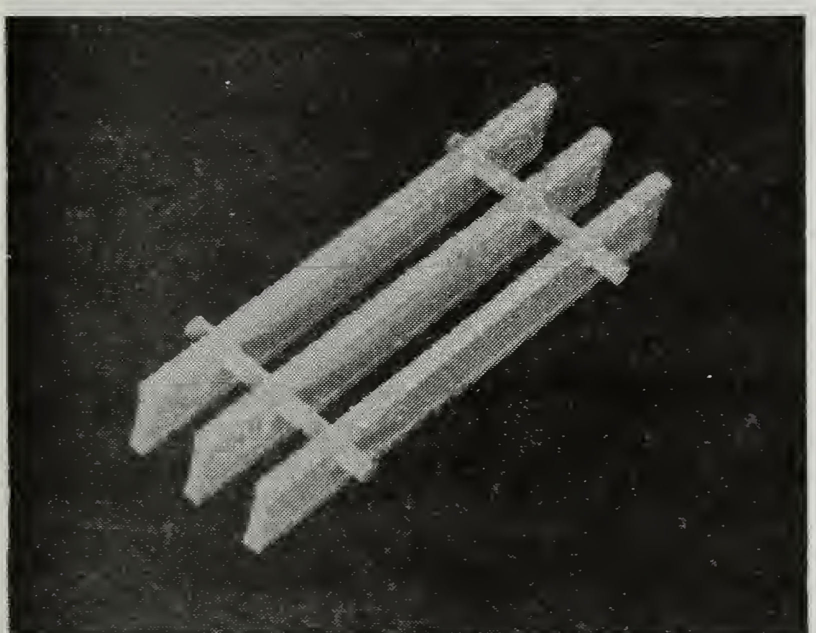

Figure 22. Pultruded fiberglass grating.

Figure 23. Typical sand road that could be used for fiberglass gratings.

Originally, riveted steel and riveted aluminum gratings were suggested as possible wetland crossings. The company was concerned with welds failing under a flexing load. SKM Associates, Inc., sales agents for IKG Industries, decided that the riveted gratings may also have problems. Because they are riveted, there would be a greater chance of the panels bowing. The panels could not be turned over to correct the bowing because one side is much weaker than the other. Two types of steel grating were suggested for the initial field tests. One is deck span safety grating. It is made from 10-gauge, pregalvanized sheet metal. It is 36 inches by 10 feet by 1 and 5/16 inches with the edges flat instead of bent into a channel. The plank has an 8-diamond design with a diamond opening size of 3 and 7/8 inches by 1 and 1/4 inches. (See appendix C.)

The other is a 4-pound regular expanded metal grating. It is made of non-galvanized carbon steel. The size is 48 inches by 10 feet by 0.618 of an inch with a diamond opening of 1.33 by 5.33 inches. (See appendix C.) Neither has welds or rivets that could potentially fail and both have a rough surface for traction. The panels will have a tendency to bow after numerous passes due to a "cold pressing" effect. If the panels are turned over, then they can be "cold pressed" back into their original form. This will not cause any fatigue problems.

The biggest problem here is just figuring out which type is best. A grating is chosen according to span, load, and environment. For wetlands, the load is known but there are no spans.

The environment typically affects corrosion and the way the grating is corroded. It is possible to narrow down the choices by designing the grating to be used in a bridge application. This way, it could be used for both a bridge deck or a wetland crossing. Fiberglass and aluminum are already very limited in this application. Both types could be used but it should be limited to sandy area applications. They are also the most costly. (See appendix B.) Because they are weak materials for this type of application, they would probably have a short life expectancy and not be cost effective. The steel gratings are heavy. (See appendix C.) It could take 3 or 4 men per panel to lift and place some types. In this case, fiberglass or aluminum could be well worth their costs just in time and labor due to their light weight.

Gratings could become very useful in timber sales. They have a smooth surface, so logs being hauled by a skidder will not get caught in the product. Yet, they have a rough enough surface to give vehicles good traction. They can be used as both a wetland crossing and a bridge deck. They can be high in cost and heavy. Yet, they are durable and should last for many years. Because of the large variety available, they can become a very versatile product.

Landing Mats

Before developing any new products, Waterways Experiment Station (WES) looked not only into commercial products but also into stored military supplies. One military system tested was military aircraft landing mats. The interconnecting panels can be used to disperse the traffic load. Landing mats have been tested at WES to satisfy specific requirements under simulated aircraft loadings and met these requirements. The individual panels of mat can be installed or retrieved by unskilled laborers. The two types of landing mats tested for access/egress applications were the M8A1 and M19.

These mats were subjected to similar testing used for the aluminum access/egress modules tests. Both of these mats met the same structural load (wheeled and tracked vehicle) requirements as the modules. (See appendix D.) However, on 25 percent sloped areas, these mats will not support the traffic because of inadequate traction (coefficient of friction). Using a geotextile to separate the mat and soil would help during retrieval of the mat. The mats already have an interconnection design to alleviate any problems with movement relative to each other. The panels are lightweight and can be stacked for transport.

There are several types of landing mats. The following two types were tested by WES as possible access/egress system. The M8A1 is a 2-feet by 12-feet by 2-inch corrugated steel panel. (See figure 24.) The M19 is a 4-feet by 4-feet by 2-inch panel made up of an aluminum honeycomb core bonded on top and bottom with aluminum skins. (See figure 25.) The M19 panels weigh 71 pounds (4.3 pounds per square foot) and the M8A1 panels weigh 144 pounds (7.5 pounds per square foot).

The panels interconnect to make any configuration. One connection between individual panels of M19 mat is made by placement of the female connector of one panel onto the male connector of the adjacent panel. The other connection is made when the overlap of one panel is placed over the underlap of the adjacent panel and a locking bar is inserted to prevent separation.

For edge connection between M8A1 panels, bayonet-type connectors of one panel are inserted into slots of the adjacent panel. The end joint between M8A1 panels is achieved by steel pins driven into slots of the adjacent panel ends, thus securing the panels together. These mats could be useful for skidder work as far as making either a road or landing. As part of the testing, runs were made with and without a membrane. The military tested a membrane, T17, which weighed 0.33 pounds per square foot. It was used in a similar manner as a geotextile. The membrane not only helped during retrieval but it also kept the soil from coming through the panel joints. The panels worked well. The M19 held up the best and could be reused after 3,000 passes of mixed traffic. The M8A1 mats had some deformation problems.

The main problem with using landing mats is availability. The mats are a military item. They are stored in a depot but are not commercially manufactured at this time. There is a company showing interest in production but it is not yet definite if they will. The military may loan out the item, but if needed, they could ask for its return at any time. Such an arrangement poses several problems. How would the Forest Service obtain the mats and who is liable for any damages to the mats? During the tests, there was a problem with the mats bowing near the edges or joints causing damage to the mats. Even if the landing mats can be purchased at some point in time, the cost and life expectancy are unknown.

The other problem is the amount of time needed to install/retrieve the mats. The M19 and M8A1 mats can be placed on a roadway subgrade at the rates of 573 and 361 square feet per man-hour, respectively. The mats would probably be picked up separately by hand. The M8A1 mats are only 2 feet wide and should be easy to move but the 4-foot-wide M19 mats could be a bit more difficult. But, they are not very heavy. The time consuming work involves connecting and disconnecting the individual panels. It is not a difficult connection and, compared to other crossings, it could be done quickly. Both mat types are usually placed in a certain pattern.

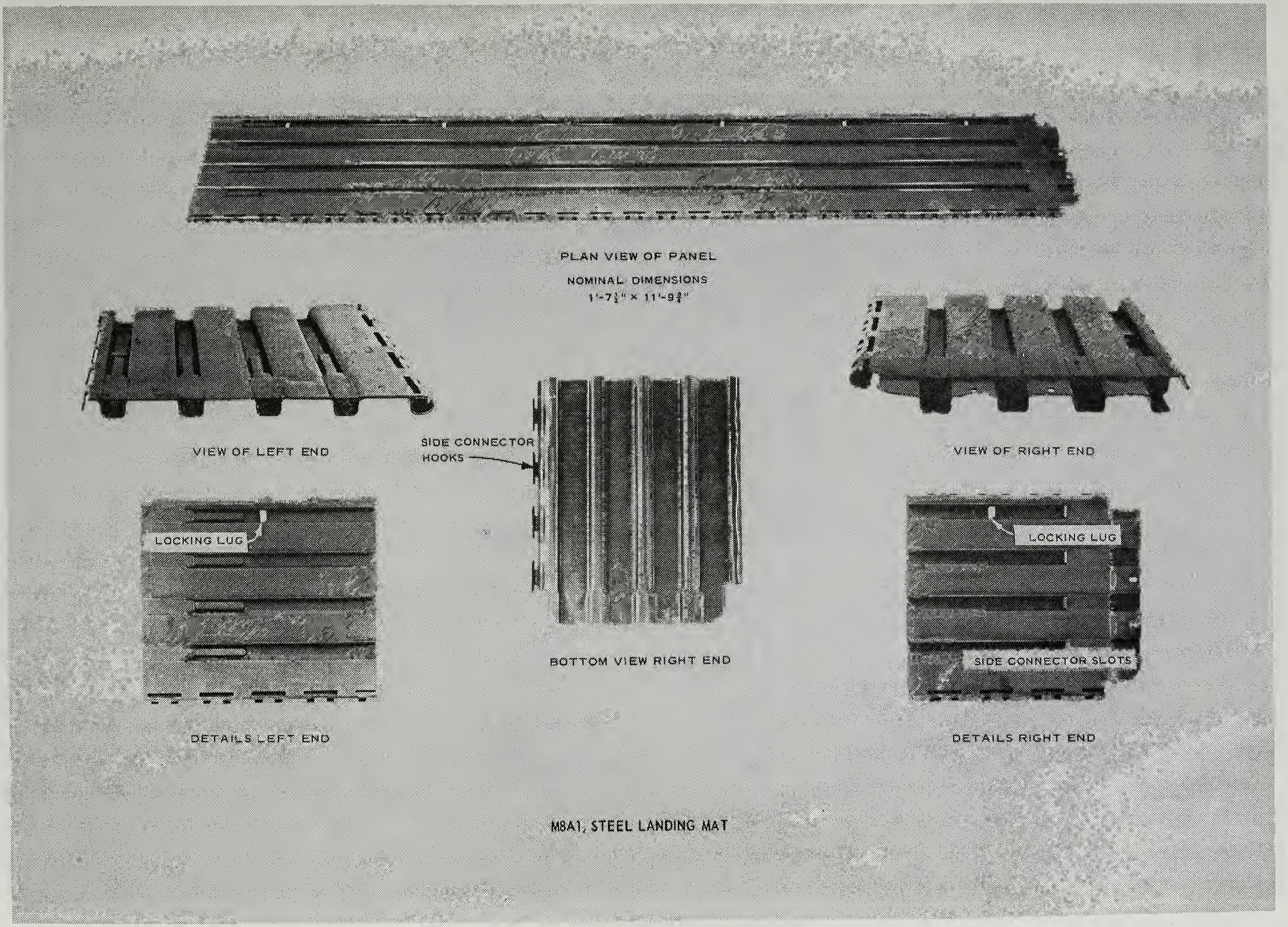

Figure 24. M8A1 Steel Landing Mat components.

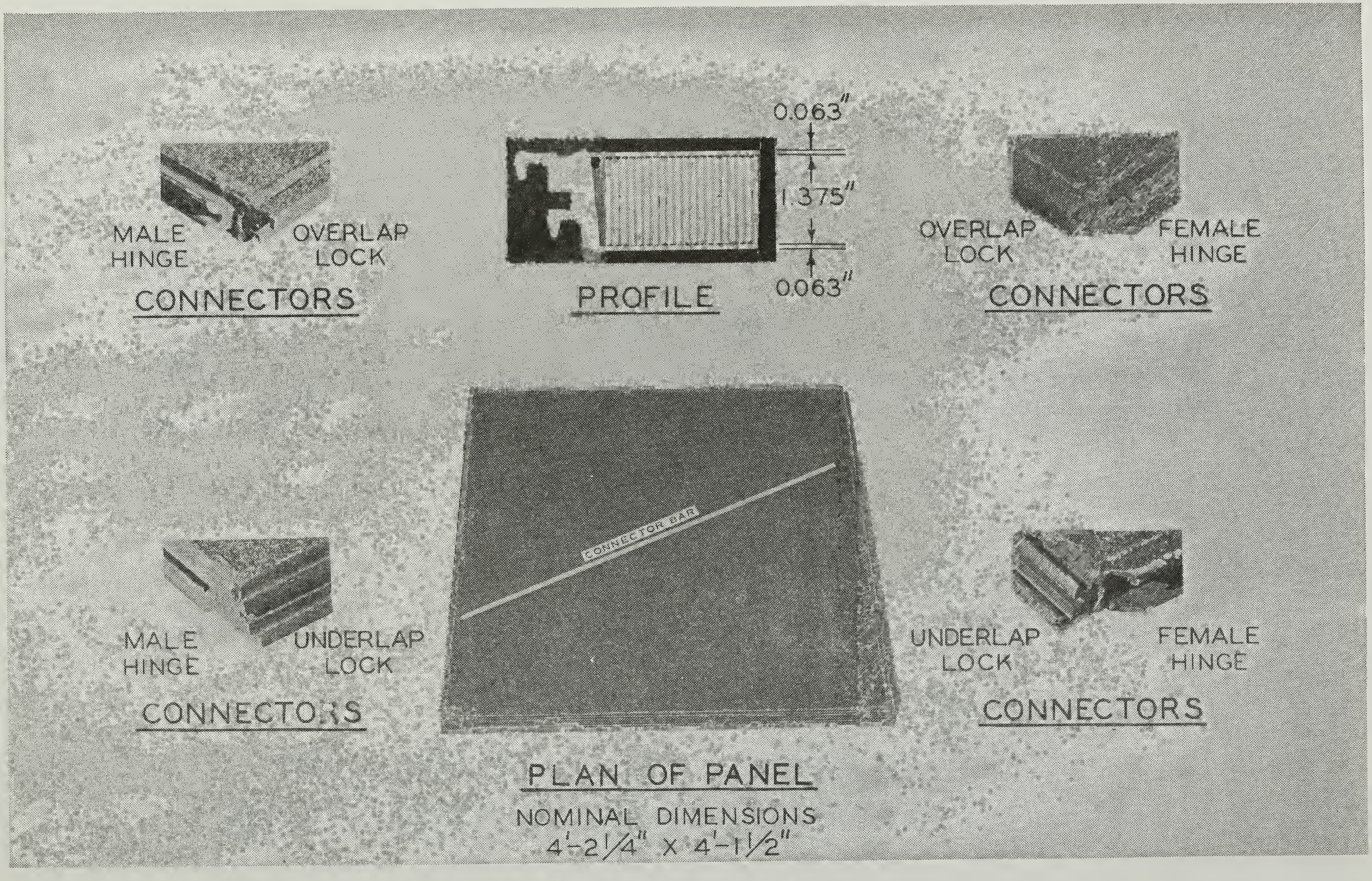

Figure 25. M19 panel components.

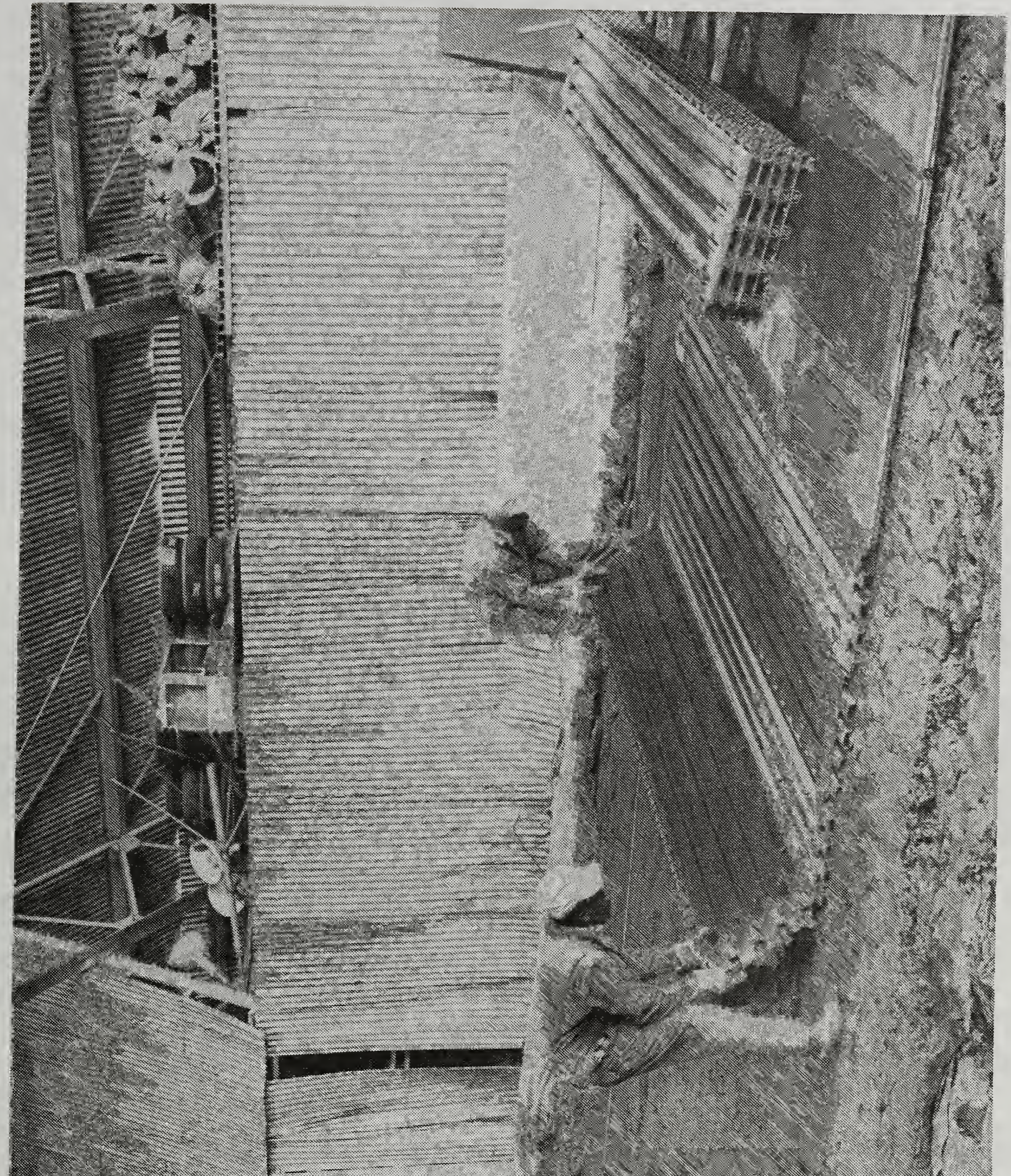

Figure 26. M8A1 Steel Landing Mat installation.

The M19 has to have the male/female connections parallel to the traffic flow. The M8A1 has to have the steel pin joints perpendicular to the traffic flow. (See figure 26.) A method could be designed to retrieve the mats using timber equipment so they all do not need to be disconnected. Analyzing the capabilities of the timber equipment will help determine an appropriate design. The M19 has a smoother surface than the M8A1. The smoother surface could cause some problems with traction.

Overall, the landing mats will work well. The availability and cost need to be determined before the mats are considered for experimentation. If a manufacturer becomes available, this could be one of the best choices not only for logging truck roads but for skidder work as well. In the meantime, the mats may be obtainable from the military for field testing.

Rubber Tires

Rubber tires are a commercial item that has been used in experiments on Forest Service roads. Tires are becoming an ever increasing problem in our country due to their very slow deterioration. Thus, they are readily available and inexpensive. Companies are beginning to look for ways to use this material. Tires are very durable and have long life attributes needed for a portable, reusable wetland crossing. One company advertises using tires as fill material. This helps decrease the cost of fill material and helps stabilize the soil in place. Another product, Terra Mat, was specifically developed to help logging trucks cross wetland areas. The mats are specifically made to be portable and reusable. No special equipment is needed to install/retrieve the mat. A loader can do all the necessary work. The amount of experimentation is limited but using tires looks promising.

Using whole tires as fill material helps reduce the amount of fill material needed to construct a road because they are a large part of the fill. The tires would help contain the fill material and would not be affected by moisture. This would increase the stability and longevity of the road. Another idea is to tie the sidewalls of tires together. The interconnected sidewalls would make up a panel. The panel would help disperse the vehicle load when crossing low-strength soils.

Terra Mat is based on this design. (See figure 27.) Although it was specifically developed for logging trucks,

Figure 27. Interconnected rubber tire sidewalls, Terra Mat.

Figure 28. Rubber tires used without additional running surface.

limited experimentation with Terra Mat has been performed on Forest Service roads. The product has performed well and more experimentation should be performed. The product is 9 by 20 feet, weighs 1,000 pounds, and can be easily transported and placed by logging equipment. Although this would make for a narrow road, damage would be in a very narrow area. The less area damaged, the easier it would be to restore. According to the manufacturer, no running surface is necessary over the mat. (See figure 28.) Logging trucks seem to have no problem driving directly on the mats. The product is inexpensive and probably long lasting. (See appendix B.) Maintenance would be minimal and simple. It typically consists of replacing connectors. All parts and tools can be purchased through Terra Mat. This product is being purchased for field testing at this time.

The main problem with using tires as a fill material is that they must be used in the construction of a permanent structure. It would become very expensive to remove the tires and fill material to be placed elsewhere. If a permanent road is needed, using tires could prove to be very economical. They should still be used on an experimental basis due to the lack of experience with this particular design. Some of the problems with Terra Mat is the unknown life expectancy, rough driving surface, and width. The life of the product is expected to be long enough due to the type of materials and the ease of maintenance.

The manufacturer promotes driving directly over the tires. The ride may be a little rough at higher speeds. Not only would the surface be rough for the drivers but it may be difficult if used on skidder trails. Logs could get caught on the mats and cause an increase in maintenance of the mats or cause the mats to move. Time would be wasted on fixing the mats or putting them back in place. It is possible to fill the tires with a 3/4-inch stone ballast to help smooth out the surface. However, this would cause problems when the mat needs to be moved. Slash or chunkwood as a fill material may help and would not be a problem if left in place after the move.

The width of the mats is narrow for logging equipment. (See figure 29.) This may be a problem not only for maneuvering but for load distribution. Only field experimentation will show if the mats are wide enough to be practical. It is possible to request a wider or longer mat from the manufacturer if it's necessary. The extra cost and time involved is unknown.

Figure 29. Narrow width of mats could create maneuvering and load distribution problems.

Anchoring could be used to keep them from moving and earth nails are sold by Terra Mat, if needed.

The idea of using tires to stabilize and reduce the fill material costs of a permanent road or to provide a durable surface for crossing wetlands is promising. Tires are rugged and long lasting, readily available, and inexpensive. With past research and more experimentation, tires could become an acceptable, economical means for crossing wetland areas.

Trackway System

During the initial search for possible crossing products, contact was made with distributors of products from foreign countries. The military in foreign countries also deal with crossing wetland areas. The Trackway System is a product initially designed for the British military. It is now produced commercially by a British company. It was designed, like many of the other products, to distribute the load and has proved very successful. It is similar in design and was tested under similar conditions as the Aluminum Access/Egress Modules. It is currently in use worldwide. Although this product is made in Britain, there is an American distributor. The system is quick and easy to install/recover. A geotextile may be necessary to separate the system from the soil for easy removal.

The Trackway System is made of extruded aluminum alloy panels of 15 feet by 9 inches and 7 feet 6 inches by 9 inches. The panels interlock together to make a continuous mat. There are two kinds of Trackway systems, the class 30 trackway and the class 60 trackway. (See appendix C.) The class 30 is for lighter weight vehicles and a lighter amount of traffic. The entire mat is 11 by 105 feet. (See figure 30.) The class 60 is for heavy loads and extreme use. There are two sizes of this mat, 15 by 50 feet and 54 by 60 feet. (See figure 31.) The mats have laying/recovery equipment. Basically, it is a large spool attached to the back of a truck. (See figure 32.) The preassembled roll of mat can be unrolled into place and rolled up for recovery.

The panels for the class 60 can also be stacked, transported, and connected or disconnected at each site. The panels slide together and are held in place by a simple locking device. It takes 10 men, 6 hours to install a 60-by 54-foot mat of class 60. The class 30 seems to come only as a roll. The systems have a non-skid surface and were made to be reusable.

Figure 30. Class 30 Trackway System laid from a heavy-duty fork lift.

Figure 31. Class 60 Trackway System laid on sand in Middle East.

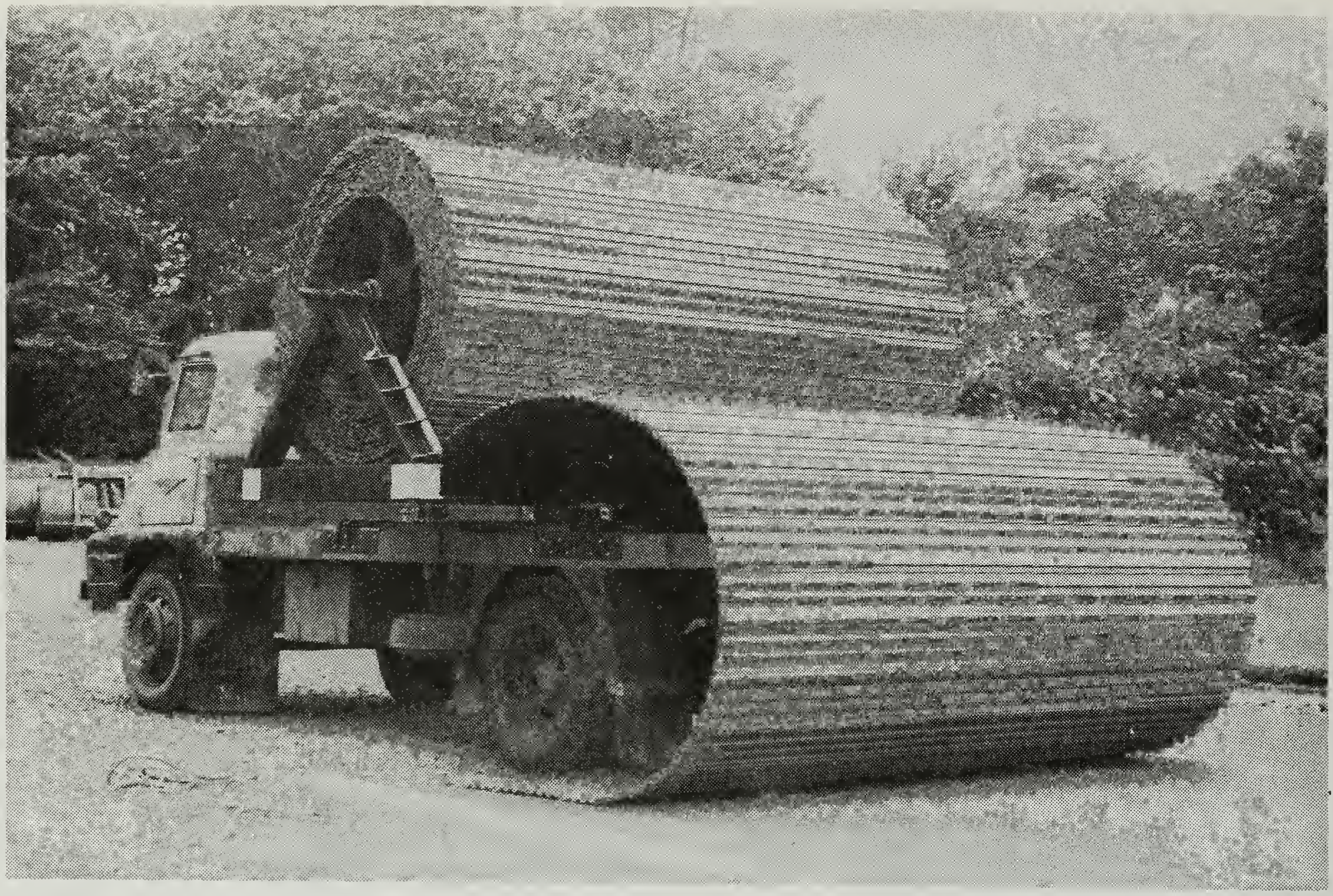

Figure 32. Rear laying of Class 30 Trackway from standard commercial truck.

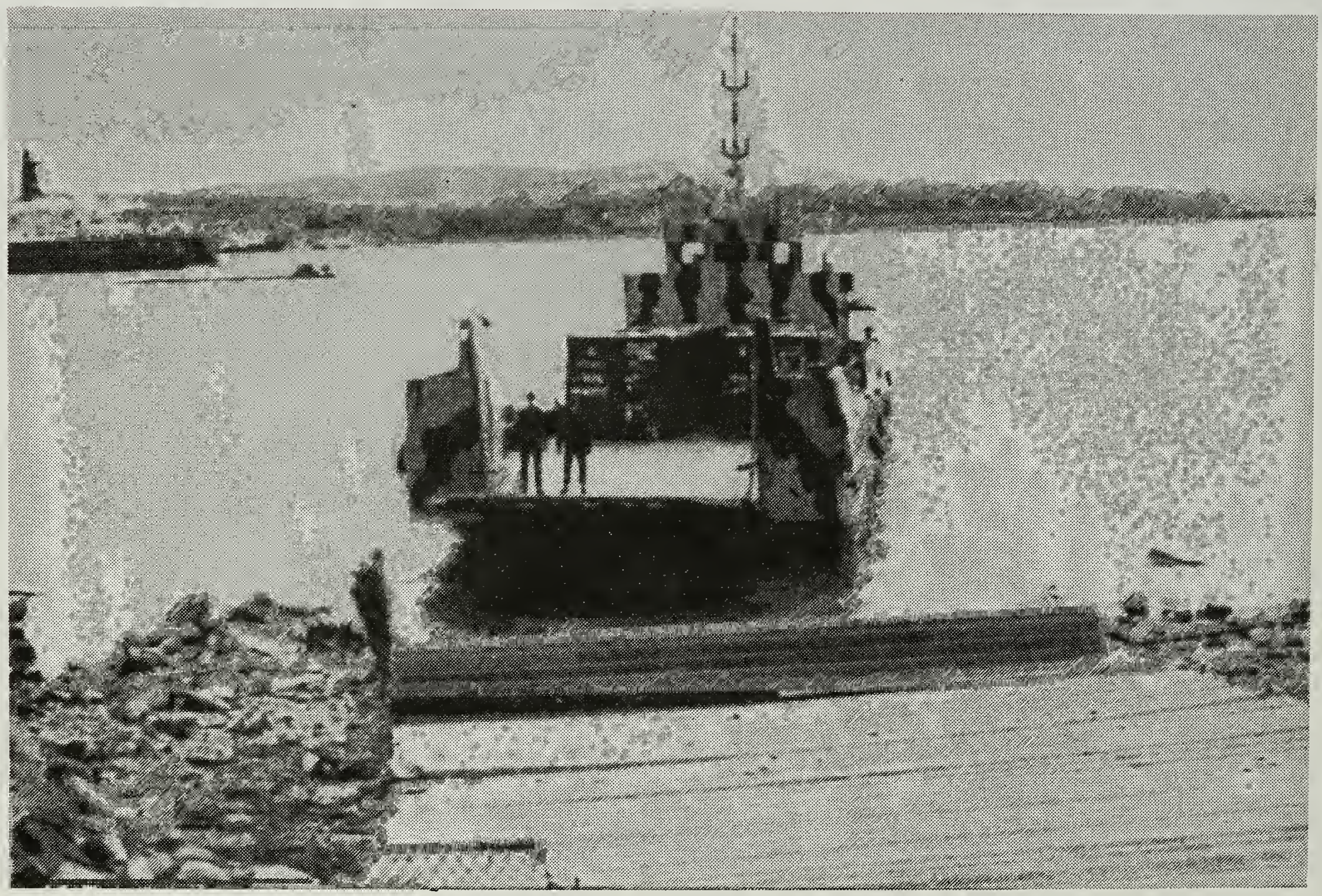

Figure 33. Class 60 Trackway used for beach landings in Falklands.

The panels can be replaced easily if damaged. More panels can be added or removed to vary the length of the system.

The main problem with both systems is cost. (See appendix B.) The initial cost is very high compared to other temporary or even permanent crossings. The product may still be worthwhile if used on shorter spans or in very difficult crossings. If the life expectancy were known, then the Trackway Systems may be worth the initial cost. The system is supposed to be very rugged but no actual field tests have been performed in the U.S.A. to determine the life expectancy.

Another added expense is the laying/recovery equipment. The equipment is not necessary but it would make the laying/recovery and transport process much easier and faster. It is not known if the area where this product is to be placed needs to be cleared before installation. (See figure 33.) It is assumed that the clearing of stumps may be necessary to reduce the possibility of bending any panels.

Although the system is expensive, it may prove to be well worth the money. The system is rugged, portable, made for heavy traffic, and reusable. If the life expectancy proves to be long, the numerous reuses would be well worth the cost. Future field tests will determine the possibility of using Trackway Systems in very difficult wetland crossings.

Bridge Flooring

When the idea of grating was considered, another similar product was brought to mind. Corrugated steel panels used as bridge flooring could also be used to distribute loads. The panels are normally used to span the space between the stringers on the bridge decks. They are strong enough to withstand traffic loading and distributing the load between the stringers.

Bridge flooring panels appear to be at least as effective as grating. The panels are readily available and easy to handle. They could be interconnected or used as separate panels. Two men could lay/recover the individual panels quickly and easily. Damaged panels could easily be replaced. It would be easier to recover the panels if a geotextile is used to separate the panels and soil.

The panels are made up of corrugated, galvanized steel. The length can range from 2 to 30 feet. The readily available width is 26 inches cover (28 inches o.a. width) in both 10-and 12-gauge material with 2-inch deep corrugations. (See appendix C.) The 2.5- by 6.5-inch, roll-formed, pregalvanized panels are lower in cost and fit together well due to a more uniform cross-section. The panels would work well at distributing a load over wet or sandy soil. On both types of soil, the corrugations would help the traction of the vehicles and would keep the panels from moving by "grabbing" into the soil.

The panels would also work well as a running surface for other wetland crossings or bridges. They would make a continuous surface and would provide traction. The panels could be stacked and transported without any specialized equipment. Because they are galvanized, a long life would be expected. The galvanizing can be damaged but the damaged area can be touched up with a zinc-rich primer to protect the exposed steel.

The main problem with bridge flooring is connecting the panels. Typically, in bridge applications, they are bolted or welded together and covered with a bituminous wearing surface. In the crossing application, having a stiff connection may help transfer some of the load to adjacent panels. But, in most of the applications, the panels should be allowed to flex. This would reduce problems with bending the panels where joined. There would be a lot of manual labor involved in connecting the panels if they are bolted together each time. Depending on length, there may also be disconnecting time required if the entire system could not be lifted and moved by timber equipment.

It would be much easier if the panels were hinge connected. This way the panels could be folded together and easily transported or at least easily disconnected and stacked. In many cases, the panels may not need to be interconnected. They may not even need to be right next to each other. The biggest problem in using these panels without being connected would be movement relative to each other and the possibility of them piling on top of each other. Other problems are that the panels are experimental in this type of situation. It is difficult to determine what the strength of the panel should be. Typically, strength is determined with the panel spanning between supports rather than the panel being continuously supported by soil. The cost is unknown and variable as well as the actual life expectancy.

Bridge flooring panels have as much a potential of working as grating. Using these panels while they are continuously supported by soil may offer a better solution than gratings. There is more soil contact area than with the gratings. This application provides more support for the panel and better distribution of the load. Also, the panels may not sink as quickly or as deeply due to the larger surface area. Field experimentation needs to be performed. Bridge flooring may weigh more and cost more than other products, but may also be more durable and effective than grating. This may be the better choice if it is also needed as bridge decking.

Figure 34. Pipe Fascine System used as fill material.

Figure 35. Loose pipes conform to the crossing configuration.

STREAM CROSSINGS (BRIDGES)

The following section discusses various possibilities for temporary bridges. There are many types of bridges, but the types described in this report are limited to those that can be installed by low or unskilled labor, are low in cost, and temporary. The proper selection of a bridge type depends on the stream crossing characteristics, especially the span. An engineer will need to be involved in the design for most of the types described in this section.

Pipe Fascine System

Many times in wetland and other areas, small gullies or streams need to be crossed. The Pipe Fascine System, designed by the British military, was specifically designed as a portable, reusable bridge over tank traps. (See figure 34.) Due to its design, logging equipment and loaders could easily install/retrieve the system. Several systems can be placed in one area to fill in long and/or deep crossings. They can be placed in dry streambeds or water flowing no greater than 5 feet per second at a depth of 5 feet or 16 feet per second at 2.5 feet depth (Maxi). The system was successfully tested and is used worldwide as an easy to install/retrieve, durable stream crossing. The British Forestry has performed field tests during timber harvests and intends to use the system on a regular basis. The system is excellent for alleviating problems of having one fixed bridging point because it is so easy to move.

