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16. Abstract

The primary objective of this study was to assess the problems associated with salmon passage through hydraulic structures, primarily corrugated culverts, on steep gradient streams in Alaska. The problem is that considerable habitat for juvenile salmon and spawning areas for adult salmon are lost if passage of fish is obstructed. Reviews with resource agency personnel and numerous field site visits have helped us identify the problems and possible solutions. Better design criteria are needed for fish passage through culverts for adult red, coho, king, chum and pink salmon, and juvenile coho and king salmon. These design criteria can be obtained through field studies of fish behavior in the vicinity of the culvert, study of the hydraulics of existing weir-baffled culverts in the field, laboratory model studies of weir-baffled culverts in the plunging mode, hydraulic studies of velocity distributions in corrugated pipe-arch culverts, determine acceptable delay times for various species of salmon and make histologic examinations between those salmon spawning close to the coast and those traveling greater distances to look at musculature differences.

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SALMON PASSAGE THROUGH CULVERTS

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ABSTRACT

The primary objective of this study was to assess the problems associated with salmon passage through hydraulic structures, primarily corrugated culverts, on steep gradient streams in Alaska. The problem is that considerable habitat for juvenile salmon and spawning areas for adult salmon are lost if passage of fish is obstructed. Reviews with resource agency personnel and numerous field site visits have helped us identify the problems and possible solutions. Better design criteria are needed for fish passage through culverts for adult red, coho, king chum and pink salmon, and juvenile coho and king salmon. These design criteria can be obtained through field studies of fish behavior in the vicinity of the culvert, study of the hydraulics of existing weir-baffled culverts in the field, laboratory model studies of weir-baffled culverts in the plunging mode, hydraulic studies of velocity distributions in corrugated pipe-arch culverts, determination of acceptable delay times for various species of salmon and histologic examinations between those salmon spawning close to the coast and those traveling greater distances to look at musculature differences.

SALMON PASSAGE THROUGH CULVERTS

A literature search for documents pertinent to this project was conducted and completed. Some papers were found which we had not previously uncovered in earlier studies related to weak swimming fish. However, we did not find any information of major significance to the project.

As a result of the 1993 summer reconnaissance of several culverts which salmon pass through in Southcentral Alaska and a nine day visit, in November, 1993, to several State and Federal agency personnel and to numerous culverts in Southeast Alaska, we feel we have obtained a good overview of problems and uncertainties which culvert designers and resource agency reviewers face with regard to passage of juvenile and adult salmon.

From interviews with several Alaska Division of Transportation & Public Facilities (AKDOT&PF), Alaska Department of Fish and Game (ADF&G), and U.S. Forest Service (USFS) personnel, it is clear that adult red, coho, pink, chum and king salmon spawn on streams where culverts exist or where culverts may be a viable alternative to highway bridges if it can be reasonably assured that these fish are capable of swimming through the culvert. Most of

those interviewed recognize passage of juvenile coho salmon as a necessity on many streams. Some streams in coastal areas and some streams in Interior Alaska are inhabited by juvenile king salmon, but these fish are not as ubiquitous as juvenile coho.

Coastal streams in Southeastern Alaska are generally steep; most are located in incised valleys. The ratio of flood flows to usual fish passage flows appears to be greater than the same ratio in Interior Alaska. Because of the significant flood flows on Southeastern streams and their incised valleys, existing culverts often extend from one side of a narrow stream channel to the other. This is a good situation for fish passage if the stream is not too steep. The use of corrugated metal, pipe-arch culverts is much more common in Southeastern Alaska than elsewhere in Alaska. Some bottomless, corrugated metal, arch culverts exist, but these are expensive and some have experienced piping and other foundation problems.

Because of the disparity between fish passage flows and culvert design floods we need to examine the hydraulics of culvert flow. The laboratory experiments on circular culvert models, previously performed by Dr. Rajaratnam (University of Alberta, Edmonton), investigated only the streaming mode of flow. However, he did study the plunging mode for rectangular channel models, and review of that work has given us some preliminary insights for the design of appropriate

laboratory studies for plunging flow in circular, weir-baffled culverts. Dr. Rajaratnam's weir-baffle studies in rectangular channels suggested that weir-baffles of height equal to 0.2 D (D = culvert diameter) may be better for fish passage in both plunging and streaming modes than the 0.1 D and 0.15 D weir-baffle heights which he studied in circular culvert models. This geometry should be considered for modelling experiments. Also, for steep, large diameter culverts, the 0.6 D spacing of weir-baffles would likely be too great for passage of juvenile salmon. A proposed U.S. Forest Service experimental 48" culvert will have 0.2 weir-baffle height and variable baffle spacings.

