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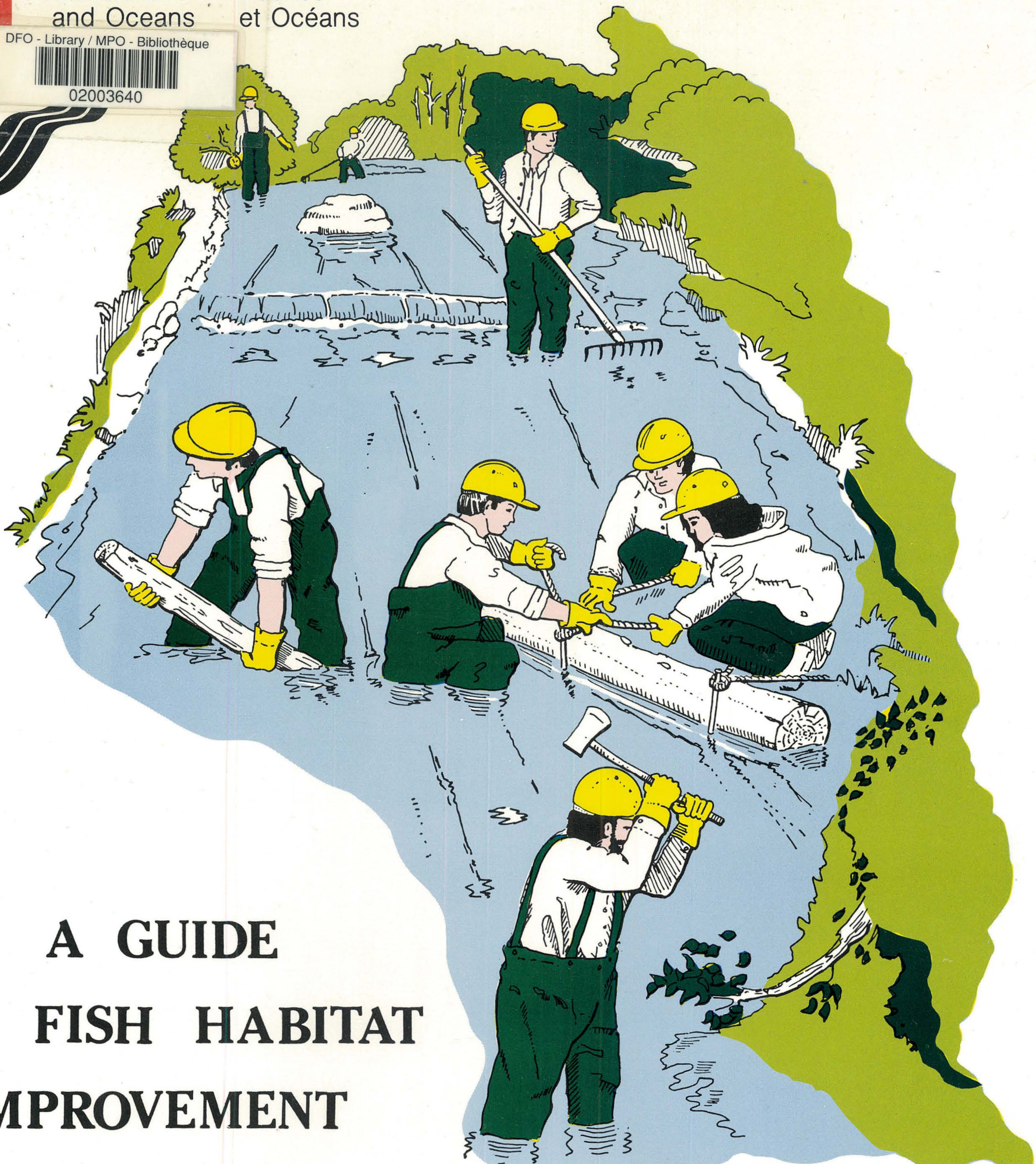

A GUIDE FOR FISH HABITAT IMPROVEMENT

NEW-BRUNSWICK

Canada

A GUIDE FOR FISH HABITAT IMPROVEMENT

December, 1988

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From the editor . . .

December, 1988

To the users of this manual,

Having prepared this revised edition of '*A Guide for Fish Habitat Improvement*', I wish to extend my personal thanks to all those who contributed to both the past and the present editions. I have tried to incorporate as many of the comments and suggestions received. This included modifying the presentation format somewhat. I believe the result is an accurate, informative and easily understood guideline for you to safely follow and achieve success with your projects.

I extend my congratulations to those planning fish habitat improvement projects. Any contribution you can make to improve the aquatic environment and enhance our fish stocks is an important one!

A. Vromans
DFO, Moncton, NB

About the manual...

Would you like to see a return of the quality fishing experienced in New Brunswick in the past? Would you like to be involved - to volunteer your time to help increase fish stocks? Well, this is a manual about what **you** can do, in co-operation with the Department of Fisheries and Oceans and the New Brunswick Department of Natural Resources and Energy, to help save New Brunswick's valuable fisheries resource. It is a manual to encourage and develop community involvement in the improvement of our valuable fish habitats. All it requires on your part is a commitment of time and effort to a fish habitat improvement project. We, in turn, promise continued guidance and technical support for the duration of your project.

Fish habitat improvement is an integral part of enhancing the salmonid populations in our streams. It is one of the most important salmonid enhancement techniques available. Without good fish habitat, salmonid populations cannot be rehabilitated through other enhancement techniques such as hatchery stocking and streamside incubation.

What you have received is a comprehensive series of Fact Sheets for the improvement of fish habitat in New Brunswick. We believe that before you start work on your project you must know your stream intimately. This is what Sections 1 to 4 of this manual are all about. Once you have analyzed your chosen stream, and are ready to start work, refer to Fact Sheets A and B detailing stream stabilization and erosion control techniques. When you are ready to employ more advanced habitat improvement techniques, refer to the remaining Fact Sheets.

The techniques detailed in this manual are believed to be the most effective for improving fish habitat in New Brunswick and are based on previous experience. You will be able to expand your habitat improvement efforts as your knowledge and confidence increase. Additional Fact Sheets on new techniques will be forwarded to you as they become available or are required.

Your efforts will not work overnight. Many of the techniques may take a number of years to become established. **Do not be discouraged.** A resource that has been deteriorating for years cannot be restored in an instant.

Good luck.

For more information on getting your project started, contact:

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For all others who provided their critical review of this manual, we thank you for your part in this publication.

Printing of this manual was funded by the Canada-New Brunswick Subsidiary Agreement on Fisheries Development under the Economic and Regional Development Agreement (ERDA), Fish Habitat Improvement Project.

Things you should know...

Section 1 of this manual is deals with the first step of our plan - getting to know your stream. Section 2 includes basic information about fish, their life cycle and habitat requirements. Section 3 provides information on what happens physically in a drainage basin. This is intended as an introduction only. If you wish to learn more, we have included a list of suggested readings in Appendix 'b'. You will find the instructions about how to carry out a stream survey and obtain a permit to work in or near the water in Appendix 'e' and in Section 4, respectively.

It's up to you. We are entrusting you with the improvement of your stream and will help you every step of the way. If we work together, we can enjoy New Brunswick's fish habitat and the fish it produces for years to come.

SECTION 1: Getting to Know Your Stream

In New Brunswick, we are blessed with many natural resources - thick forests, fertile soil, rich mineral supplies and abundant fish stocks. These resources fuel our province's economy, creating jobs and providing us with valuable trading commodities.

The oldest and most valuable of New Brunswick's natural resources is the fishery. For hundreds of years the fruits of our lakes, streams, rivers and oceans have been harvested by the native people, the fishing fleets of the French and British empires and the colonists. Since then, fishing has become more than an economic asset to New Brunswick - it has become a way of life for countless native, commercial and sport fishers.

We often tend to think that our fisheries resource will last forever. True, it is a renewable resource but it cannot continue to replenish itself if not properly cared for. Unfortunately, we have been abusing rather than protecting this precious resource.

The fisheries resource, like many natural resources, is extremely fragile. Fish are sensitive to changes in the environment and like most other creatures they have very specific requirements for survival. At the top of the list is, of course, clean water. However, it goes beyond that - temperature, oxygen, cover, food and good spawning areas are also critical. These habitat conditions must be virtually optimal to support a healthy fish population.

As an angler, conservationist or concerned member of the general public, you probably have a firm grasp of what makes good fish habitat. You picture a pristine stream flowing through a wooded area and you hear the sound of water rushing and bubbling over the rocky stream bed. You can probably remember the shock that you felt one spring when you returned to your favourite fishing hole only to find it clogged with silt - another perfect fishing pool ruined. Today, **you** can help regain your fish habitat. All it requires is a commitment from yourself and others who feel the way you do. But read on...

Let's look beyond that particular pool for a moment and take a plane ride over your river. We want to show you that all streams are part of a bigger system. It is very important, but easy to forget, that all activities that occur in a drainage basin are interrelated. Damage done to one section of stream will not remain isolated in that area. The effects spread throughout the entire system both upstream and downstream of the damaged area.

In New Brunswick you will find many hazards to fish habitat, some of a physical and others of a chemical nature. The list is long, ranging from erosion, dredging, damming and siltation to the release of sewage into our streams, contamination by pesticides and acid rain. The majority of these are from human activities such as forestry, mining, agriculture and urban development. They can and do cause serious damage to fish habitats.

You can take action to reverse the effects of erosion, the number one hazard to fish habitat in New Brunswick. Erosion, the wearing away of the earth's surface, has numerous causes, man-made and natural, from farming to forestry to flooding. Whatever the cause of erosion near streams, the effect is the same - streambeds become clogged with silt, covering spawning substrates and suffocating eggs, alevins and aquatic insects. The water becomes turbid, making it difficult for fish to find food, irritating their delicate gill membranes and preventing life-giving sunlight from penetrating the water.

The problem of siltation in New Brunswick's rivers is becoming worse each year. It is difficult to find an unaffected stream in the province. The problem is global - no stream or river can escape the long-term effects of siltation, least of all if the situation goes unchecked. This loss of habitat has had disastrous impact. For you, the result is the same year after year. There are fewer 'good spots' to fish.

What can we do to stop this dangerous cycle? First and foremost, we must look beyond the symptoms to the root of the problem. Our fish habitat, from spawning grounds to nursery areas, from riffles to pools, is obviously being destroyed by silt. Although removing the silt from spawning areas or adding gravel will provide immediate relief it is not going to create and maintain viable spawning beds for the long term. Nor will digging more pools offer a long term solution to the lack of deep-water cover for fish. The key is to eliminate the source of the silt.

We know you have the best intentions to improve your fish habitat so that someday you can return to your favourite fishing hole to catch that 'big one'. We want to help you. You have the intimate knowledge of your stream and the manpower to carry out a stream improvement project. We, on the other hand, have technical expertise and experience. In other words, together we have the perfect combination of strengths and abilities to form a powerful partnership to protect our valuable fish habitat from further destruction. That is what this guide is all about.

We have a plan and we think it's a good one. We want to avoid wasting time, money and effort on false solutions. The best way to accomplish this is to plan your stream restoration project carefully.

First, it is fundamental to remember that each problem you encounter on a stream will be unique and must be treated as such. You cannot apply a blanket solution and expect it to work in all cases. The differences between silt problem sites may not be easily detected at first glance and that is why it is essential to examine your stream very thoroughly before beginning work. This manual includes a survey we would like you to complete. It is designed to direct your assessment efforts and to give us an idea of exactly where the problem lies. From here, we can work together to develop and implement solutions.

Assess your stream by responding to the questions outlined in the **Project Proposal Form**. Using this information, you may apply for the required **Watercourse Alteration Permit.** The Fish Habitat Improvement Centre (FHIC) will be available to assist with the completion of the Project Proposal Form and to apply for the required permits if you so desire. Application for the Watercourse Alteration Permit is made to the New Brunswick Department of Municipal Affairs and Environment. If your application for watercourse alteration is accepted, you may proceed with your project. Consult with DFO experts about details of the fish habitat improvement techniques you wish to employ if you require more information than this manual provides. By the time you are ready to work **in** the water, you should have a well-organized group of volunteers behind you.

In many cases where fish and fish habitat are affected by environmental and ecological problems the simplest, most natural solutions are better than mechanical or structural ones. For example, it is more effective to plant vegetation on an eroding streambank than to install a stone or wooden support wall. Why? Well, it's much cheaper and requires no engineering skill. Furthermore, it lasts longer. A structure is more likely to be poorly installed and damaged or destroyed by the force of running water. Flexible trees, shrubs and grasses, on the other hand, will spring back from the pressure of the water. Vegetation has spin-off benefits as well. Besides binding the soil with its roots, it provides cover for fish, is a source of nutrients to the stream ecosystem, shades the water to prevent excessive heating and is home to many insects which fish eat. Finally, it maintains the natural appearance of the streamside environment enhancing the area not only for anglers but for bird watchers and other outdoor and wildlife enthusiasts.

Once you are satisfied that the erosion problems are under control, you can start looking for other habitat problems. Some may require you to build in-stream structures. If properly installed, these structures can actually create pool and riffle areas, clean gravel or trap silt. Part B of this manual contains the details of these techniques. It is most important to eliminate the silt problem, however, before moving on to more advanced projects.

The final step, once the stream has been improved, is to see you enjoy the results of your hard work. If the natural fish population is too small to restore a healthy run on its own, you may want to help it out. A number of salmonid enhancement techniques are possible for this purpose: (i) - stocking various stages of disease-free juvenile salmonids of a suitable genetic strain from a hatchery; (ii) - use of streamside incubation boxes; (iii) - transplantation of adult spawners of a suitable genetic strain; etc. When you reach this stage in your project, DFO will provide expert advice on the best way to proceed as well as Fact Sheets on these enhancement techniques.

Commitment and enthusiasm on your part are vital to the success of this program. However, we all know that too much enthusiasm can be disastrous. Jumping the gun and trying to get too much done too fast can only lead to frustration and unsatisfactory results. For this reason we suggest you plan realistic goals. Start your improvement work with the basics - stream cleanup, obstruction removal and bank stabilization. If you have completed these tasks and wish to perform more involved techniques then make those plans at that time. By planning your project in a step by step fashion we hope to end up with a more thorough, lasting result.

SECTION 2: Getting to Know Your Fish

Before proceeding with any fish habitat improvement project, it is necessary to assess the condition and character of your stream and determine the problems. By applying your observations to your knowledge of the fish and their requirements, you can develop effective solutions. In this section, we will look at the species of fish in New Brunswick's waters and what they need to survive.

New Brunswick's Aquatic Life

Perhaps the most prolific fish in New Brunswick's waterways are the highly-esteemed salmonids. The salmonids, or family Salmonidae, include several species of trout and char, as well as the Atlantic salmon. Some, such as brook and lake trout are indigenous, or native, to New Brunswick. Others were introduced to our waters early in the century. Brown trout were transplanted from Europe while rainbow, or steelhead trout, were brought here from the western coast of North America. The prized Atlantic Salmon is native to the North Atlantic.

Some salmonids can be anadromous which means they are born and reared in fresh water. They then migrate to the ocean to grow and mature prior to returning to fresh water to reproduce. Others, however, spend their entire life in fresh water (landlocked salmon are known as 'oananiche').

The salmonids' firm, pinkish flesh is delicious to eat. Their intelligence and 'fight' make them a superb game fish. If you have ever played an Atlantic salmon you are familiar with the thrill of hooking one of these magnificent fish!

While the salmonids are undoubtedly 'preferred' over other freshwater species, every creature living in an aquatic environment has an essential role to play. Thus, when considering any kind of fish habitat improvement, you must view the system as a whole consisting of millions of interdependent organisms. The removal or disturbance of just one species can create a dangerous imbalance in the system. Exercise care when working in or near the water.

New Brunswick's lakes, streams and rivers support a diverse range of plant and animal life. Salmonids share their home with other anadromous fish such as smelt and gaspereau as well as with non-migrating species such as dace, chub and slimy sculpins. Gaspereau and smelt, though not highly prized by anglers, are important commercial fish. Their young contribute to the diet of some salmonids.

A variety of other species essential to the food chain share the aquatic environment. Algae and plankton are the primary producers providing food for aquatic insects such as mayflies, caddisflies, stoneflies and mosquito and blackfly larvae. These insects, in turn, are eaten by fish. Many fish then become food for predators such as otters, bears, kingfishers and even larger fish.

It's a Salmonid's Life

Trout and Atlantic salmon have long been admired for the feats they perform to reach their spawning grounds. They have been known to overcome tremendous obstacles, such as waterfalls and dams, driven by the instinct to reproduce. Some non-salmonid fish such as smelt and gaspereau, on the other hand, cannot overcome these physical obstacles. They rely on obstacle-free streams to access their spawning habitat. One poorly installed culvert can prevent thousands of these fish from spawning successfully, spelling disaster for the population.

Anadromous fish, as explained earlier, spawn and rear in fresh water, migrate to salt water to mature, then return to their birthplace to repeat the cycle (Figure 2.1). The length of time they spend at each stage of their life cycle, and the time of year they spawn, depends on the species and other factors. Each species is slightly different.

Despite these differences, the life cycles of all anadromous salmonids follow the same essential pattern. At each stage in their life cycle they have particular needs. These include clean, cool water, plenty of food and oxygen, good spawning and rearing areas and watercourses free from obstruction. If these needs are not met, the fish cannot survive.

It is important to recognize that although trout and Atlantic salmon share similar habitats, they each have specific preferences. For instance, Atlantic salmon use the more open, riffle areas of a stream. Brook trout are more commonly found in slower moving water and areas having overhead cover such as instream vegetation and undercut banks. When making stream improvements there may be a danger of converting salmon habitat to more suitable trout habitat, or vice versa. This may be through the installation of too many cover devices (not highly desired by salmon) or by the removal of too much cover (to the detriment of trout). It is for this reason that it is important to know which fish species presently use the stream and what the fish stock enhancement goals are for that area.

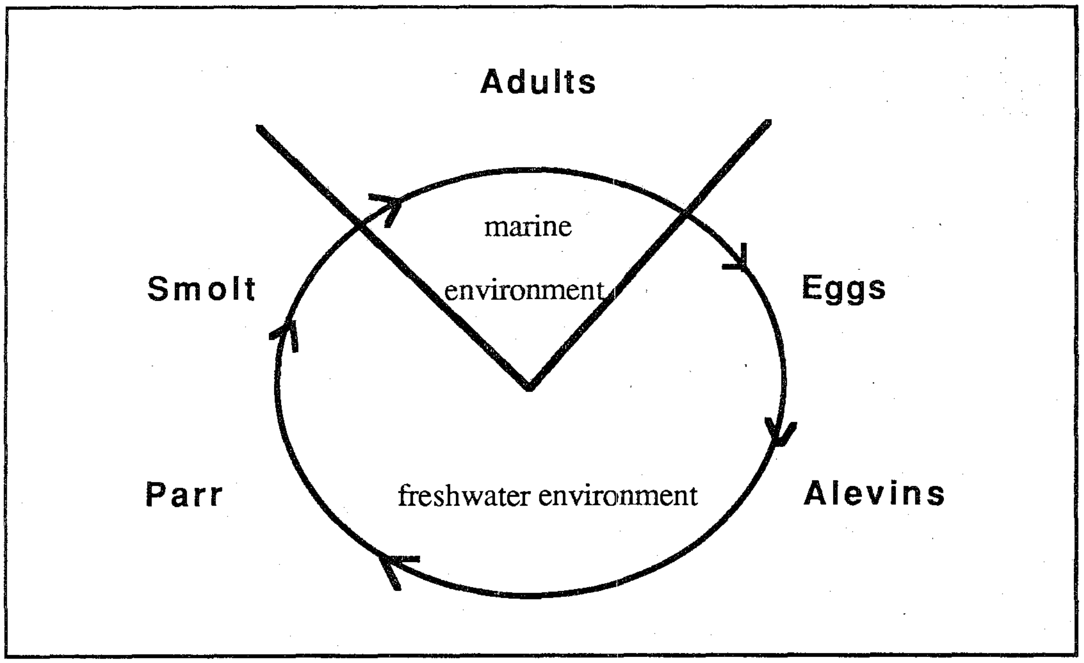

Figure 2.1. Diagramatic representation of an Atlantic salmon's life cycle. All anadromous salmonids have similar cycles. (Not all salmonids have a stage in their life cycle named 'smolt'. However, all anadromous salmonids go through a physiological process similar to smoltification before entering the marine environment.)

When adult salmonids are ready to spawn they usually choose beds of coarse, clean gravel. The relative size of the gravel is closely related to the size of the fish. The female displaces the gravel with her tail to create one or more nests, or redds, for her eggs. The creation of a number of redds is a biological protection mechanism so that if one should be destroyed all the eggs are not lost. Depending on the species, a female may deposit between 1,500 to 4,000 eggs among her redds. As the female deposits the eggs, the male lies next to her and simultaneously releases the milt to fertilize the eggs. If there are not enough suitable spawning areas, serious problems may result, such as the disturbance or suffocation of eggs already laid. Some fish may not be able to spawn at all. In any case, reduction of spawning areas reduces the number of fish developed.

The strongest adults may survive to spawn for three or four spawning seasons. Successive spawning seasons for an individual fish may not mean that spawning occurs in consectuive years.

Some years may be skipped. In some instances, the ordeal of the spawning migration severely weakens the fish and death may result soon after spawning. Some fish will return immediately to sea after spawning. Others may remain in freshwater for months (usually overwinter) before migrating back to their marine environment.

The incubating eggs are extremely fragile - environmental conditions anything less than optimal can be deadly. The water temperature must be cool, around 4 to 10 ^{o}C. Overwinter temperatures in redds regularly fall below 4 ^{o}C often remaining as low as 0.5 ^{o}C for extended periods. Warmer temperatures can speed up the incubation process causing the eggs to hatch too early in the season before there is an adequate food supply. Temperatures 20 ^{o}C and higher can be lethal. It is equally essential to their survival that the eggs have enough oxygen. Thus, there must be a free flow of oxygen-rich water over the eggs, possible only if the redd is not clogged with silt. Any physical disturbance to the redd, caused by man or nature, could have disastrous consequences.

The newly-hatched young are known as alevins. The alevins remain in their redd feeding from their attached yolk sacs. At this stage they are very vulnerable to heat, light and, because of their small size, to predation. When the young fish have absorbed their yolk sac they are known as fry and leave the gravel to swim freely.

The urge to feed prompts the fry to seek abundant food supplies in nursery areas. These fish feed mainly by sight so it is essential at this stage, and for the rest of their lives, that the water be clear. Turbid water can have another negative effect. Particles of dirt irritate the gill membranes making breathing difficult. In addition, gill damage due to unclean water can result in gill tissue infection and even death.

Small and defenseless, yet swimming freely, fry are particularly easy prey at this stage. Rubble, undercut banks and streamside vegetation will serve as protection and as food-producing areas. Their diet includes a wide range of invertebrates. Insect larvae, such as those of the blackfly and mayfly, are particularly important. As the fish grow larger, they are able to accommodate larger food items. Diets of larger fry and parr will include terrestrial and aquatic insects and their larvae, some crustaceans and other smaller fishes. Generally, if their mouths will accommodate the size of the food item, they may be expected to consume it.

Anadromous or 'sea run' fish may spend from a month (some non-salmonids) to two years or more, feeding in the river system. Each species has its own biological stop-watch which tells it when it is time to journey down to the ocean. Before an Atlantic salmon is ready to leave the fresh water it undergoes a physiological change, called smoltification, to prepare it for the saltwater environment. It turns from its greenish or brownish colour to a shiny silver which will act as camouflage in the ocean. Other species, such as trout and and smelt, undergo similar though less dramatic changes to prepare them for the marine phase of their life cycle. Refer to the text '*Freshwater Fishes of Canada*' (see Appendix 'b') for more details on life cycles of different species.

The downstream migration is frequently plagued by man-made or natural obstacles such as culverts, waterfalls, and hydro-electric dams. Some fish can surmount these obstacles and others cannot. For example, at hydro-electric dams, fish may pass through the dam facing potential death in the turbines or go over the top resulting in injury or death from the fall. The fish which survive journey to feeding grounds in the ocean.

Food is plentiful in the marine environment. The fish grow quickly on a diet of invertebrates and small fish. However, they must be wary of predators, including man. After a period in the ocean, the mature fish head back to the stream where they were born. Only about one per cent, or less, of the eggs laid will ever make it to this stage due to natural mortality and predation.

The mature fish face a long and difficult journey. They must fight their way against the current and occasionally over dams and waterfalls. Since they often do not feed on their upstream journey, they may exhaust their energy reserves before reaching their destination and become easy prey for bears, otters or man. The few fish who reach the spawning grounds will continue the cycle ensuring the survival of the species.

From the days of colonization, through the industrial revolution to today, man's activities have threatened the survival of fish at every stage of their cycle. To restore fish populations to historic levels, we must learn to identify the causes of population decline and the measures to most effectively reverse the trend. Part of this process, known as 'fish habitat improvement', is aimed at the restoration of damaged habitats and developement of new ones in order to increase the ability of fish habitat to sustain a productive fisheries resource.

SECTION 3: What Happens in a Drainage Basin?

Just as it is important to understand fish and their habitat requirements, it is necessary to have a knowledge of the origin and formation of water systems. This section is intended to be an introduction to some of the basic principles of stream dynamics. If you wish to know more about it, consult the references in Appendix 'b'. Appendix 'd' will also provide added information on stream channel formation.

The quality of fish habitat reflects the quality of the entire drainage basin (drainage basins are often commonly referred to as watersheds - see Glossary). The very character of your favourite fishing hole is determined by the quality of the water upstream (and downstream to some extent), the surrounding vegetation, the type of soil and the use of the land.

Streams and all other waterbodies are fed by precipitation. The majority of the precipitation is absorbed into the soil or groundwater aquifer, evaporates or is taken up by plant roots. Remaining water enters the stream as surface run-off and sub-surface interflow. Luckily, only a small proportion of the yearly rainfall ends up in our lakes, streams and rivers. If all the rainwater flowed directly into the surface water system, it would be too much for the banks to withstand and an erosion problem would result.

The network of water sources in a drainage basin join and form streams of various sizes. The origins of the water system, usually springs, are known as first order streams. They have no tributaries but form second order streams when they meet. When second order streams meet they form third order streams. This pattern continues, each order of stream becoming successively larger, until the largest river of the drainage basin is formed.

The Forces Acting on Water Channels

Have you ever wondered why your favourite fishing stream curves in a particular way or why the pools are spaced at nearly equal intervals? Have you ever noticed that pools and shallows tend to alternate along the course of a fertile fishing stream?

The character of a stream, its pattern and the shape of its bed and banks, are all determined by the way in which water flows. There are two forces that act on water - gravity and friction. Gravity, the force of the earth's attraction, pulls water down any slope. Friction between the water and the stream bed and banks creates resistance to the pressure of gravity. This resistance builds as the water flows over increasingly large obstacles such as rocks or boulders and as the velocity of the water increases.

Velocity, or speed, of the water in a channel is influenced by several factors such as slope, the width and depth of the channel and the degree of resistance. For example, a narrow, shallow stream flowing down a ravine will have a much higher velocity than a wide, deep stream flowing over a flood plain. Slope, width, depth and resistance are in turn determined by the lay of the land, the soil type, the vegetation and the use man is making of the land in the watershed.

The forces of gravity and resistance cause water to carve a channel out of the land. The water, as it is pulled downhill, will pick up and carry away the particles and debris that cannot resist its flow.

The stability of the channel and its suitability as a fish habitat is determined by the configuration of the channel. So we can get an idea of the kind of stream that produces good fish habitat, let's take a look at the different types of streams.

The Configuration of Stream Channels

There are three types of channel configuration - only one provides optimum conditions for fish habitat. The different configurations of streams are described by specialists in stream dynamics as: straight, braided and meandering (see Appendix 'd').

Water tends to flow in a curved path wherever it runs - whether through a swamp, a flood plain or down a mountain. This is because water will take the easiest but not necessarily the shortest path. **Straight streams** are not a natural occurrence . Usually, if a stream is fairly straight it is because man has altered its course for some reason. Straight streams generally do not provide suitable conditions for fish survival. The velocity of the water unimpeded by a winding course tends to erode the banks and create a silting problem. As well, a straight channel lacks the diversity required of a good fish habitat.

A **braided stream** cannot support productive fish habitat either. Braided streams divide into several smaller channels which meet then redivide. This is often caused by unstable banks, shallow water and high sediment content in the water - all things which make these streams unsuitable for fish to live in.

As mentioned above, water naturally follows a winding or meandering course. So it only makes sense that the most stable type of stream is one that meanders. A **meandering stream** generally has an undulating bed caused by the movement of water from one side of the stream to the other. Deep pools tend to alternate with shallow riffle areas providing the cover and spawning areas required by fish. This, coupled with stable banks, makes the meandering stream the ideal fish habitat providing man does nothing to destroy the stream's equilibrium.

It is important to remember that streams are dynamic - they are constantly changing in subtle ways. This, and the fact that the parts of a water system are interdependent, makes streams extremely fragile. You must be very careful when you work in or near a stream because anything you do will have an effect both upstream and down. For example, removing a beaver dam to allow fish through to spawn may seem like a good idea. It may, however, cause serious problems such as flooding and erosion downstream and leaving fry and eggs high and dry upstream. Every habitat situation must be examined as a separate case because the best solution to a problem in one stream may be disastrous in another.

The key to successful fish habitat improvement is to try to maintain or foster the stream in its natural state - stable banks, meandering course and an alternating pattern of pools and riffles. Altering a stream's course or straightening it will only make the situation worse.

We know that your intentions to improve New Brunswick's fish habitat are nothing but the best but even the most well-meaning actions can have serious consequences if not properly carried out. So, before starting work, consult with a trained fisheries biologist and hydrologist. He or she will be able to tell you what kinds of effects your proposed solution will have on the the stream's equilibrium and advise you as to the best course you should take.

SECTION 4: Getting Your Project Underway

A word about planning...

Before you and your group jump into a fish habitat improvement project, take the time to plan your project thoroughly. Remember, even the most well-meaning endeavors can fall flat if they lack preparation. So, sit back for a minute and go over your notes and project checklist - **carefully.**

Make sure:

- your idea or proposal is consistent with the fisheries management plan for the area and that it doesn't conflict with other resource users.

- you have fully analyzed the situation in your stream.

- you have scientific and technical guidance from your federal and/or provincial fisheries biologist(s) or your local Salmonid Enhancement Centre (DFO fishery officers may also be consulted).

- you are using the improvement technique most appropriate for your stream.

