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Northern Pike (*Esox lucius*) and White Sucker (*Catastomus commersonii*) Swimming Performance and Passage Through a Step and Pool Fishladder

by

©

Lloyd Richard Nelson

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Northern Pike (*Esox lucius*) and White Sucker (*Catastomus commersonii*) Swimming Performance and Passage Through a Step and Pool Fishladder submitted by Lloyd Richard Nelson in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Environmental Science.

Abstract

The results of the study include biological and swimming performance data for northern pike (*Esox lucius*) and white sucker (*Catastomus commersonii*), collected at Driedmeat Lake (52° 47' N. Lat., 112° 43' Long.) and Steele Lake (54° 37' N. Lat., 113° 47' Long.) and an evaluation of their swimming performance in the step and pool ladder located at Steele Lake.

Northern pike (30 - 45 cm in length) exhibited burst speeds of 3.3 m/s over a distance of 2.4 m. Exit velocities ranging from 3.1 to 4.4 m/s were calculated for observed jumps out of the water. Pike (40 - 50 cm) were found to navigate a 12.4 m long culvert with bottom exit velocities of 0.8 m/s.

White sucker (35 - 47 cm) exhibited speeds of up to 2.2 m/s over 2.4 m, and 1.9 m/s over a distance of 2.5 m.

Both species demonstrated the ability to navigate a step and pool fishladder under streaming flow conditions, and critical nappe velocities of up to 3.0 m/s. One pike (approx. 50 cm) was observed to maintain its position within a weir flow of 1.20 m/s for at least 10 s. The burst speed capability and performance of the pike within the ladder was superior to that of the white sucker.

Although both species were largely successful in moving through the step and pool fishladder (once they were in it), maintenance problems were encountered with this ladder. Ensuring fish passage under the majority of conditions

experienced in this study required constant maintenance. A list of recommended design changes for the Steele Lake ladder are provided.

Acknowledgements

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Glossary of Terms

Abbreviations:

cm = centimetre

°C = degrees centigrade

D.O. = dissolved oxygen

ft/s = feet per second

g = grams

kg = kilograms

L = litre

lengths/s = lengths per second

m = metre

man. = manipulation

min = minimum

mg/l = milligrams per litre

mm = millimetre

m/s = metres per second

oscillations/s = oscillations per second

revs/s = revolutions per second

Definitions:

Anadromous - Species (fish) which ascend rivers from the sea for spawning purposes.

Annulli - Prominent ring-like appearances on the scale of a

fish representing a series of closely spaced circulli, (this is taken as the annual period of slower growth & hence annulli are used to determine age).

Aspsect ratio - The ratio of the width or span to the chord of the caudal fin.

Baffle - A device (plate, wall, or screen) used to deflect or regulate water flow.

Circulli - Rings on the fish scale representing segments of growth.

Cleithrum - One of the supportive bones of the pectoral girdle, located immediately posterior to the operculum and just above the pectoral fin.

Cloaca - The common chamber into which the intestinal, urinary, and generative canals discharge for certain animals, including fish.

Corrugated steel sheeting - Sheet steel or iron shaped into straight parrallel regular and equally curved ridges and hollows.

Crest of the spillway - That region just downstream of the hydraulic jump where the flow becomes less turbulent (Fig. 31).

Dimorphic - Sexually dimorphic characters, or differing physical features on the surface of the male and female of a species which distinguish them comparitively.

Gonad - The primary sex organs (i.e. testes or ovaries).

Head - The vertical distance between the upstream liquid surface and the weir crest.

Headwater - The body of water upstream of the weir.

Hydraulic jump - An abrupt rise in the water due to a change from high velocity to low velocity flow.

Lipid - A cellular component which includes the fats, waxes, and other related compounds.

Milt - The secretion (including the sperm) of the male reproductive gland of fish.

Morphometry - The measurement of the external form or topographic features of a lake or river.

Nappe - The sheet or jet of water which passes over the weir crest.

Orifice - An opening or aperture through which something may pass.

Ovaries - The paired reproductive organs of the female, which produce the eggs.

Salmonid - A fish species of the family Salmonidae, such as the trout, salmon, whitefish, grayling, etc.

Sill - The upstream head over the weir crest.

Stop log - The timbers used in a step and pool fishladder to stop or control water flow through the ladder.

Streamlined - A contour or shape which minimizes resistance to motion through water or by other fluids.

Tailwater - The level of water downstream of the weir.

Target species - Those species of fish (one or more) of greatest concern to the project.

Trash deflector - A panel of steel sheeting forming a V-shaped structure which is placed upstream of the

fishladder. Trash is deflected of the edges of the V (see Fig. 57).

Tubercles - The hard, fleshy, "knob-like" protuberances on the fins of the male white sucker, esp. the anal fin.

Weir - An overflow structure built across an open channel for the purpose of water flow control.

Weir crest - the top of the weir.

For further information see King, et al. (1949), Rouse (1961), Woolf (1974), and Weichert & Presch (1975).

1. Introduction

An evaluation of the effectiveness of any fishladder requires an integrated understanding of the structural (hydraulic) aspects of the ladder, as well as a knowledge of the biology of the fish species for which the ladder is being designed. The functional fishladder should be able to accommodate the hydrologic changes of the water body it is in, conform to the morphometry of the water body, provide easy access (and movement) for all species of fish moving in the water body, and do all of these at a minimum of cost.

The fishladder of concern to this study is the so-called "step and pool" or "pool and weir" fishladder. It is one of the oldest style of ladders in existence, and has been used in the passage of anadromous and freshwater fish species, in both the old and new world (Clay, 1961).

The original intent of the study was to examine exclusively the step and pool ladder incorporated into the Driedmeat Lake stabilization weir, located near the town of Camrose, Alberta (Fig. 1). However, due to ensuing flood conditions at that location, operations were moved to the step and pool fishladder included in the Steele Lake stabilization weir, located at Cross Lake Provincial Park near Westlock, Alberta (Fig. 2).

Consequently, the study resulted in an accumulation of biological data pertinent to northern pike (*Esox lucius*) and white sucker (*Catastomus commersonii*) populations of both these areas.

Fig. 1 Driedmeat Lake Study area.

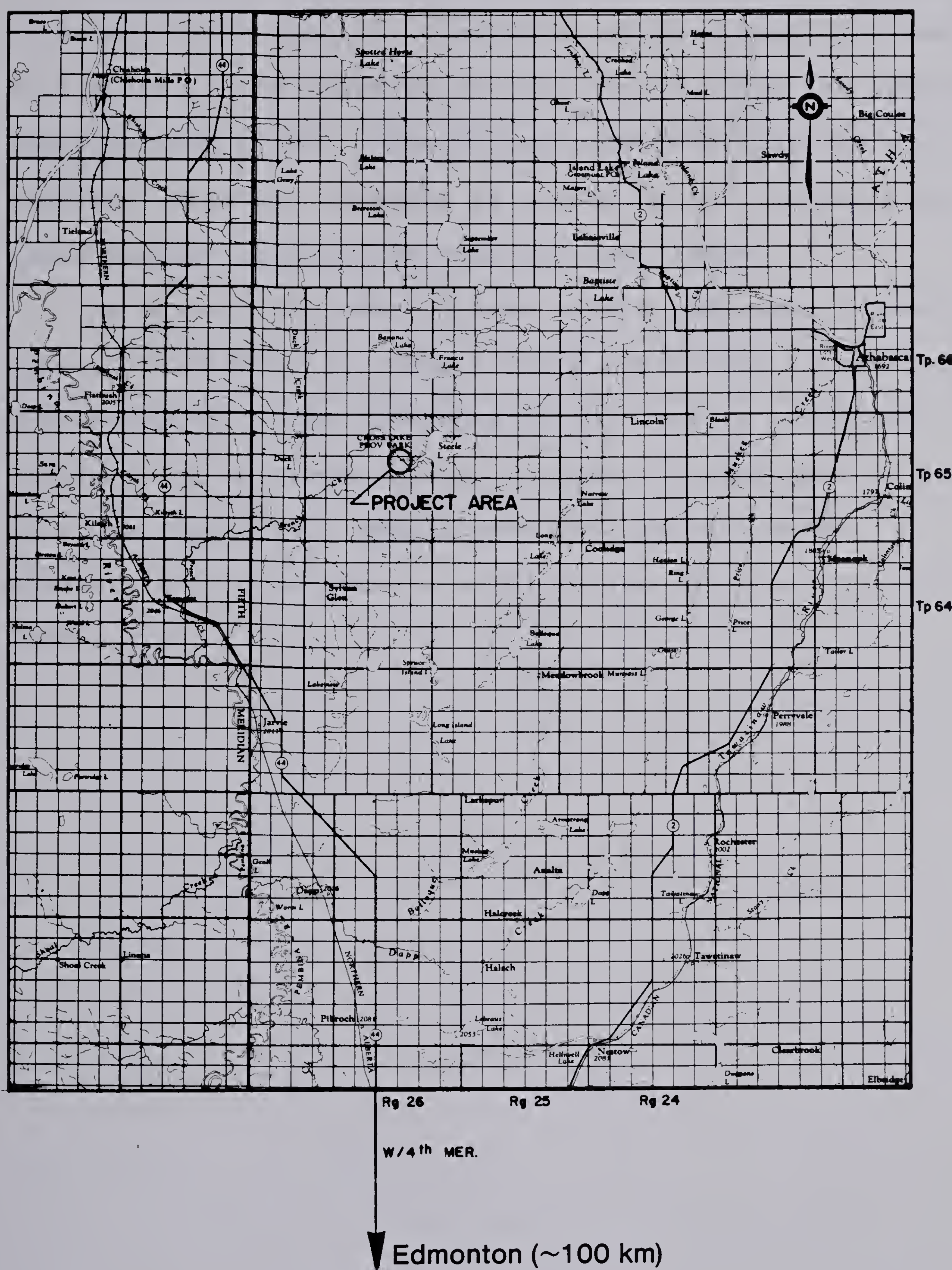


Fig. 2 Steele Lake study area.

Although a variety of circumstantial biological data is included in the results, the thrust of the study involves an evaluation of the swimming performance of these two species (particularly pike). Several performance situations are analyzed, however, emphasis is placed on the movements of these species through the step and pool ladder.

As stated, in order to make a good judgement on what type of fishladder to install for a particular situation, an understanding of the fish species involved is essential. A knowledge of the swimming performance of these species is only one aspect of a complicated biological system. However, such knowledge is vital to the rational choice of ladder type.

2. Structural Considerations

2.1 Characterization and environmental significance of fish ladders

2.1.1 Function of fish ladders

In planning the functional fishladder, one requires the knowledge of both engineering and biology for optimization of its design.

Katapodis (1981) defined an effective fishway as one which:

"(a) attracts fish and allows them to enter, pass through and exit the fishway with mininum delay.

(b) maintains hydraulic conditions within the fishway channel in harmony with the physiological limitations and behavior of the species involved.

(c) permits fish to exit the structure without the danger of them being swept back.

(d) accomplishes the above at a minimum cost."

Devices of various types have been employed to assist movements of fish through or around obstructions (natural and manmade). The fish "ladder" or fish "way", allows the fish to ascend under its own effort. Devices such as the fish "lock" or fish "elevator", however, allow transport with a minimum of effort on the part of the animal.

2.1.2 Types of ladders and their use

There are three main varieties of fish ladders; the step and pool (weir), the denil, and the vertical slot. Within each variety there are various modifications of a basic design.

2.1.2.1 Step and Pool

The step and pool or weir style fishway consists of a series of pools in a stepped pattern from the headwater to the tailwater (Fig. 3). The pools can be constructed of natural materials, (such as cutting and shaping rocks), or built of non-native material such as concrete, sheet steel piling and timbers. (Mcleod and Nemenyi, 1940; Katapodis, 1981).

Flow through the ladder is controlled by a series of vertical weirs (separating each pool). These weirs extend the width of the ladder. Their height is either fixed or adjustable.

Fish ascend the ladder pool by pool, jumping over or swimming through the flow over each weir. The fish may alternate intermittent exertion with partial resting.

Modifications of this basic weir design include the following:

(1) Addition of an orifice. These orifices may be designed to accommodate some or all of the flow through the ladder. In the former, the fish can choose ascent via the orifice or over the weir. This accommodates

species which prefer to jump over a flow as well as those which prefer to swim through a flow.

(2) The chute. This modification allows flow from pool to pool via a series of sloping surface chutes. Ascent is accomplished by swimming up through the chute. This is an early design and it is no longer used due to its low success rate.

(3) Notched weir. The notches are usually staggered from side to side along the length of the ladder. This creates regions of relatively calm water within each pool. The notched weir may also be combined with an orifice.

Further details may be found in Clay (1961); Mcleod & Nemenyi (1940); Decker (1967); and Katapodis (1981).

2.1.2.2 Denil

The basic denil design consists of a straight channel with a series of closely spaced baffles set at an angle to the flow, (Fig. 4). This arrangement dissipates the energy of the flow to a velocity range which will allow a continous, non-resting, route of ascent for the target species.

Construction materials can include various combinations of concrete, steel sheeting, aluminum plating, plywood, and timbers.

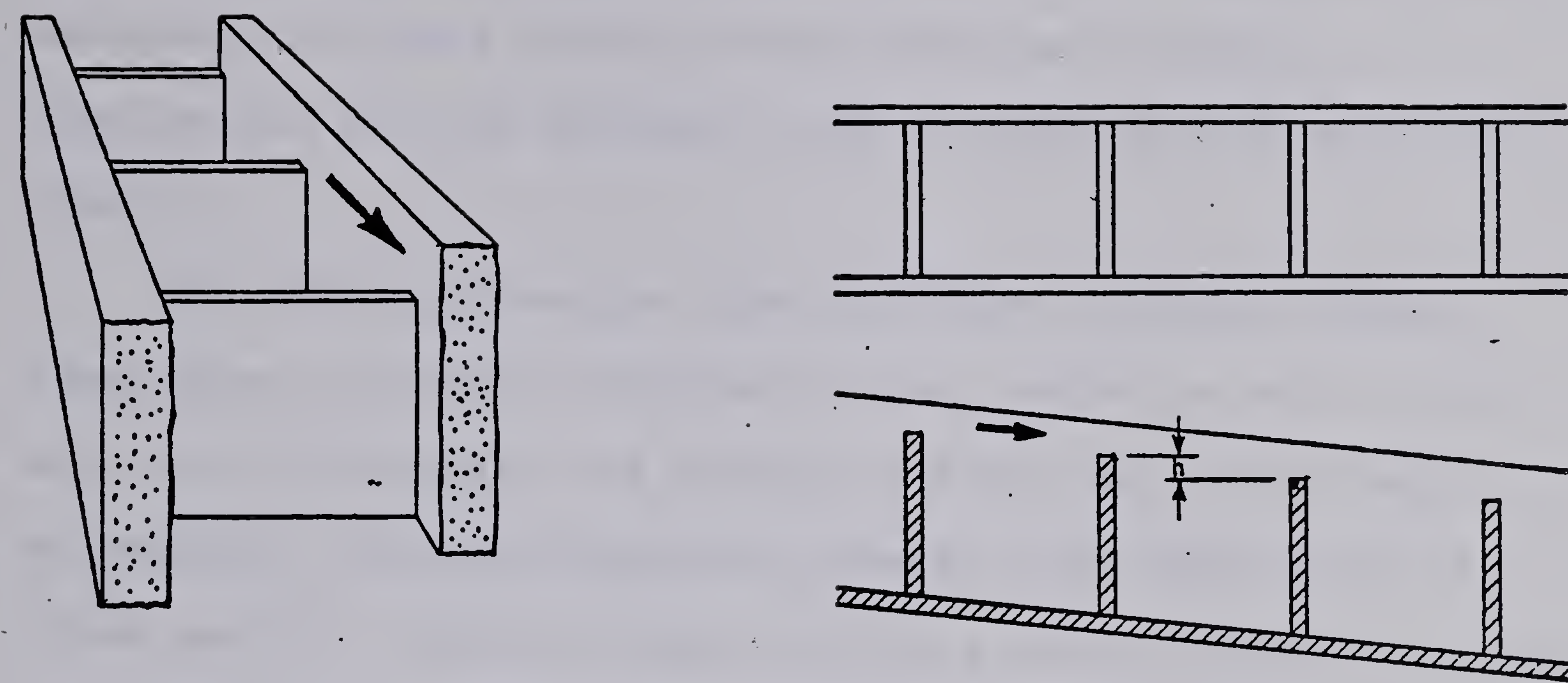


Fig. 3 The weir or step and pool style of fishway. After Katapodis, 1981.

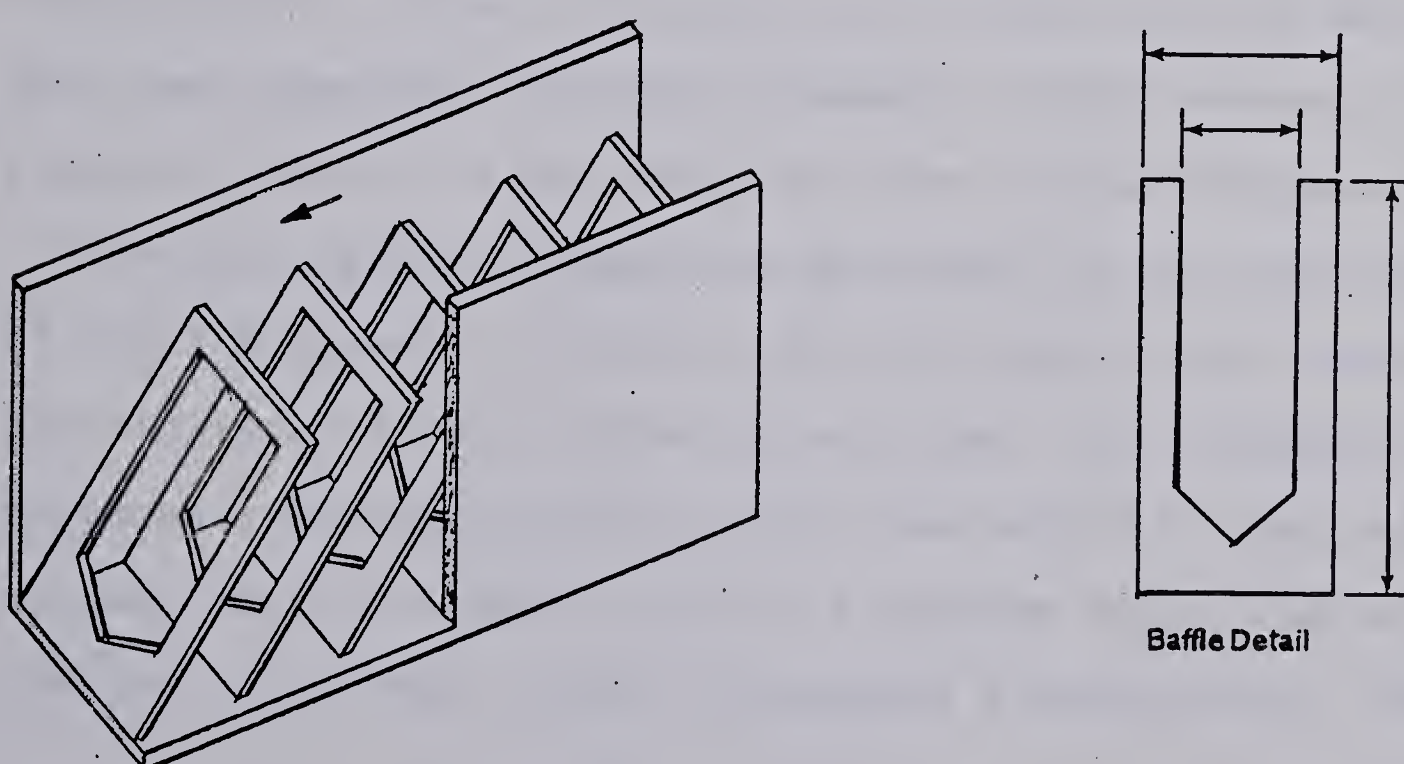
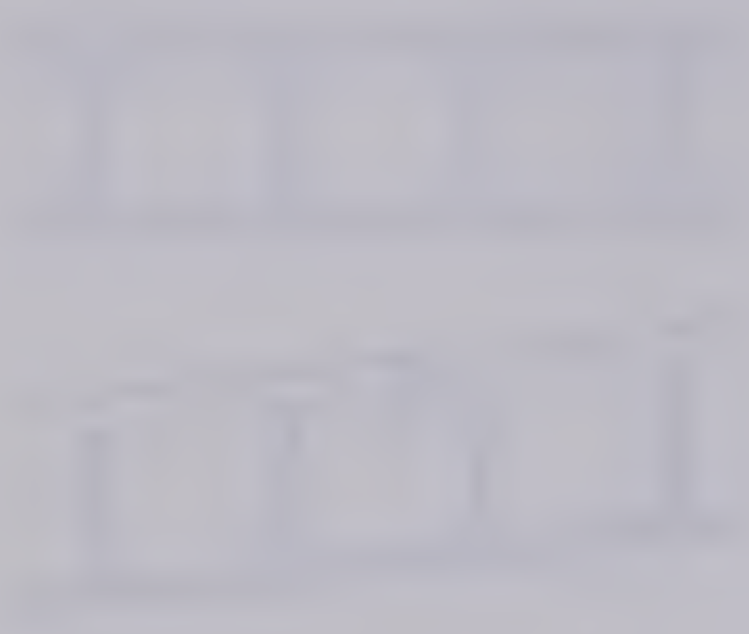


Fig. 4 The denil fishway. After Katapodis, 1981.



Mcleod and Nemenyi (1940) describe the energy dissipation as largely attributable to the "reissue of the secondary currents by the large momentum transfer' (deflecting off the baffles) 'and intense mixing occurring there."

The denil system has the advantage of being highly adaptable to various cross-sectional shapes as well as its ability to dissipate the energy of the flow effectively. Hildebrand (1980) points out, however, the importance of a trash rack in order to keep the denil free of debris, since the flow characteristics are strongly dependent on the relationship of the baffle to the open area.

Modifications range from varying the angle, location and shape of the baffles, to the inclusion of resting pools (especially when longer distances need to be traversed or turns occur). Several derivations of the original denil have been developed (Mcleod & Nemenyi, 1940) however, the two most popular in use today are the Alaska Steeppass model "A" and the Denil 2 fishway as developed by the Institution of Civil Engineers. Notably, the two models have opposite distribution of their velocity profiles. The steeppass produces a maximum velocity along the bottom of the main stream, while the denil 2 has its maximum velocities along the top of the main stream (Katapodis & Rajaratnam, 1981).

2.1.2.3 Vertical Slot

Essentially, this fishway is of the weir type. The weir, however, has a notch on one or both sides which extends its entire vertical depth (Katapodis, 1981). The modified vertical slot or Hells gate type fishway (Fig. 5) has since become the most popular of this variety. Some advantages (Decker, 1967) are:

(a) its ability to handle a wide range of water levels.

(b) its diagonal direction of flow across each pool creating a backwash effect against the central baffle, before being discharged to the next pool. This creates a complete dissipation of water energy within the pool.

Construction materials usually consist of reinforced concrete or plate steel with timbers. Modifications include having single slots on each weir, as well as a staggering arrangement along the length of the fishway. This staggering creates a more effective dissipation of the flow energy.

The vertical slot has been used most extensively in the passage of salmonid species, particularily salmon. The Hell's gate fishway on the Fraser River, B.C., is one of the more famous examples. The design can been scaled down to adapt to smaller species, such as trout. (Decker, 1967).