The Pipe Fascine System is constructed of polyethylene pipes. The pipes form a continuous loop which is held together by high tensile steel chain. Inside the loop are numerous loose pipes. Loading nets cover both ends to keep the loose pipes inside the loop. The loose pipes allow the entire system to conform to the crossing configuration. This system is called the Maxi. (See figure 35.) The other type of system is the Mini. (See figure 36.) It consists of 6 pipes held together in a loop by steel chains. The Maxi is approximately 7 feet 6 inches in diameter and 15 feet wide. The Mini is approximately 2 feet in diameter and 15 feet wide. Originally, the system was available in only two sizes. In time, it was determined that more variety was needed. The Midi's now range in various sizes from the Mini to the Maxi. They are the same design as the Maxi except there are no loading nets on the ends. All the various costs and sizes are shown in appendices B and C. The system can handle a maximum vehicle weight of 70 ton and a maximum vehicle speed of 50 miles per hour. All of the systems are easily repairable and can withstand open air storage in extreme climates for 15 years. The system is considered indestructible. It takes 15 minutes to install/retrieve the Maxi. Retrieval can be accomplished by lifting or towing, depending on the available equipment.

There are a few problems with the system. If there is any side slope, the system will take on that slope. It would be possible to build up the lower end of the slope in order to even out the running surface, but this could cause damage to the stream. At times, no running surface is placed over the system. Two problems can occur, especially for logging trucks:

1. The surface of the pipes sometimes becomes slick from mud or water.

2. Based on viewing a video of the system in use, it appears that there is some difficulty rolling over the system.

The pipes make a rough surface that is difficult for wheels to roll over. Instead of rolling, the tires tend to push the pipes until they pile up and can move no further. A vehicle must then have enough speed or power and traction to roll over this pile-up of pipes. Some type of running surface should be placed over the pipes to smooth out the surface, add traction, and protect the pipes.

Possible running surfaces could be one of the wetland crossings or a portable bridge deck. The British Forestry covers the system with logs or slash to protect it and provide a good running surface. (See figure 37.) A connection may be needed between the running surface and pipe system. Retrieval may become a problem due to an increase in the system's weight from water, mud, and debris inside the pipes. The Midi's do not have the loading nets on both ends, so tipping the system to empty the water could cause the interior pipes to come out. Also, the mud and debris could cause clogging problems while the system is in place. Occasional inspections and clean out, when necessary, should alleviate this problem. The life expectancy is unknown, but the company claims the system to be indestructible and should last a minimum of 15 years.

The Pipe Fascine System does have limitations as far as placement on slopes and its type of surface. But, because of its capability to conform, it would be very useful on many applications. Experience has shown the system to have a long life and could be worth the cost. Field tests will help to prove the system's durability and eventual worth. Its ease of installation/retrieval and transport make it an excellent choice as a portable stream and gully crossing.

Figure 36. Transporting the Mini Pipe Fascine System.

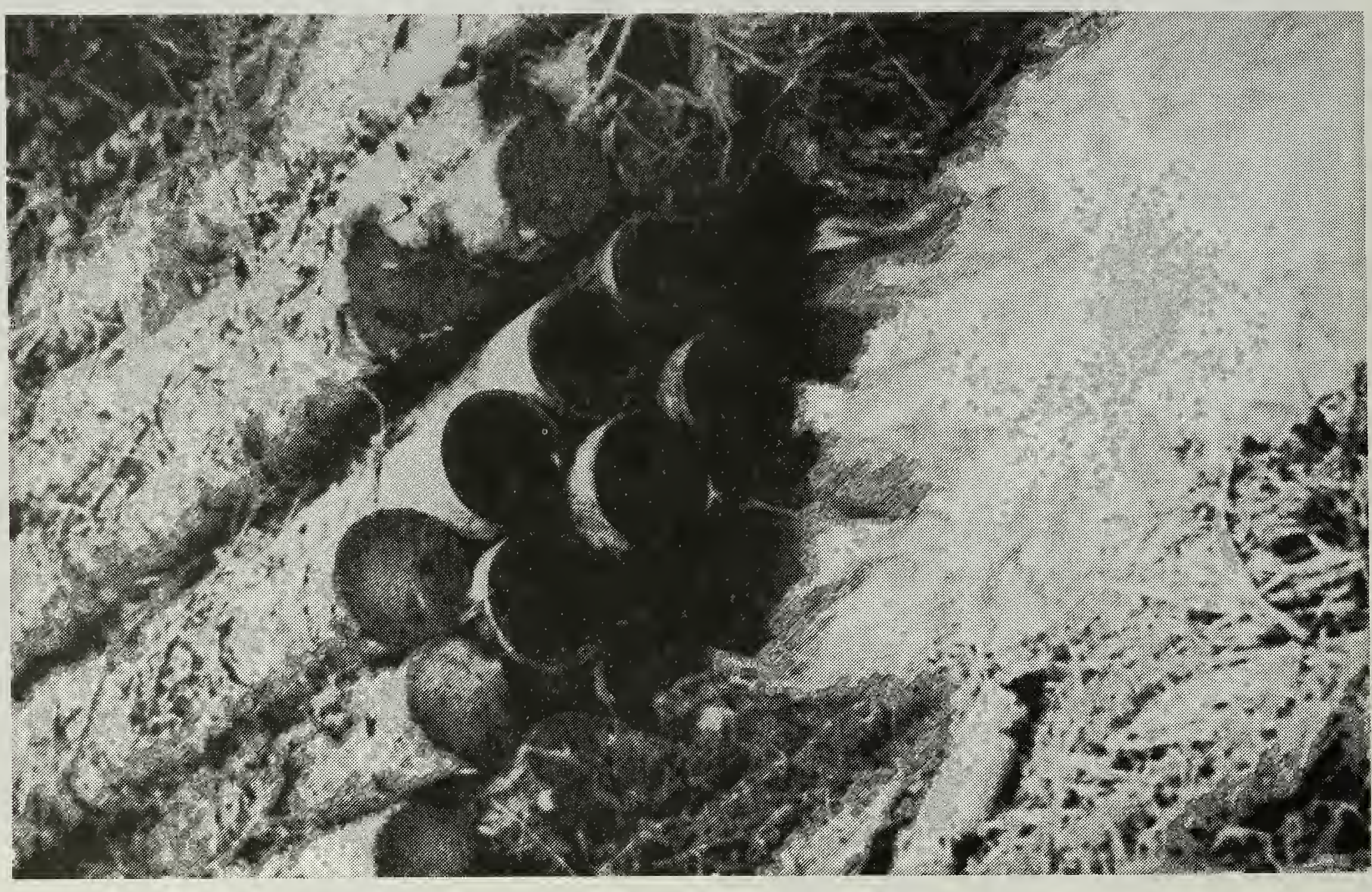

Figure 37. Pipes are no obstacle to running water.

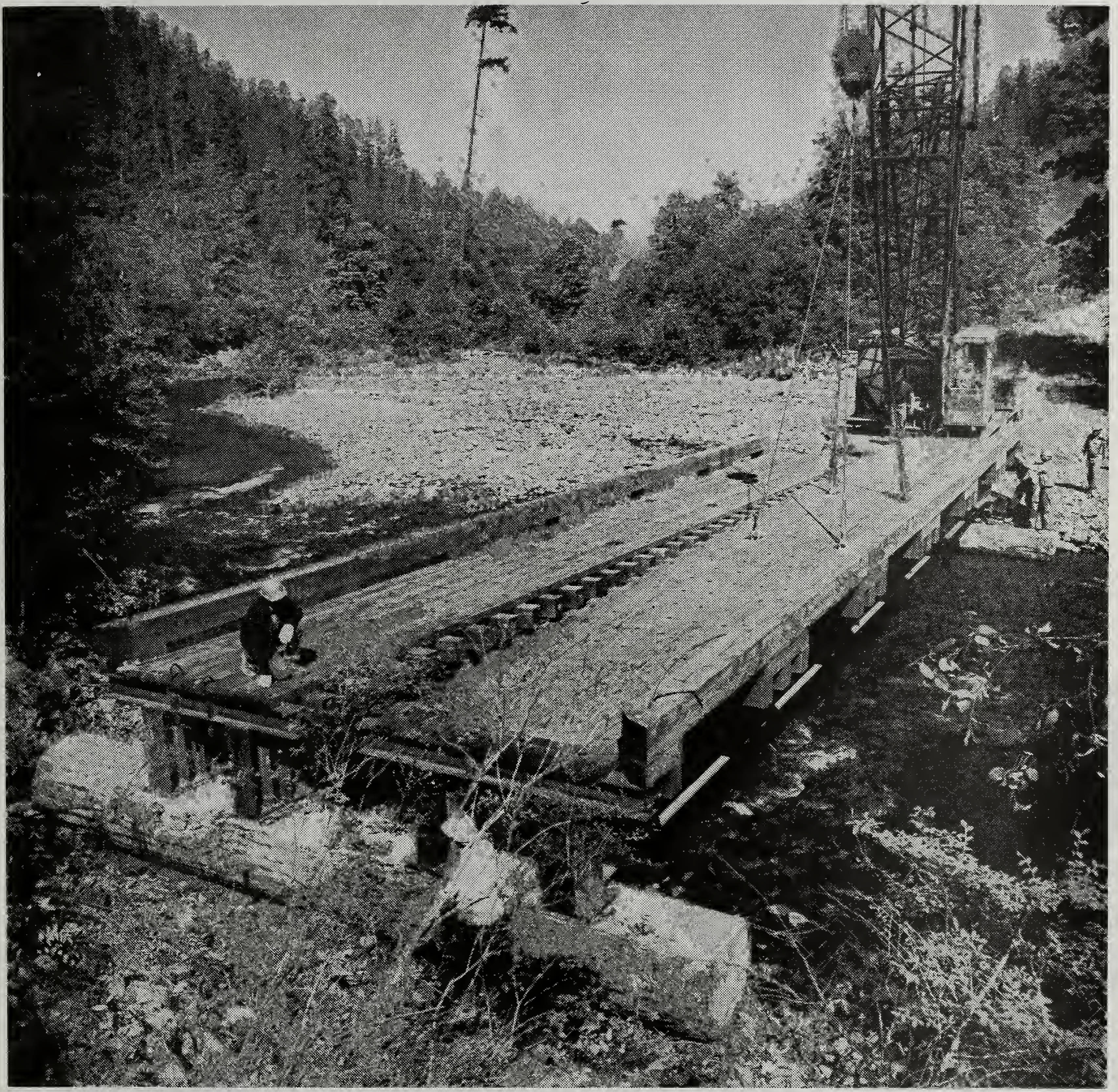

Figure 38. EZ Bridge installation.

Commercial Portable Bridges

The U.S. Army uses the Bailey Bridge as a temporary crossing. The Bailey Bridge is difficult to construct and takes time. Special training would be involved and the parts could not be purchased, only borrowed. The bridge could also be called back by the Army at any time. There are commercial sources that sell temporary, portable, easy-to-construct bridge superstructures. Some designs based on the Bailey Bridge are much easier to construct, take less time, and require no special training.

Four of these companies are EZ Bridge, Big R, Skip Gibbs, and Acrow Corporation of America. These superstructures have already been designed based on loads and spans. No design work would be necessary by the purchaser for a safe superstructure. Everything is ordered through one source and is readily available. This includes curb and guardrail systems, if needed. The purchaser has a choice of a prefabricated superstructure or one that needs to be constructed on site.

The EZ Bridge (See figure 38) and Big R (See figure 39) are very similar. Both superstructures are pre-

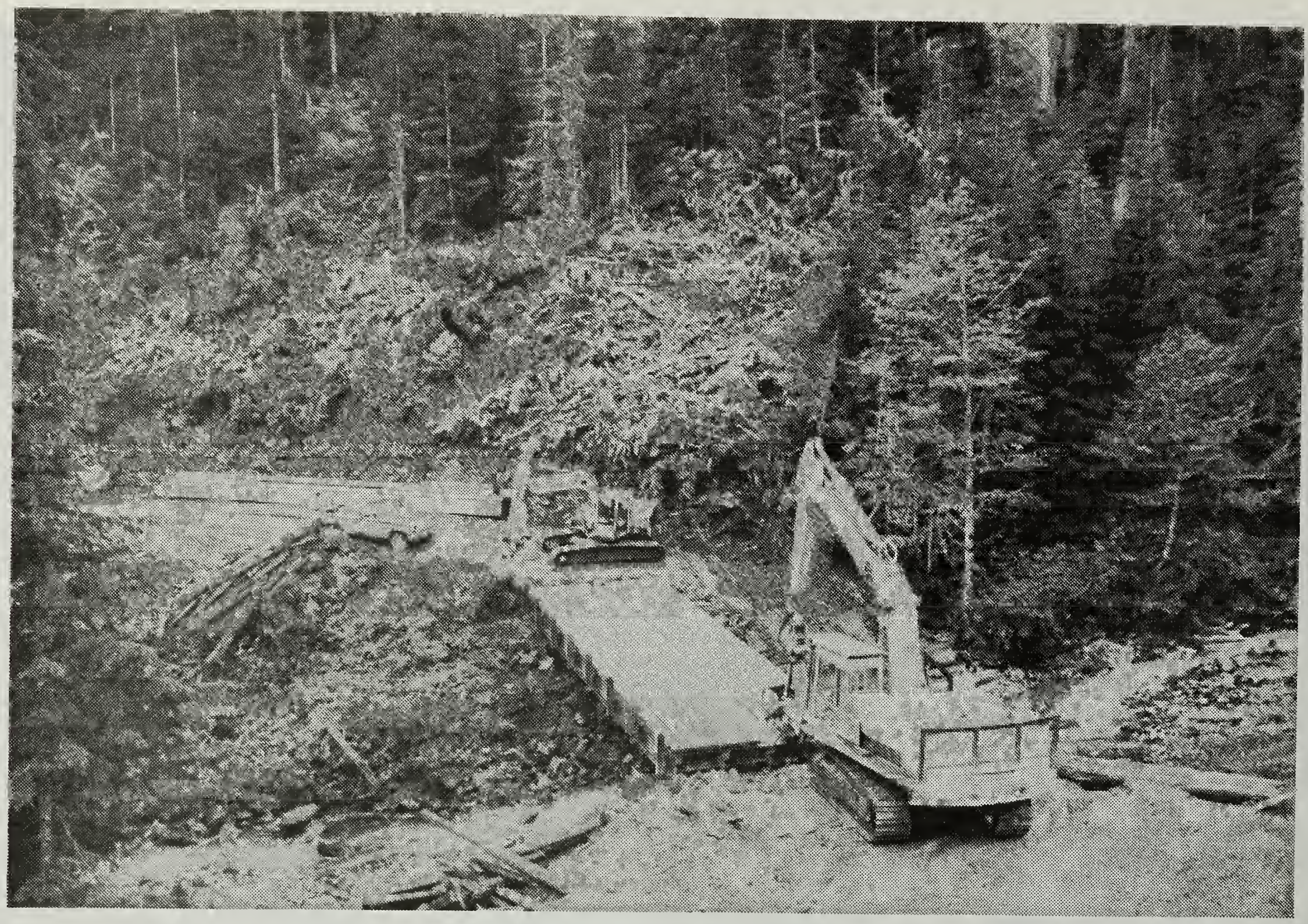

Figure 39. BIG R bridge installation.

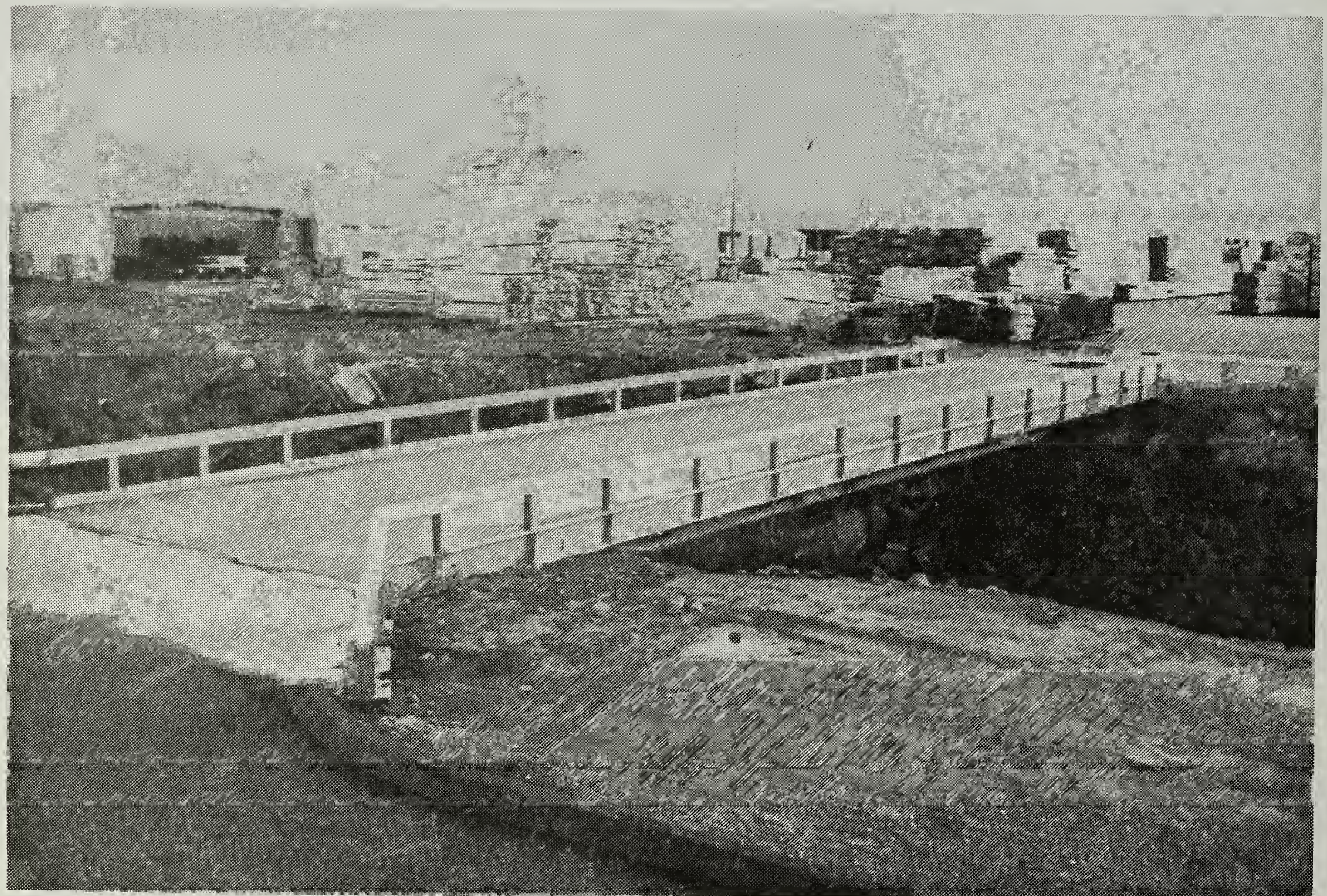

Figure 40. Skip Gibbs bridge installation.

fabricated and shipped to the site. They can be single, double, or triple lane decks ranging from 20 to 80 feet. Other sizes outside of the stock sizes can be built according to the designer's specifications. Because they are prefabricated, no construction is necessary. The EZ Bridge has a timber deck with timber running planks, whereas the Big R Bridge has a galvanized steel deck with timber running planks. Thus, Big R may be lighter, less bulky, and have a longer life.

Skip Gibbs are steel deck flatcars. They can be placed side by side for any width. Each flatcar is 8 and 1/2 by 89 feet and is designed for a 75-foot span for log truck loads. (See figure 40.) They can be placed side by side for any width. The decks have been load tested for design characteristics and are very rugged. It is not unusual for these superstructures to be dragged on the ground from one site to the next. They can be painted to extend their life and the manufacturer can cut them for shorter installations. These portable bridges can be installed within a few hours once the substructure is in place. The Acrow Panel Bridge is assembled on site using prefabricated, hot-dipped galvanized steel components. (See figure 41.) No special skills or training are required for assembly. The company provides a technical manual and assistance during erection upon request. The product can be built quickly and no special equipment is necessary. The deck widths vary from 12-foot single lanes up to 24-foot double lanes, readily available from stock. The truss construction ranges from Single Single to Quadruple Double Reinforced handling highway and off-highway loads from 20-to 250-foot clear spans. Multiple (continuous or broken) spans are possible. The bridge is made up of panels that are pinned end to end to form trusses between the abutments. Bracing frames and floor beams are bolted between the trusses.

Typically, steel diamond plate decking has been used by the Forest Service on panel bridges. Steel stringers are also available for timber decking. It can be built by hand but is much faster and easier if equipment is used to lift components into place. Costs of the various bridges are included in appendix B. Design information is in appendix C.

The design information for the Acrow Panel Bridge is for the 300 Series. A 500 and 700 Series are also available. The new 700 Series uses panels that are

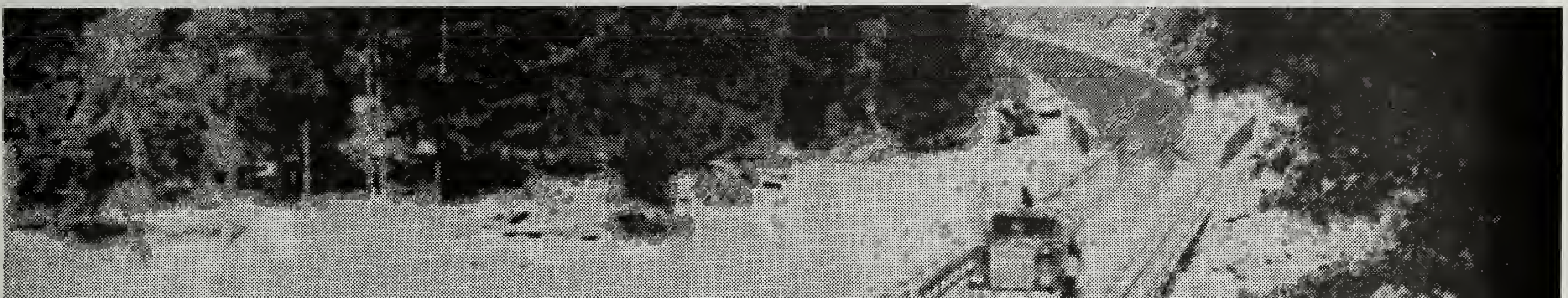

Figure 41. Large Acrow panel bridge installation.

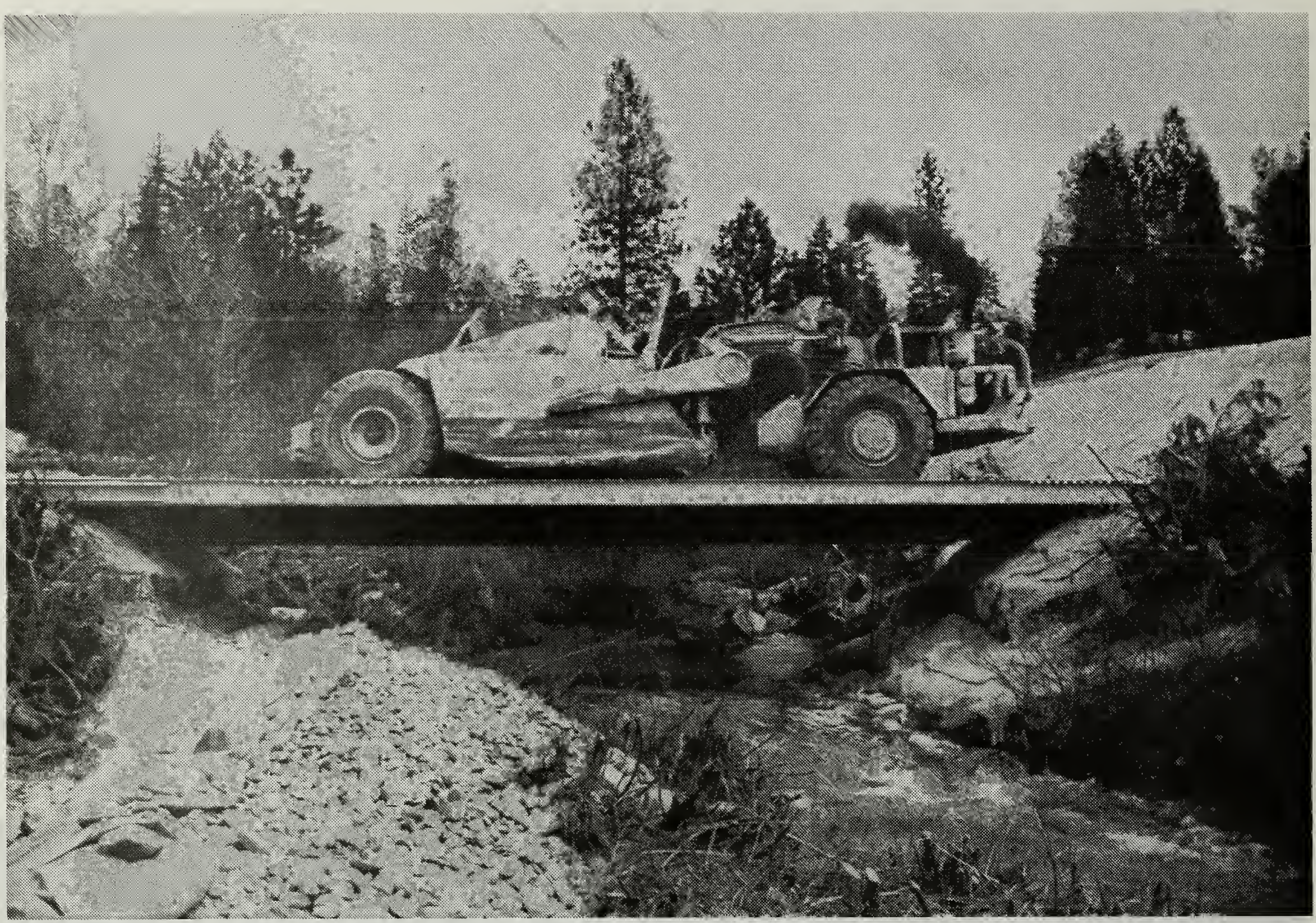

Figure 42. Skip Gibbs flatcar installation.

50 percent deeper, thus having a greater bending moment. They can be combined with the 300 Series deck system. The 700 Series is a less costly system.

There are a few problems with the EZ Bridge, Big R, and Skip Gibbs. Because the decks are prefabricated, access to the site has to allow passage of the entire deck and a large enough vehicle would have to be available for transport. (See figure 42.) These factors depend on the bridge length. Normally, if logging trucks can traverse the road, there should be plenty of room for transporting the deck. The prefabrication does, however, prohibit any changes in span length. If it is reused, it would have to be on a span the same length.

The decks are typically lifted into place using a crane. (See figure 43.) Experiments using other equipment should be conducted. (See figure 44.) In many cases, cats and loaders or possibly a cable-type launching system can be used. Although cranes make the job easier and faster, they are expensive and difficult to transport to the site. Skip Gibbs may be difficult to purchase as it is only available as a used product rather than new. This product was designed as a flatcar, and its application as a bridge is unknown.

The Acrow Panel Bridge does not have the same problems. It knocks down into components, so access to the site is not as critical. The span can be varied for every site. Sometimes the trusses are built to the side and lifted into place. Other times, on long spans, a launching nose is necessary. A cherry picker or boom truck is necessary to lay the deck once the trusses and transoms are in place between the abutments. There may be problems with the 700 Series due to the deeper panels.

Clearance over the streambed could be critical and some heavier loads could cause problems. The main problems are time and cost.

The Acrow is much more labor intensive because it must be assembled and disassembled each time it is moved. (See figure 45.) It isn't difficult and is relatively quick but not as fast as placing a prefabricated deck.

Initially, Acrow is the most expensive of the three. Because of the ease of adjusting spans, it could be the most cost efficient in the long run. It is not known which of the four is the most durable or has the longest life expectancy.

Figure 43. Prefabricated superstructures normally are lifted in place with a crane.

Commercially available superstructures are good choices for bridge crossings. They are portable, reusable, easy to construct and install, and readily available. They are proven safe designs. These commercial products are durable and conventionally used on all types of roads.

Figure 44. BIG R prefabricated bridge can be installed with logging equipment.

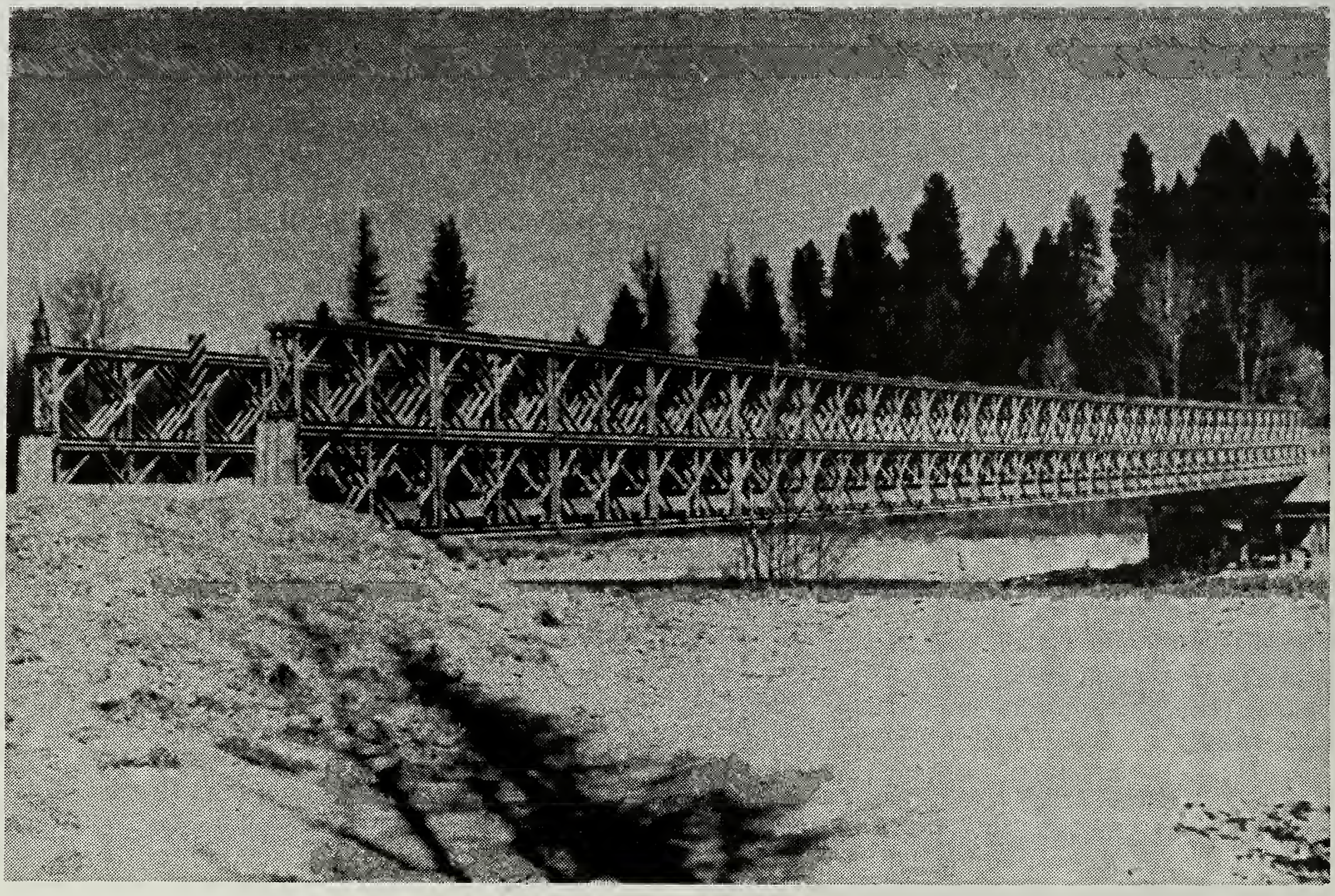

Figure 45. Acrow Panel bridge requires longer installation time.

Hinged Portable Bridge

A relatively new type of portable bridge is becoming commercially available. This bridge was originally designed approximately three years ago. The manufacturer is A.D.M. Welding and Fabrication. Until recently, advertising of the bridge has been mainly word of mouth in the Warren, PA area. The bridge has been used by private companies as well as government agencies including the Forest Service. The bridge is lightweight, competitive in cost, and easy to install/remove.

The bridge was originally designed by a private consulting firm. The bridge consists of steel stringers, a timber deck, and steel guardrails. A unique characteristic is the centerline hinge along the entire length. (See figure 46.) The bridge is literally folded in half for shipment. This makes the bridge a legal load width for transfer. Many of the bridges are within the legal weight for transport. The smallest of the bridges can handle skidder loading. Although a crane would make installation quick and easy, it is not necessary. The bridges can be easily installed using typical timber equipment. The bridges can be purchased or rented. (See appendix B.) Because the bridges can be rented, the timber industry may be more willing to use the bridges during a sale.

There may be some problems with this type of bridge. One is that the bridge has been in use for only three years. This is a very short amount of time to uncover any possible problems, or determine life expectancy. Because the bridge is constructed of steel and timber, it is expected that the timber will need to be replaced after a few years. The bridge should last a minimum of 10 to 15 years. Due to the design being a basic stringer bridge, there should be no major problem. Some of the bridges do have a restrictive 10 mph speed limit, and others do not meet all the AASHTO requirements, mainly deflection limits. This is because the manufacturer wants to keep the bridges within the weight requirements for transport yet offer various sizes capable of carrying different loads. The bridges can be made in any size and within all AASHTO requirements if requested. The bridge has the problem of only being one size and can only cross that specific span or a smaller one. Because the bridges can be rented, this is only a problem if the bridge is purchased. The hinge may need maintenance, (cleaning, oiling, etc.), and may fatigue over time. But, it may also be easy to replace, and if protected, maintenance should be minimal.

This hinged bridge is a very basic, portable, easy-to-install option. It is commercially available and can be used on a rental basis. This gives the user a chance to try it to determine its qualities and decide if purchasing is a good choice. The costs are competitive and no specialized equipment is needed. The size and weight can be within transport limits. Although there are problems, most can be solved. This bridge is another good choice as a portable stream crossing.

Figure 46. A.D.M. Welding & Fabrication hinged portable bridge.

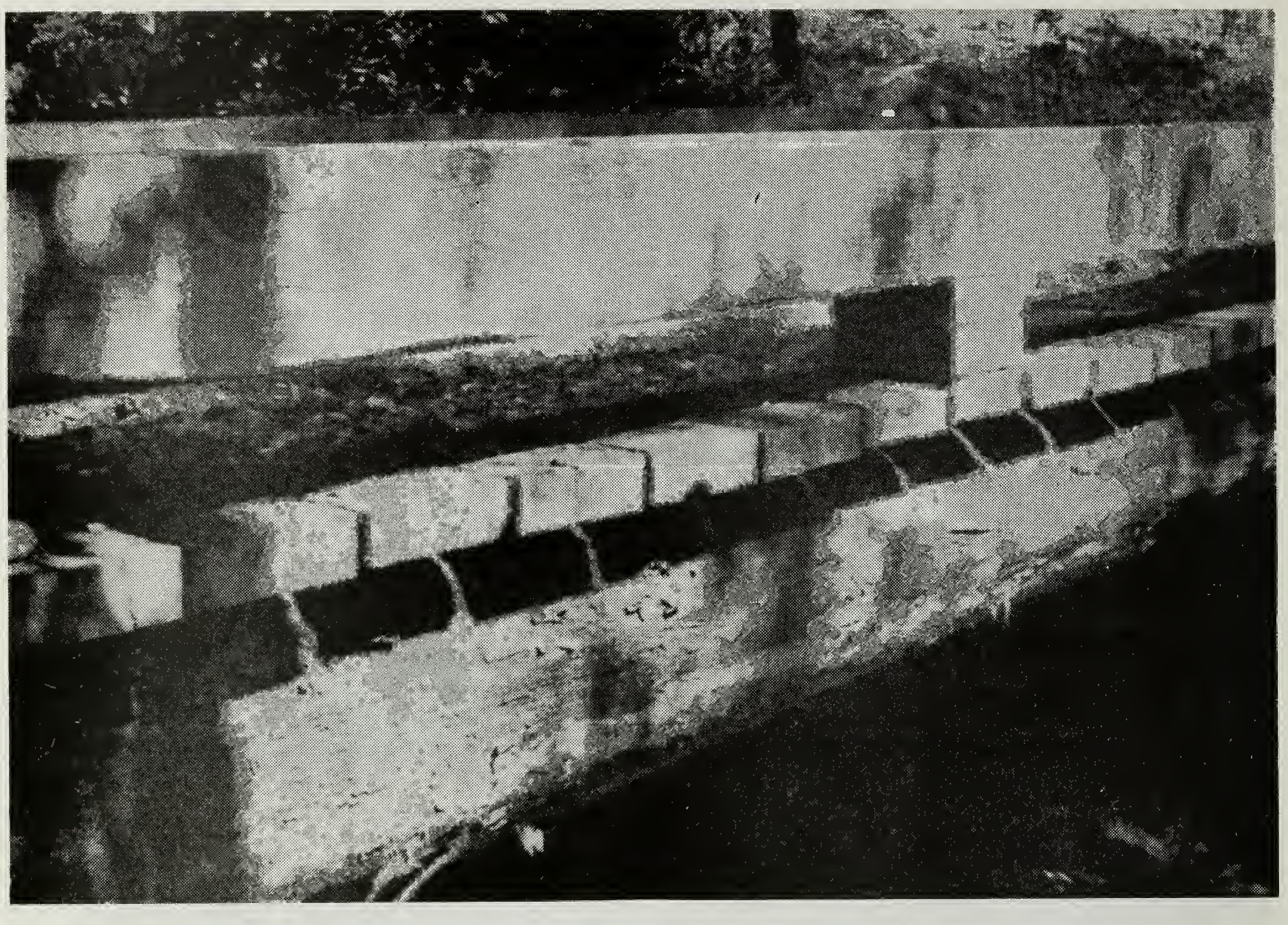

Figure 47. Log stringer bridge uses logs between abutments and may use a running surface.

