

*Exxon Valdez* Oil Spill  
Restoration Project Annual Report

Montague Island Chum Salmon Restoration  
Restoration Project 94139C1  
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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# Montague Island Chum Salmon Restoration

## Restoration Project 94139C1 Annual Report

**Study History:** This is the first year of the project.

**Abstract:** At one time, the streams of Montague Island produced a significant portion of the chum salmon (*Oncorhynchus keta*) caught by the commercial fleet in Prince William Sound. In recent years, however, the chum salmon populations have been drastically reduced by natural and man-caused events, including the *Exxon Valdez* oil spill. It was felt that the best way to restore the populations would be to rehabilitate the watersheds where populations had existed previously, in particular, those watersheds where timber harvesting had altered the stream flows and degraded the riparian areas. Although this work would not deal directly with the oiled habitat caused by the spill, it would help the overall restoration of this injured species in the Sound.

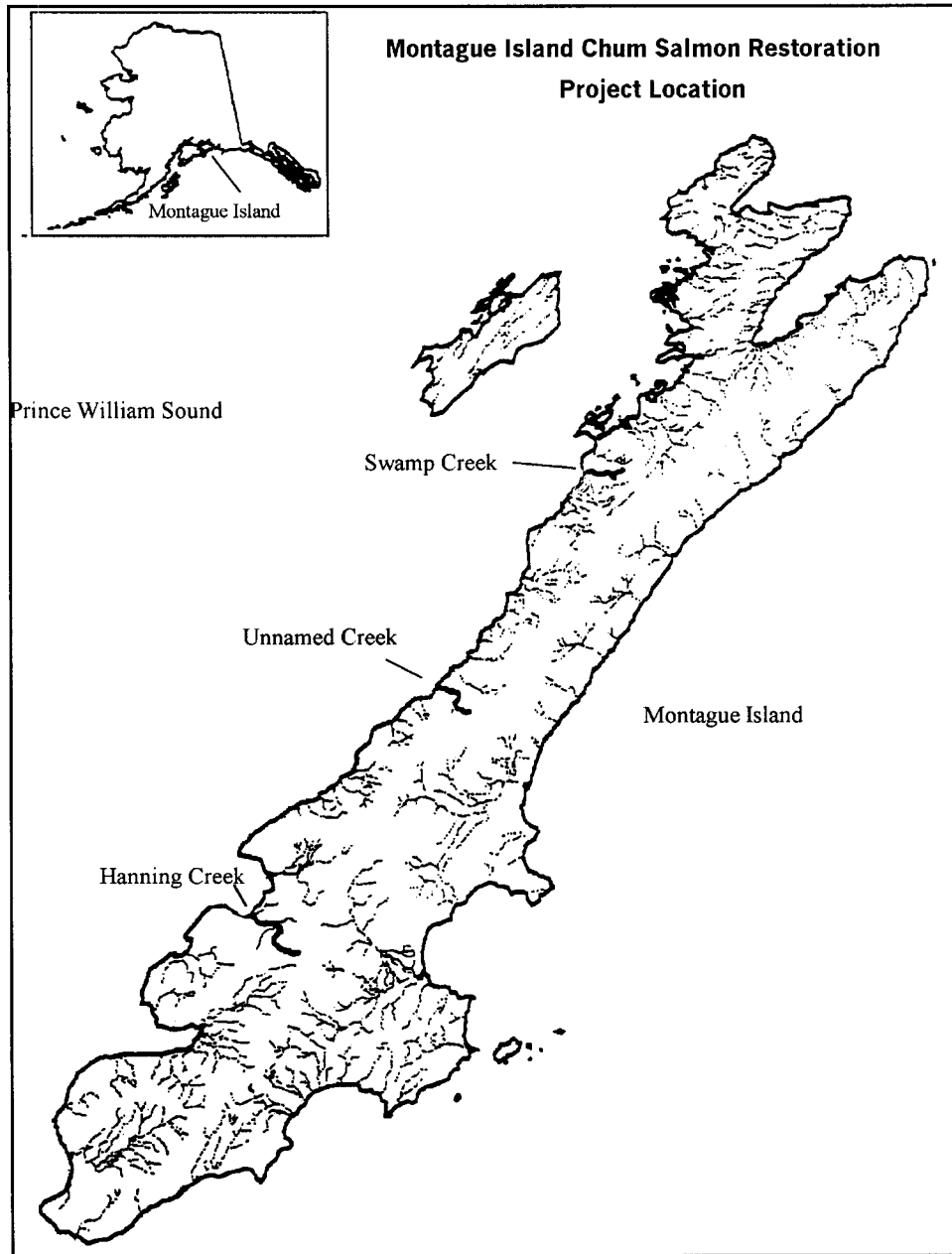
The watershed rehabilitation work consisted of two major parts: building instream structures to restore the natural stream conditions and thinning riparian vegetation to stimulate the growth of Sitka spruce (*Picea sitchensis*). The structures are intended to recreate pools, moderate flows, lower bedload movement, reduce erosion, and improve fish habitat. The thinning should hasten the restoration of the Sitka spruce forest that existed before the logging. At Hanning Creek 31 structures were built and 9.0 acres were thinned. At Swamp Creek 4.5 acres were thinned. At an unnamed stream, one structure was built and 1.5 acres were thinned. Monitoring of the structures after high flows during the first year showed that all of the structures were intact and were beginning to function as intended. Additional monitoring and evaluation is required in the future to show how effective the structures and thinning have been.

**Key Words:** *Exxon Valdez*, chum salmon, *Oncorhynchus keta*, instream structures, thinning, Montague Island

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## Executive Summary

A number of watersheds on the west side of Montague Island were clearcut in the 1960's and 1970's. While these areas were not affected by the *Exxon Valdez* oil spill, it was felt that restoration of these watersheds would improve the overall health and productivity of Prince William Sound. Of particular interest were several streams which had supported large runs of chum salmon (*Oncorhynchus keta*) prior to the 1964 earthquake and the timber harvests. Restoration of the watersheds would also help pink salmon (*O. gorbuscha*) and coho salmon (*O. kisutch*).

These areas were harvested without leaving buffer strips along the streams, and large woody material may have been removed from the channels. When trees are cut along the streams, the roots which stabilize the banks die and rot after several years. The logging also removed the source of large woody material which would enter the stream in the future. Large woody material is essential for pool formation, storing sediment, and reducing water velocities. It is felt that these logging practices have led to increased bank erosion, channel widening, loss of pool habitat, increased water velocities, and excessive input and transport of bedload material. These effects, in turn, could lead to the displacement of salmon redds and eggs, burial of the redds, and siltation and smothering of the eggs. The loss of pool habitat and increased water velocities adversely affect juvenile coho salmon which depend on pools and backwater areas for rearing.

This project addressed these problems in two ways. Thirty-two instream structures were built to create pools, reduce erosion, store sediment and excess bedload material, reduce velocities, or provide fish habitat. The second part was to thin the crowded stands of Sitka spruce (*Picea sitchensis*) that emerged after the banks were clearcut. Thinning the stands will accelerate the growth of the remaining trees and the return of the mature forest that existed previously. These trees will then be the source of large woody material for the streams in the future. A total of 15 acres were treated.

The structures have generally held up to bankfull flows. Monitoring in the coming years will show whether they function as intended. It is still too early to detect any increased growth due to the thinning, but the remaining trees do not seem to have suffered any ill effects, such as sunburn or windthrow.

This project has also been experimental in the sense that we were wondering how effective a small crew working without heavy equipment could be. The crew accomplished a substantial amount of work in one season, and given the apparent stability of the structures, it appears that working with a small crew in remote areas is feasible.

## Introduction

Montague Island was once a significant producer of chum salmon in Prince William Sound. However, chum salmon habitat has been altered and degraded by a number of natural and man-caused events since the mid 1960's. Those events include the 1964 earthquake which uplifted and destabilized intertidal spawning areas, logging operations in the 1960's and 70's which altered stream channels and flow regimes, and later, the 1989 *Exxon Valdez* oil spill.

The chum salmon populations have not recovered naturally and only a few small populations have been reported in recent years. A stocking program in Chalmers River has apparently been successful, but it has been uncertain whether the habitat has sufficiently recovered in other streams to make stocking or natural recolonization possible. Given the number of impacts that have occurred over the years, it becomes apparent that the best way to aid the restoration of the chum populations, and other species as well, is to look at the problems of the watersheds as a whole. If the natural conditions of the watersheds can be restored, the chances for recovery should be improved.

In many of the former chum producing streams, it is not possible to undo the effects of the earthquake or the oil spill. It is possible, however, to help restore the habitat affected by the logging operations and offset the impacts this species has suffered. In most of the clearcut areas, no buffer strips were left around the streams and much of the large woody material was taken out of the stream in the belief that this would assist salmon migration and increase spawning riffles. Forest Service habitat surveys have shown that these streams have low levels of woody material, and since pools form around logs and other obstructions, lower amounts of pool area.

Without the large woody material and pools to disperse the energy of the water during high flows, the stream velocities, bedload movement, and erosion all increase. Comparisons of aerial photographs from before and after the logging show stream widening and the development of larger gravel bars, which suggests increased bank erosion and increased bedload movement. These problems can affect chum salmon and other fish by displacing or crushing eggs in spawning areas during periods of high flows and bedload movement. As flows subside, spawning areas can also be affected by siltation from the eroded material.

The loss of woody material and pools also limits the amount of juvenile rearing habitat for coho salmon and other fish species. Juvenile coho prefer low velocity areas such as the pools and backwaters created by woody materials. Logs and other material also provide cover from predators, attract aquatic insects and other food sources, and provide shelter from high flows.

This project addressed these problems in several ways. To ensure the availability of woody material for recruitment into the stream in the future, the original spruce forests need to be restored. Crowded stands of spruce saplings were thinned to accelerate the growth of the remaining trees. Alders and willows competing with spruce were also removed. The benefits from this work will not be realized until the trees mature, but this will accelerate the natural

process and return the areas to the condition which existed before the logging.

In the short term, however, the instream structures that were built will play the role that fallen trees and other woody material would perform in a natural system. The structures are designed to recreate pools, increase the complexity of the channels, and lower velocities. The structures and pools will also help to trap gravel and, combined with the reduced velocities, reduce bedload movement. Erosion will be reduced with the lower velocities and with structures specifically designed to protect eroding banks.

The overall goal of this project is to return these clearcut areas to a more natural condition, and in doing so, improve the conditions for chum salmon production. Other species, such as pink and coho salmon, will also benefit from this work. It will take some time before the fish populations respond to these changes, but we feel that by treating the problems of the watershed, in both the riparian and stream areas, we can assure continued long-term production in the future.

## **Methods**

A series of surveys were undertaken to assess the conditions in the streams that had historically produced chum salmon on Montague Island. In 1991, habitat surveys were performed in most of these streams using the habitat classifications described by Bisson (1982) and the standard Forest Service habitat survey methods developed by Olson and Wenger (1991 unpublished). It was at this time that the problems in the clearcut areas were identified, particularly the lack of pool habitat and woody material in the streams. In 1992 the clearcut riparian areas were qualitatively surveyed to determine whether tree planting or thinning were needed. Erosion problems were also identified at this time. In 1993, Forest Service crews identified three streams where restoration work would be most effective: Hanning Creek (Alaska Department of Fish and Game #17100), Swamp Creek (#17390), and an unnamed creek (#17340). The crews noted the kinds of restoration work that were needed and developed the preliminary work plans. Final structure sites and thinning areas were identified in April 1994. Most of the instream structure work would be done in Hanning Creek, while Swamp and the unnamed creeks were targeted mainly for thinning work.

The project was started in June 1994. The instream structures were built first to take advantage of the lower flows in the creeks in early summer and to avoid working in the streams when pink salmon were present. After the structures were completed, the thinning work was started.

There were six types of structure designs used: the diagonal log weir, upstream V, wing deflector, log barb, tree top, and log jam (see Appendix 1). These structures were made of logs left on site from the logging period and other local material. These structures are designed to perform some or all of the following functions: reduce the energy of the stream flows, reduce bedload movement, reduce erosion, stabilize the channel, create pools, or provide fish habitat. The type of structure built depends on such criteria as the shape of the existing channel, the type of fish habitat available, bank stability, stream flow, and substrate. At each site the effects of the



proposed structures were analyzed to ensure that the structure would not cause erosion or other problems at either high or low flows.

The structures were installed with a crew of four or five people using hand tools and small power tools, such as chain saws, gas powered drills, and a gas powered winch. No vehicles or heavy equipment were used. Logs were selected that were close to the site and could be moved without causing damage to the banks or stream. The logs were generally 20 to 30 feet long and 12 to 24 inches in diameter.

The structures were held in place by cabling the logs to stumps at the site, pinning the logs to the streambed with four-foot lengths of rebar, placing the log in trenches dug into the bank, or some combination of these methods. The ends of the structure and the banks were lined with large rocks to prevent erosion.