2.1.2.4 Other fish passage facilities

The so-called fishlocks and fish elevators are passage designs which operate on the principle of moving the fish

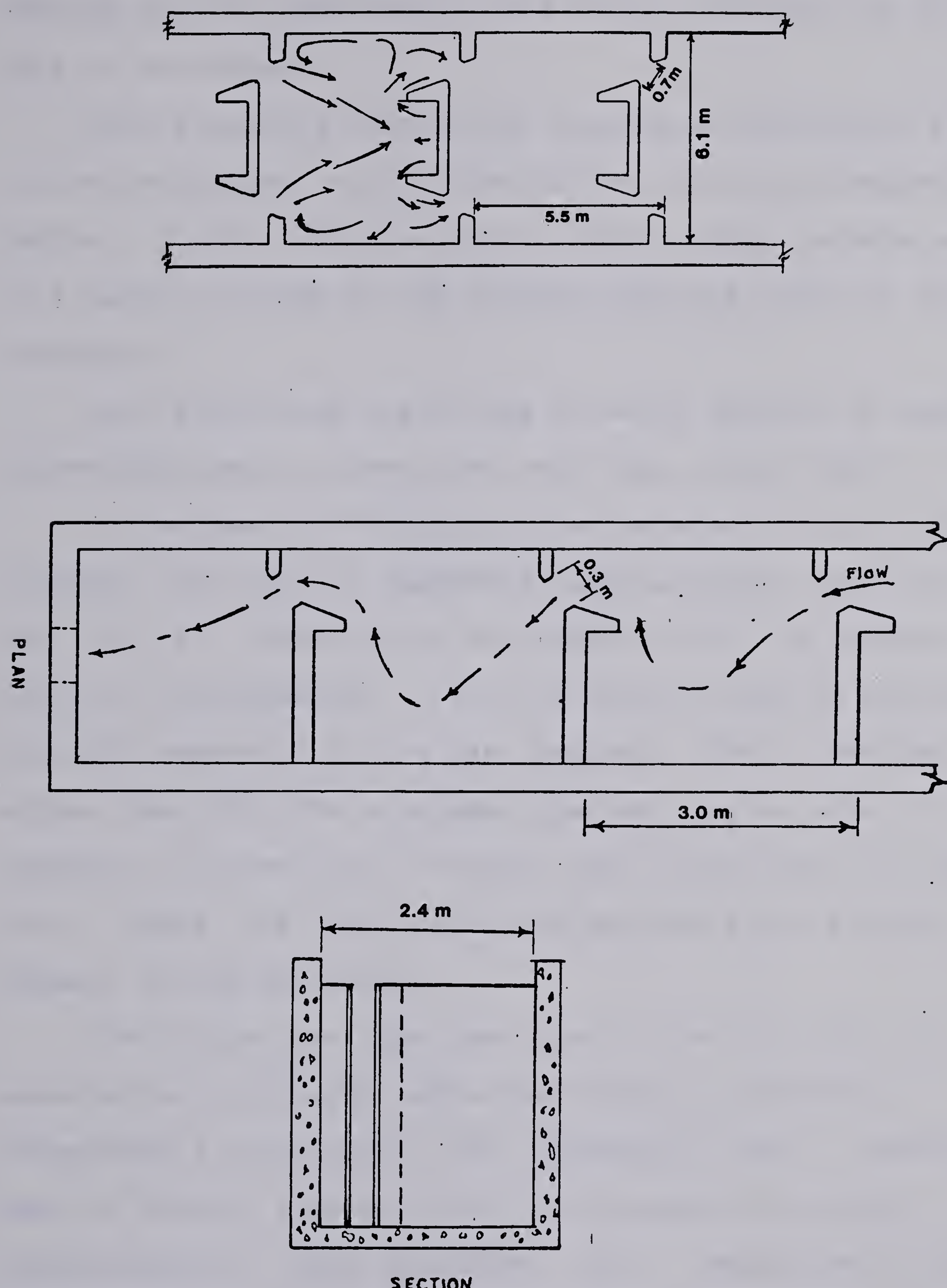


Fig. 5 Above: Hells Gate Fishway, plan view. After Clay, 1961. Below: Modified single vertical slot design. After Decker, 1967.

species over an obstruction with minimal exertion on the part of the animal.

Fish elevators function by leading or collecting fish, as they accumulate at the obstruction, into a transportation device. Trucks, tanks on rails, and/or large buckets strung on a cable are some of the possible devices used for this transport.

Such facilities are in use in North America in order to accommodate small salmon runs over dams, Clay (1961).

In the case of fishlocks (most popular in the United Kingdom) fish enter a chamber at the tailwater level of the dam (Fig. 6). Water fills the chamber until it reaches the level of the headwater. Fish are then allowed to swim out into the reservoir of the dam (Deelder, 1958). Deelder argues that only the strongest specimen may be able to surmount a conventional fishway, such as the denil or pool & weir. Hence, the fishlock should perform for a broader segment of the population.

Fish locks have also been used in the U.S.S.R. in association with large scale hydroelectric projects, (Nusenbaum & Lapitskaya, 1961; Duizhikov, 1961). Several dams in Russia, however, lack fish passage facilities (Abdurakhmanov, 1958; Duizhikov, 1961). Reduction in fish populations have, in the past, required the use of restocking programs as a mitigating measure (Ioganzen & Podlesnyi, 1958).

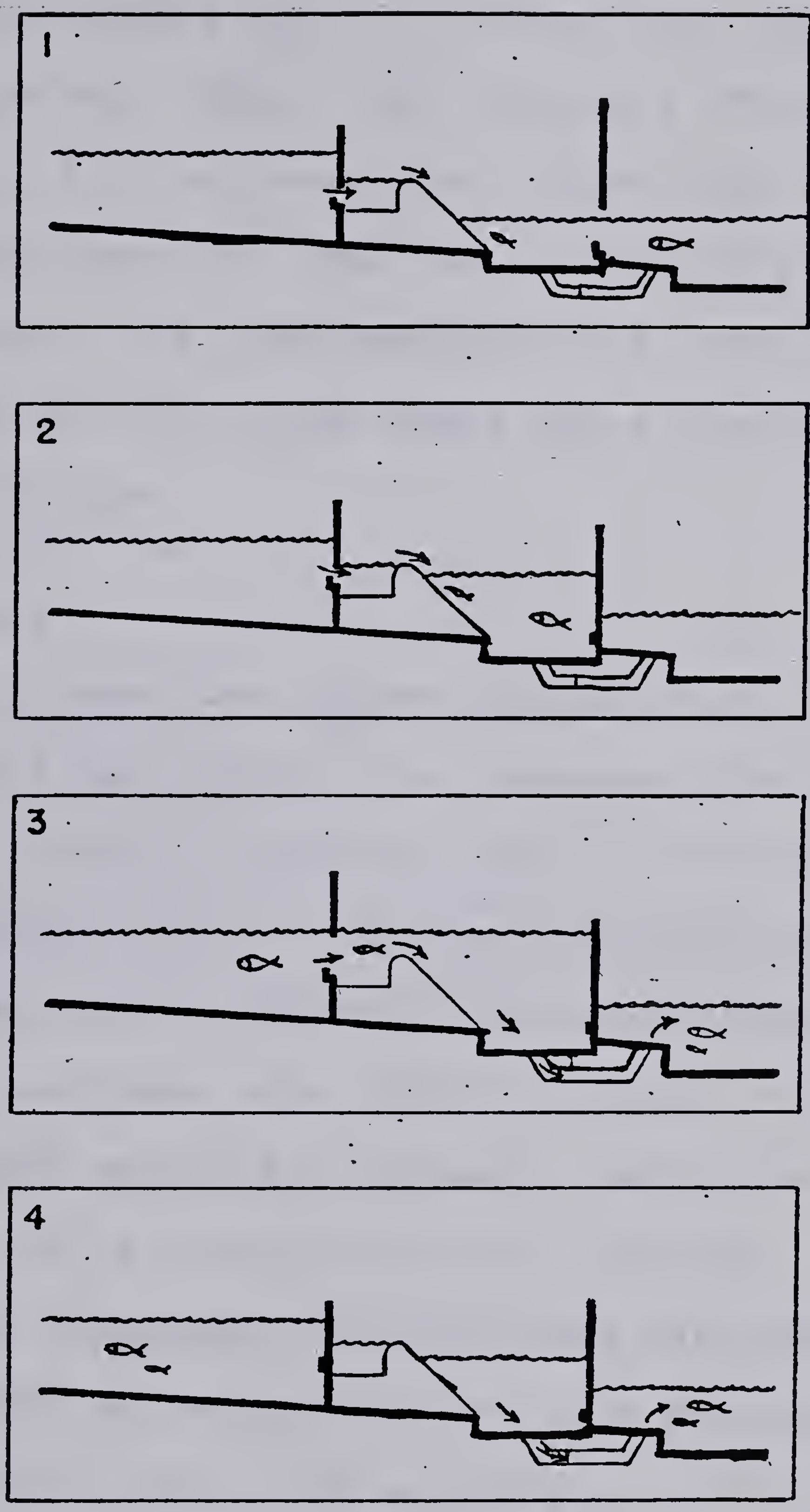


Fig. 6 Four stages of an hydraulic fishlock operation.
After Deelder, 1958.

Recently, a seasonly operated (non-conventional) fish "pipe", was developed by Ducks Unlimited Canada, for use on smaller lakes dammed up to increase water fowl habitat, (Ducks Unlimited, 1982). The structure (Fig. 7) located at Helena Lake, B.C., allows trout fingerlings to move under the dike and enter the lake via a floating pipe containing a baffle system. The pipe maintains its level in the lake through the use of a float above and a flexible coupling to the entrance pipe.

2.1.2.5 Costs

Fishways have the highest capital cost, followed by fishlocks and then fish lifts. However, for maintenance, the order is usually reversed. (Bell & Hildebrand, 1979).

Hildebrand (1980) cites the following costs.

(a) For smaller hydroelectric facilities, fishladder costs can range from $8000 to $20000 for every 30.5 cm of height needed for passage. Maintenance is estimated at 2 - 3% of the capital cost annually.

(b) For fishlocks, initial costs may range from $7000 to $30000 for every 30.5 cm, with maintenance accounting for 1 - 5% annually.

(c) Fishlifts may range from $5800 to $30000 for every 30.5 cm, with as much as 1 - 14% of the capital costs going for operation and maintenance annually.

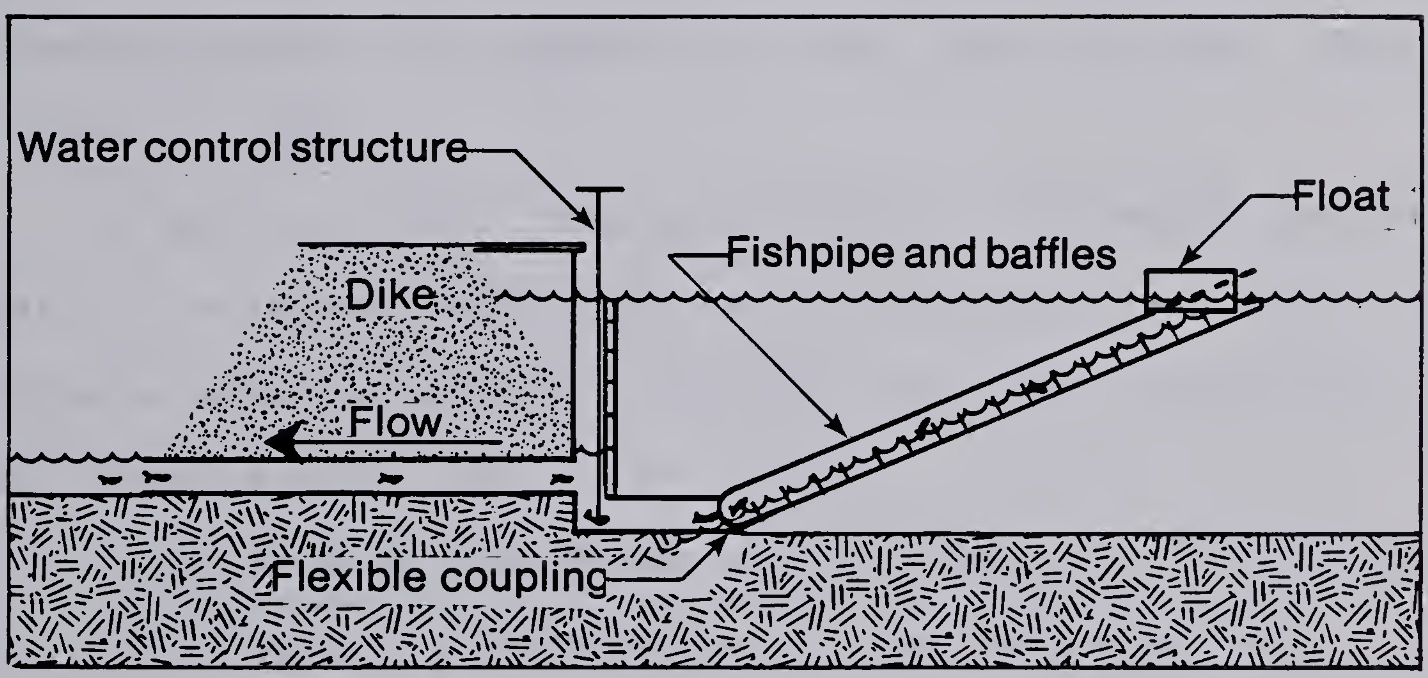


Fig. 7 A schematic of the fishpipe operation at Helena Lake. After Ducks Unlimited, 1982.

2.1.3 History of fishladders

2.1.3.1 Applications

An awareness of the need for fish passage facilities has been a problem confronting engineers for hundreds of years. Fishway construction has its origins in Europe, with the earliest recorded descriptions being from 17th century France. However, traditional mill dam building techniques in Norway appear to indicate an even older history. (Mcleod & Nemenyi, 1940).

It was not until 1909 with Denil's fishladder design that an increased understanding of structural and hydraulic criteria began to emerge. To date, the most outstanding developments have been in two areas:

(1) a growing awareness of the hydraulics of fishways.

(2) a better understanding of the mechanics and swimming abilities of some fish species. (Clay, 1961).

The greatest contributor to increased use of fishways at man-made obstructions (at least) has been public protest. These obstructions have led to dwindling sport and commercial fisheries in several inland waters, by blocking spawning migration.

Laws governing the implementation of fish facilities in Canada are under Federal jurisdiction, with administration by the provincial governments in some cases. In the U.S., each state is responsible for its own legislation. (F.H.P.G., 1980; Clay, 1961; Mcleod & Nemenyi, 1940).

Of the growing number and types of fishways constructed since the original denil, large scale projects have generally been most successful. The Bonneville Dam on the Columbia River, and the Hells gate fishways are two such cases. In both instances, the target species were the economically important salmon group. (Clay, 1961).

The stamina and sustained swimming ability of trout and salmon has been well documented by such authors as Bainbridge (1963), Connor, et al. (1964), and Brett (1965).

Research dealing with the passage of anadromous species has been most extensive and well funded. The Hells gate vertical slot baffle was designed and built as a result of intensive biological research on the movements of Sockeye Salmon (*Onchorynchus nerka*) by the International Pacific Salmon Fisheries Commission. This fishway has subsequently resulted in a dramatic increase in the average number of salmon which successfully move up the Fraser River and beyond, to spawn.

2.1.3.2 Applications in Alberta

Within Alberta there are presently 14 fishway facilities of one type or another, as well as 8 proposed facilities (Table D.1). Essentially all of these fishways are associated with some kind of water level stabilization weir, usually of the corrugated sheet steel variety. Of the 14 existing ladders, 6 are step and pool, 3 are modified vertical slot design, and 2 are denils (one steeppass and

one denil 2). The remaining 3 are simply submerged control weirs, with or without a notch (not a true ladder). (Alberta Fish & Wildlife, 1982)

Incidental observations by regional biologists indicate that the success of these facilities appears marginal in most cases (Alberta Fish & Wildlife, 1982). The step and pool ladders, for instance, are operational only under moderate or "ideal" flow conditions. Even then, other factors such as misplacement of the ladder or lack of attraction water, greatly reduce fish passage efficiency. The performance of the vertical slot and denil structures within the province remains uncertain due to the scant amount of in-field monitoring. However, recent work at Fawcett Lake outlet weir, using a denil 2, has indicated at least partial success with this design, (Halsted, 1982, in prep.).

A field inspection of eight fishways within the province by Katapodis in 1979 resulted in the following comments:

The fishways are generally poorly designed and installed. They are not functioning properly for one or more of the following reasons:

"(1) The entrance is usually too far downstream and away from the banks.

(2) Water drop per pool is excessive, resulting in streaming flow.

(3) The exit is located at the weir and/or in a high

velocity zone, thus sweeping fish back downstream as they emerge from the ladder.

(4) Fishways of the pool and weir type present maintenance problems."

The Fisheries Act of Canada requires that in streams where a development has resulted in fish blockage, a fishway must be constructed (Revised Statutes of Canada, 1970). Furthermore, the proponent is responsible for the construction of the appropriate fishway, as determined by the provincial Fish & Wildlife Division and the Federal Department of Fisheries and Oceans.

2.2 The Step and Pool Ladder

2.2.1 Hydraulics

2.2.1.1 Flow theory

The characteristics and pattern of water flow through the step and pool ladder are largely a result of potential energy differences between head and tail water elevations, as well as the approach velocity of the incoming water. The depth of the sill is a result of the total energy differences above and below the weir.

This total head value is described by Bernoulli's energy theorem for the case of flow with a free surface:

$$Ew = V^2/2g + P + h \qquad (1)$$

where;

Ew = total head energy

$V^2/2g$ = velocity head

P = pressure head

h = geodetic or elevation head

Although head levels may fluctuate from weir to weir through the ladder, Bernoulli's energy conservation theorem indicates the total energy per unit weight of fluid remains unchanged throughout the ladder, (King et al., 1949). This conservation of energy can be described according to the equation:

$$V_1^2/2g + P + Z_1 = V_2^2/2g + P + Z_2 + HL \qquad (2)$$

where;

Z = elevations above a 0 datum

HL = head loss from weir to weir.

All other terms are as defined previously.

Since the ladder is open to the atmosphere the pressure terms will cancel.

2.2.1.2 Discharge

In most cases, the basic step and pool ladder can be described as a series of standard suppressed rectangular weirs since they do not have side contractions at the weir, (W.M.M., 1967).

If the approach velocity is negligible, discharge over a weir of this type can be approximated by:

$$Q = 1.84\ L\ H^{1.5} \qquad (3)$$

where;

Q = discharge in m^3/s.

L = length of the weir in m

H = head in m

In the case of an approach velocity, it must first be converted to its head energy equivalent, using the formula for the velocity of falling water, (King et al. 1949):

$$V = (2gh)^{0.5} \text{ or } h = V^2/2g \qquad (4)$$

where;

V = approach velocity (m/s)

g = acceleration due to gravity (9.81 m/s^2)

h = head equivalent (m)

This value is then incorporated into equation (3):

$$Q = 1.84\ L\ [(H+h)^{1.5} - h^{1.5}] \qquad (5)$$

Where all variables are as previously defined.

2.2.1.3 Free vs. submerged flow

Equations (3) & (5) describe, approximately, the discharge for free flow over a suppressed weir. The term "free" describes the condition where the downstream water surface is lower than the elevation of the crest.

When the downstream surface is higher than the crest elevation, the weir is said to be submerged, and discharge is affected.

Few experiments have been done dealing with discharge over a submerged weir. Villemonte (1947), formulated an equation for several different weir types. For the suppressed rectangular weir, the equation reads as:

$$Q_1 = Q\,(1 - S^{1.50})^{0.385} \qquad (6)$$

where;

Q_1 = discharge with submergence.

Q = theoretical free-flow discharge.

S = submergence ratio (d/H), where d is the downstream head, and H is the upstream head, both in relation to the crest elevation.

Another important characteristic of the submerged weir, is the downstream standing wave. This wave is produced when the velocity of the flow over the crest is greater than that downstream. This condition results in a backing up effect (Fig. 8) at the point where the nappe enters the downstream pool. (King et al., 1949).

2.2.2 Design

Construction materials which have been utilized in the step and pool ladder include reinforced concrete, corrugated steel sheeting, and natural rock. In most cases, steel sheeting is used, due to its handling, fabrication, and cost advantages. The type of materials used, however, are largely dependent on the bedrock material and shape of the stream in which the ladder is to be placed. (Clay, 1961).

Wall elevations as well as the number of bays involved, will be directly related to the range of headwater and tailwater elevations at which the ladder must operate. Thus the use of existing hydrographs is essential to the establishment of these rating curves.

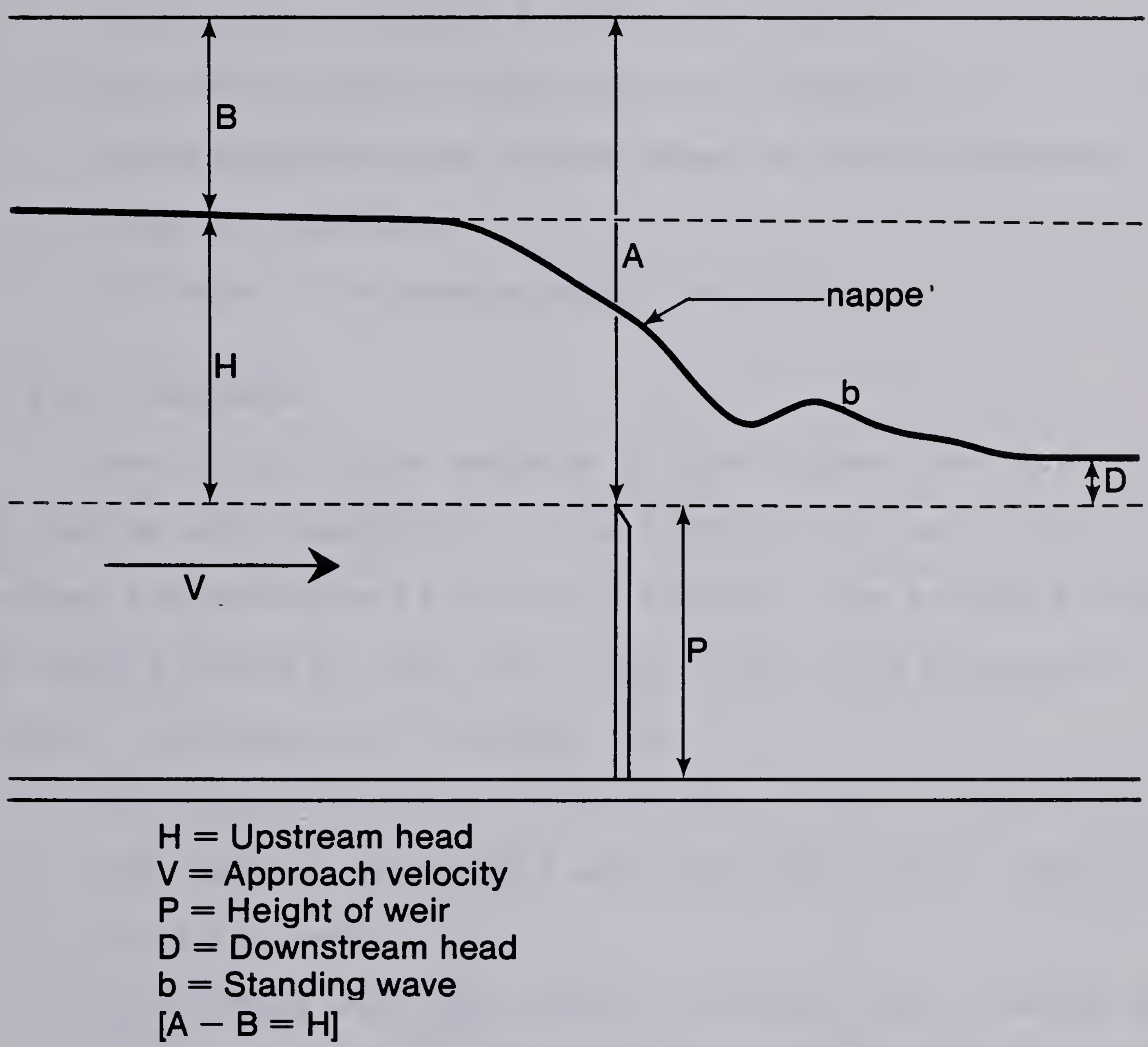


Fig. 8 Schematic of the submerged weir. After King et al. 1949.