Log Stringer

During the initial research for this project, the author recognized the need for a bridge superstructure that is portable and reusable. Such a superstructure also needed to be easy to construct, inexpensive, and consist of materials that were readily available to a timber contractor. The log stringer bridge meets most of the criteria. This bridge type has been in use for decades. Normally, they are used as permanent structures but also have application as temporary superstructures. They are easy to build and the materials required consist of timber from the area. While an entire system may be too heavy for timber equipment to install/retrieve, there may be alternatives that would make a log stringer a truly portable bridge. Maintenance is not a problem as all materials can easily be replaced.

A log stringer bridge consists of logs that are placed as stringers between the abutments. A deck is then placed over the logs. If the logs are large and placed close enough together, soil can be used as the deck. Otherwise, lumber or some other type of running surface would be used. (See figure 47.) Sometimes, logs are wired together to form a timber road. Depending on the type of traffic using the bridge and the use of small size logs, a running surface may not be necessary. There are specific design guides for log stringer bridges. (See appendix C.) *Any bridge structure should be engineered.*

The superstructure must be strong enough to support the traffic load safely no matter how short the span or how temporary the usage. In many areas, the native logs are not large enough to carry the load over longer spans. The log stringer may then only be safe for shorter spans. If the deck is to be reused, it must be used on a similar span. The deck could only be changed to fit shorter spans. In this case, a means of moving the entire superstructure needs to be provided. One alternative might be a running surface consisting of panels such as grating that could be stacked and lifted by a loader. The stringers would consist of panels of logs wired together or individual logs that would be light enough for a loader to handle.

This way, the bridge could be moved in components with no need for specialized equipment. Time and labor would be increased but it would make for an easily portable/reusable bridge. Logs need to be inspected for signs of deterioration on a regular basis.

Such logs are not normally treated so they are more susceptible to deterioration.

Log stringer bridges are a proven solution for stream crossing situations. They are easy to construct, inexpensive, and logs are readily available. There has been little experimentation in using them as portable bridges. However, they seem to be rugged enough to have a good life expectancy. They are safe as long as they are designed correctly and are an appropriate option for short spans.

Stress-Laminated and Glue-Laminated Timber Bridges

Log stringer bridges are not the only type of wood bridge. The stress-laminated timber bridge is a recent superstructure design. This type of superstructure is more expensive than the log stringer. This deck is preferred over a log stringer deck because it is practical to build it out of smaller, more readily available timber. The smaller logs used as support for stringer decking alone may not prove safe enough for the intended span. The stress-laminated bridge can be constructed from any species of timber as long as the design characteristics are known. The superstructure is very quick and easy to construct with no special skills required.

The glue-laminated superstructure, also, has been in use for many years. It can be constructed as longitudinal glulam panels or as transverse panels on stringers. The panels are prefabricated and only need to be set in place. They can be made to any desired length and have proven to be a very dependable structure.

The stress-laminated deck is made up of 2 or 4 inch lumber set edgewise, placed side by side. Their length runs longitudinal between the abutments. Transverse steel stressing rods run through holes drilled along the centerline of each lamination. The rods can be run continuously through the width of the bridge or they can be coupled half way through. These rods are posttensioned, using a jack, to a predesignated stress. Steel plates and nuts are used on both ends of the rod along the side of the deck. These plates transfer the stress of the rods into the wood to press the lumber laminations together. The compression due to the stress makes the individual laminations act as a solid plate of wood. (See figure 48.)

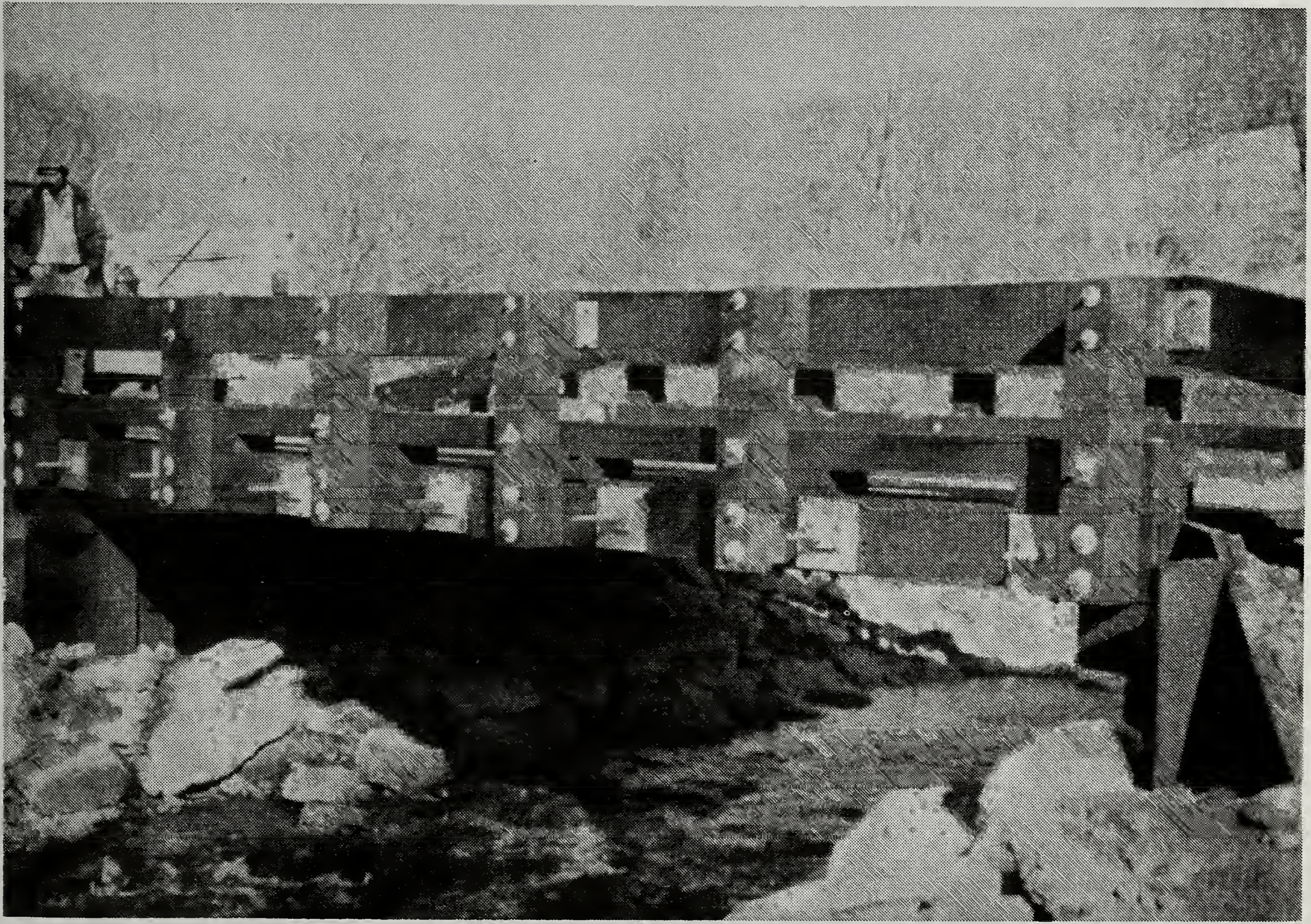

Figure 48 Stress-laminated deck installation, installed on site.

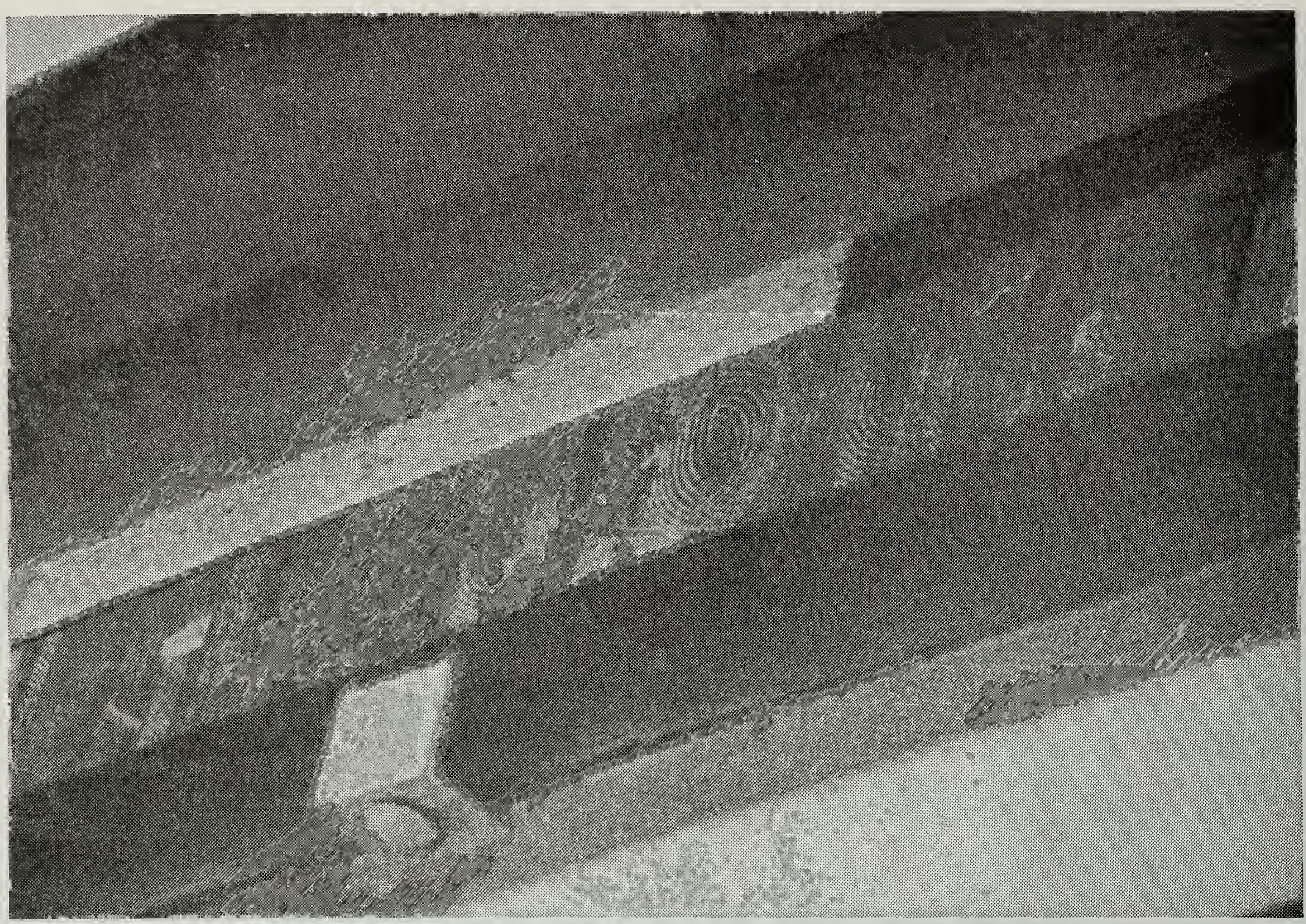

Figure 49. Glulam panels made of 1 and 1/2-inch laminae, glued together.

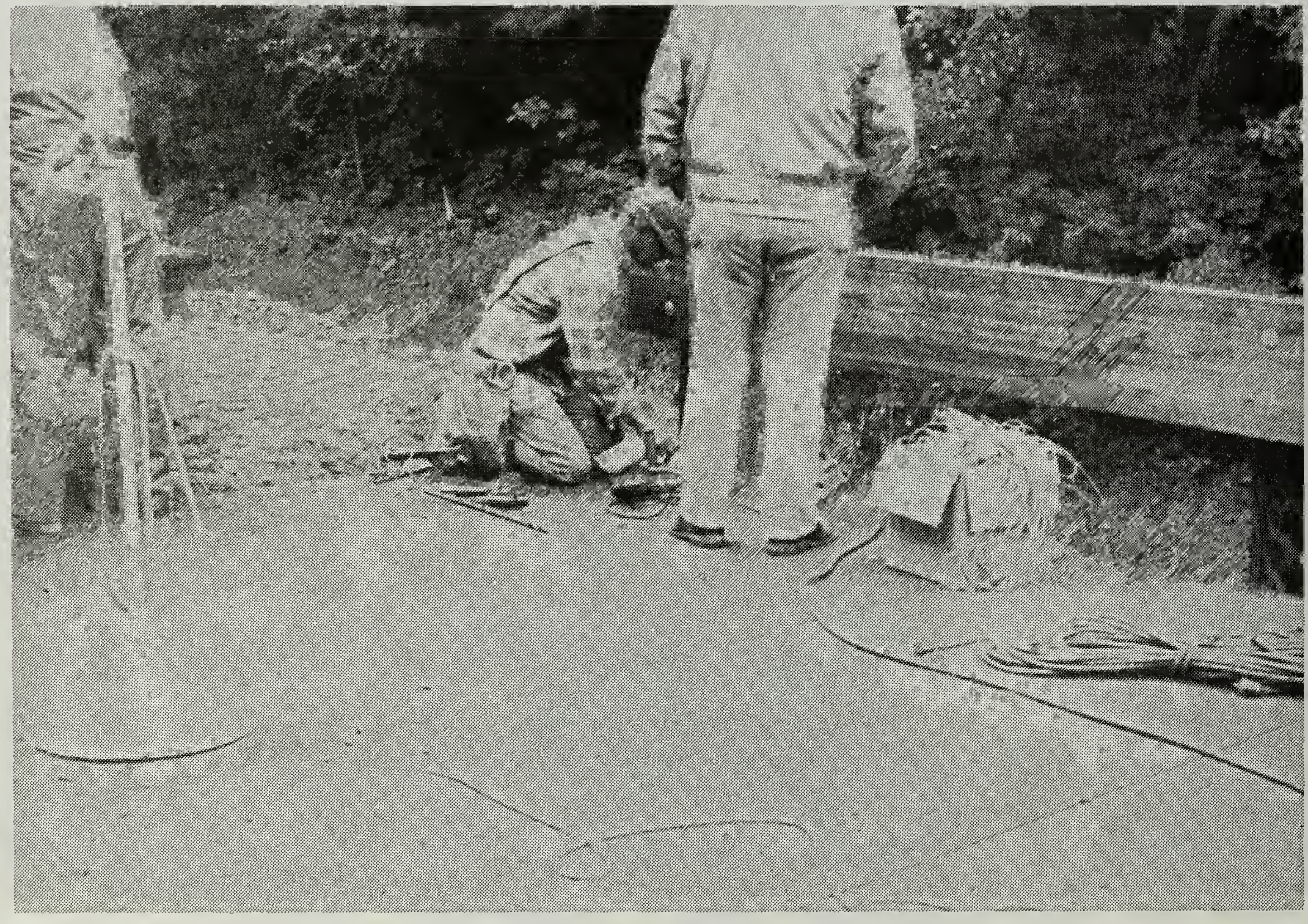

Figure 50. Glulam panels installation.

The decks can be constructed on site and lifted into place or prefabricated and transported to the site. The glulam panels are made up of 1-and 1/2-inch laminae that are glued together. (See figure 49.) The panels are much stronger than a solid timber of the species. This is due to the inherent weaknesses of the wood, such as knots, either being cut out or evenly distributed throughout the glulam panel. The panel then becomes more even in strength and can be considered stronger overall. There are special design characteristics that must be recognized when designing with glulam. The panels are pressure treated with a preservative and dried to about 19 percent moisture content. The panels are 4 feet wide and typically interconnected with dowels. (See figure 50.) The use of dowels may not be necessary for temporary bridge applications.

Design criteria must be established early in a timber bridge project. Each superstructure must be designed on a site specific basis to be considered safe. The depth of the deck will vary depending on the species of wood (strength characteristics), expected load, and span. For the stress-lam, all wood used must be graded to meet the design criteria. Length of the individual laminae is not a serious problem because the deck can have staggered butt joints. Holes larger in diameter than the rods need to be drilled through each lamination along centerline. The bars need to be re-stressed often enough to keep the deck acting as a solid plate. The lumber would not be treated so it will deteriorate. Once the wood has deteriorated, the hardware can be reused. Here, much more preparation work is involved versus using logs or glulam.

Once either deck is constructed, it should only be used on spans of the same length. A method of installing/retrieving the deck needs to be incorporated in the original design. A crane or some other means will be necessary for lifting and moving the full deck. It is possible to couple the stressing bars together along the deck centerline so that the deck can be made in panels, similar to the glulam. (See figure 51.)

Panels make using timber equipment more viable for installation/removal. Wood can be damaged easily so a certain amount of care is needed when handling such decks, especially the preservative treated glulam. Proper handling will increase the life of the deck. The glulam should have some type of running surface for protection, because it is already treated.

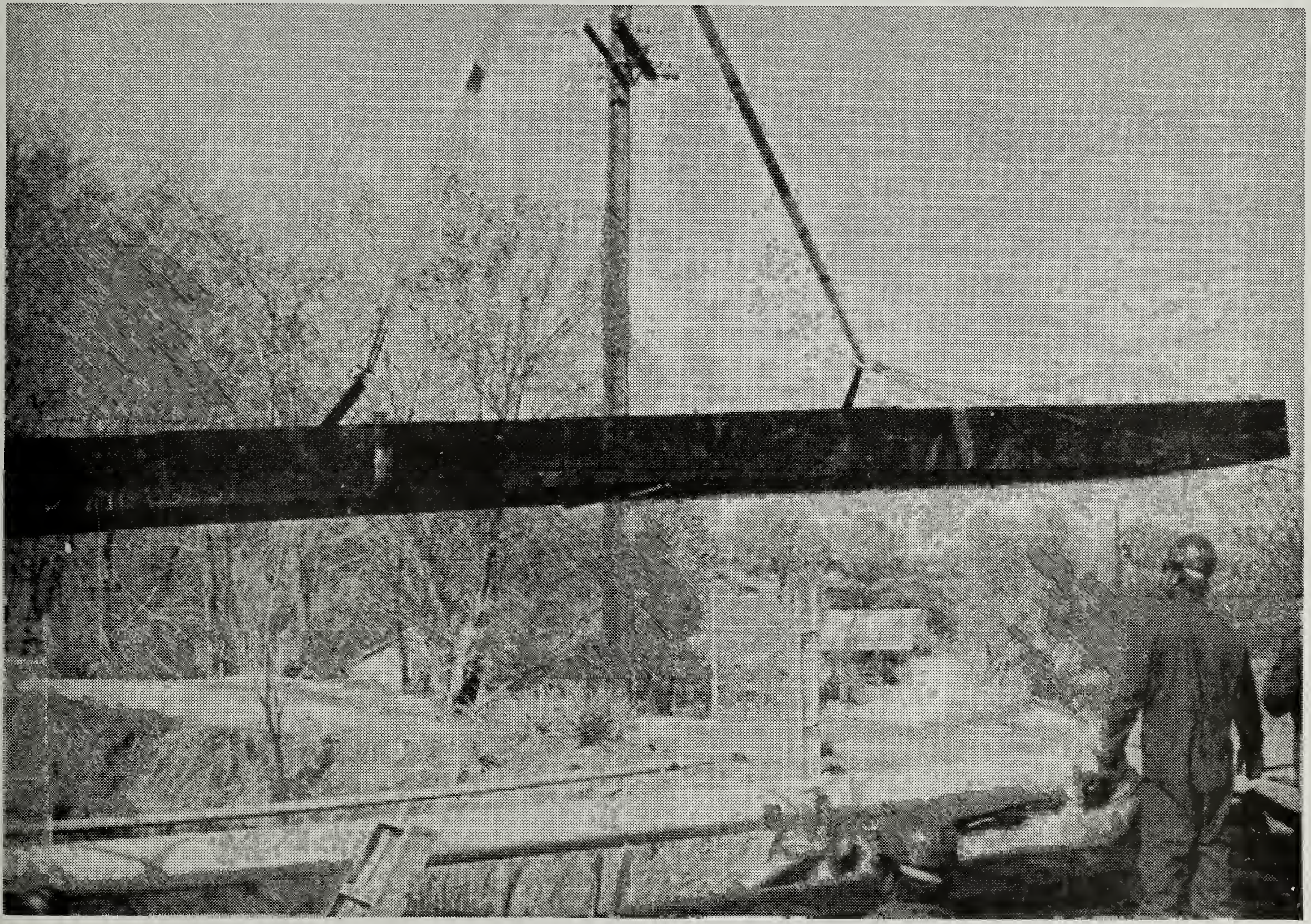

Figure 51. A crane or other equipment will be needed to lift and move a full deck.

It should not be dragged or damaged because the exposed raw wood will quickly deteriorate. This deterioration will greatly reduce the life of a high cost item. The cost will vary and the life expectancy is unknown.

Stress-laminated and glue-laminated superstructures are an alternative to log stringer superstructures. There is more work and cost involved with these structures, but they may be logical options when large enough logs are unavailable. Although the hardware is not readily available and somewhat costly for the stress-lam, it is reusable. The deck is easy to construct and with some designing should be a good preference as a portable, reusable deck. The glulam is available through manufacturers. It is costly, easy to install, but with care, can have a long life. Only through field experimentation will it be determined if this type of bridge can compete with the other types available. Cost, time of construction, and life expectancy are all variables that need to be determined and compared.

Modular Timber and Trailer-Launched Bridges

More information is needed on two other bridges that could be used as temporary crossings. One is a prefabricated modular timber bridge that was designed and is in use in Kenya. The other is a trailer-launched bridge used by the Israeli army.

The modular bridge is made from readily available materials, easy to construct, and low in cost. Most of the material used is smaller size lumber, typically found in most lumber yards. The hardware used is typical for basic construction work. All material is easy to handle with no specialized equipment required. The modular bridge is made up of trusses. (See figure 52.) The number of trusses needed depends on the type of wood, span length, and load. (See appendix C.).

The modular bridge uses timber for the upper chords of the trusses, the verticals, diagonals, bracings, and deck. Mild steel is used for the bottom chord and joints. Fabrication is simple. All frames are identical and all components are lightweight. The bridge spans from 30 to 75 feet and can be single or double lane. Unlike many other designs, the bridge can vary in length. This bridge can best be described as a low cost, easy-to-construct Bailey Bridge.

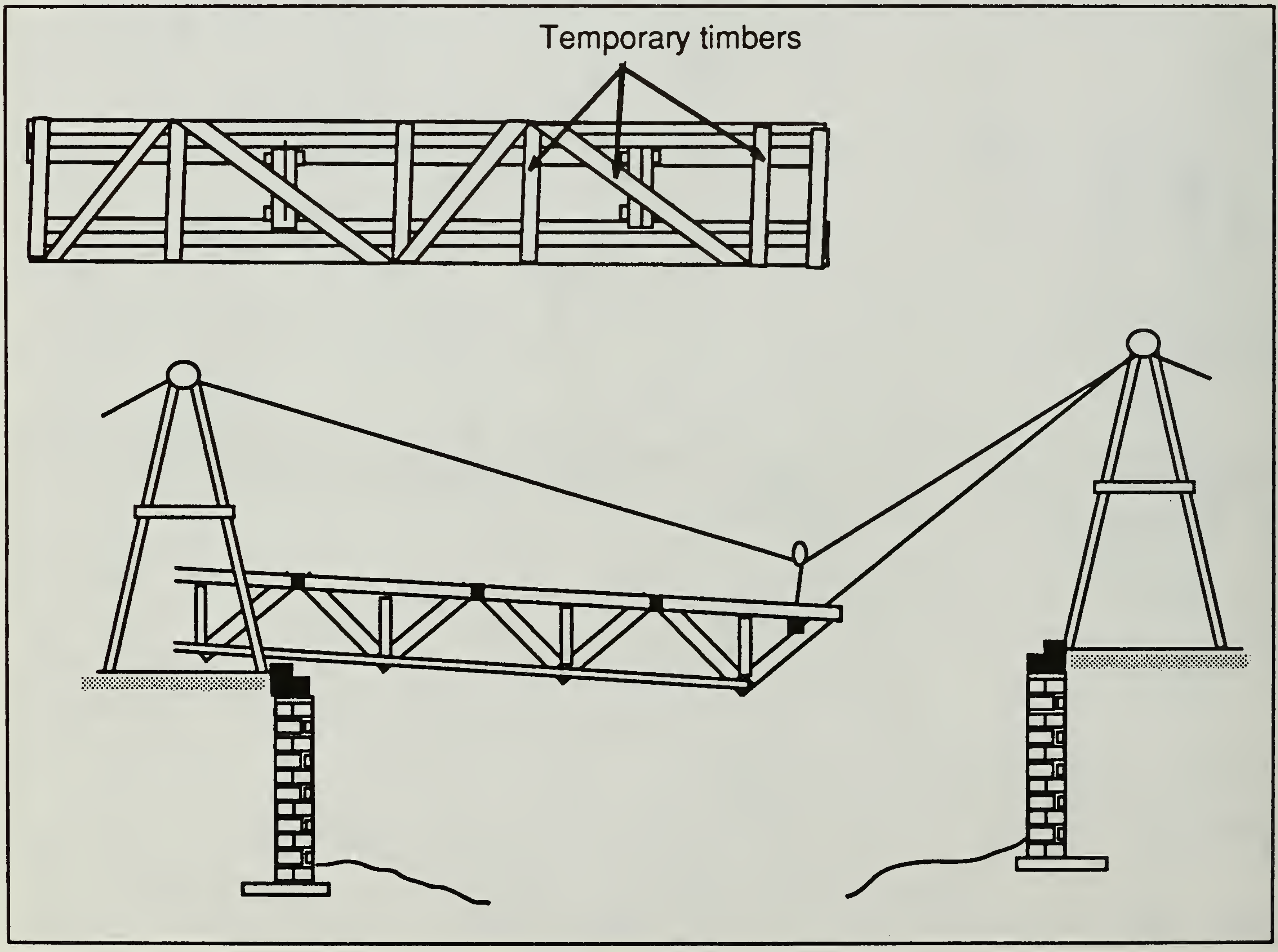

Figure 52. Modular timber bridge illustration.

The trailer-launched bridge was specifically designed to be a portable, reusable bridge that could be launched and retrieved quickly and easily. (See figure 53.) It seems to be very rugged and durable. It has been heavily used under large loads. A key advantage of the trailer-launched bridge is its simple installation/ retrieval. No crane or similar equipment is needed.

The trailer-launched bridge is made of corrosion-resistant aluminum alloy with steel in high stress areas. It is designed for the military load class 70. It spans up to 75 feet and provides a single lane. It can be launched in 5 minutes and retrieved in 10. The superstructure is folded and transported on a trailer. (See appendix C.) A tilt frame trailer with a diesel-hydraulic deploying system is used to install/retrieve the bridge. No substructure is necessary.

There are some problems with the modular bridge. Each bridge will need to be designed for specific sites. Thus, the readily available timber will need to be graded, rough-sawn, 2-inch lumber. The bridge will be more labor intensive and time consuming than many of the other types discussed in this report. Some skills in carpentry would be necessary. Due to the type of components utilized, the bridge must be handled with more care than any of the other types. The structure needs to be cable launched or set in place on most sites with a crane. The hardware used probably could not be reused once the wood is decayed. The amount of time expended removing the hardware may not be worth it.

Treated lumber should be used, although this will increase cost. Untreated 2-inch lumber would have a very short life due to deterioration. If treated lumber

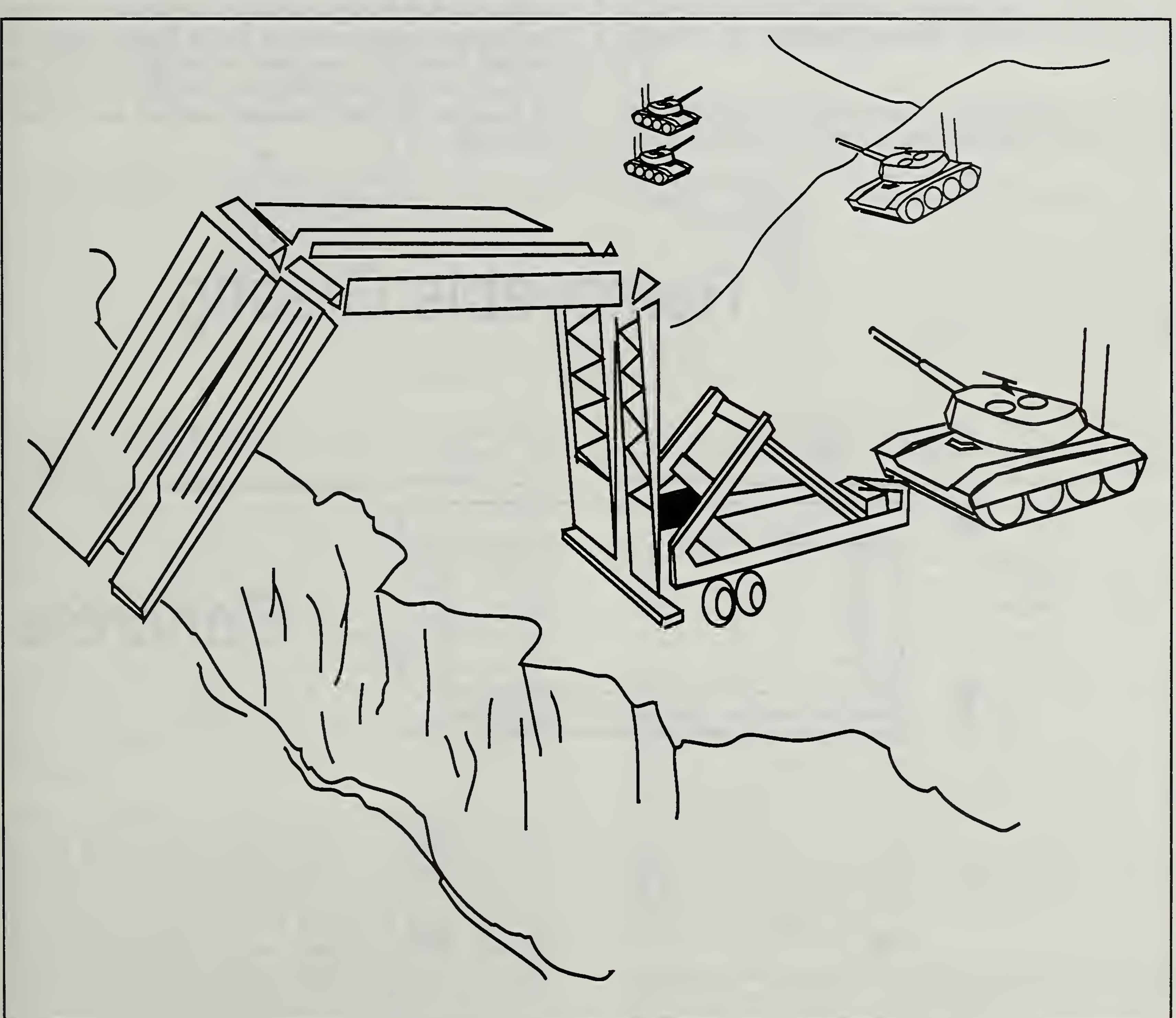

Figure 53. Illustration, trailer-launched bridge for breaching man-made and natural obstacles.

is not used, inspection for deterioration would need to be performed on a regular basis. This structure is not normally used as a portable bridge. It would have to be disassembled and reassembled for each move which could prove to be costly and time consuming. This type of bridge is considered temporary due to its expected short life. Life expectancy of this modular bridge compared with other designs is not known at this time.

Lack of availability is the major problem with the trailer-launched bridge which seems to be very popular for military applications. Unfortunately, the Israeli company, Israeli Military Ind. (IMI), has some complicated marketing arrangements with the United States. Fettig Inc., is working with IMI to sort out these problems. Once this is done, more information on cost, production, and field demonstrations will be known. There also is the problem of size. It is only one length and both sides of the stream crossing need to be level and provide enough vehicle clearance for entrance and exit.

This bridge could not be used in short, curved sections. It is assumed that the cost may be too high for Forest Service use. However, it may be worth the cost because of its ease of use, rugged construction, expected long life, and the absence of substructure cost.

Because so little is known about the modular and trailer-launched bridges, it is difficult to determine how well they will perform. The modular bridge has an advantage because it uses smaller, readily available wood and hardware. The construction does demand some skills in carpentry and time in labor. The trailer-launched bridge has been specifically designed as a portable, reusable bridge. More information is needed concerning the overall cost and life expectancy.

Grating and Bridge Flooring

Both grating and bridge flooring have been discussed as possibilities for wetland crossings. They could also be used for their intended purpose of bridging gaps. They are both easy to obtain and to install. There are many variations of grating depending on its application. The type of grating and the bridge flooring used as wetland crossings may also serve as a functional bridge deck. So, both grating and bridge flooring could be used as portable, reusable wetland and stream crossings.

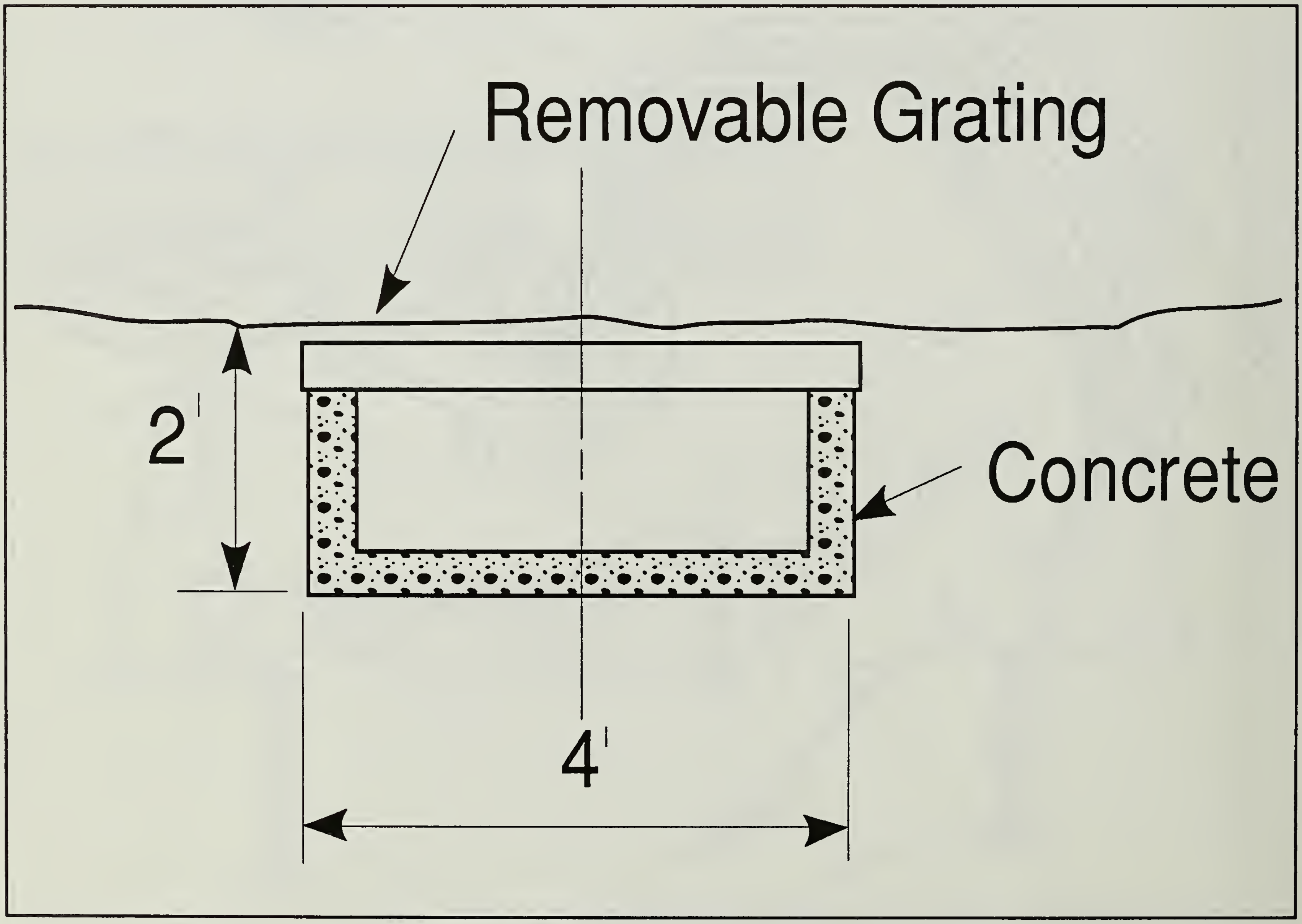

Figure 54. Side view of concrete box culvert.

