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INVESTIGATION OF CULVERTS AND HYDRAULIC STRUCTURES USED FOR FISHWAYS AND THE ENHANCEMENT OF FISH HABITAT

by

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ABSTRACT

A method for the design of slot orifice fishways for box culverts was developed. Characteristics for a satisfactory fishway are identified. Appropriate graphs for sizing slot orifice fishways for a given performance capability of a fish are presented. The hydraulics of slot orifices constructed in the face of skewed wingwalls is explained. A table listing the swimming capability of various species of fish was compiled from existing literature. A hodograph for the wake boundary behind a flat plate placed normal to free surface flow was developed. A comparison of the size of wakes produced by a flat plate, a 90-degree wedge and a circular cylinder were made. The shape of wakes produced by embedded sphere with different degrees of submergence was also studied.

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TABLE OF CONTENTS

INTRODUCTION

A three year study of problems associated with fish passages through culverts and a study of wake flow produced by various shaped objects placed in free surface flow are described in this report. Fish performance characteristics, variables which effect fish performance and the characteristics of a satisfactory fishway were identified and described.

The original objectives of the study were to:

a) study the swimming characteristics of fish and develop criterion for the hydraulic design of culverts which must be used as fishways,

b) delineate the sets of circumstances which can cause fish blockage at culverts and outline remedial measures for these problem areas, and

c) develop criteria for the enhancement of fish habitat particularly for reaches in the vicinity of culverts and hydraulic structures and where channel changes are required.

The project was to be a cooperative project with the Idaho Cooperative Fisheries Unit of the University of Idaho with a graduate student from Fisheries handling the fish characteristics aspects of the study and engineering students working on the mechanics aspect of the study. Because of personnel limitations, the Fisheries Unit was unable to participate in the study. All information concerning fish biology and fish characteristics were obtained from existing literature or from communications with persons knowledgeable in the subject area. No laboratory or field data were obtained on fish performance.

The data required for developing design aids to be used in the hydraulic analysis of slot orifice fishways and for wake flow downstream of obstacles placed in streams were obtained in the hydraulics laboratory at the University of Idaho.

A preliminary report, three Master of Science theses and one senior's project

paper were obtained from this study.

Abstracts from the five reports follow:

1. "Preliminary Report on Investigation of Culverts and Structures Used for Fishways" by F. J. Watts; September, 1969.

A drop off at the outfall of a culvert, high velocity flow through the barrel of a culvert and the contracted accelerating flow at the entrance of a culvert can each or collectively block upstream fish migration through culverts.

A satisfactory fishway must have the following characteristics: (a)stable low velocity flow in the fishway throughout a large range of discharges, (b)self-cleaning, (c)hydraulically efficient (adequate discharge capacity), and (d)simple and economical to construct.

Baffled fishways used in the past are hydraulically inefficient, operate satisfactorily only during low flow periods and tend to fill with sediment and become ineffective.

A vertical slot orifice fishway is proposed as a suitable solution for a fish passage facility within box culverts. Studies are recommended for the development of design aids for the hydraulic analysis of slot orifice fishways.

2. "Passage of Fish Thru Culverts - Design Criteria" by Bruce Berg - May, 1972.

Assuming sufficient flow depth is available and the fish has access to the barrel of a culvert, ability of a fish to pass upstream through a culvert is related to five different variables: The length of fish, velocity of water in the culvert, the length of culvert, specie of fish and to some extent, the temperature of the water and light conditions. A table of migration time as a function of specie, spawning time and water condition is presented. All available information of maximum swimming speeds by specie were tabulated. The merits of different types of fishways (such as arches with rubble bottom and baffled fishways) are discussed. End treatment at the

culvert outfall is suggested.

3. "Analysis of Slot Orifice Fishways" by Purushottam Dass - December, 1970.

The object of this study was to develop design criteria for a slot orifice fishway. Sizing and spacing of slot orifices inside the fishway can be designed to create flow conditions satisfactory for fish passage. The slot orifice fishway will function well in a wide range of discharges and should not have any serious silting problems.