- you have a group of volunteers and adequate proper materials for your project.

- everyone in your group knows when and where the project will take place.

- that you have obtained all the **necessary permits** to conduct your project. These include a Watercourse Alteration and Landowner Approval Permit!!

Don't forget that how well you have planned your project is a critical factor in the acceptance of your application!

A word about safety...

Something to keep in mind when working on your project is that you **are** working in or near the water. This means that you must **exercise caution at all times**!

Remember...

- You will be working around water, potentially dangerous in itself, and you may be working with heavy materials and sometimes heavy machinery.

- Follow all safety requirements and keep a well-stocked first aid kit nearby. Always have a vehicle at hand in case a serious accident necessitates a trip to the hospital. Have some of your members take a first aid course just in case.

- Appropriate clothing can protect you from injury. When working with heavy materials and equipment, particularly chainsaws, wear boots, gloves, hard hats and face protectors.

- Individuals with health problems must be careful to avoid over-exerting themselves. Make sure your whole crew is provided with plenty of food and water throughout the day - fatigue can lead to carelessness and carelessness to accidents!

Above all, remember that no project is worth risking life and limb for. Let caution and common sense be your guide, and have a **safe** project!

Proceeding...

The biggest hurdle to overcome to get your project underway is probably the application and approval process. This process may take several weeks. Details on information required for the application and the approval process are outlined on the following pages. The Fish Habitat Improvement Centre (FHIC) is available to assist you with preparing the proposal and submitting applications for the required permits. They will keep you informed of the status of your project in review.

If you have any questions regarding the following pages or the Project Proposal Form, feel free to contact us at:

FISH HABITAT IMPROVEMENT CENTRE
343 ARCHIBALD STREET
P. O. BOX 1268
MONCTON, N.B.
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Note: The Project Proposal Form, Request for Acceptance and the Landowner Approval Form are located in Appendix 'e'.

CONSIDERATIONS FOR PROJECT APPROVAL

To assist you in preparing an acceptable proposal and in understanding the evaluation process, the criteria for evaluating a project proposal are given below.

HABITAT:

1) Is the project addressing a situation where fish habitat is limited?
2) Will the project cause habitat damage in other locations of the waterbody?
3) Will the project increase the amount of fish habitat?
4) Will the project improve fish habitat?
5) Will the project ensure long-term protection to the area?
6) What size is the waterbody in which the work will be carried out?

FISH :

7) Are the fish species to be enhanced native to New Brunswick?
8) Will the project increase the number of fish?
9) Will the project adversely affect any other fish species?
10) Will the project enhance natural reproduction?

PROJECT:

11) Does the project seem technically and/or ecologically sound?

12) How long will the project take to complete?

13) What are the maintenance requirements for the project?

14) What types of expertise will be required for the project?

15) Does the project require immediate attention?

16) What is the benefit/cost ratio of this project?

VOLUNTEERS:

17) How many organizations will be involved in the project?

18) How many people will be involved in the project?

19) Has your organization been involved in other improvement projects?

PUBLIC RELATIONS:

20) Does the local community support the project?

21) How many people will become aware of the improvement work to be done by your organization?

22) How many people will benefit from the project?

SUPPORT:

23) What kind of support does your organization require (monetary, technical, etc.)?

PROJECT APPROVAL PROCESS

1) The association or group must obtain the *Guide for Fish Habitat Improvement*, and complete the application forms (with the help of the FHIC and/or DFO and/or provincial fisheries biologists). (If the project is environmentally sound and it meets with the FHIC's objectives, the FHIC will prepare the forms and apply for the Watercourse Alteration Permit for you.)

2) The project proposal is subjected to a formal review process*.

3) If approval is given, you may be able to receive the help** you need to complete the project. If not accepted, the project proposal is sent back to the association for modifications.

4) When the project is completed, the association must submit a report to DFO, NBDNRE and FHIC. (The FHIC may be able to make the required copies of the report for DFO and NBDNRE if you present a copy to the FHIC.)

* People from the following organizations may be involved in the formal review process:

DFO - Department of Fisheries and Oceans (federal)
DOE - Department of Environment (federal)
NBDNRE - NB Department of Natural Resources and Energy
NBDMAE - NB Department of Municipal Affairs and Environment
NBDOF - NB Department of Fisheries

** Help will be provided 'in kind' only. 'In kind' means equipment, expert help and advice, project monitoring, etc. A number of programs may provide financial assistance in certain special situations. The FHIC will have more information on this subject.

Note: Although DFO and NBDMAE both review the Fish Habitat Improvement Project Proposal Form and the Watercourse Alteration Applicaton Form, approval from one does not guarantee approval from the other. ' No' does not mean that the project proposal cannot be re-submitted. It must be changed, however, to meet the program's objectives.

PROJECT CHECKLIST

This checklist shows the steps you will have to take to organize your project(s). Remember that your project may take several years to complete. Make sure that your group is ready for this type of commitment.

A. RECONNAISSANCE (spring, year #1)

1) identify and document the general problem(s);
2) become familiar with the area where these problem(s) exist;
3) sketch the area, showing the location of the problem(s);
4) take photographs, showing the problem(s) in the area;
5) determine if any local groups or associations would be interested in assisting with the project;

B. ASSESSMENT (spring/summer, year # 1)

1) conduct the survey we have provided you with;

2) obtain a map and possibly an aerial photograph of the area (see Appendix 'a');

3) identify and document the area(s) to be improved;

4) consult with the Department of Fisheries and Oceans (DFO), provincial officials from NB Department of Natural Resources and Energy, or the NB Department of Municipal Affairs and Environment (see Appendix 'a');

5) go to the Land Registration and Information Services (LRIS) office to determine the owner(s) of the surrounding land (see list of LRIS offices, Appendix 'a');

6) get landowner approval in principle;

C. PLAN (fall, year # 1 and winter, year # 2)

1) decide on solution(s), with the assistance of DFO and/or provincial fish habitat improvement biologists;

2) design the project;

3) verify that the project will not violate any provincial or federal environmental laws;

4) obtain the landowners approval for the project in writing (see **Landowner Approval Form**);

5) get a definite commitment from the interested group(s) and/or association(s);

6) complete the **Project Proposal Form** and send it to the Fish Habitat Improvement Centre (FHIC) (see address above) or NBDNRE (see Appendix 'a');

7) complete the **Watercourse Alteration Permit** and send it to the Department of Municipal Affairs and Environment (NBDMAE). The Watercourse Alteration Application Package is available from NBDMAE and possibly FHIC;

D. AFTER PROJECT APPROVAL - PREPARE (winter/spring, year # 2)

1) obtain assistance from federal and/or provincial fisheries biologists and technicians;

2) make materials and equipment checklist;

3) organize materials and equipment, plan the time schedule and delivery route(s);

4) select work dates;

5) alert volunteer labour force;

6) make arrangements for first aid at the work site (e.g. St. John Ambulance or other trained personnel, first aid supplies, hospital route) and assign one person to ensure that security measures are respected (proper work clothes, gloves, hard hats, etc.);

7) divide task into manageable segments;

8) divide labour force into teams;

9) assign teams to task segments;

10) organize the work day. Don't forget to provide lunch, water, coffee or tea;

11) make contingency plans;

12) inform local media of your project;

E. IMPLEMENT - DO IT! (summer/fall, year # 2)

1) take photographs of before, during and after;

2) at the end of the day, check over the completed work thoroughly;

3) tell everyone about the next work day;

F. FOLLOW-UP (fall, year # 2)

1) finish any uncompleted portions of the task;

2) monitor the effects of the project;

3) write and submit a report to the Fish Habitat Improvement Centre (and see that DFO and NBDNRE get copies);

4) each year, after the spring freshet, check any structures and do the required maintenance.

APPENDIX 'a': Important Addresses

GOVERNMENT OF CANADA
DEPARTMENT OF FISHERIES AND OCEANS

GULF REGION:

MONCTON	**GULF REGION HEADQUARTERS**		
	Fish Habitat and Enhancement Division	(506)	857-6253
	Habitat Management Division	(506)	857-6977
	P.O. Box 5030		
	343 Archibald St.,		
	Moncton, N.B., E1C 9B6		
TRACADIE	**AREA OFFICE**		
	P.O. Box 1670		
	Tracadie, N.B., E0C 2B0		
	Area Manager: Normand Dougas	(506)	395-6321
SHEDIAC	**SOUTHEAST N.B. DISTRICT OFFICE**		
	P.O. Box 1120		
	Shediac, N.B., E0A 3G0		
	Area Conservation Chief: Gérard Blanchard		
	Fisheries Officer: Martin Sirois	(506)	532-6631
SUB-DISTRICT OFFICES:			
BAIE STE-ANNE	P.O. Box 240		
	Baie Ste-Anne, N.B., E0C 1A0		
	Fisheries Officer: Edmond Martin	(506)	228-4263
BLACKVILLE	P.O. Box 148		
	Blackville, N.B., E0C 1C0		
	Field Supervisor: Fred Butler		
	Fisheries Officer: Stewart Manderson	(506)	843-2229
BUCTOUCHE	P.O. Box 8		
	Buctouche, N.B., E0A 1G0		
	Fisheries Officer: Robert LeBlanc	(506)	743-2274
CHATHAM	P.O. Box 458		
	Chatham, N.B., E1N 3A8		
	Fisheries Officer: Wayne Olsen	(506)	773-3268

DOAKTOWN	P.O. Box 99 Doaktown, N.B., E0C 1G0 Fisheries Officer: James Curwin	(506) 365-7832
NEWCASTLE	P.O. Box 293 Newcastle, N.B., E1V 3M4 Field Supervisor: Bill Scott Fisheries Officer: J. Fred L. Johnston	(506) 622-4162
PORT ELGIN	P.O. Box 81 Port Elgin, N.B., E0A 2K0 Fisheries Officer: Fernand Jacob	(506) 538-2331
RED BANK	P.O. Box 100 Red Bank, N.B., E0C 1W0 Fisheries Officer: Stephen Savoy	(506) 836-7779
RICHIBUCTOU	P.O. Box 427 Richibuctou, N.B., E0A 2M0 Field Supervisor: Daniel Cormier Fisheries Officer: Eugène Robichaud	(506) 523-4435
TRACADIE	**NORTHEAST N.B. DISTRICT OFFICE** P.O. Box 1670 Tracadie, N.B., E0C 2B0 Area Conservation Chief: Raoul Breault Fisheries Officer: Jean-Yves Mallet	(506) 395-6321
SUB-DISTRICT OFFICES:		
BATHURST	700 St. Peter Ave. Bathurst, N.B., E2A 2Y8 Field Supervisor: Fisheries Officer: J.A. Marc Doucet	(506) 548-7485
CARAQUET	P.O. Box 155 Caraquet, N.B., E0B 1K0 Fisheries Officer: Clément Larocque	(506) 727-3038
DALHOUSIE	P.O. Box 328 Dalhousie, N.B., E0K 1B0 Fisheries Officer: Robert Roy	(506) 684-2202
EDMUNDSTON	121 Church St. Edmunston, N.B., E3V 1J9 Fisheries Officer: Émile Arseneau	(506) 735-6283

GRAND FALLS	P.O. Box 306 Grand Falls, N.B., E0J 1M0 Fisheries Officer: Moise Lévesque	(506)	473-2775
KEDGEWICK	P.O. Box 128 Kedgwick, N.B., E0K 1C0 Fisheries Officer: Maurice Lévesque	(506)	284-2312
LAMEQUE	P.O. Box 157 Lamèque, N.B., E0B 1V0 Fisheries Officer: Gaetan Couturier	(506)	344-2253
NEGUAC	P.O. Box 30 Néguac, N.B., E0C 1S0 Fisheries Officer: Wayne Thompson	(506)	776-3307
PLASTER ROCK	P.O. Box 489 Plaster Rock, N.B., E0J 1W0 Fisheries Officer: Stephen Sprague	(506)	356-2131
SHIPPAGAN	P.O. Box 358 Shippagan, N.B., E0B 2P0 Field Supervisor: Marcel Mazerolle Fisheries Officer: Bernard Mallet	(506)	336-8712

SALMONID ENHANCEMENT CENTRES:

CHARLO	**Charlo Salmonid Enhancement Centre** P.O. Box 161 Charlo, N.B., E0B 1M0 Manager: Paul Cameron	(506)	684-4459
MIRAMICHI	**Miramichi Salmonid Enhancement Centre** Box 780, R.R. #1 Newcastle, N.B., E1V 3L8 Manager: Arlie Wynn	(506)	622-1781

SCOTIA-FUNDY REGION:

HALIFAX	**SCOTIA-FUNDY HEADQUARTERS** Fish Habitat Management Division P.O. Box 550 Halifax, N.S. B3J 2S7	(902) 426-8398

FISH CULTURE STATIONS:

MACTAQUAC	**Mactaquac Fish Culture Station** R.R. #6 Fredericton, N.B., E3B 4X7 Manager: James W. McAskill	(506) 363-3022 or -3021
SAINT JOHN	**Saint John Fish Culture Station** 1700 Loch Lomond Road Saint John, N.B., E2J 2A3 Manager: Douglas J. Aitken	(506) 649-2370

Note: This manual was designed for the province of New Brunswick. The DFO Scotia-Fundy and Gulf Regions both have specific geographic areas of jurisdiction in this province (Figure a1). For consultation on specific projects, contact the appropriate Regional office for your project's location. Although habitat restoration is being stressed in Scotia-Fundy Region, technical and scientific support is limited to the review of proposals received through the established referral system. Therefore, most of your contacts will be in the Gulf Region at present.

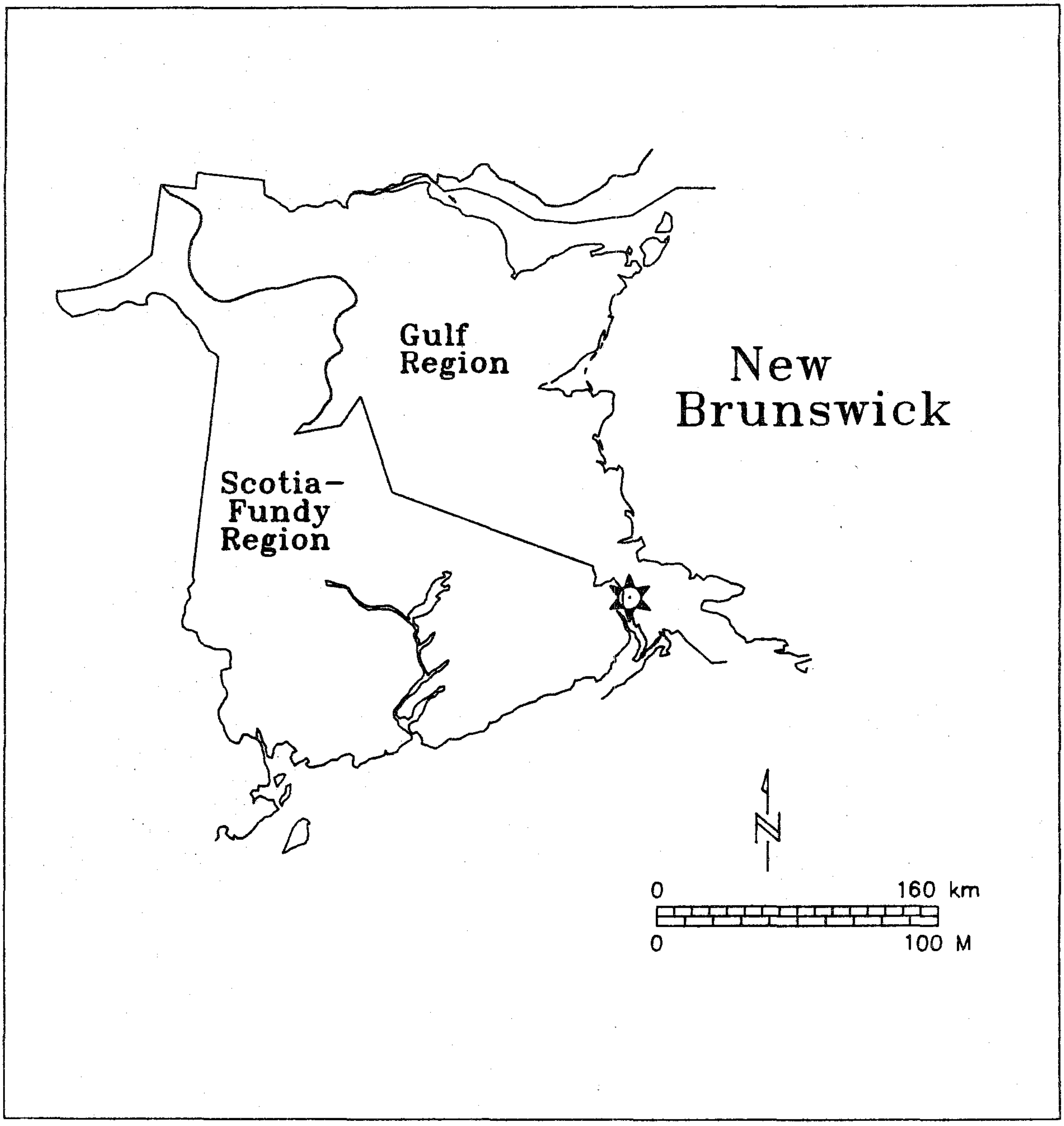

Figure a1. Map of New Brunswick showing Gulf and Scotia–Fundy Regional split.

GOVERNMENT OF NEW BRUNSWICK
DEPARTMENT OF NATURAL RESOURCES AND ENERGY

Region 1	(Headquarters) - BATHURST P.O. Box 170 Vanier Blvd. Extension Bathurst, N.B. E2A 3Z2 Fisheries Biologist: Gilles Godin (506) 546-6611	CAMPBELLTON P.O. Box 277, 164 Arran St Campbellton, N.B. E3N 3G4 Fisheries Biologist:AlMadden (506) 753-3327
Region 2	(Headquarters) - NEWCASTLE 80 Pleasant St. Newcastle, N.B. E1V 1X7 Fisheries Biologists: Bob Currie, Bernard Dubée	(506) 622-2636
Region 3	(Headquarters) - HAMPTON P.O. Box 150 (333 Main St.) Hampton, N.B. E0G 1ZO Fisheries Biologist: Tom Pettigrew	(506) 832-5532
Region 4	(Headquarters) - FREDERICTON R.R. No. 6 Fredericton, N.B. E3B 4X7 Fisheries Biologists: Peter Cronin, Tom Reid	(506) 453-1802
Region 5	(Headquarters) -EDMUNDSTON P.O. Box 398 Edmundston, N.B. E3V 3L1 Fisheries Biologists: Norman Prentice, Ed LeBlanc	(506) 735-4751

LAND REGISTRATION AND INFORMATION SERVICE OFFICES
PROPERTY RECORDS AND MAPPING DIVISION

BATHURST	159 Main St., Suite 214 Bathurst, N.B., E2A 1A6	(506)	548-4518
EDMUNDSTON	Suite 225, 121 Rue l'Eglise Carrefour Assomption Edmunston, N.B., E3V1J9	(506)	739-7731
FREDERICTON	985 College Hill Road, P.O. Box 6000 Fredericton, N.B., E3B 5H1	(506)	453-2112
MONCTON	770 Main St., P.O. Box 5001 Moncton, N.B., E1C 8R3	(506)	858-2517
SAINT JOHN	179 Charlotte St., P.O. Box 5001 Saint John, N.B., E2L 4Y9	(506)	658-2419

MAPS AND AERIAL PHOTOGRAPHS

AERIAL PHOTOGRAPHS

Maritime Resource Management Services (MRMS)
16 Station St.
P.O. BOX 310
Amherst, N.S., B4H 3Z5 (902) 667-7231

AERIAL PHOTOGRAPHS AND TOPOGRAPHIC MAPS

Department of Natural Resources and Energy
Crown Lands Branch, Map and Photo Sales
P.O. Box 6000, (Centennial Bldg., Room 675)
Fredericton, N.B., E3B 5H1 (506) 453-2764

APPENDIX 'b': Suggested Readings and References

Suggested Readings:

(See also the list of references used in compiling this manual.)

Hynes, H.B.N. 1979. The Ecology of Running Waters. 4th Edition. Liverpool University Press. Great Britain.

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APPENDIX 'c': Glossary of Terms

ADULT - fish which are mature or able to spawn

ALEVIN (sac fry) - stage of development of the salmonid embryo from hatching to absorption of the yolk sac

ANADROMOUS - a stock or species of fish which reproduces in freshwater and migrates to salt or brackish water to rear for a portion of its life, usually attaining most of its growth in salt water

BANK STABILIZATION - to control erosion of a bank

BARRIER - any obstruction that impedes the movement of fish; the stopping of a spawning run or the blocking of individuals from nursery areas or areas of maturation

BEDROCK - all exposed rock with no overburden

BOULDER - all rock over 25 cm (10 in) in diameter

BRAIDED CHANNEL - divided into several channels which successively meet and redivide; it may be an adjustment to debris load too large to be carried by the single channel

BRUSH BUNDLE - stems of species such as red osier dogwood and willow, 150 cm to 180 cm (5 ft to 6 ft) in length, tied into a bundle with wire

CHANNEL - a long, narrow, sloping trough-like depression where a natural stream flows or may flow

COBBLE - rock material between 8 cm and 25 cm (3 in to 10 in)

COVER - an area of shelter in a stream that provides aquatic organisms with protection from predators and/or a place to rest and conserve energy

CULVERT - a covered channel or a large-diameter pipe that takes a watercourse below ground level

DEFLECTOR - a triangular structure built in a stream to deflect water; it creates a deeper, narrower area and/or pool area

DRAINAGE BASIN - a concave surface (valley) collecting precipitation into a stream; commonly confused with 'watershed'

ENHANCE - to improve; commonly used in reference to such practices as addition of instream cover, creation of spawning area,etc.

ENVIRONMENT - entire group of factors likely to have an effect on living organisms and on the activities of man

EROSION - the weathering of the earth's surface by the action of wind, water, gravity and ice

ESTUARY - a semi-enclosed body of water which has a free connection with the open ocean and within which seawater is measurably diluted with fresh water derived from land drainage

FERTILIZER - a chemical or organic material used to enrich the soil

FILTER FABRIC - a granular material or woven fabric used in erosion control

FLOOD - discharge overflowing the banks of a stream

FLOODPLAIN - flat plain bordering a stream or river overflowed at times of high water; underlying materials consist mainly of unconsolidated material derived from sediments transported by the stream

FRY - young fish after the yolk sac has been used up and active feeding has commenced; this period lasts about one year

GABION - a galvanized wire basket with a removable top; the basket, filled with selected stones, is used to stabilize banks to control erosion in streams and to prevent stream gravel from shifting

GALVANIZED - metal having a coating of zinc on its surface in order to prolong its life by reducing corrosion

GRADIENT - see slope

GRAVEL - rock material between 0.2 cm (1/8 in) and 8 cm (3 in)

GROUNDWATER - water found underground in porous rock strata and in soils

HABITAT - the total environment required by an organism to sustain all its life functions; in the stream environment, habitat requirements for fish include food, space, shelter and water quality

HIGH WATER - the level of water which fills only the stream channel and not the flood plain; the normal level of water under typical rain conditions

HYDROSEEDING - ejecting a mixture of seed, fertilizer and mulch under pressure through the hose and nozzle of a hydroseeder machine; used in bank stabilization

INNER BANK - convex bank of a bend; convex means curving outwards like the surface of a sphere

JUVENILE - a young fish not yet mature enough to spawn

LOG CRIB - a structure made of vertically and horizontally placed logs which stabilizes the bank and provides cover for fish

MARSH - an area of soft, wet or periodically inundated land generally treeless and usually characterized by grasses and other low growth

MEANDERING - the process by which a stream winds or snakes its way across a floodplain continually changing its course by erosion, transportation, or deposition of sediment

MULCH - a protective covering, such as straw, spread on the ground to reduce evaporation and erosion, control weeds or improve the soil

NURSERY HABITAT - habitat required by juvenile fish; usually found near major spawning areas, relatively shallow compared with mature fish habitat, and has many small shelter areas for small fish; log debris and jumbles of rock along the shallow, swift margins of the stream are excellent locations for young salmonids because they provide ample protection from other fish and animals yet are near major food sources

OUTER BANK - concave bank of a bend; concave means curved like the inside of a hollow ball

POOL - water of considerable depth for the size of the stream; pools generally have slowly flowing water and a smooth surface but they often have a swift, turbulent area where the water enters them

PLUNGE POOL - depression in streambed material scoured out by the action of falling water

REARING HABITAT - see nursery habitat

REDD - the gravel nest which salmonid fishes lay their eggs in

REHABILITATION - the restoration or rebuilding of degraded fish habitat and/or water quality

REVETMENT - a sloped facing built to protect existing land or newly created embankment against erosion by wave action, currents or weather; revetments are usually placed parallel to the natural shoreline

RIFFLES - shallow water with a rapid current and surface flow broken by gravel or rubble

RIPARIAN - pertaining to the banks of a body of water

RIP RAP - a foundation or wall made of broken rock and/or logs; the wall created can be either of an irregular or predetermined design

RIVER - a large, natural freshwater surface stream having a permanent or seasonal flow and moving toward a sea, lake or another river in a definite channel

RUBBLE - see cobble

RUN - moderate to rapid current flow in a deeper, narrower channel than a riffle; the depth and materials found in runs make them excellent cover locations for salmonids

RUNOFF - water from precipitation flowing above ground to a surface water containment (eg. lake, river, etc.) without entering the groundwater table

SALMONID - refers to a member of the fish family classed as Salmonidae including salmon, trout , char, whitefish and grayling

SAND - material of cystalline rock origin between 0.0625 mm and 2 mm (0.0025 in to 0.08 in) in diameter

SCOURING - gradual or rapid erosion of particles on the channel walls or bed by concentration of the current

SEDIMENTATION - deposition of eroded soil material on the streambed

SHORE - the narrow strip of land in immediate contact with the water including the zone between high and low water lines

SILT - fine particles of soil (finer than sand)

SLOPE - the degree of inclination to the horizontal; usually expressed as a ratio such as 1:25 or 1 on 25 indicating 1 unit vertical rise in 25 units of horizontal distance or given in a decimal fraction (0.04) or percent (4%)

SPAWN - to produce or deposit eggs or discharge sperm

SPAWNING HABITAT - most species of salmonids prefer rock, rubble and gravel areas in which to spawn; spawning of salmonids usually occurs in locations of moderate to strong current, found below pools and runs, in riffles

SPRING-FED - to be supplied with water from a discharge of deep-seated, hot or cold, pure or mineralized water

STREAM - a watercourse which has a flow of water for all or part of the year and has a defined channel showing signs of scouring and washing

STREAMBANK - the rising ground bordering a stream channel; right and left banks are determined while facing downstream

STREAMBED - the bottom of the stream; below the usual water surface

STREAM FLOW - the discharge of water at any particular time period; measurement is in a unit volume per second such as cubic feet or cubic metres per second

STREAM WIDTH - the distance between vegetated banks taken normal to the general direction of flow

SUBSTRATE - the materials making up the streambed; usually described as bedrock, boulder, cobble, gravel, sand or silt

THALWEG - the path of maximum depth in a river or stream; it normally follows a meandering path back and forth across the channel

TURBULENCE - irregular motion or swirling agitation of water

TWIG BUNDLE - twigs of species such as red osier dogwood and willow, approximately 30 cm (1 ft) in length, all pointing in the same direction and tied together with string or rubber bands

VEGETATION - woody or non-woody plants; in reference here to plants used to stabilize banks and shores and to retard erosion

VELOCITY - a measurement of speed recorded as distance travelled over time (eg. feet or metres per second)

WATER QUALITY - a general term denoting a category of properties of water; commonly used in reference to chemical, physical and biological characteristics and temperature of the water

WATERSHED - a convex surface, such as a mountain or hill, which sheds water from one point or ridge into several streams which may form its boundary; commonly confused with "drainage basin", a concave surface collecting precipitation into one stream

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APPENDIX 'd': Formation of Stream Channels

Excerpts adapted from: Ontario Ministry of Natural Resources, Community Fisheries Involvement Program, Field Manual: Part 1, 1984.

A healthy, natural stream channel is in conservative equilibrium. The stream's stability results from a counterbalance of several interlocking physical processes: discharge, velocity, depth, slope, channel width and others. These variables are determined by the topography, the physiography and the size and land use of a watershed.

In a stream channel, gravity and friction are the principal forces acting on the water. Gravity causes water to move downstream. Friction is created between the water the streambed and banks resulting in resistance against the downstream movement. As the water flows over larger and larger materials such as rocks, boulders and debris, the friction in the stream will increase. The stream's roughness is determined by the amount of friction caused by the materials in the streambed. The water velocity is determined by the slope, streambed roughness and the depth of the flow.

The resistance to flow in natural or man made courses is influenced by several factors:

- size of material on the stream bottom and banks.
- vegetation type and amount along the stream banks. This would also include the vegetation within the wetted area.
- degree of meandering of the stream and the frequency of pools and rapids. These affect the stream bottom uniformity.
- flow obstructions such as log jams and rock outcrops.

The results of resistance may form eddys, local reserves in flow, standing waves, chutes and waterfalls. These may eventually dislodge and move the resisting object downstream. The following factor applies to all turbulent flow conditions. The resistance to flow will increase as the square of the velocity. For instance, if the flow doubles, then the drag force on an object will increase by a factor of four. Therefore, the major physical processes in the stream are influenced by the peak or dominant discharge. It is suggested that the section of the river during peak discharge in the spring should be observed for determination of how the river is affecting the area. This should be done prior to planning stream work and determining the type of structure needed.

Natural streams are rarely straight over a distance greater than 10 channel widths. As water flows in a meandering pattern, it minimizes its velocity and cutting action while still travelling to its final destination. In different streams, there are basic types of channel forms which may be described in three general terms: braided, straight and meandering (Figure d1).

Straight channel pattern will apply to relatively straight or non-meandering channels. A straight channel is relatively unstable since the water still bounces back and forth as it travels down the channel.

Braided channels have poorly defined, unstable banks. They also have steep, shallow watercourses with multiple channel divisions around small islands. These are created by a channel overloaded with sediment from tributaries or eroded banks.

A meandering channel will have alternating bends giving an "S" shape or sinuous channel pattern. It is also fairly stable. With a meandering channel, the amount of bending may be defined as the comparison between channel length and valley length. It is the ratio of the distance measured along the centre line of the channel (channel length) to the distance measured in a straight line across the bends (valley length) (Figure d2). Streams with a channel length versus valley length ratio of 1.5 or more are classified as meandering.