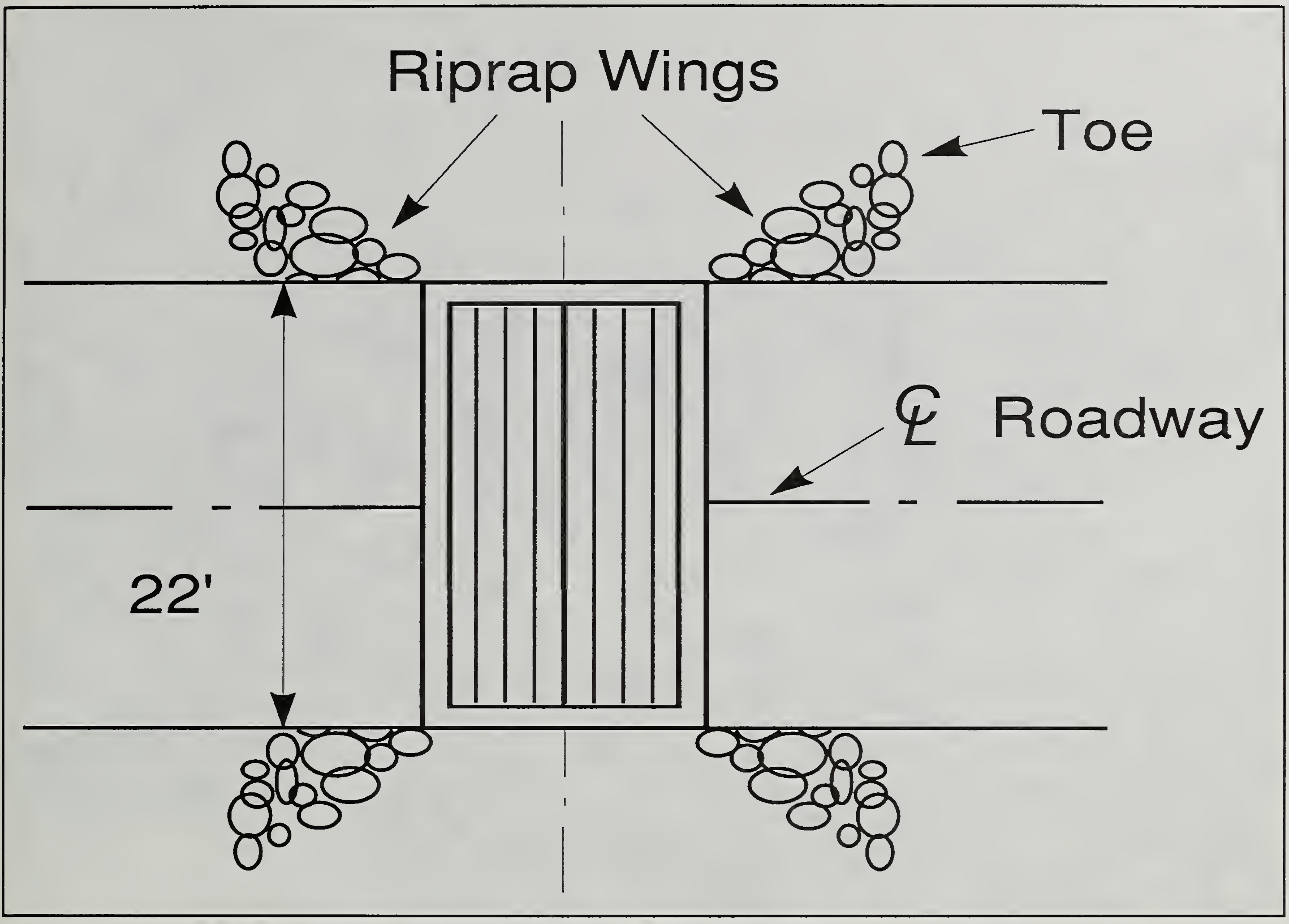

Figure 55. Top view of concrete box culvert.

The type of grating needed will depend on the bridge conditions. There is a wide range of selections, but companies offer design guides and assistance. The choice depends on the span and the load. Bridge flooring is not available in a large number of selections. Gratings will vary in material, design, depth, etc. Bridge flooring does vary in the gauge of steel used. Stringers are necessary for this superstructure using grating or bridge flooring. These stringers are typically made of steel. The use of steel provides a surface for connecting the panels and a means of transferring vehicle load to the abutments. Construction is simple as it consists of bolting the individual panels to the stringers.

This superstructure can best be moved, especially with timber equipment, after it has been dismantled into individual panels and stringers; then reassembled at the new site. Steel components make this type of bridge very durable. The length of span can vary because stringers can be spliced together. For very short crossings, a combination concrete box culvert and grating could be used. (See figures 54 and 55.) The grating can be easily removed once the crossing is no longer in use.

There are problems to be solved. The number and size of stringers need to be determined. Design work will also be needed on the size and span limit for the type of grating or bridge flooring specified. There will be considerable time involved in assembly and disassembly. This will not be difficult work, mainly bolting connections between the panels and stringers. Costs will vary. Using bridge flooring will probably be more expensive than timber bridges yet less expensive than the commercial portable bridges. The life expectancy of this type of bridge using bridge flooring is unknown. Because all components are steel, it would probably last a number of years. If the panels used for wetland crossings are used for the bridge deck, the width could only be 10 feet. This may be too narrow in some areas. Field testing of panels used as wetland crossings will be conducted this fall in Florida. This research should help determine if the panels possess the attributes of both a wetland crossing and a bridge deck.

If gratings and bridge flooring can be used as wetland crossings, they could also be used for bridge decks. While a steel stringer and deck may not be as inexpensive and readily available as some of the timber bridge choices, this combination is easy to transport,

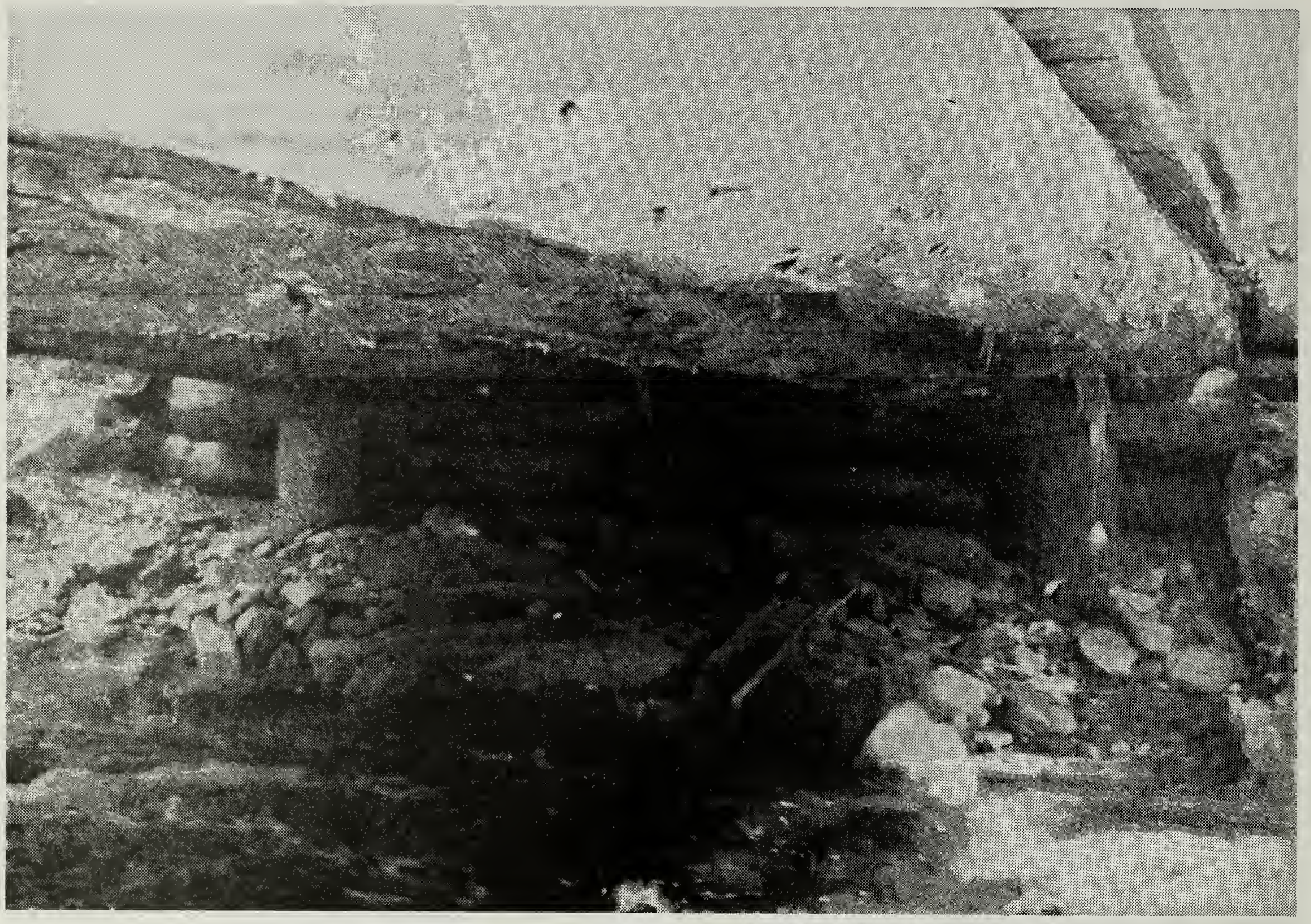

Figure 56. Timber substructures can be constructed out of sawn timber or logs.

install, and should be durable enough to last several years. The costs will vary but this type of bridge may be well worth the cost because the deck components may be used in other applications.

Substructure

The substructure is a permanent part of all portable bridges except the Pipe Fascine System and trailer-launched bridge. Basically, the substructure consists of abutments which hold the ends of the deck and transfer the load to the soil. There are a wide range of possible abutments. The chosen type will depend on the load, the soil, and the construction material. In all cases, the substructure will be constructed and left in place. Superstructures can be installed/retrieved whenever the road is open/closed. Several variations of abutments use concrete and steel. These types are typically very costly, difficult to construct, and will probably be unnecessary for the portable bridges. These types of alternatives will not be discussed here. Construction by typical logging and road construction equipment is one of the desired characteristics of the substructure as well as needing to make a level surface for the deck on steep side slopes. Someone has suggested designing an abutment that includes jacks on both ends. With such a design the cap could be jacked to a level position. No known research has been performed on this type of abutment.

Some of the more basic, less costly substructures consist of culverts filled with rock or concrete, gabion baskets, and variations using timber. Typically, all of the materials are readily available but will vary in cost depending on location.

Culvert abutments employ culverts placed on end, forming piles. They are filled with rock or concrete for strength. The number and size of culverts needed depends on the design requirements. For steep side slopes, the length of culvert can be varied so a level surface can be made for the deck surface. Gabion baskets, rectangular baskets made out of wire netting, can also be used as substructures. For baskets in direct contact with water, a polyvinyl chloride (PVC) coating can be applied to the wire. The baskets are filled with 3-to 8-inch rock and used as building blocks. They are stacked on top of each other to build an abutment. (See appendix C.)

Timber variations include a footing set directly on the ground, a combination footing-post-cap with backwall and wingwalls for increased elevation, or a combination pile-cap with backwall and wingwalls. These timber substructures can be constructed of sawn timber or logs. (See figure 56 and appendix C.) Height variation is a matter of sawing the timber into the varying lengths.

Every situation will be different so every abutment may need to be redesigned. The culvert types may have scouring problems, are expensive, and may be more difficult to construct. It may be too expensive to purchase rock and concrete in some areas. Construction might require special equipment for installation of the culverts depending on size and depth of installation. Gabion baskets catch a lot of debris which could eventually rip the basket. Gabions can easily change shape. Rock could be expensive in some areas. In order to construct a substructure on a steep side slope, height variation would have to be obtained by excavating in a stair-step manner. This could be very difficult and time consuming. If the supporting soil changes, the abutments will change resulting in a loss of even support of the superstructure.

The timber types of substructures would be the most labor intensive. If piles are needed, special equipment needs to be provided to drive the piles. All timber must be treated because it is a permanent structure in direct contact with soil. This will increase cost. All the timber must be graded to meet the design criteria. Logs would be treated a little differently but they would still need to be a specified size, depending on the species. Costs as well as life expectancy will vary depending on design factors.

Abutments are a necessary part of all bridges. There is a wide variety of designs. Each site may need a different type abutment. Abutments will typically be permanent structures, reused whenever the road is needed again. Materials cost and life expectancy depend on the type of abutment selected and where it is being built. Typically, the abutment will be the most difficult and costly part of the bridge. If properly designed and constructed, it can be reused for many years.

CONCLUSION

This project report identifies a number of options that can be used as portable, reusable wetland and stream crossings. All of these options need to be further evaluated under conditions relevant to Forest Service roads. All of the options identified have positive points as well as negative characteristics. Some of the products have a higher initial cost yet provide a longer life expectancy. Others may only be used under certain conditions. Some of the alternatives have been examined under field conditions while others are still on the design table. Field testing needs to be conducted to narrow the choices. Research needs to continue on what experimentation has been performed and what additional alternatives are available.

In wetland areas, the goal is to use portable crossings that result in the least amount of damage to the environment. Some of the least expensive products that can be currently installed include grating, bridge flooring, and Terra Mat. Some of the more expensive and more difficult to obtain choices that may provide longer life include Flexmat, Trackway, Aluminum Access/Egress Modules, landing mats, and bridge decks. Portable crossings that need to be designed include inflatable rubber and log panels. Permanent crossings include geomatrices and rubber tires. Many of the materials used in these crossings need to be separated from the soil by using a geotextile, chunkwood, or forest debris.

For stream crossings, any of the choices can be used but it is unknown which would be best. Pipe Fascine, commercial portable bridges, log stringer, stress-laminated and glue-laminated timber, modular timber, trailer-launched, and grating and bridge flooring all vary in cost, life expectancy, and ease of construction. In most cases, the substructure will be the most difficult, time consuming, costly part of the project.

This report identifies a wide variety of temporary crossing choices that can be used during timber harvest and other Forest Service applications including floods and fires. Hopefully, some of these alternatives will protect the environment while reducing the cost of road construction. Research should continue and testing of the various choices expanded to determine the most advantageous wetland and stream crossings.

and wingwalls for increased elevation, or a combination pile-cap with backwall and wingwalls. These timber substructures can be constructed of sawn timber or logs. (See figure 56 and appendix C.) Height variation is a matter of sawing the timber into the varying lengths.

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Abutments are a necessary part of all bridges. There is a wide variety of designs. Each site may need a different type abutment. Abutments will typically be permanent structures, reused whenever the road is needed again. Materials cost and life expectancy depend on the type of abutment selected and where it is being built. Typically, the abutment will be the most difficult and costly part of the bridge. If properly designed and constructed, it can be reused for many years.

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This report identifies a wide variety of temporary crossing choices that can be used during timber harvest and other Forest Service applications including floods and fires. Hopefully, some of these alternatives will protect the environment while reducing the cost of road construction. Research should continue and testing of the various choices expanded to determine the most advantageous wetland and stream crossings.

APPENDICES

Appendix A - Manufacturers *

* manufacturers listed in order of reference in body of report.

Geotextile

Mirafi Inc.
P.O. Box 240967
Charlotte, NC 28224
1-800-438-1855

Aluminum Access/Egress Modules

Department of the Army
Flexmat Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
CEWES-GP-Q, Dewey W. White
(601) 634-2785

Foam Inflated Fabric

U.S. Army
Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820
Orange Marshall, Materials Engineer
1-800-USA-CERL ext. 766, (217) 373-6766

Geomatrices

Presto Products Inc.
P.O. Box 2399
Appleton, WI 54913-2399
Geosystems Office
1-800-558-3525, (414) 739-9471

Landing Mats

Bridge Division
Belvoir Research Development & Engineering Center
Ft. Belvoir, VA
Marvin Wilkins
(202) 664-5326

Stock Numbers: M8A1 5680-00-782-5577 (13 full & 2 half panels) M19 5680-00-930-1524 (32 full panels) 5680-00-930-1525 (32 half panels)

Tires

Tires for Wet Spots
13012 Eldorado St. NE
Blaine, Minnesota 55434
Monte Niemi
(612) 757-0544

Terra Mat Corporation
462 Arbor Circle
Youngstown, Ohio 44505
Jerry Goldberg
(216) 759-9412

Trackway and Pipe Fascine

Cinkar International
Pipe Fascine
103 Willow Way
Cherry Hill, NJ 08034
Alene Ammond
(609) 429-0844

Bridge Flooring

Buffalo Specialty Products, Inc.
77 W. Broad Street
N. 4 Payson House
Bethlehem, PA 18018
1-800-247-7479, (215) 865-5144

Fiberglass Panels

IKG Industries
P.O. Box 449
Madera, CA 93639
Steve Vague
(209) 673-6081

Grating

SKM Associates, Inc.
12915-A Telegraph Rd.
Santa Fe Springs, CA 90670
Maggie Leyendecker
(213) 941-1999

Commercial Bridges

EZ Bridge
Hamilton Construction Co.
P.O. Box 659 Springfield, OR 97477
Jack Hamilton
(503) 746-2426

Big R Manufacturing and Distributing, Inc.
P.O. Box 1290
Greeley, CO 80632
Rich Warner
(303) 356-9600, Denver (303) 893-8480
1-800-234-0734

Acrow Corporation of America
P.O. Box 812
Carlstadt, NJ 07072-0006
Thomas Dabb
1-800-524-1363, (201) 933-0450

Skip Gibbs
P.O. Box 686
Redwood Valley, CA 95470
Skip Gibbs
(707) 463-3777

Hinged Portable Bridge

A. D. M. Welding & Fabrication
2818 Pennsylvania Avenue West - Rear
Warren, PA 16365
(814) 723-7227

Trailer-Launched Bridge

Fettig Inc.
Springfield Tower Office Building
6320 Augusta Dr., 15th Floor
Springfield, Virginia 22150
William Cook
(703) 866-5900

Gabions & Culverts

Maccaferri Gabions West Coast Inc.
P.O. Box 410
West Sacramento, CA 95691
(916) 371-5805, 1-800-328-5805

Appendix B - Costs*

* manufacturers, products, and prices listed in order of reference in body of report.

Geotextile

Mirafi 600X 12-1/2'x360' (500 s.y.) $420.

Central Tire Inflation

Currently, prototype, retrofit kit costs up to $16,000 for logging trucks, should be less than $10,000 within 3 to 4 yrs.

Aluminum Access/Egress Modules

Department of the Army - Waterways Experiment Station. Extruded aluminum modules, panel weight 244 pounds, $30.37** per square foot. - panel weight 200 pounds, $30.37** per square foot.

Flexmat, panel weight 1,920 pounds, $12.75** per square foot. **Costs for initial prototypes purchased in small quantities for R & D evaluation. Prices for production quantities should be lower.

Grating

Deck span safety 1-5/16"x36"x10', 10 gauge $240/ea.
Expanded metal 0.618"x48"x10' $105/ea.
Riveted steel 1-1/2"x1/4" 4'x10' $8.19/s.f.
Riveted aluminum 1-1/2"x1/4" 4'x10' $10.73/s.f.
Fiberglass approximately $20/s.f.

Tires

Terra Mat corporation. Mats 9'x16' $130/ea., 9'x20' $150/ea., assembly tool $40/ea., earth nails $4/ea., lifing chains $45/ea.

Trackway, Class 60

F.O.B. UK Port $432/l.f., 50' lengths $21,600, 20' shipping container $3,200, container can hold 4-50' rolls or 400' of individual planks.

Pipe Fascine Systems

PD Technical Mouldings PLc. Mini, $1,000 & Maxi $15,000 with Midi costs ranging from $2,224 for a 9-pipe fascine 4 meters wide with a 0.9 meter diameter to an 18-pipe fascine 4 meters wide with a 1.6 meter diameter for $5,535. Prices US$ EX Works.

Commercial Portable Bridges

EZ Bridge. Prices are for just the superstructure, no railing system: 20'-$16,700, 40'-$26,400, 60'-$41,600, 80'-$64,600.

BIG R bridge. One-piece 14'-wide, single-lane superstructure 20' length $7,906 with various sizes including 30, 40, 50, and 60-foot lengths ranging in price from $12,288 to $30,542. The two-piece single-lane modular product runs from $9,257 for a 20 footer to $60,235 for a basic 80' superstructure. Guard rails and treated timber curbs are options.

Skip Gibbs $7,000-$9,900.

A.D.M. Welding & Fabrication - Hinged portable bridges, 15 to 50-ton capacity, full-length guardrail with 3" hardwood decking, *10 mph speed restriction. Prices range from $10,000 for a 14-foot wide by 20-foot long bridge to $22,700 for a 14-foot wide by 50-foot long bridge. Primer and paints are additional. (*Portable bridges without speed restriction can be quoted on request.)

Rental bridges run from $30 per day for a bridge 11 1/2-feet wide by 26-feet long with a 15-ton capacity to $50 per day for a 50-ton capacity unit 14-feet wide and 50-feet in length. Minimum rentals range from $500 to $750, depending on size of the bridge.

SPECIFICATIONS

Mirafi Construction Products: Typical Property Values
The product specifications are average values. For minimum certifiable values contact your local Mirafi Representative or the Mirafi Technical Department at 1-800-438-1855.

SR=Soil Reinforcement   SC=Sedimentation Control   EC=Erosion Control
D=Drainage   L=Landscaping   PU=Pond Underlining

Property	Unit	Test Method	Miradrain 6000 (D)	Miragrid (SR)	Miramat 2400 (EC)	100x (SC)	140NSL (D,EC)	140NL (D,EC)	140NS (D,EC)	140N (D,EC)	500X (SR)	600X (SR,EC)	700X (D,EC)
Weight	oz/sy	ASTM D-3776-79		8	24	3.0	3.5	3.5	4.3	4.5	4.0	6.0	6.5
Grab Strength	lbs	ASTM D-4632-86		2900x1700[6]	18x6[4]	120	115	100	145	120	200	300	425x250
Grab Elongation	%	ASTM D-4632-86		21x26[6]	150x100	30(max)	60	50	70	55	30(max)	35(max)	35(max)
Trapezoid Tear Strength	lbs	ASTM D-4533-85				65	40		75	50	115	120	110x55
Mullen Burst Strength	psi	ASTM D-3786-87				280	150	200	180	265	450	600	525
Puncture Strength	lbs	ASTM D-3787-80[1]					45		50	70	85	130	130
Wide Width Strip Tensile	lbs/in	ASTM D-4595-86		220x134							150x150	200x180	250x160
Wide Width Strip Elongation	%	ASTM D-4595-86		15x20							20x20	20x15	20x18
Thickness	mils	ASTM D-1777-64			250	17		57		60	23	30	19
Permittivity	sec	ASTM D-4491-85[5]				.5	1.3	2.2	1.0	0.35	.3	.4	.3
Water Flow Rate	gal/min/sf	ASTM D-4491-85[5]				40	110	180	95	170	35	50	60
Apparent (AOS)													
Opening Size (EOS) U.S. Std Sieve		ASTM D-4751-87				20-35	50-100	70-100	70-100	100+	30-50	30-50	70-100
Efficiency	%	VTM-51				75							
Slurry Flow Rate	gal/min/sf	VA DOHVTM-51				0.5							
Ultraviolet													
Stability	%	ASTM D-4355-84[2]				90					90	90	90
Porosity	%	Calculated			85-90								
Flexibility	mg-cm	ASTM D-1388-64			2000								
Core Compressive	psf	ASTM D-1621											
Strength		(Modified)	15,000										
Lateral Flow Rate	gpm/ft width	PDS Flow Test[3]	15[a]										
Core Amplitude	in	Measured	.38										

Specifications (Continued)

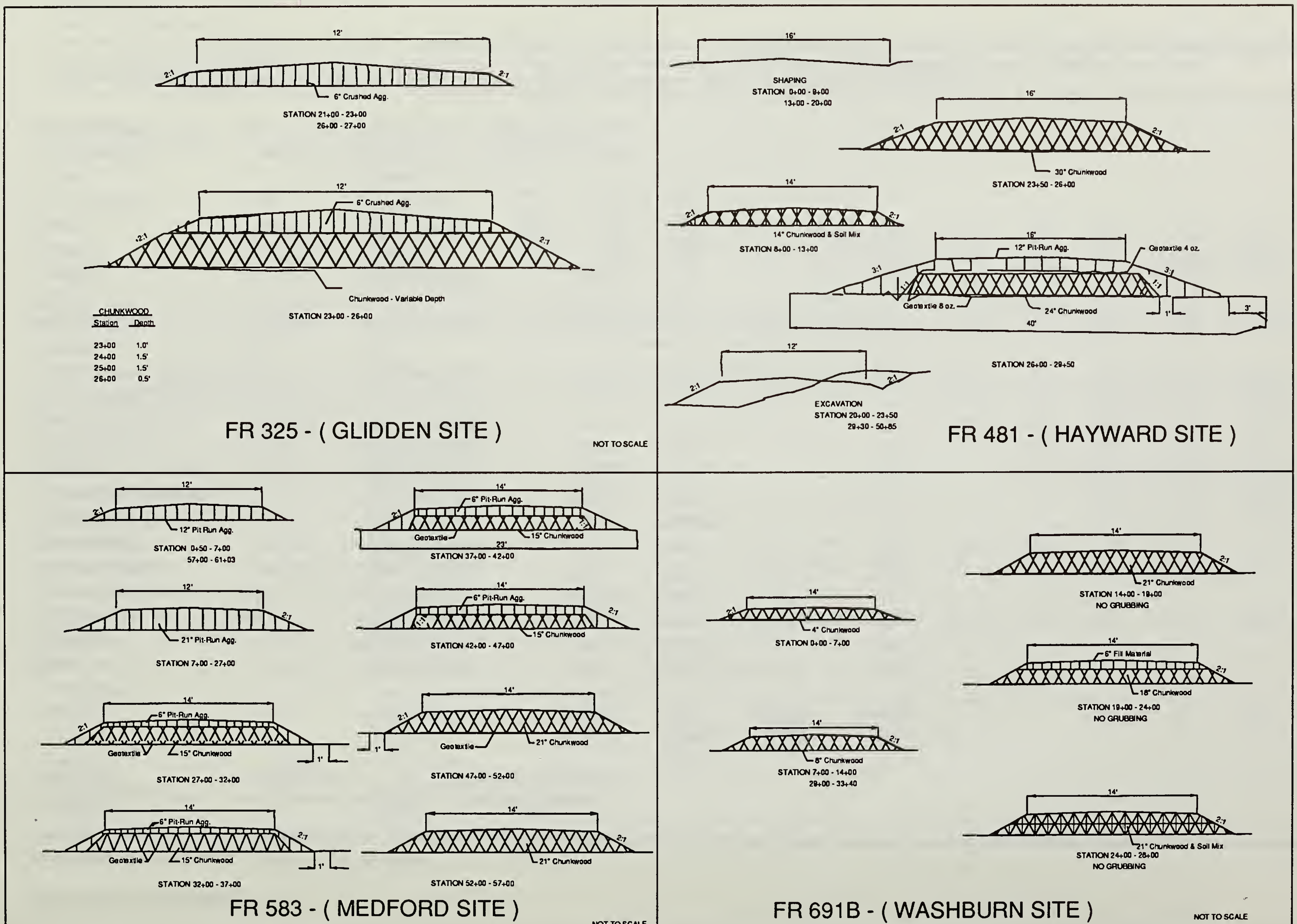
Mirafi Construction Products: Typical Property Values
The product specifications are average values. For minimum certifiable values contact your local Mirafi Representative or the Mirafi Technical Department at 1-800-438-1855.

SR=Soil Reinforcement SC=Sedimentation Control EC=Erosion Control
D=Drainage L=Landscaping PU=Pond Underlining

Property	Unit	Test Method	1200HP (SR,EC)	2120HP (SR)	160NS (PU,EC)	180N (PU,EC)
Weight	oz/sy	ASTM D-3776-79	12.0	14.0	6.0	8.0
Grab Strength	lbs	ASTM D-4632-86	600	1300x550	240	240
Grab Elongation	%	ASTM D-4632-86	30x30	25x15	>70	50
Trapezoid Tear Strength	lbs	ASTM D-4533-85	250x250	400x275	90	75
Mullen Burst Strength	psi	ASTM D-3786-87	1500+	1000+	270	450
Puncture Strength	lbs	ASTM D-3787-80[1]	350	75x150	75	125
Wide Width Strip Tensile	lbs/in	ASTM D-4595-86	400x400	1000x500		
Wide Width Strip Elongation	%	ASTM D-4595-86	20x20	18x20		
Thickness	mils	ASTM D-1777-64	50	40		105
Permittivity	sec	ASTM D-4491-85[5]	.2	1.0	.3	1.8
Water Flow Rate	gal/min/sf	ASTM D-4491-85[5]	95	80	25	100
Apparent (AOS)						
Opening Size (EOS) U.S. Std Sieve		ASTM D-4751-87	50-120	40x70	100+	100+
Efficiency	%	VTM-51				
Slurry Flow Rate	gal/min/sf	VA DOHVTM-51				
Ultraviolet						
Stability	%	ASTM D-4355-84[2]	90	90		
Porosity	%	Calculated				
Flexibility	mg-cm	ASTM D-1388-64				
Core Compressive	psf	ASTM D-1621				
Strength		(Modified)				
Lateral Flow Rate	gpm/ft width	PDS Flow Test[3]				
Core Amplitude	in	Measured				

1. Tension testing machine with ring clamp; steel ball replaced wth a 5/16 inch diameter solid steel cylinder centered within the ring clamp; (f).
2. ASTM D-4632-86 after 250 cycles in an Xenon-arc Weatherometer (TypeBH or C). One cycle consists of 102 minutes of light followed by 18 minutes of light with water spray.
3. Flow rate measured in Mirafi flow tester. (a) = (H/1 = 1 at 3600 psf confining soil pressure) b=(h/1 = 1 at 10,800 psf confining soil pressure) c=(h/1 = .80 at 10,000 psf confining soil pressure)
4. Two-inch strip method. (lbs/in)
5. 5cm Constant head.
6. Modified for geo grid using sample size 1 strand by 4 junctions with two junctions between jaws. Results reported in lbs/foot

Chunkwood demonstration road cross sections



Chunkwood Demonstration Site Descriptions

Forest Road (FR) 481 (Hayward Site). This was a swamp crossing. The total length of the road was 0.67 miles. The project included an existing grade with an appproximate 1,700-foot location, of which 600 feet was through the swamp. Soils were classified as loamy sand (LS) with the swamp being classed as Carbondale. The trees were predominantly aspen, black spruce, and lowland brush.

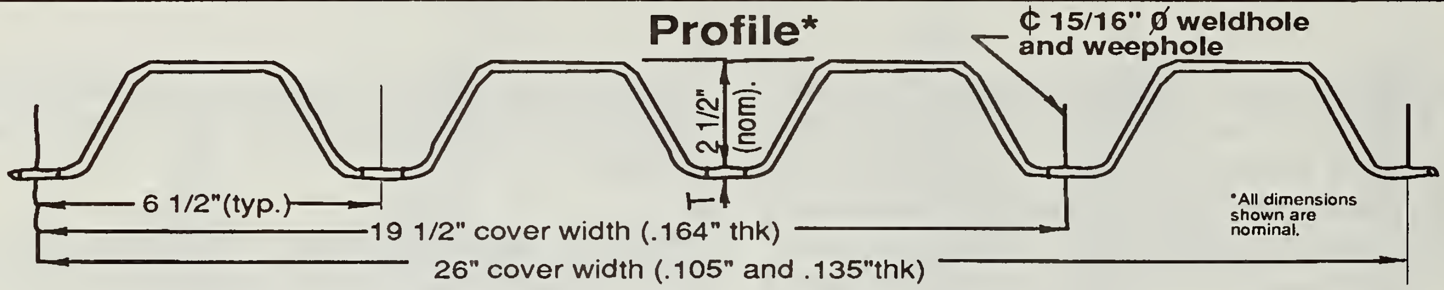
There was a substantial depth of peat beneath the vegetative swamp mat. The maximum peat depth was about 18 feet, and it had a high moisture content and very low shearing strength.

FR 583 (Medford Site). This was a poorly drained site with soils classified as silty loam (SiL) to sandy loam (SL). The total length of the project was 1.14 miles including a 3,000-foot section having assorted chunkwood test sections. The remainder was built of pit-run gravel. The timber stand was predominantly aspen and sugar maple with pockets of lowland brush and tamarack. The nature of the soils on this site makes it impossible to operate conventional logging equipment during the spring of the year and wet periods.

FR 691B (Washburn Site). This involved 0.6 miles of new construction. The soil is classified as a medium to coarse sand often referred to as "sugar sand" because of the similarity to granulated sugar when dry. Due to the lack of cohesion and uniform particle size, these soils have very little capacity to support traffic when dry. The timber on this site was mostly jack pine with smaller amounts of aspen and scrub oak.

FR 325 (Glidden Site). This was an existing grade with a total length of 0.11 miles that included a 300-foot-long section having a series of mud holes with free-standing water. The soils ranged from loamy sand (LS) to sandy loam/loamy sand (SL/LS). The timber stand included black spruce, swamp hardwoods, spruce hardwoods, spruce-fir, and northern hardwoods.

BRIDGE FLOORING DESIGN DATA & RIGID FOAM PROPERTIES



Nom Gage	Design Thickness "T" in.	Yield Strength min ksi	Weight approx. psf	Mom. of Inertia in. 4'	Section Modulus in. 3'	*Allowable Net Span "L" in.
12	.105	40	6.5	1.633	1.131	24
10	.135	40	8.3	2.110	1.447	28
8	.164	40	10.1	2.577	1.750	32

*For AASHTO Loadings HS20, H20,HS15, or H15; based on allowable stress of 24 ksi and an assumed wheel-load distribution of 20 by 20 in. (Net span "L" is clear span between stringer flanges.)

Specifications

Material: pregalvanized steel sheet per ASTM A446, Grade C.
Zinc coating per ASTM A525, Coating Designation G-210.
Maximum panel length: 30 ft (without splices).
Weldholes and weepholes: 15/16-in. diameter rounds.
Bituminous fill: an average of 1 in. of bituminous concrete is required to fill the valleys.

APPROXIMATE WEIGHT OF BRIDGE FLOORING SYSTEMS (DEAD LOAD)

Section Selected	Thickness, in.	Section Weight psf	Surfacing Weight *psf	Total Weight psf
2.5 by 6.5	.105	6.5	28.2	34.7
	.135	8.3	28.2	36.5
	.164	10.1	28.2	38.3

* Based upon bituminous surfacing unit weight of 135 lb/cu ft with 2 in. at centerline of roadway tapering to 1 in. at roadway edge. Average thickness of bituminous concrete in Flooring valleys: 1" for 2.5"x 6.5".

RIGID FOAM PROPERTIES*

Density, lb/cu ft	2
Compressive strength, psi	30
Tensile Strength, psi	40
Shear strength, psi	24
Closed Cell Content, percent	94

* Source: *Isonate System CPR 399-2*, Technical bulletin (CPR Division, The Upjohn Company).