In designing the fishway, Katapodis (1981), recommends the following procedure:

"(a) Fix the fish entrance.

(b) Determine fishway type.

(c) Design a typical fishway section.

(d) Locate appropriate areas for the exit.

(e) Arrange fishway layout based on cost, avoiding turns if possible.

(f) Select the most economic materials."

2.2.2.1 Entrance

Even if all other aspects of the fishway are optimized in design and construction, the fishway will be a failure, unless the entrance is properly located. The entrance must be easily found by the fish. Clay (1961), and Katapodis (1981), recommend the entrance be:

(a) located close to those areas of the stream where fish tend to congregate and move most often, usually along the banks.

(b) aligned with the crest of the spillway created by the hydraulic jump. The fish will tend to follow the stronger currents up to the point where they can move no further, and then move laterally along this crest.

(c) emitting a large enough flow that the fish will be attracted to it.

In the event that the entrance cannot be aligned with the crest of the hydraulic jump, Sakowicz and Zarnecki

(1954) recommend it be positioned not more then 5-10 m out from the weir partition. As well, the entrance should be sufficiently deep in the stream bed, that it will remain functional even during low flows.

Jens (1973) recommends that the entrance be placed at an elevation low enough in the tailwater zone that the fish do not have to jump more than 20 cm. Jens feels that the design of the fishway itself is secondary to the location of the entrance. The fishway should be located along that bank where the current is greatest. For example, if the stabilization weir were located at or upstream of a bend in the river, the ladder should be situated along the outside shoreline of the bend. This is where the current would be greatest.

The use of an attraction water pipe is another alternative to the fish attraction problem. Jens advises that a pipe carrying water from the headwater to the fishway entrance should have its outlet located close to the water surface, either just above or below.

When the pipe is above the water, attraction is accomplished in three ways:

(1) noise from the falling water.

(2) increased dissolved oxygen concentration in the water flowing away from the ladder entrance.

(3) increase in the velocity of the water flowing away from the ladder entrance.

2.2.2.2 Fishway type

The type of fishway selected should be largely dependent upon the physiological capabilities and behavior characteristics of the fish species involved. Katapodis (1981), notes the refusal of some fish species such as the alewife (*Alosa pseudoharengus*) to jump over obstacles, or to swim through orifices. This characteristic would eliminate the step and pool as a possible fishway for this species.

As well, the strong dependency of the weir type fishway on stable hydraulic conditions limits its performance. Since discharge over the weir is a function of the head (or $H^{1.5}$), there is strong flow sensitivity to changes in available head. For example, decreasing the head by 50% can decrease the discharge by as much as 35%.

The flow pattern of the nappe is easily disrupted by small changes in flow. During periods of low discharge (about 30 cm. of head) a plunging flow is produced (Fig. 9a). This produces a thorough mixing of the water in the pool, and energy dissipation is complete. Streaming flow occurs at higher heads (about 35 cm. and more) with the flow being largely confined to the surface layers (Fig. 9b) (Pretious, et al. 1957, cited in Clay, 1961). Little energy dissipation occurs within the pools. Fishladders which have a turbulent or whirlpool type of flow through the bays cause the fish to expend more energy than when the flow pattern is more steady (Clay, 1961). Bell (1973) recommends velocities through the ladder be well under a species darting speed,

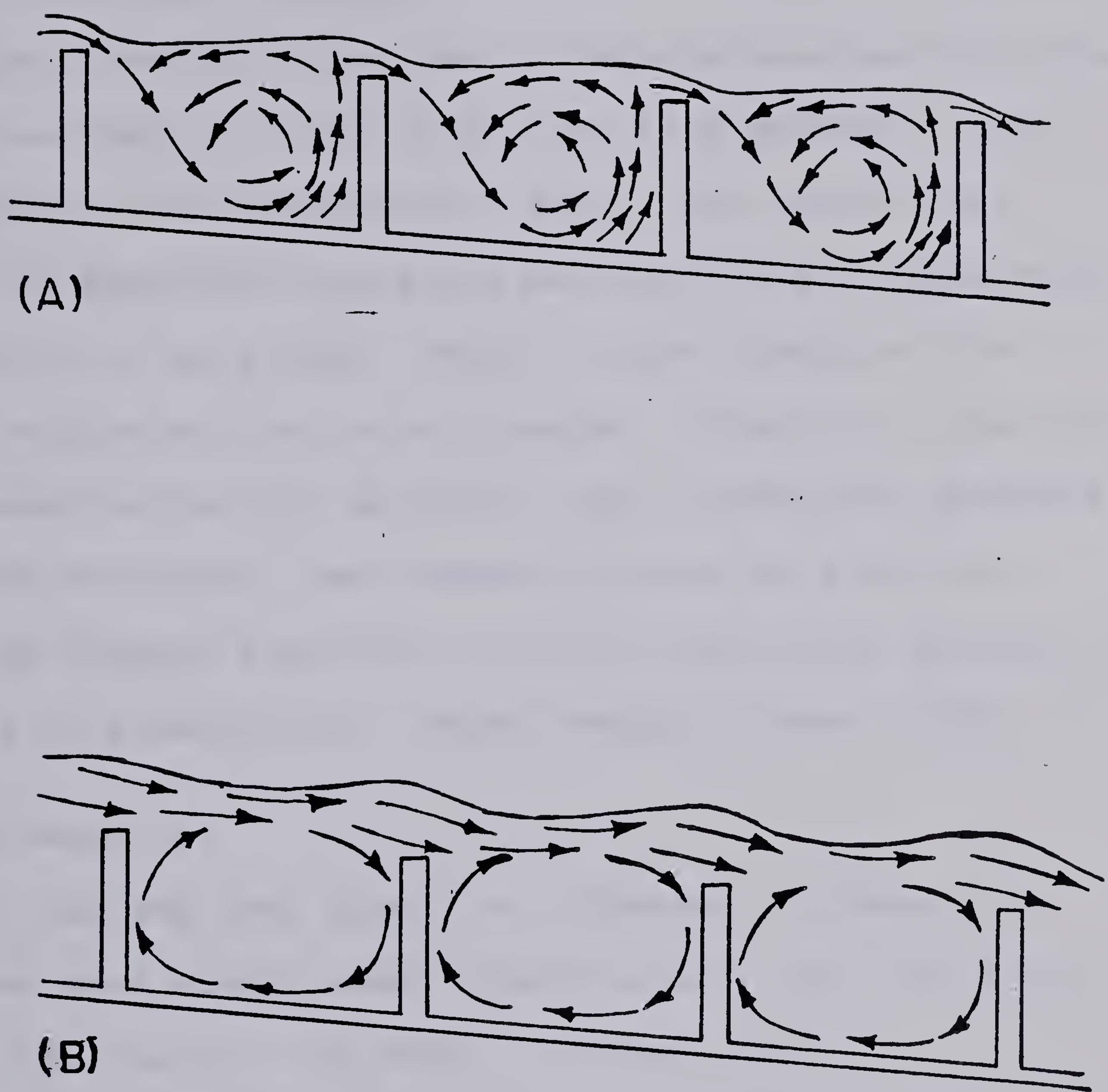


Fig. 9 Cross section through a fishway showing a plunging flow pattern (A), and a shooting or streaming flow (B). After Pretious, et al. 1957, cited by Clay, 1961.

but they may exceed its cruising speed. Average flow velocities of 0.5 m/s through a pool style fishway are suggested by Jens (1973), with maximum velocities of 1.5 to 2.0 m/s at the weir crests.

The vertical slot and denil fishways have met with the greatest success in terms of general fish passage, (Clay, 1961; Decker, 1967; Katapodis, 1981). The appropriate sequence of behavioral cues can be vital to the successful reproduction of an animal. Delays in the timing of the spawning migration can be detrimental. Therefore, the fish ladder should allow the quickest, most convenient possible passage of the fish. Development of such an efficient ladder may require the observation of the target species in a variety of experimental ladder designs. (Hoar, 1958).

2.2.2.3 Dimensions

The step and pool family of fishways are among the oldest and most widely used. Traditionally, the pools are square to rectangular in shape. (Decker, 1967).

Sakowicz and Zarnecki (1954) recommend the following pool dimensions:

-For large species, such as salmon (*Onchorhyncus* spp.)

Length approx. 6.0 m

Width approx. 3.0 m

Depth approx. 1-1.5 m

-For smaller species

Length approx. 2-3.0 m

Width approx. 2.0 m

Depth approx. 0.5-0.8 m

Similar dimensions are recommended by Jens (1973):

Length: 2.0 m (min)

Width: 0.8 m

Depth: 0.8 m (min)

Other authors such as Clay and Decker give similar size criteria.

The sizing of pools within the fishway is usually based on the amount of energy which is to be dissipated by each pool, as well as the burst speed velocity of the target species (Katapodis, 1981).

Other factors to be considered (Mcleod & Nemenyi, 1940) are:

(1) the size of the migration. If the ladder is to experience periods of heavy use, such as during spawning migrations, it must be of sufficient size to accommodate the large number of fish which will be moving through it at any one time.

(2) the average size of the fish. Both the number and size are important here.

Bell (1973), recommends a ratio of 14 L/kg of fish as a volumetric criterion.

2.2.2.4 Exit

A common error is locating the fishway exit in a high velocity zone and/or in close association with the main weir wall (Decker, 1967; Bell, 1973). In this case, fish are in danger of being swept back downstream upon emergence from the ladder. Katapodis (1981) recommends keeping the exit away from these draw down regions, however, a small current should exist in order to act as a lead for emerging fish.

Also associated with the exit, there may be a counting pool and/or trash rack. The counting pools can be used to evaluate the performance of the ladder in terms of fish numbers (Decker, 1967). The trash rack or deflector acts to keep the ladder clear of debris. Trash racks must meet two requirements in their design. They must block debris, while continuing to allow even the largest fish to pass through. In Alberta, for example, a bar spacing of 15 x 30 cm has been used.

2.2.2.5 Operation

Maintaining proper head levels over each weir, is one of the more difficult tasks in ensuring a step & pool ladder will operate properly. Jens (1973) suggests a sill level of 15 cm to 30 cm. Also, the crest of the weir should not be submerged.

Provided there is a proper maintenance schedule, head manipulations can be accomplished through the use of "stop logs". Stop logs are generally constructed of timber. They

are portable, in that they can be removed or placed on the weir as required. The weir may be constructed entirely of these logs (placed one on top of the other) or it may be made of a permenantly positioned steel sheet on top of which logs may be stacked as needed.

Work has been done by the U. S. Army Corps of Engineers in attempting to determine the best shape of weir crest for both fish passage and water flow, (1957, cited by Clay, 1961). These shapes include rounded, bevelled and flat crested weirs . Clay concludes that only slight changes in flow patterns have resulted from the different shapes. Therefore if one shape appears to be more readily accepted by a fish species, in terms of ease of passage, then it may be used without adversely affecting the flow characteristics of the ladder.

2.2.3 History of the step and pool

As mentioned, the weir style of fishladder is one of the oldest designs in existence (pre-1900). Its hydraulics have been studied and found to be best for mild slopes such as those encountered at stabilization weirs. (Mcleod & Nemenyi, 1940).

Although the simplest form of this ladder consists of overflow weirs (Fig. 3), more commonly the weirs are notched or combined with a submerged orifice, (Decker, 1967).

As a result of its spill over type of flow, the step and pool has been most successful in passing the more

actively jumping game fish, such as trout and salmon. Thus the behavior or the fish species involved is an important consideration. Adult salmonids were tested by Collins, et al. (1962) for their ability to ascend a step and pool ladder. The ascent through the fishway appeared to be easily accomplished by the species. One specimen ascended a total of 2027 m over 5 days (averaging about 1.2 minutes per pool).

The combination of behavioral selectivity and sensitive hydraulic requirements, has resulted in fewer step and pool ladders being constructed (Decker, 1967; Katapodis, 1981).

2.2.3.1 Applications in Alberta

The step and pool fishways within Alberta are of the suppressed rectangular weir variety. The sides of the ladder act as the ends of each weir with little or no contraction of the nappe (the stop log brackets may cause some side contraction at lower heads).

Historically, the reasoning behind the use of the step and pool ladder in Alberta is somewhat obscure. Of the six step and pool ladders presently operating in the province, all were built during the 1970s. The engineers involved had available only scant information concerning design parameters of freshwater fishladders. Consequently, much has been based upon the general opinion of regional fishery biologists, as well as guidelines by authors such as Clay (1961) and Bell (1973), which deal in large part with salmon

ladders. Continued use of this type of facility throughout the 70's was not questioned because of a lack of information on the success of ladder performance. Recent biological monitoring studies by Alberta Environment of existing facilities, have resulted in questioning the effectiveness of the step and pool ladder as a passage facility. (Lindner, 1982, person. comm.). "Fishways currently in the design phase by Alberta Environment are scheduled to have temporary vertical slot and/or denil inserts tested in them, before permanent types are selected.", (Kemper, 1982. Pers. Comm.).

Fawcett Lake

Prior to the recent conversion to a denil fishway (1982) the Fawcett Lake fishladder was of the step and pool variety. The ladder was divided into a series of 10 pools separated by stop log weirs (a situation similar to the Driedmeat fishladder).

Minchau (1980) conducted an evaluation of the ladder during the spring of 1979. Minchau indicated that the species involved in the study had difficulty in finding the entrance to the fishway. White sucker, "appeared to have no difficulty in negotiating the velocities", once they were in the ladder, however, the pike, "were unable to negotiate the velocities within the fishway".

Velocity readings in the report indicate that a streaming flow existed through the ladder, with velocities being as high as 1.2 to 1.5 m/s between weirs, while velocities over the weirs ranged from 0.7 to 1.2 m/s.

Minchau felt that a burst speed estimate for pike of 0.95 to 1.35 m/s (M.M. Dillon Ltd., 1979, cited by Minchau, 1980) over a distance of 1.0 m was too high, since a significant number of pike did not pass through the fishway.

Gregoire Lake

Watters (1980) conducted a two year monitoring program (1977/78) of the step and pool fish ladder of Gregoire Lake. The study was to determine the range of water velocities through the ladder which permitted the largest number of fish to ascend.

The Gregoire ladder is constructed of corrugated steel sheet piling with flat sheet steel weirs. Each weir has an attached fixed crest of sheet steel. The vertical drop between each step is about 15 cm. There are 5 pools, each approximately 3.0 m long , 1.5 m wide and 1.0 m in depth.

Although pike was the major fish species involved, five other species were present; White Sucker (*C. commersonii*), Longnose Sucker (*C. catastomus*), Lake Whitefish (*Coregonius*

clupeiformis), Burbot (*Lota lota*), and Arctic Grayling (*Thymallus arcticus*).

Velocities were measured at two locations: over each step, and about 14 cm above the bottom of the pool. Velocities were manipulated by the use of 50 mm x 100 mm stop logs.

The results were somewhat inconsistent, but appear to indicate that velocity (within the range of 0.22 m/s to 1.05 m/s over the crest) had little effect on either success rate or size of fish that would move through the ladder. Rather, it appeared variables such as water temperature and flow characteristics were more highly correlated with the number of fish which found or attempted to move through the ladder at any one time.

Driedmeat Lake

A small amount of incidental monitoring was done on the Driedmeat ladder in 1979, as a result of a tagging study conducted by Rhude (1980).

No velocities or discharge measurements were taken, and an unspecified number of stop logs were missing from the ladder. The monitoring was relatively inconclusive, except that some fish (175 white sucker and 10 pike) had successfully navigated the ladder.

Role of Alberta Environment

All fishladder facilities within the province have been designed and/or approved by the Planning Division of Alberta Environment. Recently, Planning Division has engaged in more active monitoring of some of these fishways. The results of the present study form a part of this general evaluation of existing facilities. (Kemper, 1982, person. comm.).

3. THE ANIMAL

3.1 The Hydrodynamics and Energetics of Fish Propulsion

3.1.1 The movement of objects through water

3.1.1.1 Form and drag

Drag can be described as that total force which resists the movement of immersed bodies. This resistance is attributable either directly or indirectly to the influence of fluid viscosity, or the resistance of a fluid to comply with angular deformation. The two main forces involved in bringing about this deformation are frictional (viscosity gradients) and inertial, (the force of the moving object attempting to accelerate the static water). (Webb, 1975).

Drag and power requirements for swimming fish have most commonly been calculated by using rigid bodies of similar shape. In some instances, dead or anesthetized fish have been used. (Magnan, 1930, Brett, 1965, cited by Webb, 1975).

The total drag which confronts a fish as it moves through water is the result of three factors (Gero, 1952).

(1) The surface area of the fish causes "friction drag". This is a function of the surface texture of the fish and the velocity of the water relative to the fish's body.

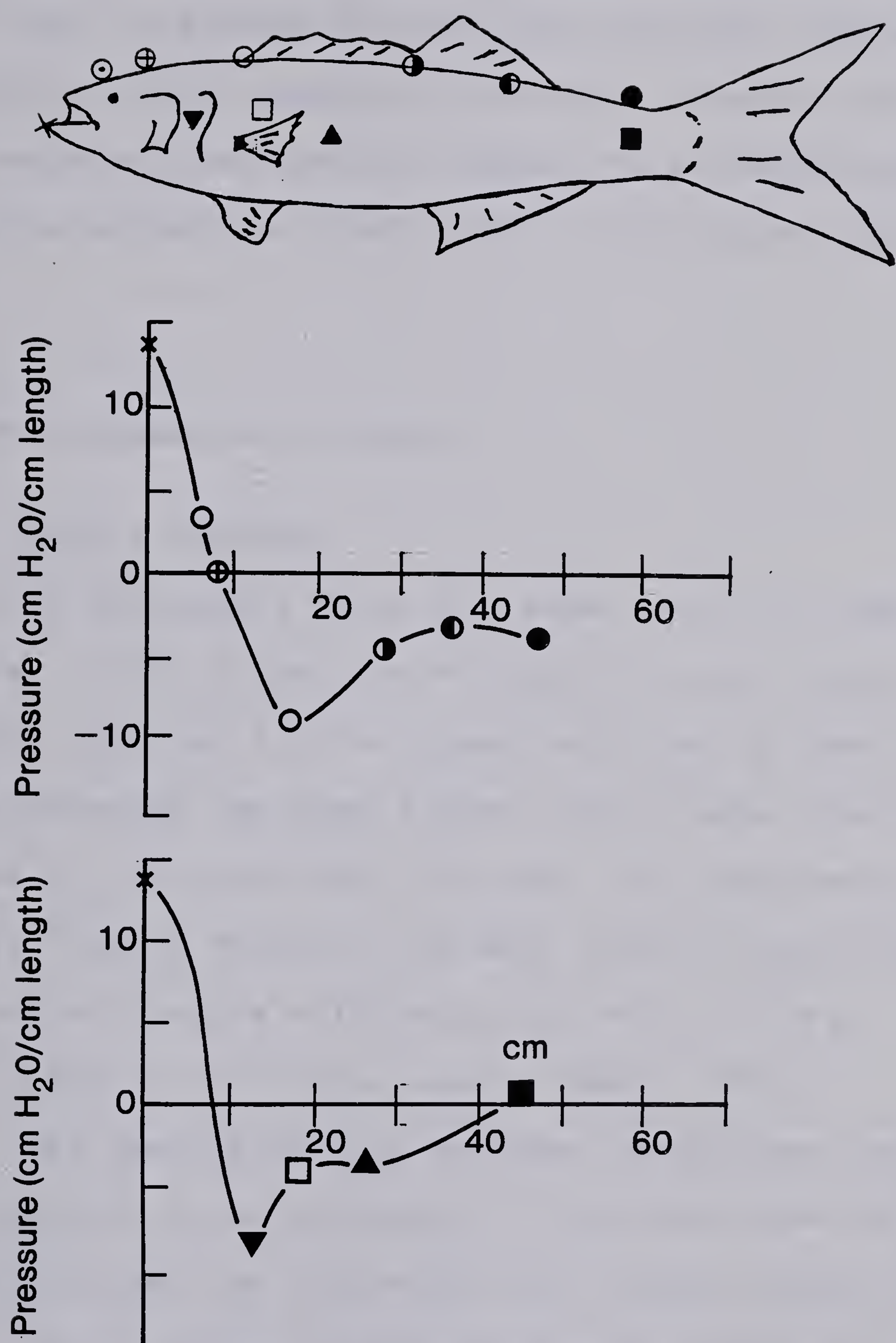
(2) The fish's physical configuration causes "form drag". Depending on the speed and shape of the fish,

the boundary layer will begin to separate (move away from the surface of the fish) sooner or later along the body of the fish. This separation produces a wake behind the fish which exerts an overall lower pressure component than at other points on the fish's body. Thus the resultant pressure force that the fish must overcome is greater than if this pressure differential did not exist.

(3) The oscillating motion of the tail itself tends to disrupt the flow of fluid around it, adding to the wake conditions already created. The energy lost as a result of overcoming this added resistance is referred to as the "induced drag".

Webb (1978) identifies form drag as the most important of these three forces. The more streamlined the body, the greater the delay in separation of the boundary layer.

The velocity of the water passing over the fish reaches a maximum at the point of greatest body thickness, due to the Bernoulli effect. Dubois, et al.(1974) established a pressure force profile for the bluefish (*Pomatomus*) from front to back (Fig. 10). Apart from an initially high positive pressure on the frontal region of the fish (due to the opposing forces of the fish meeting the water), it was found that pressures were negative along the rest of the body length even as far back as the tail. As expected, the greatest negative pressure was found at the shoulder (point of greatest thickness).



Note: The symbols in the charts correspond to the matching symbols on the diagram of the fish.

Fig. 10 Pressure profile along the length of a 60 cm. Bluefish , moving at 1.8 m/s. After Dubois et al. 1974.

It has been found that the resistance met by an inert fish moving in water is about the same as that of a wooden model, that is similar in form and velocity, (Richardson, 1936; Gero, 1952). However, resistance to water flow about a live, swimming fish does not appear to be mechanically similar to either the inert fish or the wooden model (Webb, 1975).

3.1.2 The locomotion of fish

3.1.2.1 Gray's paradox

In an hypothesis first put forward by Sir James Gray (see Gray, 1957) it was found that the muscle power estimates required for the speeds attained by some fish species exceeded the muscle power which these species appeared to have available to them. This phenomenon, known since as "Gray's Paradox" has been based on approximations of vertebrate muscle efficiency, as well as drag coefficients of non-living models (Webb, 1975).

It was postulated that because insufficient muscle power appeared to be available to overcome expected drag at such velocities, the fish must have certain mechanisms whereby it can reduce its drag below the critical level required.