Straight streams are those with a ratio less than 1.5. A stream will always attempt to maintain a meander shape as it requires less work in turning. As a result, it will be the most likely path for the water to follow. This principal holds true for oceans. Even where the channel appears straight, the line of maximum depth, called the thalweg, will wander back and forth across the channel in a meandering pattern (Figure d2). If there are obstructions which cause the flow of the stream to depart from its normal meander shape, the stream will always tend to restore itself to its natural configuration.

There are several factors which govern meander shape:

1) Channel width, meander length and radius of curvature are closely associated with each other.

2) The meander length may range from 7 to 10 times the channel width as measured in a straight line across one complete meander. The distance between

identical points on the meander waves may vary from 10 to 16 channel widths. The measurement is taken along the centre line of the channel.

3) The thalweg successive crossovers, which are 1 per meander, are spaced 5 to 7 channel widths apart. This resembles the spacing of successive riffles in a stream.

4) Meandering is related to a narrow channel width relative to the stream's depth. It is also related to greater stability of the stream bank boundaries. If unstable streambanks are reinforced with rock, for example, the result will be that the stream will deepen, increase meandering and become stable.

In moving downstream, water will move back and forth laterally within a channel. In Figure d3, there are two cross-sections of a meander channel shown. One cross-section is taken at a point downstream of the axis of the bend and shows the transverse spiral flow developed at the curve of a meander. The transverse flow occurs along the bottom of the channel towards the inside of the curve and then on toward the outside bank. The result of the transverse flow at the bend is the bedload deposition at the point of a meander creating a point bar (Figures d2 & d3). On the outside of the curve, floating debris will accumulate.

In Figure d3 the transverse flow in a straight section of the channel is shown. The transverse flow will unite at the surface near the stream center as the two spiralling cells will instigate the material deposition across the bed to create a shallow, rectangular channel.

In determining where a fish habitat improvement structure should be placed, the flow characteristics for straight and meandering sections of a stream are important factors. In a river, the pool and riffle occurence is an important physical influence on the natural production of fish. A straight, non-meandering channel will have a fluctuating bed alternating between pools and riffles at a repeating distance of 5-7 channel widths. This will apply to a meandering stream where pools occur at every curve and riffles at each point of crossover. Most channels with bed material larger than coarse sand will have the alternating pool and riffle sequence. Streams with sand bottoms will be less stable. Meandering streams will instigate pool creation.

Erosion and the movement of sediments should also be considered when determining where to place a fish habitat improvement project. Channel shape cross-sections will vary depending on bank material characteristics. When streambanks are resistant to erosion, the hydraulic forces of the stream will scour a deeper channel. The shape of the cross-section of a stream channel will be determined by several factors. These include discharge and characteristics of the materials which make up the bed and banks of the channel and the vegetation type within and adjacent to the channel.

Cross-sections of river beds are rectangular rather than U-shaped. The river bed becomes increasingly rectangular as the river becomes larger downstream due to the fact that the width increases faster than the downstream depth. In a stream channel, as the discharge increases the water level will rise and the streambed will be lowered due to scouring. The scoured depth will be minimal for gravel streambeds. In streams with sandy bottoms, scouring will be greater relative to the rise in water surface level. These streambeds will scour to 1/3 the depth of the overall rise in water level. This is important to know when doing stream improvement work on stream channels formed in silt, sand and other fine materials. Improvement structures such as gabions and wing dams will be unstable unless designed specifically for sandy streams. The structures may be undermined resulting in the lowering, break-up and downstream movement of the structure's fragments.

Streams subject to large freshets or fluctuations in water levels will have higher rates of erosion and greater amounts of sediment transport. A particle which requires more force to begin its movement than to keep it in motion is apparent in any stream with widely fluctuating flows. Particle movement will begin in extreme peak flows. Lower water flows will have enough power to keep the particle moving.

In bedload movement, uniformity of particle size will be a key factor. With two samples of bed material of the same average size, the sample with the less uniform particle size will be more stable. This is due to the fact that smaller particles will fill the voids and thus lock the larger grains in place. Table d1 gives the minimum transport velocities for the various sizes of particles.

Use Table d1 to estimate the velocities usually occuring in a river channel by looking at the riverbed materials. The stream will have velocities in excess of 200 to 800 cm/sec (8-10 ft/sec) if the channel is made up of cobble with little gravel or sand. If the maximum velocity of a specific section of channel is known, the bed material size can be determined so that it will be relatively stable. This is important to know if gravel is to be added to the stream channel to improve spawning conditions.

Table d1. Transport velocities for various classes of streambed materials. (Ministry Natural Resources. 1984.)

Materials	Diameter	Transport velocity
Silt	0.005 mm - 0.05 mm (0.00002 in - 0.002 in)	15 - 20 cm/sec (0.49 - 0.66 ft/sec)
Fine to coarse sand	0.25 mm - 2.5 mm (0.01 in - 0.10 in)	30 - 65 cm/sec (0.98 - 2.13 ft/sec)
Fine to coarse gravel	5.0 mm - 15 mm (0.2 in - 0.6 in)	80 - 120 cm/sec (2.62 - 3.94 ft/sec)
Fine to coarse stone	25 mm - 75 mm (1.0 in - 3.0 in)	140 - 240 cm/sec (4.59 - 7.87 ft/sec)
Cobble	100 mm- 200 mm (4.0 in - 7.8 in)	270 - 390 cm/sec (8.86 - 12.80 ft/sec)

The simplest method for measuring small to large water flows, with medium accuracy, is the float method. This method is best used in streams with calm water and during good weather so the float's normal speed is not disrupted. Two people are needed. Follow these steps:

a) Prepare a float - a piece of wood or smooth tree branch 30 cm long and 5 cm wide or a well capped bottle 10 cm tall filled with enough soil or water so that it floats just above the surface.

b) Mark the stream - find and mark a length AA to BB along the stream at a place where the stream runs straight for at least 10 m and is relatively free of plants.

c) Find the average water velocity - one person places the float in the middle of the stream a few metres upstream of line AA and releases it into the current. The person stands at line BB and times with a stopwatch how many seconds it takes for the float to travel from AA to BB. Repeat this procedure three times. Then average your times. Divide the distance between AA and BB by the average time. Multiply your result by 0.85 (a correction factor) to estimate the average water velocity of the stream.

d) Find the average stream width - measure the width (in m) of the stream in at least five places. Take the measurement that occurs most frequently as the average width.

e) Find the average stream depth - measure the water depth of the stream at at least five places along its width. Take half of the deepest measurement as an approximation of the average depth.

f) Calculate the water flow - to calculate the water flow (in cubic metres per second), multiply the average water velocity (in m/sec) by the average width (in m) and by the average depth (in m).

Flow = (average velocity) x (average width) x (average depth)

Example: Flow = (2 m/sec) x (3 m) x (6 m)

Flow = 36 m^3 /sec

REFERENCES

Ontario Ministry of Natural Resources. 1984. Community Fisheries Involvement Program. Field Manual. Part 1: Trout Stream Rehabilitation. Ontario Queen's Printer. Toronto, Ontario.

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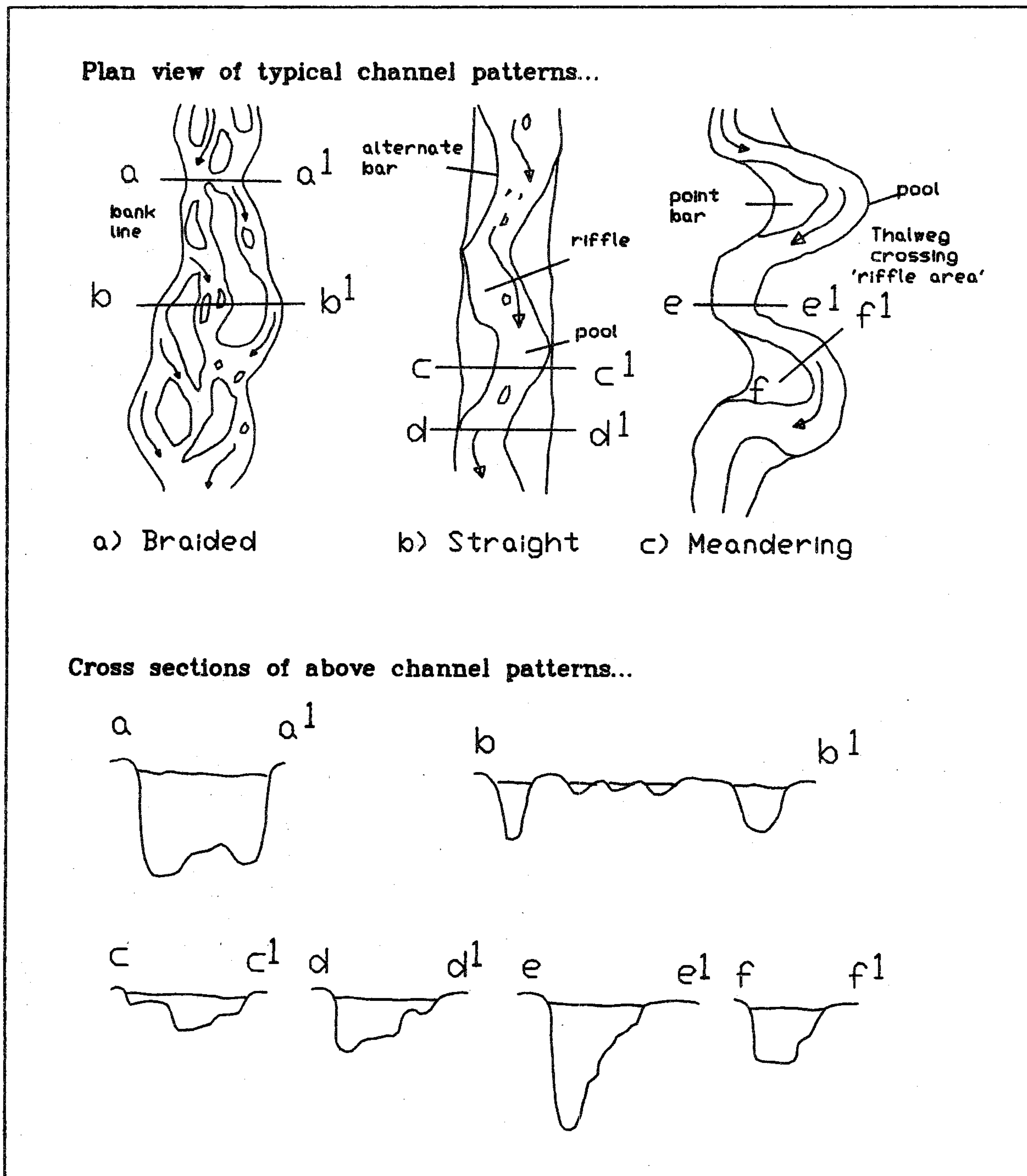

Figure d1. River channel patterns. (Adapted from Community Fisheries Involvement Program, Field Manual, Part 1. 1984. Ontario Ministry of Natural Resources.)

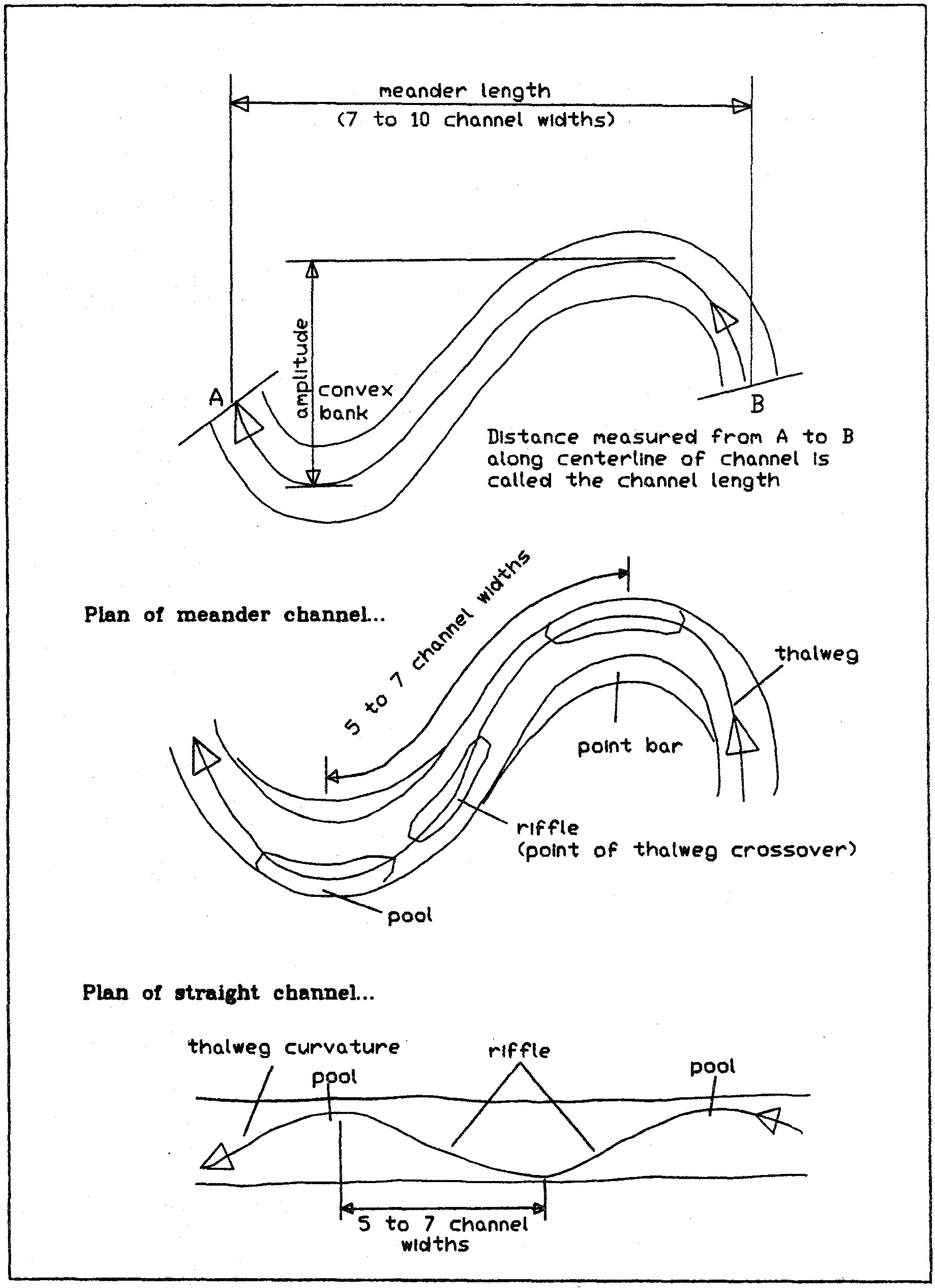

Figure d2. Elements of various channel forms and their physical relationships. (Adapted from Community Fisheries Involvement Program, Field Manual, Part 1. 1984. Ontario Ministry of Natural Resources.)

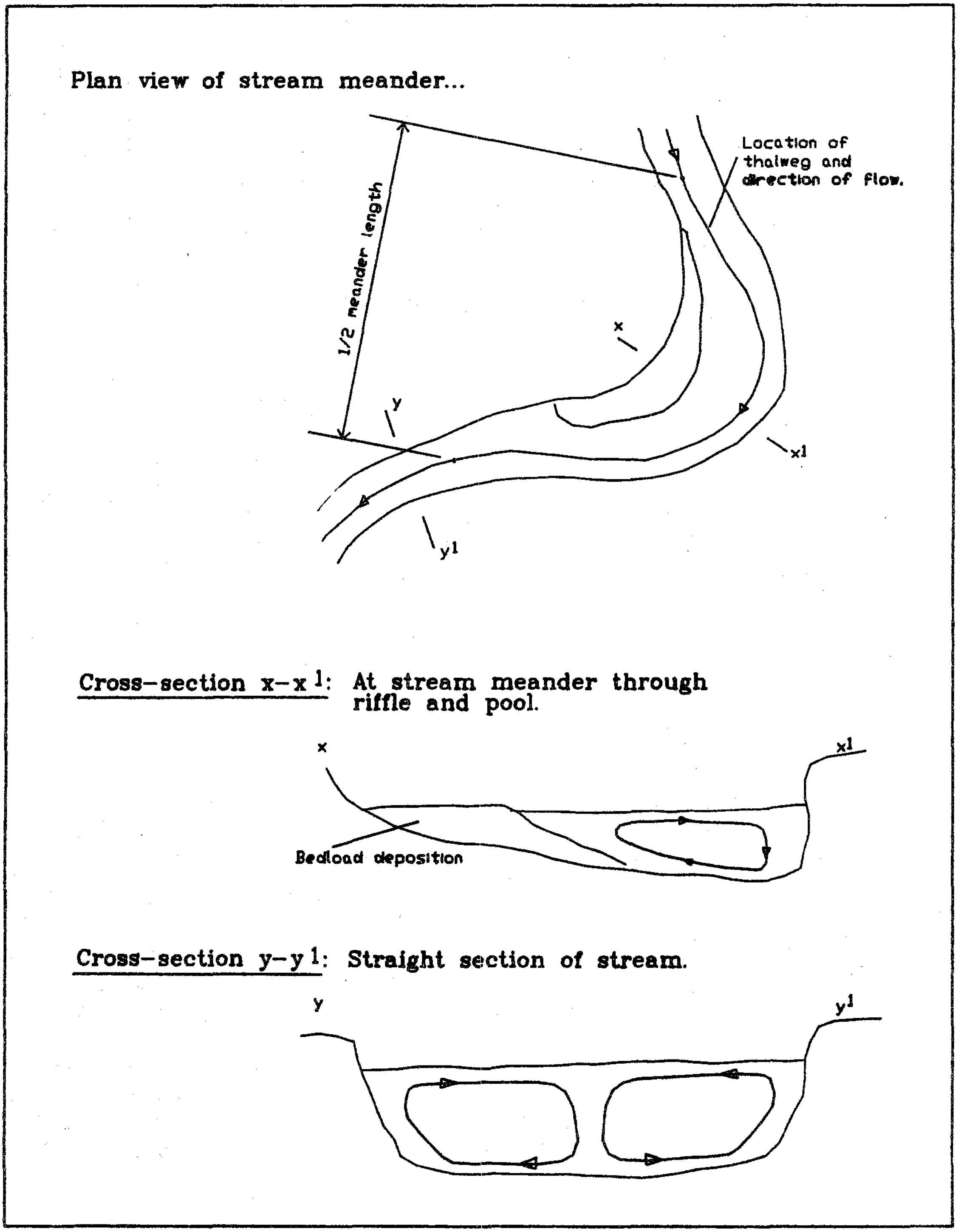

Figure d3. Transverse flows at various parts of a stream: section $x-x^1$, at the bend of a meander, shows that surface water spirals toward the outer bank. Bottom water and bedload spiral toward the inside bank; section $y-y^1$, in a straight section, shows that the spiral transverse flows converge at the surface near the centre of the stream. (Adapted from Community Fisheries Involvement Program, Field Manual, Part 1. 1984. Ontario Ministry of Natural Resources.)

APPENDIX 'e'

FISH HABITAT IMPROVEMENT PROJECT PROPOSAL

You will be required to provide the following information:

1. Name of Volunteer Group or Association Information *
2. Topographical Map
3. Description of the Project Area *
4. Problem Identification
5. Fisheries Resource
6. Project Description *
7. Drawing of Proposed Improvement Work
8. Project Benefits
9. Request for Acceptance
10. Landowner Approval Form

* This information will also be required in order to obtain the Watercourse Alteration Permit and will be used to determine the eligibility of your project. Please include as much information as possible. Take your time and do a thorough job.

Remember: The Fish Habitat Improvement Centre is available to assist you with preparing this proposal.

PROJECT PROPOSAL FORM

1. VOLUNTEER GROUP OR ASSOCIATION

a) Group/Assoc. Name ______________________________

Address ______________________________

Postal Code ______________________________

Telephone ______________________________

b) Name of key contact ______________________________

Address ______________________________

Postal Code ______________________________

Telelphone ______________________________

c) Briefly describe your organization, including the number of members, your objective(s), your interest in this project, other activities in which you have participated, etc.

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d) How many people in your organization will participate in this project? ______________________________

e) Please name any other organizations which may assist with this project and the number of people involved.

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2. TOPOGRAPHICAL MAP

A topographical map should be photocopied to show the area where you will be conducting your habitat improvement work. Please indicate the waterbody to be altered and the following information:

SCALE;

MAP NO;

NEAREST COMMUNITY.

Attach the map to the last page of this proposal.

3. DESCRIPTION OF PROJECT AREA

a) General Information

Name of waterbody: ______________________________

Nearest community: ______________________________

This project will be on:	crown land	( )
	private land	( )
	both	( )

For the following questions, please check (✓) the pertinent information and give further details:

b) Type of Waterbody		Details
stream	( )	______________
river	( )	______________
lake	( )	______________
marsh	( )	______________
estuary	( )	______________

coastal site	( )	____________________
other	( )	____________________

c) Waterbody Characteristics		Details
shallow, calm	( )	____________________
shallow, slow current	( )	____________________
shallow, swift current	( )	____________________
deep, calm	( )	____________________
deep, turbulent	( )	____________________
other	( )	____________________

d) Bottom Characteristics		Details
fines (silt, sand, clay)	( )	____________________
gravel	( )	____________________
cobble (baseball to soccerball)	( )	____________________
boulder (larger than soccerball)	( )	____________________
rock ledge	( )	____________________
vegetation	( )	____________________
other	( )	____________________

e) Bank Stability:		Details
no erosion	( )	____________________
little erosion (less than 50%)	( )	____________________
much erosion (more than 50%)	( )	____________________
eroding slowly	( )	____________________
eroding actively	( )	____________________

f) Shoreline Vegetation (within 10m of banks)		Details
cropped pasture grasses	( )	____________________
grass and shrubs	( )	____________________
dense shrubs	( )	____________________
mature trees	( )	____________________
freshwater marsh vegetation	( )	____________________
salt marsh vegetation	( )	____________________
dune vegetation	( )	____________________
other	( )	____________________

g) Aquatic Vegetation		Details
none	( )	____________
algae	( )	____________
grass-like	( )	____________
leafy	( )	____________

h) Cover for Fish		Details
undercut bank	( )	____________
boulder	( )	____________
aquatic vegetation	( )	____________
logs/trees	( )	____________
other	( )	____________

4. PROBLEM IDENTIFICATION: For the following questions, please check (✓) the pertinent information and give further details. Select the appropriate general categories before choosing the specific problems.

a) Passage Problems		Details
beaver dams	( )	____________
man-made dams	( )	____________
inoperative fishways	( )	____________
improperly installed	( )	____________
culverts	( )	____________
log jams	( )	____________
other obstructions	( )	____________

b) Industrial Operations		Details
forestry (e.g. clearcutting)	( )	____________
agriculture (e.g. ploughing)	( )	____________
land fill	( )	____________
dredging and/or dumping	( )	____________
road building	( )	____________
gravel removal	( )	____________
channelization	( )	____________
other	( )	____________

c) Erosion/Siltation

		Details
cattle along bank	( )	________________
eroded gullies	( )	________________
siltation	( )	________________
no vegetation (within 10m of shoreline)	( )	________________
improperly placed drainage ditches	( )	________________
other	( )	________________

d) Water Quality/Quantity

		Details
water withdrawal	( )	________________
wastewater discharge(industrial)	( )	________________
wastewater discharge (municipal)	( )	________________
recreational uses	( )	________________
fish waste disposal	( )	________________
intense housing development	( )	________________
garbage or other debris	( )	________________
other	( )	________________

e) Miscellaneous

		Details
poorly placed breakwater,wharf, etc.	( )	________________
ice damage	( )	________________
limited spawning area	( )	________________
limited nursery/rearing area	( )	________________
limited adult habitat	( )	________________

If more space is required, please attach notes.

5. FISHERIES RESOURCE - please check ✓

a) Fish Species Present	many	some	few
speckled/brook trout	____	____	____
rainbow trout	____	____	____
lake trout	____	____	____
Atlantic salmon	____	____	____
landlocked salmon	____	____	____
gaspereau	____	____	____
smelt	____	____	____
striped bass	____	____	____
others	____	____	____

6. PROJECT DESCRIPTION

a) Which fish species are being enhanced?

b) Describe the proposed work. **(If more space is required, please attach notes.)**

c) What is the proposed work schedule?

d) What is the lifespan of this project?

e) What are the maintenance requirements of the proposed work?

7. DRAWING OF PROPOSED IMPROVEMENT WORK

Please indicate the following information on your drawing:

- location of the waterbody(s) and their name(s);
- roads, bridges and houses in the immediate area of concern;
- problem areas and types in the waterbody or along its shoreline;
- direction of water flow, location of pools, riffles, falls, etc.;
- surrounding land type, use (e.g. fields, forest, clearcut area), and ownership;
- approximate distances (e.g. stream width, length of area involved, distance from roadway, etc.);
- the approximate direction of magnetic north.

Attach the drawing to the last page of this proposal.

8. PROJECT BENEFITS

State briefly the benefits to be derived from your project (e.g. increased fish habitat, improved awareness of this resource, promotion of community feeling, etc.)

Place attachments here (maps, notes, etc.).

REQUEST FOR ACCEPTANCE

We, the____(name of group) of______________________________ (location in New Brunswick) hereby make application for acceptance of the above proposal to undertake a fish habitat improvement project. We acknowledge that if approved, we shall provide the Department of Fisheries and Oceans and the Fish Habitat Improvement Centre with progress reports and a final report of our activities.

We acknowledge that if successful, we will be prepared to obtain liability insurance to cover those people who may be involved in our activities. Furthermore, we acknowledge that the Fish Habitat Improvement Centre and the Governments of Canada and New Brunswick are not liable for any personal injury or destruction of property caused by members of participating groups.

Signed __________________________________ Position ___________________________

Signed __________________________________ Position ___________________________

Date ___________________ Place ____

Note: Filing of this application form does not guarantee acceptance of the proposal or any portion thereof. When a proposal has been accepted the group or association will be formally notified.

LANDOWNER APPROVAL FORM

I, ______________________________(name) of ______________________________(address) in New Brunswick, certify that I am the owner of the parcel of land no: ________________ (LRIS #) located on the banks of ______________________________________(name of waterbody) in ________________________ county.

I hereby authorize the ____(name of association) to utilize that parcel of land for access, materials, modification, etc. to improve fish habitat. I understand that this right is granted for the period between ________________(date) and ________________(date) and that I may annul this authorization immediately by giving written notice to the association. I will not be held responsible, nor will I hold the Department of Fisheries and Oceans, the association or any other persons involved in this fish habitat improvement project responsible for any personal injury or destruction of property.

Signed ____ Date ______________________

Witness ____ Date ______________________

FACT SHEET - A - REVISION: 03-11-88

INSTREAM DEBRIS REMOVAL

***ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

The accumulation of various types of debris in New Brunswick's waterways has long been a matter of grave concern. Our streams have been littered with everything from tree stumps to branches, from boulders to silt, from car bodies to tin cans. On the surface, the complete removal of these items seems to be in order. The solution, however, is not so simple. Certainly, any and all unnatural substances, metal and plastics for example, must be removed to maintain a pristine fish habitat. Excess amounts of woody debris may create barriers to fish migration, lower the water's oxygen content, create silt build-ups, lessen the flow, or cause flooding upstream. Some natural debris, on the other hand, such as tree trunks and branches, serves an essential function (see Figure A-1). Such woody debris provides cover for many fish such as salmonids, and is the beginning of a food chain which supports the aquatic insects fish feed upon.

The question of whether or not to remove the debris is further complicated by the fact that removing a log jam, for instance, may release large amounts of silt that had been trapped behind it into the water downstream, wiping out spawning beds and trapping fry.

Each situation must be individually evaluated before action is taken to remove the debris. We recommend that you consult your local fisheries biologist or fishery officer, before commencing a debris removal project, to obtain a professional assessment of the possible effects, negative and positive, of your project.

2.0 PURPOSE

The removal of instream debris allows fish access to upstream spawning, rearing and feeding areas increasing the net habitat available for the fish. In addition, it will prevent extreme temperature fluctuations (deadly to fish) and help maintain a high level of oxygen in the water. Eliminating debris has physical benefits to the stream as well. It may prevent stream diversions, and subsequent bank erosion, and it encourages natural stream flows to scour silt and debris deposits from the streambed.

3.0 CONDITIONS WHERE APPLICABLE

An instream debris removal project should be considered in the following situations.

a. The debris is creating an obstruction to fish passage.

b. Silt and other debris have blocked the streamflow.

c. Pond formation above the debris has led to flooding upstream and decreased flow downstream. Slower flows may lead to warming of the water in summer, freezing in the winter and reduced oxygen levels during all seasons.

d. Inoperative man-made or beaver dams are blocking the streamflow and obstructing fish passage.

e. Woody debris and silt have accumulated on the streambed. Such accumulations, if not removed, will smother eggs, fry and aquatic insects, cloud the water and make the area uninhabitable for fish.

f. Rock jams have increased water velocity over their crest creating a chute impassable by migrating fish.

g. Log or rock jams threaten to change the direction of the streamflow (this may lead to bank erosion downstream).

h. The streamflow velocity is not adequate to remove the debris on its own.

NOTE: Debris removal is appropriate not only in streams but in lakes and rivers suffering from excessive debris accumulations as well.

4.0 DESIGN AND IMPLEMENTATION GUIDELINES

4.1 General recommendations

a. No instream work should be done except at the specific locations where problems have been identified. Never undertake a mass cleaning of an entire stream section (ie. don't remove all debris). Before beginning your project, survey the stream and consult an expert to determine the problem areas, how much debris should be removed and how. Obtain permission from both the landowner and the government before beginning your project (see Getting Your Project Underway).

b. It is illegal to remove beaver dams. If problems are being caused in your stream by a beaver dam(s), you must refer your request to remove it to the New Brunswick Department of Natural Resources and Energy as this is entirely under their jurisdiction. For more information, refer to the N.B. Fish and Wildlife Act.

c. Avoid disturbing the streambed and banks. If any damage is done to streamside vegetation, or the bank is exposed, revegetate the area (see Fact Sheet B). Restrict your activity to one bank.

d. Do not use heavy equipment near the stream unless absolutely necessary (e.g. the removal of extremely large trees). Most smaller trees and stones can be removed with the help of a few strong backs aided by a block and tackle, levers and/or winches (hand winches or those mounted on a vehicle) or a small motorboat.

e. If heavy equipment is necessary, obtain prior permission to use it from a fishery officer. Choose your access routes carefully. Use roads if possible and avoid heavily wooded areas. Any damage to the woods, floodplain or streambank may cause a serious erosion problem.

f. Partial removals are usually more effective than complete ones as they reduce the chances of flooding and debris accumulation downstream of the project.

g. The timing of your project is crucial! Never attempt instream work during spawning or egg incubation periods since silting downstream could cause serious egg and/or fry mortality.

h. If areas downstream of your project support fish populations, measures such as silt trapping and removal to reduce the movement of silt downstream should be taken.