### *Riparian vegetation rehabilitation*

Although one of the goals was to plant Sitka spruce seedlings where natural regeneration had not taken place, most all of the areas had thick salmonberry growth which was preventing spruce growth. If we cut back the salmonberry, we were uncertain whether the salmonberry would simply grow back and overwhelm the planted seedlings. We decided to conduct the thinning and structure work first, and perhaps do some experimental planting in later years.

Another project goal is to restore the original Sitka spruce forest that existed previous to the logging activities. A standard silvicultural practice is to thin crowded stands of trees to promote faster growth and obtain a mature forest in a shorter amount of time.

Small Sitka spruce saplings, Sitka alder (*Alnus crispa*), and willow (*Salix spp.*) were thinned with chain saws within 100 feet on both sides of the streams, except for a 10-foot buffer of uncut trees along the stream side to prevent new bank erosion. The thinning was not necessary along the entire lengths of the streams, however, since the vegetation is very unevenly distributed.

The spacing between trees was determined using a simple standard formula. Generally, the distance between trees should be three feet plus the breast height diameter of the tree. The crews also saved the larger, healthier spruce. In areas where small spruce trees were being crowded out or shaded by thick willow and alder, the other species were cut back to give the spruce more room and light. The cut trees were used in erosion control structures or, in some cases, put into brush piles for wildlife cover.

## **Monitoring Methods**

### *Structures*

To evaluate the performance of the structures and to document what changes occur over time, a monitoring program was built into the project. The objective of this study is to determine

the changes in channel morphology, fish habitat, and substrate at each of the structure sites and in an untreated area downstream from where the structures were placed.

To measure changes at each structure site a detailed map was drawn. This map contained information on the width of the stream, the bankfull width, habitat types, depths, and substrate types. The substrate was examined visually and estimates were made of the percent composition of each substrate class.

The information was collected on the upstream and downstream side of the structure. Photographs were taken to document the site before and after the structure was installed. We will also identify each site using a Global Positioning System (GPS). This will enable future crews to identify the structure sites if, for some reason, the structures are washed away or are otherwise unrecognizable.

Changes in stream channels will be evaluated by remapping the structure sites and comparing this to the map made after construction. The effectiveness of the structures can then be assessed in several ways. Since some of the structures are meant to re-create pool and backwater areas, their success can be measured by the increase in these features. The increase in fish habitat and spawning area is also easily measured. Other structures are meant to disperse energy and help moderate flows. This can be assessed indirectly by changes in substrate sizes or the formation of bars and other depositional features.

To determine the cumulative effects of the structures, a 100-yard section of stream was chosen as a control site downstream from all of the structures. The site contains two riffles and a pool. Each habitat type was mapped and channel cross sections were taken. To analyze the substrate, two Wolman pebble counts were conducted for each habitat type as described by Harrelson et al. (1994). A pebble count involves the random measurement of 50 pieces of substrate and gives a quantitative measure of the substrate composition for an area.

In the future, re-examination of the control site will help to determine if the structures are working as planned. Changes in the cross section will tell if the structures are dissipating energy or moderating flows. For example, if the bankfull width decreases or if the vegetation is able to recolonize the bare gravel bars, we can infer that high flows and energy are being reduced. Re-creation of the pebble count will also show whether there has been a change in substrate size or a reduction in sedimentation. An increase in the amount of smaller materials can indicate that energy is being dissipated by the structures and the size of the material that the stream can move is being reduced.

#### *Riparian vegetation thinning*

Monitoring of the thinning work is more difficult since the full effects are not going to be seen for many years. In the short term, there are several things to look for which will indicate whether the thinning has been done properly. Most of all, the remaining trees should appear healthy, with vigorous new growth by the middle of the growing season. The crews can also check to see that there is no windthrow or sunburnt stems, which would indicate that the trees

check to see that there is no windthrow or sunburnt stems, which would indicate that the trees had been thinned too much. The areas where alder and willow were thinned should also be checked to make sure that they haven't overgrown the smaller spruce again.

To determine the long-term effects of thinning, unthinned control sites will need to be compared with treated areas. The test sites have not yet been established. We will need to identify control sites and thin new areas for comparisons since the areas which have already been thinned have had approximately one-third of a growing season. There are still areas which need to be thinned, so this will not be a problem. We propose to establish 1/10 acre plots in which the average stem diameter and tree height will be determined. Two control and two treated areas will be established at each of the three watersheds. The stem diameters and tree heights can then be compared at regular intervals in the future to determine whether there are any significant differences in the growth rates.

### **Results (preliminary)**

After the structures were completed, there were several storms which raised the flows in the creeks considerably. The main branch of Hanning Creek was close to bankfull flow and the tributaries all appeared to be at bankfull heights. This gave the crews a good opportunity to see how the structures were holding up and to correct any problems.

Of the 32 structures, only two were disturbed by the high flows. One diagonal log which had been held in place by boulders shifted downstream as the boulders moved. This log was put back into place, pinned with rebar, and resecured with larger boulders. The structure has held up to subsequent high flows. One other diagonal log was attached to a stump in a log pile. The stump shifted and wedged farther into the pile, changing the angle of the diagonal log. This did not cause any problems with flows or erosion, so there was no need for correction.

The preliminary assessment of the structures showed that they were beginning to function as designed, with the drop pools and scour pools beginning to form as predicted. The erosion control structures also appeared to be protecting the banks. It will take additional high flows, especially during the spring runoff, to truly test the structures. They will also need to be monitored over a number of years to see how durable they are. It appears, however, that the structures will do well.

There has been no assessment of the thinning work yet, other than to say that there is no evidence of erosion, sunburnt stems, or windthrow. It is still too early to adequately assess these matters, however, as well as any assessment of growth.

Diagrams of the structures and the downstream monitoring site are presented in Appendix 1. Channel profile data and Wolman pebble count data from the monitoring site are listed in Appendix 2. Stream survey data from 1991 are included in Appendix 3.

## Discussion

The theory behind the rehabilitation work on Montague Island was based on the results of a number of different studies and projects in Alaska, the Pacific Northwest, and the rest of the country. There are, for example, a number of papers describing the successful use of instream structures to improve habitat for salmon and trout (Payne and Copes, 1986; Fuller, 1990; House and Boehne, 1986). It has also been widely documented how large woody material, or instream structures functioning as woody material, serve to reduce flows, store sediment, reduce erosion, and generally improve the hydrologic characteristics of streams for salmonids (Swanston, 1991; Chamberlin et al., 1991; Smith et al., 1993). Thinning and removal of competing vegetation has been shown to accelerate the growth of Sitka spruce (Fowells, 1965) and has been a standard silvicultural practice for many years (Smith, 1962). Thus, we feel confident that the methods for our work were sound and the work should have the desired effect.

There are several topics that need to be discussed further, however. Initially, there were some questions as to how effective a small crew working with hand tools would be, especially since the crew would be working in a remote location where weather, logistics, and other factors could create problems. There are also some questions about how the conditions on Montague Island may affect the regrowth of spruce. Lastly, given the experience gained from this year's work, there is the question of how this sort of restoration work can be applied to other fish species and to other areas in Prince William Sound.

### *Effectiveness of the Crew*

Most of the stream rehabilitation projects described in the literature have taken place in areas where there are roads for vehicle access, heavy equipment, and transportation of the equipment and materials. On Montague Island there is boat or float plane access to the shore, but from there all of the camp equipment, tools, materials, and other gear must be carried to the sites. There is, of course, no way to bring heavy equipment to the sites. In spite of these circumstances, the crew completed a substantial amount of work during the season. The size of the logs that the crew was able to move and the size of the structures that were built were also impressive. It appears that a four- or five- person crew can be highly effective in streams that are comparable in size to those on Montague Island.

The bankfull widths of the streams where instream structures were built were usually 25 to 50 feet. In larger streams or streams with greater velocities, it would probably not be possible for the crew to install structures across the entire width of the stream. The relatively dry weather this summer enabled the crew to build the structures during low flow periods, but this could not be done after heavy rains when a person cannot stand in or cross the streams. It would be possible, however, for the crew to build other types of effective structures along the shores. Obviously there are limits to what can be done without heavy equipment during high flows or in large streams, but with a little imagination and innovation, a great deal can be accomplished even with a small crew.

Perhaps the most difficult part of the project was not the work itself, but rather the

necessary logistics. Transporting the crew, equipment, and supplies to the remote areas required a great deal of planning, coordination, and, as weather and other circumstances required, a great deal of flexibility. Fortunately the weather this season was exceptionally good, and the work schedule was only minimally disturbed. If the weather had been worse, however, the schedule could have been severely disrupted, and the crew would not have been able to accomplish as much as it did.

Although the crew accomplished a great deal, there are a few areas which could use some additional work. The unnamed creek could use a few more instream structures to create additional pools. There are also a few areas along Hanning Creek where the thick salmonberry should be removed so spruce seedlings can be planted. Natural regeneration does not appear to be possible at the present time because of the salmonberry.

### *Spruce Regeneration*

The most difficult part of this project to assess will be the response of the spruce to thinning, simply because the benefits may not be seen for many years to come. As noted before, thinning is a standard silvicultural practice and Sitka spruce is said to respond well to this treatment (Fowells 1965). Montague Island, however, is at the extreme northern limit of the range for Sitka spruce. The colder temperatures and shorter growing season may result in slower growth rates and a longer recovery period than in other areas. Although it has been 18 to 25 years since the logging on Montague Island, most of the spruce in the crowded stands are less than 15 feet tall.

Fowells (1965) cited Sitka spruce production figures based on a rotation age of 80 to 90 years in areas of optimal growth. Hopefully, the thinning that was done on Montague Island will accelerate growth and reduce the amount of time needed to restore the mature forest. It will be hard to predict, however, when the mature trees will die and fall into the streams, or otherwise become a source of large woody material for the streams.

By establishing permanent monitoring sites where the growth of thinned and unthinned stands can be measured over time, we should get a better idea of Sitka spruce growth rates on Montague Island. This information should prove especially valuable if restoration efforts are made in the other areas of Prince William Sound which are currently being logged.

### *Future Applications*

We found that our work this year was both technically and logistically feasible, in spite of having to work in remote locations with only a small crew. In other areas where access is less difficult, the work could become much easier and more efficient. The question is whether there are other areas in Prince William Sound that could benefit from this sort of activity.

On the Cordova Ranger District, the only riparian areas which have been significantly degraded are the clearcut areas on Montague Island. Of these, the project work in 1994 targeted those streams which seemed best suited for rehabilitation work and which had good historical

runs of chum salmon. Some other areas were not selected for a variety of reasons, including high gradients, naturally uncontrolled channels, inadequate flows, or a lack of potential fish habitat. Although there are some areas where additional work can be done, the amount of restoration work on Forest Service land is limited.

On private or State lands in the Prince William Sound area, there may be some potential for restoration work in areas which have been recently logged. Much of this would depend, however, on whether buffer zones were left along the streams and whether any of the woody material has been removed from the channels. Although current state law requires a 66-foot buffer along both sides of the streams, some areas were cut prior to the passage of the law. In addition, some of the smaller streams may not have been recognized as providing fish habitat and may not have been protected. As an example, recent Forest Service studies have found cutthroat trout spawning in channels less than five feet wide and less than a foot deep (unpublished Forest Service data, Cordova Ranger District). In any case, the logged areas should be surveyed to see whether any action is necessary.

## Summary

As mentioned earlier, it was not possible to undo the direct effects on the habitat oiled by the *Exxon Valdez* oil spill. There was a need, however, to remedy the problems caused by the logging practices in the 1960's and 1970's and to try to restore the natural conditions that existed before the watersheds were clearcut. The instream structures should serve the same function that large woody material would serve in an unlogged watershed: creating pools, lowering water velocities, reducing bedload movement, and providing fish habitat. The thinning of the crowded riparian vegetation should accelerate the growth of Sitka spruce and help restore the spruce forest that had existed previously. The effects of this work will not be seen immediately, but it was felt that restoration of the watershed was the best long-term strategy for improving fish habitat and production.