MATERIALS USED TO CONSTRUCT FLEXMATS

Design	Wire Fabric, gage	Membrane	Support Members: Type	Support Members: Spacing	Fasteners	Mat Size, ft.: Width	Mat Size, ft.: Length	Weight lb/sq ft
I	9	T16	1- by 4-in. oak planks	12-in. centers	1-in. staples	14	40.33	2.78
II								
Item 1	9	T16	1- by 4-in. oak planks	12-in. centers	1-in staples	14	15.67	2.78
Item 2	9	T16	Aluminum rectangular tubes, 2 by 5 in.; wall thickness, 0.125 in.	12 in. centers	Adhesive and adjustable stainless steel hose clamps	14	20.67	2.57
III								
Item 1	6	T17	Aluminim rectangular tubes, 2 by 5 in.; wall thickness, 0.125 in.	12-in. centers	Aluminum clips, 2 by 3/4 in.; self-drilling and tapping hex head screws, 1/4 by 3/4 in.	14	25.67	4.44
Item 2	6	T17	Aluminum channels, American Standard, 4 by 1.65 in.; web thickness, 0.247 in.	2 ft. centers	Aluminum clips, 2 by 3/4 in.; self-drilling and tapping hex head screws, 1/4 by 3/4 in.	14	24.67	2.29
IV	6	T17	Aluminum channels, 4 by 1.75 in.; web and flange thickness, 0.188 in.	3 ft centers	Aluminum clips, 2 in. by 3/4 in.; self-drilling and tapping Phillips pan head screws, 1/4 in.-14 UNC by 1 in.	16.4	48.33	2.21

Specifications: GEOWEB Structural Properties

1.	Expanded Dimension	8 by 20 feet by 8 inches or 4 inches
2.	Collapsed Dimension	11 feet by 5 inches by 8 inches or 4 inches
3.	Panel Thickness (Normal)	0.045 ± .002 inches
4.	Weight	103 or 51.5 pounds
5.	Cell Area	41 $inches^2$
6.	Cell Seam Node Pitch	13 inches
7.	Welds/Seam	7 or 3, for 8 inches or 4 inches
8.	Seams Tensile Peel Strength	450 pounds or 225 pounds
9.	Installation Temperature Range	-16°F to +110°F
10.	Polymer Material	High Density Polyethylene
11.	Color	Black
12.	Carbon Black Content	2%
13.	Chemical Resistance	Superior

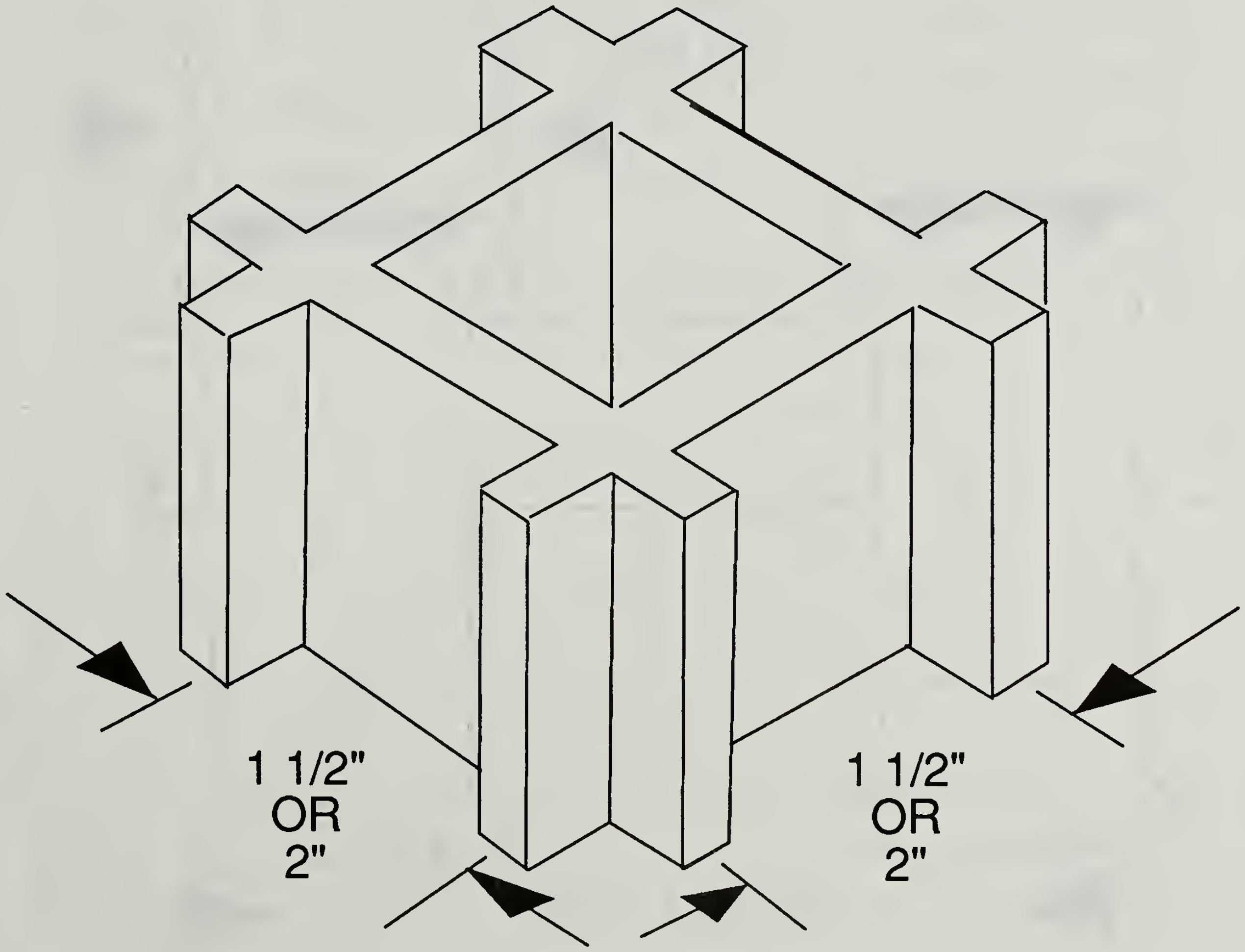
MOLDED FIBERGLASS GRATING AND TREADS

Corgrate Molded SM

Resin	Depth and Panel size	Type SM	Weight lbs/SF	Sq. ft. per panel	Span XX See note below
Dark Gray Polyester Non-Fire Retardant (PN)	1" x 4' x 12'	1"SM48PN*	2.5	48	29 in.
	1-1/2" x 3' x 10'	1-1/2"SM30PN*	3.7	30	38 in.
	1-1/2" x 4' x 12'	1-1/2"SM48PN*	3.7	48	38 in.
	1-1/2" x 5' x 10'	1-1/2"SM50PN	3.7	50	38 in.
	2" x 4' x 12'	2"SM48PN	4.2	48	46 in.
Green Polyester Fire Retardant (PF)	1" x 4' x 12'	1"SM48PF*	2.5	48	29 in.
	1-1/2" x 3' x 10'	1-1/2"SM30PF*	3.7	30	38 in.
	1-1/2" x 4' x 12'	1-1/2"SM48PF*	3.7	48	38 in.
	1-1/2" x 5' x 10'	1-1/2"SM50PF*	3.7	50	38 in.
	2" x 4' x 12'	2"SM48PF*	4.2	48	46 in.
Orange Vinylester Fire Retardant (VF)	1" x 4' x 12'	1"SM48VF	2.5	48	29 in.
	1-1/2" x 3' x 10'	1-1/2"SM30VF	3.7	30	38 in.
	1-1/2" x 4' x 12'	1-1/2"SM48VF*	3.7	48	38 in.
	1-1/2" x 5' x 10'	1-1/2"SM50VF	3.7	50	38 in.
	2" x 4' x 12'	2"SM48VF	4.2	48	46 in.

*Stock item—special run may be required on all non-stock items.

xx The maximum spans shown will produce a deflection of 1/4 inch or less, under a uniform load of 100 lbs. per square foot. The spans listed in the tables meet the recommended grating industry standards to provide pedestrian comfort. These spans may be exceeded at the design engineer's discretion. More information and detailed load tables may be obtained by inquiry to IKG Borden.



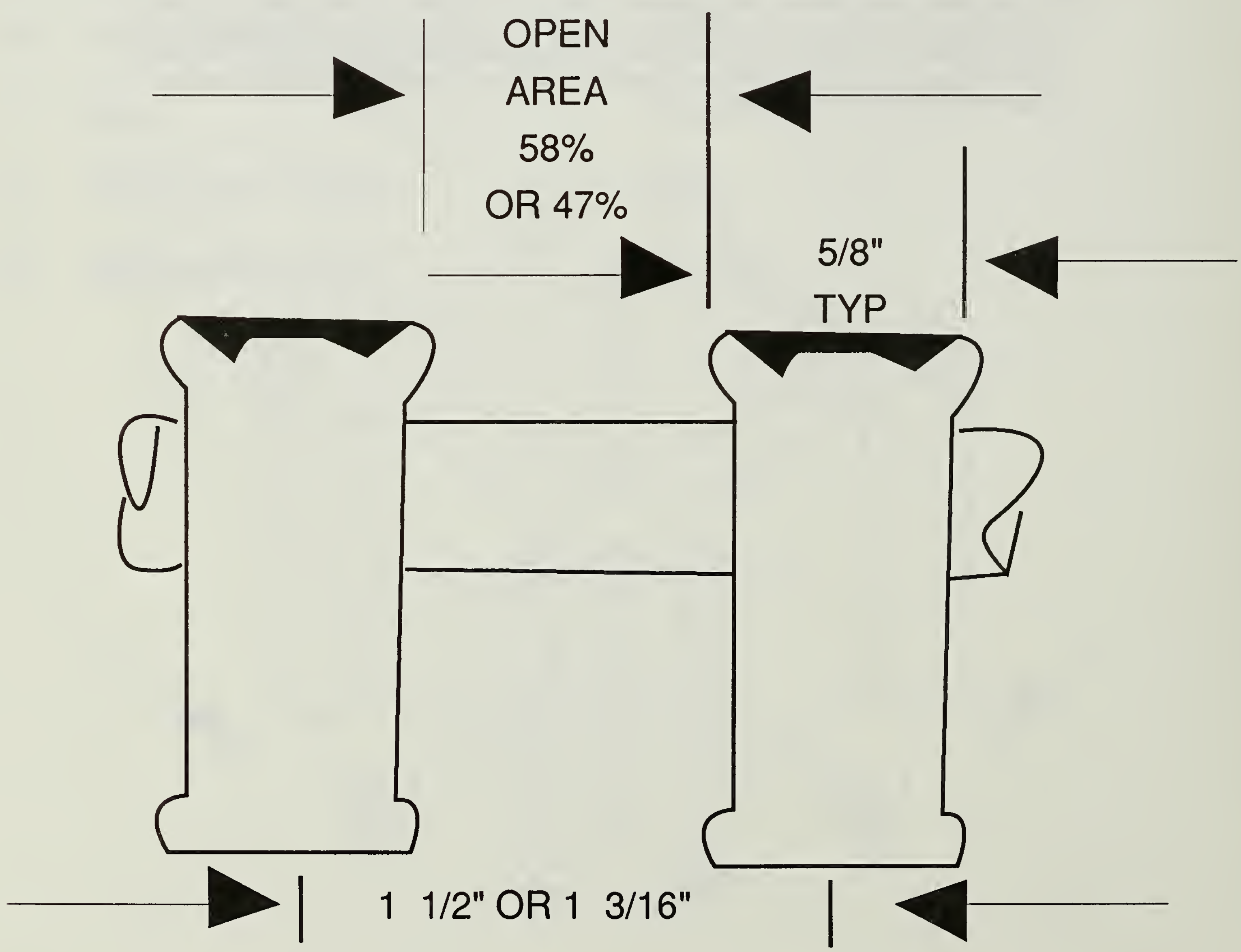
PULTRUDED FIBERGLASS GRATING AND TREADS

Corgrate HI (Heavy Duty)

Resin	Depth & spacing (inches)	Type HI	Width of top flange	Width of open space	% open area	Weight lbs./SF	Span** See note below
Yellow Polyester	1 x 1-1/2 x 6	1"HI58PF	5/8 in.	7/8"	58	4.5	22 in.
Fire Retardant	1-1/2 x 1-1/2 x 6	1-1/2"HI58PF*	5/8 in.	7/8"	58	6.4	34 in.
(PF)	1 x 1-3/16 x 6	1"HI47PF	5/8 in.	9/16"	47	5.6	24 in.
	1-1/2 x 1-3/16 x 6	1-1/2"HI47PF	5/8 in.	9/16"	47	8.0	36 in.
Green Vinylester	1 x 1-1/2 x 6	1"HI58VN	5/8 in.	7/8"	58	4.5	22 in.
Non-Fire	1-1/2 x 1-1/2 x 6	1-1/2"HI58VN	5/8 in.	7/8"	58	6.4	34 in.
Retardant	1 x 1-3/16 x 6	1"HI47VN	5/8 in.	9/16"	47	5.6	24 in.
(VN)	1-1/2 x 1-3/16 x 6	1-1/2"HI47VN	5/8 in.	9/16"	47	8.0	36 in.
Dark Gray	1 x 1-1/2 x 6	1"HI58VF	5/8 in.	7/8"	58	4.5	22 in.
Vinylester	1-1/2 x 1-1/2 x 6	1-1/2"HI58VF	5/8 in.	7/8"	58	6.4	34 in.
Fire Retardant	1 x 1-3/16 x 6	1"HI47VF	5/8 in.	9/16"	47	5.6	24 in.
(VF)	1-1/2 x 1-3/16 x 6	1-1/2"HI47VF	5/8 in.	9/16"	47	8.0	36 in.

*Stock item—special run may be required on all non-stock items.

** The maximum span shown for Corgrate HI (heavy duty) is the maximum span to support a concentrated load of 2,000 lbs. distributed over a 12 inch width with a deflection of no more than 1/4 inch. Nevertheless, whenever you are designing with Corgrate HI, we strongly recommend that you discuss the particular anticipated application with IKG engineers.



HEAVY DUTY GRIP STRUT SAFETY GRATING

4 pound/square foot opening is standard. Sheet metal punched across width 2" flat.

PLANK SELECTION & DESIGN LOADS /DEFLECTIONS

Plank					Clear Span																
Material/ Gauge	Channel Depth in.	Weight lb./ft.	Catalog Number	Load Type	2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"
STEEL 11ga.	2	18.0	H-82011	U	620	397	275	203	155	122	99	82	69	59	50	44	39	31	25	21	17
				D	0.05	0.08	0.11	0.15	0.19	0.24	0.30	0.35	0.41	0.47	0.54	0.62	0.69	0.85	1.04	1.24	1.45
				C	1860	1488	1240	1063	930	827	744	677	620	572	531	496	465	413	372	338	310
				D	0.04	0.06	0.09	0.12	0.15	0.19	0.24	0.28	0.33	0.38	0.44	0.49	0.55	0.68	0.81	0.98	1.16
	2-1/2	18.4	H-82511	U	940	601	418	307	235	185	150	124	104	89	77	67	59	47	38	32	26
				D	0.05	0.07	0.10	0.14	0.18	0.23	0.27	0.32	0.36	0.42	0.49	0.55	0.62	0.79	0.96	1.15	1.35
				C	2820	2256	1880	1611	1410	1254	1128	1025	940	868	806	752	705	626	564	513	470
				D	0.04	0.06	0.08	0.11	0.14	0.18	0.22	0.25	0.29	0.34	0.39	0.44	0.50	0.63	0.76	0.91	1.08
	3	18.9	H-83011	U	1000	640	445	327	250	197	160	132	111	95	82	71	62	50	40	33	28
				D	0.04	0.06	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.44	0.48	0.58	0.68	0.80	0.95
				C	3000	2400	2000	1715	1500	1333	1180	1091	1000	923	857	800	750	667	600	545	500
				D	0.03	0.05	0.07	0.09	0.12	0.15	0.17	0.21	0.24	0.28	0.31	0.35	0.39	0.47	0.55	0.64	0.76
	4	19.7	H-84011	U	1640	1049	729	536	410	324	263	217	182	156	134	117	103	81	66	54	45
				D	0.03	0.05	0.07	0.09	0.12	0.14	0.17	0.20	0.23	0.27	0.31	0.35	0.39	0.47	0.56	0.66	0.78
				C	4920	3936	3280	2812	2460	2187	1968	1789	1640	1514	1406	1312	1230	1094	935	895	820
				D	0.03	0.04	0.06	0.07	0.09	0.11	0.14	0.16	0.19	0.22	0.25	0.28	0.31	0.38	0.45	0.53	0.63
STEEL 10ga.	2	19.9	H-82010	U	689	441	306	225	172	136	110	91	77	65	56	49	43	34	28	23	19
				D	0.05	0.08	0.11	0.15	0.19	0.24	0.30	0.35	0.41	0.47	0.54	0.62	0.69	0.85	1.04	1.24	1.45
				C	2067	1653	1378	1181	1033	919	827	752	689	636	590	551	517	459	413	376	344
				D	0.04	0.06	0.09	0.12	0.15	0.19	0.24	0.28	0.33	0.38	0.44	0.49	0.55	0.68	0.81	0.98	1.16
	2-1/2	20.4	H-82510	U	1044	668	464	341	261	206	167	138	116	99	85	74	65	52	42	35	29
				D	0.05	0.07	0.10	0.14	0.18	0.23	0.27	0.32	0.36	0.42	0.49	0.55	0.62	0.79	0.96	1.15	1.35
				C	3133	2507	2089	1790	1567	1393	1253	1139	1044	964	895	836	783	696	627	570	522
				D	0.04	0.06	0.08	0.11	0.14	0.18	0.22	0.25	0.29	0.34	0.39	0.44	0.50	0.63	0.76	0.91	1.08
	3	20.9	H-83010	U	1111	711	494	363	278	219	178	147	123	105	91	79	69	55	44	37	31
				D	0.04	0.06	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.44	0.48	0.58	0.68	0.80	0.95
				C	3333	2667	2222	1905	1667	1481	1311	1212	1111	1026	952	889	833	741	667	606	556
				D	0.03	0.05	0.07	0.09	0.12	0.15	0.17	0.21	0.24	0.28	0.31	0.35	0.39	0.47	0.55	0.64	0.76
	4	21.8	H-84010	U	1822	1166	810	595	456	360	292	241	202	173	149	130	114	90	73	60	50
				D	0.03	0.05	0.07	0.09	0.12	0.14	0.17	0.20	0.23	0.27	0.31	0.35	0.39	0.47	0.56	0.66	0.78
				C	5467	4373	3644	3124	2733	2430	2187	1988	1822	1682	1562	1458	1367	1215	1039	994	911
				D	0.03	0.04	0.06	0.07	0.09	0.11	0.14	0.16	0.19	0.22	0.25	0.28	0.31	0.38	0.45	0.53	0.63

Allowable Design Loads/Deflections—for Heavy-Duty GRIP STRUT® Walkways/Planks: UNIFORM and CONCENTRATED loads (U and C), corresponding siderail DEFLECTIONS (D); for individual grating struts: CONCENTRATED Loads (C_s) and corresponding strut DEFLECTIONS (D_s)—see load application details in "General Load Information."

PLANK SELECTION & DESIGN LOADS /DEFLECTIONS

Plank					Clear Span																
Material/ Gauge	Channel Depth in.	Weight lb./ft.	Catalog Number	Load Type	2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"
STEEL 9 ga.	2	22.1	H-8209	U	758	485	337	248	189	150	121	100	85	72	62	54	47	37	31	25	21
				D	0.05	0.08	0.11	0.15	0.19	0.24	0.30	0.35	0.41	0.47	0.54	0.62	0.69	0.85	1.04	1.24	1.45
				C	2274	1818	1516	1299	1136	1011	910	827	758	700	649	606	569	505	454	414	378
				D	0.04	0.06	0.09	0.12	0.15	0.19	0.24	0.28	0.33	0.38	0.44	0.49	0.55	0.68	0.81	0.98	1.16
	2-1/2	22.7	H-8259	U	1148	735	510	375	287	227	184	152	128	109	94	81	72	57	46	39	32
				D	0.05	0.07	0.10	0.14	0.18	0.23	0.27	0.32	0.36	0.42	0.49	0.55	0.62	0.79	0.96	1.15	1.35
				C	3446	2758	2298	1969	1724	1532	1378	1253	1148	1060	985	920	861	766	690	627	574
				D	0.04	0.06	0.08	0.11	0.14	0.18	0.22	0.25	0.29	0.34	0.39	0.44	0.50	0.63	0.76	0.91	1.08
	3	23.9	H-8309	U	1222	782	543	399	306	241	196	162	135	116	100	87	76	61	48	41	34
				D	0.04	0.06	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.44	0.48	0.58	0.68	0.80	0.95
				C	3666	2934	2444	2096	1834	1629	1442	1333	1222	1129	1047	978	916	815	734	667	612
				D	0.03	0.05	0.07	0.09	0.12	0.15	0.17	0.21	0.24	0.28	0.31	0.35	0.39	0.47	0.55	0.64	0.76
	4	24.2	H-8409	U	2004	1283	891	655	502	396	321	265	222	190	164	143	125	99	80	66	55
				D	0.03	0.05	0.07	0.09	0.12	0.14	0.17	0.20	0.23	0.27	0.31	0.35	0.39	0.47	0.56	0.66	0.78
				C	6014	4810	4008	3436	3006	2673	2406	2187	2004	1850	1718	1604	1504	1337	1143	1093	1002
				D	0.03	0.04	0.06	0.07	0.09	0.11	0.14	0.16	0.19	0.22	0.25	0.28	0.31	0.38	0.45	0.53	0.63

STRUT CONCENTRATED Loads/Deflections[2]

plank width	steel thickness	Concentrated C_s (lb/ft)	
		Serrated	Non-serr
36" wide	11 ga.	447	510
	10 ga.	515	587
	9 ga.	586	667
	DEFLEC (in)	0.16	0.15

(2) See "General Load Information" for complete explanation of design load deflection conditions.

STRUT UNIFORM Loads/Deflections[2]

plank width	steel thickness	Uniform U (lb/ft^2)	
		Serrated	Non-serr
36" wide	11 ga.	298	340
	10 ga.	343	391
	9 ga.	391	444
	DEFLEC (in)	0.20	0.19

(2) See "General Load Information" for complete explanation of design load deflection conditions.

EXPANDED METAL GRATING

Carbon Steel — Regular

Design Number	Style	Lbs. Per Sq. Ft. Plain	Galv Wt.	Design Size (Inches) SWD	LWD	Opening Size (Inches) SWO	LWO	Strand Size (Inches) Width	Thick-ness	Overall Thick-ness (ins.)	No. of Designs Per Ft. SWD	LWD	% Open Area
* 93	3.0 lb.	3.0	3.15	1.33	5.33	.940	3.44	.264	.183	.540	9	2.25	60
* 94	3.14 lb.	3.14	3.30	2.00	6.00	1.625	4.88	.312	.250	.656	6	2	69
* 95	4.0 lb.	4.0	4.18	1.33	5.33	.940	3.44	.300	.215	.618	9	2.25	55
* 96	4.27 lb.	4.27	4.46	1.41	4.00	1.00	2.88	.300	.250	.625	8.5	3	58
* 97	5.0 lb.	5.0	5.20	1.33	5.33	.813	3.38	.331	.250	.655	9	2.25	50
* 98	6.25 lb.	6.25	6.47	1.41	5.33	.813	3.38	.350	.312	.715	8.5	2.25	50
* 99	7.0 lb.	7.0	7.25	1.41	5.33	.813	3.38	.391	.318	.740	8.5	2.25	45

Above material meets all requirements of Military Specifications MIL-M-17194C and MIL-G18015 and the deflection requirements of Federal Specification RR-G-661-B.

Aluminum— Grade 5052-H32—Standard

100	2.0 lb.	2.0	1.33	5.33	.940	3.44	.387	.250	.730	9	2.25	48

Concentrated and Uniform Load Deflection Tables/Fixed Span

CARBON STEEL

Style (lbs. per sq. ft.)		Span 24"	36"	48"
Carbon				
3#	U	275	100	
	D	.250	.220	
	C	275	165	75
	D	.250	.250	.250
3.14#	U	375	150	50
	D	.250	.240	.250
	C	375	155	75
	D	.250	.250	.250
4#	U	350	150	50
	D	.240	.245	.250
	C	440	220	100
	D	.250	.250	.250
4.27#	U	500	165	60
	D	.245	.245	.250
	C	400	225	100
	D	.250	.240	.250
5#	U	600	175	100
	D	.240	.240	.250
	C	540	310	140
	D	.245	.250	.250

Style (lbs. per sq. ft.)		Span 24"	36"	48"
Carbon				
6.25#	U	800	300	115
	D	.220	.250	.240
	C	800	300	150
	D	.220	.240	.240
7#	U	800	400	165
	D	.210	.250	.240
	C	800	350	175
	D	.220	.240	.250
Aluminum				
2#	C	250	100	50
	D	.250	.250	.250

U=Uniform Load in Lbs. Per Sq. Ft.
C=Concentrated Load in Lbs. Per Sq. Ft.
D=Deflection in Inches

CLASS 60 AND CLASS 30 TRACKWAY

Class 30 Dimensions and Weights

Length of Trackway Roll (current British Army)		:	32m (105ft)
Width		:	3.35m (11ft)
Weight :	per metre run	:	68 kg approx.
	per foot run	:	46 lbs approx.
	Carriage Assembly	:	759kg (1672 lbs) approx.
	Launching Assembly	:	340kg (750 lbs) approx.
	Recovery Equipment	:	41kg (92 lbs) approx.
	Total Weight of Trackway & Components	:	3504kg (7723 lbs) approx.
	Individual plank	:	3.35m x 0.23m (11ft x 9 ins) 15.6kg (34.5 lbs)

Class 60 Trackway Dimensions and Weights

Typical Class 60 Mat
Length : 18.3 m (60 ft)
Width : 16.46 m (54 ft)
Area : 301m^2 (3240 ft)
Weight per m^2 (ft^2) : 34.2 kg (7 lb)
Total Weight : 10294 kg (22688 lb)

Typical Class 60 Track
Length : 15.3 m (50 ft)
Width : 4.6 m (15 ft)
Weight per metre (ft) run : 156 kg (105 lb)
Total Weight : 2385 kg (5257 lb)

Individual planks

Long plank - Length :	4.57 m (15ft) Width : 0.23 m (9 in)
Weight :	33.1 kg (73 lb)
Short Plank - Length :	2.28 m (7 ft 6 in) Width : 0.23 m (9 in)
Weight :	16.8 kg (37 lb)

Weights
The length of trackway that can be carried by typical military vehicles that are equipped with a laying and recovery system fitted are:

4 x 4	8 tonne up to 30 metres
6 x 6	10 tonne up to 50 metres

Equipment weights for assessment are:

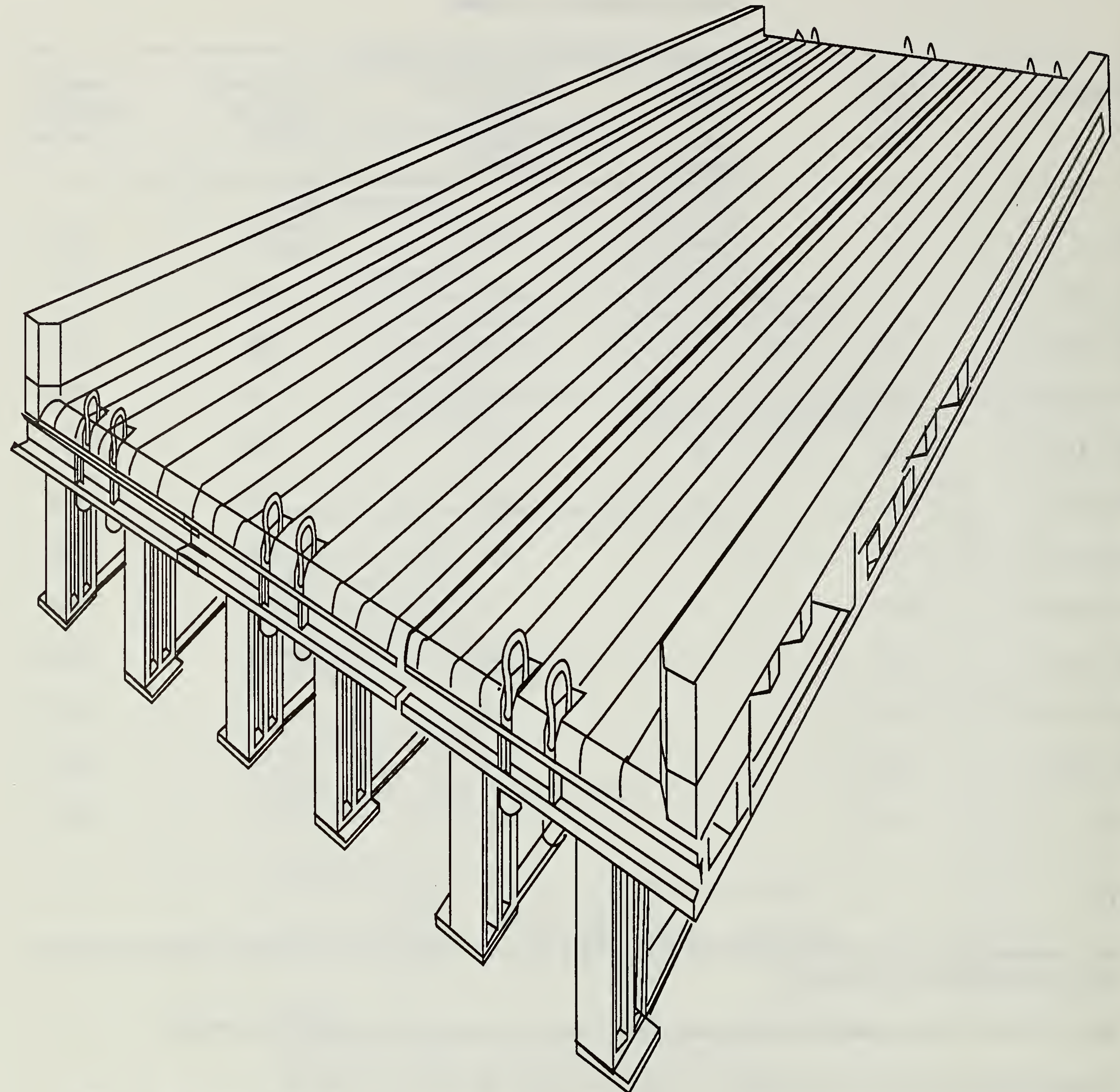
Trackway (including mud allowance)	175 kg per meter run
Spool and Stand	2160 kg
Subframe and Turntable	500 kg
Rear Roller frame	200 kg

PIPE FASCINE SYSTEMS

Type/Model	No. Of Outer Pipes	Width of Fascine (Meters)	Approximate Dia. of Fascine (Meters)	Full Load Per 12M ISO	Weight KGS Per Fascine
MINI	6	4.6	0.55	30	200
MIDI - 9x4	9	4	0.9	24	412
MIDI - 10x4	10	4	1.0	22	473
MIDI - 11x14	11	4	1.1	18	553
MIDI - 12x4	12	4	1.1	16	614
MIDI - 13x4	13	4	1.2	15	674
MIDI - 14x4	14	4	1.3	14	755
MIDI - 15x4	15	4	1.4	11	835
MIDI - 16x4	16	4	1.4	10	896
MIDI - 17x4	17	4	1.5	9	957
MIDI - 18x4	18	4	1.6	9	1,017
MAXI	30	4.6	2.2	2	2,500

NOTES:

1. Midi specifications: All outer pipes fully reinforced. Complete with construction and recovery chains, but no end nets (not necessary for most uses).
2. Mini and Maxi Pipe Fascine to NATO specifications. Optional 4 meter models available on request.
3. Transport prices: FOB UK £500 ($850). CIF New York £1,880 ($3,196) per 12M ISO.
4. Prices valid to 31 December 1990.
5. The design of Pipe Fascine is the property of the UK Government and is protected by patents & trade marks. PD Technical Mouldings PLC is the sole licensee under these patents.



The EZ Bridge

Specifications:

1. Structural design meets 1977 AASHTO requirements (modified for deflection).
2. All structural steel is ASTM A588 weathering steel, and bolts are A307, except where high strength A325 bolts are specifically called for.
3. Timber is treated Douglas Fir (1500f). Treatment with pentachlorophenol is recommended. Unit weight of treated timber is taken at 46 PCF.
4. Maximum live load plus impact deflection not to exceel L/300 (L = span length).

2-LANE E-Z BRIDGE RATING SUMMARY (LIVE LOAD DISTRIBUTION—1.4 WHEELS/BEAM)

Bridge Length	Inventory (Design) Stress		Operating (Overload) Stress	
	Rating	GVW, Tons	Rating	GVW, Tons
20'	HS 28.9	52.0	HS 40.0	72.3
30'	HS 26.4	47.5	HS 37.0	66.6
40'	HS 21.8	39.2	HS 30.8	55.5
50'	HS 23.6	42.4	HS 33.5	60.4
60'	HS 23.5	42.3	HS 33.7	60.6
70'	HS 25.2	45.4	HS 36.3	65.3
80'	HS 25.3	45.5	HS 36.9	66.5

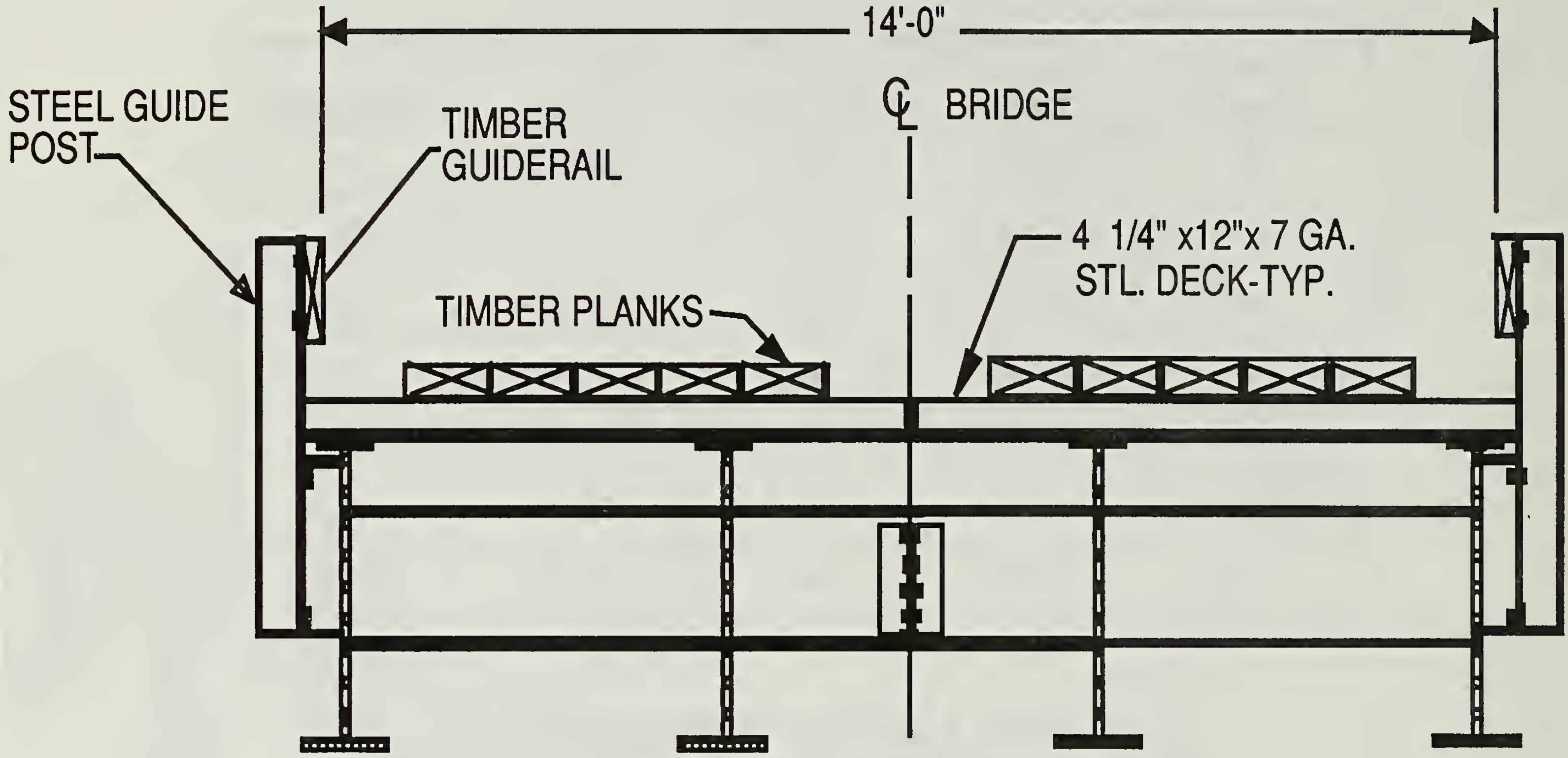
2-LANE E-Z BRIDGE RATING SUMMARY (LIVE LOAD DISTRIBUTION—1.1 WHEELS/BEAM)

Bridge Length	Inventory (Design) Stress		Operating (Overload) Stress	
	Rating	GVW, Tons	Rating	GVW, Tons
20'	HS 36.8	66.2	HS 50.9	92.0
30'	HS 33.6	60.5	HS 47.1	84.8
40'	HS 27.7	49.9	HS 39.2	70.6
50'	HS 30.0	54.0	HS 42.6	76.9
60'	HS 29.9	53.8	HS 42.9	77.1
70'	HS 32.1	57.8	HS 46.2	83.1
80'	HS 32.2	57.9	HS 47.0	84.6

Operating Rating is defined as the load which will produce unit stresses of 0.75 of the yield point of the material (approx. 36 ksi) and is the maximum load allowed on the bridge by special permit.

The **Inventory Rating** is the load which will produce allowable design stresses (approx. 26 ksi) in the bridge. Minimum design loading is the standard HS20 truck with a gross vehicle weight (GVW) of 36 tons.