It is suggested that the absence of any noisy, rattling, or vibrating mechanisms favours the maintenance of an idealized (less turbulent) boundary-layer flow, (Hoerner,

1965). As well, fresh fish mucous has been shown to reduce frictional drag, (Hoyt, 1975 cited by Webb, 1975).

Other possible drag reducing mechanisms include:

(1) body shape, particularly fineness ratio. Torpedo shaped bodies with a fineness ratio of 4-5 appear to be most streamlined (Webb, 1975).

(2) propulsive wave motion of the caudal fin area. The oscillating movement of the tail accelerates water coming in contact with it. This may delay the onset of boundary layer separation, to a point further down the length of the fish's body (Gray, 1957).

(3) conformity of the skin. It has been demonstrated that the damping effect produced by the pliable nature of a dophin's skin results in a reduced drag (Kramer, 1960, cited by Webb, 1975).

(4) ejection of kinetic energy (i.e. water from the gills) into the boundary layer, to retard the onset of separation (Gray, 1968, cited by Webb, 1975).

In general, it appears that these drag reducing mechanisms apply mainly to cruising speeds and lower level burst speeds (see forms of swimming).

Webb (1975) concludes that because efforts to determine drag coefficients and drag reduction mechanisms in fish have been done largely with models and dead specimens, the results of different studies have appeared contradictory or inconclusive; the paradox remains largely unresolved.

3.1.2.2 Forms of swimming

The types of movement observed in fish have been broken down into three basic types (Bainbridge, 1958):

(1) Anguilliform - undulations which extend down the whole length of the body, such as in the eel.

(2) Carangiform - typifying the "normal" kind of movement we see in most fish. Oscillations occur, normally over the posterior 1/3 of the body, such as in the pike or salmon.

(3) Ostraciiform - the body is encased in a solid cover and oscillations are restricted to a rigid tail fin.

Within the Carangiform mode, the extent of the posterior portion involved can vary. At lower speeds, large amplitude, slow sweeping motions of the posterior half of the body may be used. At higher velocities, movement tends to become restricted to the caudal fin and peduncle. (Gray, 1957; Webb, 1975).

Movement is accomplished through the action of the tail. The anterior, less flexible, portion of the body tends to act as a fulcrum for the flexible lever like tail and peduncle (Gray, 1957). The high inertia of the moving tail acting against the resisting inertia of the still or opposing water, produces two forces. One force acting transversly, the other acting parallel to the axis of movement (Fig. 11). The longitudinal force results in a forward movement, while the transverse force is largely absorbed by the higher resistance of the body to a lateral

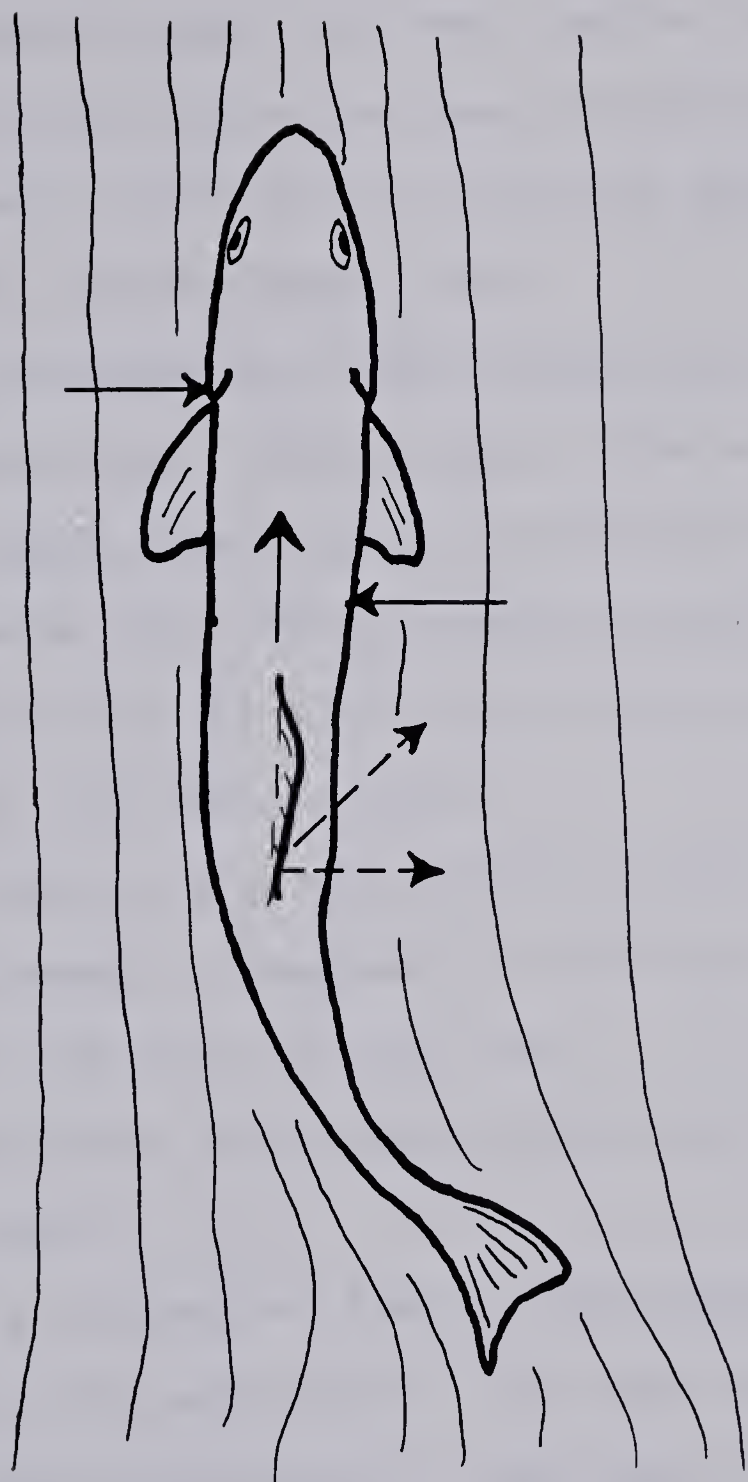


Fig. 11 The forces exerted on a fish as it moves through the water. After Gray, 1957.

movement, (Bainbridge, 1958). Lateral flattening, typical of most fish, enhances the magnitude of the inertial forces (Webb, 1978).

Evidence suggests that for most species no point of the body moves continously along the mean line of progression. All parts oscillate about this line with a greater or smaller amplitude, (Bainbridge, 1963).

The typical movements of the carangiform fish, as described by Bainbridge (1963), explain the streamlining effect of what would otherwise be a much more intermittent thrust by the caudal fin. These characteristics would be:

"(a) to allow a rapid initial acceleration of the tail by virtue of its smaller area.

(b) to maintain a high and uniform thrust when the transverse speed of movement is falling, by increasing the area of the tail at that time.

(c) to facilitate the slowing of the tail by this increased area.

(d) to add a minimum of drag to the moving body by presenting a minimum area to the water when at the extreme lateral positions in the cycle of movement."

Bainbridge concludes that the fish has active control over the speed, amount of bending and area of the caudal fin presented during tail oscillation.

The Carangiform mode of swimming can be further subdivided into three activity levels (Webb, 1975):

(1) Cruising or sustained speed - (maintained for greater then 200 minutes) used in low levels of routine activity, such as foraging, station holding, exploratory movements and territorial behaviors.

(2) Prolonged or steady speed - (maintained for periods of 15 s to 200 minutes) used for active movement over a longer distance.

(3) Burst or sprint speed - (maintained for less than 15 sec.) used for escape, food capture and other activities requiring high exertion for a very short duration.

Cruising and prolonged speeds can be characterized by the sequence of movements just described. The rapid acceleration of burst speed, however, is generally accompanied by more vigorous large-amplitude tail movements. Weihs (1973) describes the good accelerating fish as having a large tail area without sacrificing the slenderness of the fish's shape. In this way, the vortices shed by movement become concentrated at the rear of the body (Lighthill, 1960). Fish swimming models and efficiency are now largely based on theoretical hydrodynamic models, such as those of Lighthill and of Weihs.

3.1.2.3 The rapid start

In theory, the highest thrust at a minimum energy loss should be attained when the tail is moved at high speeds, while the angle of curvature is minimized. Weihs (1973) describes the three stages of the fast start:

"(1) The preparatory stage - the fish changes from a stretched out straight position, into an L-shape.

(2) The propulsive stroke - the tail is moved perpendicular to the heading of the fish, ending up in the other direction. This stage is sometimes repeated several times, the tail moving back and forth.

(3) The final stage - the fish settles down to either a normal propulsive rhythm, or returns to a stretched configuration, gliding usually at an acute angle to the original orientation."

Weihs feels that during accelerated or burst swimming, there appears to be no need for drag reducing mechanisms to explain performance. The hydrodynamic forces produced by the fish appear sufficient to produce the short term acceleration observed.

3.1.2.4 Physiology of swimming

The three principal demands for energy within a fish are body maintenance, gonadal development, and muscular activity used in locomotion. The energy used for these activities appears to come from the breakdown of intermuscular fat tissue. An excellent review of

carbohydrate metabolism in fish is provided by Black et al. (1961).

In all fish groups, muscle contraction occurs serially, by working backward along a connective tissue system attached to the flexible but resistant "backbone". The addition of intermuscular bones, such as spines and ribs add strength to the muscle segments (Nursall, 1956).

Although the caudal fin is quite flexible, it is supported by a series of boney rays which act like flexible girders. These rays can bend with a hydrodynamic load, but at the same time they orient the fin to oppose the load. In this way the fin automatically adjusts itself to meeting a more constant loading (McCutcheon, 1970). The fin can be voluntarily moved ray by ray in a variety of ways. The fish can relax or extend it, thereby changing the aspect ratio of the fin quite rapidly (Nursall, 1958).

The muscle segments (myotomes) contain two basic types of muscle fibre; red and white. Histologically, the red muscle breaks down fat (glycogen) aerobically, and is therefore used in sustained activity such as long distance migrations. White muscle, on the other hand, functions through anaerobic glycolysis, and appears to be useful in vigorous short duration activity, where an oxygen debt may be incurred (Bainbridge, 1958; Brett, 1965; Hudson, 1973; Beamish, 1978). Fish that normally swim at high levels of sustained activity tend to have greater proportions of red muscle fibre, than those which are not as capable at

sustained activity.

It has been suggested (Black, 1958) that the glycogen reserves of the muscle are of greatest importance during short spurts of high activity. The build up of lactic acid due to an oxygen deficit during glucose breakdown helps to explain the limited duration of burst speeds.

There is also evidence to suggest that more active fish species demonstrate an increased gill surface area, than less active species. This is accomplished through longer filament length and a larger number of secondary folds per filament (Hughes, 1966).

3.1.3 Approaches to the measurement of performance in fish

Efforts to measure the swimming performance of fish in the laboratory have generally concentrated on sustained and/or prolonged levels of activity, (Jones, 1973; Brett, 1965; Bainbridge, 1960).

Burst levels of performance are much more difficult to measure experimentally due to the inconsistency of the response level that is produced. As Fry (1958) pointed out, "Experimental laboratory determinations of swimming performance are subject to the establishment of conditions that will consistently evoke the maximum or 'normal' response from the animal.".

The swim chambers that have been used to measure sustained performance in fish can be grouped, broadly, into one of two categories:

(1) the chamber itself is rotated (Fig. 12a).

(2) water is pumped through a stationary cylindrical chamber (Fig. 12b)

Although these chambers have been useful in helping to establish the present level of knowledge concerning sustained performance levels of various species, several design problems exist. Some of these include (Jones, 1973; Beamish, 1978):

(1) motivational stimulus. Mechanical prodding as well as an electrified grid have been used in order to motivate swimming.

(2) wide flucuations in velocity profile and drag effects on the fish depending on dimensions and flow conditions in the chamber.

(3) conditioning and orientation of the fish to the chamber.

(4) extended exposure of the fish within the vessel as velocity increases incrementally. This allows lactic acid build up over time.

Jones (1973) performed a field and laboratory evaluation of the sustained swimming performance of several fish species from the Mackenzie River system. The problem for several of the species was the lack of a consistent response for any one size class. Regression plots revealed a wide scattering of results (in several cases), and a poor correlation between length and sustained velocity.

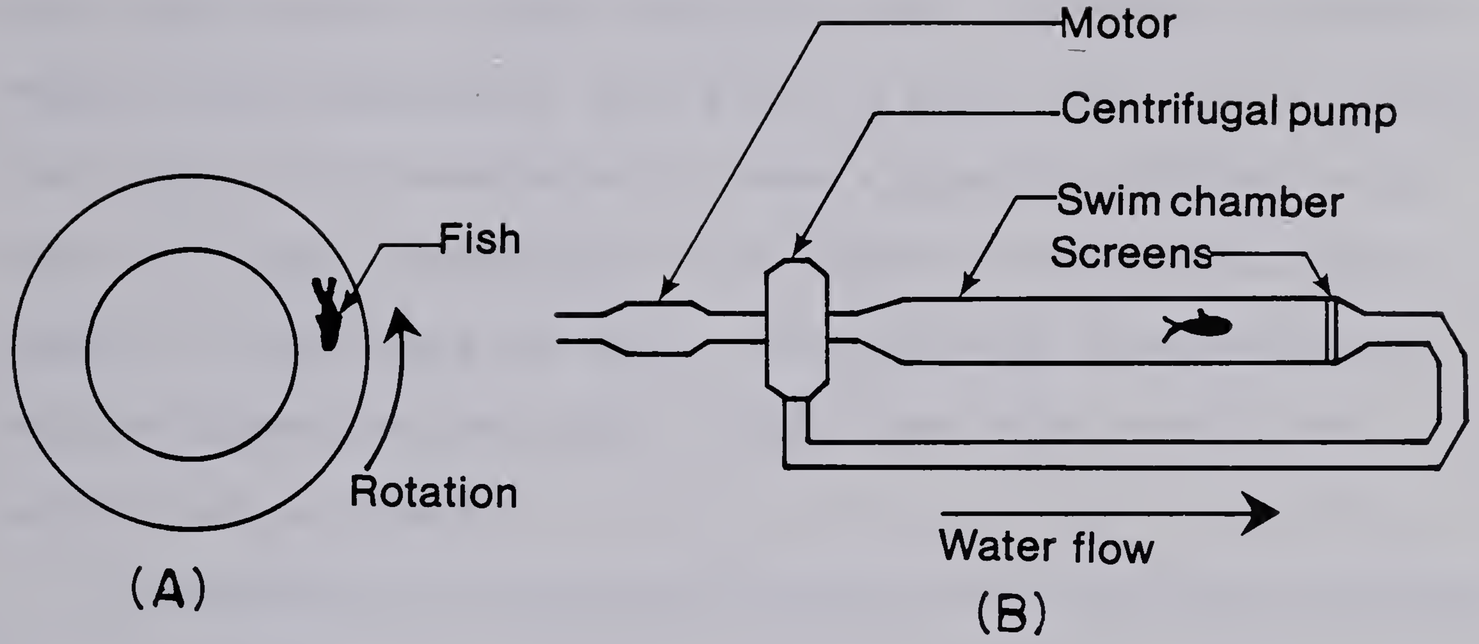


Fig. 12 A: Rotating chamber design. After Beamish, 1978.

B: Stationary chamber design. After Brett, 1964.

3.1.3.1 Burst performance

Gray (1957) and Bainbridge (1958) did similar experiments using the rotating style fish chamber, in trying to establish a generalized formula for maximum swimming speeds of fish.

Both authors established a positive relationship between length and attainable speed, and between tail beat frequency and attainable speed. However, an inverse relation was found between length and tail beat frequency. Although smaller fish generally were able to beat their tails faster, the larger fish were able to move a greater distance with each tail beat, resulting in an overall greater measured speed. On the basis of these relationships a generalized maximum speed on the order of 10 times body length per second was proposed.

Bainbridge also generalized maximum attainable velocity by the formula:

$$V = 1/4[L(3F-4)] \tag{7}$$

Where:

V = speed (maximum) cm/s

L = length, cm

F = frequency of the tail beat, oscillations/s

Maximum speed estimates for various species have been summarized by Beamish (1978) who suggested a performance maximum of 20 lengths per second for some species, such as the Alewife (*Pomolobus pseudoharengus*). Wardle (1975) indicated speeds of up to 26 lengths/s for 10 cm. sprots

(*Clupea sprattus*) based on video recordings. Bell (1973) indicated burst performance to be about 6 times the cruising speed. Hildebrand (1980) gives 8 lengths/s as a burst speed criterion for fish.

Notably, if Beamish's summary table of burst speeds (See table 4, pgs. 118 - 121 of Beamish, 1978) is analyzed by plotting maximum burst speed against maximum length, the regression established is fairly linear (r = .82), with burst speed being quite closely approximated by ten times the length (Fig. 13).

Also, if the shape of a species is compared with the burst speed it can attain, it will generally approximate one of the six shapes outlined in Fig. 14. Species such as the eel (*Anguilla*) and flatfish (*Pleuronectes*) exhibit the poorest performance, the suckers and minnows (Cyprinnids) being intermediate, and the barracuda (*Sphyraena barracuda*) and tuna (*Thunnus*) demonstrating the greatest speeds. Such a relationship is strongly dependent on size. If velocity is measured in terms of body lengths per second, a different ordering sequence occurs. If the species are arranged by sustained swimming ability, a different order results again.

Short duration, high speed sprints are more associated with the work required to overcome the inertia of the body mass, rather than boundary layer drag (Webb, 1975). The energy required to move the long cylindrical shaped body of the pike or barracuda is lower than in the case of the

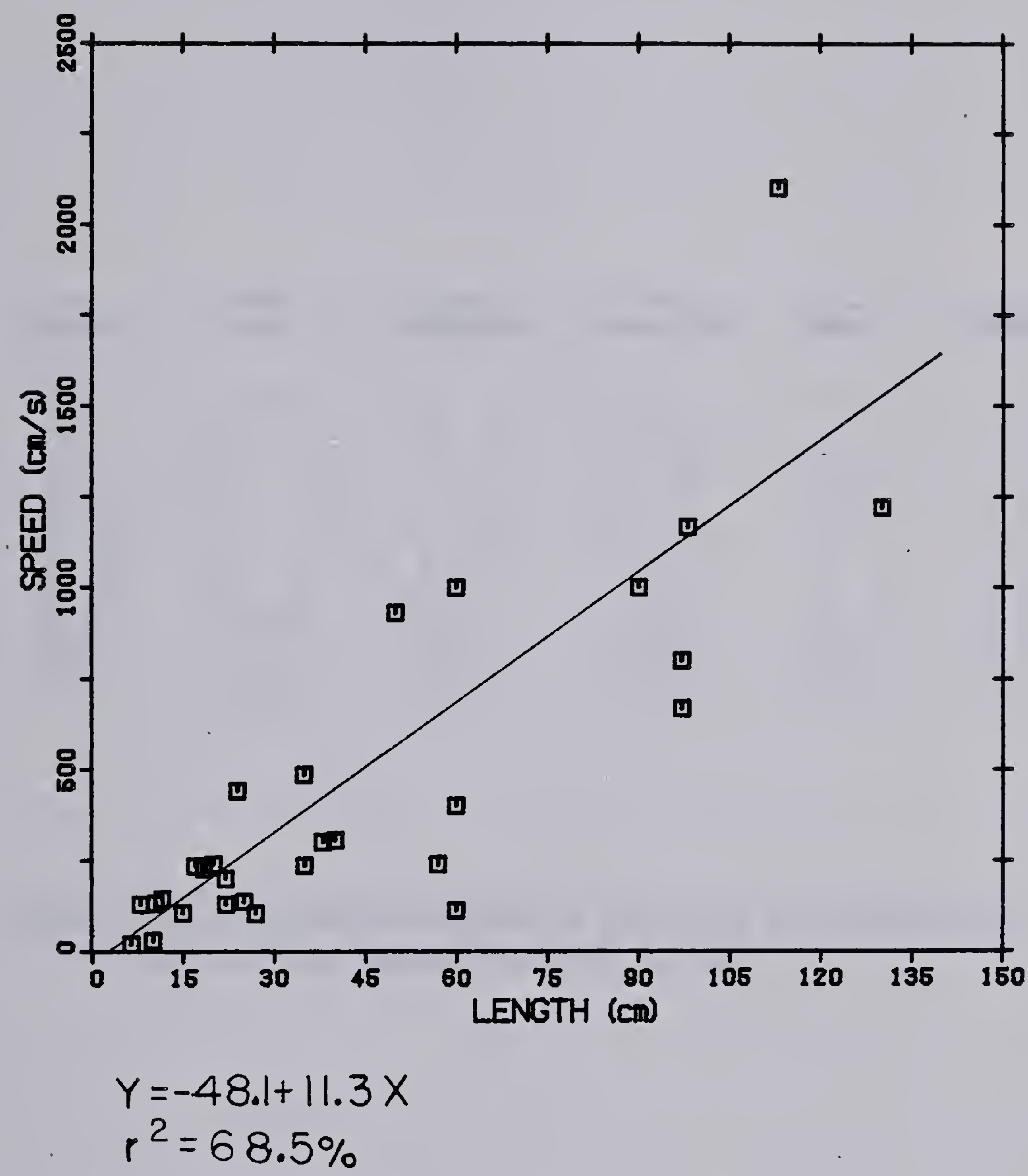
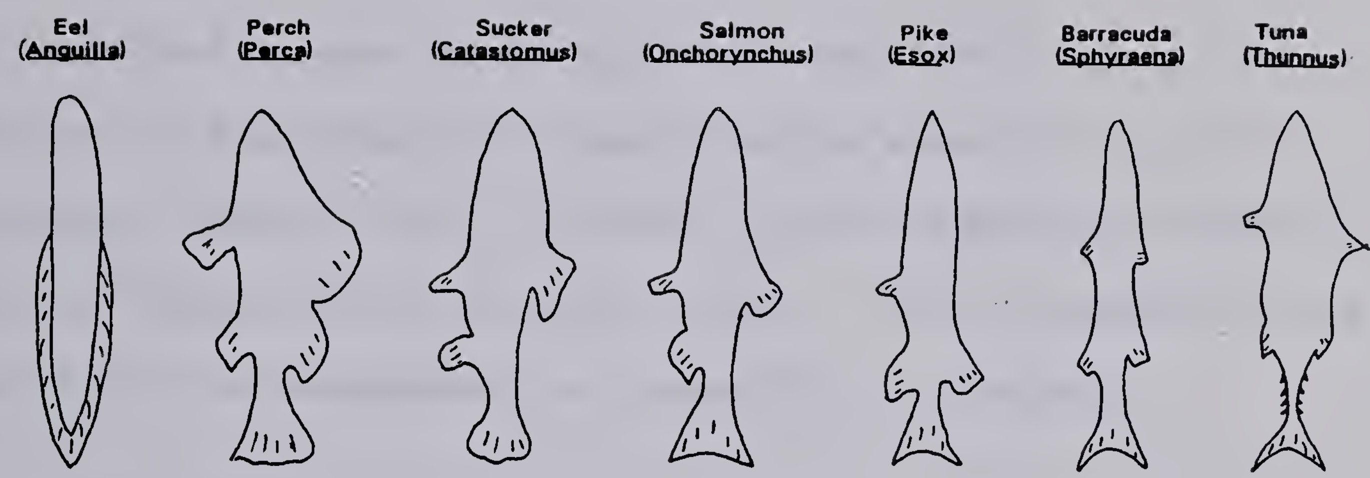


Fig. 13 Plot of measured burst speed performance vs. specimen length for various species of marine and freshwater fish. See also Table 4 of Beamish, 1978.



Note: Burst speed performance (in terms of distance per second) increases from left to right.