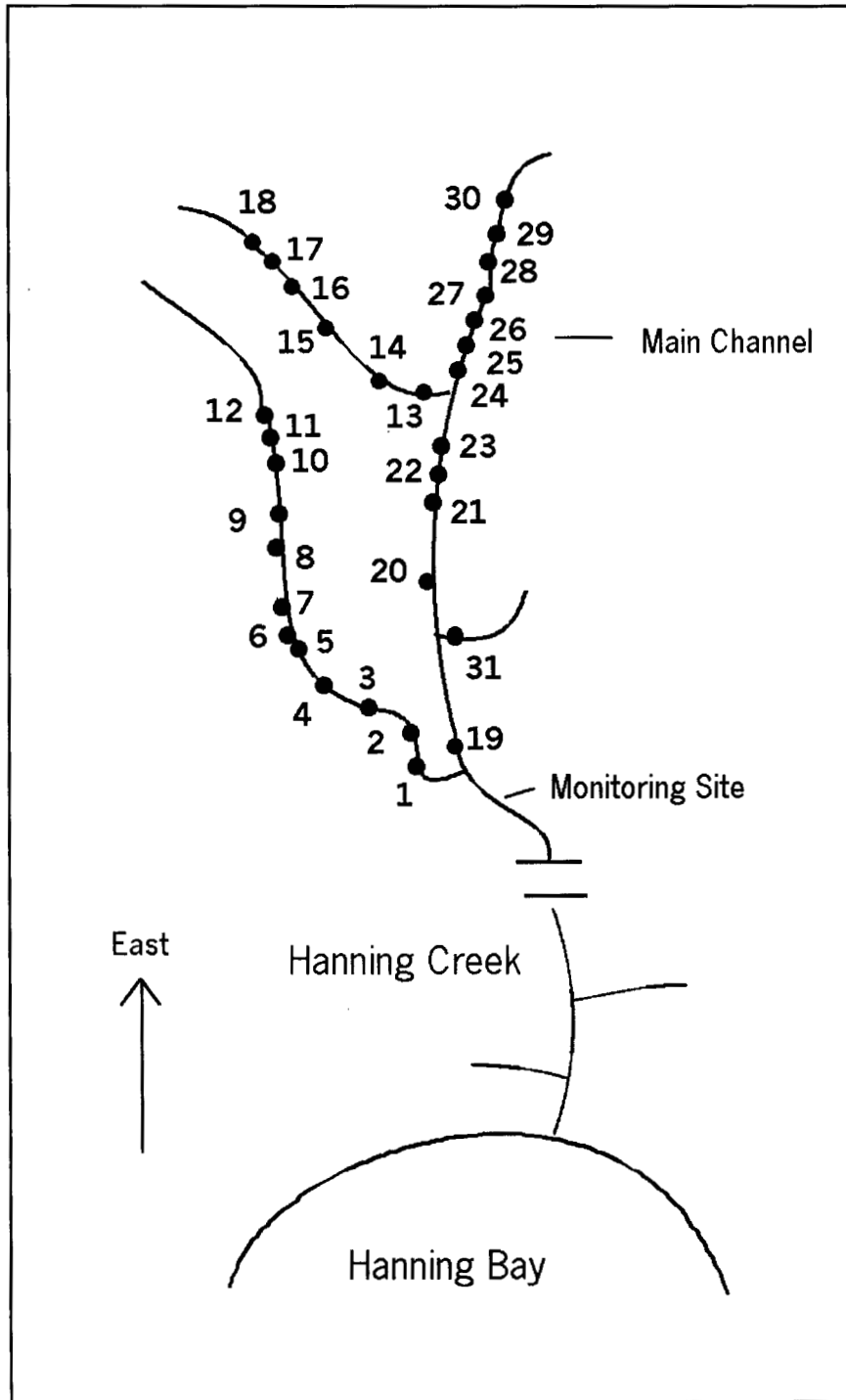
In the future the structures and the thinning will have to be evaluated to make sure the work is having its intended effects and to document the results in case similar projects are proposed elsewhere. The structures, however, have withstood several high flows and appear to be functioning as planned.

The work in 1994 has also shown that a small crew using hand tools can be highly productive and can build effective structures in a creek with substantial flows. Given the capabilities of such a crew, it would be feasible to perform similar work in other areas where logging has occurred. It would also be possible to use the same techniques to restore cutthroat trout habitat around Eyak Lake near Cordova.

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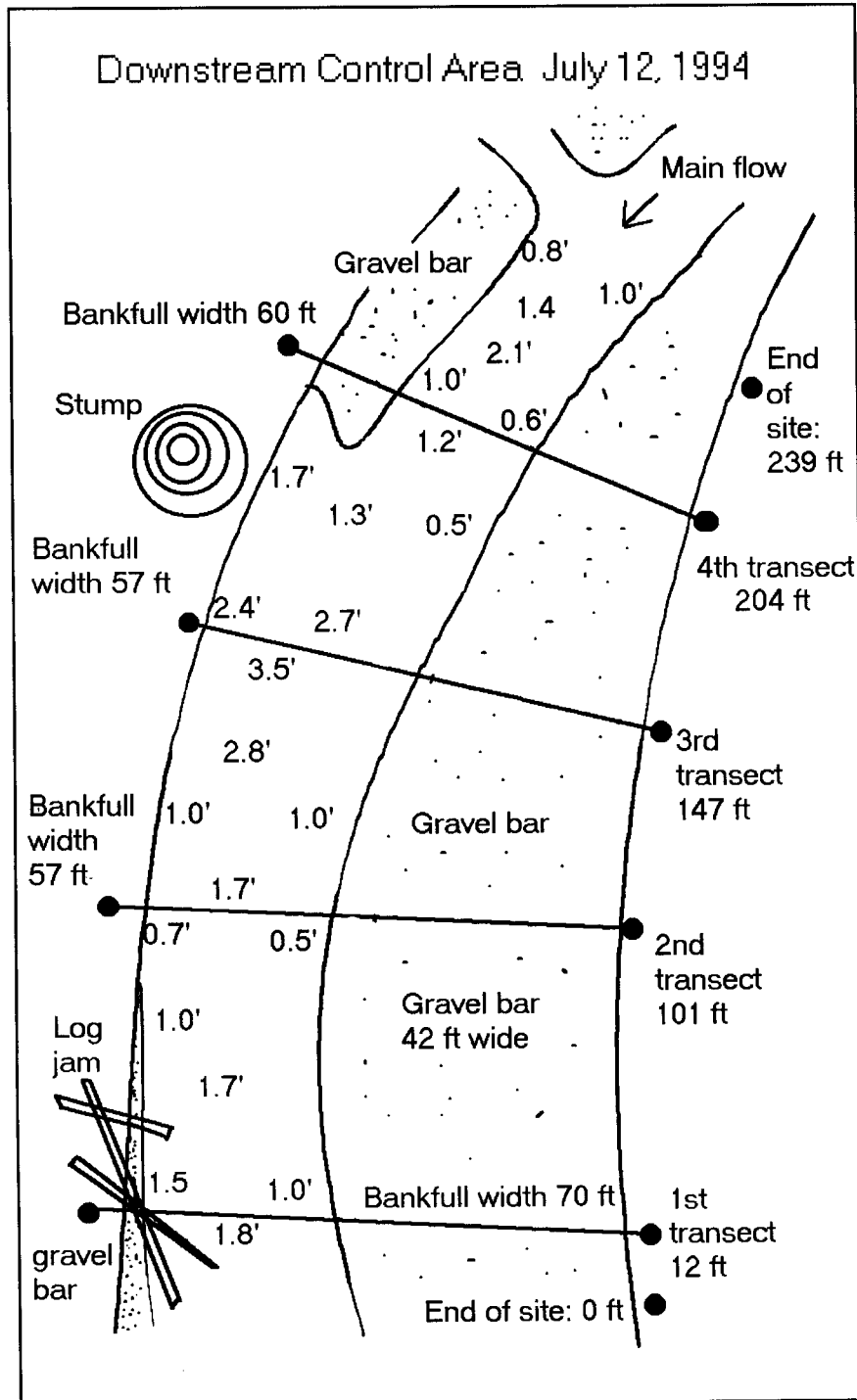
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**Appendix 1.** Structure locations, monitoring site location, monitoring site diagram, and structure diagrams. The structure diagrams depict the habitat and other features as they existed when the structures were built. The effects of the structures have not yet occurred in these diagrams. Future monitoring will be conducted to determine what effects the structures have caused.

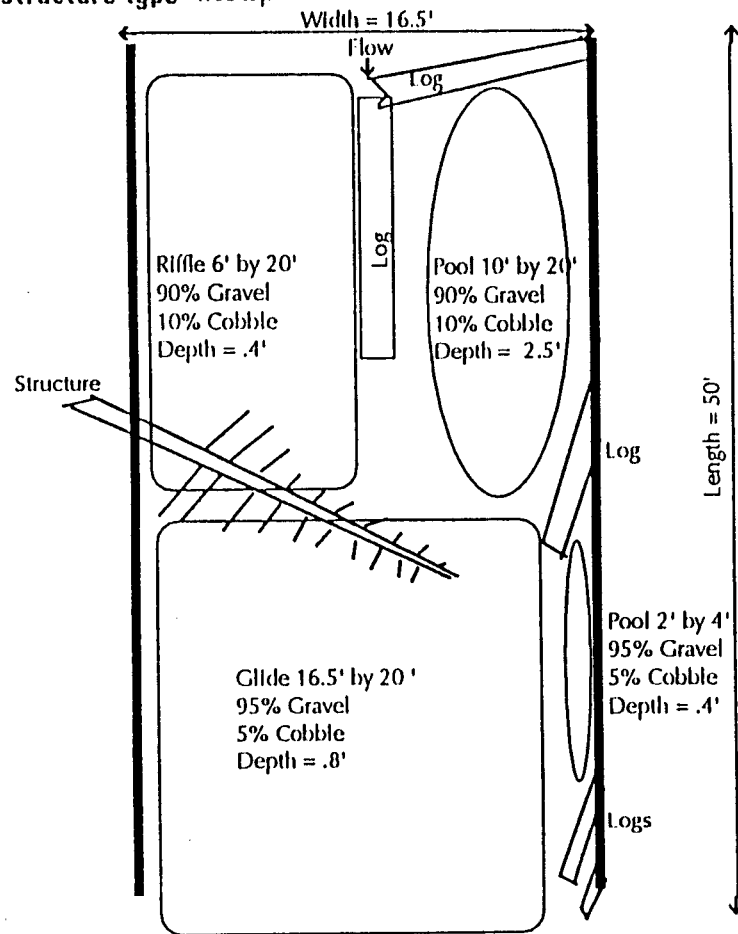




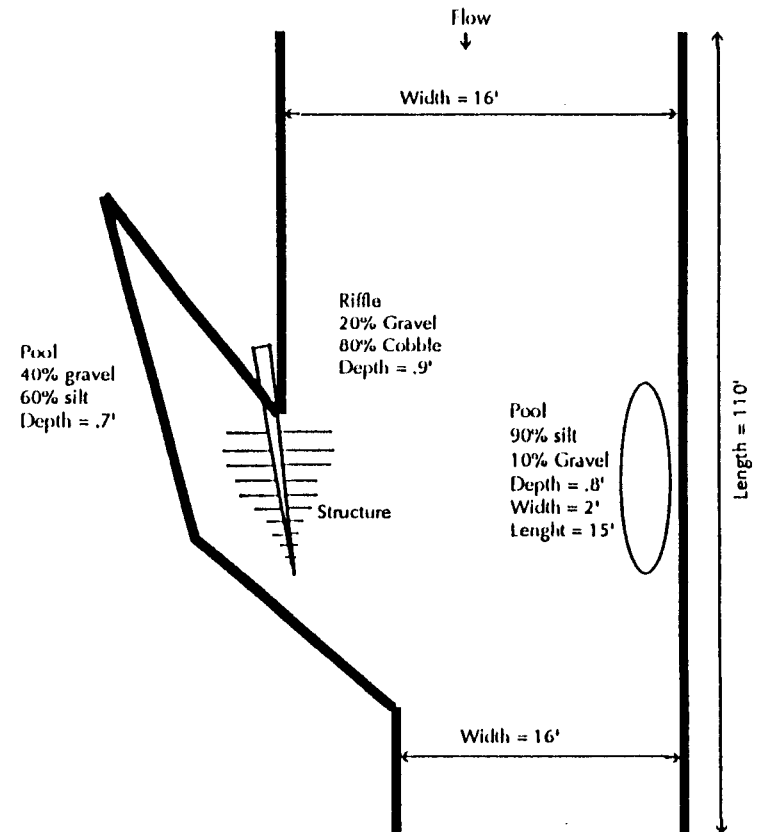
Appendix 1. continued. Downstream monitoring area diagram. Monitoring area data are presented in appendix 2.