Big R Bridge Illustration & Design Data



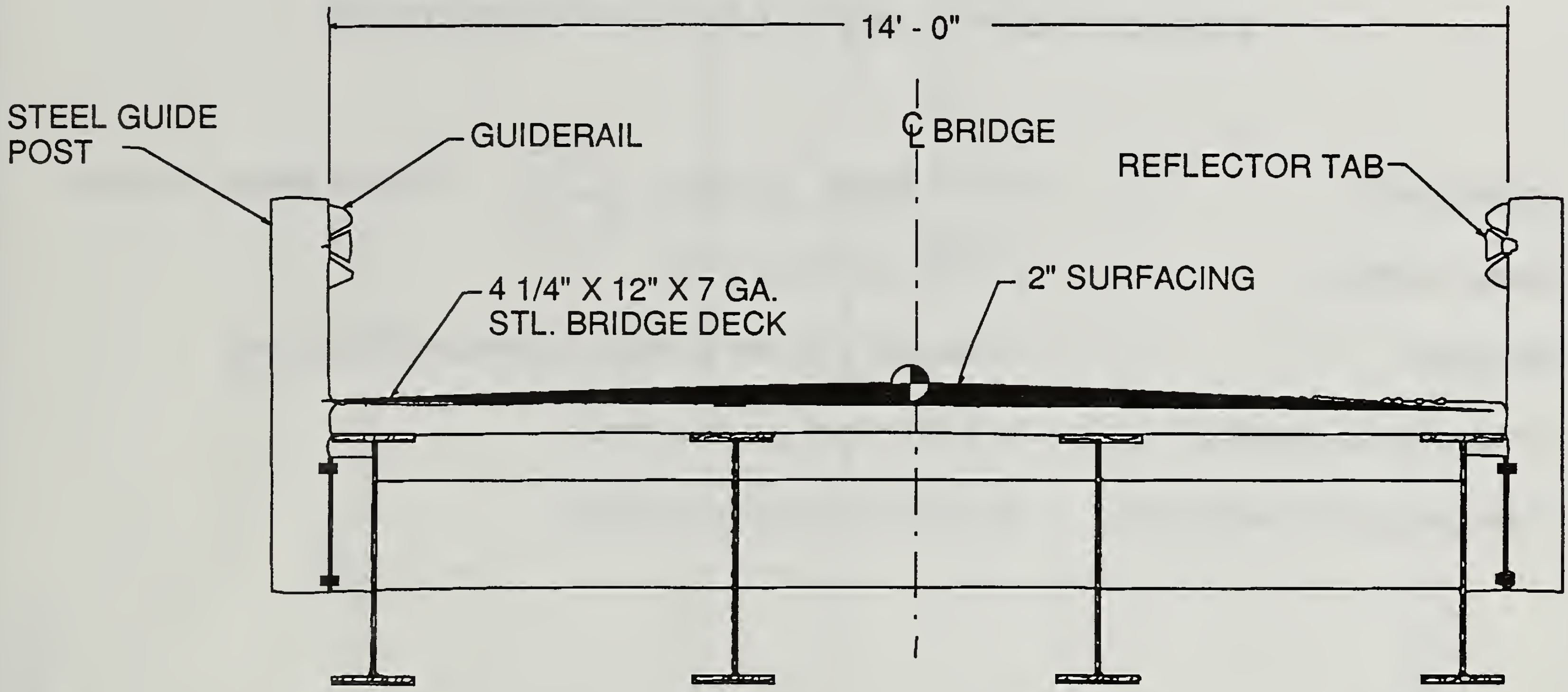
TWO PIECE TYPICAL SECTION

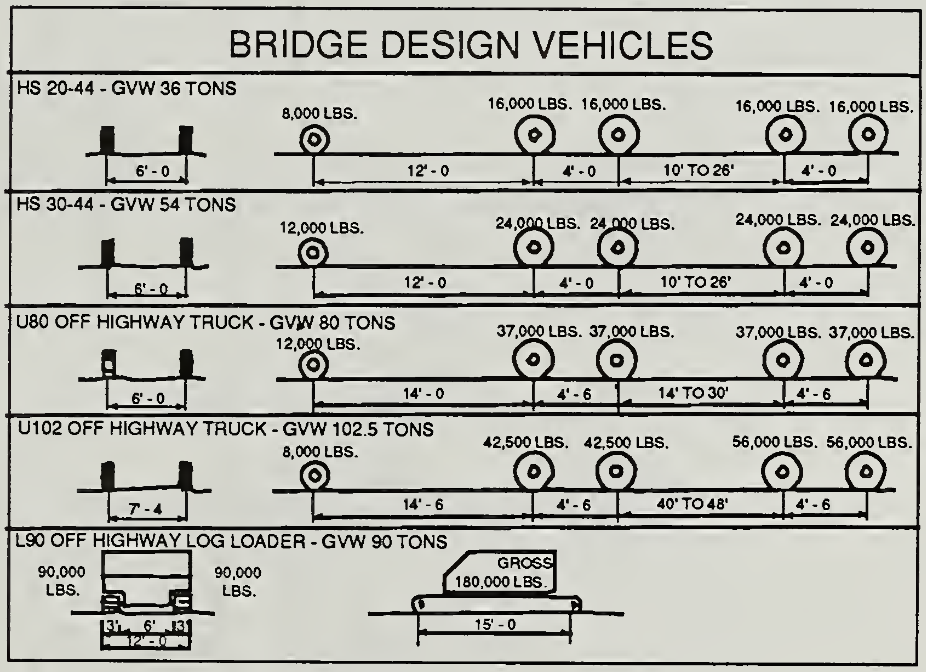
14' 6" WIDTH

Length	HS20			HS30		
	Total Wt.	**Wt. of heaviest panel**	**Depth**	**Total Wt.**	**Wt. of heaviest panel**	**Depth**
30'	14,973#	7,971#	25"	17,057#	9,486#	29"
40'	23,268#	13,020#	29"	26,858#	15,136#	32"
50'	35,519#	20,141#	31"	38,876#	22,169#	35"
60'	49,000#	28,013#	35"	55,310#	31,618#	41"
70'	63,688#	36,609#	41"	72,438#	41,859#	41"
80'	78,762#	45,425#	41"	102,762#	59,825#	41"

Information is for two panel modular bridges, which are 14'6" wide. However, other widths are available as described above.

Big R Bridge one piece typical section & bridge design vehicles

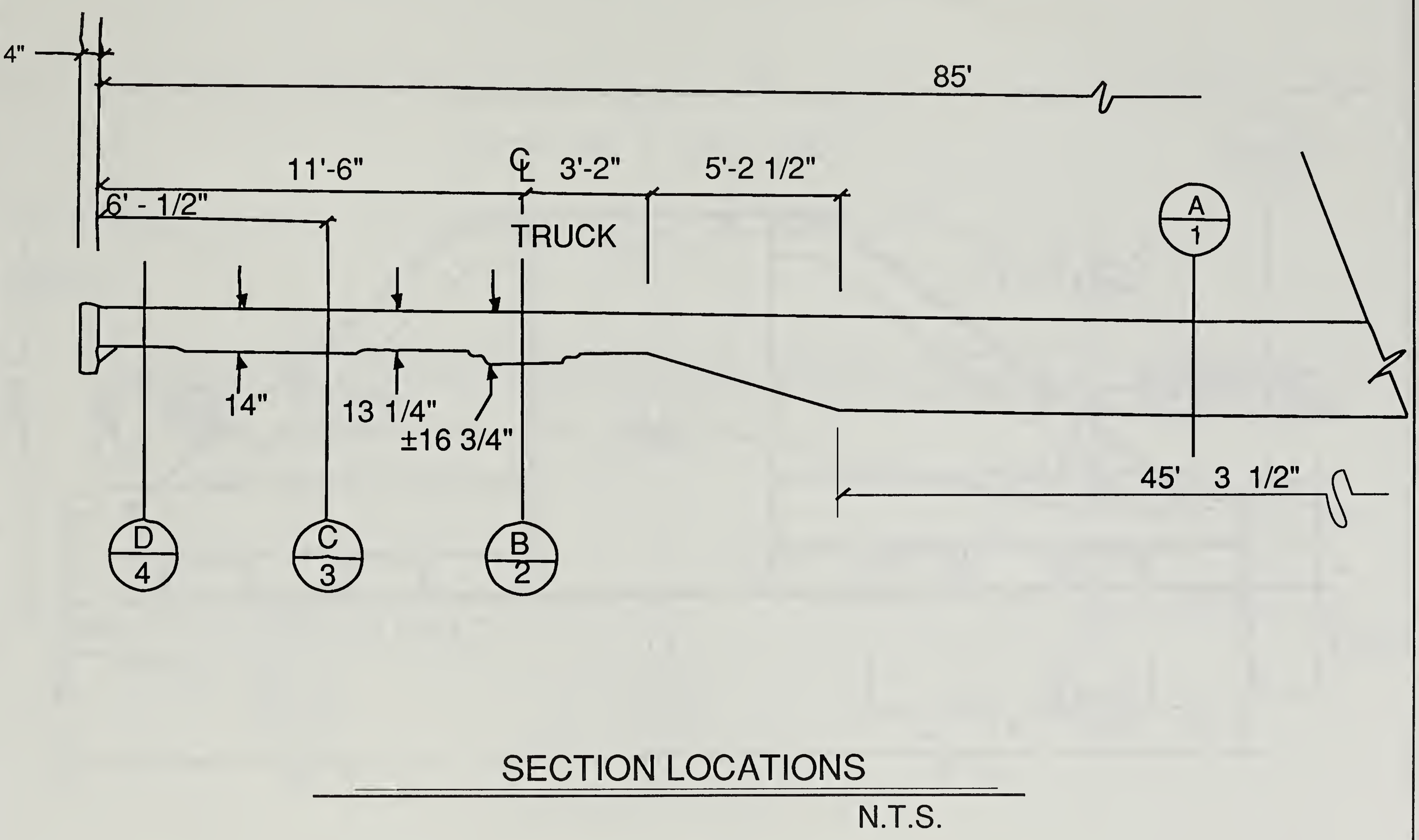




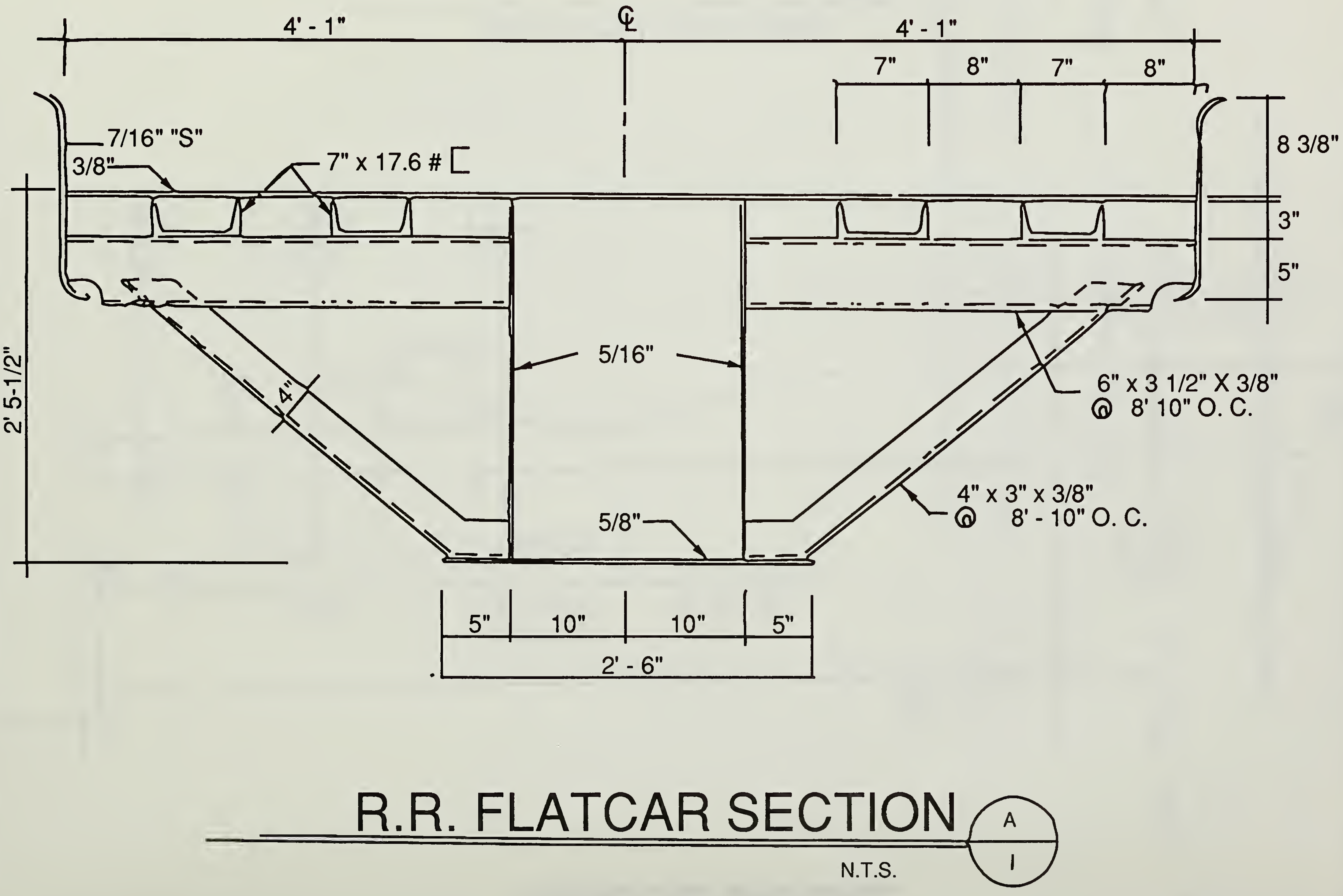
LOAD CAPACITY OF 85-FOOT AND 89-FOOT FLATCARS

Design span:	85-foot flatcar: 62 feet	89-foot flatcar: 66 feet
Design loading:	130,000 pounds or more	
Distribution:	50 percent in center of span, 25 percent at each end	
Normal highway loading:	34,000 pounds per axle group	
Maximum permit loading (CA):	55,000 pounds per axle group	

Skip Gibbs bridge section locations



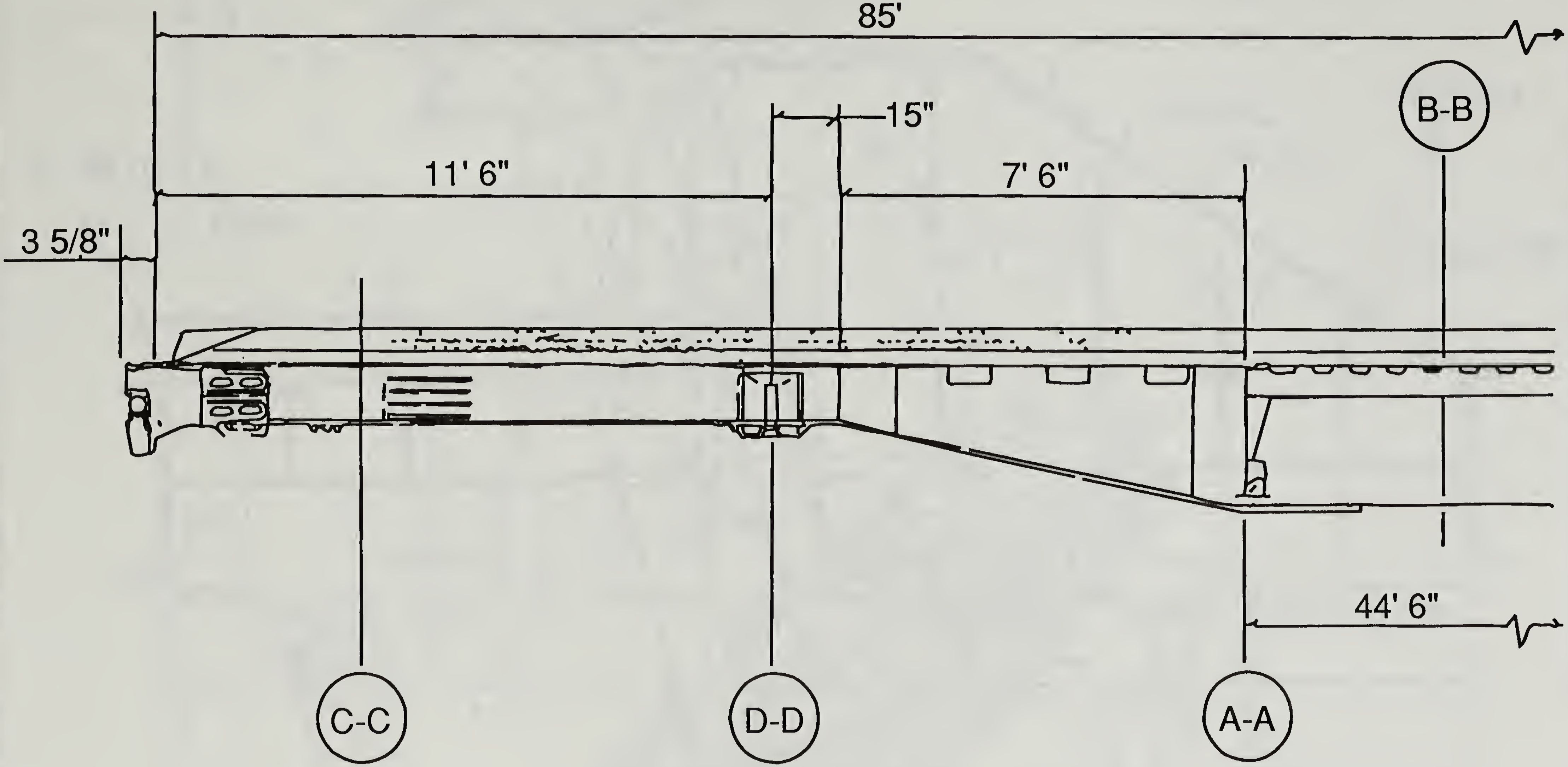
Skip Gibbs bridge "S " car section



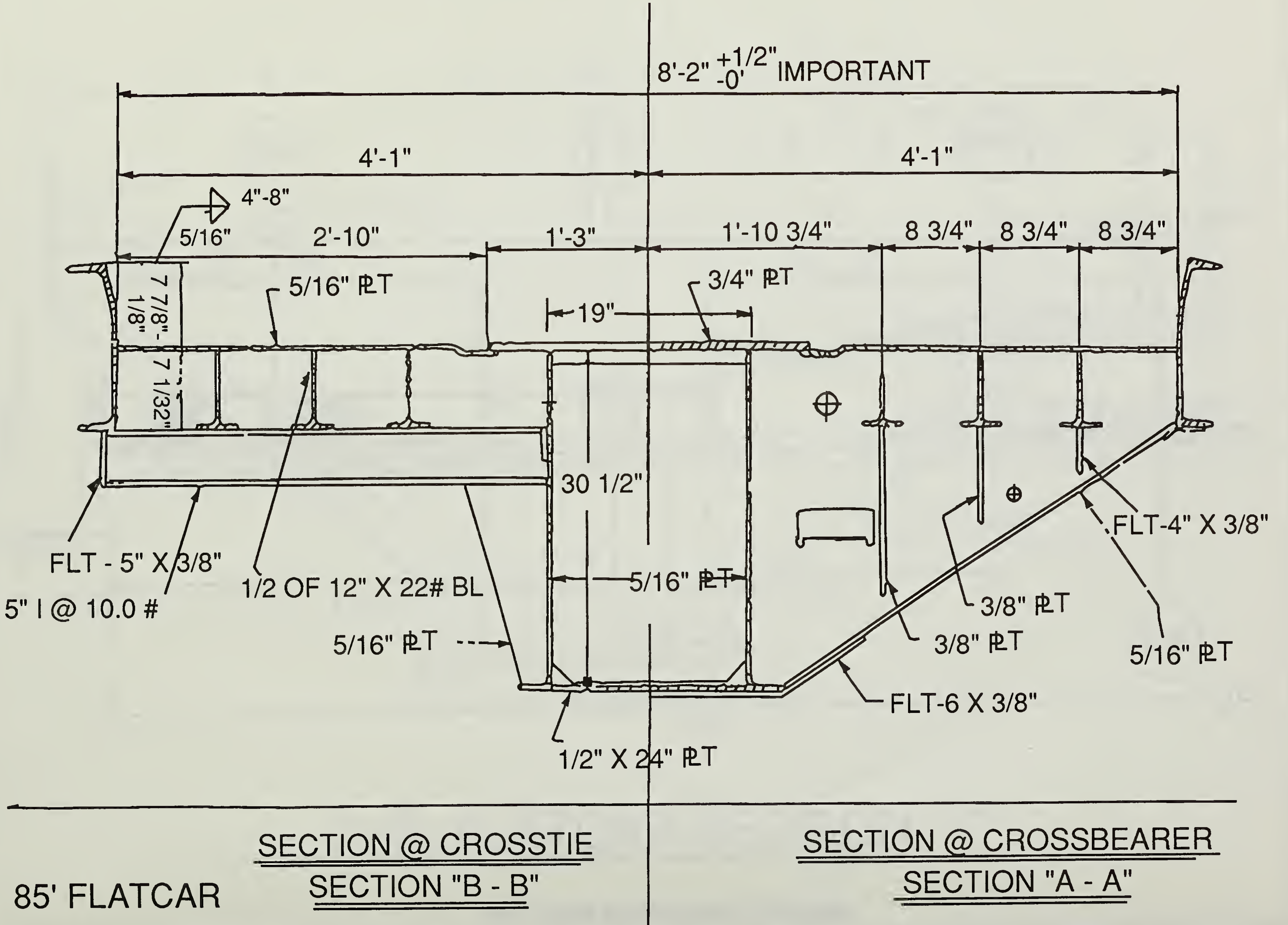
R.R. FLATCAR SECTION

N.T.S.

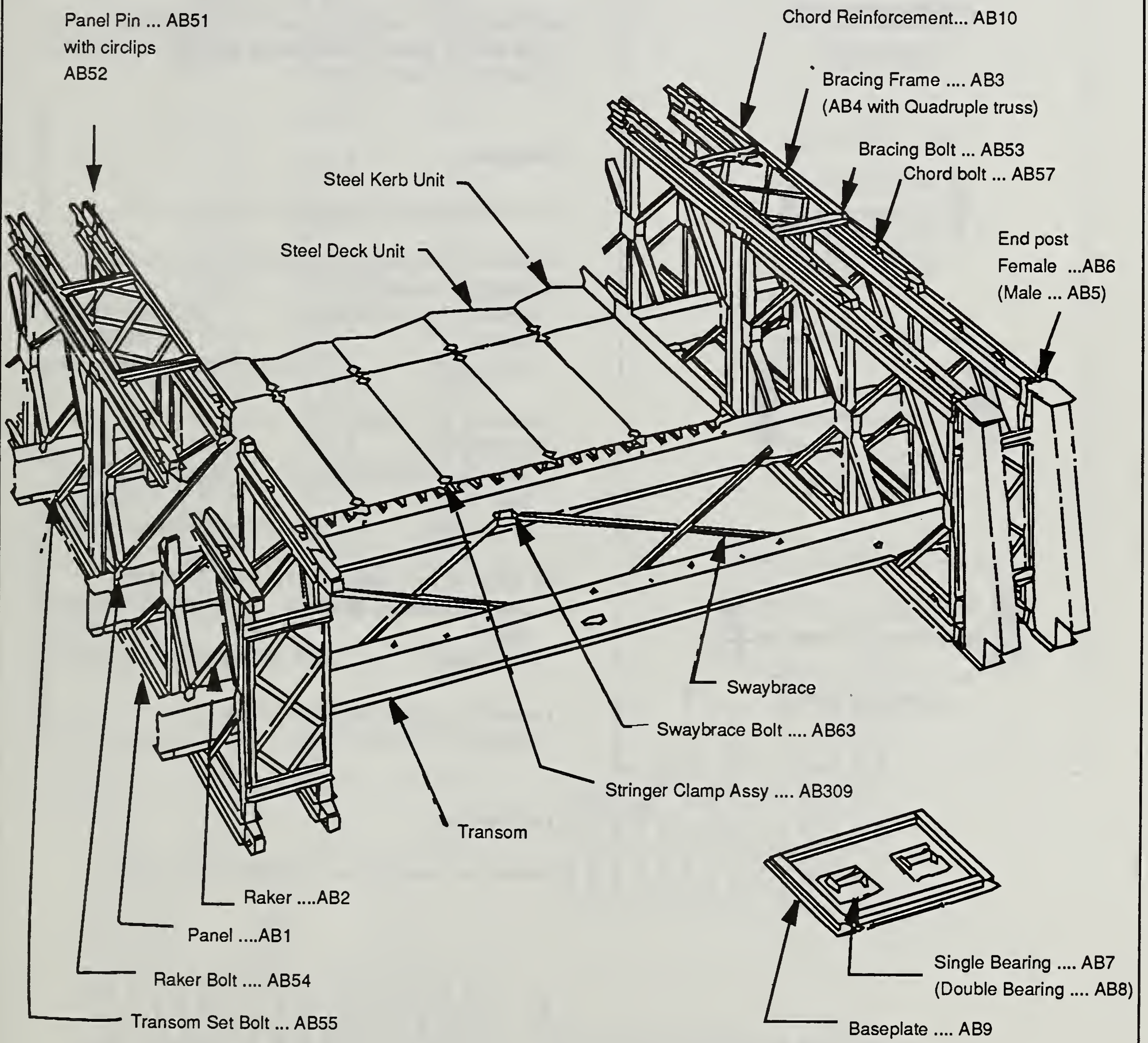
Skip Gibbs 85-foot flatcar illustration



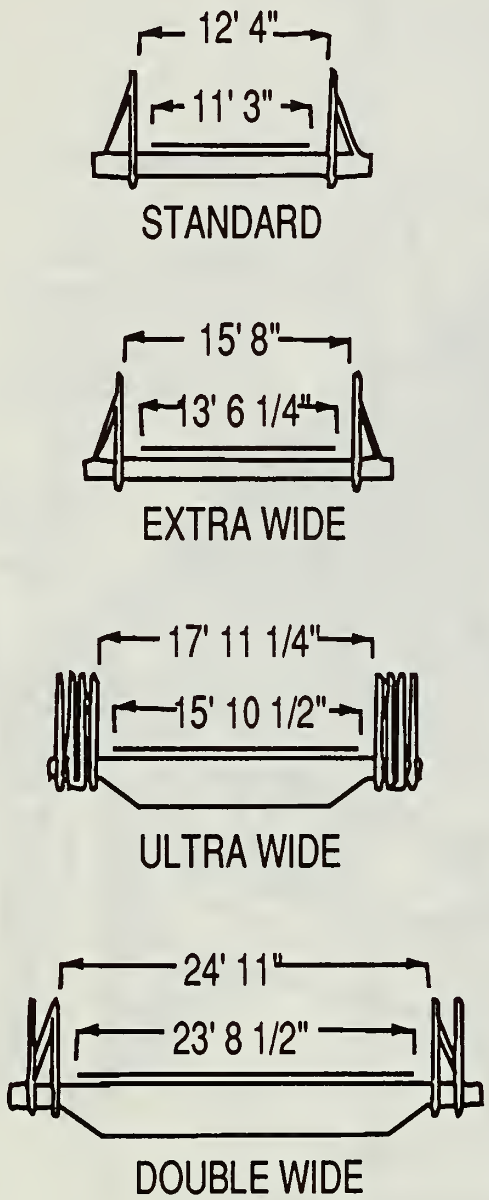
Skip Gibbs 85-foot flatcar section at crosstie & crossbearer



Acrow Panel Through Bridge components illustration



TYPICAL CROSS-SECTIONS



General Specification

The bridge shall be as specified in the plans and these provisions and shall be as furnished by Acrow Corporation of America. An Acrow Panel Bridge shall be furnished with a roadway width of ________________feet.

All components shall be new current production and shall have a galvanized coating equal to ASTM A123 for all major components.

Materials

Components shall conform to the following:

Panels & Reinforcing Chords - ASTM 572 - Grade 65 - BSS4360 - Grade 55C

Ultimate Tensile Strength	80,000/100,000 psi
Yield	65,000 psi
Elongation	17% on 8-inch gauge length

Transoms and Deck Units - ASTM 441 - BSS4360 - Grade 50B

Ultimate Tensile Strength	70,000/90,000 psi
Yield	50,000 psi
Elongation	18% on 8-inch gauge length

All other components - ASTM A36 -BSS4360

Ultimate Tensile Strength	63,000/75,000 psi
Yield	36,000 psi
Elongation	20% on 8-inch gauge length

Panel Pins - Special Molybdenum

Ultimate Tensile Strength	144,000/168,000 psi

Engineering

Spans and loadings are per individuals needs.

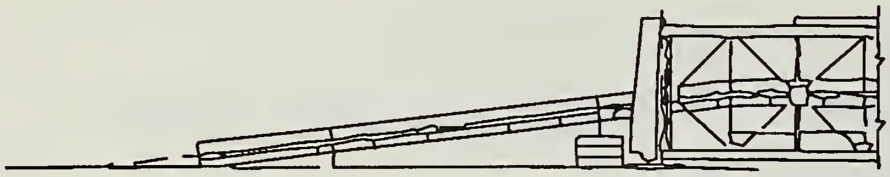
AASHTO LOADINGS — SUGGESTED CONSTRUCTIONS

Nominal Span ft.	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
HS20-44 LIGHT Deck																			
Standard	SS	SS	SS	SS	SSR	SSR	SSR	TS	TS	TS	DSR	DSR	DDR	DDR	DDR	DDR	DDR	DDR	DDR
Extra Wide	SS	SS	SS	SS	SSR	SSR	SSR	TS	TS	TS	DSR	DSR	DDR	DDR	DDR	DDR	DDR	DDR	DDR
Double Wide	DS	DS	DS	DS	DSR	DSR	DSR	TSR	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	QDR	QDR
HS25-44 HEAVY Deck																			
Standard	SS	SSR	SSR	DS	DS	TS	TS	TS	DSR	DSR	DSR	TSR	TSR	DDR	DDR	DDR	DDR	DDR	TDR
Extra Wide	SS	SSR	DS	DS	DS	TS	TS	TS	DSR	DSR	TSR	TSR	TSR	DDR	DDR	DDR	DDR	TDR	TDR
Double Wide	DS	DS	DS	TS	TSR	TSR	TSR	TSR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	QDR	QDR	—	—
HS15-44 LIGHT Deck																			
Standard	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR
Extra Wide	SS	SS	SS	SSR	SSR	SSR	SSR	SSR	SSR	TS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR
Double Wide	DS	DS	DS	DS	TS	TS	TS	DSR	DSR	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	QDR

Legend

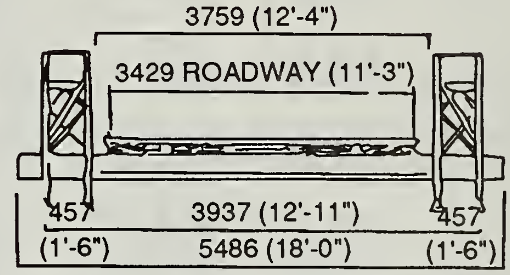
SS = Single Single
DS = Double Single
SSR = Single Single Reinforced
TS = Triple Single
QS = Quadruple Single
DSR = Double Single Reinforced
DD = Double Double
TSR = Triple Single Reinforced
TD = Triple Double
QSR = Quadruple Single Reinforced
QD = Quadruple Double
DDR = Double Double Reinforced
TDR = Triple Double Reinforced
QDR = Quadruple Double Reinforced

Acrow Panel bridge -"A"

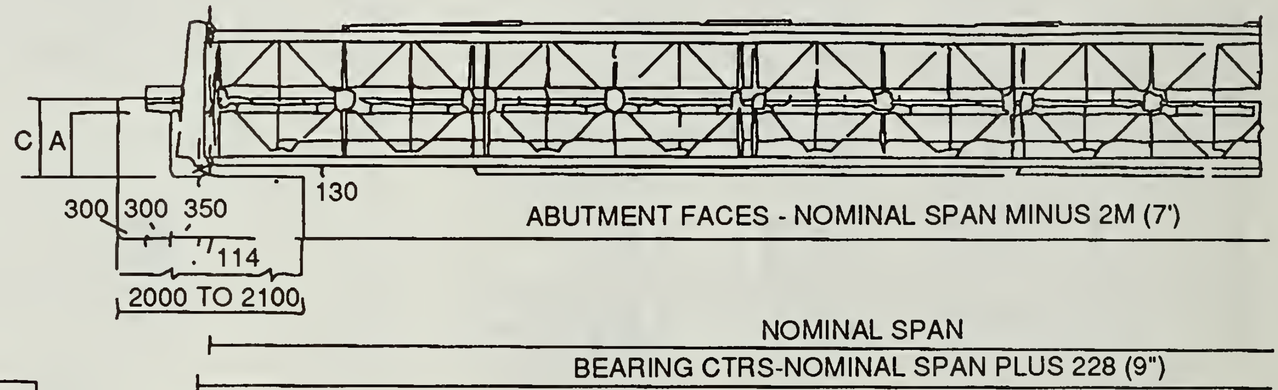


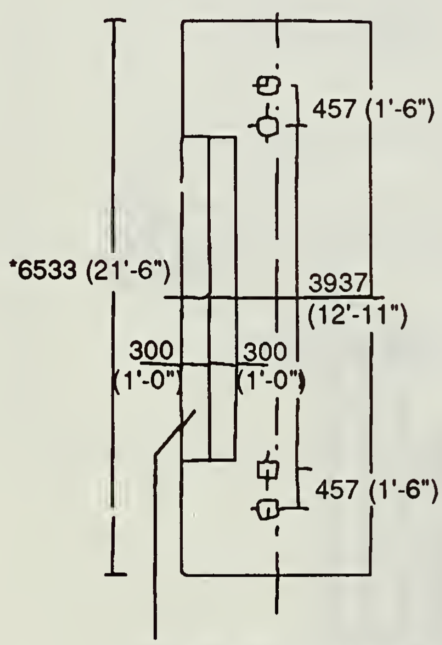
Elevation showing 6.1 m (20') Timber Deck Ramp

Elevation showing 3.05m (10') Timber Deck Ramp

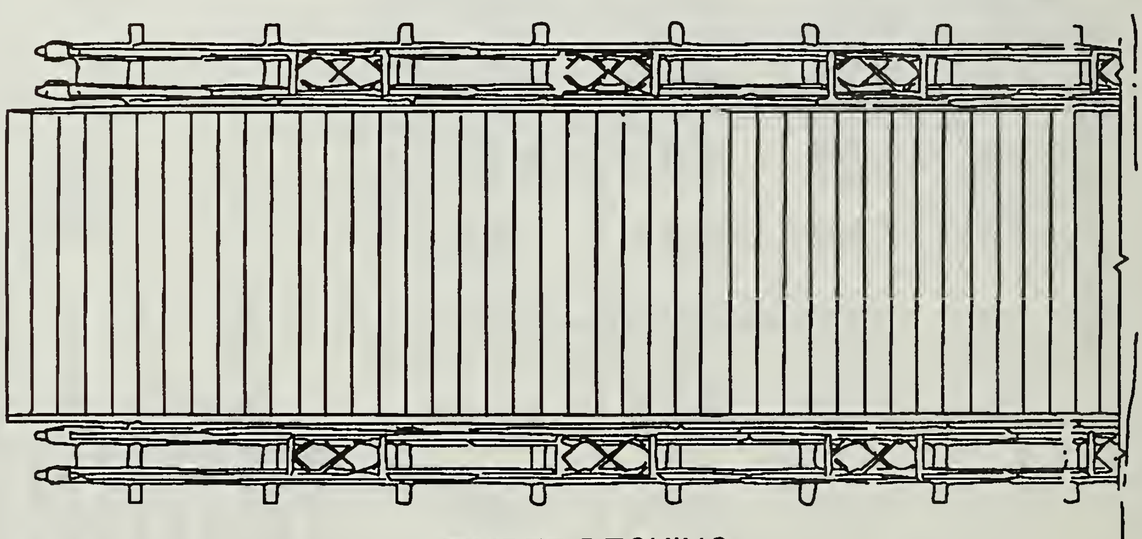


Section showing Timber Decking





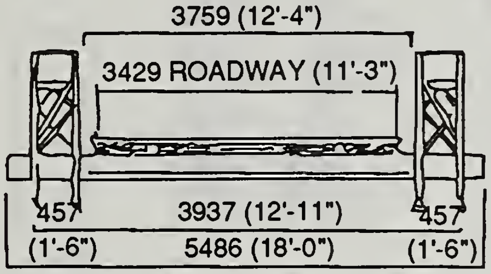
End dam to support Deck Extension normally constructed after bridge has been launched and jacked down



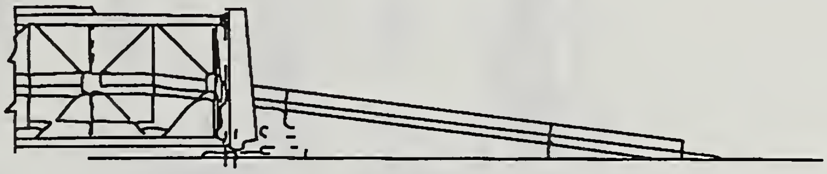
TIMBER DECKING

GENERAL ARRANGEMENT - STANDARD (DOUBLE SINGLE REINFORCED SHOWN)

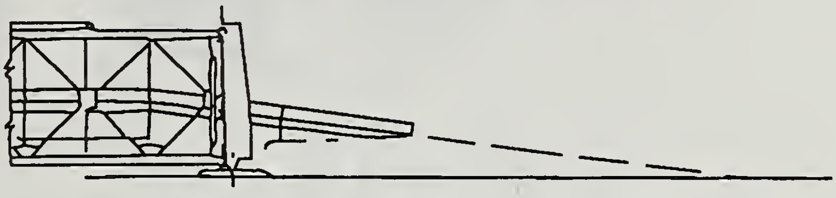
Acrow Panel bridge - "B"