4.2 Materials to be removed

a. You should remove any badly damaged or dead trees and/or trees leaning sharply over the water along the streambank that appear to be in danger of falling into the water. This will prevent the creation of future silt collectors or fish passage obstructions. Leave the stump and roots in place to prevent bank erosion. Some trees that you cut may be repositioned parallel to the streambank to provide cover. Remember, all dead, damaged or leaning trees will not necessarily pose a future problem!

b. Remove all unnatural substances (ie. metals and plastics) from the streambed and banks such as tires, car bodies, bottles and paper and plastic litter.

c. Remove sediment accumulations large enough to obstruct flow. Smaller accumulations shoud be left undisturbed to avoid clouding the water.

d. Remove or reposition debris accumulations creating or likely to create unacceptable flow problems or obstruction to fish passage (e.g. logs jammed crossways can be repositioned parallel to the bank and maintained as fish cover). Do not disturb logs that do not span the channel. Remove only the mid section of logs spanning the channel. Leave each end in place to prevent bank erosion and to provide fish cover.

e. Gravel, rubble and boulder accumulations large enough to restrict flow or create a dam or waterfall may have to be removed. These should be assessed on an individual basis by a qualified person. Most isolated rock piles do not cause problems and should be left undisturbed.

5.0 IMPLEMENTATION STEPS

a. As with all habitat improvement projects, be sure to plan your project carefully and follow a systematic approach. As mentioned above, conduct a survey of the stream and consult with a fisheries biologist or fishery officer to determine where and how much debris to remove.

b. Select the area. The length of the stream section should be no more than 100 m (330 ft).

c. Begin work at the lowermost section of the designated improvement area and work upstream. If you start upstream, disturbed debris will drift downstream worsening the jams below making more work for you.

d. Cut instream root systems of shrubs and small trees using a hatchet, hand-saw or pruning shears. (It is recommended not to use chainsaws in the water ! The streambed may be slippery or unstable.) Remove the material from the watercourse.

e. Remove twigs and loose debris wrapped around logs on the stream bottom. If the logs do not span the channel and are not rotting, leave them instream. They will provide good fish cover once unclogged of debris accumulations.

f. Remove any loose, non-living logs lying near the surface of the water.

g. Remove any obvious obstructions (e.g. rock and log jams) which may be damming the stream, preventing fish passage or trapping silt. Start from the center of the stream working your way toward either bank.

h. Jams of larger logs or trees may be most effectively removed using logging equipment. If this is unavailable, manual labour combined with power saws can be used to dismantle the jam. Remove the material from the stream with the help of a vehicle (four-wheel-drive) fitted with a winch. Heavier equipment may be necessary in the case of large boulders blocking the stream.

i. After completing one thorough pass through your stream section, stop. Let the steam currents do their job - they should remove most of the remaining loose debris on their own. Return after two or three days to evaluate the stream's condition. If the original stream bottom is clearly visible, your task is complete. If, however, new logs have appeared or you still cannot see the stream bottom, repeat the above procedure.

j. All debris removed should be taken from the area and secured (e.g. burned, buried or piled) so that it cannot re-enter the watercourse.

k. If your work has exposed the streambanks, be sure to revegetate the area (see Fact Sheet B).

6.0 MAINTENANCE AND MONITORING

You should check your stream section periodically for two or three years. Remove any debris which has re-accumulated or any loose materials likely to form a new obstacle. As well, remove any litter along the streambanks. Check the banks to ensure that they are still stable and that any vegetation you planted has established itself.

7.0 FACTORS INFLUENCING COST

Debris removal projects are inexpensive providing they do not involve the use of heavy euipment. Costs would include chainsaw fuel, safety gear and the rental (if necessary) of logging equipment. If heavy equipment is required project costs can soar into the thousands of dollars range. Funding may be available in such special cases.

8.0 ADVANTAGES OF THE TECHNIQUE

a. re-opens fish migration routes;

b. exposure of gravel and rock on the stream bottom encourages recolonization of the area by fish and aquatic insects;

c. the size and diversity of fish populations will increase;

d. increased streamflows will scour accumulated silt deposits;

e. the width of the stream channel will be reduced by up to one third;

f. the water temperature may be reduced improving the stream's capacity to support fish;

g. faster streamflows will result in higher oxygen levels in the water also beneficial to fish populations.

9.0 DISADVANTAGES OF THE TECHNIQUE

a. obstruction removal may require intensive labour;

b. occasional maintenance is required to ensure that the debris does not re-accumulate;

c. release of silt could adversely affect downstream habitat;

d. beneficial habitat could be accidentally removed by workers;

e. stream barriers separate fish populations - their removal may cause detrimental competition between species.

10.0 EXAMPLES OF USE

The Department of Fisheries and Oceans sponsored a number of obstruction and debris removal projects on the Bartholomew River in New Brunswick during the late 1970's and early 1980's. A defunct dam, part of an old logging operation, was blocking flow at the river's origin. The dam was removed and woody debris which had been collecting in the headpond for years was cleaned out.

In the early 1980's, Dutch Elm disease swept through the province. Hundreds of these huge trees were killed along the Bartholomew River creating major obstructions along the entire watercourse when they fell. DFO, with the help of a number of public associations, removed the trees from the watercourse preventing serious stream diversion and bank erosion problems from occuring.

Since then, over 30 stream cleaning operations have been carried out in New Brunswick. Groups such as the Mirimachi Salmon Association, the Moncton Fish and Game Association, the Mirimachi Outdoor Club, and many others, have sponsored successful projects on the Mirimachi and Restigouche systems.

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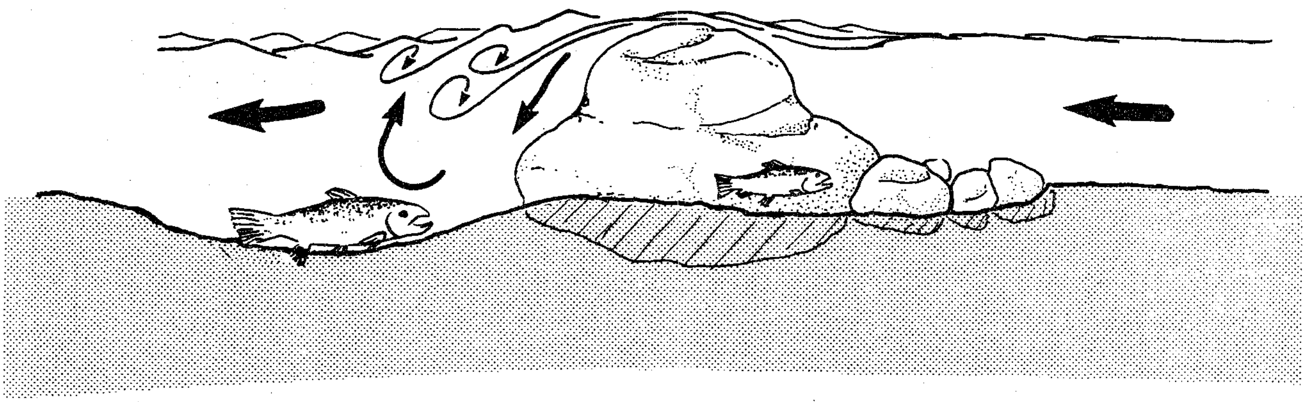
FACT SHEET "A"
INSTREAM DEBRIS REMOVAL
REVISED:



BOULDERS AND LOGS THAT DO NOT RESTRICT THE FLOW, SHOULD BE LEFT IN PLACE FOR COVER.

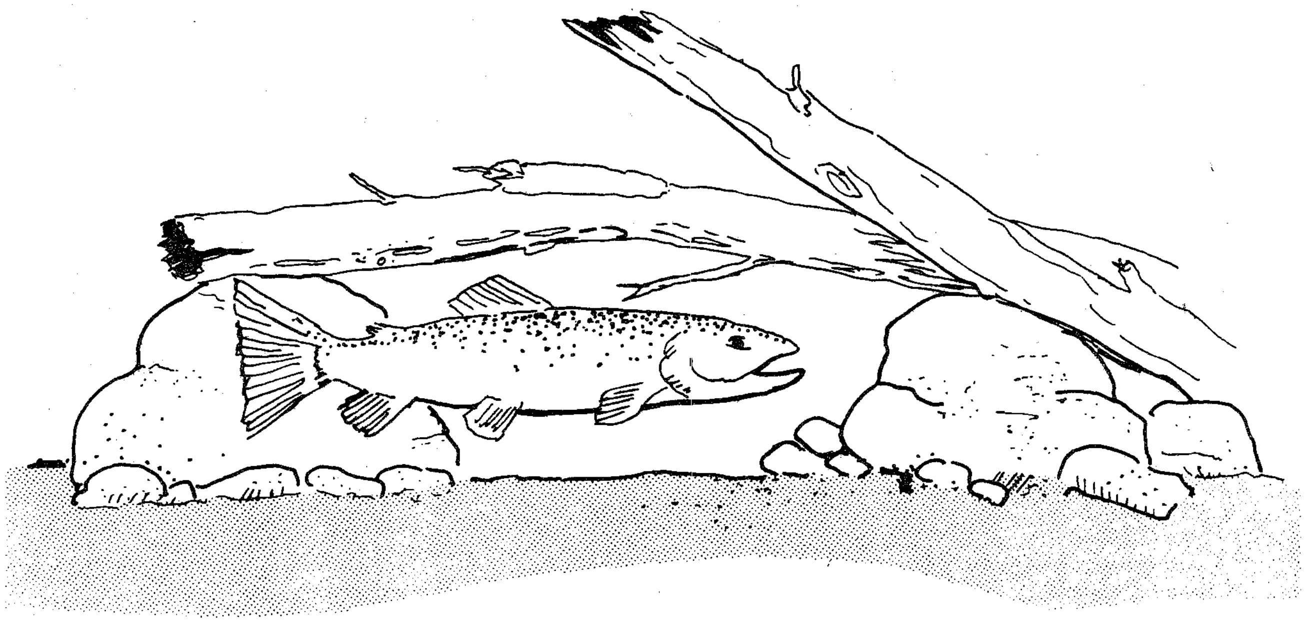


FIGURE A-1: *SOME TYPES OF DEBRIS PROVIDE COVER FOR FISH.*

FACT SHEET - B - REVISION: 07-11-88

STREAMSIDE PLANTING OF VEGETATION

*** ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

Vegetation planted along a waterbody stabilizes the bank and improves water quality. This technique should be used whenever a habitat improvement project will expose the streambank or where past activities have resulted in erosion. Surprisingly, the plants suggested here are more effective in certain situations than engineered structures for stabilizing banks. Natural methods of stream improvement should always be considered first although engineered structures are more appropriate when erosion must be controlled immediately.

This fact sheet describes the techniques used to plant grass and trees. The specialized technique of bank stabilization using brush and twig bundles is also described. Facts sheets E, F and G describe engineered structures.

2.0 PURPOSE

Streamside vegetation is important for the following reasons:

a. Plant roots stabilize the streambanks reducing erosion and the resulting sediment deposition.

b. The roots and overhanging branches of the plants along the water's edge provide cover for fish.

c. Large trees provide shade and reduce solar heating of water in the summer.

d. Streamside vegetation provides a resting and breeding place for insects which may eventually fall into the water to become food for fish.

e. Leaves and other organic matter which fall into the water provide food for aquatic insects and nutrients for micro-organisms.

f. Streamside vegetation is aesthetically pleasing and provides food and cover for birds and other wildlife.

3.0 CONDITIONS WHERE APPLICABLE

This technique is used along fresh water (e.g. streams, rivers, lakes) and salt water shorelines (e.g. estuaries, bays, oceans) where vegetation has been removed either through man's activities (e.g. agriculture, forestry, etc.) or trampling by livestock.

4.0 DESIGN AND INSTALLATION GUIDELINES

4.1 General Recommendations

a. It is preferable for the shoreline to be at a stable slope. If not, it may be necessary to grade or stabilize the bank (see Table 4.1).

b. Examine the area to determine which species thrive along the streambanks under local conditions.

Table 4.1 Guide for stabilizing slopes.

Slope*	Technique	Treatment
0.5 : 1 unstable	brush and twig bundles, or rip rap	These slopes sometimes hold without treatment. If the soil is unstable, the bank must be resloped to a lower angle.
1 : 1 unstable	combine brush and twig bundles with planting	Mulching and fertilization is almost always necessary. Brush and twig bundles can be used alone or in combination with rip-rap.
2 : 1 stable	plant	Can loosen soil to apply fertilizer and seed. Should use light mulch on droughty soils.
4 : 1 stable	plant	Can cultivate with machinery. Drill in fertilizer and seed.

*ratio of horizontal to vertical distance

c. Determine planting objective(s) to decide what mixture of grasses, legumes, shrubs and/or trees should be planted. For example:

i) ground cover - plant grasses and legumes

ii) shade and ground cover - plant shrubs and trees

iii) maneuverability for fisherman - plant low shrubs

iv) fish food production - plant densely

d. To ensure the bank of the watercourse is not over-planted, follow these guidelines:

- stream width less than 4.5 m (15 ft)	- plant grasses and annuals
- stream width 4.5 to 9 m (15 to 30 ft)	- plant a combination of low shrubs approximately one metre apart
- stream width greater than 12 m (40 ft)	- plant shrubs and trees

e. Consider soil type, drainage conditions, high water levels, water salinity (if applicable) and wind and sun directions before selecting the areas and species to be planted.

f. On a gradually sloping bank a strip at least 10 m (33 ft) wide should be planted along the bank above the high water level (see figure B1).

i) the first 2 to 3 m (7 to 10 ft) above the high water level should be planted with species resistant to flooding and ice damage such as alder, willow and sweet gale (see figure B1 and B2).

ii) the other 7 or 8 m (23 to 26 ft) should be planted with shrubs and possibly tree species (see figure B1).

g. If the slope is steep, the width of the planted strip along the bank should be greater than 10 m (33 ft). The width increases with the steepness of the slope.

h. If the bank has been stabilized with a retaining wall, the area in front of the base of the wall should be planted unless it is below the low water level.

i. In estuarine areas, grasses and shrubs resistant to salt water (e.g. sweet gale) should be selected.

4.2 Plant Species Selection

In general, streamside vegetation should consist of a mixture of grasses, shrubs and trees. Grasses and legumes should be seeded first. Legumes supply nitrogen to the soil and consequently enhance the establishment of other plants. Planting shrubs helps to activate the natural process of regeneration and to ensure more complete stabilization of the soil. Trees shade the stream.

4.2.1 grasses and legumes

Five mixtures of herbaceous seeds are suggested in Appendix B-1. Mixtures 1, 2 and 3 should be sown at a rate of 0.8 kg/100 sq m (80 kg/ha). Mixtures 4 and 5 should be sown at 1.3 kg/100 sq m (130 kg/ha). Hydroseeding can be done from spring thaw until late September. Seeding by hand should be carried out in late spring or early summer when conditions are neither too wet nor too dry. The suggested species and patented mixes of seed are available commercially from agriculture co-operatives and dealers in grain and feed-crop seed. The individual species are described in Appendix B-2.

4.2.2 shrubs

Shrub species suitable for the revegetation of streambanks are listed in Appendix B-3. Soil moisture conditions under which they grow, and suitable reproduction methods, are given for the species that are tolerant to flooding. The shrub species listed in Table B-2 are intolerant to flooding and therefore should be planted further back from the water's edge. Individual species are described in Appendix B-4.

Shrubs should be planted less than 1 m apart. Alternate the plants so that they are arranged in a zig-zag pattern (see Figure B-3). Plant shrubs deep where a greater amount of moisture is available and pack firmly. The ideal time for transplanting shrubs is in the spring but pot cultivation allows this period to be extended into the summer. Cuttings should be planted as soon as possible after spring thaw.

On steep or abrupt slopes it is necessary to use a special planting method. Shrubs are used to make twig and brush bundles and stakes (see Figure B-4). These are placed along the slope and will create a vegetated bank in 3 years. During the first year, the twig bundles will root while the stakes hold them in place. The brush bundles will root during the second year and further stabilize the bank. By the third year, the slope is stabilized and has a natural appearance.

4.2.3 trees

Trees should be planted in locations where the soil is stable: not close to the water's edge or on the crest of a slope. In general, it is preferable to plant trees above the high water line (see Figure B-1). When planting trees, try to follow the natural line of tree growth along the bank. They should be placed at least 5 m apart. Several tree species suitable for streamside planting are red maple, sugar maple, balsam poplar and grey birch. These species are tolerant to flooding. Other suitable species, intolerant to flooding, are white birch and trembling aspen.

5.0 IMPLEMENTATION STEPS

5.1 Description of techniques (see Figure B-4)

5.1.1 twig bundles

Twig bundles should be made in the fall and kept in a cool, moist place throughout the winter. Select species which root easily as cuttings, such as willow and red oiser dogwood. Each twig should be approximately 30 cm (12 in) in length with at least one or two buds. Tie a fist-sized bundle of twigs together with a rubber band or string. The twigs should all be pointing in the same direction.

5.1.2 brush bundles

Brush bundles should also be gathered in the fall and stored throughout the winter. Select the same plant species as for twig bundles. Stems should be 150 cm to 180 cm (5 to 7 ft) in length. Tie bundles together with wire. The bundles should point alternately in opposite directions.

5.1.3 stakes

Select alder shrubs and cut to a length of 60 to 90 cm (2 to 3 ft). Sharpen their points with an axe. These stakes should not rot quickly or root in the soil.

5.2 Application of the Technique (see Figure B-4)

a. The work should be done in the spring.
b. Terrace the bank slightly.
c. Begin at the bottom of the slope and complete one terrace at a time .
d. Put vertical stakes in place.
e. Put horizontal stakes in place and wire to vertical stakes.
f. Place brush bundles horizontally along the slope.
g. Cover with soil .
h. Cover the brush bundles with twig bundles. Stick the twig bundles 12 to 15 cm (5 to 6 in) into the ground.
i. Cover partially with soil.
j. If more height is required, a second brush bundle can be added over the horizontal stakes. This would fall between

steps (d) and (e).

k. Continue to the next terrace.

6.0 MAINTENANCE AND MONITORING

The sites should be monitored to determine the survival of the planted vegetation. Plants lost to animal damage or winter kill should be replaced. Some shrub species may require cutting back every 3rd or 4th year to improve low, dense growth characteristics.

7.0 FACTORS INFLUENCING COST

The primary factors contributing towards overall cost are the price of the plants and transportation expenses. Soil cultivation costs may be significant if hydroseeding is used. Plants suggested in this fact sheet should thrive with minimal care.

8.0 ADVANTAGES OF THE TECHNIQUE

a. This technique has many direct and indirect benefits for fish (e.g. improves water quality).

b. The improvement work has a natural appearance and is self-renewable.

c. Many of the plant species are beneficial to birds and other wildlife.

d. The improvement work is relatively simple to perform.

e. Planting costs are low.

f. In most circumstances long term maintenance will not be necessary.

g. It does not require the use of heavy equipment.

9.0 DISADVANTAGES OF THE TECHNIQUE

a. Restricts other land use possibilities.

b. Improper planting may do more harm than good (e.g. shrubs planted too close to water's edge may cause excessive shading, silt and debris accumulation).

c. Some maintentance of planted areas may be required.

d. In some areas (e.g. steep banks, high velocity currents) this method may have to be combined with engineered structures.

10.0 EXAMPLES OF USE

A project was carried out by Fisheries and Oceans in Nova Scotia on Pinevale Brook, a tributary of South River. Reed canary grass was used to stabilize areas where silt had accumulated near half log structures. The grass was seeded manually. Fertilizer appeared to be very important for the establishment of the grass.

A hydroseeding project was carried out in the Bathurst area by the Department of Natural Resources and Energy. Three road and stream crossing sites were seeded with a mixture of red fescue, Kentucky bluegrass, rye grass, red top and white clover. No prior site preparation was done. The hydroseeder was used to spread and cover the mixture of seeds, fertilizer and mulch. The two level sites seeded successfully. The third site, sandy with a 30 degree slope, was not successful. For severe critical erosion areas, it was felt that site preparation should be done.

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APPENDIX B-1

RECOMMENDED MIXES OF HERBACEOUS PLANTS

These mixtures should be available commercially from agriculture co-operatives and dealers in grain and feed-crop seed.

Mixture 1 - ground temporarily flooded in the spring

alsike clover	10%
creeping white clover	10%
timothy	40%
reed canary grass	40%

Mixture 2 - ground gently sloping

alsike clover	15%
red fescue	55%
red top	15%
timothy	15%

Mixture 3 - ground sloping, well drained

Canada bluegrass	30%
creeping white clover	15%
orchard grass	35%
smooth broome grass	20%

Mixture 4 - ground poor, rocky without organic soil

Patented mixes MR-77 and LAB 2001 produce a resistant perennial herbaceous cover of moderate growth, without addition of surface earth.

Mixture 5 - sandy ground

Patented mix LAB 2009 is useful for retaining sand, even under saline conditions, in areas where wind erosion is moderate to average.

APPENDIX B-2

HERBACEOUS PLANT SPECIES

Grasses

The following grasses have been selected for their aggressiveness which allows them to colonize soils quickly. If your stream is close to an agricultural area, inform local farmers that these grasses are not weeds.

a. **Canada bluegrass** (*Poa compressa*) - This is a rustic plant with a coarse texture resistant to drought and trampling. It survives and grows on dry, sandy soilsas well as on poorly drained clay soil.

b. **orchard grass** (*Dactylis glomerata*) - This plant grows vigorously and tall.

c. **reed canary grass** (*Phalaris arundinacea*) - This plant grows very tall and erect. It prefers moist soil but tolerates both prolonged spring flooding and drought.

d. **red fescue** (*Festuca rubra*) - This plant prefers dry, sandy soils but can tolerate shade and boggy conditions.

e. **red top** (*Agrostis alba*) - This is a hardy plant which reproduces by rhizomes and stolons. It prefers moist soils but can survive for a short time in well drained areas.

f. **smooth broome grass** (*Bromus inermis*) - This plant may spread into large colonies in scattered locations. It is resistant to drought.

g. **timothy** (*Phleum pratense*) - This plant grows erect and has a rough texture. It tolerates drought and flooding.

Legumes

a. **alsike clover** (*Trifolium hybridum*) - This plant can tolerate poor, badly drained soil.

b. **creeping white clover** (*Trifolium repens*) - This is a hardy, stoloniferous plant. It survives in acidic, poorly drained soils.

APPENDIX B-3

RECOMMENDED SHRUB SPECIES

Table B-1. Non-native shrub species tolerant to flooding.

SPECIES	SOIL MOISTURE			PROPOGATION		
	M	A	D	S	HC	WC
bank wild rose	*	*	*		*	
silverberry	*	*	*		*	

Soil Moisture - M (moist), A (average), D (dry)
Propogation - S (seed), HC (herbaceous cutting), WC (woody cutting)

NOTE: Seed and herbaceous and woody cutting refer to methods of propogating your plant species. Herbaceous cuttings (soft parts of the plant such as a stem and leaf) are rooted in water, then planted. Woody cuttings, such as twigs and branches, can be rooted directly into the ground.

Table B-2. Native shrub species intolerant to flooding.

SPECIES	SOIL MOISTURE		
	M	A	D
beaked hazel (*Corylus cornuta*)		*	
choke cherry (*Prunus virginiana*)		*	*
elderberry (*Sambucus canadensis*)	*	*	
high-bush cranberry (*Viburnum triloburn*)		*	*
serviceberry (*Amelanchier* sp.)		*	*
staghorn sumac (*Rhus typhina*)			*
Virginia creeper (*P. quinquefolia*)	*	*	*

Soil Moisture - M (moist), A (average), D (dry)

Table B-3. Native shrub species tolerant to flooding.

SPECIES	SOIL MOISTURE			PROPOGATION		
	M	A	D	S	HC	WC
bayberry					*	
broad-leaved meadowsweet	*	*				*
buffalo-berry		*	*	*		
red osier dogwood	*	*	*	*		*
shrubby cinquefoil		*	*		*	
speckled alder	*			*		
sweet gale (salt resistant)	*				*	
willow	*					*
witherod	*					

Soil Moisture - M (moist), A (average), D (dry)

Propogation - S (seed), HC (herbaceous cutting), WC (woody cutting)

APPENDIX B-4

CHARACTERISTICS OF RECOMMENDED SHRUB SPECIES

a. **bank wild rose** (*Rosa johanensis*) - This rosebush grows on the shores of lakes and streams. It can survive temporary flooding. It grows up to 1metre tall with a more or less erect, thick stem. This shrub has a running and suckering root system.

b. **bayberry** (*Myrica pensylvanica*) - The bayberry's root nodules fix nitrogen from the air. This bushy and pleasant smelling plant can withstand salinity and grows spontaneously on seashores.

c. **broad-leaved meadowsweet** (*Spiraea latifolia*) - This shrub grows in a wide variety of soils preferring wet, open environments such as the banks of streams and ditches. It grows 1.5 to 2 metres in height and stands erect. The roots are fibrous.

d. **buffalo-berry** (*Shepherdia canadensis*) - The root nodules of this shrub fix nitrogen from the air. This species is very resistant to dryness and salinity. It grows from 1.5 to 2 metres in height with a more or less erect, thick stem. The nodulated roots are suckering.

e. **red osier dogwood** (*Cornus stolonifera*) - This is a stoloniferous shrub which adapts to all environments: dry, wet, temporarily flooded, shaded or sunny. Its stoloniferous root system and its adaptability make it an ideal shrub for fixing soils. The red osier dogwood grows 1 to 3 metres in height in a spreading pattern. It has a running root system.

f. **shrubby cinquefoil** (*Potentilla fruticosa*) - This species grows in a variety of soils but prefers open places or rocky shorelines. It tolerates salinity. The shrubby cinquefoil grows to 1 metre in height with a short, thick stem. Its running roots are very fibrous.

g. **silverberry** (*Elaeagnus commutata*) - This is a suckering shrub whose root nodules fix nitrogen from the air. It can survive in poor, dry soils and tolerates salinity. The silverberry grows 1 to 4 metres in height on its thick, erect stem. The roots are nodulated, running and very stoloniferous.

h. **speckled alder** (*Alnus rugosa*) - This is a very hardy shrub whose root nodules fix nitrogen from the air. It grows best in a wet environment. It can survive prolonged flooding but does not tolerate dryness well. It grows 2 to 4 metres in height and usually in clumps. The roots are shallow. Although alders are often considered pests, they are among the most well-adapted shrubs for stabilizing soil. To avoid problems, never plant alders in low gradient streams.

i. **sweet gale** (*Myrica gale*) - This shrub's root nodules fix nitrogen from the air. It grows on sandy shorelines and can survive prolonged flooding. The sweet gale, a bushy, pleasant-smelling shrub, grows to about 1 metre in height. It has a running root system.

j. **willows** (*Salix* sp.) - Willows are suited to wet terrain and tolerate more or less prolonged flooding depending on the species. Their height is variable and they have running root systems.

k. **witherod** (*Viburnum cassinoides*) - This plant, also known as wild raisin, is usually found in the moist, acid soils of swamps, bog edges and shores but can grow in a variety of soils.