Fig. 14 Various fish shapes arranged according to Burst speed performance. See also Table 4 of Beamish, 1978.

shorter elliptical shaped bodies of the carp (*Carpiodes*) or sucker.

There appears to be an ideal temperature for maximum performance in sustained speeds (usually 10-15°C). Burst performance, however, exhibits no apparent relationship with temperature (Blaxter & Dickson, 1959, cited by Beamish, 1978).

Dissolved oxygen concentrations can result in a 60% reduction in sustained swim performance when at only 33% saturation, (Bell, 1973). However, burst speed performance is not so dramatically affected (Webb, 1975), apparently as a result of its dependancy on anaerobic glycolysis.

3.1.3.2 Pike and sucker performance

One of the earliest recorded estimates of burst speed in pike appears to be the value given by Stringham (1924), based on the running speed of a person attempting to spear a pike of unknown length. Stringham estimated the speed of the fish at between 3.5 and 4.5 m/s. Magnan (1930) reports a maximum speed of 1.5 m/s for a 38 cm. pike. Lane (1941) estimated the speed of a hooked pike of unknown size, at between 5.9 and 13.7 m/s (by measuring the length of line taken). Gray (1953, cited by Beamish, 1978) recorded a swimming speed of 2.1 m/s for a 16.5 cm pike.

Ohlmer & Schwartzkopff (1956) timed 8 pike, averaging 40 - 44 cm., as they moved between markers placed 10 m apart. Average velocities of 2.7 m/s were

recorded. Observations indicated that initial velocities were highest and then declined in the latter stages of the 10 m sprint.

Jones (1973) estimated sustained speed for pike of any length according to the equation:

$$V = 4.9\ L^{0.55} \qquad (8)$$

where:

V = critical sustained velocity, cm/s

L = fork length (cm.)

Dryden & Jessop (1974) observed "larger" pike to pass through a 65 m long culvert with centre line velocities ranging from 0.9 to 1.6 m/s. Observations, however, indicated that most of the pike which attempted the culvert failed.

Due to the lack of consistency in both sustained as well as burst speed estimates, the swimming capabilities of the pike remain largely uncertain.

Studies on fast start performance done by Weihs (1973) and more recently Webb (1978 & 1980) point out that the pike is capable of extremely high initial acceleration rates, up to 50 m/s^2. Weihs attributes this ability to the elongate shape of the species and the large surface area produced by the caudal fin and the posteriorly located dorsal and anal fins (Fig. 14). It would appear that burst swimming followed by a gliding motion (a characteristic typical of pike) is a very efficient, energy saving, mode of fast swimming, (Weihs, 1974).

Webb observed the fast start kinematics of seven species of fish, including an *Esox* hybrid species. The pattern of the movement was similar to that outlined by Weihs (see the rapid start). The velocity increased through the fast start and reached a maximum at the end of stage 2. Observations covered extremely small time periods (fractions of a second) and therefore burst speed velocity estimates could be misleading (Webb, 1982, person. comm.).

The extremely limited economic importance of sucker species such as *C. commersonii*, have resulted in even less performance data than in the case of the pike. Western suckers (*Catastomus occidentalis*) were observed by Wales (1950) attempting to swim up a culvert with a flow averaging about 2.5 m/s. Ten specimens (approx. 30 - 35 cm in length) attempted the flow, all failed. However, from the distances attained, Wales estimated an overall burst speed of between 3.0 - 3.4 m/s.

A cruising speed of 0.6 m/s, sustained speed of 1.7 m/s, and burst speed of 3.0 m/s have been cited for 30 - 40 cm white sucker by Bell, 1973. Long nose sucker appear to have similar swimming abilities to that of the white sucker and western sucker (Jones, 1973).

4. Objectives

The objectives of the present study are summarized below.

(1) To evaluate observations made on pike and white sucker swimming performance. These two species were observed in several situations. These situations are discussed individually and collectively in order to provide a partial assessment of the swimming ability of these fish, specifically of their burst speed capabilities.

(2) To perform an evaluation of the effectiveness of the step and pool fishladder in allowing the passage of pike and white sucker. Various flow conditions through the ladder were manipulated, in order to assess ladder performance for various fish sizes (lengths).

(3) To provide recommendations for possible improvements to the ladder, based on this authors evaluation of the ladder, and the performance of the two species using the ladder.

In the pursuit of these objectives, a variety of other pertinent biological data were collected for these fish. These data are briefly discussed.

5. Methodology

5.1 Procedures

5.1.1 Fish sampling

5.1.1.1 Live sampling

All fish captured were held in 70 L heavy duty plastic tubs to await handling.

Fish were sized by fork length using a standard wood measuring board graduated in mm (see Lagler, 1968, pg. 40). In instances where an animal proved difficult to handle, it was first placed in an elongate clear plastic bag.

Due to a lack of distinctive sexual dimorphism, pike were sexed by expressing each animal for milt or eggs. The thumb and forefinger were gently pressed against the latero-ventral edges of the fish and directed posteriorly from about the midregion to the cloaca. The fish was placed in an upside down posture and tilted posteriorly for this procedure.

White suckers were sexed as male by the presence of breeding fin tubercles on the fins, or females by the absence of such tubercles. Each animal was also expressed in an attempt to confirm these sexually dimorphic characters.

Sexual condition was classified in the following groupings:

(1) Ripe - If gonadal products (milt or eggs) were easily displayed with little pressure.

(2) Expressing - If gonadal products were displayed, but in smaller quantities and with more difficulty.

(3) Spent - If very little gonadal product was displayed.

(4) Non-ovulated - In the case of female white suckers, if it was apparent by the condition of the specimen that its gonads were full, but no eggs were displayed.

Weights were taken on every second or third fish, of each species, using a pan balance. Specimens were generally weighed to the nearest 10 g.

Scales were removed from every second or third fish for aging purposes. A fine tip, needle nose, tweezer was used for extraction of two to three scales from the left side just above the lateral line, and slightly in front of the dorsal fin.

Each fish was tagged with a "Floy" anchor tag ("spaghetti tag"). A "Dennison" Mark II tagging gun was used to anchor the tag into the dorsal musculature, anterior and slightly lateral to the dorsal fin on the left side.

At the Driedmeat Lake site, pike were tagged with florescent red tags, marked as Alberta Environment property, and displaying a six digit number prefixed by the letter "B" (series: B000001 - B000396). White sucker were tagged with a white tag marked as Alberta

Fish & Wildlife property, and displaying a five digit number prefixed by the letter "R" (series: R02210 - R02499).

At Steele Lake, all fish were tagged with the florescent red tags (series: B000397 - B001119).

After handling procedures, each fish was placed in a recovery tub (of the type described above) for 3 - 5 minutes, before being released.

5.1.1.2 Destructive sampling

Fish that were to be destructively sampled were first put through all live sampling procedures (except tagging) before being killed. Specimens were killed by a blow to the base of the skull.

The body cavity was cut open to confirm sexual condition. The males identifiable by the solid, non-granular, texture of the gonads (white in color if ripe and red when spent). The females having granular sac-like ovaries, containing eggs when ripe and light yellow (sucker) or light pink (pike) in color , when spent.

The cleithrum was also dissected out, in the case of the pike, for age confirmation purposes.

A total of 10 pike and 10 sucker were destructively sampled from the Driedmeat area. At Steele Lake, 30 pike and 5 sucker were killed. (Tables C.1 & C.2).

5.1.2 Aging

The cleithra removed from the pike were boiled in water, to remove remaining flesh, then allowed to dry before being aged. Aging of the cleithra proved difficult due to an excessive amount of lipid material within the bone. The cleithra were placed in an acetone solution (at room temperature) for 15 - 30 minutes, in an attempt to clear them (Mackay, 1982, person. comm.).

Most of the aging work done was by scale reading. Two to three scales from each sample were placed along an acetate slide. Acetone was then applied to the four corners of the slide, and a second acetate slide placed on top to flatten out the scales (the top slide being fused to the bottom by the acetone).

The prepared slides were then placed under a dissecting microscope and the scales aged by counting annulli. Due to the difficulty in distinguishing the actual first year annulus, the first annulus seen was generally counted as year 2. Annulli were then counted sequentially, out from this point. For the outermost circulli, a complete year was not given unless a definite trend toward annulus formation was observed, or if some distance between the last annulus and the outside border of the scale was present.

Further details of this procedure are provided by Tesch (1968).

5.1.3 Physical/chemical parameters

Temperature, conductivity, and dissolved oxygen were monitored at both the Driedmeat and Steele Lake locations.

Temperature and dissolved oxygen readings were acquired using a Yellow Springs Instruments (YSI) model 54A D.O. meter. The instrument was calibrated by adjusting the meter to saturation value for the appropriate temperature and atmospheric pressure of the site concerned. The probe was then placed in the water and allowed to acclimate by gentle agitation. Dissolved oxygen was read off the scale in mg/L. Temperature was read off the same scale in °C.

Conductivity was measured using a YSI model 33, S-C-T meter. Calibration was done using a standard 0.01 M KCl solution. Specific conductance was read off the scale in micromhos/cm.

5.1.4 Velocity readings

Two different instruments (Plate 1) were used for determination of water velocities:

(1) Price model AA current meter - This instrument is placed in the flow with the wheel facing into the current. The wheel holds a contact chamber which translates each revolution (or every fifth revolution) of the wheel into an electrical signal that is heard as a "tick" by the operator through a headset. (Further details are provided in W.M.M., 1967, pg. 122).

(2) Cushing model 611-P water current meter converter-

Plate 1 Instruments used in measurement of water velocities: Price model AA current meter (right); Cushing model 611-P water current meter converter (left).

The instrument consists of two separate parts. A camber shaped wading rod (approx. 20 cm long by 5 cm wide) is connected to a readout meter via a 15 m long cord. The rod is placed upright into the flow (so water passes smoothly over the cambered surface). The velocity is then read directly off the meter in ft/s. These readings were later converted to m/s.

Both meters were calibrated at known flume velocities in the T. Blench Hydraulics laboratory of the Department of Civil Engineering, University of Alberta. Conversion to m/s, for the Price meter, was found to be related to 0.67 times the number of wheel revs/s.

5.1.5 Head measurements

Head levels over each weir within the fishladder (at both Driedmeat and Steele Lakes) were recorded on a regular basis. The top of the fishladders were determined to run in a level plane, and therefore were utilized as the zero datum for all head measurments. A meter stick (graduated in mm) was used to establish the distance from the zero datum to:

(a) the water surface at the half way point within each bay.

(b) the top of each weir.

Subtraction of the former from the latter gave the head (Fig. 8).

5.2 Field Study

5.2.1 Driedmeat Lake

The Driedmeat lake stabilization weir is constructed of corrugated steel sheet piling. The weir was installed in 1974 by Alberta Environment, in order to stabilize lake levels and optimize recreation potential, (Melnychuk & Galatuik, 1973). The fishladder was incorporated into the structure during weir construction.

The step and pool fishladder is made of corrugated steel sheet piling, (Fig. 15). There are seven bays separated by eight weirs. The weirs are constructed of a series of 150 mm x 150 mm timber stop logs, piled on top of each other. The weirs run the entire width of the ladder, and are suppressed (no end contraction). Each bay is approximately 1.7 m long, 2.0 m wide (shortest width), and 2.2 m deep (water depth being dependent on weir height).

The logs are held in place by brackets welded to either side of the ladder. They are prevented from floating by placing wood wedges at either end of the top log. Stop logs can be removed or inserted as needed, in order to obtain the desired level of water moving across each weir.

The first weir controls the flow of water entering the ladder from the lake. Following weirs are arranged (by decreasing the number of logs) so that a steady successive head drop is achieved throughout the ladder. Generally, a 150 mm sill is desired. The Driedmeat ladder is designed to

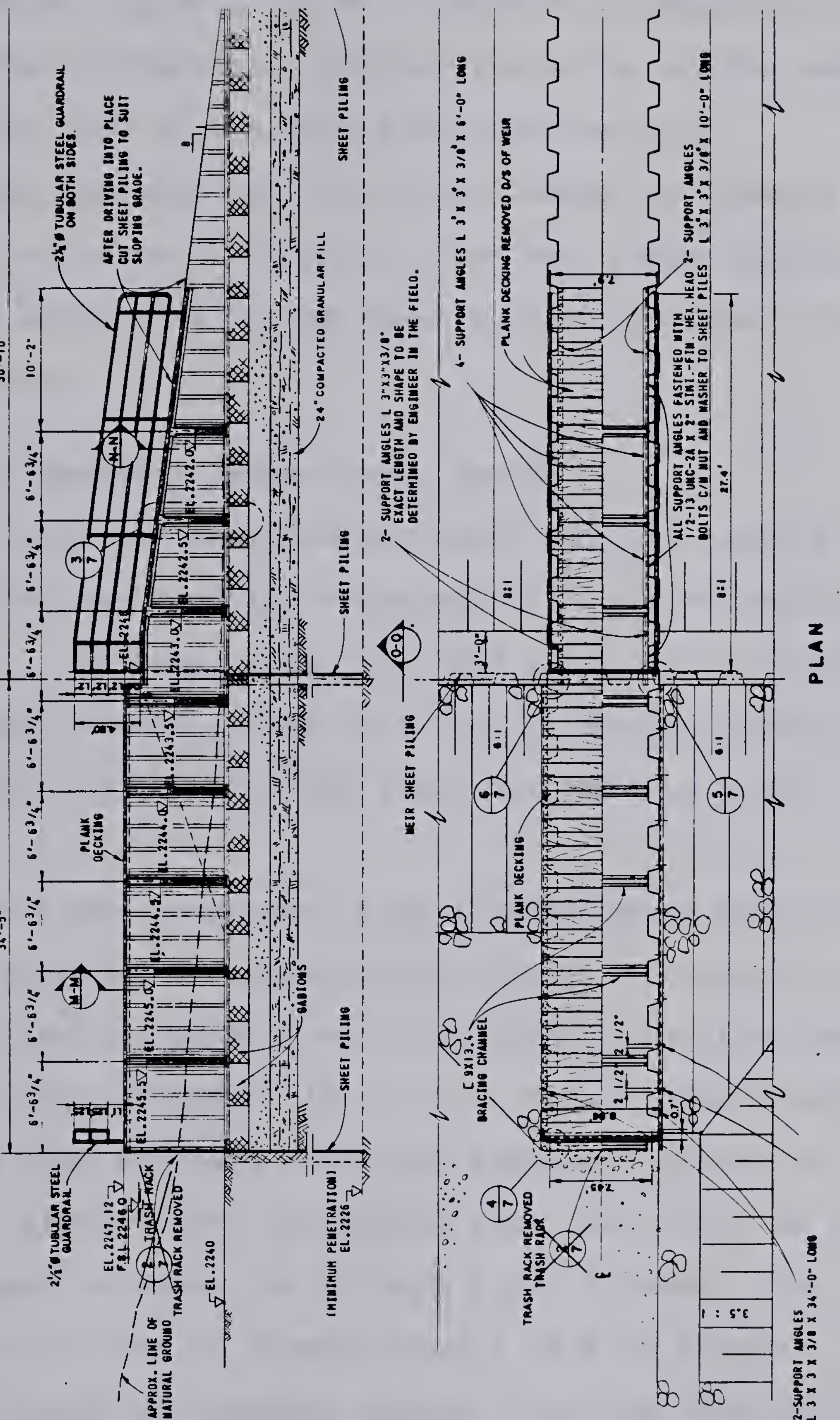


Fig. 15 Step & pool fishladder located at the Driedmeat Lake stabilization weir. Source: Planning Division, Alberta Environment.

accommodate up to a 1.2 m difference in headwater and tailwater elevations. The top elevation of the ladder is 30 cm above that of the main stabilization weir.

The upstream portion of the ladder is covered by a series of 50 mm x 300 mm x 2.7 m long timber planks. These planks are bolted to the sheet piling in order to deter vandalism.

5.2.1.1 Upstream ladder trap, design

A trap was designed and built for the capture of fish which had successfully negotiated the entire length of the ladder. The trap, (Fig. 16), was constructed of 25 mm x 100 mm timber planks. Vexar netting (a sturdy plastic mesh material) of 30 mm^2 mesh size, was used to cover the frame.

In order to prevent fish from escaping back downstream, (once they had entered into the trap), a series of one-way fingerlike projections were installed along the leading edge of the trap entrance, (Fig. 17). These fingers were cut and formed from standard wire coat hangers. Pieces of 20 mm inside diameter PVC (plumbing) pipe, cut to 10 mm widths, were used to space the fingers along a dowel. The wood dowel was 18 mm in diameter and 1.82 m in length. A 1.0 mm thick length of standard speaker wire was used to connect the top ends of the fingers to each other, and thereby prevent spreading. The fingers operated to allow fish to easily glide or swim into the trap, however, movement was

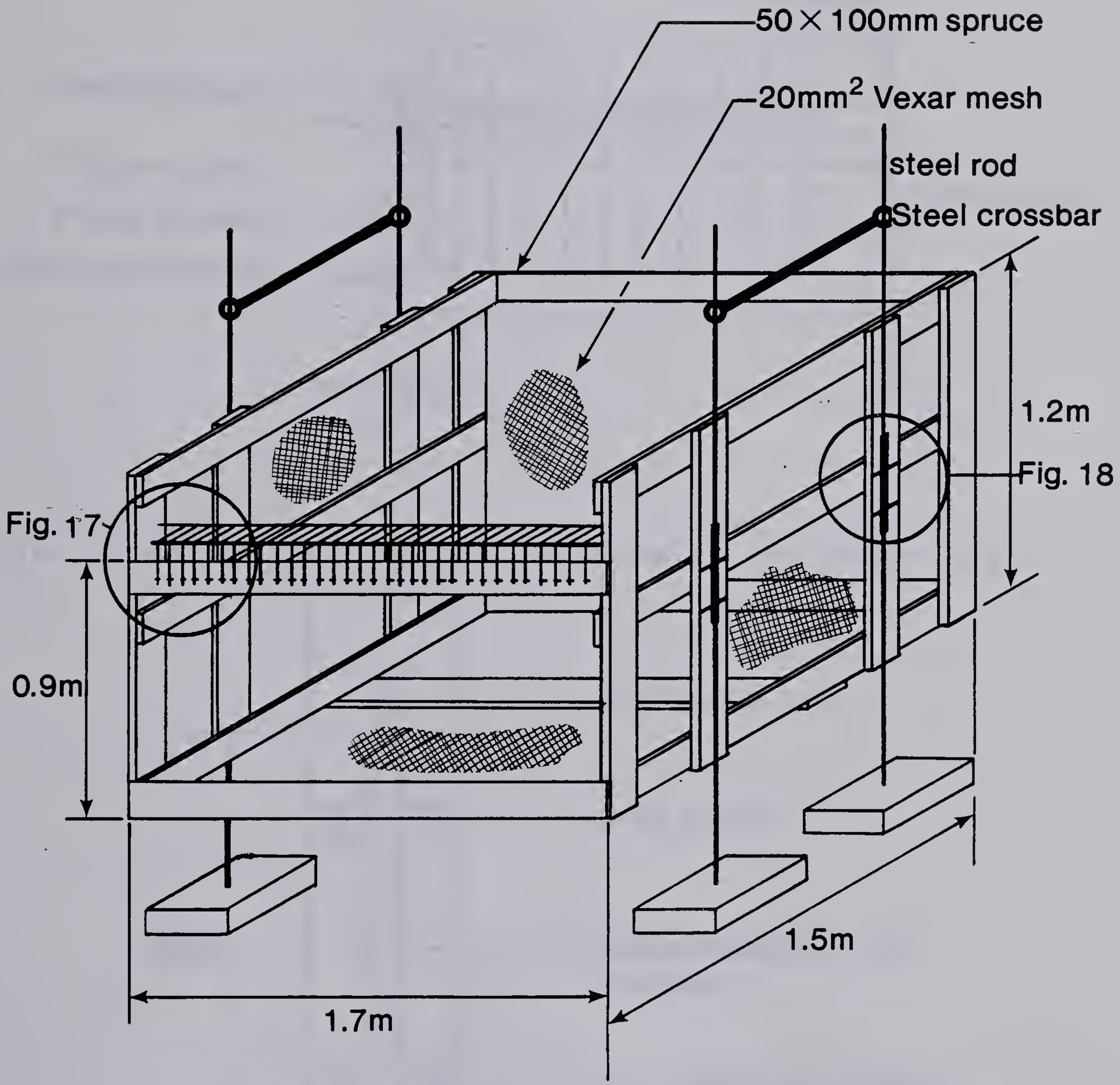


Fig. 16 Ladder trap used for fish capture at the Driedmeat & Steele lake fishladders

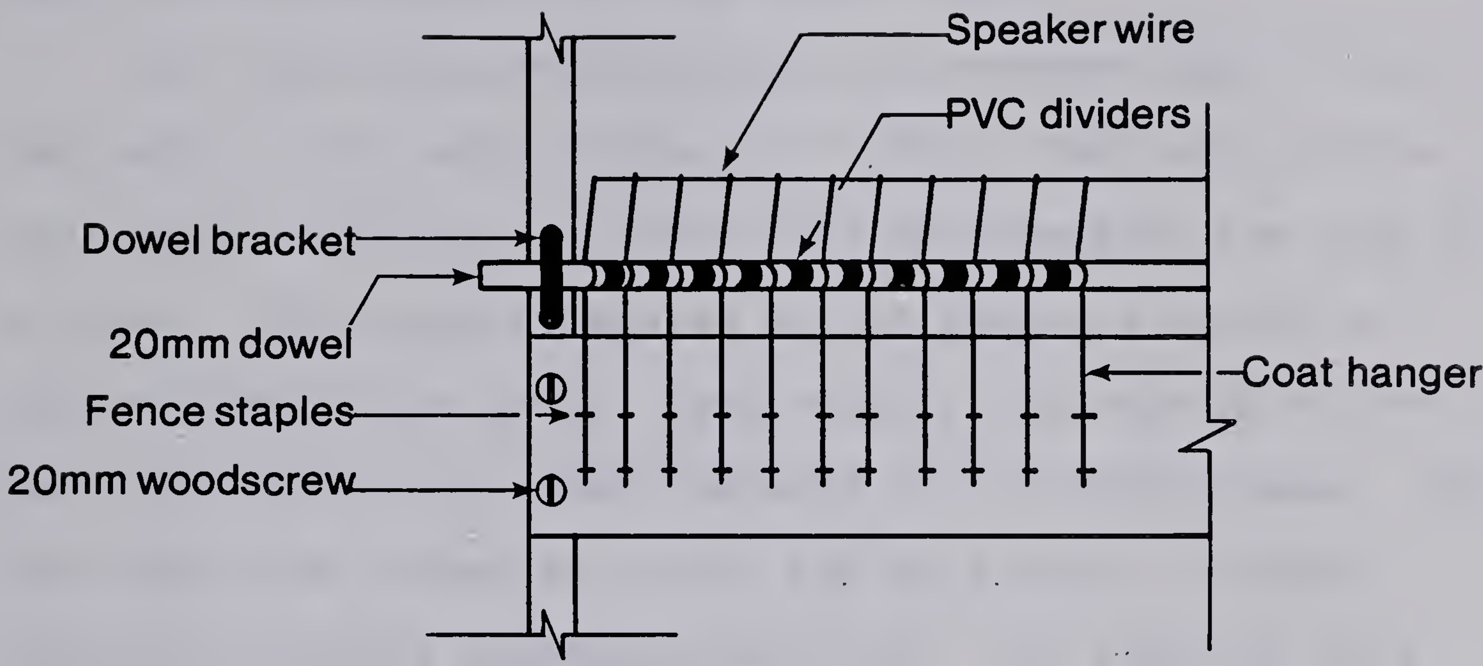


Fig. 17 Detail of finger-projections of the ladder trap.