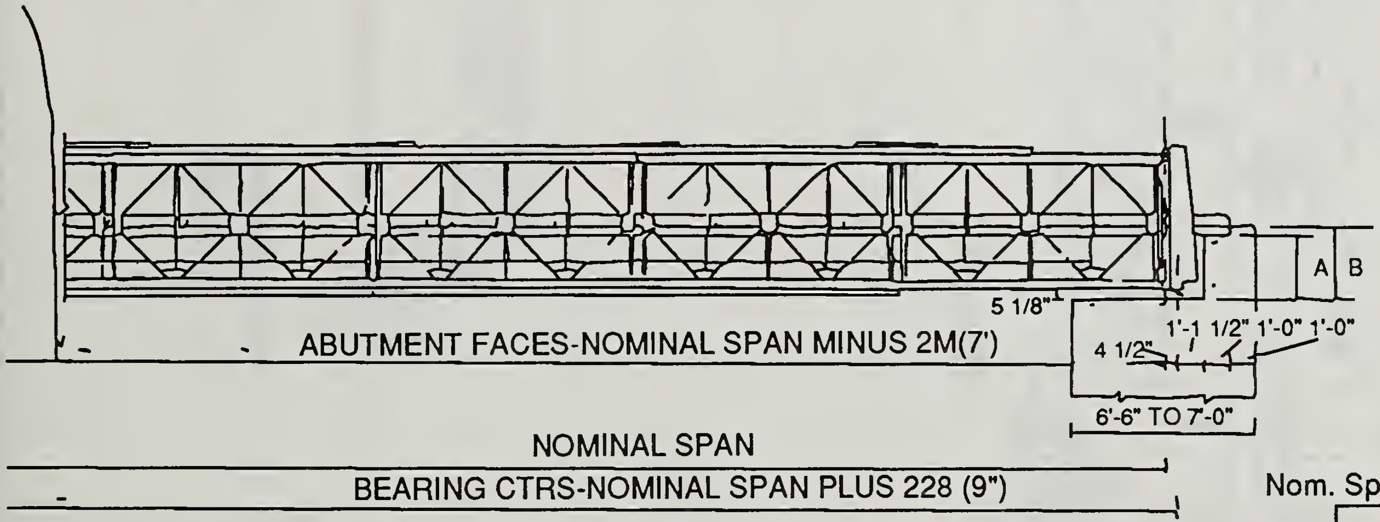
Section showing Steel Decking

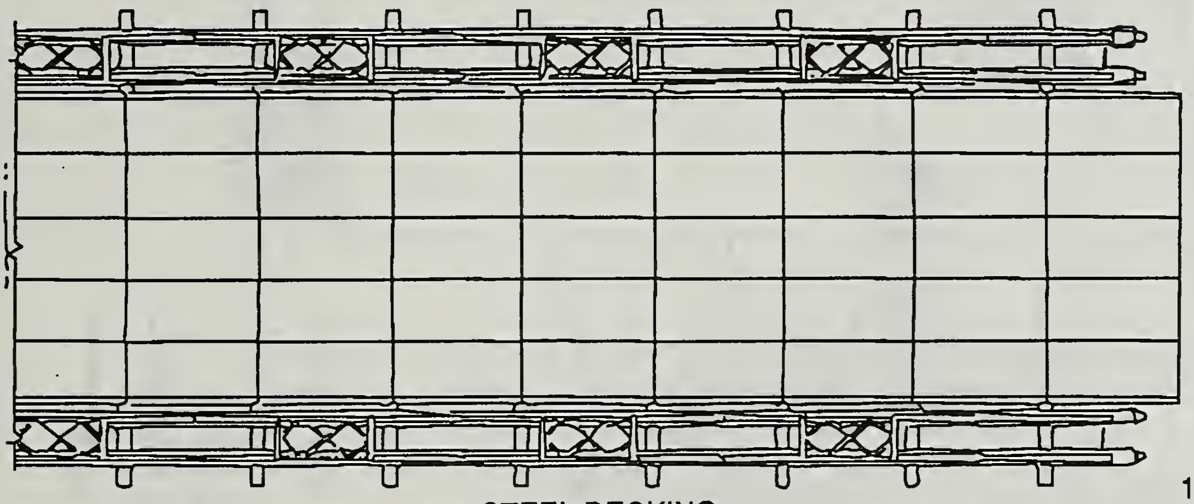


Elevation showing 6.1m(20') Steel Deck Ramp

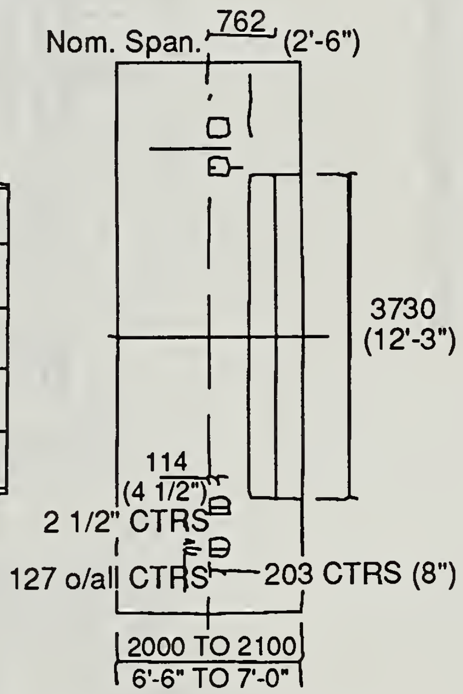


Elevation showing 3.05m(10') Steel Deck Ramp





STEEL DECKING

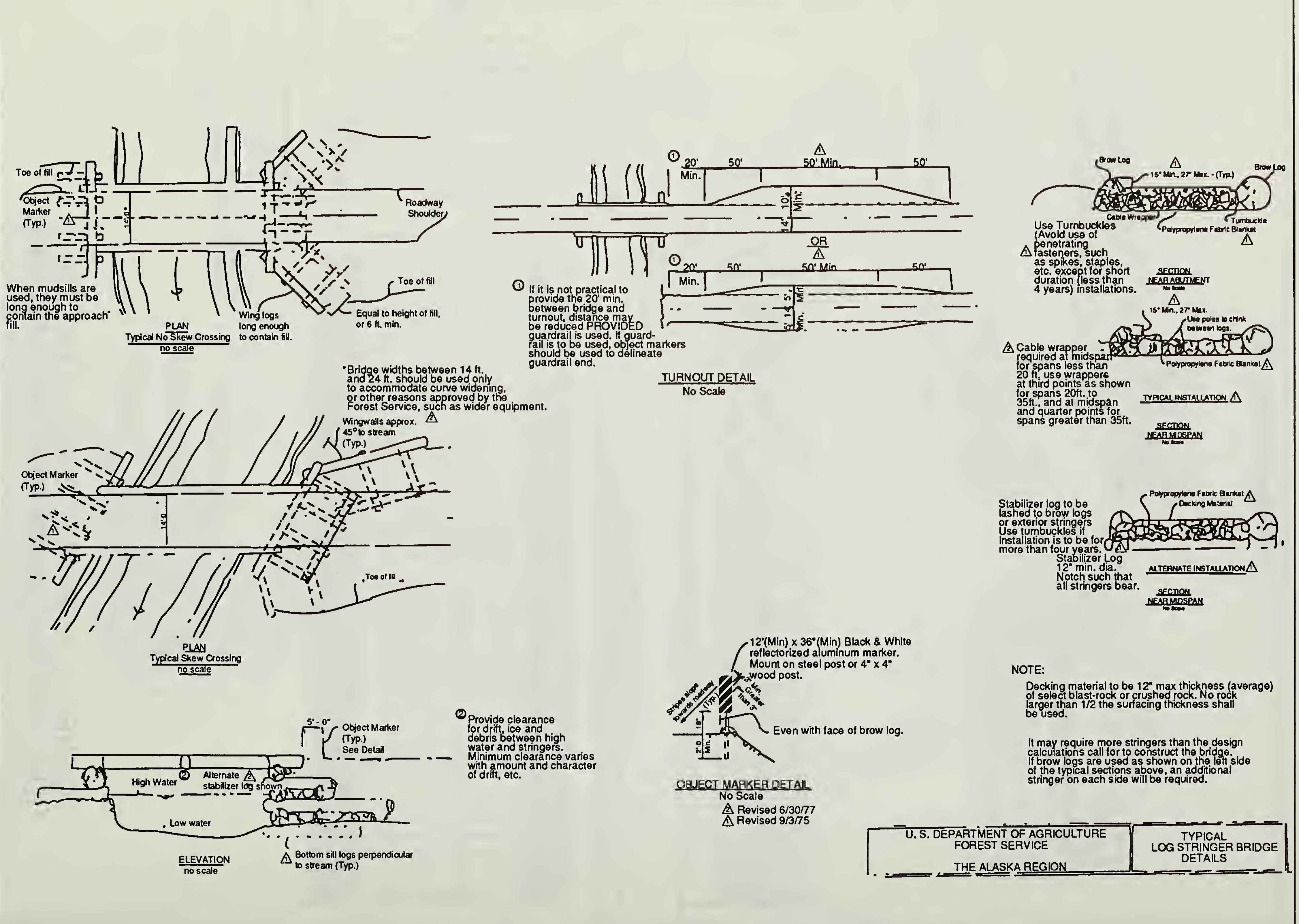


PLAN ON CONCRETE ABUTMENT

	LIGHT	HEAVY	
A	651	752	ABUTMENT TO U/SIDE OF DECK UNIT
	25 5/8"	29 5/8"	
B	757	857	ABUTMENT TO ROAD LEVEL - STEEL DECK
	29 7/8"	33 7/8"	
C	803	930	ABUTMENT TO ROAD LEVEL - TIMBER DECK
	31 5/8"	36 5/8"	

GENERAL ARRANGEMENT - STANDARD (DOUBLE SINGLE REINFORCED SHOWN)

Forest Service - log stringer bridge details



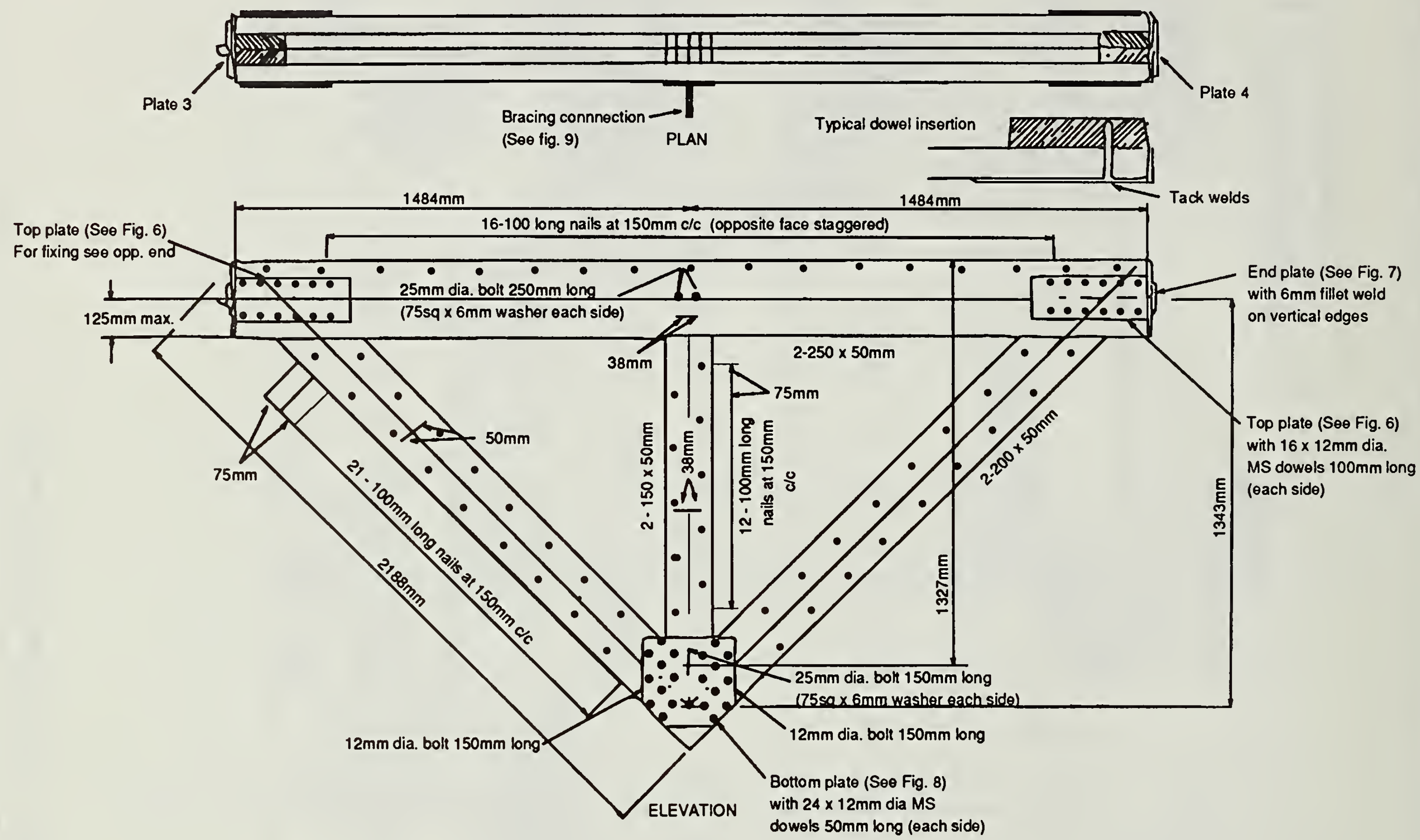
APPROXIMATE DOUGLAS-FIR/LARCH STRINGER DIAMETERS.

Span Length (ft)	Vehicle Type			
	HS20	U54	U80	U102
10	12	12	14	15
15	15	15	16	18
20	16	16	18	20
25	18	18	20	23
30	19	20	23	25
35	22	22	26	28
40	23	22	27	29
45	25	26	29	30
50	26	27	31	31
55	28	30	33	33
60	29	31	35	35
65	31	33	37	36
70	33	35	39	38
75	34	37	41	39
80	36	39	43	41

Note: Diameters shown are average midspan diameters in inches. This table applies *only* to the type of bridge described in the R-10 "Design Guide for Native Log Stringer Bridges."

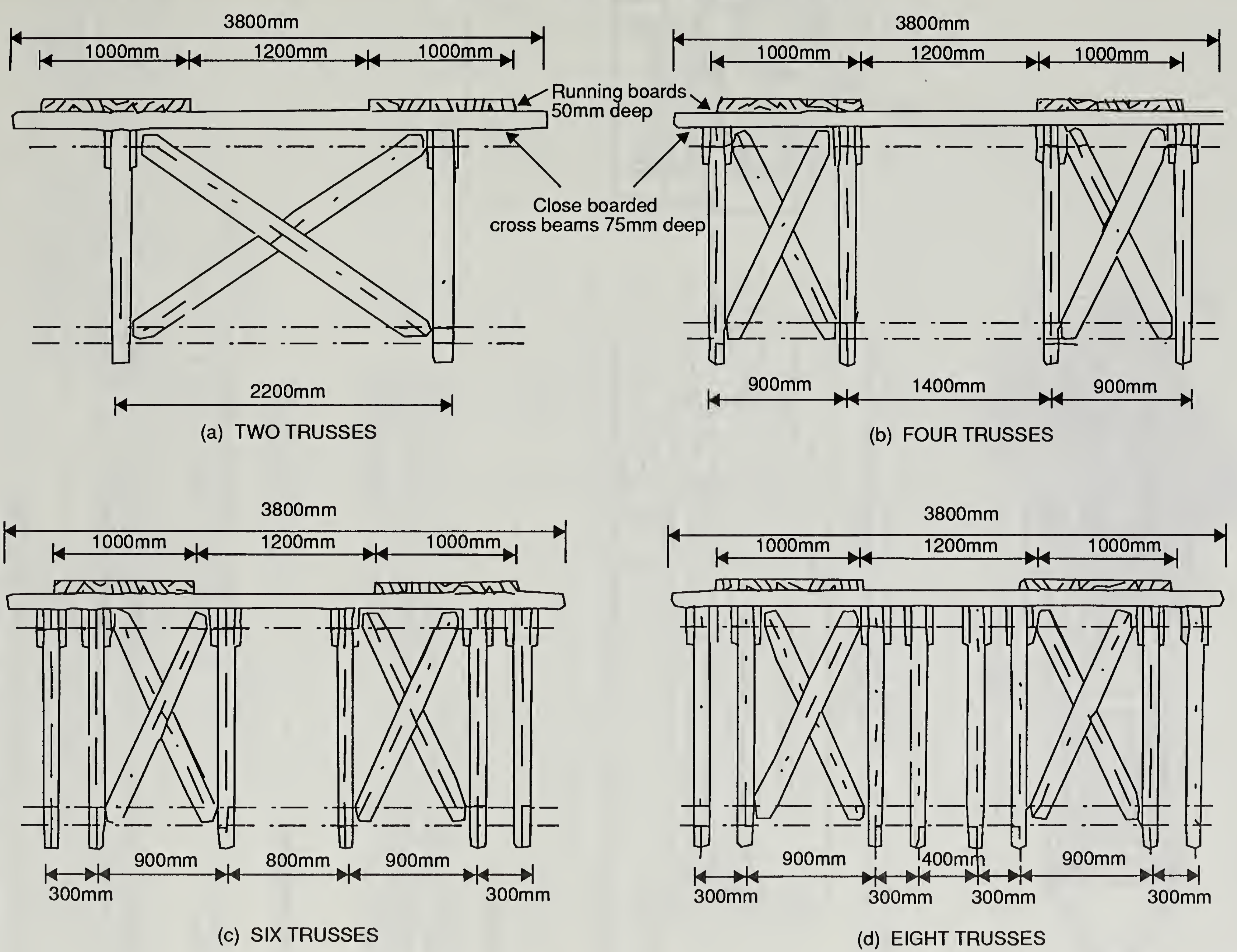
The diameters shown are calculated for 6 inches of rock surfacing over the stringers.

Frame assembly - Modular Timber Bridge



Loading Duty	Span (m) 12	15	18	21	24	27
HA	6	8	-	-	-	-
H20-44	4	4	6	6	8	-
H10-44	2	2	4	4	4	6

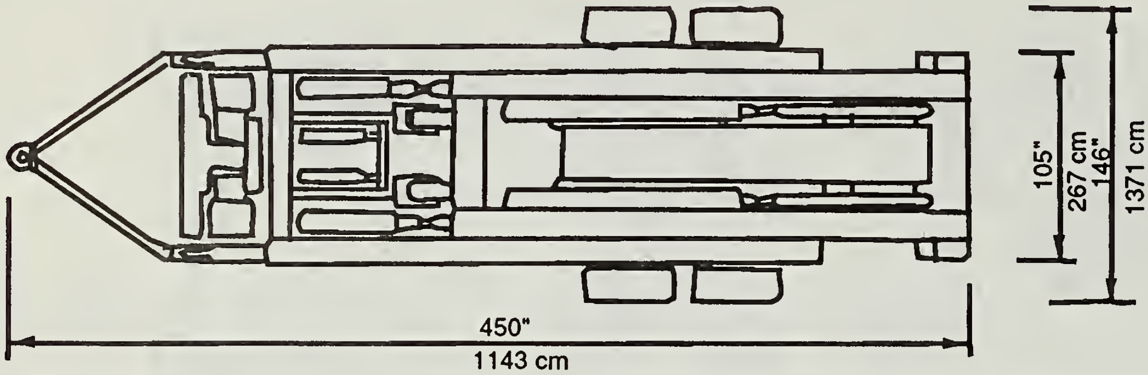
Modular Bridge - Typical Cross Sections

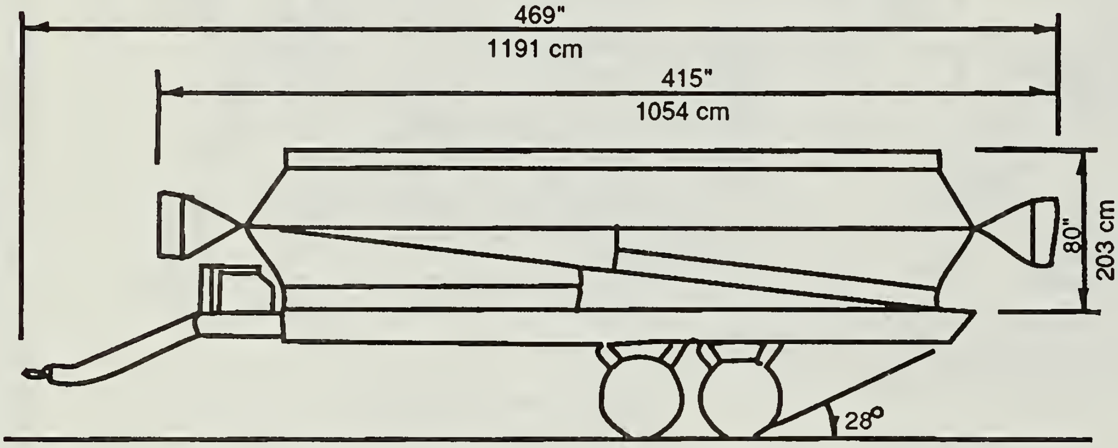


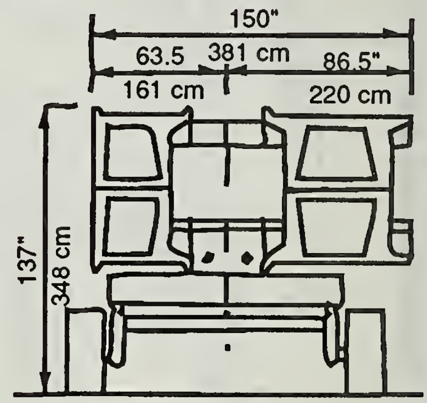
Typical cross-sections using (a) 2 trusses, (b) 4 trusses, (c) 6 trusses, and (d) 8 trusses

Trailer-launched bridge specifications and illustrations

Data - Targeted maximum weight, length, etc.







Weights

Total Weight of System : 14,000 kg (31,000 pounds)
Weight of Bridge : 6,000 kg (13,500 pounds)
Weight of Trailer : 7,900 kg (17,500 pounds)

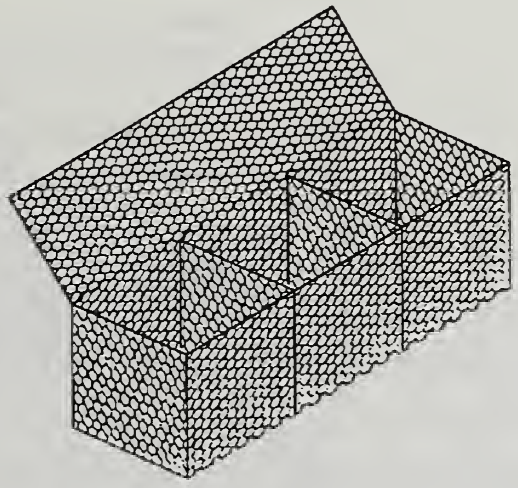
Dimensions

Bridge : 24 m long; girder height 102 cm (40 inches)
Trailer : 11.25 m long, 3.65 m wide, 1.5 m high

Deployment time : Estimated total time: 5 minutes
Retrieval time : Estimated total time : 10 minutes

ISRAEL MILITARY INDUSTRIES reserves the right to make such alterations in design, dimensions, specifications and manufacture as are deemed necessary to ensure continued improvement.

Gabion basket specifications and illustration



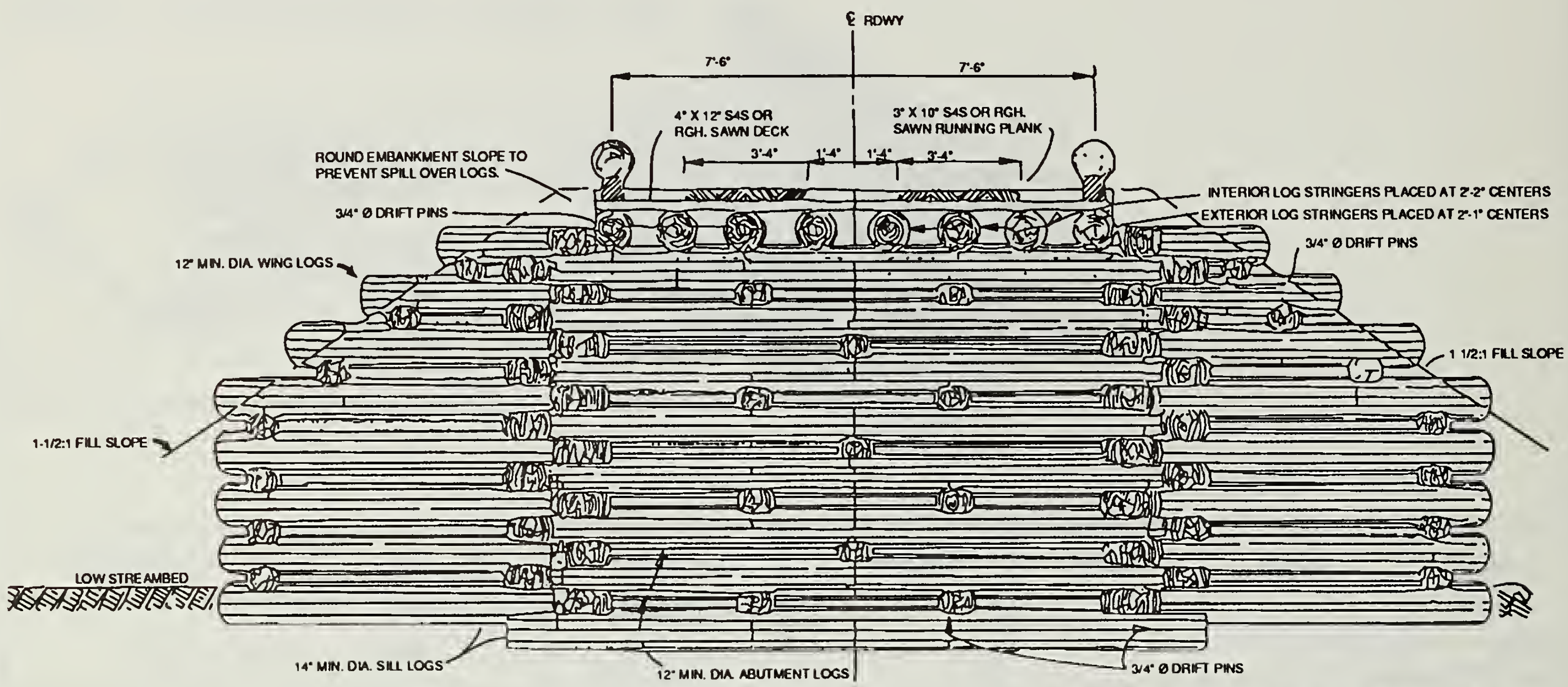
Letter Code	Length	Width	Height	Number of Diaphragms	Capacity Cubic Yards	Color Code
A	6 feet	3 feet	3 feet	1	2.0	BLUE
B	9 feet	3 feet	3 feet	2	3.0	WHITE
C	12 feet	3 feet	3 feet	3	4.0	BLACK
D	6 feet	3 feet	1 foot 6 in.	1	1.0	RED
E	9 feet	3 feet	1 foot 6 in.	2	1.5	GREEN
F	12 feet	3 feet	1 foot 6 in.	3	2.0	YELLOW
G	6 feet	3 feet	1 foot	1	0.66	BLUE-RED
H	9 feet	3 feet	1 foot	2	1.0	BLUE-YELLOW
I	12 feet	3 feet	1 foot	3	1.33	BLUE-GREEN

SPECIFICATIONS

	ZINC COATED	PVC COATED
Mesh opening	Hex. nom. 3 1/4 in. by 4 1/2 in.	Hex. nom. 3 1/4 in. by 4 1/2 in.
Wire for netting	0.1181 inch nom. diam.	0.1062 inch nom. diam. plus nom. 0.02165" PVC
Wire for selvedges	0.1535 inch nom. diam.	0.1338 inch nom. diam. plus nom. 0.02165" PVC
Wire for binding	0.0866 inch nom. diam.	0.0866 inch nom. diam. plus nom. 0.02165" PVC
Zinc coating	0.80 ozs. per sq. foot	0.80 ozs. per sq. foot plus nom. 0.02165" PVC

Minimum thickness of PVC coating shall be not less than 0.015 inches.

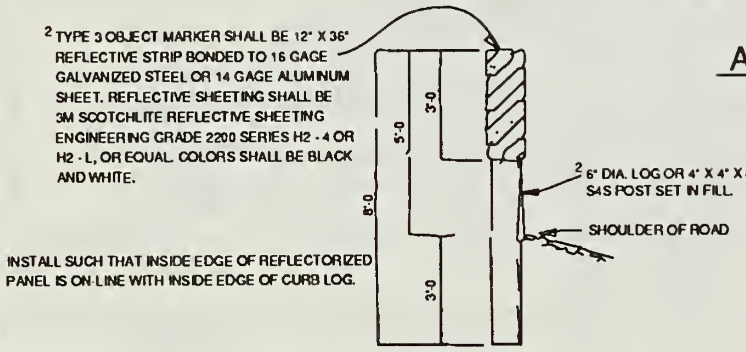
Forest Service - Standard Stringer Bridge And Log Crib Abutments - "A"



NOTE: NUMBER OF ABUTMENT LOGS VARY ACCORDING TO "H" AND DIA. OF LOGS SELECTED.
NUMBER OF WING LOGS VARY ACCORDING TO "H"-"H1" AND DIA. OF LOGS SELECTED.
ELEVATION VIEW SHOWN IS A DIAGRAMATIC AND IS NOT DRAWN TO SCALE.

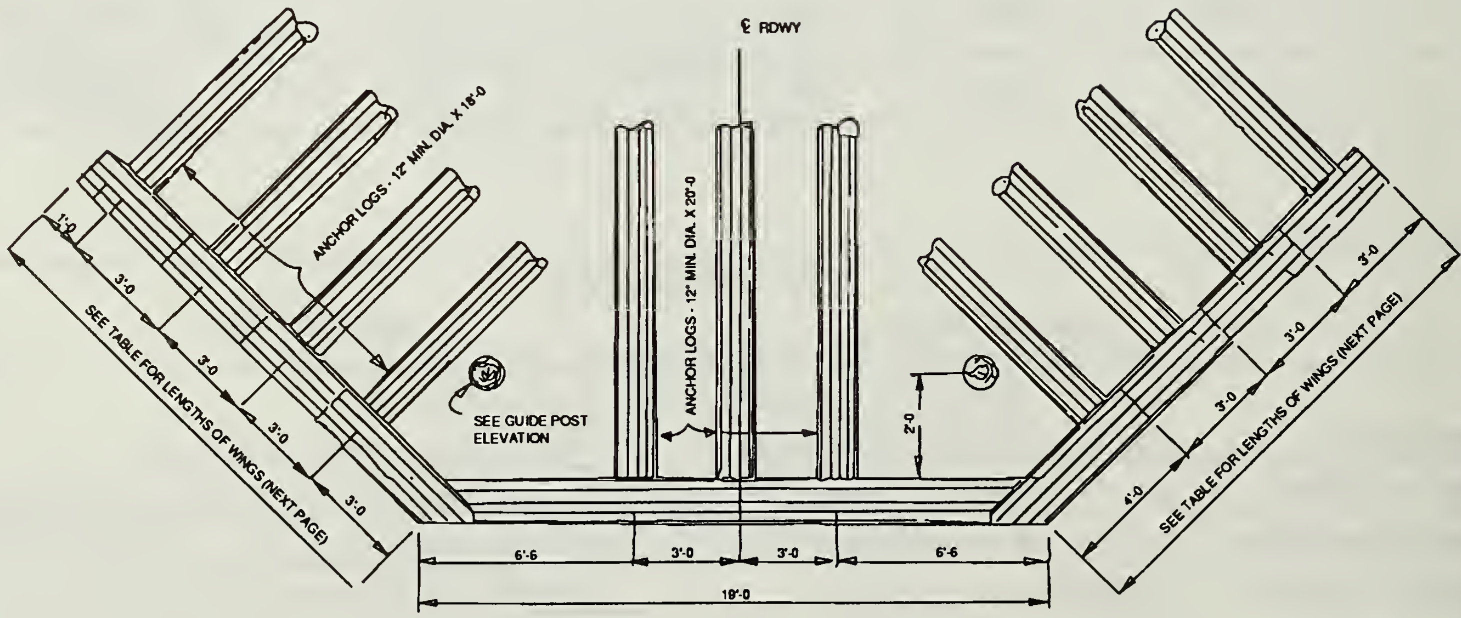
ABUTMENT ELEVATION

NO SCALE



GUIDE POST ELEVATION

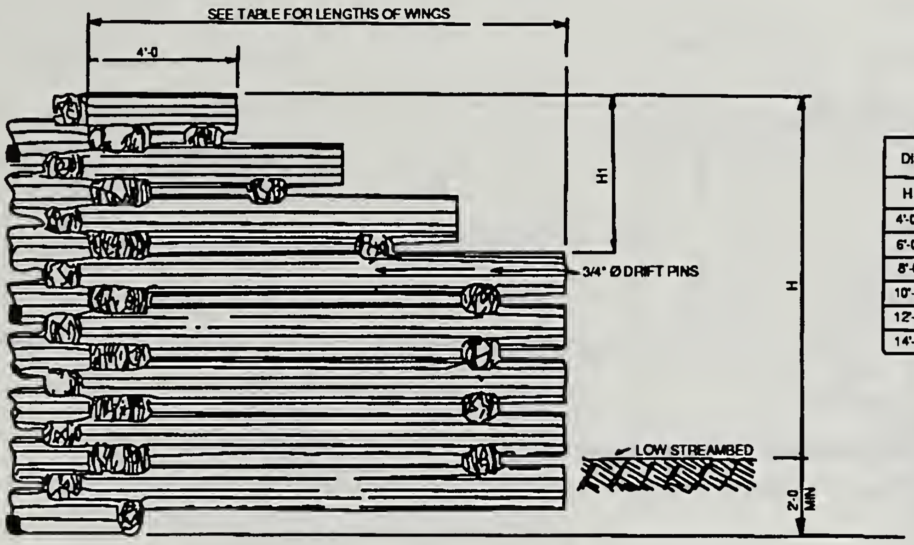
(RIGHT HAND SHOWN - LEFT HAND OPPOSITE)



ABUTMENT PLAN

NO SCALE

Forest Service - Standard Stringer Bridge And Log Crib Abutments - "B"



DIMENSIONS OF WINGS		
H	H1	LENGTH
4'-0	1'-4	7'-0
6'-0	2'-9	10'-0
8'-0	4'-2	13'-0
10'-0	4'-2	13'-0
12'-0	5'-6	16'-0
14'-0	7'-0	19'-0

WING ELEVATION

NO SCALE

[2] LOG STRINGERS (8 REQ'D.)				
SPAN	DOUG. FIR OR LARCH		LODGEPOLE PINE	
	DIA. AT MIDSPAN	DIA. AT TIP	DIA. AT MIDSPAN	DIA. AT TIP
13'-0	12 1/2"	10 1/2"	14"	12"
15'-0	13 1/2"	11"	15"	12 1/2"
17'-0	14"	11 1/2"	15 1/2"	13 1/2"
21'-0	15"	12"	17"	14"
25'-0	16 1/2"	13"	18 1/2"	15 1/2"
29'-0	18"	14 1/2"	20 1/2"	17"
33'-0	19 1/2"	15 1/2"	22"	19 1/2"
37'-0	21"	17"	23 1/2"	20"

1 MINIMUM ALLOWABLE DIAMETER REQUIRED AT MID-SPAN

2 MINIMUM ALLOWABLE DIAMETER REQUIRED AT SMALL END (TIP).

[2] DESIGN UNIT STRESSES: UNIT LOG STRESSES: DOUGLAS FIR OR LARCH 2100 PSI BENDING, 250 PSI COMPRESSION PERPENDICULAR TO GRAIN. AND 125 PSI SHEAR. LODGEPOLE PINE, 1500 PSI BENDING, 170 PSI COMPRESSION PERPENDICULAR TO GRAIN, AND 95 SHEAR.

SAWN LUMBER: MAY BE S4S OR ROUGH SAWN, DOUGLAS FIR OR LARCH, NO. 2 GRADE OR BETTER IN ACCORDANCE WITH WWPA OR WCLB STANDARD GRADING RULES.

[2] LOG STRINGERS: ONLY LARGE POLE PINE, DOUGLAS FIR OR LARCH, SHALL BE USED. LOGS SHALL BE PEELED AND OF SOUND WOOD. FREE OF DECAY AND INSECT ATTACK. NOTCHING NOT TO EXCEED THREE INCHES DEEP SHALL BE PERMITTED AT THE BUTTS OR TIPS FOR BEARING. HEWING AT THE ENDS ALONG THE TOP SIDES OF THE LOGS SHALL NOT EXCEED THREE INCHES DEEP FOR A DISTANCE NOT TO EXCEED 1/4 SPAN LENGTH. WOOD SHIMS NOT LESS THAN THREE INCHES WIDE MAY BE USED ALONG THE TOP SIDES OF LOG STRINGERS TO ACCOMODATE THE LAYING AND FASTENING OF THE DECK PLANKS. THE SHIMS SHALL BE SECURELY FASTENED WITH SIX INCH OR LONGER RING-SHANK NAILS. THE LOG STRINGERS SHALL BE PLACED SO THAT THE MAJORITY OF SURFACE KNOTS ARE ON THE TOP.

DECK PLANKS: FLOORING SHALL BE SECURELY NAILED WITH 6 INCH TO 6 1/2 INCH RING-SHANK NAILS USING TWO NAILS AT EACH STRINGER PER PLANK. RUNNING PLANK SHALL BE SECURELY NAILED OR BOLTED WITH TWO ROWS OF 60D NAILS OR 1/2" X 6" LAG BOLTS PER PLANK AT 18 INCH CENTERS STAGGERED AND TWO AT EACH END.