FACT SHEET "B"
STREAMSIDE PLANTING OF VEGETATION
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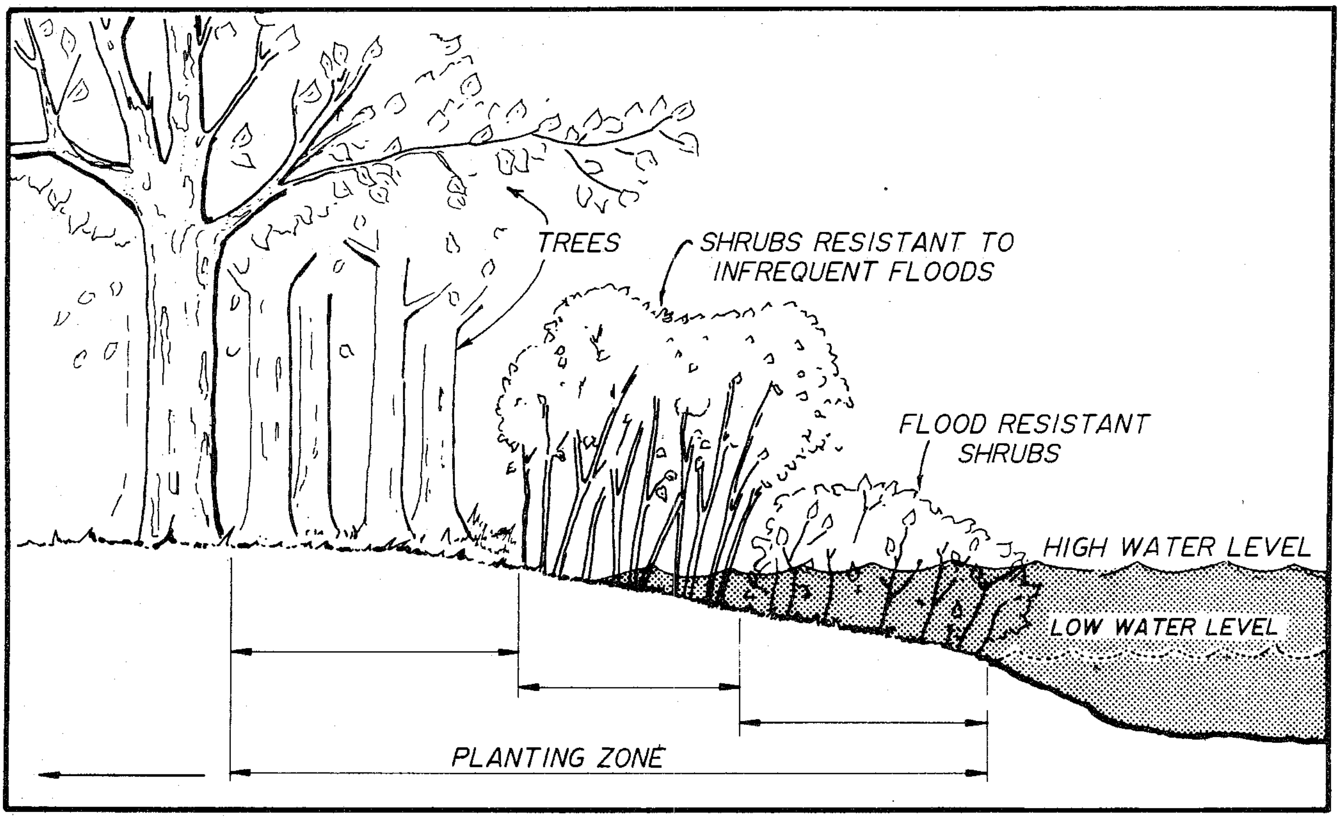

FIGURE B-1: REVEGETATION ON A GRADUALLY SLOPING BANK

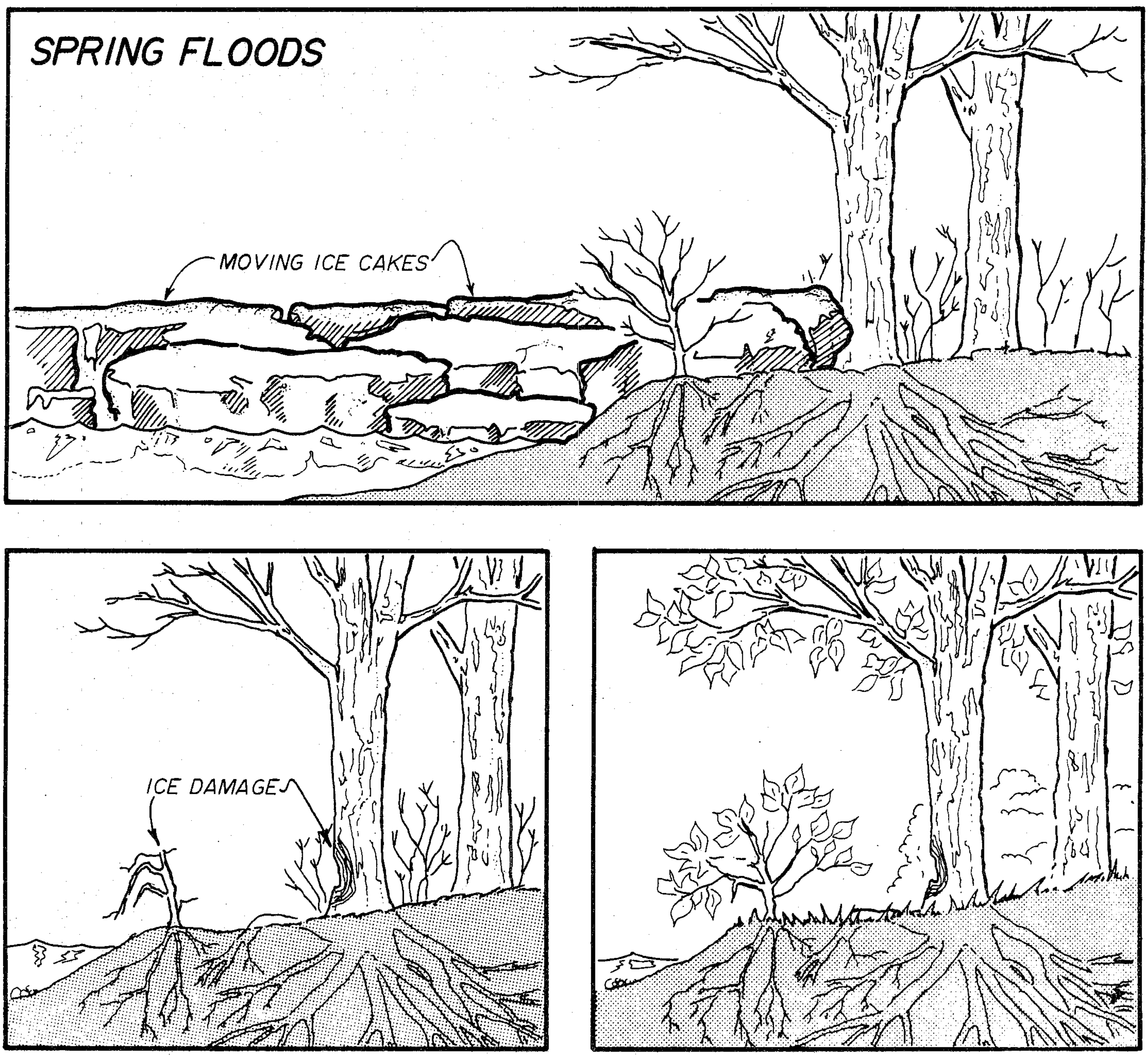

FIGURE B-2: ACTION OF ICE ON BANK VEGETATION IN THE SPRING SHOWING REJUVENATION OF A DAMAGED SHRUB. EVEN WHILE DAMAGED, THE ROOTS OF THE SHRUB STILL RETAIN SOIL, PREVENTING BANK EROSION.

FACT SHEET "B"
STREAMSIDE PLANTING OF VEGETATION: SHRUBS
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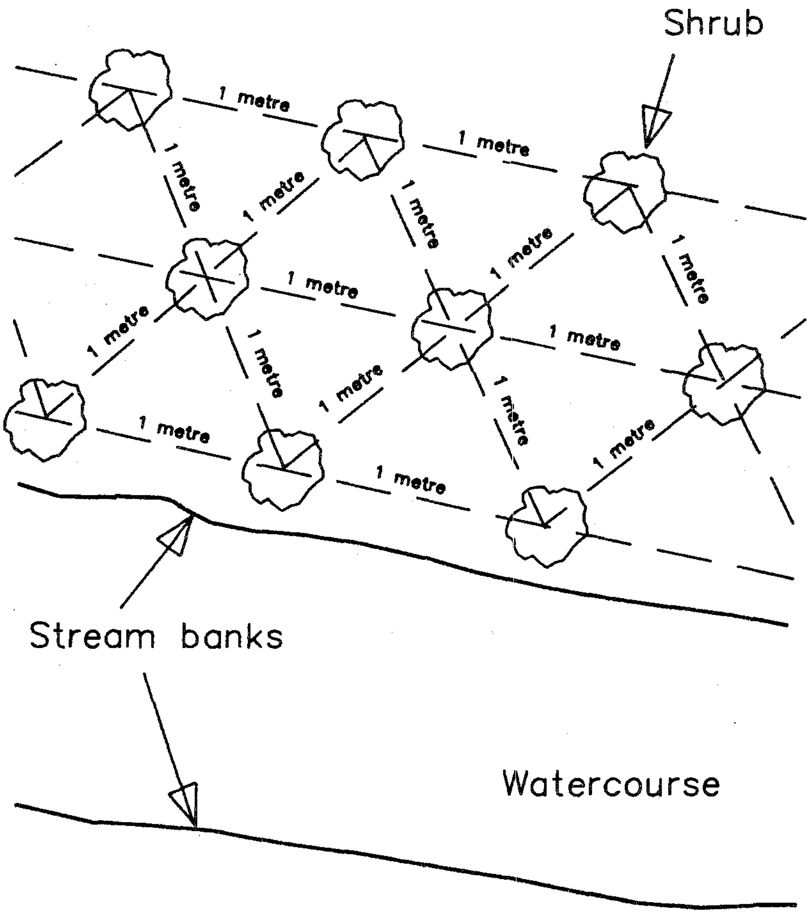
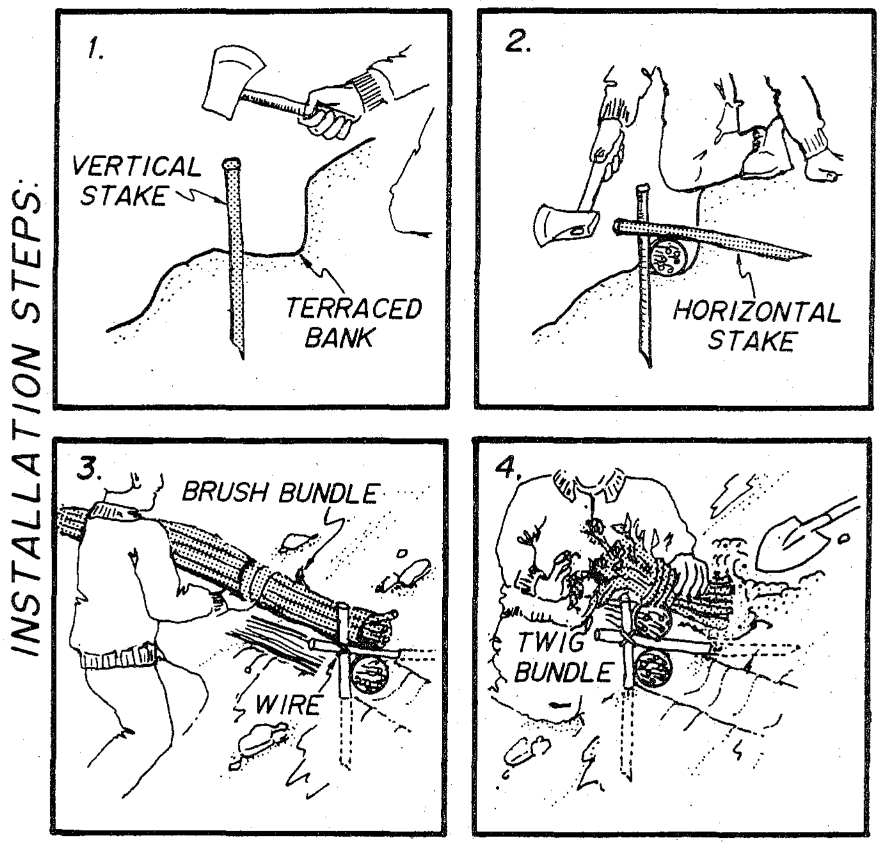
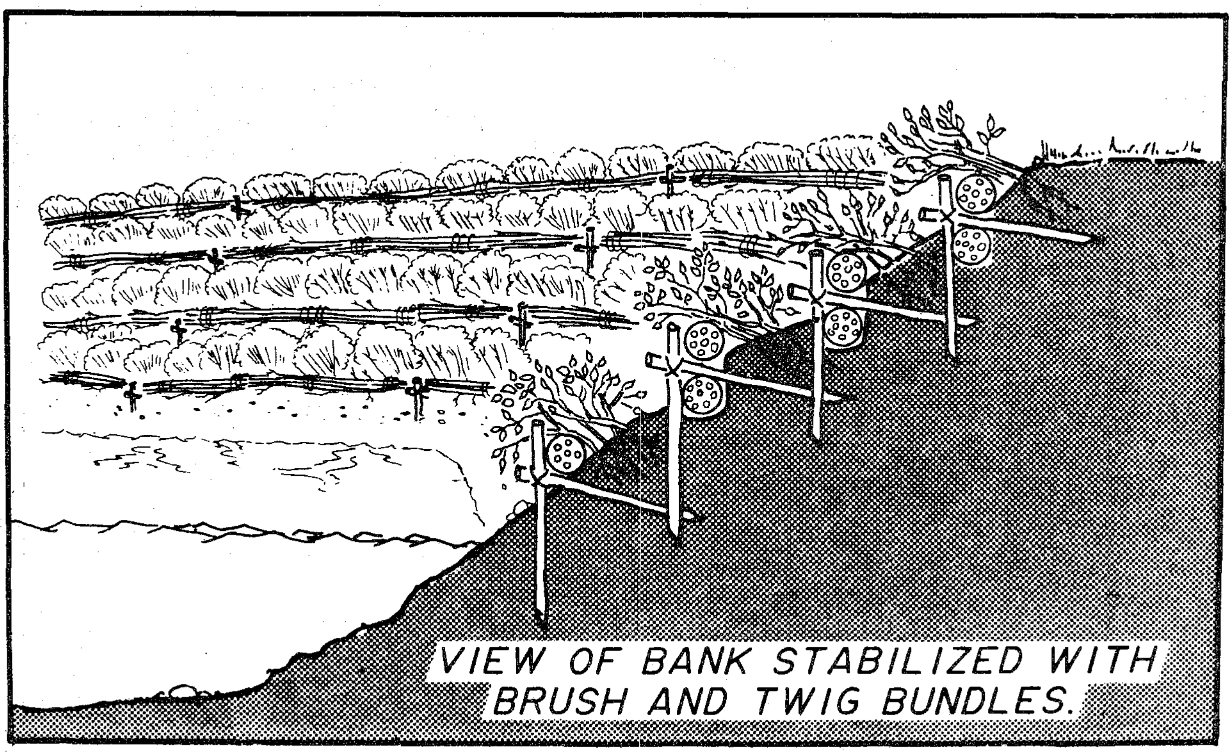


FIGURE B–3: ZIG–ZAG PATTERN BY WHICH SHRUBS SHOULD BE PLANTED FOR SHORELINE STABILIZATION.

FIGURE B-4:





VIEW OF BANK STABILIZED WITH BRUSH AND TWIG BUNDLES.

FACT SHEET **- C -** **REVISION: 09-11-88**

INSTREAM PLACEMENT OF BOULDERS

*** ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

Boulders are rocks 25 cm (10 in) or greater in diameter. They can be placed in a watercourse to accelerate, slow down or break up the current. Boulders also improve fish habitat by creating cover in areas where it is lacking. Scour holes develop on the downstream side of the boulders providing a sheltered area for the fish to rest and feed (see Figure C-3). Boulders can be placed individually but work well in groups of two, three, four or more.

2.0 PURPOSE

a. nursery cover

Boulders located along the edge of a stream provide a place for fry to escape fast currents and hide from predators. A dense placement of individual boulders provides good nursery cover.

b. cover in riffles and runs

In faster currents, boulders provide resting and feeding places for juvenile and adult salmonids. Fish tend to lie downstream of the boulders where they don't have to fight a continuous current. They can dart from either side to pick up food carried in the current. Boulders may cause a reduction in fighting among juvenile fish and a decrease in the size of their territories. Boulders also provide refuge for adult fish migrating upstream.

c. cover in pools

Adult fish use boulders for cover in pools. These boulders are particularly effective during periods of low flow when little cover is provided by the water's depth.

d. winter shelters

Boulder placement in areas described in parts a., b. and c. above will also provide these fish with areas where they can remain relatively inactive during the winter season, thus conserving energy.

e. bottom cleaning

Boulders can act as small deflectors, concentrating and accelerating the stream flow. This cleans the stream bottom by dislodging fine sediments and carrying them downstream.

f. surface turbulence

Placing boulders directly beneath the water's surface will riffle the otherwise smooth surface decreasing the visibility of the fish from above the water.

3.0 CONDITIONS WHERE APPLICABLE

This technique is used in streams lacking cover. This may be a natural occurrence or the result of the removal of substrate from the streambed to prevent log jams during stream drives. It should not be used in streams where ice scouring and flooding are a problem.

Boulder placement is most effective in wide, shallow, swift-flowing stream channels. It is often used in slow-moving sections to increase the water velocity. This technique is most effective in stable channels with large gravel and/or rubble bottoms. Unstable streambeds, consisting of fine gravel or sand, will shift under the pressure of the stream flow, burying the boulders. Boulders, therefore, should be used only where the bed material will remain relatively stable during floods. Stream bottoms consisting of large gravel or cobble are reasonably stable if flood velocities do not exceed 2.4 m/sec (8 ft/sec).

Elevated banks are preferable. Ensure that the streambanks of the section to be improved are stable because large rocks may divert the stream current against one or both banks. If the banks are easily eroded, bank protection will be required. It is preferable to work on straight stretches rather than sharp curves and meanders.

Normally, boulder placement is not necessary when the pool : riffle ratio exceeds 20 percent pools.

4.0 DESIGN AND INSTALLATION GUIDELINES

a. Conduct a stream survey during moderate or low flow conditions when the bottom substrate can be seen easily:

i) assess the need for boulders
ii) determine if ice scouring or flooding is a problem
iii) determine if banks are stable
iv) note access to various river reaches

b. Determine whether there is a nearby source of boulders. Angular boulders which will not disintegrate and are large enough to resist the force of the water are preferable.

c. From the survey, draw a plan view of the stream channel(s) to be improved.

i) identify areas where boulders should be placed
ii) determine the number of boulders required
iii) determine the size of the boulders required
iv) rocks must be large enough to resist displacement during floods

NOTE: If the bottom is stable, a rock of 0.6 m (2 ft) diameter weighing about 454 kg (1000 lbs) will resist movement in current velocities up to 3 m/sec (10 ft/sec). A 1.2 m (4 ft) rock will be stable in velocities up to about 4m/sec (13 ft/sec). Table C-1 shows the correlation between the size and weight of rocks.

d. A rock should not be greater in its largest dimension than one fifth of the width of the channel at normal summer flows.

e. As a general rule, allow one large rock per 27 sq m (300 sq ft).

f. Stockpile boulders by the stream edge (above the high water level) during the winter months if necessary.

g. Move the boulders to the improvement site(s) with a loader. Remember, heavy equipment will be used only if absolutely necessary.

h. Carry out boulder placement during the summer low flow period in trout streams and from mid-July to mid-September in salmon streams. Remember that streambank damage and costs are reduced by the careful choice of access points.

i. For smaller boulders, the final arranging can be done after they have been deposited at the site.

5.0 IMPLEMENTATION STEPS

5.1 Placement of single boulders.

a. Boulders should be placed at the upstream end of a shallow pool or run and the middle or downstream end of a riffle.

b. Riffle areas must have an adequate, even flow of water so the boulders will not cause the filling in of gravel.

c. Angular, elongated boulders are best for forming scour holes. The longest side should be placed at 90 degrees to the bank.

d. Larger scour holes will form in swifter currents.

e. Ensure all boulders fit snugly into the stream bed (10-30 cm or 4-12 in) and are placed on bed material relatively free of larger rocks.

f. Boulders should never be closer than 1m (3.3 ft) to the bank. Avoid diverting the current directly towards the streambank.

g. Boulders should not obstruct more than 20% of the stream.

h. Place all boulders so that they will be operational in low water periods. Those which protrude above the water at low and medium flows provide superior benefits to habitat.

i. Clumps of boulders resist ice movement, form large scour holes, reduce stream velocities by increasing channel roughness and provide cover for fish (see section 5.2).

j. If the water becomes murky easily, begin placing boulders at the downstream end and work upstream.

k. If a canoe channel exists before the improvement work is begun, ensure it is kept clear of boulders.

5.2 Placement of groups of boulders (see Figure C- 1)

5.2.1 General Guidelines

a. These guidelines are for streams 4 to 8 m (13 to 26 ft) wide.

b. Boulders should weigh approximately 50-100 kg (110-220 lbs).

c. Banks should be stable and elevated 1 m (3.3 ft) or more above the high water level

d. Boulders should be placed at least 10 cm (4 in) into the streambed (see Figure C-2).

5.2.2 Two Boulders

a. Place the boulders at least 1 m (3.3 ft) from the bank.

b. Groups can be placed randomly.

5.2.3 Three Boulders (triangle shape)

a. Place in the middle third of the stream.

b. The point of the triangle should be facing upstream.

c. Groups can be placed randomly.

d. If placed behind one another, leave a distance of 8 to 16 m (26-53 ft) between groups.

5.2.4 Four Boulders (diamond shape)

a. Place the boulders in the middle third of the stream.

b. The point of the diamond should be facing upstream.

c. Groups can be placed randomly.

d. If placed behind one another, leave a distance of 8 to 16 m (26-53 ft) between groups.

5.2.5 Three Boulders (parallel rows)

a. Groups should be at least 1m (3.3 ft) from the bank.

b. Rows should be parallel to the current.

c. Place two rows, with 1m (3.3 ft) between rows.

5.2.6 Five to Six Boulders (semi-circle)

a. Place the boulders at least 1m (3.3 ft) from the bank.

b. The center of the arc faces upstream.

c. Leave 1m (3.3 ft) between rows.

d. It is preferable to alternate from one side of the stream to the other.

e. Leave 8m (26 ft) between groups, measuring along the center of the stream.

6.0 MAINTENANCE AND MONITORING

Depending on the stream and the placement of the boulders, monitoring and maintenance work may be necessary on an annual basis. Ice scour and flooding may cause movement of the boulders. Undesirable currents may cause bank or streambed erosion and sediment or gravel deposition may occur if boulder placement creates flow separations and eddies.

7.0 FACTORS INFLUENCING COST

The primary factor influencing the cost of this technique is the proximity of boulders. The relative ease of access to the streambank is another consideration.

8.0 ADVANTAGES OF THE TECHNIQUE

a. Boulders may be readily available near potential improvement sites.
b. The improvements can be relatively long-lasting.
c. The improvement work has a natural appearance.
d. The technique requires no engineering skill.

9.0 DISADVANTAGES OF THE TECHNIQUE

a. The structures may require frequent maintenance.
b. It can be very expensive if boulders are not nearby.
c. Placement of boulders often requires the use of machinery in the watercourse.
d. Boulders near banks can cause erosion where the substrate is not stable.
e. Boulders will disappear in time in certain rivers (e.g. gravel bottom).

10.0 EXAMPLES OF USE

Boulder placement has been used as an enhancement technique in New Brunswick on the Big Tracadie River (see NBDNRE, 1978). Results have been variable. Some enhancement sites have remained unsilted and the rocks have retained their positions. Other sites have filled in with gravel and the rock formations have broken up. Rocks fractured because sandstone, available at a nearby quarry, was used. In the unsilted improved sites, sampling has revealed salmon parr and juvenile brook trout populations of over 50 fish per 100 sq meters compared with virtually no fish older than fry in the same sections prior to enhancement.

Boulder placement has been used in Nova Scotia for habitat improvement on Elderkin Brook, Kings County, and on Frenchvale Brook, Cape Breton (personal communication, B. Sabean, Nova Scotia Dept. of Lands and Forests). Habitat improvement in both streams involved the use of several techniques in addition to boulder placement. Changes in adult trout populations were documented although such changes cannot be attributed to particular improvement techniques. Maintenance of structures is an ongoing need for both streams.

11.0 REFERENCES

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APPENDIX C-1
BOULDER WEIGHT AND SIZE APPROXIMATIONS

TABLE C-1. Approximate weights and measurements for a square rock assuming 150 lbs/cu ft.

LENGTH		WEIGHT		VOLUME	
m	in	kg	lbs	cu m	cu ft
0.25	10	50	105	0.02	0.6
0.50	20	310	690	0.13	4.4
0.75	30	990	2,200	0.42	14.8
1.00	40	2,360	5,250	1.00	35
1.26	50	4,720	10,500	2.00	70
1.44	57	7,090	15,750	3.00	105

FACT SHEET "C"
INSTREAM PLACEMENT OF BOULDERS
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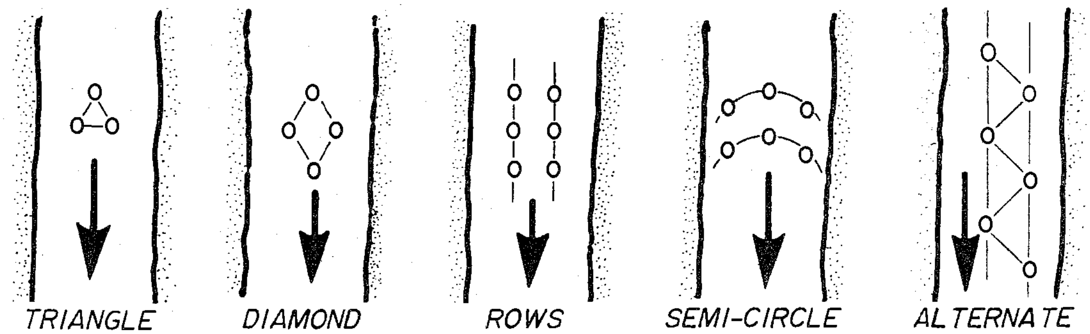

FIGURE C-1: GROUPING OF BOULDERS

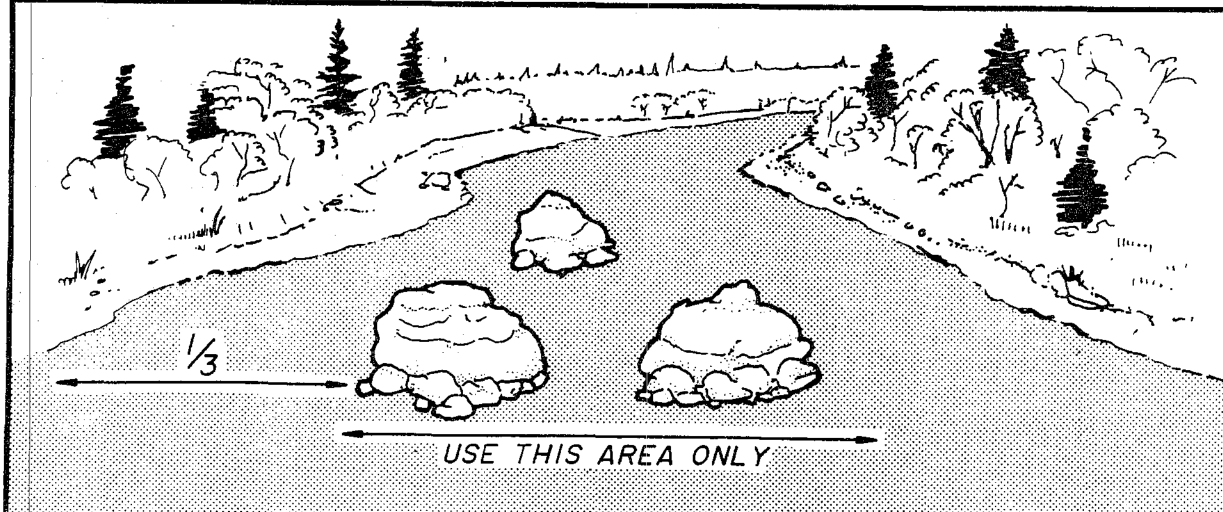

FIGURE C-2: AERIAL VIEW

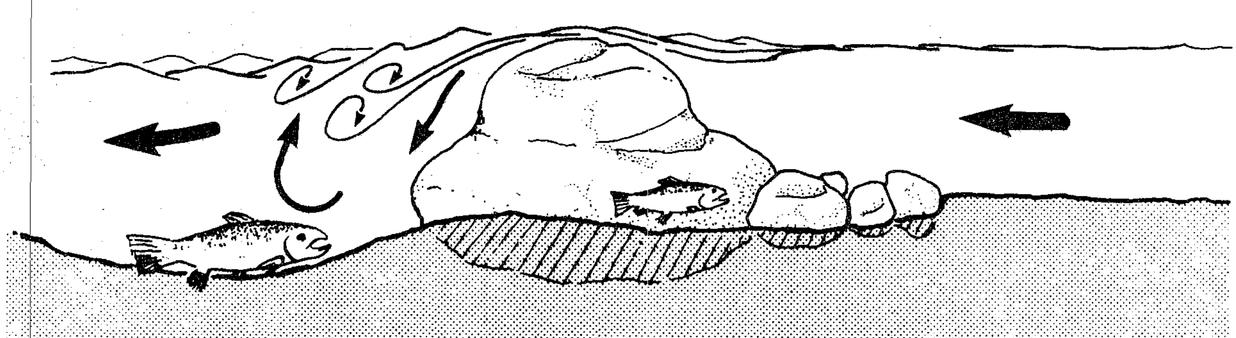

FIGURE C-3: CROSS-SECTION

FACT SHEET - **D** - REVISION: 17-11-88

INSTREAM WOODEN SHELTERS: HALF LOG and TREE

*** ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

These wood base techniques are easy to assemble structures which can be used to improve fish habitat in streams lacking cover. These techniques can be used alone or in combination with other stream improvement structures.

Tree shelters are felled trees placed parallel to the current along the bank with their tops angled downstream. The trunk of the tree can be secured onto the shore using several methods. If necessary, rebar can be used at regular intervals along the trunk to hold the tree in place.

Half log structures are constructed using a log split in two lengthways. The flat side of the log is supported underneath at each end with a wooden block. The half log is held in place by driving rebar through pre-drilled holes in both ends of the structure and into the streambed.

There are a variety of other techniques which can be used in streams to provide shelter for fish. Those discussed in this Fact Sheet are recommended.

2.0 PURPOSE

These techniques provide cover for juvenile and adult fish. Fish use both tree and half log structures for shelter and feed in the water flowing past.

Tree shelters may be useful for bank stabilization particularly along the outside of meanders. They should not be used as deflectors as this could cause erosion problems.

Remember, cover devices do not necessarily improve habitat for young salmon. These devices may be better suited to trout habitat improvement.

3.0 CONDITIONS WHERE APPLICABLE

3.1 HALF LOG STRUCTURE (see Figure D-1)

These structures should be used in low to medium gradient streams less than 10 m (33 ft) wide lacking cover. Larger, steeper streams are more likely to suffer ice scouring resulting in damage or burial of the half log structures. Also, flooding should not be severe. Half log structures will last longer if completely submerged at all times.

Half logs should be shelters, not sediment collectors. Your half log structure should be used in relatively sediment-free areas only and placed on solid substrate.

Caution - Large, steep streams can form huge ice sheets. When broken up during spring thaws these sheets can scour stream and river bottoms putting your labours to waste.

3.2 TREE SHELTER (see Figure D-2)

Tree shelters should be used in streams lacking cover and approximately 4 to 8 m (13 to 26 ft) wide. Trees for construction should be available nearby. Streams where this technique is applied may have varied flow and ice conditions. Extreme environmental conditions will increase maintenance requirements.

4.0 DESIGN AND INSTALLATION GUIDELINES

4.1 HALF LOG STRUCTURES

a. Survey the stream at low water to determine if there is a need for additional cover. Substrate type and water depth during summer flow conditions are important as the structure must remain submerged at all times. The water depth should be between 30 (12 in) and 90 cm (48 in).

b. The half log structures should be placed below spawning sites and/or riffle areas near banks, in shallow pools with enough current to scour silt or behind large, angular rocks.

c. Cedar should be used, if possible, because it resists rot. Other softwoods can be used as well.

4.2 TREE SHELTER

a. Survey the stream during low water conditions to determine if there is a need for additional cover. Water depth during summer flow conditions is important.

b. Tree shelters should be placed in areas of relatively slow-moving water.

c. Softwoods, preferably cedar, should be used to build tree shelters. Remember when securing the butt end of the tree that softwood trees are shallow-rooted and additional anchoring may therefore be required.