**Structure Number 1** Location Left trib, 264' from mouth.  
 Hanning Creek, Hanning Bay, Montague Island, AK.  
 Structure type Tree top



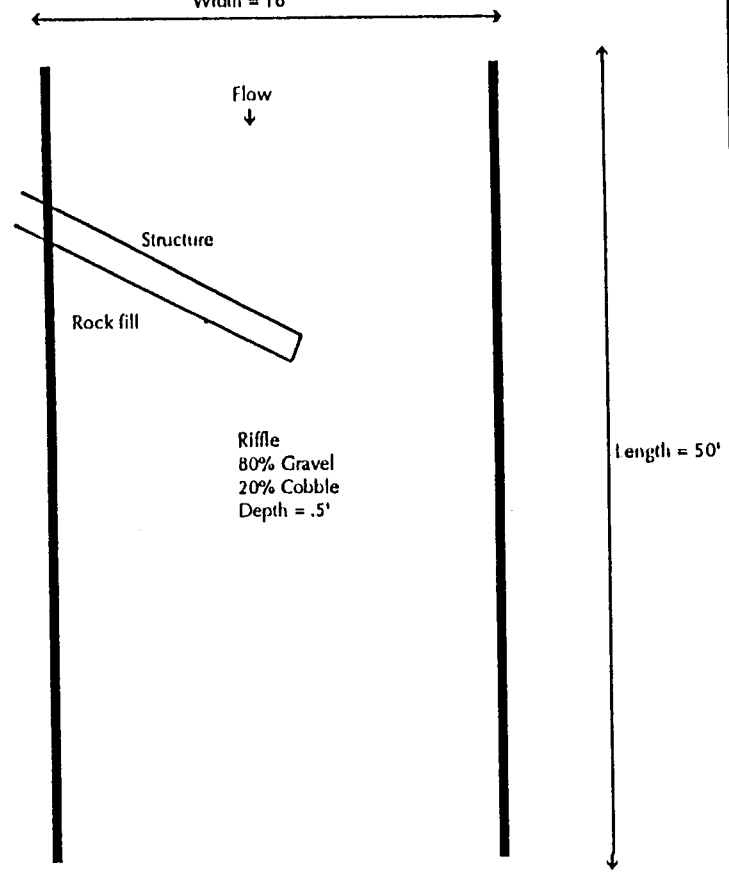
**Structure Number 2** Location Left trib, 1000' from mouth.  
 Hanning Creek, Hanning Bay, Montague Island, AK.  
 Structure type Tree top



**Structure Number 3** Location Left trib. 1075' from mouth

Hanning Creek, Hanning Bay, Montague Island, AK.

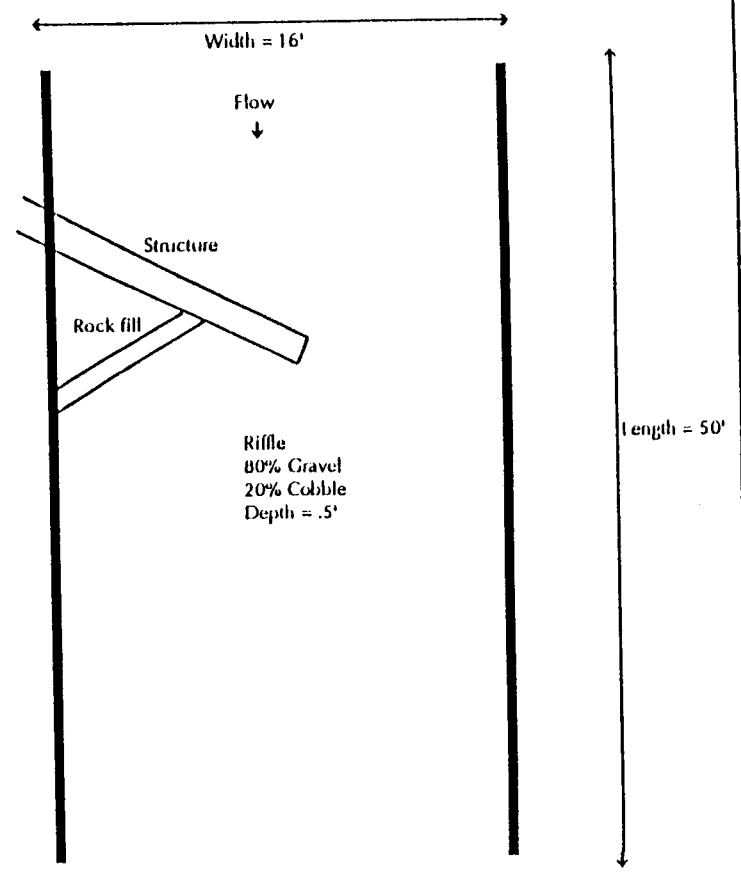
Structure type Log barb  
Width = 16'



**Structure Number 4** Location Left trib. 1650' from mouth.

Hanning Creek, Hanning Bay, Montague Island, AK.

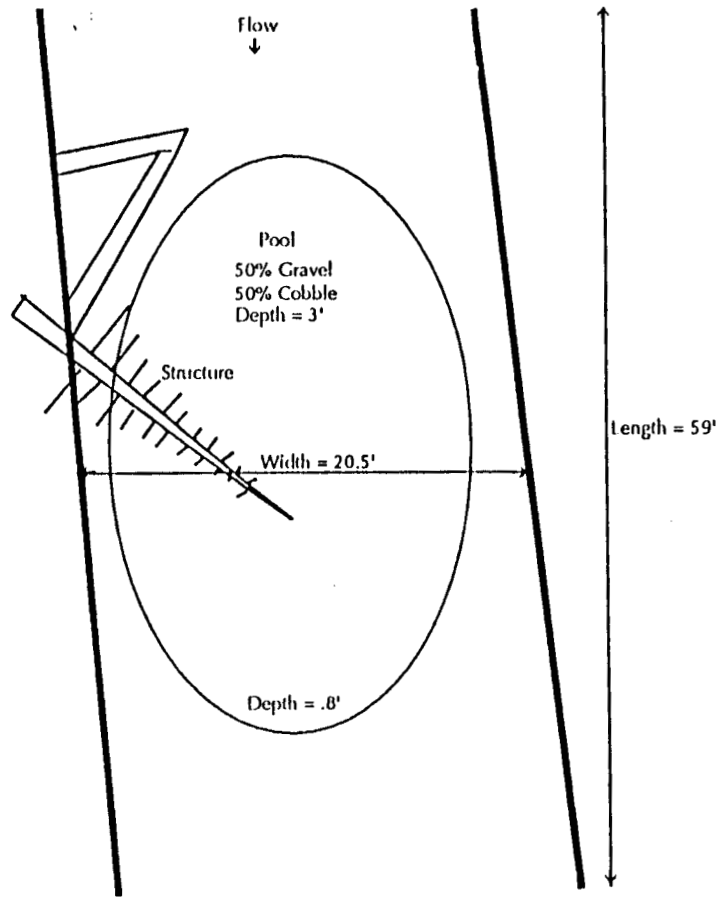
Structure type Wing deflector  
Width = 16'



**Structure Number 5**    **Location** 100' up from structure 4 on the left trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

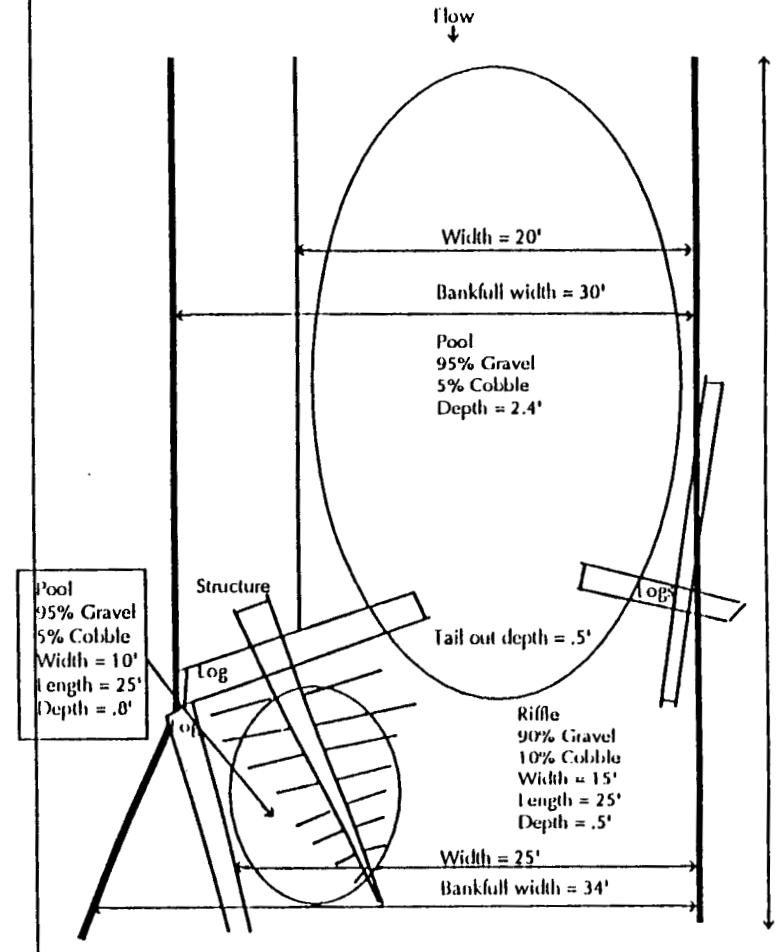
**Structure Type** Tree top



**Structure Number 6**    **Location** 1500' from mouth of left trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

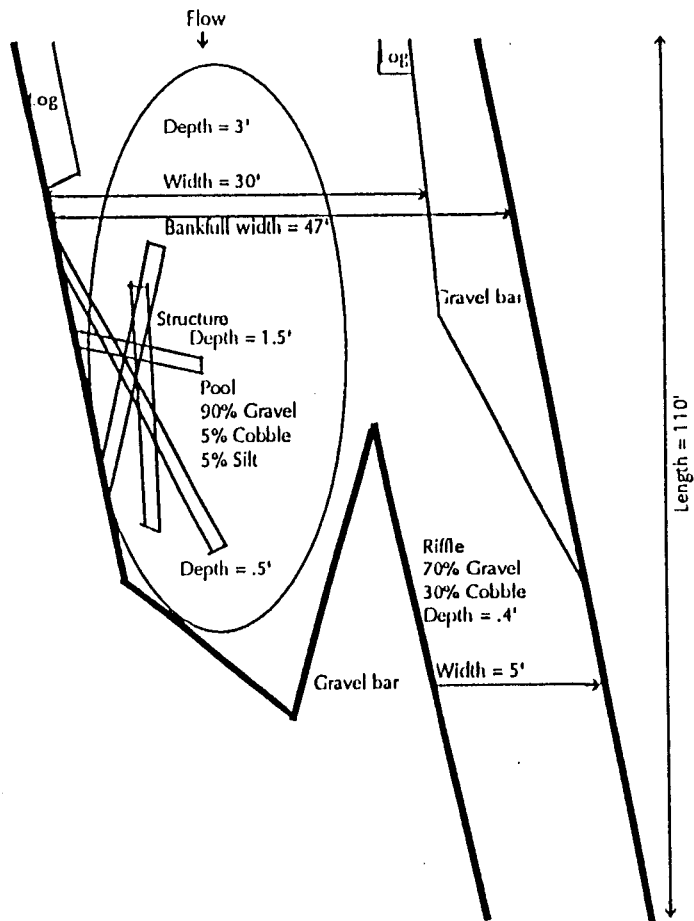
**Structure Type** Tree top



**Structure Number 7**      **Location** 1600' from mouth of left trib.

**Hanning Creek, Hanning Bay, Monague Island, AK.**

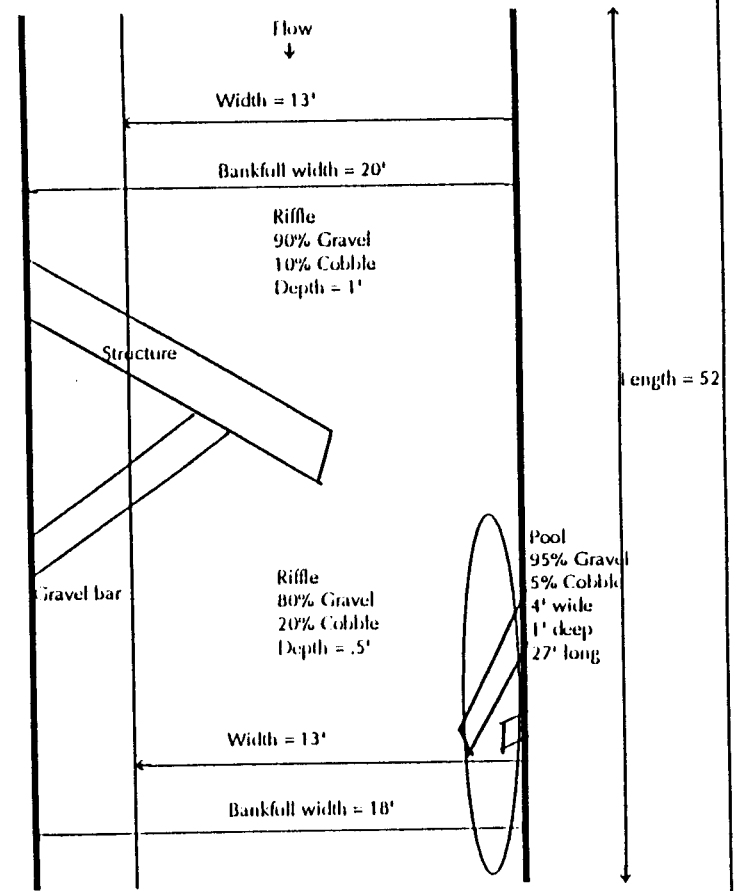
**Structure type** Log Jam



**Structure Number 8**      **Location** 1650' from mouth of left trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