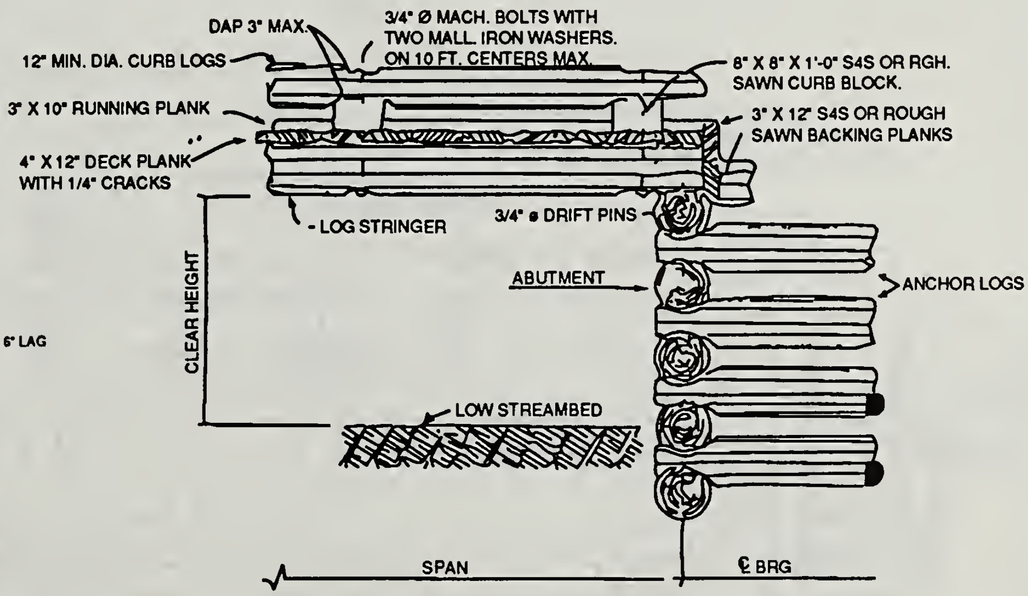
LOG CRIB ABUTMENTS: LOGS SHALL BE NOTCHED TO KEEP THE CRACKS BETWEEN THE LOGS TO A MAXIMUM OF THREE INCHES. HOWEVER, IF A BACKFILL IS COMPOSED OF FINE SANDY MATERIAL, THE SIZE OF THE CRACKS BETWEEN THE LOGS SHOULD BE REDUCED AS NECESSARY TO HOLD THE FILL IN PLACE. BACKFILL SHALL BE TAMPED IN LAYERS NOT TO EXCEED SIX INCHES.

FASTENERS: BOLT HOLES SHALL BE BORED TO 1/16 INCH OVERSIZE AND APPROPRIATE SIZE MALLEABLE IRON WASHERS USED UNDER BOLT HEADS AND NUTS. HOLES FOR DRIFT PINS SHALL BE 1/16 INCH UNDERSIZE. DRIFT PINS SHALL BE SMOOTH BAR STOCK OR NO. 6 REINFORCING BARS.

FIELD TREATMENT: A PRESERVATIVE TREATMENT SHALL BE APPLIED UNTIL REFUSAL\ TO ALL CUTS, DAPS, SURFACE KNOTS, AND BOLT HOLES BY SOAKING OR BRUSHING. ONE OF THE FOLLOWING PRESERVATIVES SHALL BE USED:

(1) FIVE PERCENT PENTACHLOROPHENOL SOLUTION MADE BY ADDING CONCENTRATED PENTACHLOROPHENOL SOLUTION TO KEROSENE OR NO. 2 FUEL OIL, OR A PREPARED COMMERCIAL SOLUTION.

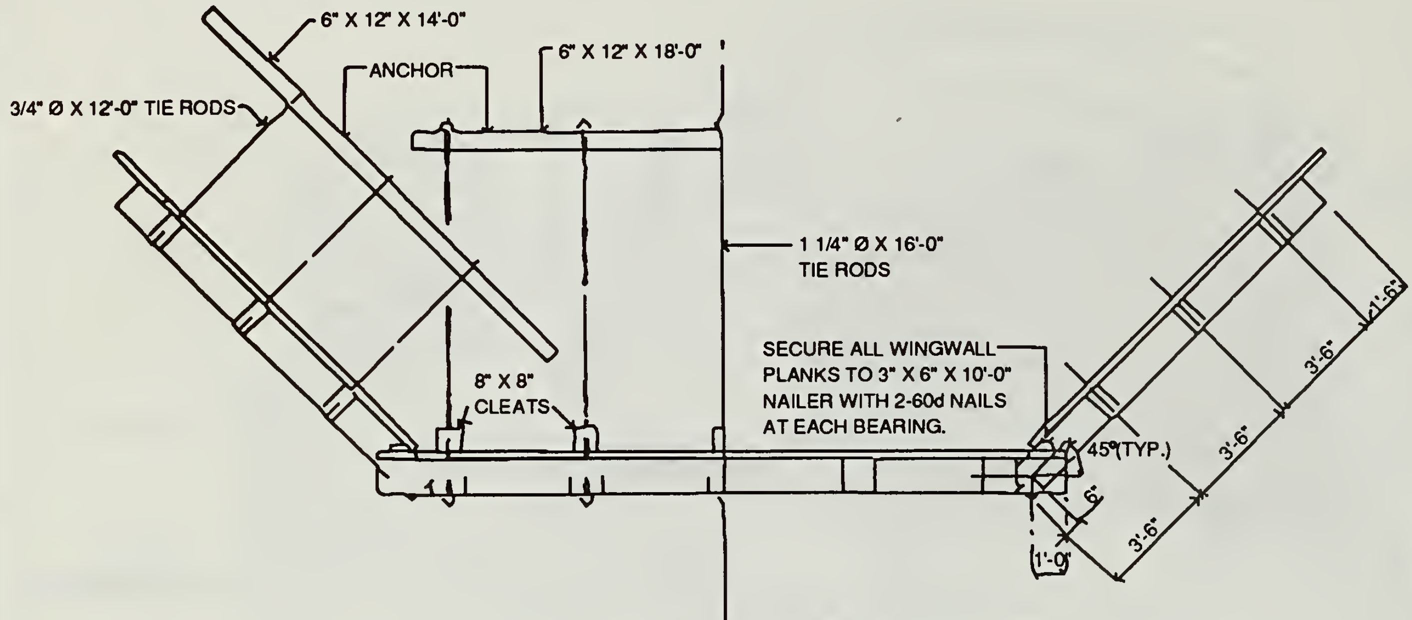
(2) HOT CREOSOTE OIL.



BRIDGE ELEVATION

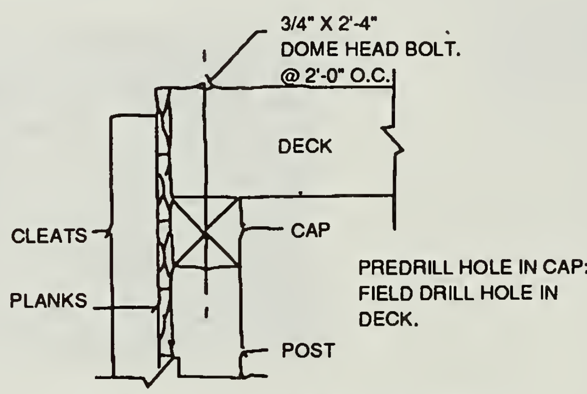
NO SCALE

Substructure details - "A"



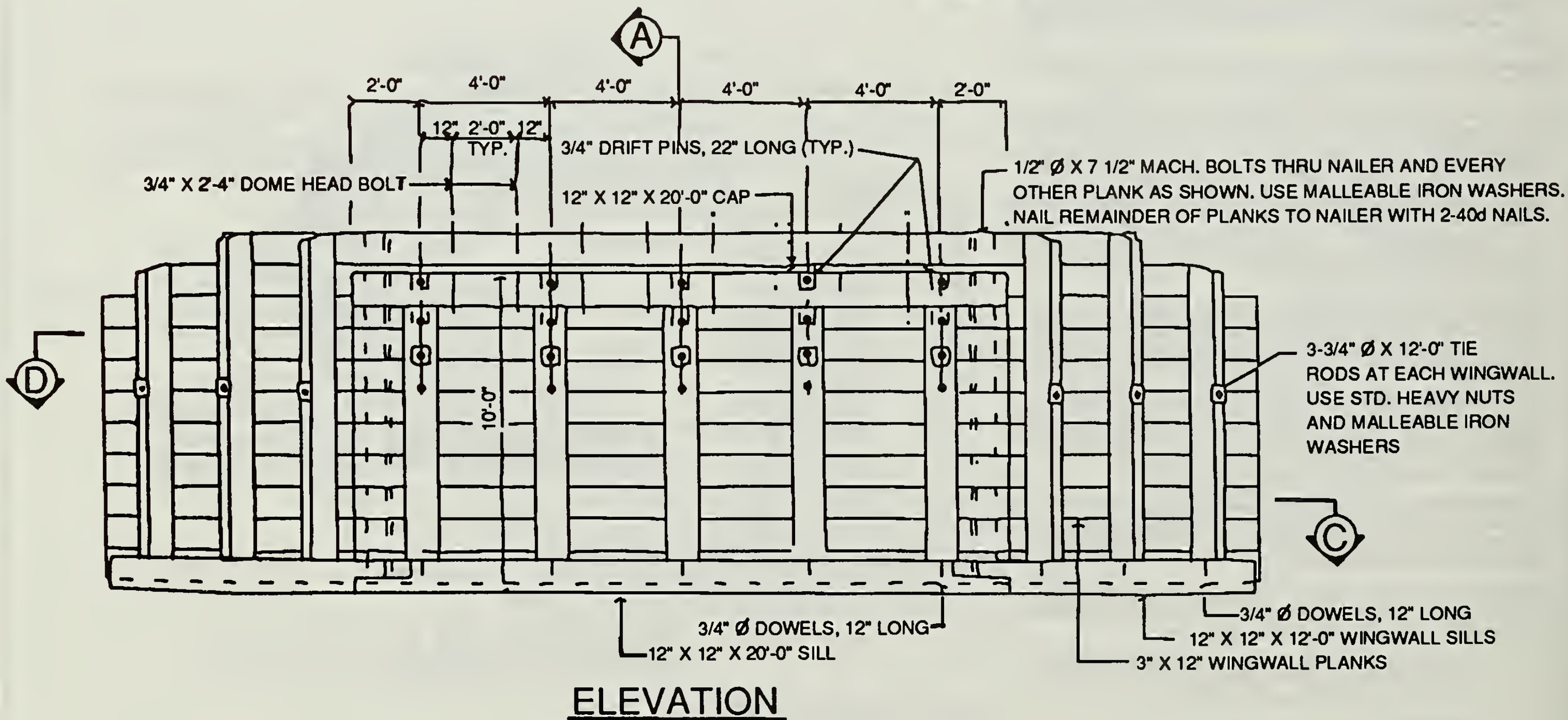
SECTION "D" | SECTION "C"

SCALE: 3/8" = 1'-0"



DECK TO CAP CONNECTION

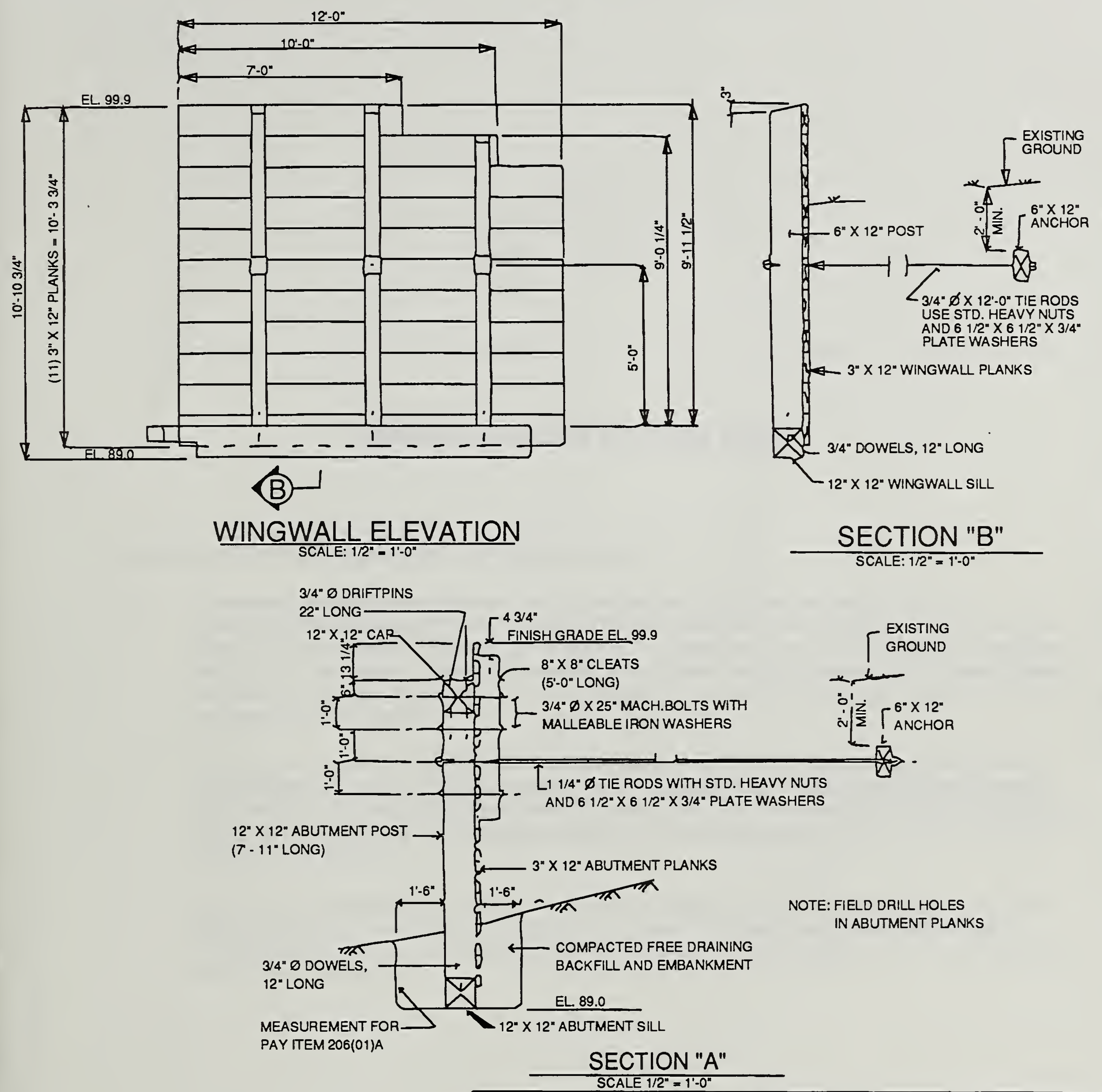
SCALE: 3/4" = 1'-0"



ELEVATION

SCALE: 3/8" = 1'-0"

Substructure details - "B"



DATE	DESCRIPTION	APPROVAL	U. S. FOREST SERVICE — SOUTHERN REGION
			CHATTAHOOCHEE N.F. — BR 244-00.1
			SUBSTRUCTURE DETAILS
			DESIGNED / CHECKED / APPROVED REGIONAL ENGINEER
REVISIONS			DWG. NO. R-50600 — SHEET 4 OF 6

SPECIFIC CRITERIA FOR WES TESTS

A summary of the major requirements of the LOA is as follows:

A. The assault vehicle egress role must allow swimming and fording combat vehicles to exit streams that have slopes within their normal climbing capabilities (maximum 25 percent). The egress points must be capable of withstanding 25 passes by vehicles up to and including Military Load Class (MLC) 70. The system will enable one squad of an Engineer Combat Company, using current organic equipment, to simultaneously install two egress points, 16.4 ft wide and 49 to 66 ft long, within 15 min. after arriving at the exit bank.

B. The bridge equipment access role must provide access lanes for use by gap crossing equipment to reach bridge launch sites. The access lanes must be capable of withstanding 50 passes by vehicles up to and including MLC 25. The system will enable 10 people from the Engineer Assault Float Bridge Company (ribbon), using current organic equipment, to install single lanes 13.1 ft wide, at the rate of 328 to 410 ft in 30 min.

C. The bridge traffic access/egress role must provide roadways capable of withstanding 2,000 to 3,000 vehicle passes (10 percent rated at MLC 70). The system will enable one platoon of the Engineer Combat Company (Corps) using current organic equipment, to install single 13.1 ft lanes at the rate of 820 to 984 ft in 45 min.

TEST VEHICLES

A. Five-ton M54 cargo truck (40,000 lb gross weight, 70 psi tire pressure)

B. Five-ton ribbon bridge transporter (RBT) truck (47,400 lb gross weight, 50 psi tire pressure)

C. M48A1 tank (140,000 lb gross weight)

D. M113 APC (24,000 lb gross weight)

ALUMINUM ACCESS/EGRESS MODULES

Table 1
Order of Traffic Applied in Traffic Tests

Vehicle	No. of Passes
M54	600
RBT	600
M54	600
M48A1	200
M54	150
RBT	150
M54	150
M48A1	50
M54	150
RBT	150
M54	150
M48A1	50
	3000

Table 2
Order of Traffic Applied in Slope Tests

Slope Condition	Vehicle	No. of Passes
Dry	M54	10
	RBT	15
	M48A1	10
Wet	M54	10
	RBT	15
	M48A1	10
Muddy	M54	15
	RBT	10
	M48A1	10
Lake Site	M113	27

Table 3
Comparison of Flexmat Test Parameters

Test	Date	Percent Slope	Subgrade	Test Vehicle	Weight of Vehicle (lb.)	No. of Passes	No. of Men	Time Required to Position Mat (min)
I	8/81	25	Lean clay	M113 APC	23,500	12	4	12
II	9/82	25	Lean clay	M113 APC	22,600	25	5	10
III	9/83	25	Lean clay	M113 APC	24,800	57	5	13
IV	5/84	25	Lean clay	M113 APC	24,800	51	5	13
IV	6/84	0	Heavy clay 1.9 CBR	M113 APC	24,800	25	N/A	N/A
IV	6/84	0	Heavy clay 1.9 CBR	M48A1 tank	140,000	6	N/A	N/A
IV	6/84	0	Heavy Clay 1.9 CBR	Ribbon bridge transporter	47,400	50	N/A	N/A

GEOMATRICES

Table 4
Summary of Traffic Tests on Paper and Aluminum Grids

Materials	Grid Size	Grid Depth	Weight (Wt./Area)	Panel Size: Unexpanded	Panel Size: Expanded	Cost	With/Without Membrane	Number of Passes	Rut Depth in.	Comments
None	—	—	—	—	—	—	W/O	0*	>12	Truck became immobilized after going about 20 ft in loose sand
None	—	—	—	—	—	—	W/O	10	7-8	Truck undercarriage touched sand subgrade after 50 passes
								50	11-12	
Paper honeycomb	6 in.	6 in	57 lb (0.29 lb/sq ft)	2-15/16 in. x10 ft, 8 in	24x8 ft.	$0.61/sq ft	W/O	10	7.4	Paper grid after 200 passes had lost all usefulness in confining the sand
							W	10	6.8	
							W/O	200	9.0	
							W	200	10.8	
Aluminum honeycomb	6 in	4 in	55 lb (0.34 lb/sq ft)	1-5/16 in. x10 ft, 1-1/2 in	20x8 ft	$1.38/sq ft	W/O	10	5.8	Grid with membrane had failed after 500 passes and was no longer effective in confining the sand. Grid without membrane had failed after 1000 passes and was no longer effective in confining the sand
							W	10	4.4	
							W/O	500	7.4	
							W	500	7.3	
							W/O	1000	6.7	
Aluminum honeycomb	6 in	6 in	86 lb (0.53) lb/sq ft	1-3/8 in. x10 ft, 1 in	20x8 ft	$2.06/sq ft	W/O	10	4.1	Slight benefit from membrane
							W	10	3.8	
							W/O	1000	7.7	
							W	1000	7.2	
Aluminum honeycomb	6 in	8 in	127 lb (0.79 lb/sq ft)	1-1.2 in x10 ft, 2-5/8 in	20x8 ft	$2.75/sq ft	W/O	10	3.6	Slight benefit from membrane
							W	10	3.7	
							W/O	1000	4.9	
							W	1000	4.6	
Neoprene Kevlar membrane**	–	–	67 lb (1.7 oz/sq ft)	–	15x40 ft	$2.58/sq ft	—	—	—	

* Test vehicle was an M54 5-ton cargo truck with 40,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown on this summary were made with an M54 5-ton cargo truck with 20,000-lb gross weight and tires inflated to 35 psi.

** Material thickness, 0.013 in.

Table 5
Summary of Traffic Tests on Borden and IKG Fiberglass Panels

Materials	Grid Size	Grid Depth	Weight (Wt./Area)	Panel Size	Cost	With/ Without Membrane	Number of Passes*	Rut Depth in.	Comments
None	—	—	—	—	—	W/O	0	12	Truck became immobilized after going about 20 ft in loose sand
None	—	—	—	—	—	W/O	10 50	7-8 11-12	Truck undercarriage touched sand subgrade after 50 passes
IKG fiberglass	7/8x5-5/8 in.	1 in	97 lb (2.5 lb/ sq ft)	3x13 ft	$8.35/ sq ft	W/O W W/O W	10 10 1000 1000	2.8 2.3 4.5 3.4	After 700 passes, material worked out of sand; anchor weight added; at 1000 passes rut depth as shown at left
Borden fiberglass	1x4 in	1 in	130 lb (2.7 lb/sq ft)	4x12 ft	$6.71/ sq ft	W/O W W/O	10 10 1000 1000	2.2 2.0 2.0	Material worked out of sand after 200 passes; anchor weights added; and after 1000 additional passes, material worked out of sand
Neoprene Kevlar membrane**	—	—	67 lb (1.8 oz/sq ft)	15x40 ft	$2.58/ sq ft	—	—	—	—

* Test vehicle was an M54 5-ton cargo truck with 40,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown on this summary were made with an M54 5-ton cargo truck with 20,000-lb gross weight and tires inflated to 35 psi.
** Material thickness, 0.013 in.

Table 6

Mat Type*	Prepared Subgrade Material	CBR**	Test Vehicle†	Lay Pattern	No. of Passes††	Max. Deformation in Item, in. Perpen-dicular to Traffic	Max. Deformation in Item, in. Parallel to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
Traffic Tests on Landing Mat (Appendix B)									
M19 (Item 1)	Buckshot clay (24-in thickness)	0.5	M54	Brickwork	0-32	—	—	0.5	Little movement; some subgrade material forced through joints
			M54		33-70	—	—	0.75	No visible damage
			M54		71-150	—	—	—	No visible damage
			M54		151-2700	1.7	1.7	4.0	No visible damage
			M48A1		2701-2702	—	—	6.0	Mat sprang up 3 in
			M48A1		2703-2756	7.8	4.0	20.0	Connectors broke on 6 panels; other panels reusable. Tank dragging undercarriage (~15 in.)
M8A1 (Item 2)	Buckshot clay (24 in thickness)	.5	M54	One panel wide	0-32	—	—	6.0	Bow wave forced subgrade material through joints and to side
			M54		33-70	—	—	20.0	
			M54		71-150	17.6	16.6	—	Truck immobilized—slipped off mat. Traffic discontinued. Mat was undamaged and reusable.
Evaluation for Bridge Access/Egress Surfacing (Appendix C)									
M8A1 (Item1)	Buckshot clay (24 in thickness)	1.2	M54	One panel wide (no runners)	0-200	2.0	1.5	3.0	
			M54		201-1000	—	—	8.0	
			M54		1001-1800	3.0	3.0	14.0	Mat ends off subgrade 4 in., 0.75 in. permanent set
			M48A1		1801-1830	—	—	—	Mat ends off subgrade 4 in.
			M48A1		1831-2000	3.5	3.0	—	Mat ends off subgrade 5 in., 1.25-in. permanent set

(Continued)

* Item refers to description of test subgrade and surfacing system in appropriate appendix.

** The second CBR value shown during a traffic sequence reflects the measured change in subgrade strength due to test conditions.

† The test vehicle for a sequence of passes was an M54 cargo truck (40,000 lb gross) or an M51 dump truck (40,000 lb gross) and an M48A1 tank (106,000 lb gross).

†† The sequence of traffic was 2700 truck and 300 tank passes for the initial tests described in Appendix B, Tactical Bridge/Access Preliminary Investigation, WES, September, 1980; the sequence of traffic for all other tests summarized in this table was as follows: truck 1-1800, 2001-2450, and 2501-2950 passes, tank 1801-2000, 2451-2500, and 2951-3000 passes.

Table 6 (Continued)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Max. Deformation in Item, in. Perpen-dicular to Traffic	Max. Deformation in Item, in. Parallel to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
M8A1 (Item 1) (Cont'd)	Buckshot clay (24-in. thickness)	1.4	M54	One panel (no runners) (Cont'd)	2001-2450	—	—	—	Mat ends off subgrade 2-1/2 in.
			M48A1		2451-2500	—	—	—	Mat ends off subgrade 4 in.
	(Cont'd)		M54 & M48A1		2501-3000	3.5	4.0	—	End connector hooks broken off 3 panels, 3 others cracked, but panels were reusable; 1.25 in. permanent set
M8A1 (Item 2)	Buckshot clay (24 in. thickness)	1.2	M54	One panel wide placed on M8A1 runners	0-20	—	—	—	Little permanent set
			M54		21-200	2.0	1.5	1.0	Mat seated 1 in. and increased only slightly to 1800 passes
			M54	10 ft apart unwelded	201-1800	2.5	2.0	—	
		1.4	M48A1		1801-2000	2.0	2.0	—	Mat sprang off embedded runners 2 in.
			M54 & M48A1		2001-3000	2.5	3.0	—	Mat sprang 2 in. off runners; two 1/4 -in. breaks at base of connector hooks. Mats were reusable
M8A1 (Item 3)	Buckshot clay (24-in. thickness)	1.2	M54	One panel wide welded to M8A1 runners	0-200	1.5	1.5	—	More than half the mat embed-ment occurred in 200 passes
			M54		201-1800	1.5	2.0	—	Runners rebounded 2 in. above subgrade
			M48A1		1801-2000	2.0	2.0	—	
		1.4	M54 & M48A1		2001-3000	2.5	2.5	—	Two panels had one weld each broken. Panels were in good condition for reuse
Traffic Tests Landing Mat (Appendix D)									
M19 (Item 1)	Buckshot clay (24 in. thickness)	1.2	M54	Brickwork, male-female joints perpendicular to	0-200	—	—	—	Standard lay pattern rotated 90°
			M54	direction of traffic and continuous across width of item	201-1800	1.00	0.75	—	A 3-in. transverse slope and traffic caused lateral movement of 4.5 in.
			M48A1		1801-2000	1.25	1.0	1.5	Lateral movement corrected prior to tank traffic. No lateral movement due to embedment. Subgrade material was extruded through mat joints. No damage to mat.
		1.3	M54 & M48A1		2001-3000	1.75	1.0	1.75	

(Continued)

Table 6 (Continued)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Max. Deformation in Item, in. Perpendicular to Traffic	Max. Deformation in Item, in. Parallel to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
Traffic Tests Landing Mat (Appendix D) (Cont'd)									
M19 (Item 2)	Buckshot clay (24 in. thickness)	1.2	M54	Brickwork, overlap-underlap joints perpendicular to direction of traffic and continuous across width of item	0-200	—	—	—	1.0 in. of lateral movement
			M54		201-1800	1.0	1.0	—	3.0 in. of lateral movement
			M48A1		1801-2000	1.75	1.0	1.5	Lateral movement corrected prior to tank traffic. Subgrade material was extruded through mat joints
		1.3	M54 & M48A1		2001-3000	1.75	1.25	—	
M19 (Item 3)	Buckshot clay (24 in. thickness)	1.2	M54	Brickwork, male-female joints parallel to direction of traffic and continuous along length of item	0-200	—	—	—	Less downward mat movement than in items 1 and 2. No lateral movement
			M54		201-1800	0.75	0.75	—	Subgrade material was extruded through mat joints
			M48A1		1801-2000	1.25	1.0	—	
		1.3	M54 & M48A1		2001-3000	1.50	1.25	—	
None	Buckshot clay (24-in. thickness)	1.3	M48A1	Unsurfaced test section	0-1	3.0	3.0	NA	Tank produced 3-in. ruts in 2 passes
					2-9	11.0	11.0	NA	Undercarriage of tank touching subgrade (~15 in.)
					10-50	—	—	NA	Undercarriage dragging enough to stop test. Distance from top of subgrade to bottom of rut about 30 in.
Traffic Tests Landing Mats With and Without T17 Membrane Underlay (Appendix E)									
M8A1 (Item 1)	Buckshot clay (24 in. thickness)	1.2	M51	Brickwork, 1 and 1/2 panels wide, adjacent sides connected by bayonets & slots, ends joined by connector bars & bending, coverplate tabs down (No underlayment)	0-200	2.0	2.75	—	Subgrade extruded through mat joint
			M51		201-1800	2.7	3.0	—	Mat sprang off subgrade 3 to 4-1/2 in. in 1800 passes
			M48A1		1801-2000	3.5	3.0	—	Mat sprang 7-1/2 in. off subgrade
		1.6	M51 & M48A1		2001-3000	3.75	3.5	—	10 of 24 panels had breaks (summary of damage on Incl 18 of Appendix E) Panels unsuitable for reuse

(Continued)

Table 6 (Continued)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Max. Deformation in Item, in. Perpendicular to Traffic	Max. Deformation in Item, in. Parallel to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
Traffic Tests on M8A1 and M19 Landing Mats with and Without T17 Underlay (Appendix E) (Continued)									
M8A1 (Item 2)	Buckshot clay (24 in. thickness)	1.2	M51	Brickwork, same lay pattern as item 1 but used T17 membrane underlay	0-200	1.5	2.2	—	Mat sprang 2 in off subgrade.
			M51		201-1800	2.25	1.75	—	Mat sprang 3 in. off subgrade
			M48A1		1801-2000	2.75	2.00	—	Mat sprang 6-1/2 in. off subgrade
		1.5	M51 & M48A1		2001-3000	2.60	2.00	—	Mat still serviceable; 13 of 24 panels contained breaks, permanent set would hinder reuse; one punctured hole was observed in T17 membrane
Traffic Tests on M8A1 and M19 Landing Mats with and Without T17 Membrane Underlay (Appendix E)									
M19 (Item 3)	Buckshot clay (24 in. thickness)	1.2	M51	Brickwork, male-female joints parallel to direction of traffic and continuous along length of item, with T17 underlay	0-200	0.75	0.80	—	Small hinge movement at connectors
			M51		201-1800	1.5	1.25	—	
			M48A1		1801-2000	1.6	1.5	—	No significant change in mat
		1.5	M51 & M48A1		2001-3000	1.6	1.6	—	Mat in good condition; no holes in T17 membrane. No subgrade extracted through mat joints
M19 (Item 4)	Buckshot clay (24 in. thickness)	1.2	M51	Brickwork, male-female joints parallel to direction of traffic and continuous along length of item, without T17 underlay	0-200	0.5	0.75	—	Small hinge movement at connectors
			M54		201-1800	0.75	1.00	—	
			M48A1		1801-2000	1.00	1.25	—	No significant change in mat
		1.5	M51 & M48A1		2001-3000	1.20	1.50	—	Mat in good condition. No subgrade extruded through joints on 1.2 CBR subgrade without T17
Unsurfaced subgrade	Buckshot clay (24 in thickness)	1.5	M51	NA	1	14.5	—	—	Test conducted on items 1 and 2 above with surfacing removed. After 10 passes, rear springs were dragging and test was discontinued.
					10	19.0	—	—	
Membrane surfaced subgrade	Buckshot clay (24 in. thickness)	1.5	M51	NA	1	6.25	—	—	Test conducted on items 3 and 4 above with T17 membrane only for surfacing
					10	14.25	—	—	After 10 passes, rear springs on truck dragging and test was discontinued

Table 7
Summary of Traffic Test on 25 Percent Slope

		Dry		Wet		Wet Clay*		
Mat Type	Vehicle	Passes	Maximum Mat Moved, in.	Passes	Maximum Mat Moved, in.	Passes	Maximum Mat Moved, in.	Remarks
Unsurfaced soil (no mat)	M113	25	—(1)**	2	—	—	—	(1) Rut depth of 4-1/2 in. after traffic of three vehicles
	M54	25	—	0	—	—	—	
	M48A1	25	—	1	—	—	—	
M19 anchored	M113	25	1/8	25	3/8	25	1/8	
	M54	25	6-3/4	25	1-1/2	0	0	
	M48A1	25	6-3/4	25	6-1/4	5(2)	1-1/4	(2) Plus three attempts
M19 unanchored	M113	25	3-7/8	25	7-1/4	—	—	
	M54	25	19-5/8	25	4	—	—	
	M48A1	25	16-1/4	25	8-1/8	—	—	
M8A1 anchored	M113	25	3/8	25	1/2	—	—	
	M54	25	3/4	25	1-3/8	—	—	
	M48A1	25	1/2	25	1-1/8	—	—	
M8A1 unanchored	M113	25	3/8	25	1/4	25(3)	5/8	(3) Slid off of mat edge on last pass
	M54	25	1/4	25	1	0(4)	1/8	(4) Attempted three passes
	M48A1	25	1/2	25	5/8	3(5)	—(6)	(5) Plus three attempts
								(6) Slight
M8A1, inverted anchored	M113	—	—	—	—	25	5-1/2(7)	Failed first attempt. Successful after tank traffic
	M54	—	—	—	—	0	—	
	M48A1	—	—	—	—	25	12-1/4(7)	(7) Clay superwet
T17 membrane anchored	M113	25	1-1/2	25	3(8)	4(11)	—	(8) Caused 5-1/4 and 2-1/4 in. tears
	M54	25	3	25	3/8(9)	0	2-1/2	(9) Caused 1 and 1-1/2 in. tears
	M48A1	25	5	25	3-3/4(10)	0	—(12)	(10) No change
								(11) Ten attempts with 20-ft. start made four passes, membrane severly damaged
								(12) Membrane torn across entire width

* Tests requred vehicles to track through wet clay at toe of slope.
** Numbers in parentheses refer to similarly numbered comments under the Remarks heading.

Table 8

Summary of Tests - M8A1 on 25 Percent slope

Test	Attempts	Passes	Mat Surface Up/ Down	Mat End in Water 1st	Distance from Water's Edge to 1st Mat,* ft	Slope Condition	Remarks
1	5	0	Up	Hook	NA**	Dry	11 runs in water, 5 runs on slope
2	2	1	Down	Rolled	NA	Dry	10 runs in water, 6 runs on slope
	5	2	Down	Rolled	NA	Dry	13 runs in water, 3 runs on slope
	31	26	Down	Rolled	NA	Dry	After 3 passes, all mats in water, and after 8 passes, all mats 18 in. in water
3	15	15	Down	Rolled	1.5	Wet	16 runs in water
	19	18	Down	Rolled	1.5	Wet	Anchor failed. Bank 5 runs disconnected from 11 runs. Half panel loose in 5 runs. Replaced with 2 runs in water.
	28	25	Down	Rolled	2.0	Wet	
4	5	0	Up	Rolled	4.0	Wet	5 runs
5	5	0	Down	Hook	2.5	Wet	5 runs only. 2 slow and 3 fast attempts
6	4	0	Down	Hook	4.0	Wet	Slow and fast speed
7	10	8	Down	Hook	4.0	Wet	2 runs only. After 2 passes, mat 6 ft. in water
8	11	9	Up	Rolled	4.0	Dry	2 runs only. Poor control of vehicle

Note:In the last test, the slope in and near the water had probably decreased because of traffic.

* Other mats were farther out in the water.

** Not available

Table 9
Summary of Tests - M8A1 on 25 Percent slope

Test	Cumulative Attempts	Cumulative Passes	Type Surfacing	Mat Surface Up/Down	Mat End in Water, 1st	Distance from Water's Edge to 1st Mat,** ft	Slope Condition	Remarks
1	1	1	T17	NA	NA	NA	Dry	Membrane anchorage inadequate; excess membrane fold needed to allow membrane to conform to ruts; membrane and sandbag ropes became entangled in left track, pulling membrane from slope
2	1	0	T17	NA	NA	NA	Dry	Membrane anchored better with 4 ft. fold at water's edge; M113 could not pull out of lake. Small tear noted near waterline
	2	0	T17	NA	NA	NA	Dry	Membrane shredded in numerous places, immobilizing the M113 by damaging the bearings and shaft inside the left sprocket. The vehicle apparently cannot climb the membrane after it is wet from being pushed into the lake bottom
1	5	0	M8A1	Up	Hook	NA	Dry	Eleven runs of mat in water, five runs on slope. Insufficient traction for M113 to move up slope
2	2	1	M8A1	Down	Rolled	NA	Dry	Ten runs in water, six runs on slope; unanchored. M113 slowly exited up slope
	5	2		Down	Rolled	NA	Dry	Thirteen runs in water, three runs on slope; anchored. Halted when mat slipped completely into the water
	31	26		Down	Rolled	NA	Dry	After one pass, all mats pulled into water. After eight passes all mats pulled 18 in. underwater. Success of attempts seemed to be operator-dependent
3	15	15	M8A1	Down	Rolled	1.5	Wet	Anchor failed. Bank five runs of mat disconnected from 11 runs in lake. M8A1 was heavily damaged after 15 passes
	19	18		Down	Rolled	1.5	Wet	
	28	25		Down	Rolled	2.0	Wet	Anchor failed again before completing 25 passes
4	5	0	M8A1	Up	Rolled	4.0	Wet	Five runs only
5	5	0	M8A1	Down	Hook	2.5	Wet	Five runs only. Two slow and three fast attempts
6	4	0	M8A1	Down	Hook	4.0	Wet	Slow and fast attempts
7	10	8	M8A1	Down	Hook	4.0	Wet	Two runs only. After two passes, mat 6 ft in water
8	11	9	M8A1	Up	Rolled	4.0	Dry	Two runs only. Poor control of vehicle. M8A1 mat provides only marginal assistance in egress

* All tests at Brown Lake were conducted with the M113 armored personnel carrier loaded to 22,865 lb gross. In the last test, the slope in and near the water had probably decreased because of the traffic.

** Other mats were farther out in the water.

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