5.0 IMPLEMENTATION STEPS

5.1 HALF LOG STRUCTURE

a. Determine where the structure should be placed. Consider water depth, stability of the substrate and nearby banks, sedimentation and the presence of large boulders, spawning and riffle areas, and trees suitable for construction materials.

b. Obtain the necessary equipment: ladder; impact plate; maul; rebar. Wire should be wrapped around the head of the maul to secure it to the handle. This will reinforce the maul's strength and protect the handle from chipping or splintering.

c. The log used for this structure should be 3.5 m (8 ft) long and about 20 cm (8 in) in diameter. The log should be cut in half along its length.

d. Pre-drill holes in the half log 15 cm (6 in) from each end.

e. Set the log on two blocks, called spacers, which are 10 x10 x10 cm (4 x 4 x4 in) in size.

f. Pre-drill the centre of the spacers.

g. Place the half log slightly off from the current with the flat side down and supported at each end by the spacers.

h. Drive #15 rebar through the holes in the log and spacers until the rebar is only 30 cm (12 in) above the top of the log. We suggest that the rebar be driven at a slight angle into the current for maximum holding in the substrate.

i. Bend the rebar over until it is flush and parallel with the log or top off the end of the rebar with surveyors' caps. The end of the rebar should be facing downstream so it will not snag floating debris.

5.2 TREE SHELTER

a. Determine where the tree shelter should be placed. The streambanks should be elevated and stable and the water should be relatively slow-moving and at least 30 cm (12 in) deep.

b. Fell the entire tree so that it is lying almost parallel to the current along the bank. The tree should be 3 to 4.5 m (10 to15 ft) long and the branches should be no longer than 1.5 m (5 ft). The stump must be at least 30 cm (12 in) tall in order to secure the tree with it.

c. There are several methods to secure the butt end of the tree:
   i) Leave it attached to the stump.
   ii) Secure the tree to the stump, another tree or a metal post with a steel cable. The post should be 1.5 (5 ft). long and driven 1.0 m (3 ft) into the ground.

d. The butt end should be secured above the high water line or in such a way that it will not snag floating debris.

e. Drill holes in the tree where rebar is required.

f. Drive the rebar through the holes in the tree until it is 30 cm (12 in) above the top of the tree.

g. Bend the rebar over until it is flush and parallel with the log or top off the end of the rebar with surveyors' caps. The end of the rebar should be facing downstream so it will not snag any debris.

6.0 MAINTENANCE AND MONITORING

Regular monitoring of these techniques after installation is a must.

a. Ensure that the structure is serving the purpose for which it was installed. Numbers and size of fish using the structure may be determined by electrofishing the area in late summer. (Electrofishing can be done only with the assistance of fisheries biologists or fishery officers.)

b. Inspect the structures after the ice is gone to see if they have shifted or need to be repaired or replaced.

c. Ensure that they are not collecting debris.

d. Monitor sediment deposition around half logs.

7.0 FACTORS INFLUENCING COST

The construction costs of half log and tree shelters depend on the proximity of the materials. If the materials are available nearby, the costs will be low.

8.0 ADVANTAGES OF THE TECHNIQUES

a. simple to design and install;
b. can be easily adjusted for optimum success;
c. provides cover;
d. natural appearance;
e. inexpensive to build;
f. only simple tools are required.

9.0 DISADVANTAGES OF THE TECHNIQUES

9.1 HALF LOG STRUCTURES

a. may erode bank or dam stream;
b. proper placement of the structure is crucial;
c. may require periodic repairs and/or replacement;
d. susceptible to ice damage and prone to filling with sediment;
e. structure may collect unwanted debris.

9.2 TREE SHELTERS

a. are essentially a temporary measure which may require periodic replacement;
b. may collect unwanted debris and sediment.

10.0 EXAMPLES OF USE

Half log structures have not been used in New Brunswick. In Nova Scotia, half log structures were among a variety of techniques used to enhance habitat on the Elderkin Brook in Kings County. These structures were installed during the summer of 1984. They were monitored after one year. Populations of fry and adult brook trout increased after one year. However, there was also a noticeable decline in the number of trout in the same brook, suggesting localized habitat improvement but not necessarily an absolute increase in stream productivity.

Tree shelters were used in Green River near Edmundston during the summer of 1986 in conjunction with other improvement techniques. Lack of cover for trout is a major problem in this river. Movement of juvenile trout towards the tree shelters was noticed immediately after installation.

11.0 REFERENCES

Government of Canada, Department of Fisheries and Oceans, and the Province of British Columbia, Ministry of the Environment. 1980. Stream Enhancement Guide. Vancouver, British Columbia. 82p.

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FACT SHEET "D"
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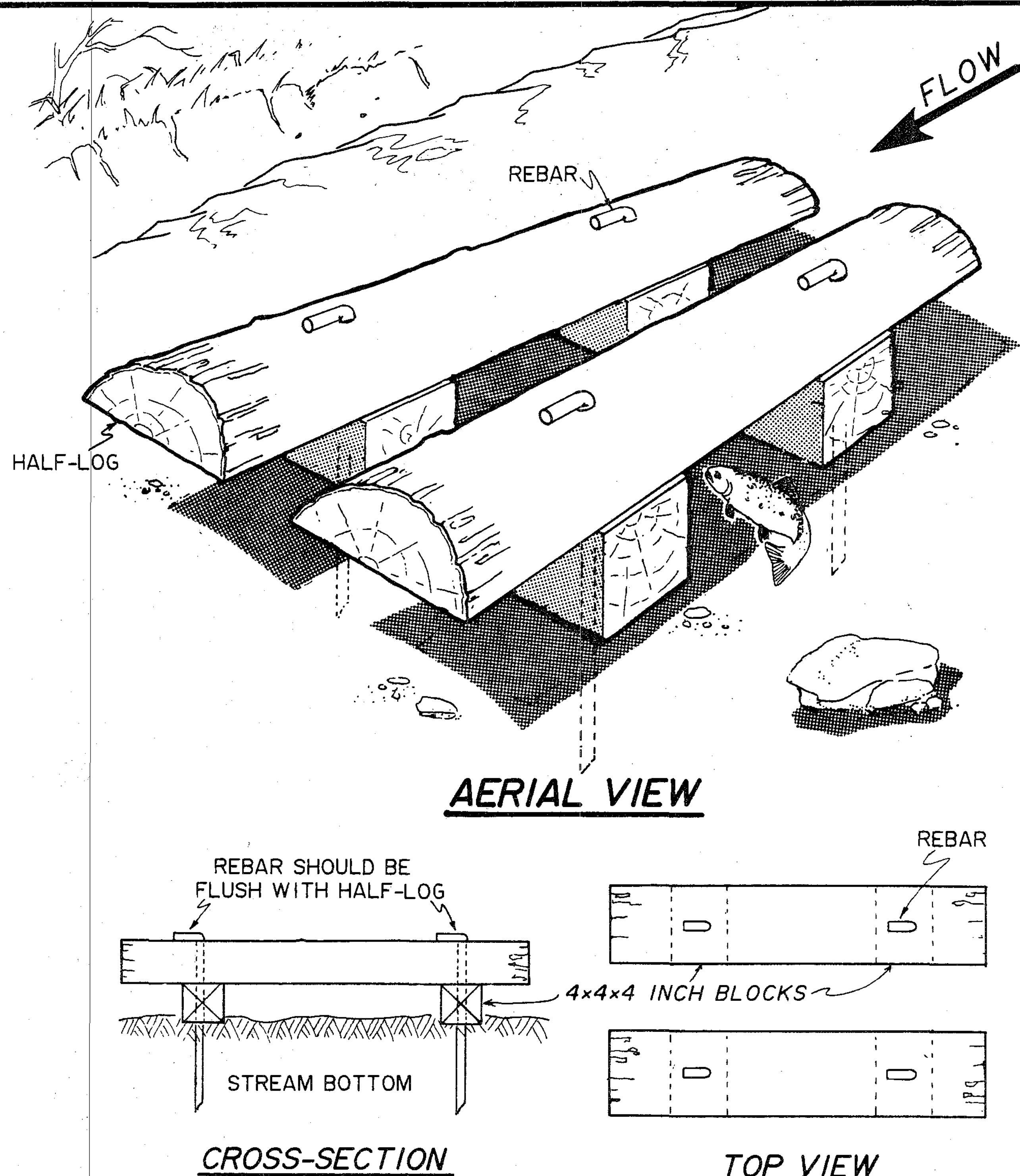

FIGURE D–1: INSTREAM PLACEMENT OF HALF-LOGS.

FACT SHEET "D"
INSTREAM WOODEN SHELTERS: TREE
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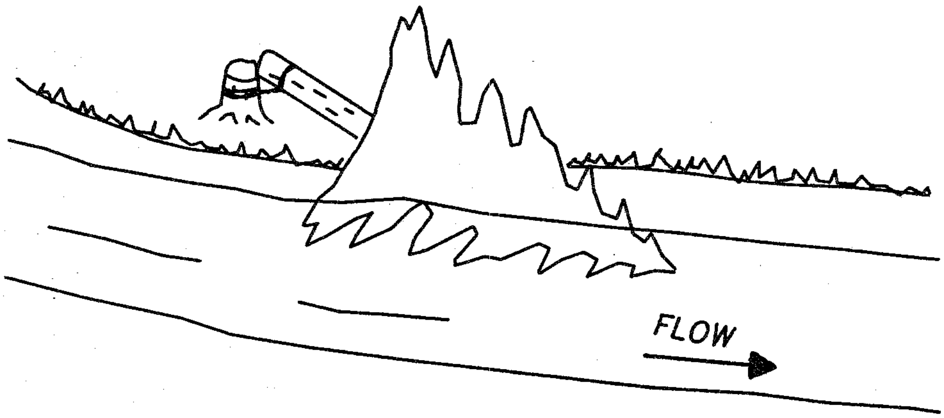
AERIAL VIEW



CROSS-SECTION

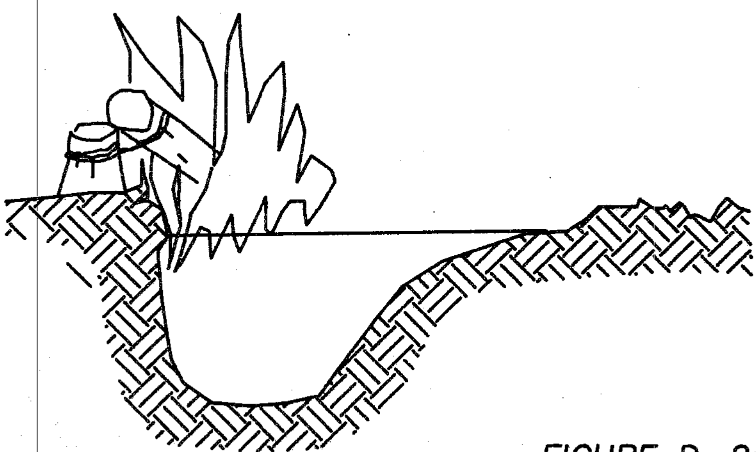


FIGURE D-2: PLACEMENT OF TREE SHELTERS IN A STREAM.

LOW HEAD BARRIERS

***ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

A low head barrier is a structure built across a stream perpendicular to the flow of water. They are intended to funnel water towards the center of a stream to create a small waterfall. This, in turn, forms a scour hole at the foot of the dam creating a small pool known as a plunge pool. Gravel carried by the current from the scour hole and deposited downstream may form suitable spawning beds.

There should be several centimetres of water flowing over the dam most of the year. The water above the dam is known as the head. Many dams are built with spillways to allow fish to migrate upstream during low flow periods.

2.0 PURPOSE

Dams or barriers are often used to contain water thereby obstructing fish passage. The low head barrier, on the other hand, is used to increase fish habitat. The structure, combined with the plunge pool created underneath, provides overhead cover for fish. The water in the plunge pool preserves fish habitat in times of low flow. The standing wave created in the plunge pool provides fish with a means of jumping over the low head barrier (see Figure E-2).

3.0 CONDITIONS WHERE APPLICABLE

This technique should be used on:

a. streams less than 4.5 m (15 ft) wide at the high water level;

b. streams where pools make up less than 50% of the stream's surface area (stream habitat should be composed of 50% riffles and 50% pools);

c. fairly straight, flat, uniform streams or stream sections shallow during low water periods (10 to15 cm or 2 to 6 in) usually between the end of July and the end of September;

d. a section in which the streambed is made up of a thick layer of sand and gravel, at least twice the depth of the planned dam;

e. sections with at least moderate gradients;

f. sections where the banks are approximately 0.75 m to 1.3 m (2 ft to 4 ft) tall for a stream 1.6 m to 3.3 m (5 ft to 11 ft) wide;

h. sections where the banks on each side of the structure have a slope of at least 45 degrees in order to avoid overflow.

i. streams with banks composed of stable materials such as shrub-like vegetation, solid rock, stones,tree roots, various plants, etc.;

j. sections where natural pools and spawning beds will not be disturbed;

k. sections where there are no beavers. They may use the dam to block the stream complctely, creating an obstruction to fish passage.

4.0 DESIGN AND INSTALLATION GUIDELINES

a. Dams must not create an obstacle taller than 30 cm (12 in).

b. The water's flow should be directed towards the center of the dam to reduce bank washout. Wing walls built into the dam serve this purpose.

c. The width of the dam's opening should be no smaller than the width of the narrowest section of stream in the area.

d. Protect the bank up and downstream of each dam by installing log cribs and/or rock rip-rap.

c. To retard the rotting of the wood, build thc dam so that most of the structure is submerged.

f. Use softwood to construct the dam. Cedar and tamarack are particularly rot-resistant.

g. The dam should be embedded at least 30 cm (12 in) into the streambed.

h. Preferably, water should not be impounded upstream of a dam. If this is not possible, be sure the pool is no longer than the distance of five channel widths.

i. Normally a plunge pool will form 1.25 times the height of the waterfall (excellent depth to assist fish passage). The pool should be at least 0.6 m (2 ft) deep and 3 m (10 ft) long.

j. Do not build a dam too close to a tributary, whether it be a spring or a brook. During floods, the flow of these small streams adds to the flow of the main stream, possibly causing damage to the dam or bank.

k. Do not build the dams closer than 23 m (75 ft) together. Separate small dams by a distance five to seven times the average width of the stream section.

l. Rock dams work best in low gradient streams because stronger currents may dismantle the dam.

m. Work in the stream should be carried out during summer low flow periods.

5.0 IMPLEMENTATION STEPS

5.1 Rock Dam (see Figure E-1)

This type of dam works best on low gradient stream sections because the stronger currents in high gradient streams may shift the rocks and damage the dam.

a. Choose a suitable site to construct the dam.

b. Excavate a trench across the stream. The center of the dam should be further upstream and deeper than the edges near the bank. This will divert flow towards the center of the stream and reduce bank erosion.

c. Construct the base with several rows of rocks remembering that the cross section of the dam must be triangular. The slope of the upstream sides should be approximately 30 degrees or less. A narrow top is better for fish passage.

d. Each rock should be keyed or hand placed to ensure stability.

e. The large rocks should be placed on the downstream edge of the dam to hold the smaller rocks in place and provide cover.

f. The largest rocks should be placed in the center of the dam or where the current is fastest.

g. Fill the crevices in the upstream side of the dam with sand and gravel.

h. Place filter fabric underneath the base and along the upstream edge of the dam to prevent deterioration. Cover with small rocks and gravel.

i. Rip-rap should be installed along the banks at the ends of the dam.

j. When constructing a series of rock dams, start downstream so that you can see the amount of water that will be impounded above each dam.

5.2 Single Log Plank Dam (see Figure E-4)

This dam is designed for streams 1.5 m to 3m (5 ft to 10 ft) wide. A variation of this dam is the single log-rock dam which is constructed in precisely the same manner but minus the plank (see Figure E-5).

5.2.1 Levelling the Streambed and Excavating the Banks

a. The streambed should be levelled manually, from bank to bank, in a strip 75 cm (30 in) wide. Take care to make it as level as possible.

b. Dig holes into the banks at both the upstream and downstream limits of the levelled site to accomodate logs that will be laid across the streambed. The holes should be 30 cm to 40 cm (12 in to 16in) wide and extend 1.4 m (4.6 ft) into the bank.

5.2.2 Building the Frame

Keeping in mind that given sizes are for the smallest of streams (generally, the larger the stream, the larger the material required), the following pieces of wood will be required:

1) transverse beam - 10 cm (4 in) in diameter
2) longitudinal braces - 5 cm (2 in) in diameter, 75 cm (30 in) in length
3) single log - 15 cm to 20 cm (6 in to 8 in) in diameter
4) vertical braces - 5 cm (2 in) in diameter

a. Lodge a transversal beam (not shown in diagram) into a pre-excavated trench in the streambed, laying its ends in the holes dug in the bank at the upstream edge of the site.

b. Place the longitudinal braces perpendicular to the transversal beam. Nail the upstream end of the braces to the downstream side of the transverse beam at 45 cm (18 in) intervals.

c. Place a single log at the downstream limit of the prepared site on top of the downstream end of the longitudinal braces. Lay the ends of the log into the holes dug in the bank. Trenches should be dug in the stream bottom to allow the longitudinal braces to be embedded totally in the streambed.

d. Use short pieces of wood as vertical braces (not shown in diagram). Nail the upper end of each brace to the center of the log. Nail the vertical braces to the longitudinal braces so the ends of the vertical braces extend slightly beyond the center and 30 cm (12 in) below the transverse log and can be driven into the streambed.

When using large enough material, rebar may be used (10-15mm dia.; 3/8" to 1/2") to fasten the structure to the streambed. Large enough holes can be drilled through the transverse beam and the larger 'single log' to allow the rebar to be nailed through the logs to the stream bottom. The rebar should be 1 to 1.5 m long (3 to 5 feet). Leave about 10 to 15 cm (4-6") of rod protruding above the logs (after having been driven into the streambed) and bend this over (in a downstream direction) to hold the logs in place.

e. Use other sections of logs, 10 to 15 cm (4-6") in diameter, to brace the main 'single log', both upstream and downstream, as indicated in Figure E-4.

5.2.3 Building the Spillway

If a spillway is desired, it should be constructed before the plank floor is put in place.

a. Cut a groove in the center of the single log of the dam 20 to 40 cm (8 to 16 in) in length and 2.5 to 4.0 cm (1 to 1.5 in) in depth.

b. Attach a piece of wood 10 to 12 cm (4 to 5 in) in diameter parallel to this log opposite the groove. The planks will be nailed to this piece of wood in the same manner as the others are nailed to the top of the log.

c. The top of this piece of wood must be flat and low enough so that the planks nailed to it will be flush with the groove.

d. The space between the planks which form the spillway and those nailed to the log must be sealed with a plank cut in the form of a triangle.

5.2.4 Building the Plank Floor

Construct the plank floor with softwood planks (fir, larch, spruce, etc...) 3.8 cm (1.5 in) thick and 1.2 m (4 ft) long.

a. Dig a hole up to 1 m (3.3 ft) wide and 0.3 m (1 ft) deep from bank to bank in the streambed,upstream of the frame already built.

b. Nail the planks in place no higher than the top of the 'single' log.

c. The end planks should be driven into the banks when possible (half their width should suffice). If this is impossible, place them as close to the bank as possible. It is very important that no water filter into the bank.

d. Fill any space under the planks upstream of the transversal beam with some of the sand and gravel removed from the streambed during excavation. Fill the hole dug at the end of the plank floor with the remainder. Cover the area with flat stones or coarse gravel to better resist the current.

e. For optimum results, use two layers of wood to construct the plank floor. Lay a plastic sheet between the layers to prevent leakage and excessive undercutting of the structure.

f. The plank floor and supporting structure should form an angle of approximately 20 degrees to offer maximum resistance to water pressure during floods.

5.2.5 Bank Protection (See also Fact Sheet "F")

To protect the bank from flooding and ice movement, rock rip-rap and/or a log crib can be built on the upstream and downstream sides of the dam. This should be at least as high as the stream bank. Cedar, red spruce, or larch should be used for the log crib.

Log crib is more difficult to construct than rock rip-rap. It helps keep the dam in place, regulate water flow and increase the digging action of the water.

5.2.5.1 Rock rip-rap

a. Rock rip-rap should be placed 1.6 m (5 ft) upstream and downstream from each end of the dam, up to the spring flood line. Cover the rocks with soil and seed the area for increased bank protection.

b. When building rock rip-rap, use oblong and flat rocks weighing 100-125 kg (220 lbs to 275 lbs) on the upstream section of the dam. Use heavy, angular rocks on the downstream section.

5.2.5.2 Log crib

a. Log crib can be used on the upstream section of the dam to build wing walls. First, place a log 4 m (13 ft) long and 20 cm (8 in) in diameter along the bank. Nail it to the dam 15 cm (6 in) out from the edge of the bank.

b. A second and third log can be placed on top of the first log.

c. Three or four braces (at least 1 m or 3 ft in length) should be nailed at one end to the top log and at the other end to stakes driven 1 m (3 ft) into the bank.

d. Place short sections of logs parallel to the braces along the top of the dam to meet the logs forming the wing wall. Nail these logs in place.

e. Fill the empty space between the logs and the bank first with a layer of filter fabric and then with gravel and cobble up to the top of the braces.

f. If building log crib on the downstream side of the dam, the logs should be only 2 m (7 ft)long, and placed against the stream bank.

g. Place large boulders at the approach to the wing walls of the log crib so water cannot flow behind the structure. If a crib structure is built on the downstream section of the dam, boulders should be placed where the walls of the log crib and the bank meet.

6.0 MAINTENANCE AND MONITORING

The most serious problems which occur after a dam is built are bank erosion and undermining. These can be avoided by proper dam construction. Make sure that the stream bank is properly stabilized using rock rip-rap and/or log cribbing.

Undermining is caused by the current in the plunge pool as it flows up and underneath the dam eroding the streambed. This provides cover for fish but may eventually cause the collapse of the structure.

Another potential problem is the rotting of wood due to the constant wetting and drying caused by fluctuating water levels. This problem can largely be avoided by using softwood and by submerging as much of the structure as possible.

Low head barriers should be checked each spring for erosion, rotting or other problems.

7.0 FACTORS INFLUENCING COST

Building these structures is labour intensive. Therefore, the cost of labour is a critical factor. The availability of proper materials is another major factor.

8.0 ADVANTAGES OF THE TECHNIQUE

a. Lowhead barriers can be constructed of basic, locally available materials.
b. They are an alternative to wing deflectors on steeper grade streams.
c. The plunge pool provides habitat during periods of low water flow.
d. Habitat is created both above and below the barrier.

9.0 DISADVANTAGES OF THE TECHNIQUE

a. Building these structures is labour intensive.
b. Barriers need to be checked periodically for damage and repaired accordingly.
c. Placement of large boulders requires the use of heavy equipment.

10.0 EXAMPLES OF USE

Low head barriers were built on Sandy Brook, a tributary of the Canoose Stream near St. Stephen, and on Sucker Brook near Canterbury. These small dams were constructed of wood. The low head barrier built on Sandy Brook was a simple one-log structure with a spillway. A blanket was used underneath the dam, in place of filter fabric, to prevent undermining.

Squared timber was used to build the low head barrier on Sucker Brook. The timber was grooved so the planks on the upstream side of the dam could be raised or lowered, depending on the stream flow. The level of the planks controls the size of the pool upstream of the dam.

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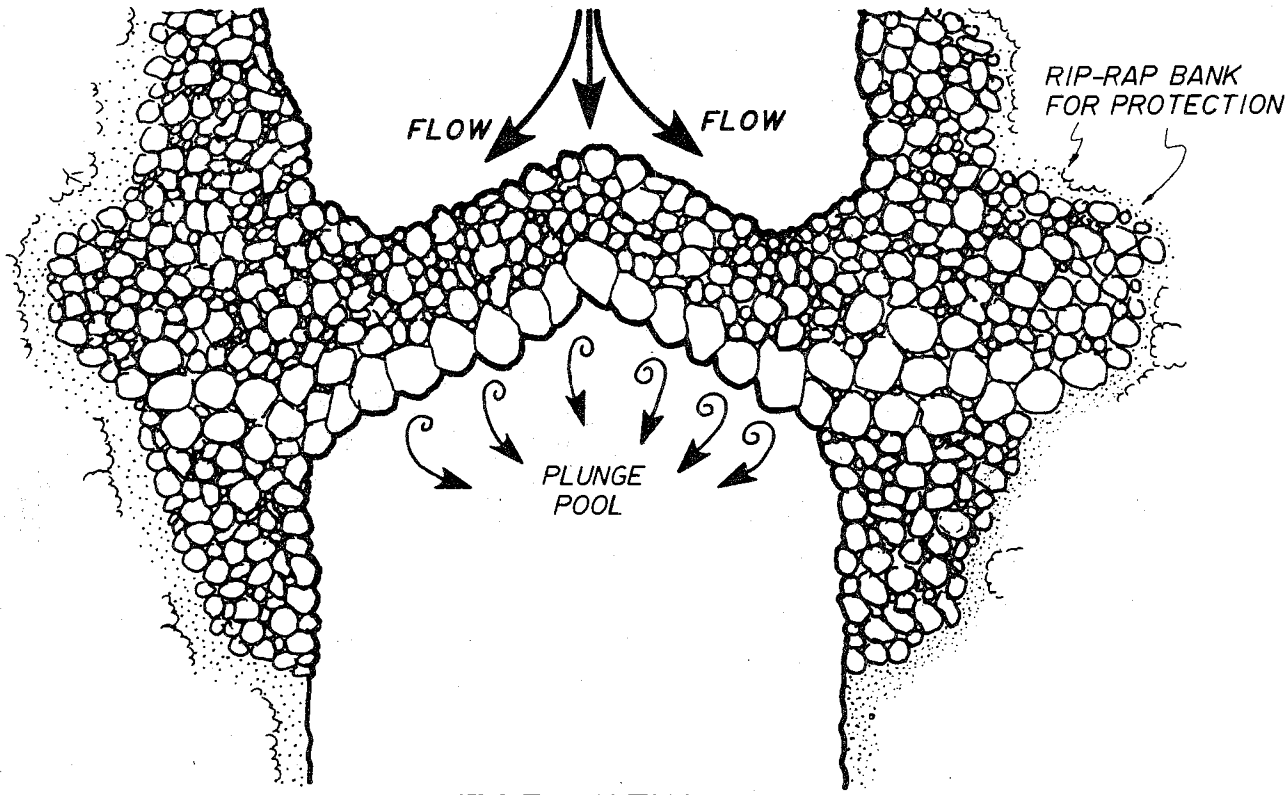
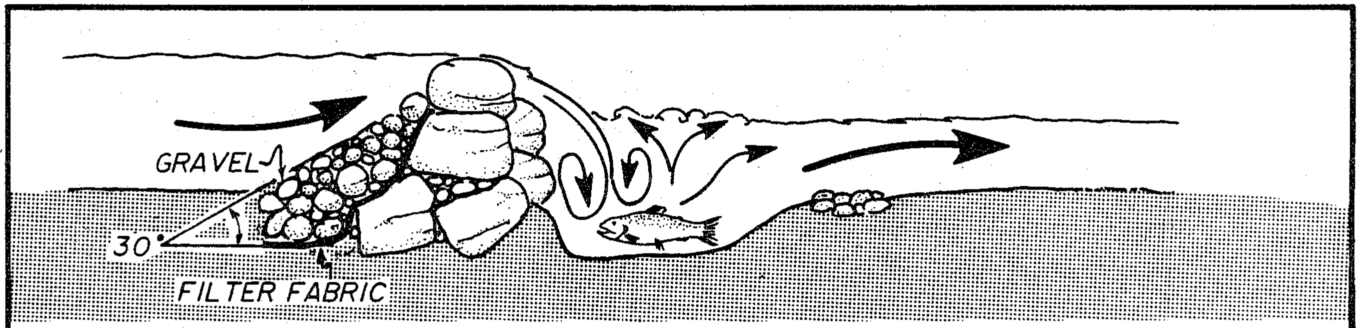
FACT SHEET "E"
LOW HEAD BARRIER: ROCK DAM
REVISED:

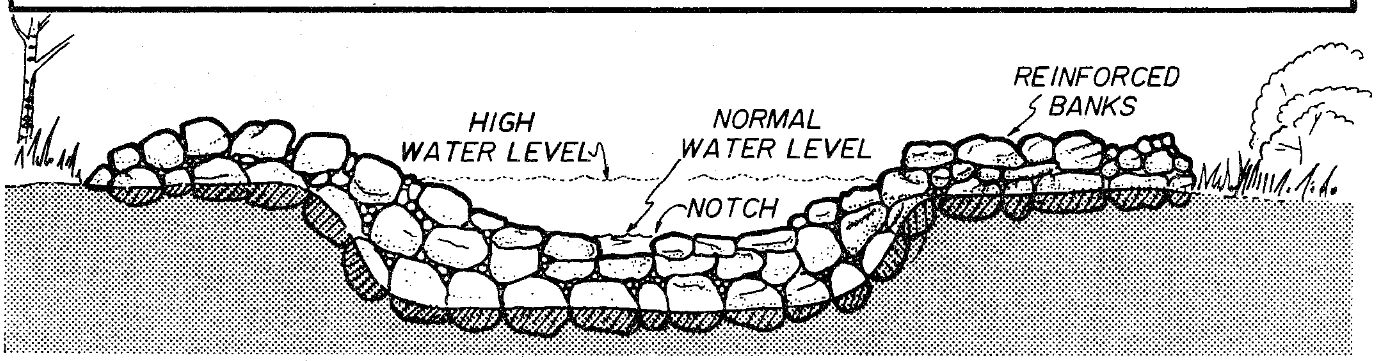
FIGURE E-1: THREE VIEWS OF A ROCK DAM



TOP VIEW



CROSS-SECTION



FRONT VIEW

FACT SHEET "E"
LOW HEAD BARRIER:
REVISED:

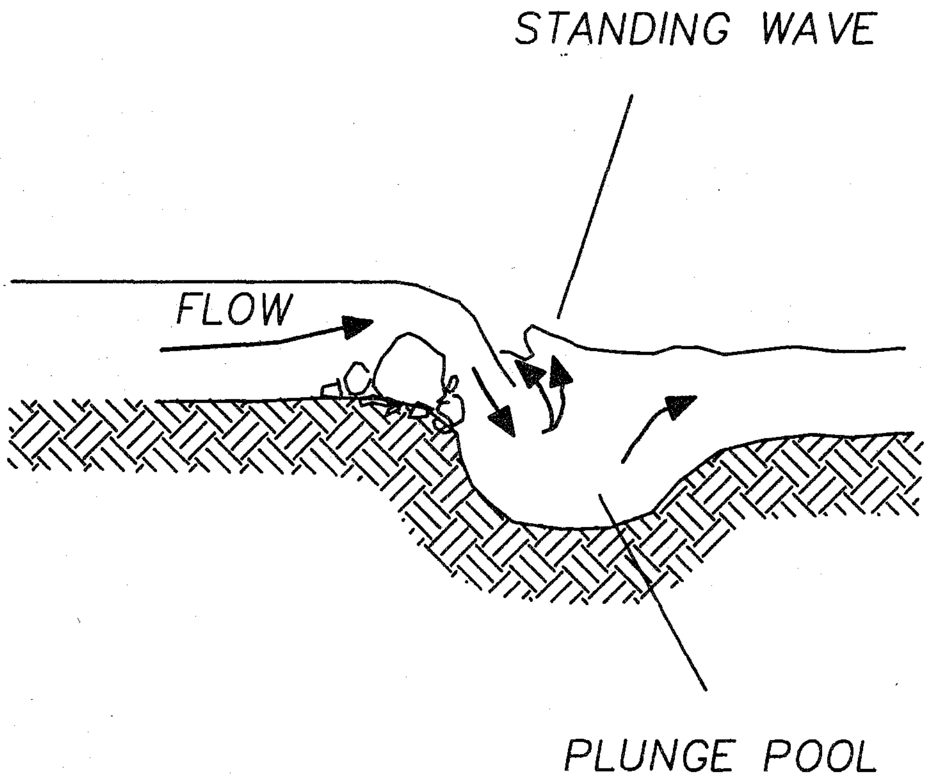


FIGURE E-2: CROSS-SECTION OF A LOW HEAD BARRIER SHOWING THE PLUNGE POOL AND STANDING WAVE.