Values of drag coefficients for the slot orifice constrictions were evaluated by model studies for a range of slot openings varying from 0.6 to 0.85 of fishway width and culvert slope varying from horizontal to five percent. Three longitudinal spacings, 4, 5 and 6 times the fishway width, were considered for the slot orifices in the fishway. The effect of tailwater on the flow conditions at the fishway entrance was studied. The backwater relation of the slot orifice also was developed in the above range.

Nondimensional curves are given for the values of the drag coefficients of the slot orifices. An equation based on the momentum principle was developed which enables the designer to find the rate of flow through the fishway. Necessary criteria regarding suitability of flow for fish passage are also developed.

4. "Analysis of Skewed Slot Orifice" by M. B. Harrison - August, 1972.

The object of this study was to develop design criteria for a skewed slot orifice fishway exit. Using these criteria, the fishway exit can be constructed in culvert wingwalls. The outlet would terminate in a skew angle and be designed to create flow conditions necessary for fish passage.

In this design, values of slot orifice contraction ratios varied from 0.65 to 0.82 of culvert width; culvert slope varied from .015 to .045, and skew angles measured from 30° to 75°. Three lateral positions of the fishway channel were tested. Dimensional analysis was used to determine the significant design parameters.

Design curves displaying the relationship between the backwater ratio, H/h and the Froude number are presented.

The design curves and an equation based on the momentum principle are used to design two types of skewed orifice exits. One problem uses the same contraction ratio for the skewed exit and normal slot orifices placed downstream; the other uses different values of contraction ratio for the skewed exit and normal slot orifices downstream. Necessary criteria regarding suitability of flow for fish passage are also discussed.

5. "Wake Boundaries for Objects Placed in Open Channels" by Chyr Pyng Liou - July, 1972.

A hodograph for the wake boundary behind a flat plate placed normal to the flow was developed and verified with experimental results. In this mathematical treatise, velocities along the shear layer can vary. The classical Kirchoff's solution is a special case of this model.

A comparison of the sizes of wakes produced by a flat plate, a 90-degree wedge and a circular cylinder were made. The effect of the depth of water relative to the width of the obstacle on the wake size was investigated. The shape of wakes produced by an embedded sphere with different degrees of submergence was also studied. All experimental work was done in a horizontal straight open channel using water as the experimental fluid.

The information from these studies will be condensed into a design manual for distribution to those agencies and individuals interested in the design of fish passage structures. The design manual is expected to be available in the fall of 1973 from either the principal investigator of this report or the Director's Office of the Water Resources Research Institute, University of Idaho.

CONCLUSION

The objectives of the study with respect to fish passage through culverts were generally attained. Vertical slot orifice fishways can be designed analytically (using design aids developed during this study) for any specified size or slope of culvert for a specified performance capability of fish.

The objective relating to fish performance capability and the enhancement of fish habitat was not completely accomplished. When the Fisheries Unit was forced to withdraw from the project because of personnel and time limitations, our capability to handle fish characteristic problems was severely limited. We were forced to utilize limited data obtained from current literature.

The stream enhancement problem proved to be too extensive to be accomplished with the time and money allotted to the project. There was very limited data available on wake flow adjacent to obstacles placed in free surface flow. This forced us into a basic investigation of wake phenomena downstream of flat plates in free surface flow. During this study, significant progress toward the development of prediction equations defining wake boundaries in free surface flow was accomplished. However, the prediction of wake boundaries in a three dimensional flow field in real fluids is still well beyond existing technological capability. Further basic research is needed in this area.

LIST OF PUBLICATIONS AVAILABLE
FROM THIS STUDY:

1. Dass, Purushottam, "Analysis of Slot Orifice Fishways," M.S. Thesis, University of Idaho, Moscow, Idaho, August, 1972.

2. Harrison, M.B., "Analysis of a Skewed Slot Orifice," M.S. Thesis, University of Idaho, Moscow, Idaho, August, 1972.

3. Liou, C. P., "Wake Boundaries for Objects Placed in Open Channels," M.S. Thesis, University of Idaho, Moscow, Idaho, July, 1972.

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