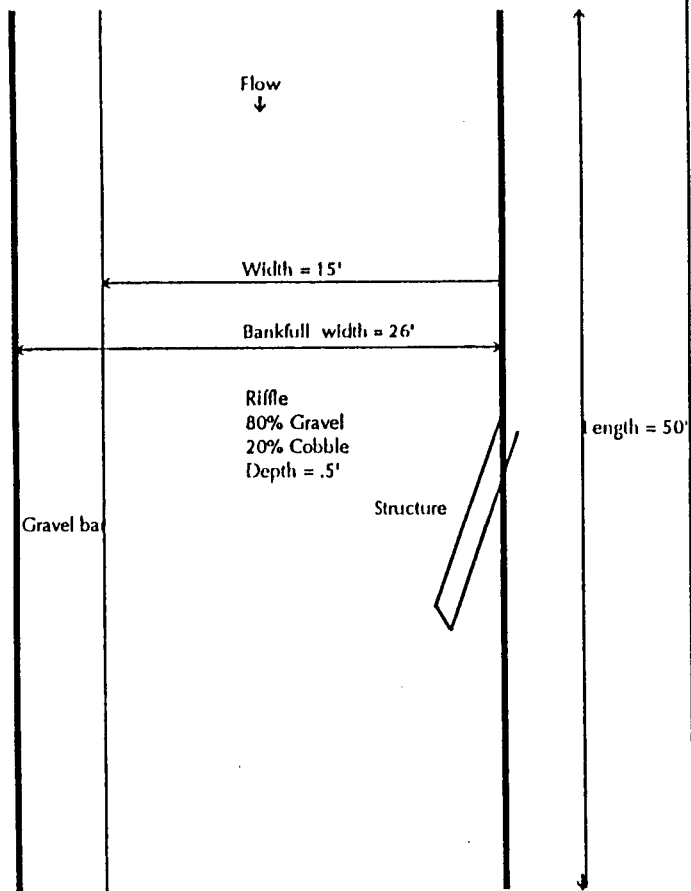
**Structure type** Wing deflector



**Structure Number** 9 **Location** 1675' from mouth on left trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

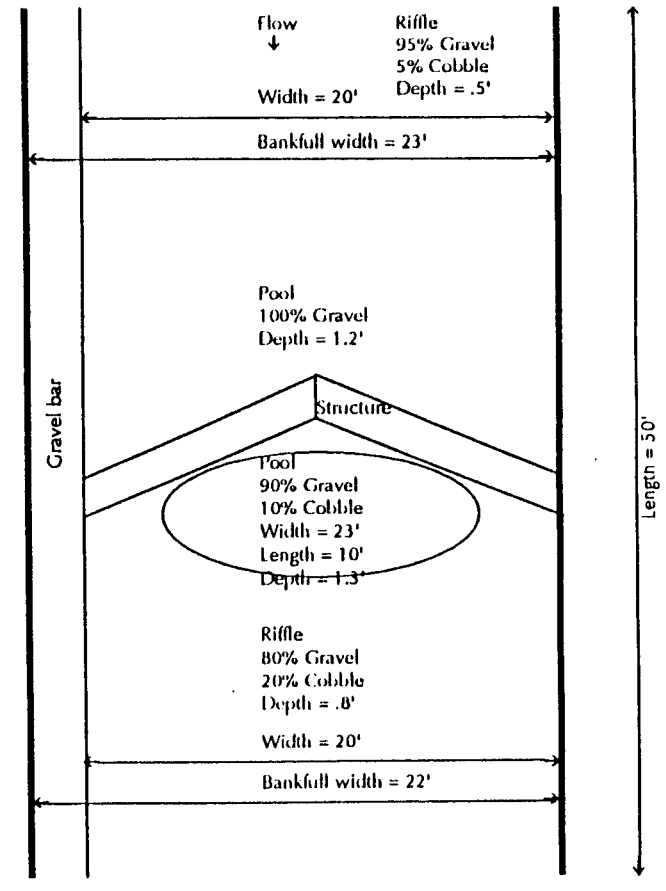
**Structure type** Log barb



**Structure Number** 10 **Location** 1800' from mouth of left trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

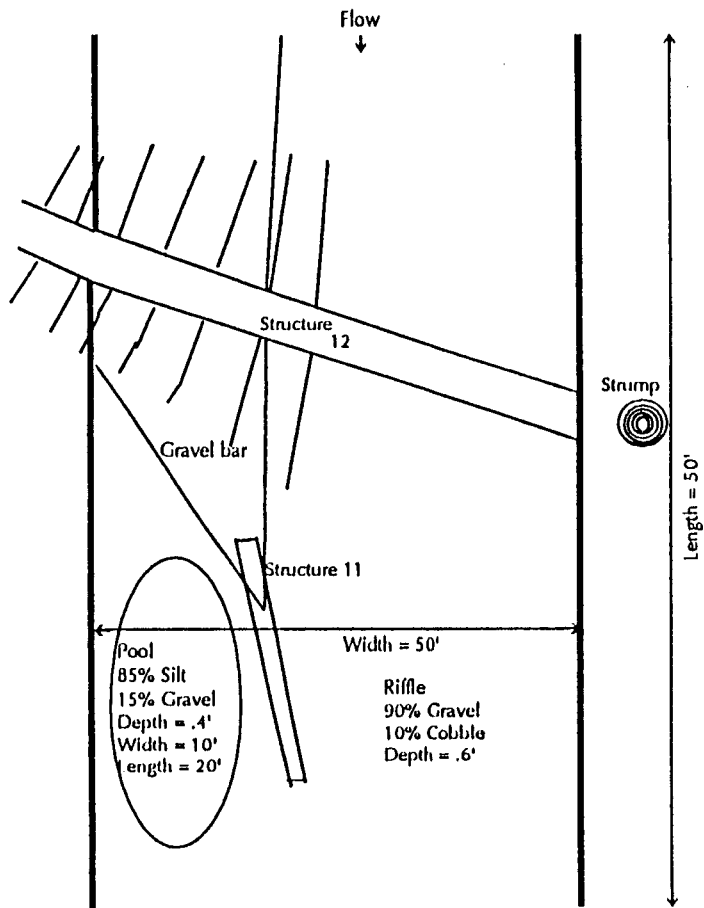
**Structure Type** Upstream V



**Structure Number 11** Location 1920' from mouth of left trib.

Hanning Creek, Hanning Bay, Montague Island, AK.

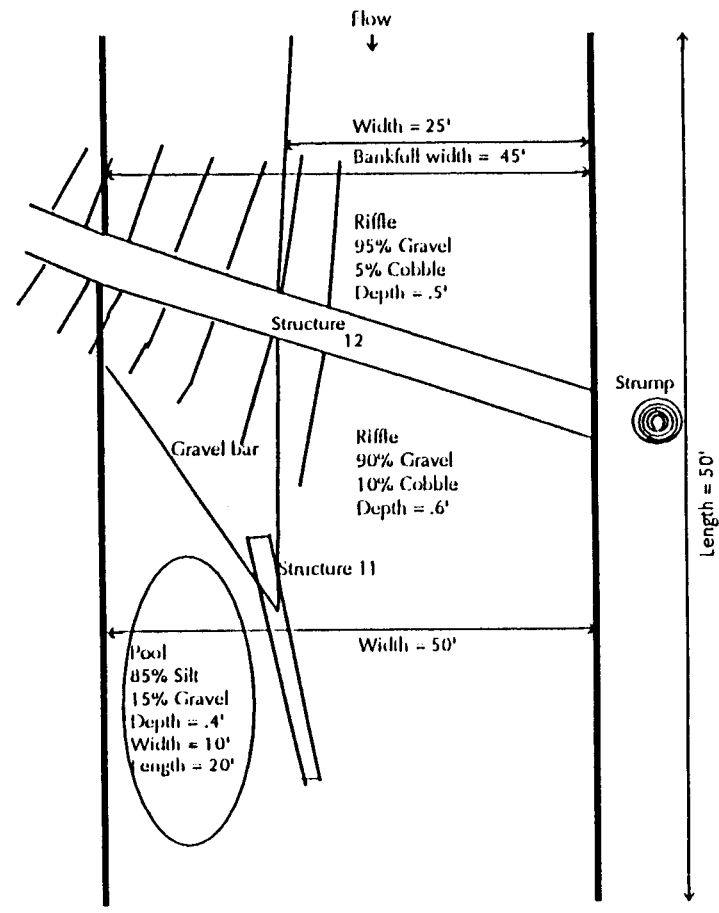
Structure Type Log barb



**Structure Number 12** Location 1950' from mouth of left trib.

Hanning Creek, Hanning Bay, Montague Island, AK.