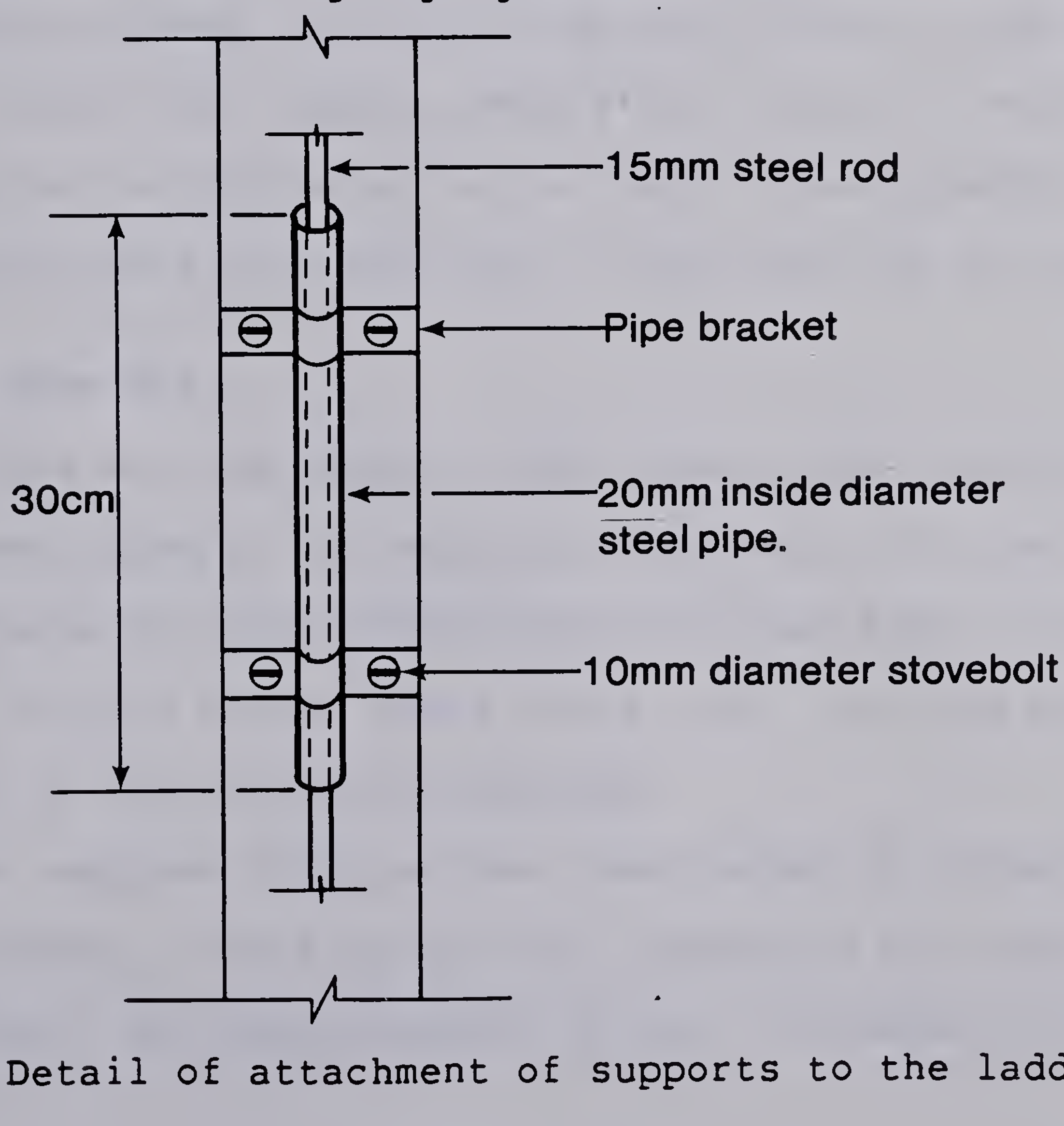


Fig. 18 Detail of attachment of supports to the ladder trap.

deterred in the opposite direction. Also, because the upper ends of the fingers were not fixed to the side of the trap, they could be adjusted to any water level.

The trap was placed against the upstream edge of the top weir in the ladder (Figs. 19 & 20). The level of the trap within the bay was controlled by attaching the trap to a stand. The stand consisted of two supports placed on either side of the trap. Each support was made up of two 15 mm thick steel rods, each fastened to a concrete base. The two rods were connected at the top by a steel crossbar, which had eyelets welded to each end. The supports were connected to the trap by running the rods through four 30 cm long pieces of 20 mm inside diameter steel pipe, (Fig. 18). This stand allowed the trap to be positioned in the water column so that the leading edge of the fingers could be placed level with the top of the weir. Once placed, adjusting screws were used to fix the position of the trap.

5.2.1.2 Fyke net

A fyke net was placed in the Battle River approximately 100 m downstream of the stabilization weir. The net incorporated two wings which stretched out from a centrally located trap to either shore, (Fig. 21). In this way, early movement of fish could be detected.

The complete fyke net was constructed of 25 mm^2 mesh, vexar netting. The trap portion, supported by a series of steel hoops, was approximately 50 cm. in diameter and about

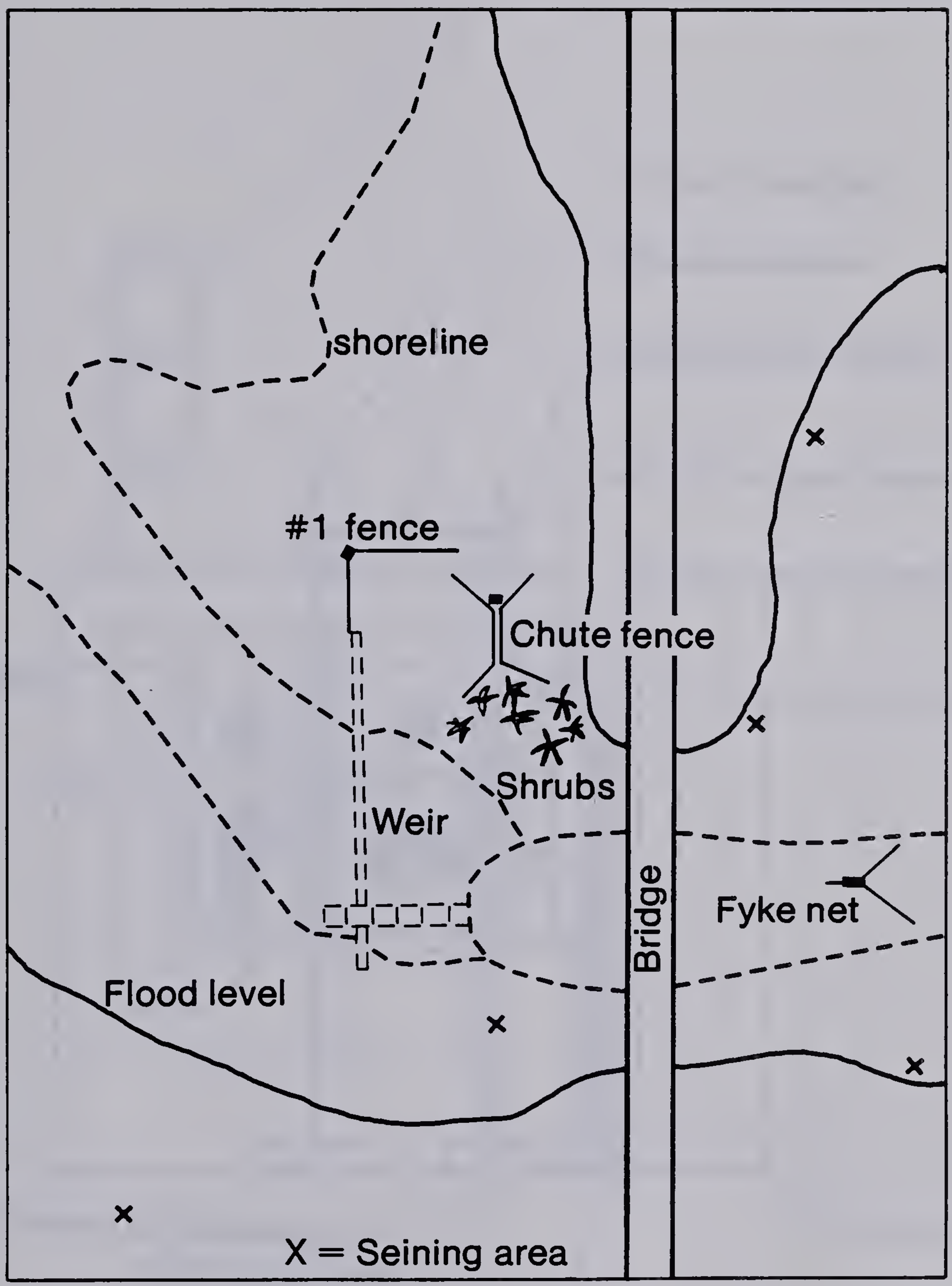


Fig. 19 Diagramatic representation of the Driedmeat Lake stabilization weir study site.

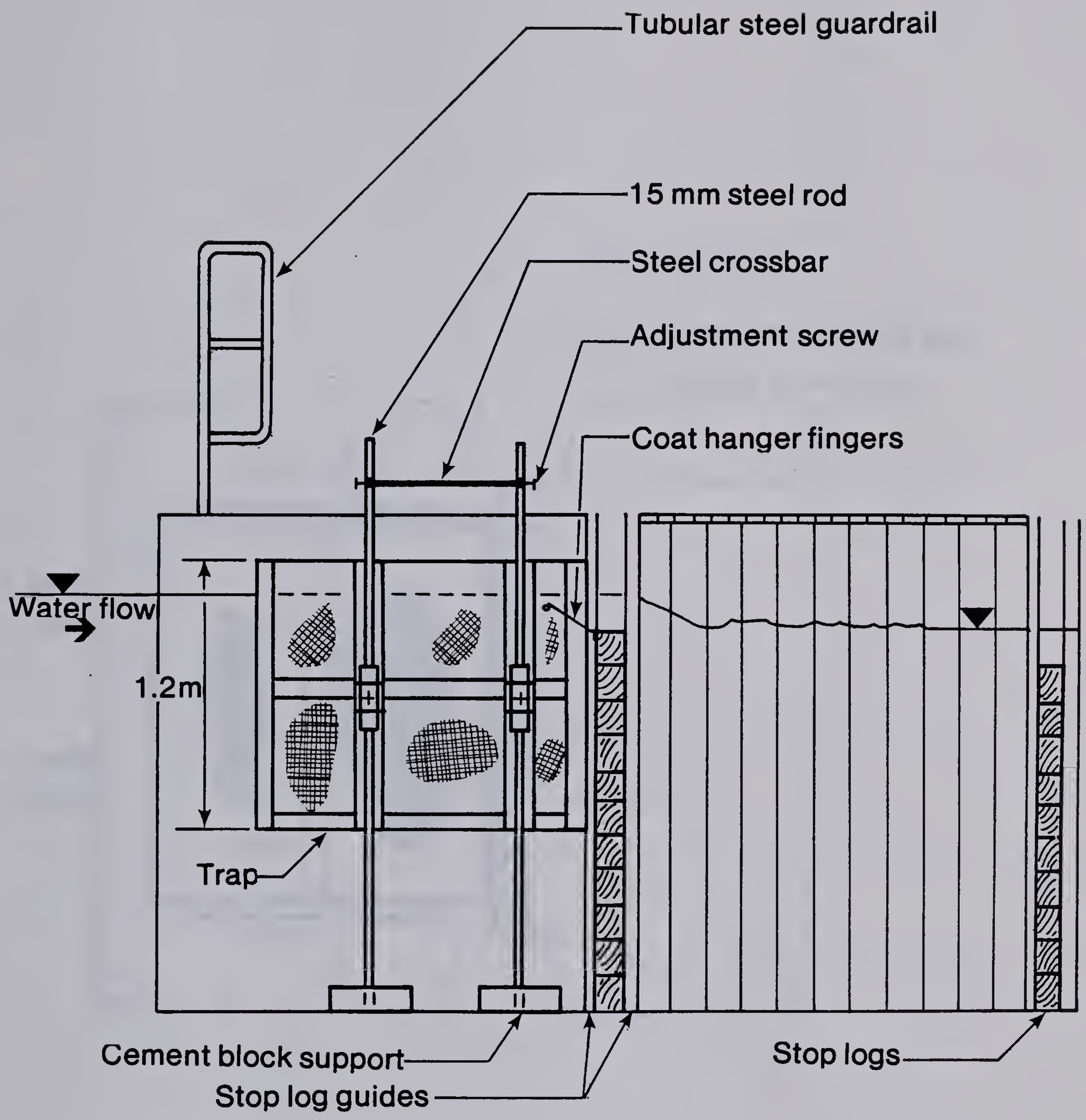


Fig. 20 Placement of the ladder trap in Driedmeat Lake fishladder, cross section.

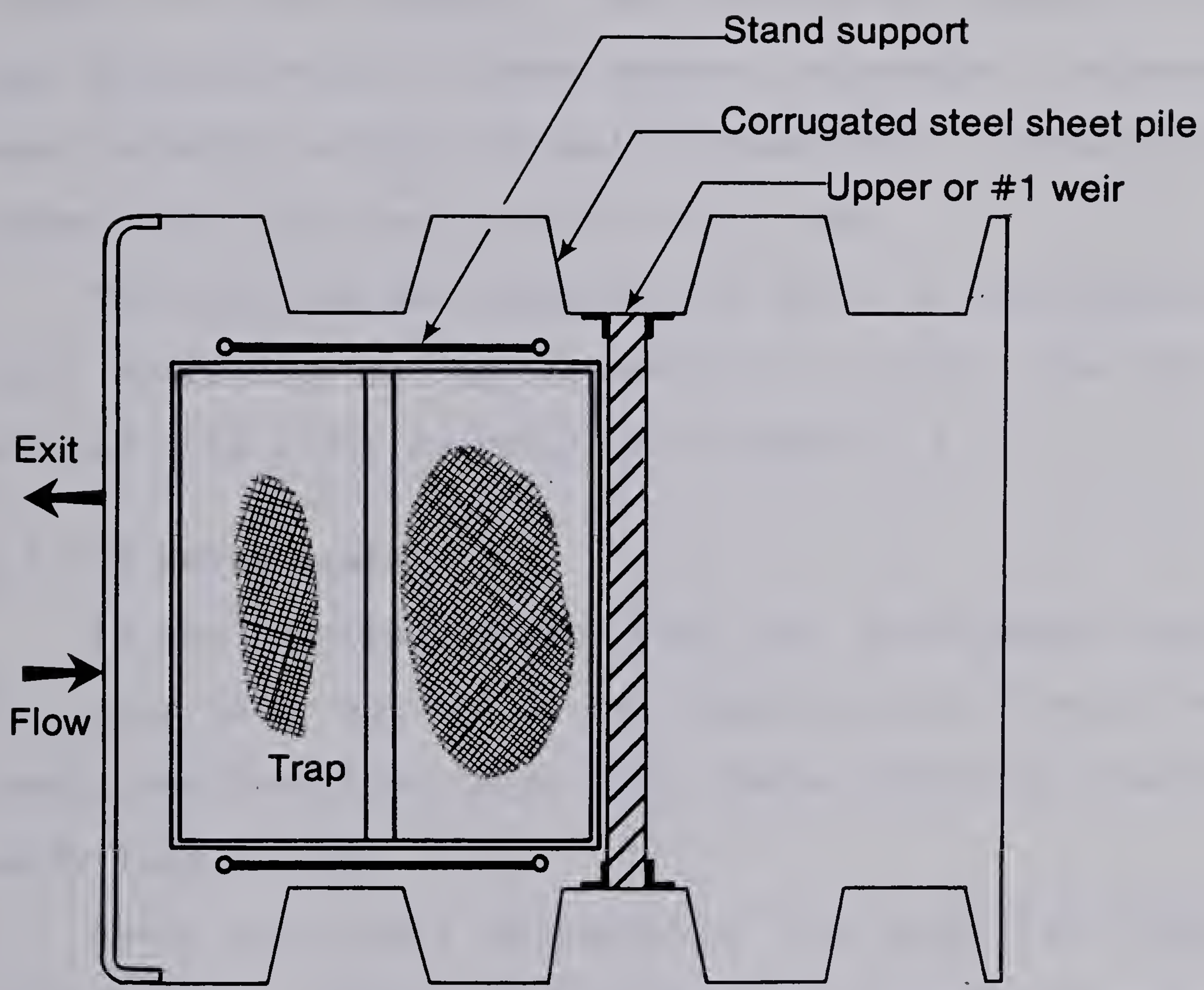


Fig. 21 Placement of the ladder trap in Driedmeat Lake fishladder, plan view.

2.5 m in length, (Fig. 22). The trap end wings were held in place within the stream by attaching them to a series of 6 mm thick T-rails. These T-rails, 3.0 m in length, were embedded in the stream bottom about 0.5 to 1.0 m, and protruded about 0.2 to 0.5 m above the water surface.

As spring thaw progressed, rising water levels and ice breakup occurred rapidly. The fyke net was unable to handle such conditions and it soon became inoperable. Increases in water velocity within the main stream made it possible to recover only the trap portion of the net.

The fyke net was installed on April 18 and operated until April 23. During the monitoring period, the trap was checked once a day as outlined in Table C.3.

5.2.1.3 Seine hauls

In conjunction with the fyke net, seine hauls using a 10 m long seine net (of 25 mm^2 meshing) were done at several downstream locations (Fig. 21). Seine locations changed as water levels rose.

Seine hauls were conducted as time permitted (generally twice a day). Table C.5 outlines the schedule of seine hauls performed.

5.2.1.4 The fish ladder

Upon arrival at the site, icecover conditions still existed in and around the fishway. While preparing the ladder for monitoring and installation of the upstream trap, it was discovered that 45 of the 60-65 stop logs necessary

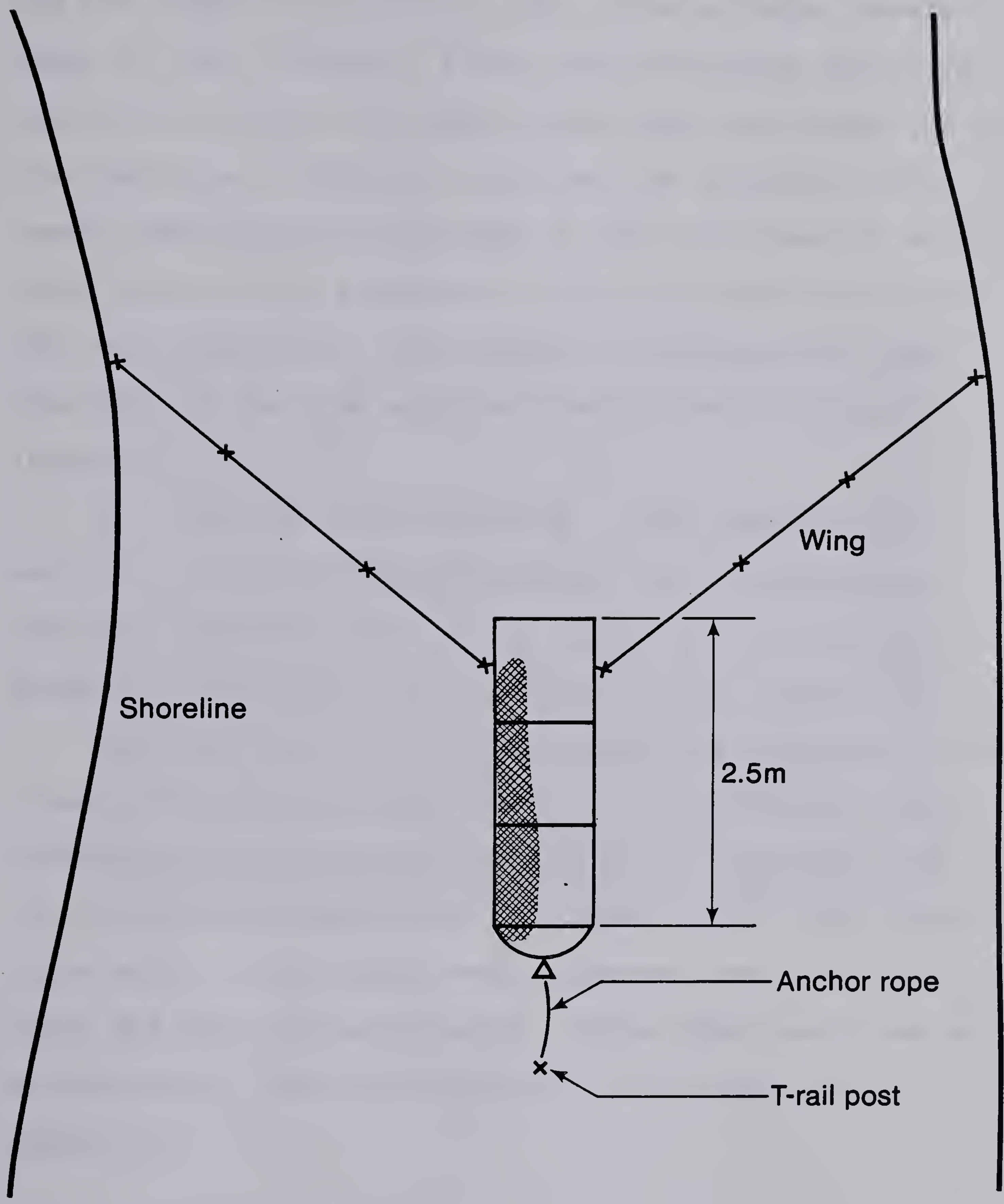


Fig. 22 Detail of the fyke net trap used at both Driedmeat and Steele Lakes.

to operate the ladder were missing. Replacement stop logs and the ladder trap were put into place as water levels began to rise. However, flood conditions soon prevailed putting the top of the ladder under water and rendering it non-functional. Table C.7 outlines the observed water levels upstream and downstream of the stabilization weir (note that the top elevation of the fishladder occurs at 685.100 m geodetic). The ladder was submerged for the remainder of the time spent at the Driedmeat location, (Plate 2).

The trap was installed April 17 and operated until April 23. It was generally checked three times daily; morning, afternoon and evening. Table C.4 outlines the schedule followed for the operation of the ladder trap.

The stop log weirs in the ladder were arranged to allow a mean velocity of 0.6 m/s. over top of each weir. This corresponded to a mean head of 175 mm at each weir. No velocities were measured in the nappe itself. The lower three weirs of the ladder were submerged under the tail water and were not manipulated. These flow conditions were maintained for the entire period that the trap was in operation.

5.2.1.5 Counting fences

Due to the inoperative condition of the fishladder, two counting fences were constructed on the north shore area of the Driedmeat weir site (Plate 3).

Plate 2 Driedmeat fishladder under flood water.

Plate 3 Placement of #1 counting fence (left) and chute fence (right) on the north shore area of the Driedmeat weir site.

The first fence consisted of two 15 m long wings converging on a centrally located trap (Fig. 23). The wings were constructed of steel T-rail fence posts and 50 mm^2 mesh "chicken wire" (light galvanized wire netting of hexagonal mesh). The posts were placed at 1.0 m intervals for support against detritus build-up. The trap (Fig. 25) consisted of a 50 mm x 100 mm timber frame. The frame was covered with 25 mm^2 mesh vexar netting. The entrance to the trap was funnel shaped, allowing fish to easily move into the trap, but deterring escape.