Many existing and potential culvert sites in Southeastern Alaska are in very steep locations. These range up to 14%. We visited some steep newly constructed weir-baffled culverts on Prince of Wales Island. Few of these appear to have been properly designed for fish passage. A few slight (obviously unintentional) construction errors have, however, indicated that for small fish passage there is value in having some cross-slopes on weir baffles in culverts. Also, the design errors (for fish passage) apparent in these culverts lend some credence to the geometry and spacing of weir-baffles which we recommended in our previous weak-swimming fish passage study and included in our software (Fishpass, Behlke et al.,1991).

USFS engineers in Petersburg, with long-time experience in controlling upstream and downstream channel changes in the vicinity of culverts, have adopted both cross-channel log controls and heavy rip-rap channel stabilization roughening to maintain channels in their proper vertical locations in relation to installed culverts outlets. These methods have generally worked quite well for fish passage. Those engineers recognize potential problems associated with steeper culverts, and they have offered some experimental assistance aimed at proper culvert design of weir-baffles for fish passage through culverts in steep streams. Through their interest and efforts it appears that variable spacing, experimental weir baffles will be installed in a 48" culvert during the winter of 1994-95 or in the spring of 1995.

We wish to acknowledge, gratefully, the wonderful cooperation which we have received from the U.S. Forest Service's Petersburg office. On two occasions they have provided travel and guidance to remote culvert cites on logging roads distant from Petersburg. Their assistance has been of great value to this project. They have available equipment, personnel, etc. which would be expensive to duplicate elsewhere. Also, because of their considerable interest in this topic, they would monitor installations which they construct, and participate by informing us when fish runs are occurring and taking fish passage, flood flow and low flow data through such culverts. This group of engineers would probably continue to monitor any experimental installations to

determine long time effects well beyond our final report's preparation and submittal. Certainly, not all streams in Southeastern Alaska are steep, so there is an adequate opportunity there to observe fish behavior in relatively flat culverts as well as in steeper sloping culverts. Long term monitoring of prototype experimental culvert baffling is very important and may lead to continuing improvements in coming years.

Most salmon rearing streams in Southeastern Alaska and in some of the remainder of Alaska are quite short, so salmon do not have far to go from salt water to their spawning grounds. However, especially in Southcentral and Western Alaska, some salmon spawning grounds are distant from salt water. The muscle makeup of those fish destined to swim short distances on their spawning migrations appears different from that of fish travelling long distances to spawn. These differences appear not to be known or considered by culvert designers at present, but they probably lead to the necessity for differing design criteria in differing locations for fish passage culverts--those salmon destined for distant spawning grounds are probably stronger swimmers at the initial phases of their migration than are those which are close to their spawning grounds.

Conclusions: Briefly, the purpose of this year's studies was to attempt to determine what fish problems exist for passage of salmon through culverts and what studies would be needed to solve these problems. As a result of

discussions with various agency personnel who have design or regulatory relationships to fish passage through culverts and as a result of field observations of culverts in both Southcentral and Southeastern Alaska, it is clear that we should strive to develop:

1) Design criteria for culvert passage of adult red, chum, pink, coho, and king salmon.

2) Design criteria for culvert passage of juvenile coho and juvenile king salmon.

The above discussion suggests that meeting these two broad goals requires the following actions:

1) Field studies of fish behavior in and near culverts which support salmon runs of the various species must be made to determine fish swimming behavior and capabilities in the culvert environment. It presently appears that most of these studies would be best carried out in Southeastern Alaska--principally on Prince of Wales Island (PWI) because of the species diversity there.

2) The existing weir-baffled culverts on PWI should be carefully monitored to gain hydraulic insights for improvement of weir-baffle design for steep sloping culverts.

3) Because it appears that fish passage flows in many Southeast Alaska culverts are considerably smaller than culvert design-flood flows, the hydraulics

of weir-baffled culverts operating in the plunging mode should be studied in the laboratory at the University of Alaska Fairbanks or elsewhere.

4) Hydraulic field and laboratory studies of water velocity distribution in corrugated metal, pipe-arch culverts (not of the bottomless type) should be made. Our literature search did not reveal any existing, detailed hydraulic studies of flows in potential fish passage zones of this type of culvert.

5) Acceptable delay times for passage of the various species of salmon should be determined in order to aid in identifying economic culvert sizes and weir (or other) baffling as they relate to fish passage flows.

6) Histologic examinations should be made of several salmon whose spawning grounds are close to salt water and on several whose spawning grounds are distant from the sea to determine the musculature differences between the two.

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