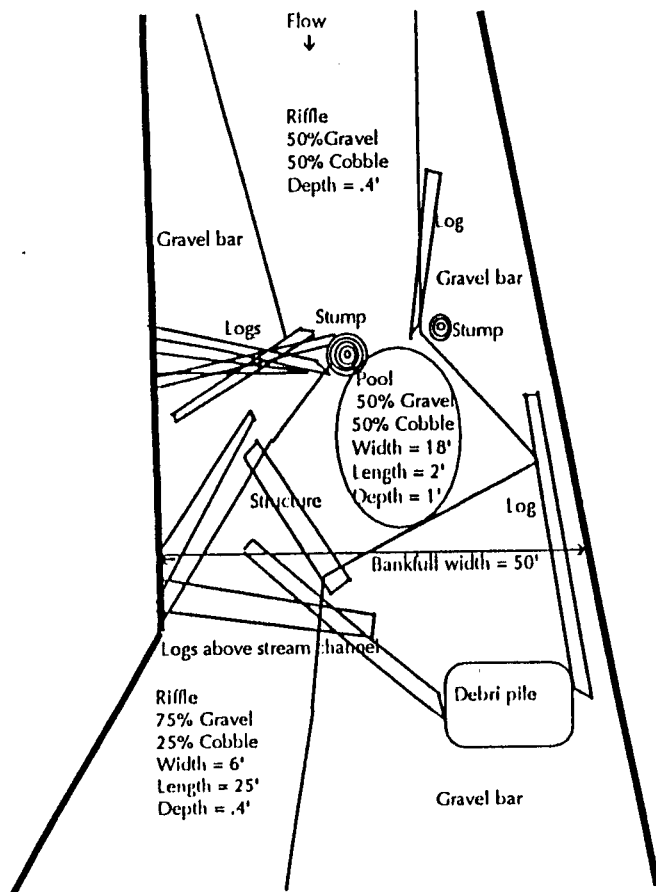
Structure Type Tree top



**Structure Number 13**    **Location** 100' From mouth of second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

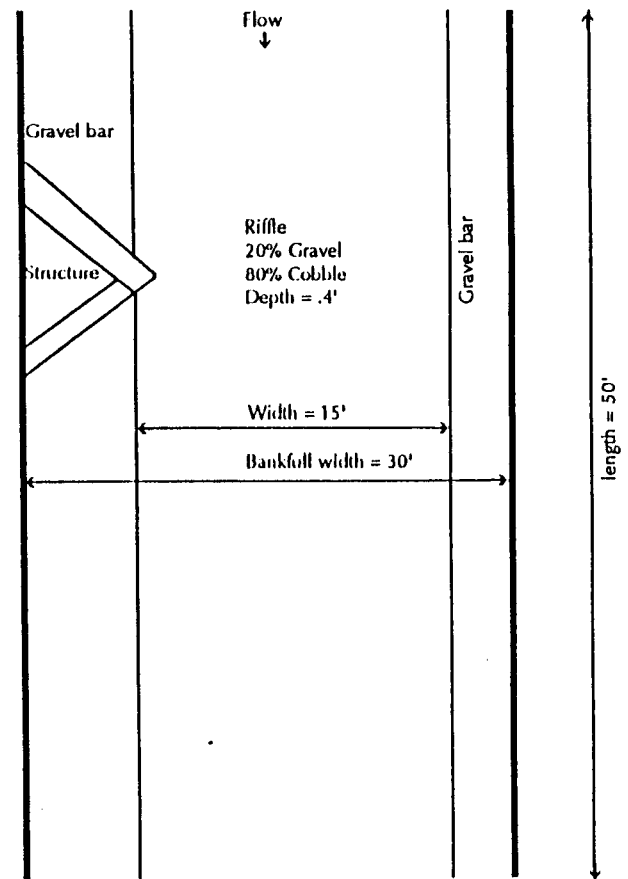
**Structure Type** Diagonal log weir



**Structure Number 14**    **Location** 210' from mouth, on second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

**Structure Type** Wing deflector

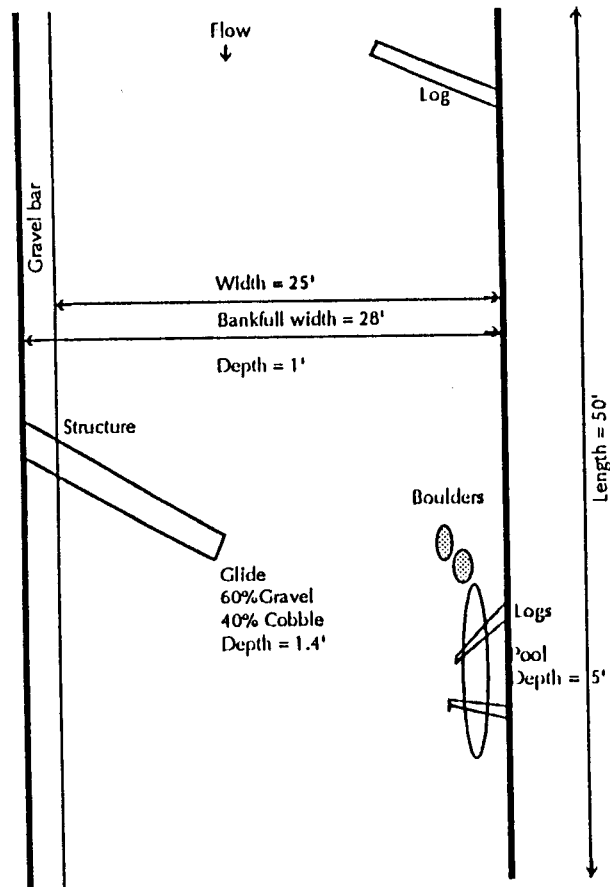




**Structure Number** 15 **Location** 350' from mouth, on second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

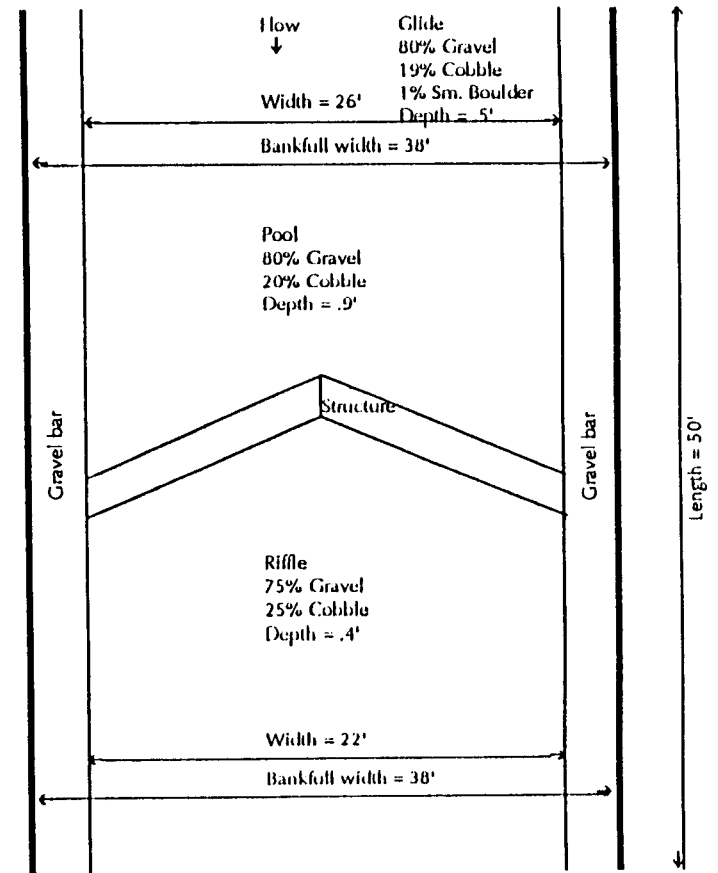
**Structure Type** Log Barb



**Structure Number** 16 **Location** 515' from mouth of second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

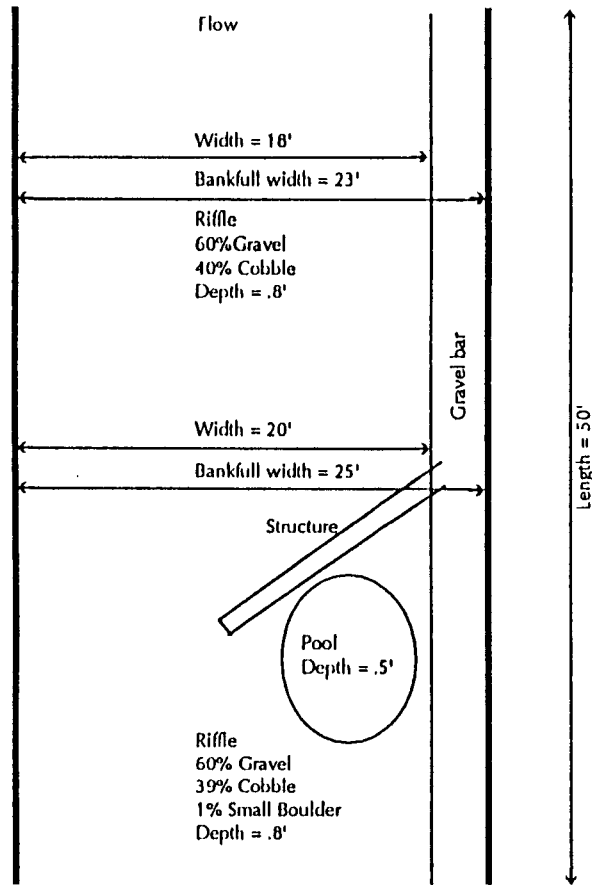
**Structure Type** Upstream V



**Structure Number 17**    **Location** 565' from mouth of second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

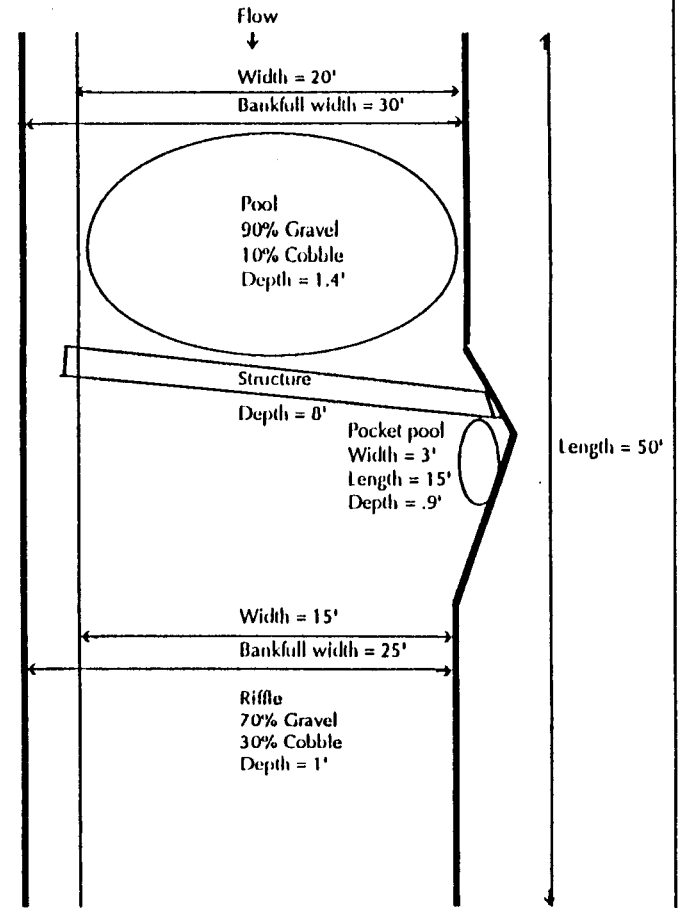
**Structure Type** Log barb



**Structure Number 18**    **Location** 615' from mouth of second trib.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

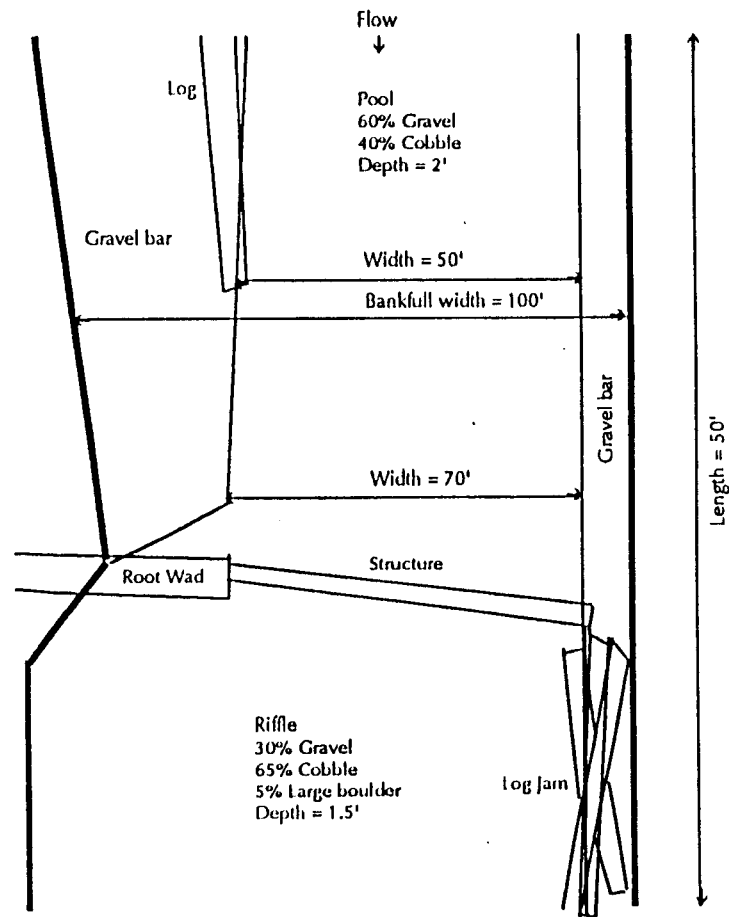
**Structure Type** Diagonal weir



**Structure Number 19** Location 25' above where first trib. on left joins the main branch.

Hanning Creek, Hanning Bay, Montague Island, AK.

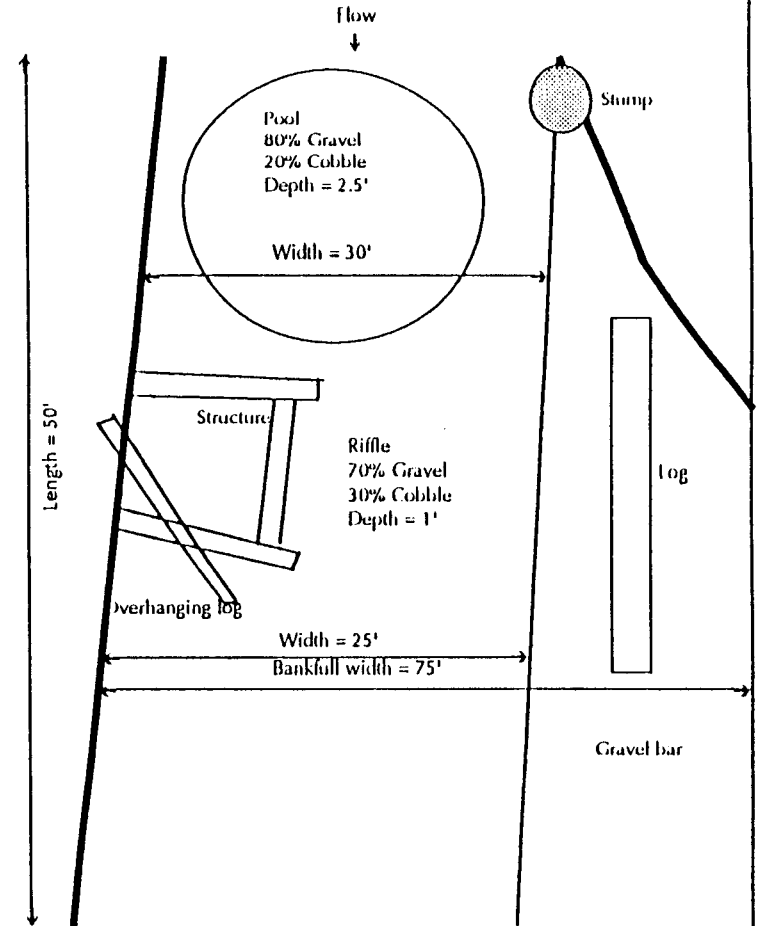
Structure Type Diagonal log weir



**Structure Number 20** Location 1200' down from junction of the second trib on the left and the main branch.

Hanning Creek, Hanning Bay, Montague Island, AK.