The second fence was located closer to shore. It consisted of two 5.0 m long wings converging on a 5.0 m long "venturi" style chute (Fig. 24). This chute in turn diverged into two 5.0 m long plywood wings at its upstream end. These plywood wings were used to funnel water down through the chute.

A trap was also located at the upstream mouth of the chute. This trap was of the same style as that shown in Fig. 25. The dimensions of the trap were; 0.9 m wide, 0.9 m long and 0.6 m deep.

The downstream wings were built of 10 mm rebar steel pieces supporting 25 mm^2 mesh chicken wire. The chute and upstream fence consisted of 1.0 m plywood sections supported by 50 mm x 100 mm wood struts.

The first fence was installed on May 2 and operated until May 14. It was checked twice daily (morning and evening) depending on fish numbers.

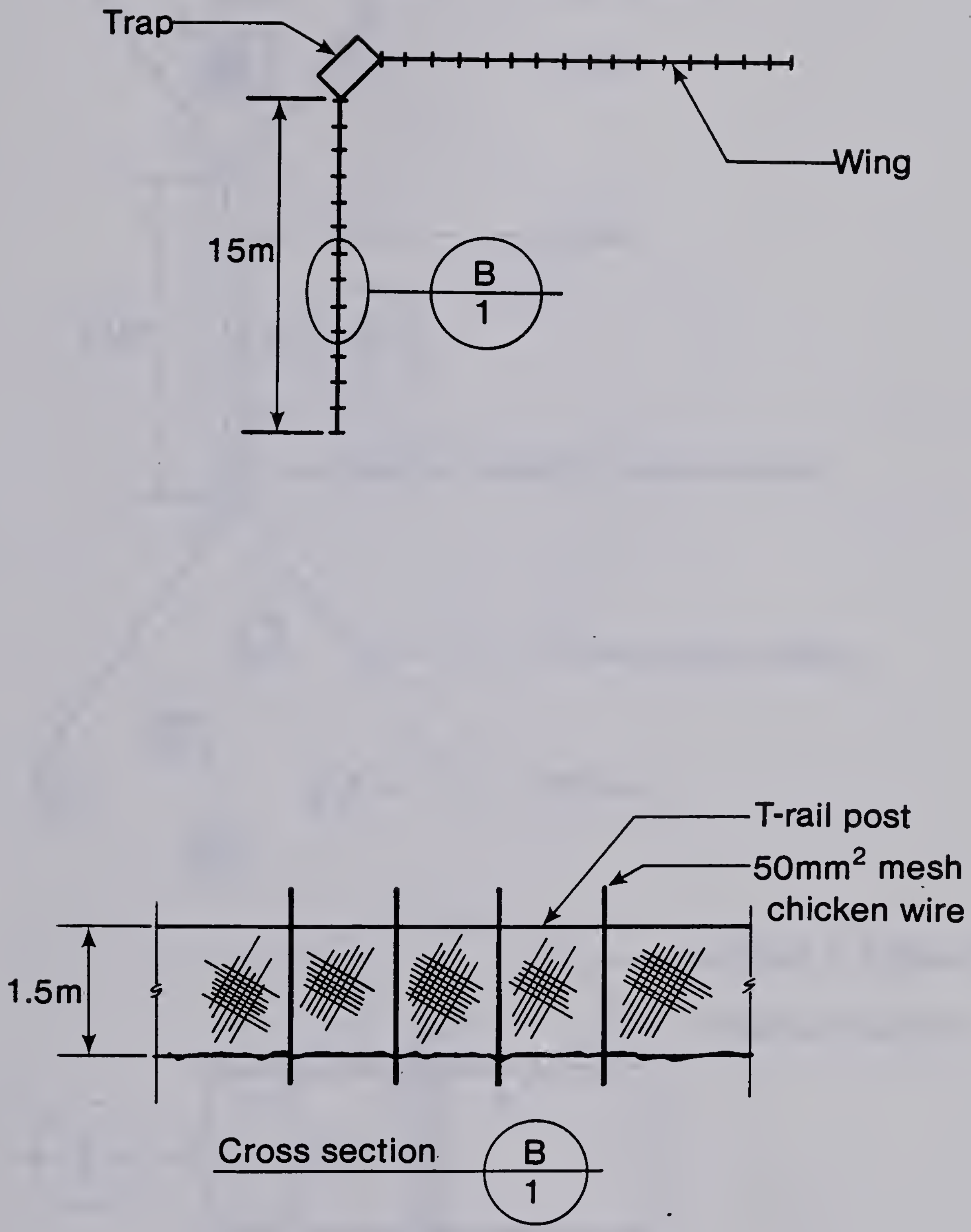


Fig. 23 Detail of the #1 counting fence at the Driedmeat weir site.

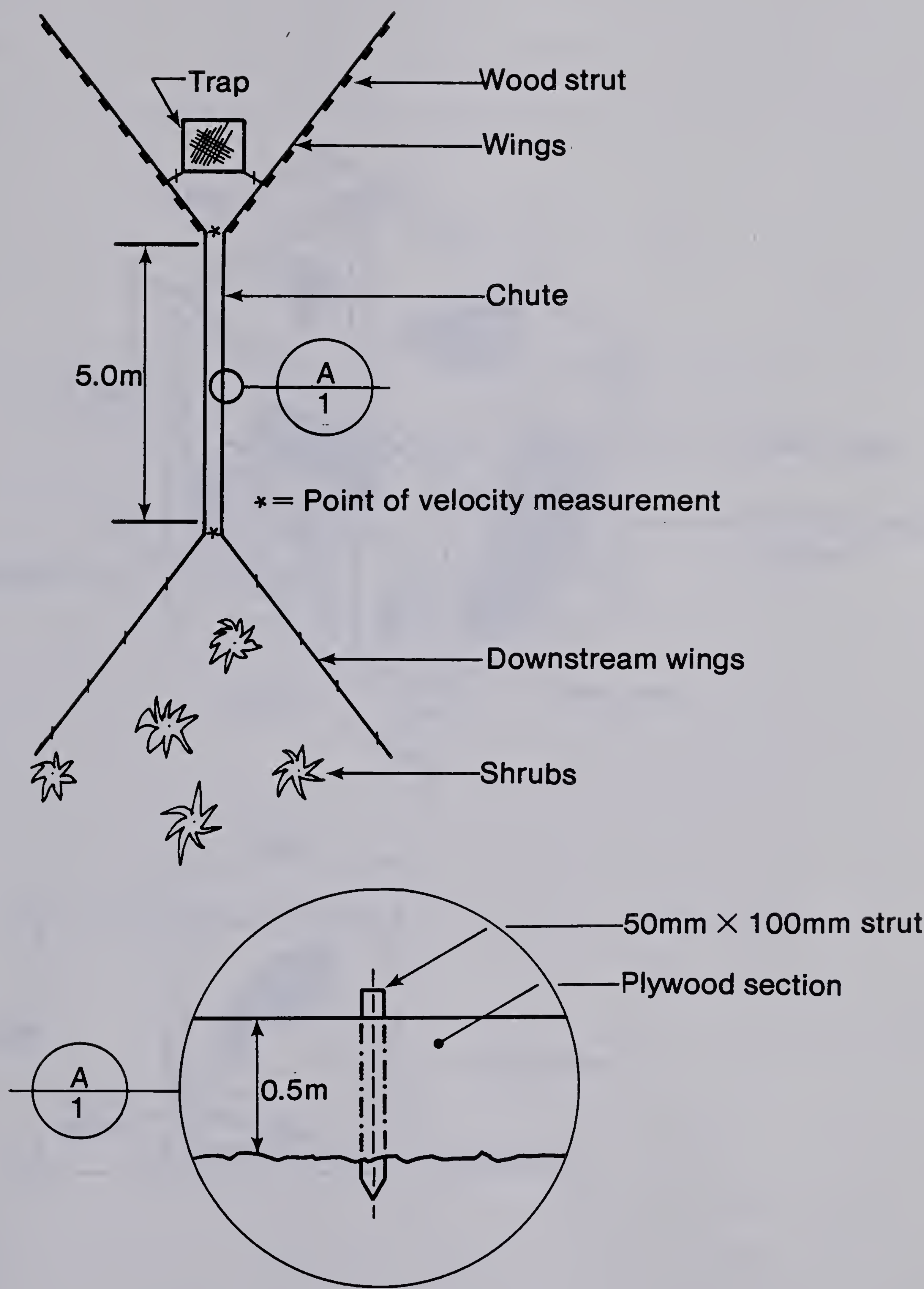


Fig. 24 Detail of the chute fence at the Driedmeat weir site.

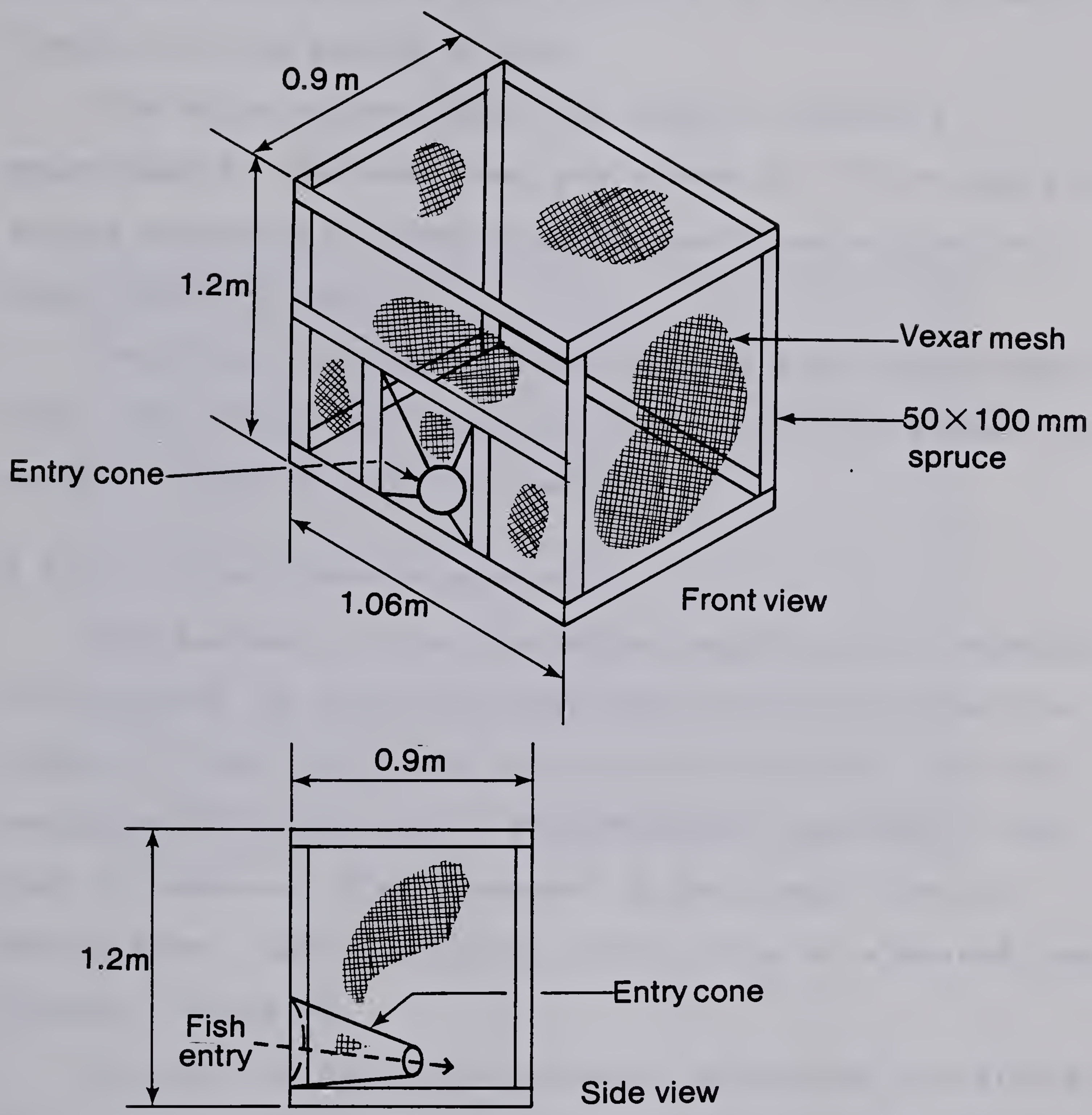


Fig. 25 Detail of the trap used in conjunction with the #1 counting fence.

The chute fence was installed on May 11 and operated until May 14. It was checked at the same times as the #1 counting fence. The width of the plywood chute was set at 25 cm, and maintained a mean velocity of 0.8 m/s through its length (for the period in use).

The Price current meter was used for velocity measurements. The wheel was positioned 20 - 30 mm above the bottom substrate at three separate positions within the chute (see Fig. 24).

Two "overnight" checks were done on both fence traps at 2100, 2400, 0300, and 0600, in order to try and assess the movement times of the fish species.

5.2.1.6 Silver Creek stream work

The flooding of the fishladder required that temporary alternatives for measuring pike and sucker performance be found. It was discovered that a pike and sucker run was occurring on Silver Creek (SW4-20-46-W4) southwest of the town of Camrose. Fish proceeded up the creek from the Battle River, until halted by outfall from an elevated road culvert, (Plate 4).

In order to assess the swimming ability of the fish as they moved up the creek, it was necessary to direct their movement through a controlled "venturi" like chute, which led the fish into a trap located at its upstream end, (Figs. 25 & 26). The dimensions of the trap (of the same style as in Fig. 25) were 0.9 m wide, 0.9 m long, and 0.8 m high.

Plate 4 The elevated culvert at Silver Creek which obstructed fish passage.

This arrangement ensured that all fish captured had navigated the chute water velocities.

Initially a smaller chute (61 cm in length) was installed on May 4 and operated until May 8. This was then replaced by a 2.5 m long chute, which was monitored until May 11. This "venturi" system was set up in a riffle area in the stream, changes in the width between the two wings of the chute resulted in a speeding up or slowing down of the flow.

The velocities through each chute were determined with the Price current meter. The wheel was positioned 20 - 30 mm above the gravel substrate, at three different positions within the chute (see Figs. 26 & 27).

The various chute settings used, together with their corresponding velocities, are outlined in Table C.8.

5.2.1.7 Gwynne road washout

Due to the flood level conditions of the Battle River at the time of the study, several secondary roads became impassable as a result of washouts. Such a washout occurred immediately south of the town of Gwynne (SE26-22-45-W4) approximately 30 km west of Camrose. This washout provided a second observation site for fish movement.

Flood waters from a bordering farm field were passing over a gravel road and down into another field on the opposite side. The water then passed from this field into the Battle River (Fig. 28). Pike and white sucker were

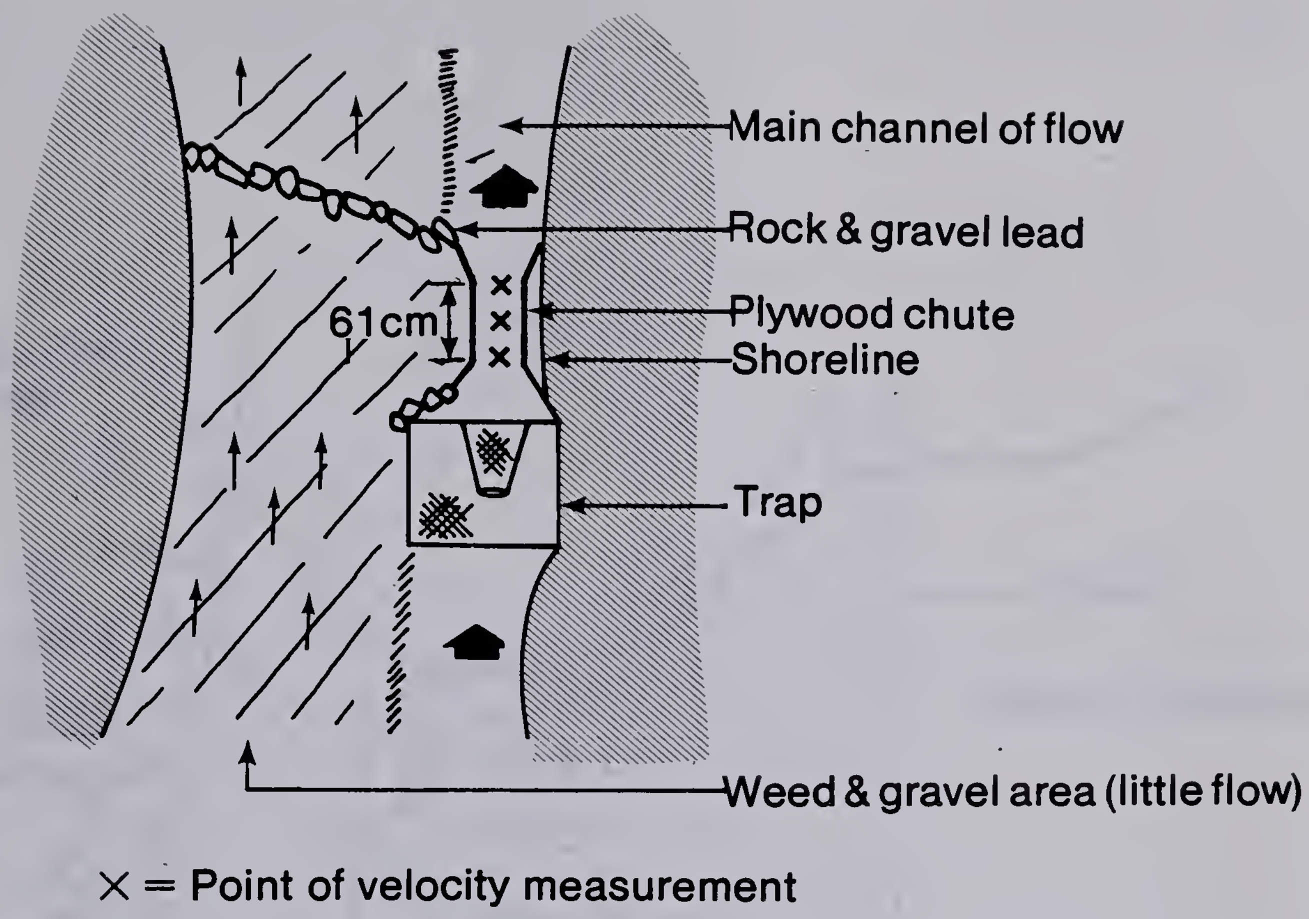


Fig. 26 Detail of 61 cm long chute used at Silver Creek.

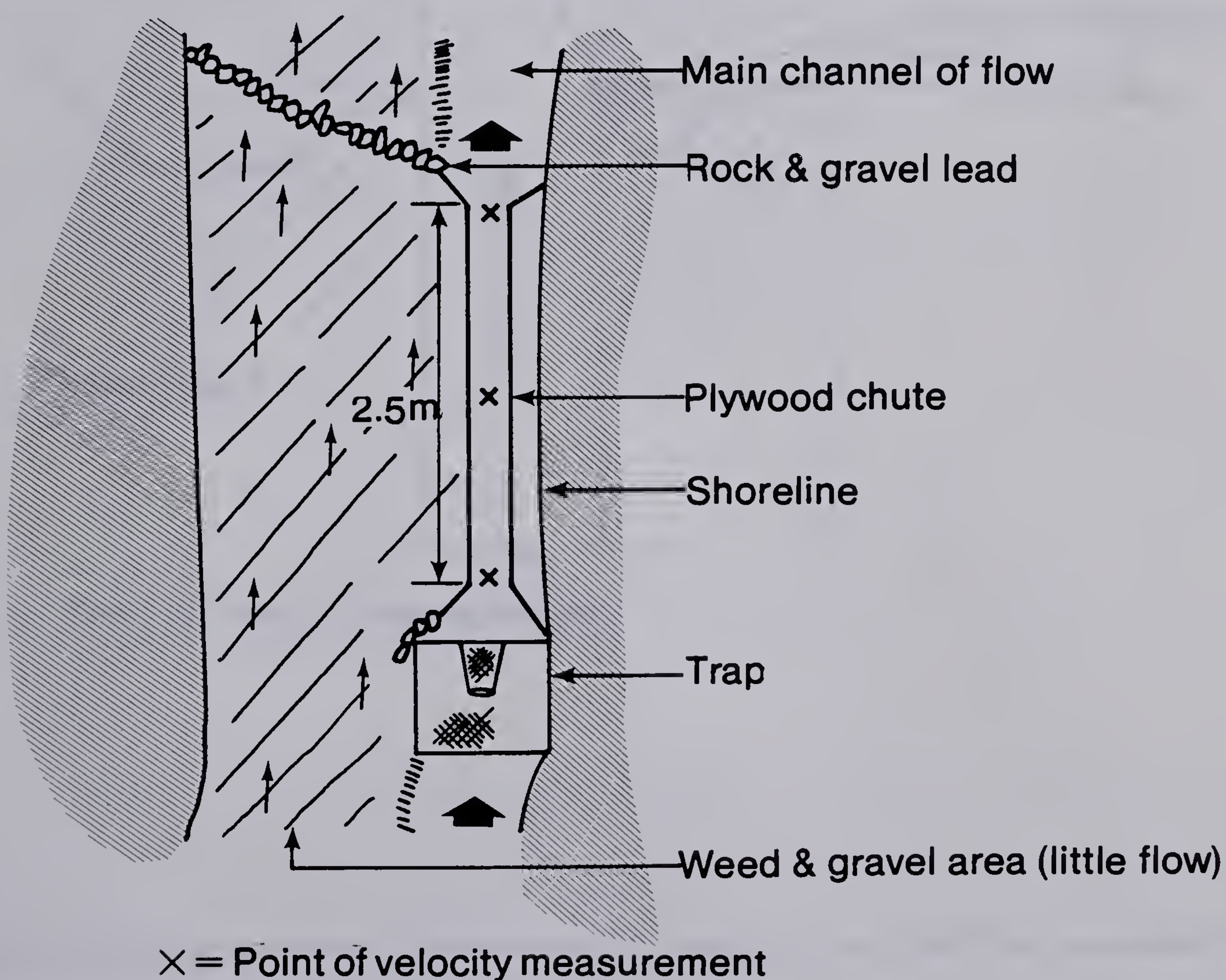
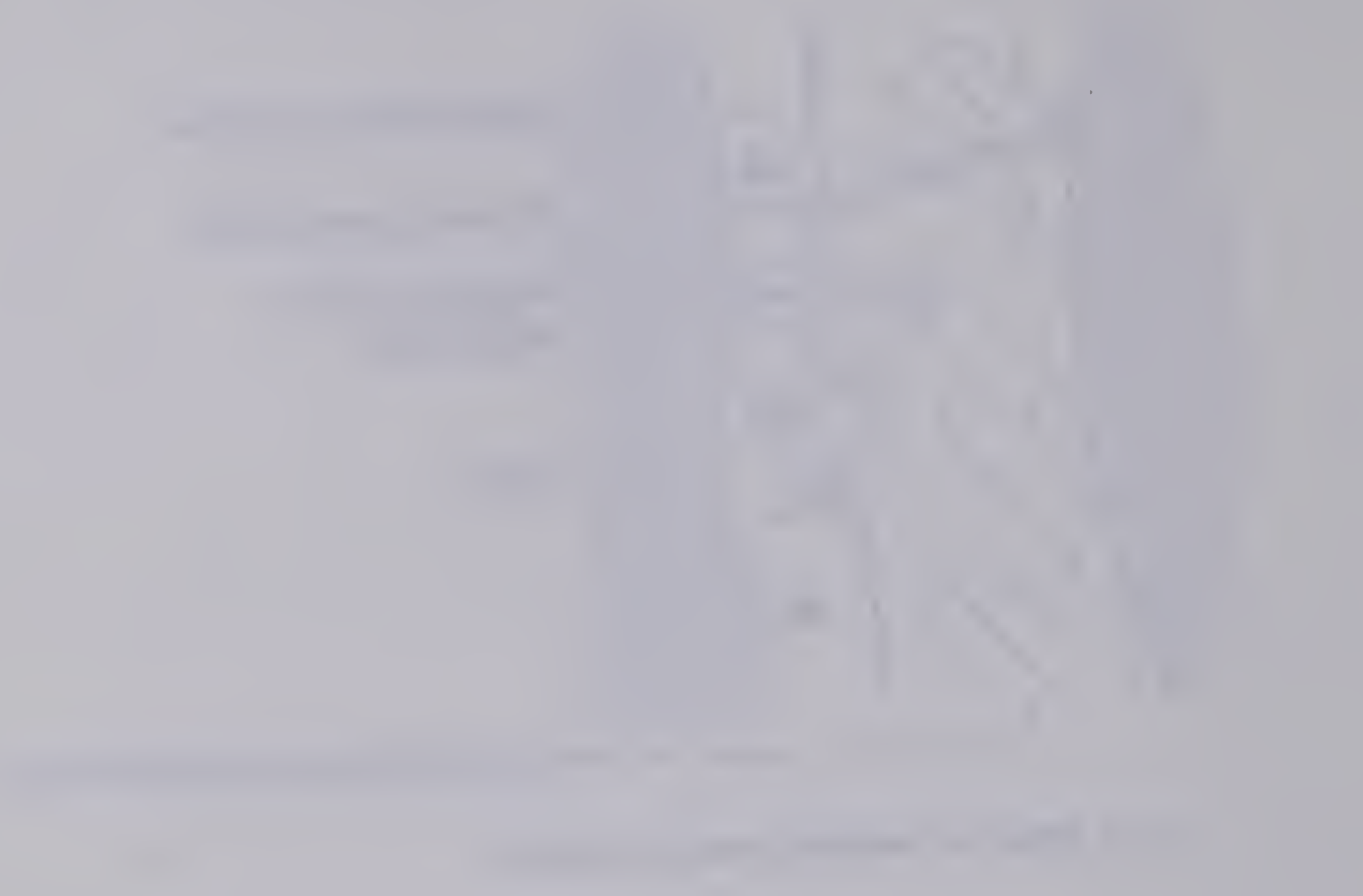


Fig. 27 Detail of 2.5 m long chute used at Silver Creek.