FACT SHEET "E"
LOW HEAD BARRIER: SINGLE LOG PLANK DAM
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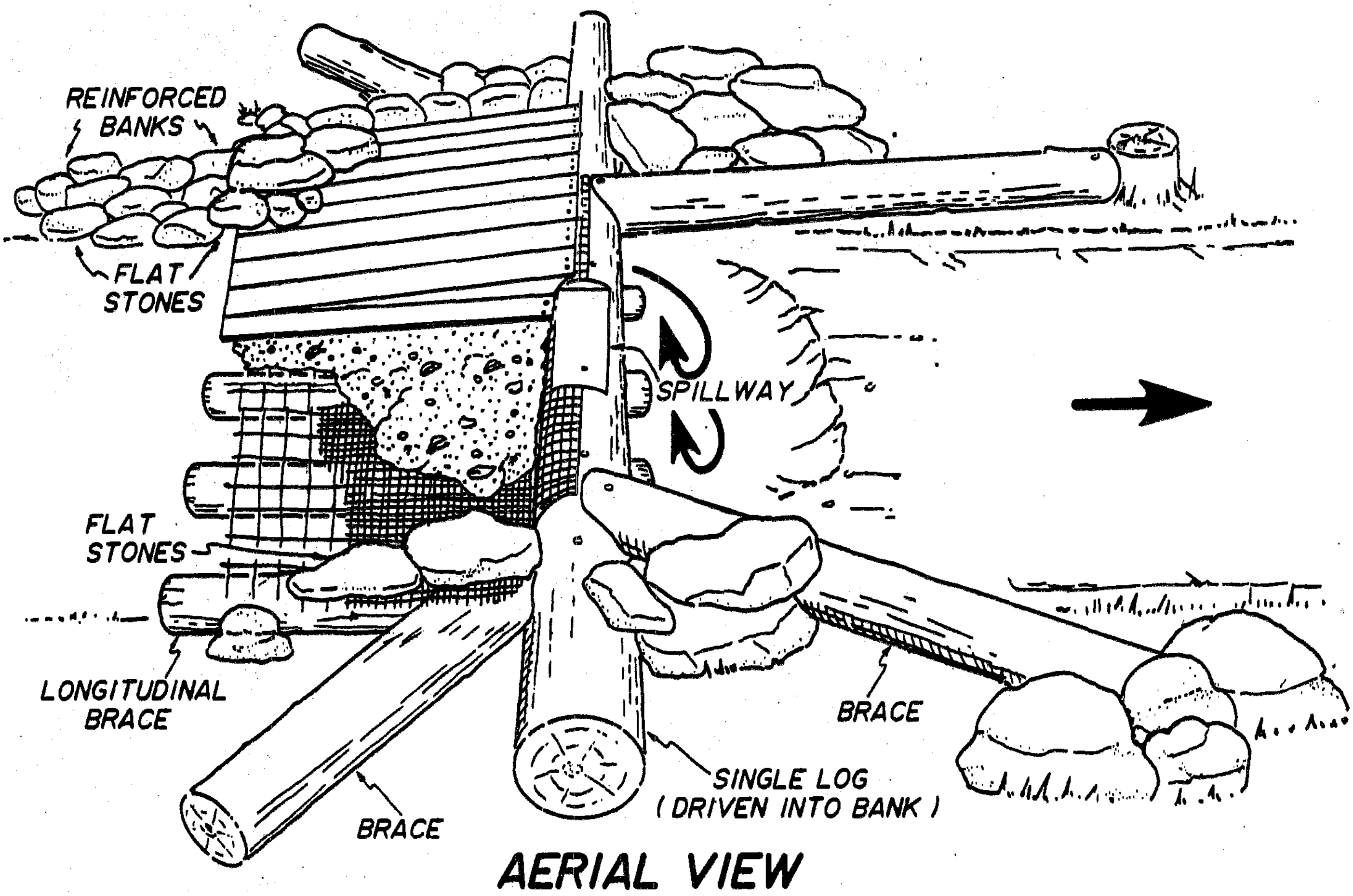

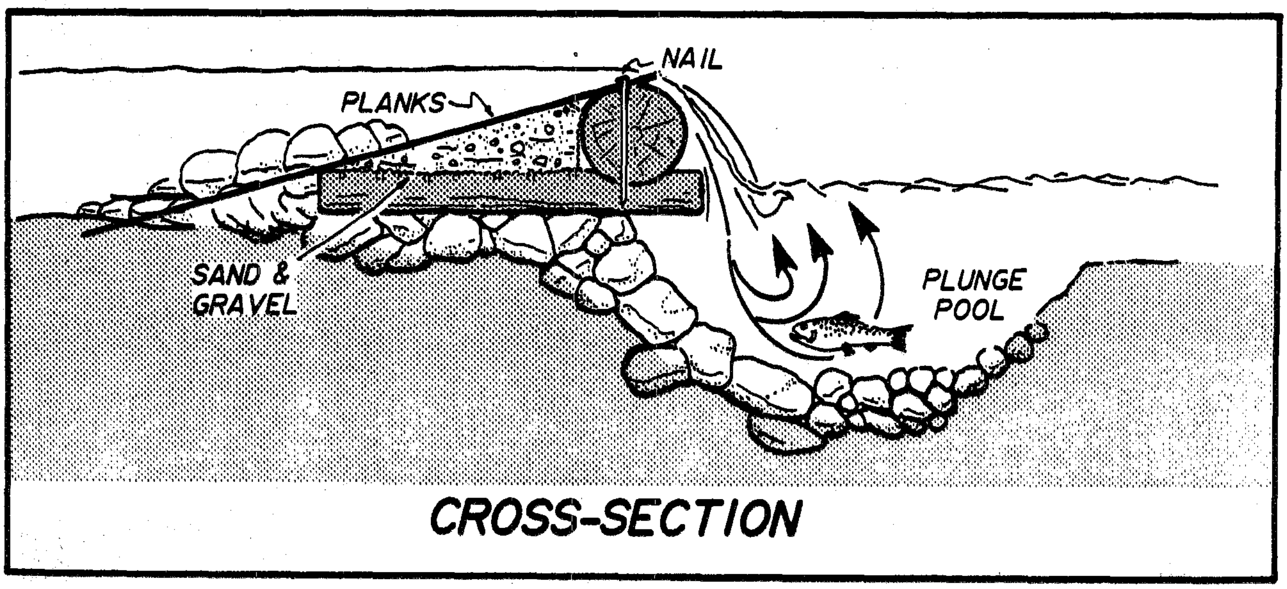

FIGURE E-4: *SINGLE LOG DAM WITH PLANK FLOOR.*

FACT SHEET "E"
LOW HEAD BARRIER: SINGLE LOG-ROCK DAM
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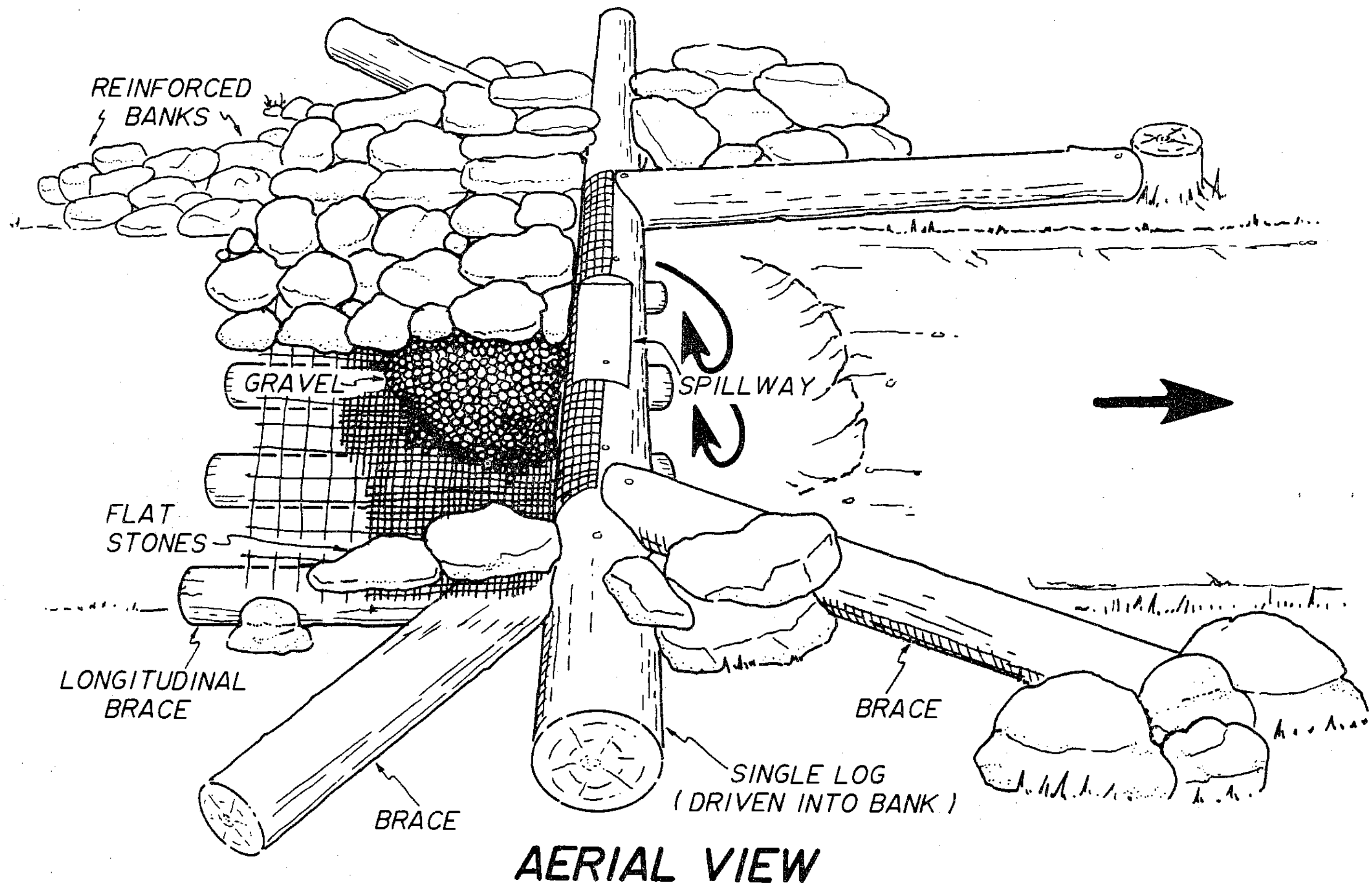

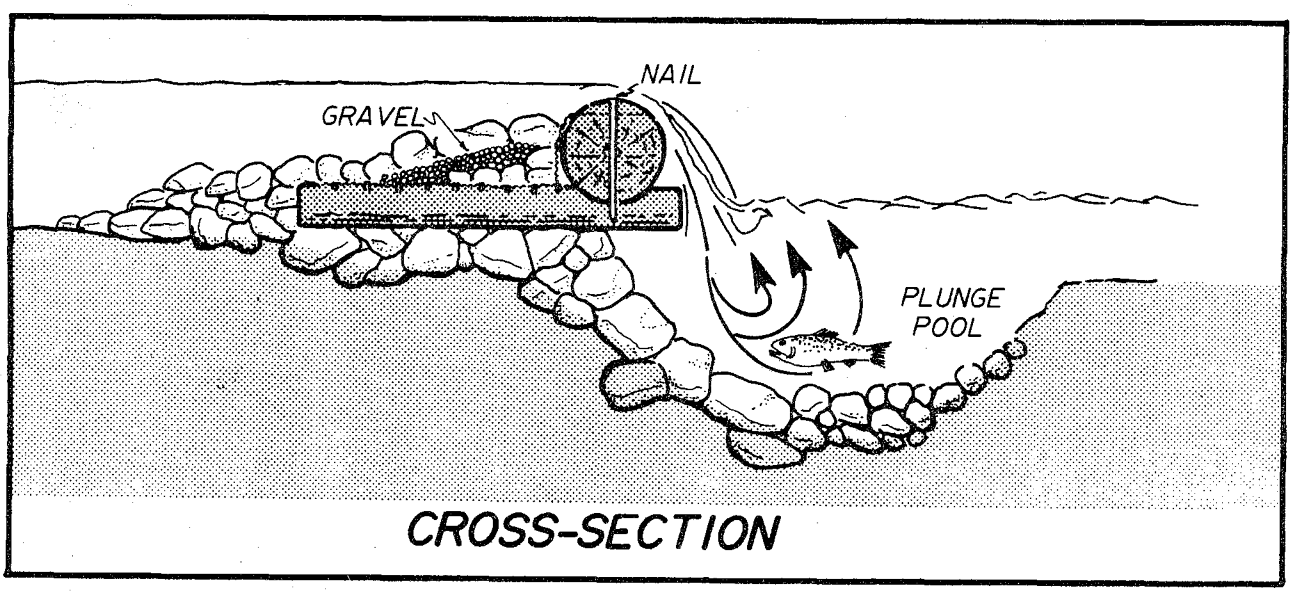

FIGURE E-5: *SINGLE LOG DAM WITH FLAT STONES INSTEAD OF PLANK FLOOR.*

BANK STABILIZATION - LOG RIP-RAP, ROCK RIP-RAP, GABIONS

***ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

This fact sheet presents three mechanical low bank stabilization techniques. These techniques should be used only when vegetation cannot provide adequate bank support. Refer to Fact Sheet B. You may want to consult with an engineer before employing the following techniques, to ensure correct design.

Log rip-rap, consisting of logs and rebars, stabilizes eroding streambanks and may even narrow the width of a stream.

Rock rip-rap provides immediate protection against streambank erosion while allowing seepage of water from above or through the bank. Rip-rap lining is constructed by the random dumping or hand placement of rocks of specicfic sizes.

Gabion basket lining consists of pre-constructed steel wire baskets with rocks placed in them. This can be used when slopes are too steep for rip-rap lining or when there is no suitable rock available for it.

2.0 PURPOSE

Log and rock rip-rap and gabion basket linings stabilize eroding stream banks, narrow stream width and protect fish habitat. Which of these low bank stabilization techniques is used depends on the individual situation and what materials are available.

The stream banks consist of sand, soil or gravel - materials easily eroded by running water. Most eroding stream banks have steep sides of loose, raw dirt or gravel and, at the bottom of the bank, there may be clumps of grass sod.

Bank erosion (see Figure F-1) can occur:

a. if the stream channel is machine-altered and the stream flows against the raw, exposed earth;

b. if the protective plant cover is removed from the streambanks by over-grazing by livestock or by burning;

c. man-made obstructions are placed in the stream channel (they may eventually deflect the water flow into the banks);

d. if fallen trees or rocks force the stream flow into the banks;

e. through groundwater seepage or even surface water runoff (eroded material wll probably be carried away when the stream flows are high);

f. by ice scouring in the spring;

g. if stream flow creates unstable undercut banks.

The effects of stream bank erosion are:

a. Exececssive sediment loads affect fish habitat causing a decline in fish populations.

b. Sediment can plug up the stream channel reducing channel capacity possibly increasing overbank flooding.

c. Sediment from eroding banks deposited downstream in riffles and pools will smother aquatic organisms fish feed on.

d. Silt will settle into the gravel of spawning beds, blocking the flow of oxygen-rich water and smothering the eggs.

e. Cover will be reduced as pools fill with sediment. The deep pools usually provide shelter for adult fish.

3.0 CONDITIONS WHERE APPLICABLE

Rip-rap and gabion lining are used to provide bank protection when vegetation alone is not able to prevent erosion. This might occur in areas submerged for more than a few days or where the streambank material will not support vegetation.

3.1 Log rip-rap may be used in streams:

a. with low to moderate gradient;
b. less than 15 m (50 ft) wide;
c. with light or moderate flooding;
d. where the bank requiring stabilization is not more than 1.0 m (3.1 ft) high.

3.2 Rock rip-rap lining may be used:

a. when the bank requiring stabilization is less than 3 m high;

b. when the grade is no steeper than 2:1;

c. when the stream flow velocity is 3.5 m/s (11.5 ft/s) or less.

3.3 Gabion baskets may be used:

a. when the bank requiring stabilization is less than 3 m high;

b. when the flattest possible bank slope is steeper than 2:1;

c. when there are no suitable sizes and types of rock available for rock rip-rap.

4.0 DESIGN AND INSTALLATION GUIDELINES

A stream survey should be done to determine the cause of the streambank erosion, the level of erosion protection required and how the bank's slope will affect the choice of technique to be installed. If the streambank erosion is caused by streambed deterioration, examine the streambed instability before choosing your protection technique. If you don't, your efforts may be wasted. These techniques are designed to withstand peak stream flows. Work on the structures should be done in mid-summer when water flow is low. Remember to check upstream of the site to make sure the erosion is not the result of another impacting activity.

4.1 Log rip-rap

To stabilize a streambank, build a log wall up to the height of the eroding bank (see Figure F-4). To narrow stream width, keep the structure's profile low so that in the spring the high water will be able to flow over the structure. The wall acts as a deflector in the summer and fall. Build the structure along an eroding bank where the the water is 0.3 -1.0 m (1 ft to 3.3 ft) deep. The bank may be along a straight stretch or an outer bend.

The structure should be wide enough to extend into the stream current but no more than 150 cm (60 in) from the eroding bank's edge (Figure F-4).

Use woods like cedar or hemlock as they are slow to rot. The diameter of the logs must be 15 cm to 35 cm (6 in to14 in). Make sure you have enough logs to stretch the entire length of the erosion site and to stack up to the original bank height. The bank wall should be one log layer thick. The backfilled area should be sloped into the bank to enable the spring floods to flow over the crib structure. Keep the structure's profile low.

Use heavy duty rebars or metal posts at least 3.3 m (7 ft) long for main supports. Drive in the entire length of the rebar. If you are using metal posts, drill a hole 10 cm (4 in) from the top to secure the wire. On older banks, use shorter wooden or metal stakes to stabilize the log rip-rap structure. Heavy-duty galvanized fencing of 9 to16 gauge may be used for lashing material.

To fill behind the structure, use brush, stumps, or rotten wood or gravel depending on the availability of the materials. Fagots or wooden bundles, made up of branches and small logs held together by wire or bailer twine, are a good alternative filler. The bundles should be 1.0 m to 1.5 m (3.3 ft to 5.0 ft) long and 30 cm (1 ft) in diameter. Do not use silt for fill.

4.2 Rock rip-rap

Several properties that enable rock rip-rap lining to resist erosion are the size of the rock, the shape, weight and gradation, the slope of the channel sides, the roughness, shape and alignment of the lining and the thickness of the rip-rap layer. The slope of the channel sides must be considered when determining whether to use a rip-rap or gabion basket (see Figures F-2 and F-3).

Rock type and availability are crucial to the design of rock rip-rap lining. Rock should never be taken from the stream or river bed. Select hard, durable rock, such as granite, shot rock, field stone, rubble, glacial till and gravel. Never use soft rock, such as sandstone, as you will soon see the results of your work disappear. Use angular rock of varying sizes to construct the rip-rap layers. The smaller rocks will fill the voids between the larger ones. Place large rocks near the stream bottom and smaller rocks above the flow line. The rip-rap layers should be at least 1.5 times the thickness of the largest rocks (no less than 0.3 m thick) and extend to the top of the bank to about 0.6 m above the peak flow.

It is important to fix woven or granular filter fabric between the layers of rip-rap to prevent or reduce washout of the underlying soil caused by groundwater seepage or stream flows. Make sure that the liners do not constrict the channel width and that they are securely fixed at the top of the bank, at the toe and at the upstream and downstream ends of the installation.

4.3 Gabion basket lining

Gabion basket lining should be used in cases where the banks to be stabilized are too steep to install rock or log rip-rap or when rocks of a suitable shape and size are not available for rock rip-rap. Plastic or galvanized baskets may be used.

When installing gabion basket liners, make sure that you firmly secure them to the bank and that you fill them with rocks larger than the mesh holes.

5.0 IMPLEMENTATION STEPS

5.1 Log rip-rap

a. Determine where to construct the log rip-rap structure.

b. Mark the outside edge of the new bank by driving temporary wooden stakes into the stream current. Stand back and examine the flow of the current as it runs along the edge of the stakes. If the stakes obstruct the stream flow, you will have to construct your rip-rap closer to the bank. Your structure should follow the natural flow of the water (see Figure F-5).

c. Have the logs, bundles, rebars, wire and other equipment at the site before starting work.

d. Start work at the upstream edge of where the structure will be.

e. Drive a line of metal fence posts into the streambed at 1.0 m to 1.5 m (3.3 ft to 5.0 ft) intervals so that they lean into the current at approximately a 10 degree angle. This will prevent the logs from lifting the stakes out of the water. Replace the temporary wooden stakes with permanent metal ones.

f. Remove enough silt and mud from the streambed to expose the underlying gravel. Place the logs in the stream bed. Then, with heavy gauge fence wire, lash a row of logs to the metal posts forming a wall. When lashing the logs together, form a figure eight pattern with the wire. (see Figure F-6).

g. Repeat step (f.) until you have rows of logs built to within 10 cm (4 in) of the top of the metal posts. Wire the logs to the metal posts passing the wire through the gaps between the horizontal logs.

h. If the spring runoff at the site is quite intense, drive a second row of stakes into the bank side of the horizontal logs. This will increase the strength of the structure.

i. Fill the space between the log wall and the old bank to within 15 cm (6 in) of the top of the metal posts. Use brush, ends of logs and other wood, turf, rocks (but not from the streambed) for filler. Compact the filler by jumping on it. Place the heaviest materials on top to hold down the lighter ones.

j. Drive a set of wooden or metal stakes, staggered with the main stakes, about 50 cm to100 cm (2 ft to 3 ft) from the old bank's edge, angled back from the stream. Wire the stakes to the outside line of stakes with double strands of heavy gauge fence wire (see Figure F-7). Bury the wire in a shallow trench (see Figure F-8). Figure F-8 suggests a crossover pattern of wire wrapping. Tighten the structure by inserting stick between the strands of wire and twisting.

k. Cover the bracing wire with turf and bundles of brush. The outside metal posts or bars should be bent, driven down or cut off. Place a surveyors cap on top of the rebar.

l. This structure should last several years. Strong rooted wood shrubs such as red osier dogwood may be planted behind the streamside logs for extra bank support. The root system will eventually grow to form a firm, permanent bank (see Figure F-9).

5.2 Rock rip-rap (see Figure F-3)

5.2.1 To prepare the installation site:

a. clear area of debris;
b. grade banks to slope design;
c. dig out toe trench;
d. install seepage drain if required;
e. divert stream flow with sandbags if possible.

5.2.2 Install rip-rap liners by laying out the filter material first:

a. by hand or machine placement;
b. full thickness has to be placed in one operation;
c. if placed under water, the thickness has to be increased by 50 % over the portion of the layer above water.

5.2.3 A vegetative cover should be re-introduced on the sloped area. This can be done by sticking red osier dogwood and willow cuttings in and around the interstices of the rip-rap. The root system will establish the stability of the structure.

5.3 Gabion basket liners (see Figure F-2)

5.3.1 Gabion baskets:

a. may be galvanized or plastic. Plastic gabions are used in more serious conditions.
b. Put a row of empty baskets into place. Tie them to each other and to the bank.
c. Fill with rock larger than the mesh openings.
d. If the basket is deeper than 0.3 m, fill it with 0.3 m increments in order to avoid deformation and foster a longer life expectancy.
e. Close and tie down the first row.

f. Repeat steps for the rest of the rows.

g. Backfill open spaces between the stream bank and the gabion baskets then plant vegetative cover.

6.0 MAINTENANCE AND MONITORING

6.1 Log rip-rap

a. The structure will require maintenance every spring and fall.

6.2 Rock rip-rap

a. Little upkeep is required once the lining is in place.

b. Check periodically for undermining and streambank erosion where the linings meet.

c. Replace rocks in rip-rap lining if they become displaced.

6.3 Gabion baskets

a. Check periodically for undermining and streambank erosion where the linings meet.

b. Repair any breaks in the wiring of the gabion basket lining.

7.0 FACTORS INFLUENCING COST

7.1 Log rip-rap

a. availability of the right types of wood and their proximity to the site;

b. ease of access to the site and working conditions.

7.2 Rock rip-rap

a. proximity and type of rock fill available;

b. ease of access to site and working conditions.

7.3 Gabion baskets

a. proximity and type of rock fill available;

b. access to site and working conditions;

c. whether plastic or galvanized baskets are used.

8.0 ADVANTAGES OF THE TECHNIQUE

8.1 Log rip-rap

a. This technique provides exellent streambank stabilization.
b. The natural materials used are inexpensive.
c. The structure blends into the natural surroundings.

8.2 Rock rip-rap

a. This technique is inexpensive when the materials are nearby.
b. It is easy to install and requires no engineering expertise.

8.3 Gabion baskets

a. stable;
b. relatively easy to install.

9.0 DISADVANTAGES OF THE TECHNIQUE

9.1 Log rip-rap

a. requires intensive labour;
b. application is limited to streams less than 15 m (50 ft) wide;
c. will not tolerate wide fluctuations in water levels;
d. will not last as long as rock rip-rap;
e. maintenance has to be done every spring and fall;
f. wood might not be available at the site.

9.2 Rock rip-rap

a. Heavy machinery is needed for transportation of material to the site.
b. The erosion problem may shift upstream or downstream if the structure is improperly installed.
c. Undermining of the banks may occur.
d. A large scale project could be expensive.

e. Cost of rock increases as the distance from the source increases if trucking is necessary.

f. The final result may be aesthetically unattractive.

9.3 Gabion Baskets

a. This technique requires intensive labour and is very expensive.

b. Heavy machinery is needed to transport rocks if they are not readily accessible to site.

c. Design assistance may be required.

d. Baskets may eventually deteriorate (ie. 10-20 years).

e. The result can have an unattractive, unnatural appearance unless vegetated.

10.0 EXAMPLES OF USE

10.1 Log rip-rap

Log rip-rap was used by the Fish Habitat Improvement Centre in Sandy Brook, near St. Stephen, N.B., to narrow a channel that was too wide. At low water periods, there was inadequate water to allow fish passage. Log rip-rap structures were built on each side of the brook to narrow the channel width and increase the water depth.

Log rip-rap was also used by NBDNRE and FHIC at Dead Brook, Oromocto Lake, for protection of an unstable stream bank.

10.2 Rock rip-rap and Gabion basket lining

Rock rip-rap and gabion basket lining have been used for bank stabilization in many instances in New Brunswick and the other Atlantic provinces. These techniques have been used to stabilize eroding agricultural lands, streambanks at bridge abuttments and culvert inlets and outlets.