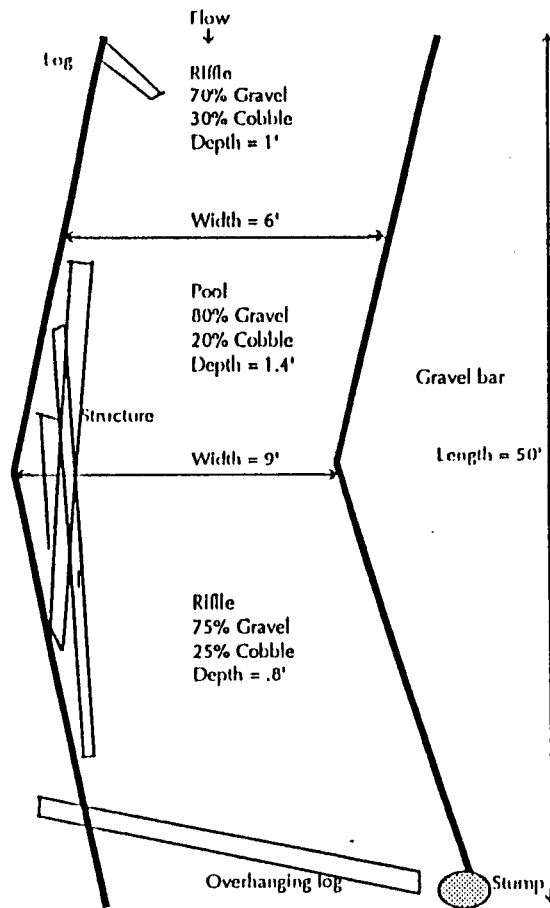
Structure Type Wing deflector



**Structure Number 21** Location 660' feet down from junction of second trib. on main branch.

Hanning Creek, Hanning Bay, Montague Island, AK.

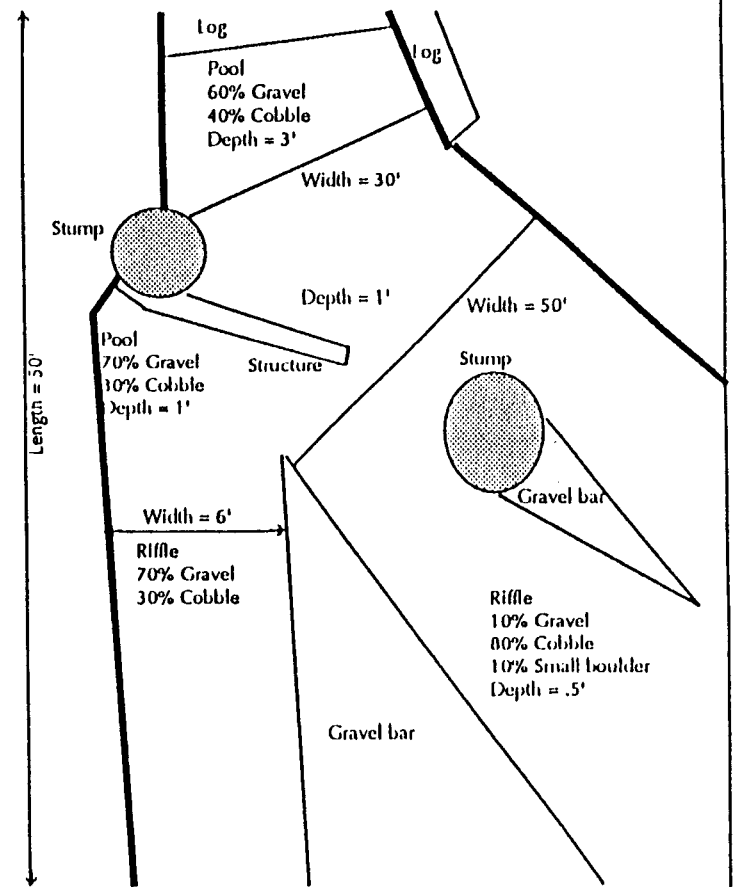
Structure Type Log pile to prevent bank erosion.



**Structure Number 22** Location 600' below where the second left trib joins the Main branch.

Hanning Creek, Hanning Bay, Montague Island, AK.

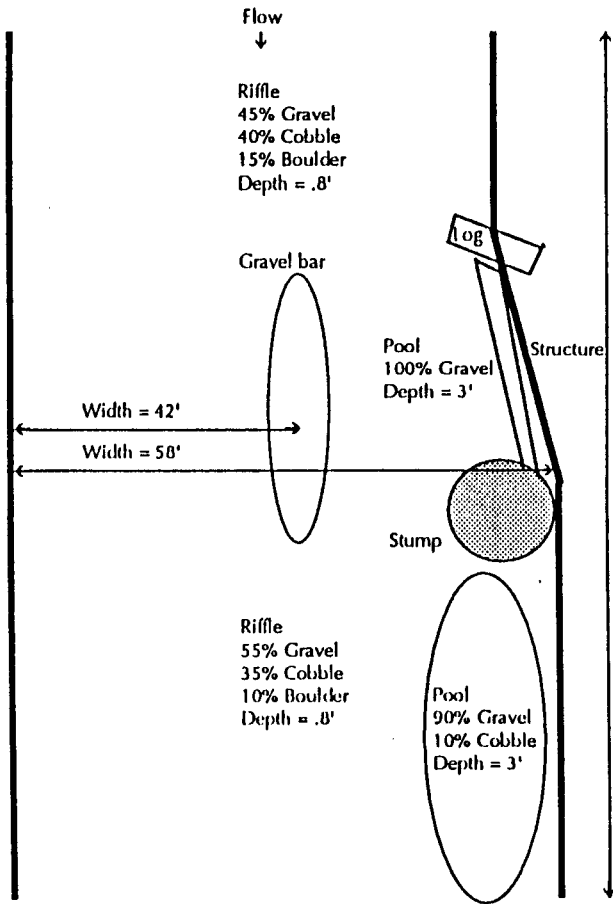
Structure Type Log barb



**Structure Number 23**    **Location** 100' down from where second left trib. join main branch.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

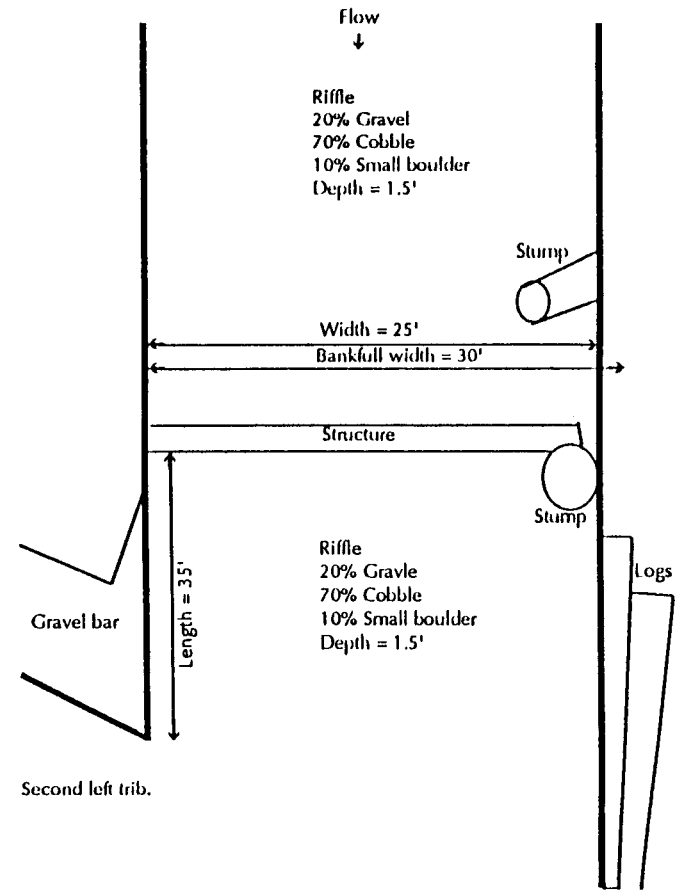
**Structure Type** Bank protection



**Structure Number 24**    **Location** 35' up from where second trib. on left joins main branch.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

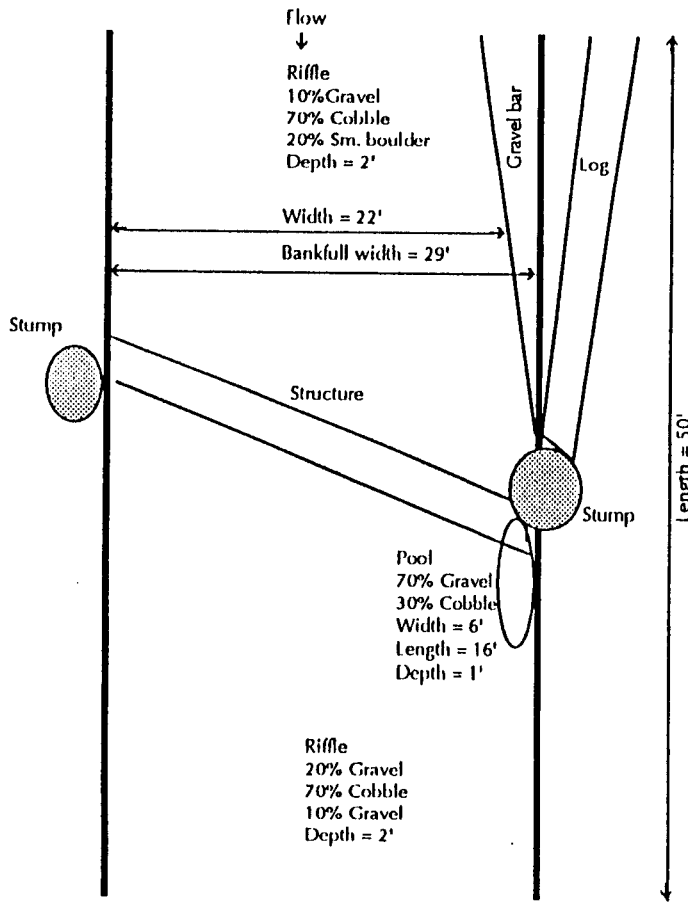
**Structure Type** Diagonal log Weir



**Structure Number** 25 **Location** On Main branch 300' above junction of second trib on left.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

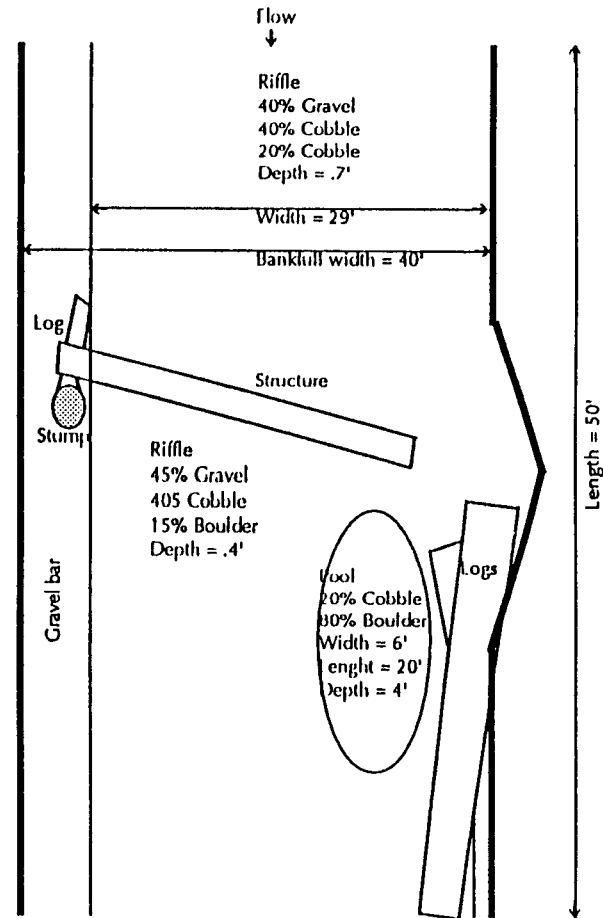
**Structure Type** Diagonal log weir



**Structure Number** 26 **Location** 525' upstream from where second left trib joins main channel

**Hanning Creek, Hanning Bay, Montague Island, AK.**

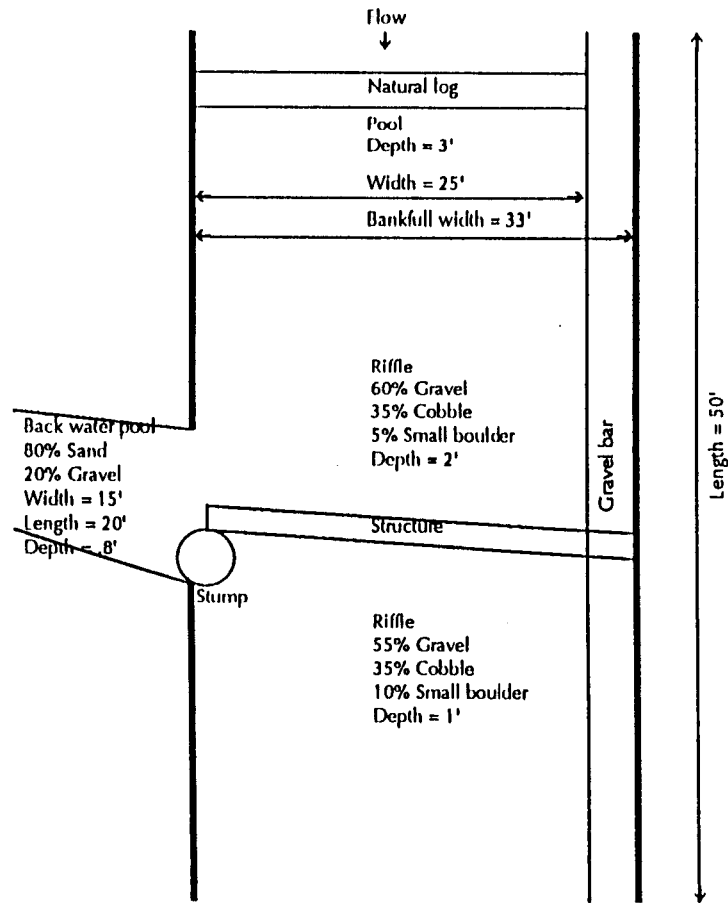
**Structure Type** Log Barb



**Structure Number** 27 **Location** 625' above where second left trib joins the main branch.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

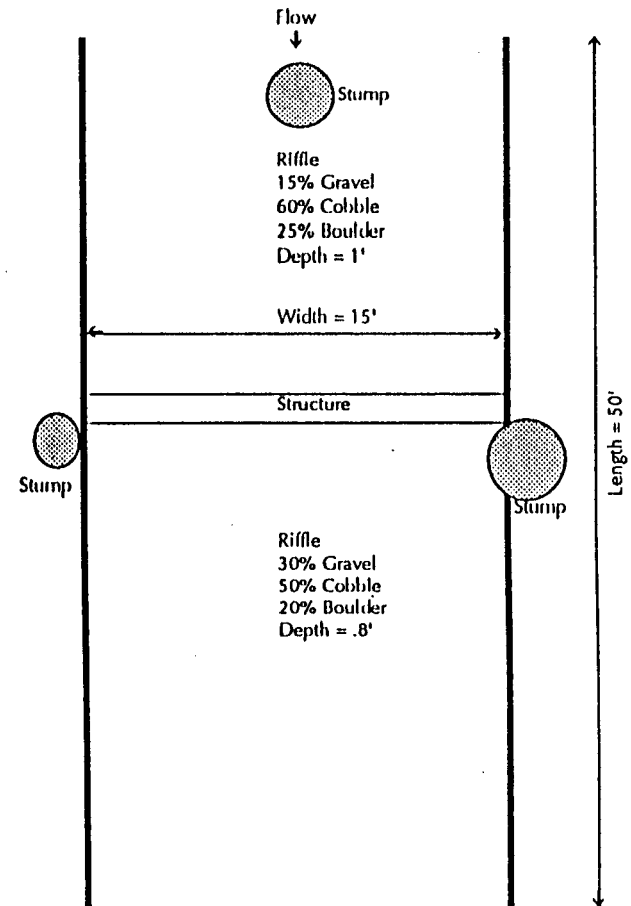
**Structure Type** Diagonal log weir



**Structure Number** 28 **Location** 875' above where second trib joins the main branch.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

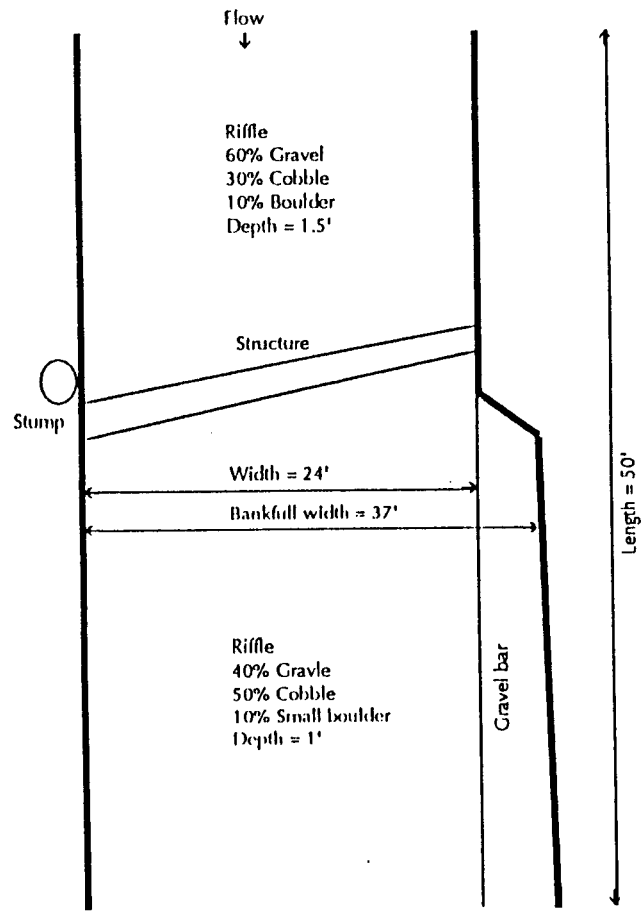
**Structure Type** Diagonal log weir



**Structure Number** 29 **Location** 1125' from where second left tributary joins the main branch.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

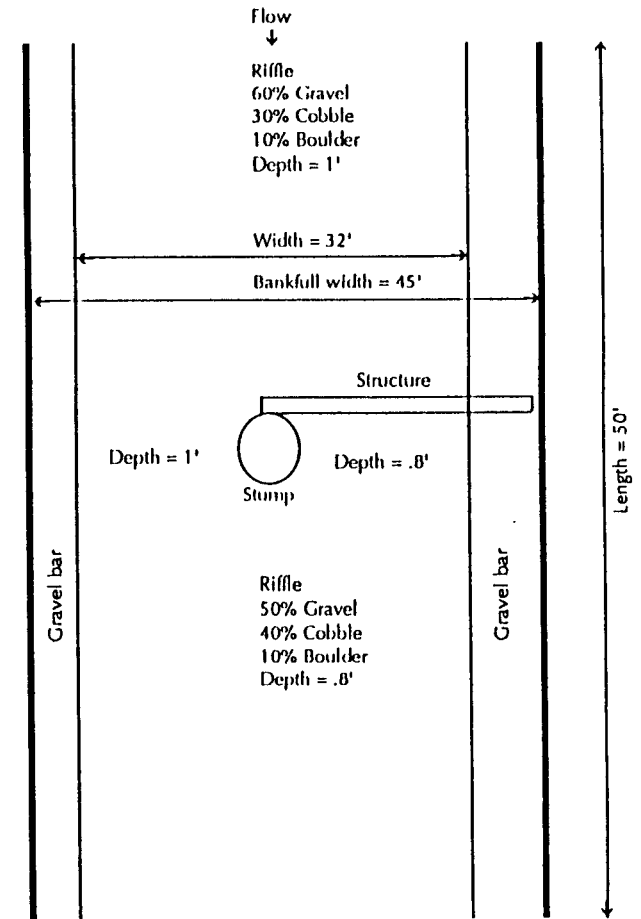
**Structure Type** Diagonal log weir



**Structure Number** 30 **Location** Last structure on main branch before stream makes sharp turn to the west.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

**Structure Type** Diagonal log weir

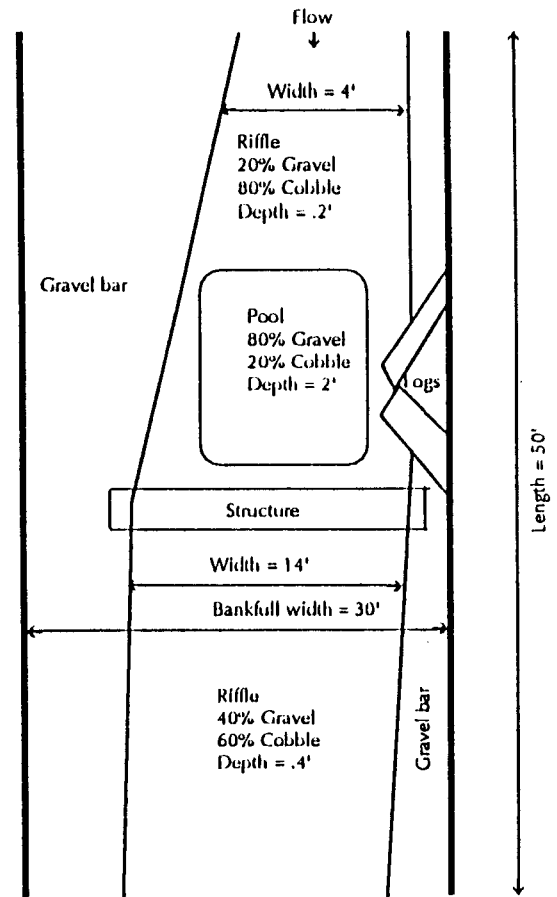




**Structure Number** 31    **Location** 300' from mouth of first trib. on right.

**Hanning Creek, Hanning Bay, Montague Island, AK.**

**Structure Type** Diagonal log weir



**Appendix 2.** Stream channel profile data and results of Wolman pebble counts from the downstream monitoring site. Distances are from the left bank. Active distance and depth refer to the distance where the water begins within the channel and the actual depth. BF is bankfull. All measurements are in feet. Two 50- pebble counts were made in each section.

	Left Bank					Right Bank
Transect 12 ft. upstream from downstream end of monitoring area						
Distance	0	14	28	42	56	70
BF depth	2.1	4.2	2.6	2.0	2.1	0
Act. Dist.	3	8	13	18	23	28
Act. Depth	0	1.5	1.8	1.8	1.0	0
Transect 101 ft. upstream						
Distance	0	11.4	22.8	34.2	45.6	57
BF depth	1.2	2.6	1.6	1.0	0.9	0
Act. Dist.	0	4.2	8.4	12.6	16.8	21
Act. Depth	0.7	1.3	1.7	1.2	0.5	0
Transect 147 ft. upstream						
Distance	0	11.2	22.4	33.6	44.8	56
BF depth	1.1	4.8	3.3	0.9	0.7	0
Act. Dist.	0	5.7	11.4	17.1	22.8	28.5
Act. Depth	0	2.4	3.5	2.7	1.8	0
Transect 204 ft. upstream						
Distance	0	12	24	36	48	60
BF depth	1.2	1.7	3.2	2.1	1.9	0.8
Act. Dist.	12	16.8	21.6	26.4	31.6	36
Act. Depth	0	1.1	1.2	1.1	0.6	0

### Wolman Pebble Counts

Site	Silt < .002 in.	Sand .002 - .16 in.	Fine gravel .16 - 1.3 in.	Large gravel 1.3 - 2.5 in.	Sm. cobble 2.5 - 5.0 in.	Lr. Cobble 5.0 - 10 in.	Sm. boulder 10 - 40 in.
Riffle 1	1	2	25	18	27	19	8
Pool	0	4	16	29	33	16	2
Riffle 2	0	6	21	31	31	10	1

### Appendix 3.

Stream survey results for Hanning and Swamp creeks. At Hanning Creek, four 300-yd surveys were conducted in different Rosgen (1985) channel types. Data from Swamp Creek in 1991 are limited to one 300-yd section due to high flows. No quantitative surveys were conducted at the unnamed creek. Habitat there was almost all riffle in lower stream section. Habitat types are from Bisson (1982). Rif = riffle, Gli = glide, Run = run, Rap = rapids, USP = upsurge pool, CRP = corner pool, LSP = lateral scour pool, PLP = plunge pool, Cas = cascade.

Stream	Channel type	Habitat type	Area sq. ft	% Total	Total area	% Pool
Hanning	C-3	Rif	17470	80.6	21670	0%
		Run	4200	19.4		
	C-1.1	Rif	20,125	74.0	27200	4.8%
		Run	1200	4.4		
		Rap	4575	16.8		
		Gli	1500	5.5		
		USP	1000	3.7		
		LSP	300	1.1		
	C-1	Rif	9125	38.6	23650	19.0%
		Gli	6850	29.0		
		CRP	3200	13.5		
		LSP	2525	10.7		
USP		1200	5.1			
Run		750	3.2			
B-2	Rif	11600	67.2	17260	4.9%	
	Rap	3500	20.3			
	Cas	1320	7.6			
	PLP	600	3.5			
	CRP	240	1.4			
Swamp	C-3	Rif	10500	20.6	51000	0
		Gli	40500	79.4		