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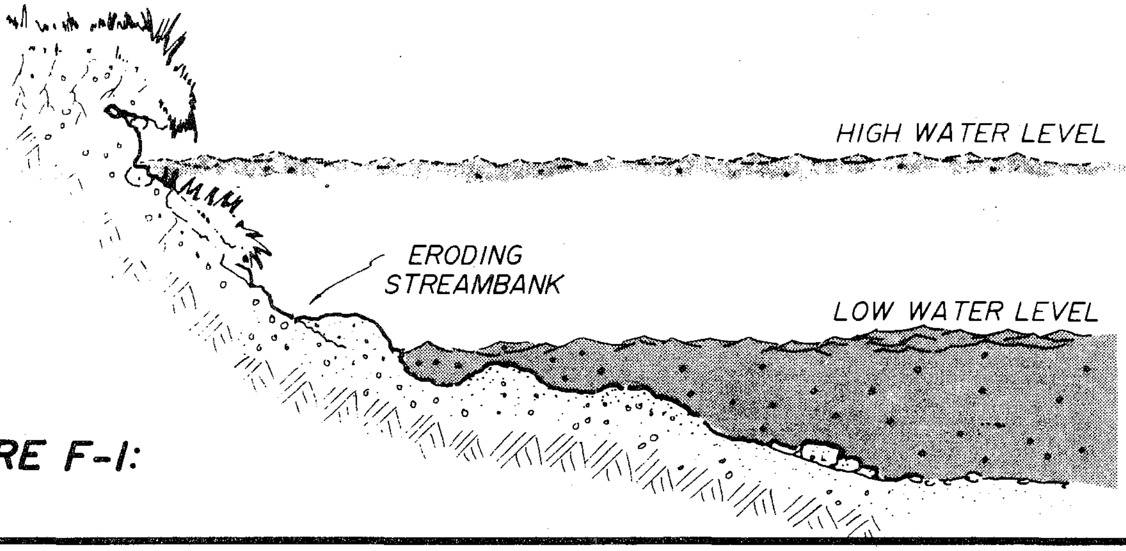

FIGURE F-1:

FACT SHEET "F"
BANK STABILIZATION: GABIONS

CROSS-SECTION

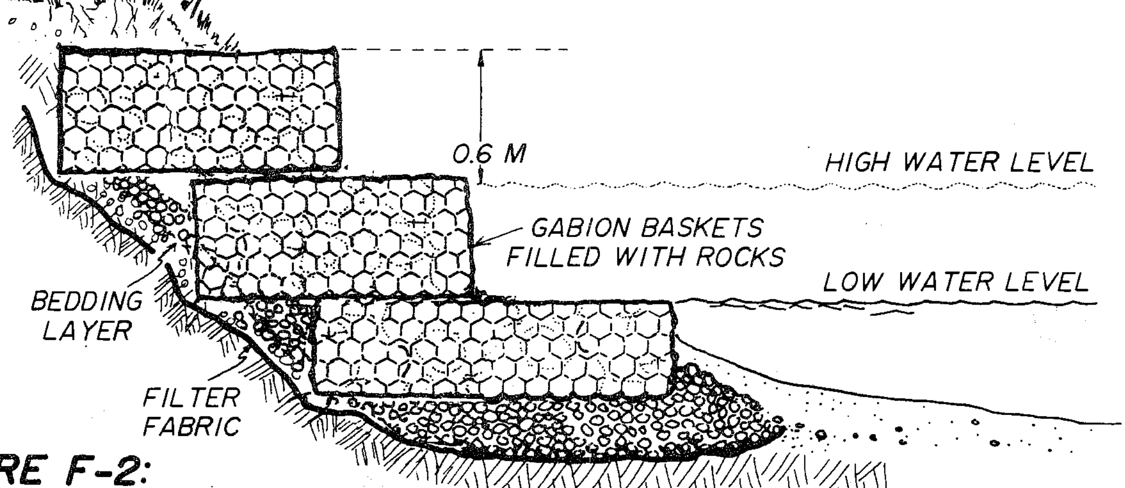

FIGURE F-2:

FACT SHEET "F"
BANK STABILIZATION: ROCK RIP-RAP

CROSS-SECTION

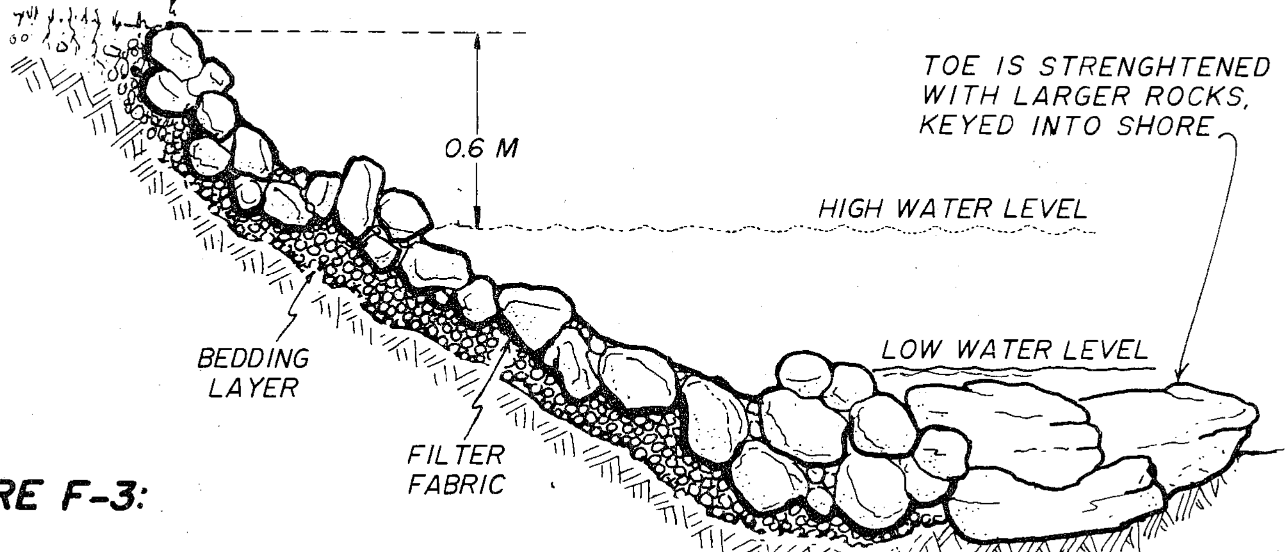

FIGURE F-3:

FACT SHEET "F"
BANK STABILIZATION: LOG RIP-RAP
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FIGURE F-4: LOG RIP-RAP IS BUILT TO THE LEVEL OF THE ERODING BANK.

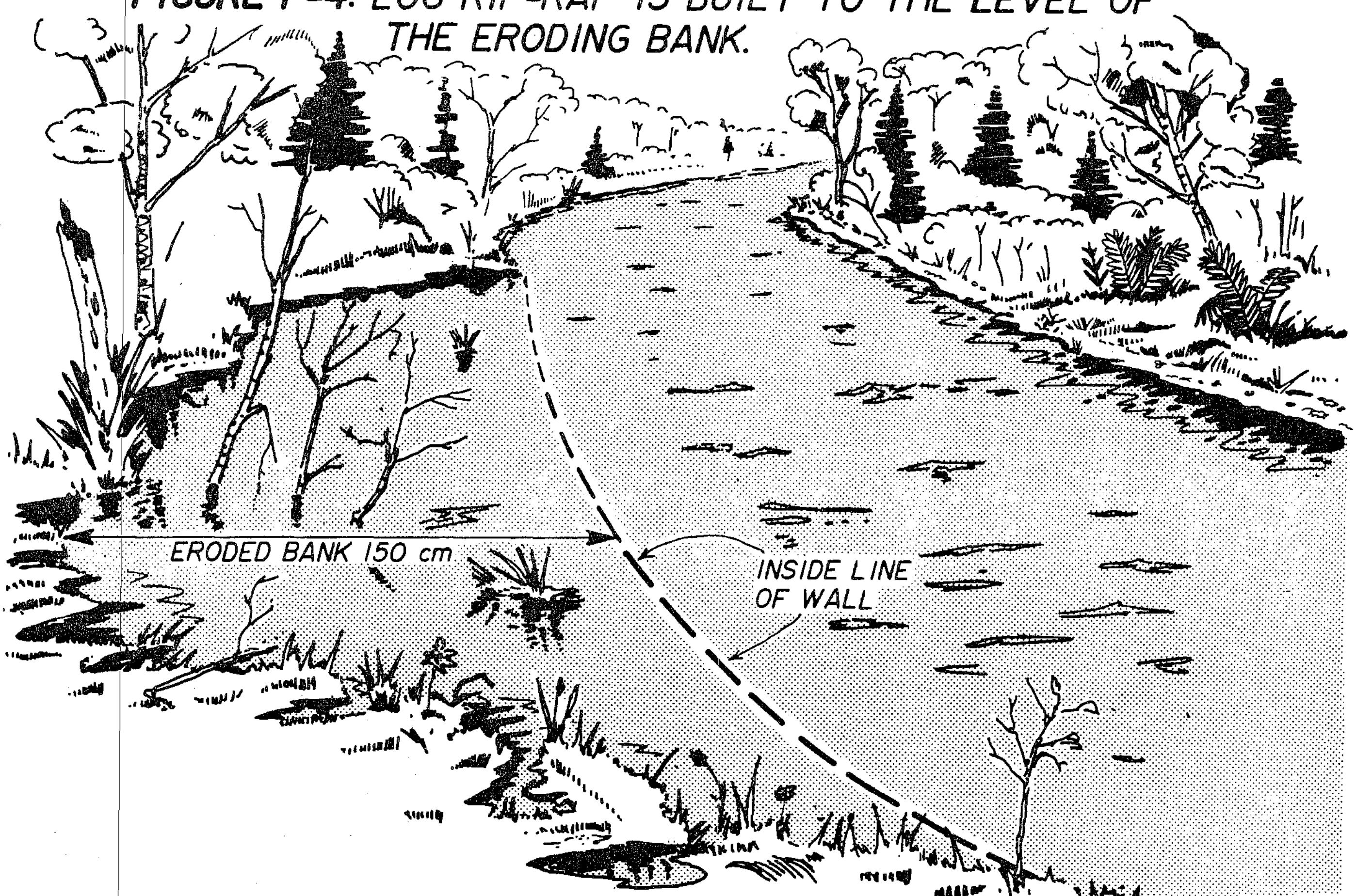


FIGURE F-5: POSTS MARK THE EDGE OF THE NEW BANK.

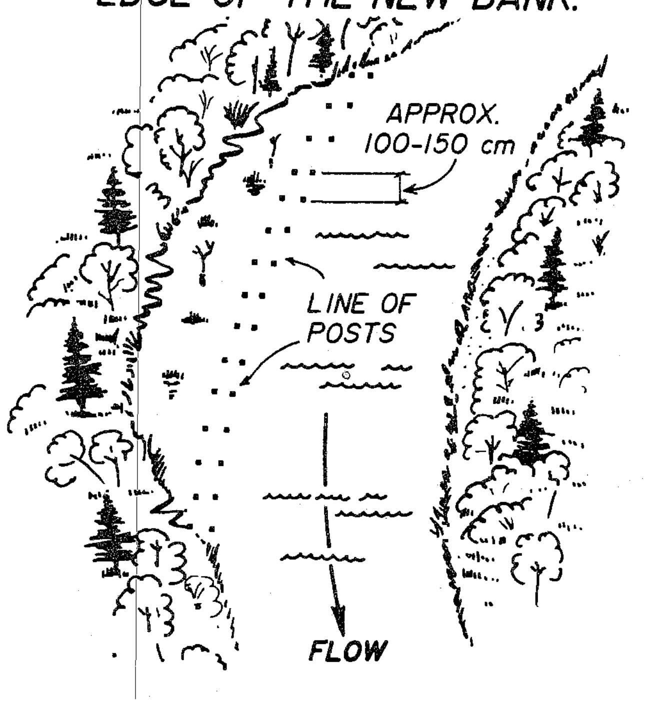
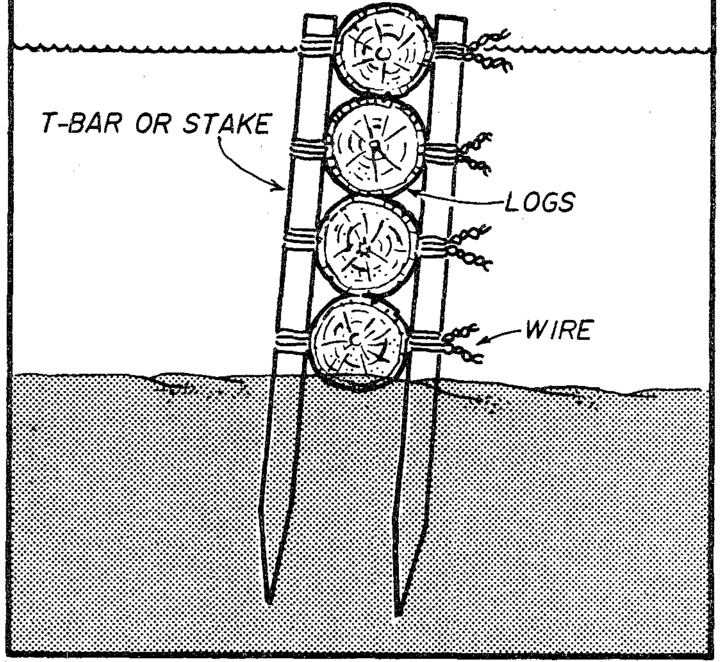


FIGURE F-6: LASH LOGS TOGETHER TO FORM WALL.



FACT SHEET "F"
BANK STABILIZATION: LOG RIP-RAP
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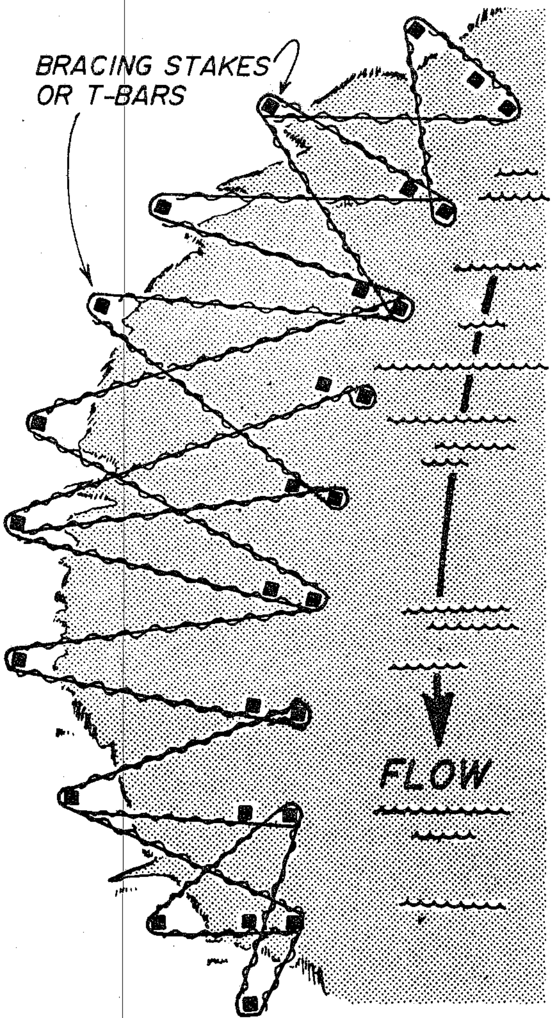


FIGURE F-8: BURY THE WIRE IN A SHALLOW TRENCH.

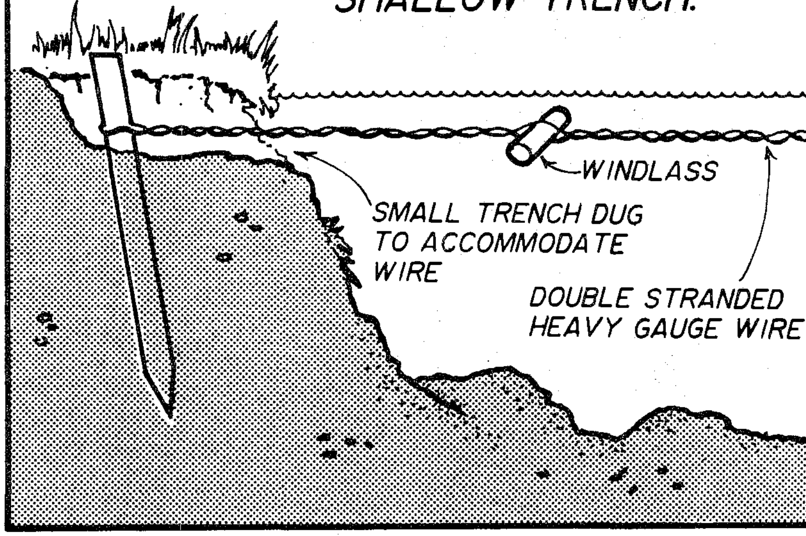
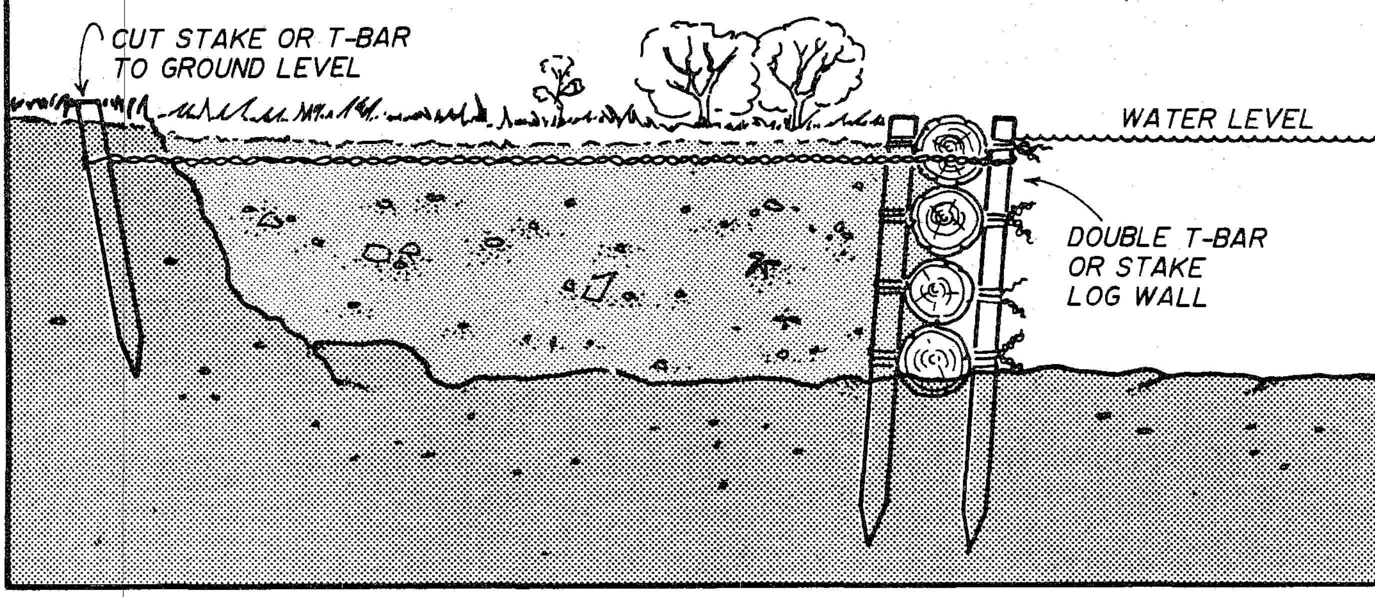


FIGURE F-7: WIRE THE OUTSIDE LINE OF STAKES TO THE WALL WITH DOUBLE STRANDS OF HEAVY GAUGE WIRE.

FIGURE F-9: CROSS-SECTION OF COMPLETED LOG RIP-RAP. TOP THE NEW BANK WITH SOIL AND PLANT WITH GRASS & SHRUBS.



FACT SHEET - G - REVISION: 22-11-88

WING DEFLECTORS: LOG CRIB AND ROCK

*** ATTENTION: DO NOT ATTEMPT THIS OR ANY OTHER IMPROVEMENT TECHNIQUE WITHOUT PRIOR APPROVAL

1.0 DESCRIPTION

A wing deflector is a triangular structure built at the edge of a watercourse to improve fish habitat. The deflector can be constructed of wood, rocks, gabions or any combination of these materials.

Deflectors can be installed as single structures alternating along both banks or as twin units alone or with several together. In a straight channel, alternating deflectors can divert the flow into a meandering pattern. Double deflectors placed opposite each other can cause a long deep trench to form downstream.

Deflectors are designed low to ensure that unfavorable conditions, such as heavy ice build up or high water levels, do not result in damage or the total removal of the deflector.

2.0 PURPOSE

Wing deflectors decrease the width of the stream thus increasing the deep water cover for fish. The increased velocity causes the formation of a scour hole providing more fish cover. The stronger current also carries silt downstream.

The material from the scour holes is deposited to one side of the stream usually off the ends of the downstream deflectors. Vegetation may establish itself in this material when exposed during periods of low flow. This may become permanent whether the deflector remains in place or not.

3.0 CONDITIONS WHERE APPLICABLE

Wing deflectors should be used in shallow or slow-moving streams or stream sections. Deflectors narrow and deepen the stream while creating a meandering effect. The scour holes which develop due to the increased water velocity provide pools for fish.

Deflectors should not be used in unstable flood plain or braided channel reaches as they may become ineffective rapidly or add to existing instability.

Deflectors should not be placed on the outside of a curve as this may create an erosion problem.

4.0 DESIGN AND INSTALLATION GUIDELINES

a. Conduct a comprehensive stream survey for the area(s) in which the wing deflectors are to be installed. The survey should be done during low flow periods when streambed material is visible and can be examined in greater detail. However, when possible, a second survey should be done during high flow periods to measure the current patterns. Through examining these high flow patterns you can determine where to place the deflectors since streambed scouring occurs during these periods.

b. Examine the streambank carefully to determine how much erosion would occur if the water currents were significantly altered.

c. If the deflector is to be constructed next to an eroding bank, contour the bank to a natural slope. If the bank is not of porous material, place a layer of gravel 15 cm (6 in) deep on the slope before laying any boulders to prevent undermining from bank runoff and groundwater seepage.

d. Wing deflectors are best located on long sluggish stretches or riffle sections well below the riffle crest (the crest of a riffle already impounds water in the pool above it).

e. Place deflectors opposite one another on both sides of a stream to scour a run. Install deflectors on alternate banks in a staggered fashion to create a meandering flow pattern.

f. Situate deflectors approximately five to seven stream widths apart. The pool length should not exceed five channel widths.

g. A deflector, or any other structure, must not block more than 1/3 of the width of a stream.

h. Since flooding is common in New Brunswick, it is preferable to construct deflectors with log crib or rock-filled gabions as they tolerate flooding better than other materials.

i. Construct the deflectors during summer low flow periods.

j. Deflectors should be triangular so that water passing over the structure will be deflected at a 90 degree angle. When overtopped during flooding, triangular deflectors will not direct the water at the streambank.

k. The upstream angle of the deflector can range from 30 degrees to greater than 45 degrees. Deflectors with a greater upstream angle direct more water towards the opposite bank but dig scour holes more efficiently. Unfortunately, the larger this angle the greater the water force flowing against the deflector increasing the likelihood of it being damaged or destroyed. Deflectors jutting straight out (large upstream angle) from the bank tend to create short, wide pools or riffles, while deflectors that are angled downstream (small upstream angle) tend to create long, narrow pools or riffles.

l. The height of the wing deflector depends on stream flow characteristics and anticipated ice conditions. Deflectors are designed to work at normal flows protruding only a few inches above the normal flow at the offshore tip then tapering upwards, above the highwater line, toward the bank. This design will protect the bank and prevent the stream from washing around the bank end.

m. Use rip-rap or gabions to protect areas where the wing deflectors touch the bank. Stabilize the bank to above the flood line so the streambank does not erode behind or above the structure during high flow periods.

n. If the bank opposite the deflector is not stable, protect it from erosion with rip-rap.

o. Where the stream bottom is composed of coarse material, pre-excavate the intended pool or run to speed up the natural erosion process and ensure development of suitable habitat.

5.0 IMPLEMENTATION STEPS

5.1 Log Crib With Rock Deflectors (see Figure G-1)

This method should be used when water resistant logs (hemlock or cedar) are available. Log crib deflectors can be built on sites subject to moderate to high levels of flooding.

a. Determine a suitable location to build the deflector.

b. Determine the size and area to be covered by the deflector.

c. Obtain necessary materials such as the logs, reinforcing rods (rebars) and spikes long enough to go through the logs.

d. Excavate the streambed to a firm bottom to prevent undermining. The hole should at least 30 cm (12 in) deep.

e. Prepare a trench in the stream bank to accomodate the ends of the main and brace logs. The logs should be embedded 1.2 m to 2.4 m (4 ft to 6 ft) into the streambank. Take care to place the logs at the correct angle.

f. Drill holes in the bottom logs of the crib. Lay them in place and drive the rebar through the holes and into the stream bottom to hold the logs in place. Drive T-bars into the streambed adjacent to and on the inside of the deflector to further anchor the structure. Secure the T-bars to the log(s) with galvanized wire. T-bars should not extend beyond the top of the log(s).

g. The brace log should be pinned 46 cm to 61cm (18 in to 24 in) from the tip of the main log. It must not protrude beyond the main log at the apex of the deflector.

h. When the structure is greater than one log high, secure the logs together with galvanized spikes. Drill the logs first to avoid splitting.

i. Cross-brace the main log inside the crib structure with diagonal and vertical logs.

j. Peel the bark from any logs which will be exposed to both wet and dry conditions. Logs which are always below the water level are very resistant to decay.

k. Fill the crib with rock once it is built to the specified height.

l. In areas where flood water will not go above the deflector, add soil to the top of structue and plant grass and shrubs.

m. Protect the bank behind the deflector.

5.2 Rock Deflectors

Rock deflectors should be built in areas subject to low to moderate levels of flooding because they do not resist the forces of floods and ice as well as the log crib deflectors. There should be plenty of rock nearby or within a reasonable distance.

a. Determine a suitable location to build the deflector.

b. Determine the size and area to be covered by the deflector.

c. Excavate the streambed to a firm bottom to help prevent undermining. The hole should be at least 30 cm (12 in) deep.

d. Use large boulders 36 cm to 38 cm (14 in to 15 in) to construct the outside edge of the deflector. Place the largest boulder at the apex. The larger boulders should be placed on the upstream side of the deflector near the bottom. Use the smaller rocks to fill the center of the deflector. When rock structures are used, the outside boulders should be at least 60 cm in diameter.

e. To ensure stability of the deflector, the upstream side should have a double line of large boulders. The first row should be fitted into the streambed. Stagger the boulders to help support the deflector.

f. Place finer rock and gravel in the open spaces along the upstream face and top of the deflector. If the top of the deflector is above the flood line, it can be seeded.

g. There should be no break between the deflector and the rock rip-rap used to protect the bank.

6.0 MAINTENANCE AND MONITORING

Check the deflectors every year to ensure they are in good repair. Stabilize eroding streambanks. Make sure that the pools and/or runs are being scoured in the proper places and that they are deep and large enough to provide cover for fish.

7.0 FACTORS INFLUENCING COST

The main factors influencing the cost of this technique are the cost of the purchase and transport of the construction materials.

8.0 ADVANTAGES OF THE TECHNIQUE

a. provides cover for fish;
b. may keep downstream reaches of the stream clear of sediment deposits;
c. may stabilize streambanks thus controlling erosion.

8.0 DISADVANTAGES OF THE TECHNIQUE

a. can be very expensive to build;

b. may require the use of heavy equipment in the stream;

c. can cause erosion problems and add to bank instability if not properly located and installed.

10.0 EXAMPLES OF USE

Wing deflectors have been used to improve streams for many years. In New Brunswick, they have been employed on the Tracadie and Tabusintac River stream enhancement projects. Experience on these has suggested that the design using a 45 degree angle does not scour a pool as large or as deep as desired. To get the required size and depth, deflectors have been constructed at right angles to the stream bank, or even angled slightly upstream, causing the formation of deep elliptical pools extending 15 m to 18 m (50 ft to 60 ft) downstream from the tip of the deflectors.

The lack of success in New Brunswick of wing deflectors positioned less than 90 degrees is probably due to the rocky nature of the streambeds in those rivers . A structure installed at right angles or angled upstream will create more turbulence than those angled 45 degrees or more downstream and generate the water velocity necessary to scour the rocky bottom. The 45 degree angle is recommended on the basis of experience in Ontario and Pennsylvania where streambed materials are often finer and scour with less flow. Experience in British Columbia suggests that deflectors oriented downstream do not create enough velocity to properly scour coarse bottom material.

A deflector angled at right angles or upstream will tend to trap more debris than the normal design. This may result in the danger of damming and flooding of the stream. This is of less concern in New Brunswick where streams tend to be more remote than is true for more populated regions with agricultural land adjacent to the streams.

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FACT SHEET "G"
WING DEFECTORS: LOG CRIB AND ROCK
REVISED:

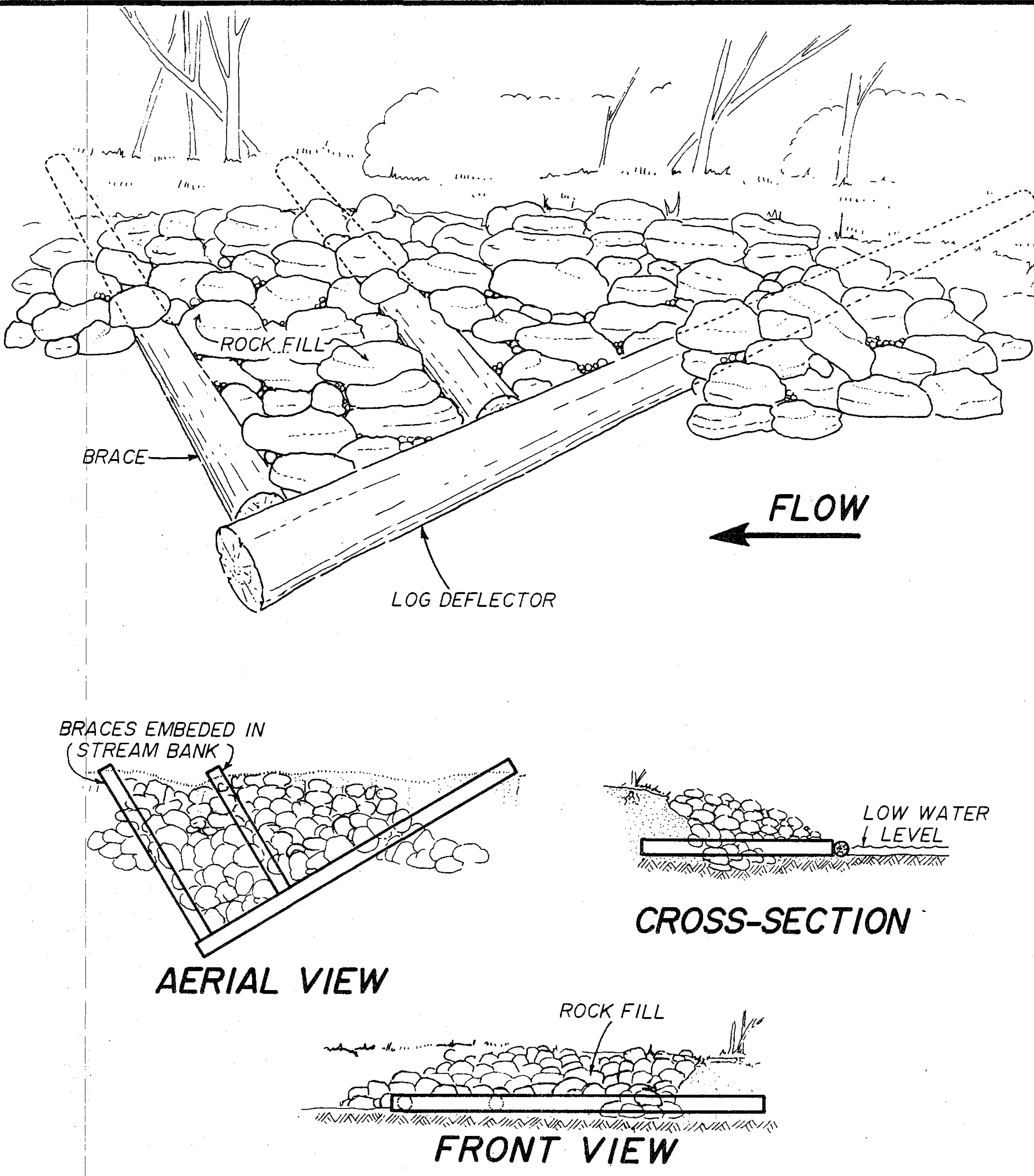

FIGURE G-1: LOG CRIB WITH ROCK DEFLECTORS