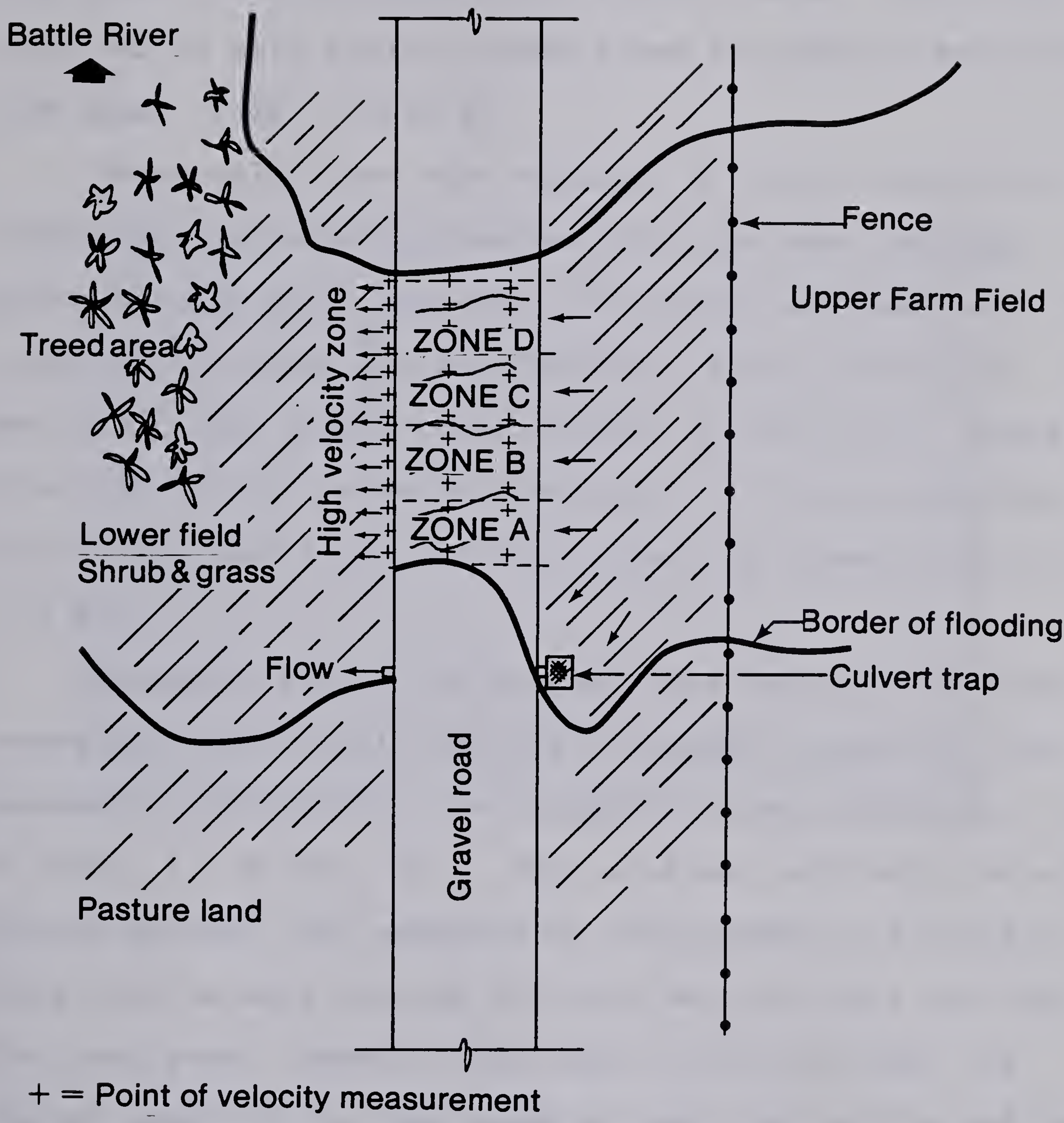


Fig. 28 Diagramatic representation of the Gwynne washout observation site.

moving from the river up into the lower field and then across the road into the upper field.

The incline created by the ditch between the road and the lower field produced swift flowing water. Migrating fish had to swim against these flows in order to move into the upper field, (Plate 5).

Water velocities were measured at several points in both the high velocity zone and the flow over the road. The Price current meter was used. The wheel was positioned as close to the substrate as possible (usually within 15 - 20 mm) due to the weedy, uneven nature of the ditch. Flows in the high velocity zone averaged 2.0 m/s, while velocities across the road itself were considerably slower at 0.2 to 1.0 m/s.

Movements across the washout were monitored on three occasions (April 30 to May 2). In order to observe fish movement consistently, the flooded area was staked out into 4 zones, A - D (Fig. 28). Each zone was monitored for a 30 minute period, with emphasis on the success or failure of each fish to move through the high velocity zone and onto the road area. Several individual fish were timed (by manual counting) as they moved up over the incline and onto the road.

Table C.10 outlines each observation period as well as the mean velocities at each zone. Due to time constraints, only confirmatory velocity measurements were taken during period #3. These were found to be similar to those of the

Plate 5 Incline between the road and lower field (high velocity zone) at the Gwynne washout site.

previous period.

5.2.1.8 Gwynnee culvert

While monitoring movement over the above washout, it was noticed that a culvert was positioned under the road, providing drainage from the upper field to the lower one (Fig. 28). The culvert measured 12.4 m in length with a 78 cm. diameter.

A trap (of the same style as in Fig. 25) was placed at the upstream end of the culvert. The trap measured 0.9 m in width, 0.8 m in length, and 0.9 m in height.

The culvert trap was installed on May 6 and checked twice daily until May 8, when it was removed due to receding waters and to allow unimpeded movement of fish in the upper field back down to the Battle River.

Velocities were taken prior to each set, at the upper end of the culvert (just as the water entered), and at its bottom end (just as the water left the culvert). The Price current meter was used; the wheel was positioned at the centre of the culvert, between 50 - 75 mm off the bottom. This was done on the assumption that the fish would tend to move along the bottom.

Table C.12 outlines each set of the culvert trap along with corresponding mean water levels and velocities. Water levels were determined by measurements from the top of the culvert to the water surface at the upper and lower ends, and the mean calculated.

5.2.1.9 Physical/chemical measurements

Water temperature, conductivity and dissolved oxygen readings were taken immediately upstream of the fishladder and approximately 10 m downstream of the ladder entrance. A record of geodetic water levels was also maintained upstream and downstream of the stabilization weir (Table C.7).

Temperature, dissolved oxygen, and conductivity were also measured during monitoring activities at the Silver Creek site.

5.2.2 Steele Lake

The Steele Lake stabilization weir is constructed of sheet steel. The weir was installed in 1974 by Alberta Environment. The fishladder was incorporated into the structure at that time.

The step and pool fishladder is made of corrugated sheet steel piling (Fig. 29). There are six bays separated by seven weirs. The weirs are constructed of sheet steel and are fixed in position. The weirs run the entire width of the ladder, and are suppressed. Each weir, as well, has stop log brackets placed on top, at either end. These brackets are of sufficient height to allow two to three 100 mm x 100 mm stop logs to be placed on top. Each bay is about 1.8 m wide, 2.0 m long, and 1.5 m in depth.

Water flows (velocities) can be manipulated in the same manner as the Driedmeat ladder, through manipulation of the stop logs. However, the range of manipulations attainable

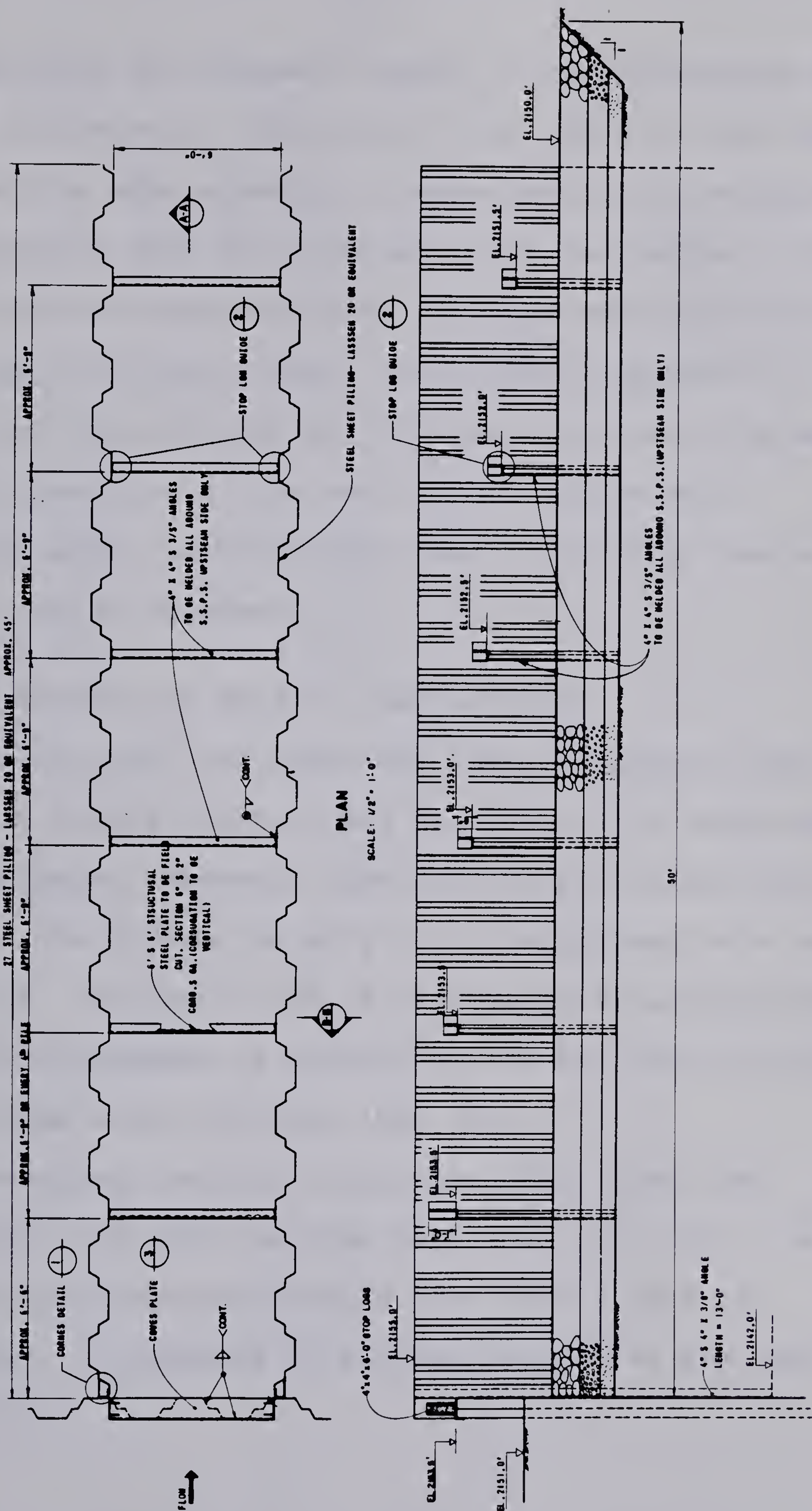


Fig. 29 Step & pool fishladder at Steele Lake stabilization weir. Source: Planning Division of Alberta Environment.

is restricted by the small number of stop logs that can be placed on the weir. The first three weirs in the ladder are fixed at the same elevation, approximately 46 cm below the top elevation (657.012 m geodetic) of the ladder. Thus, the ladder becomes non-functional once upstream elevations drop below the first weir crest (or 656.554 m geodetic). As well, the top elevation of the ladder is about the same as the top elevation of the main stabilization weir.

The ladder is completely open on the top, having no planking as at Driedmeat.

5.2.2.1 Downstream fyke net and seining

The fyke net (as described under Driedmeat Lake) was placed in French creek on May 18, about 15 m downstream of the fishladder entrance. The net did not extend the full width of the stream, as only 2.0 m long wings were used, (Fig. 30). Due to a lack of fish capture success combined with the entrapment of muskrat in the the trap, the fyke net was removed after two days (May 20).

Downstream seining (using the seine described previously) was done as time permitted (Fig. 30). No seining was undertaken during the first 5 days of operation. A schedule of seining procedures are outlined in Table C.14.

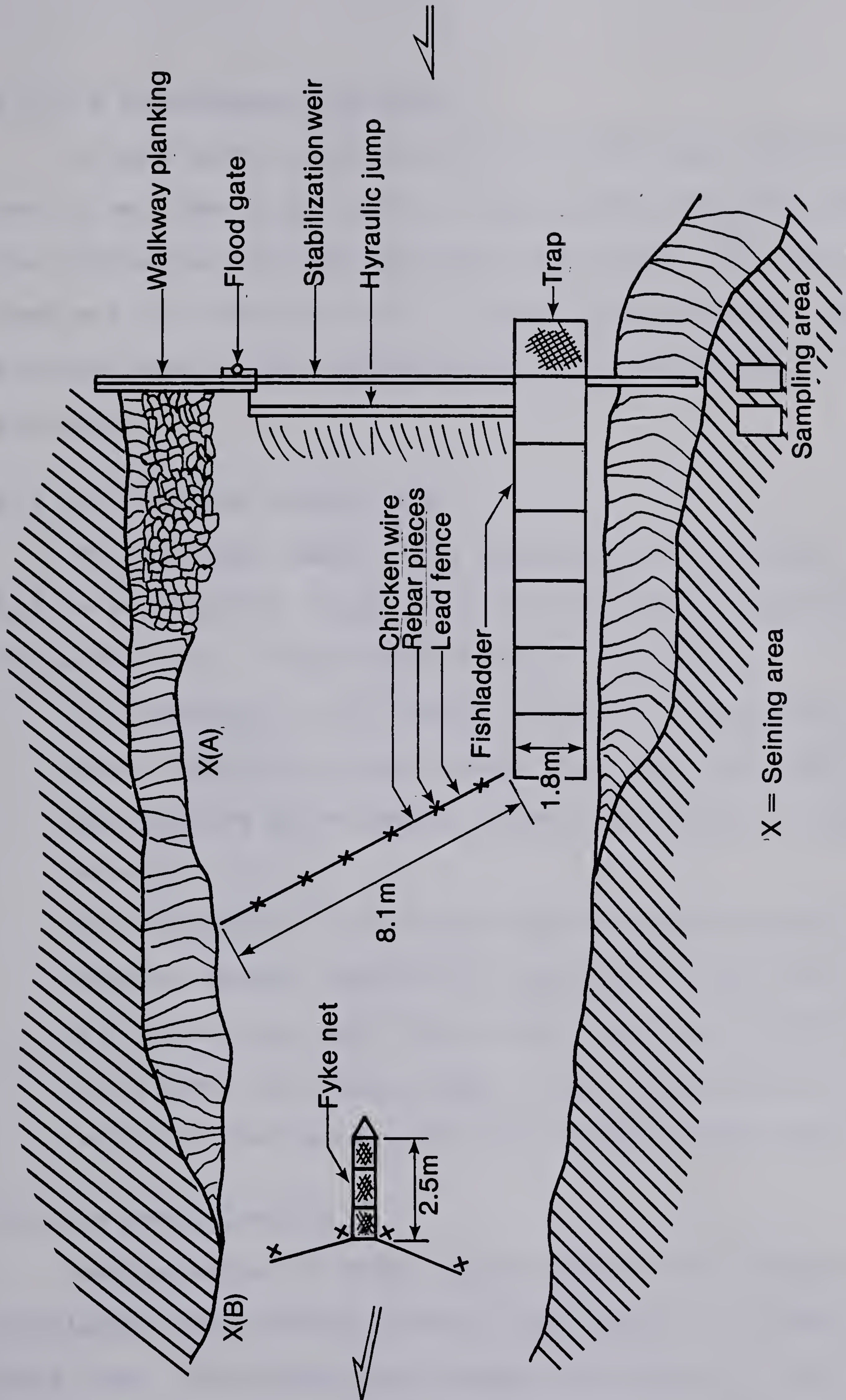


Fig. 30 Diagramatic representation of the Steele Lake study site.

5.2.2.2 Downstream lead fence

A lead fence, constructed of 25 mm^2 mesh chicken wire and 15 mm rebar steel pieces, was placed diagonally between the fishladder entrance and the north shore (Fig. 30). This lead was not installed until 5 days after arrival. Its function was to lead approaching fish to the ladder entrance.

5.2.2.3 Upstream ladder trap

The upstream ladder trap described for Driedmeat Lake had to be modified slightly to fit the Steele Lake ladder (Figs 31 & 32). These modifications included:

(1) deletion of the support stand. The upstream water depth was fairly shallow and thus the trap could be manipulated quite easily without the use of a support stand.

(2) lowering of the finger trap entrance due to the shallow depths immediately upstream of the weir.

(3) fixing the back end of the trap to a T-rail post such that the leading edge of the fingers were level with and abutted to the top of the upstream weir.

5.2.2.4 Manipulations

Manipulation of flows (water velocities) through the fishladder were accomplished by the removal or insertion of stop logs. The essentially equal elevations of the top of the ladder and main stabilization weir negated the possibility of a consistant head drop in the upper end of

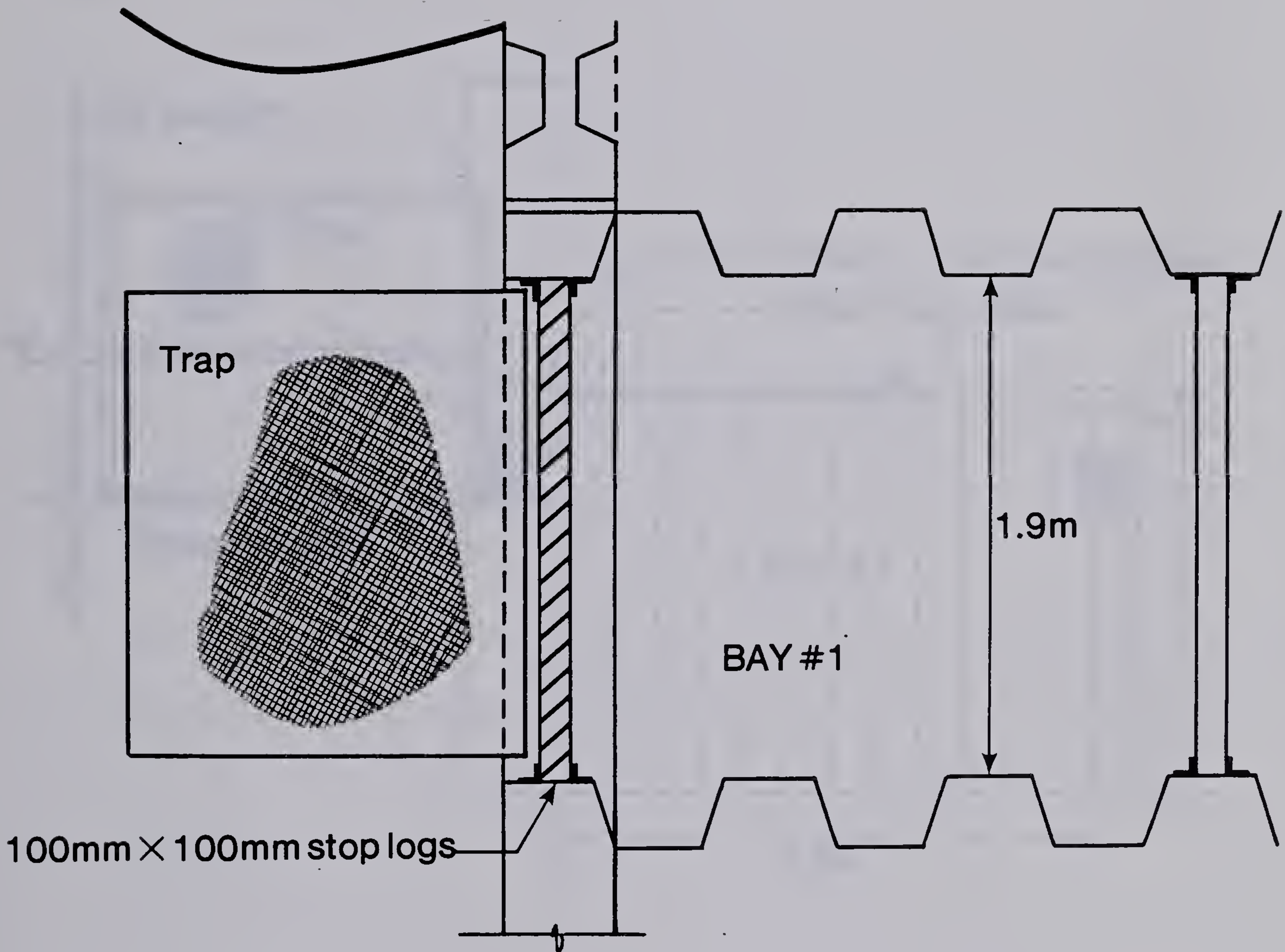


Fig. 31 Placement of the ladder trap at the Steele Lake site, plan view.

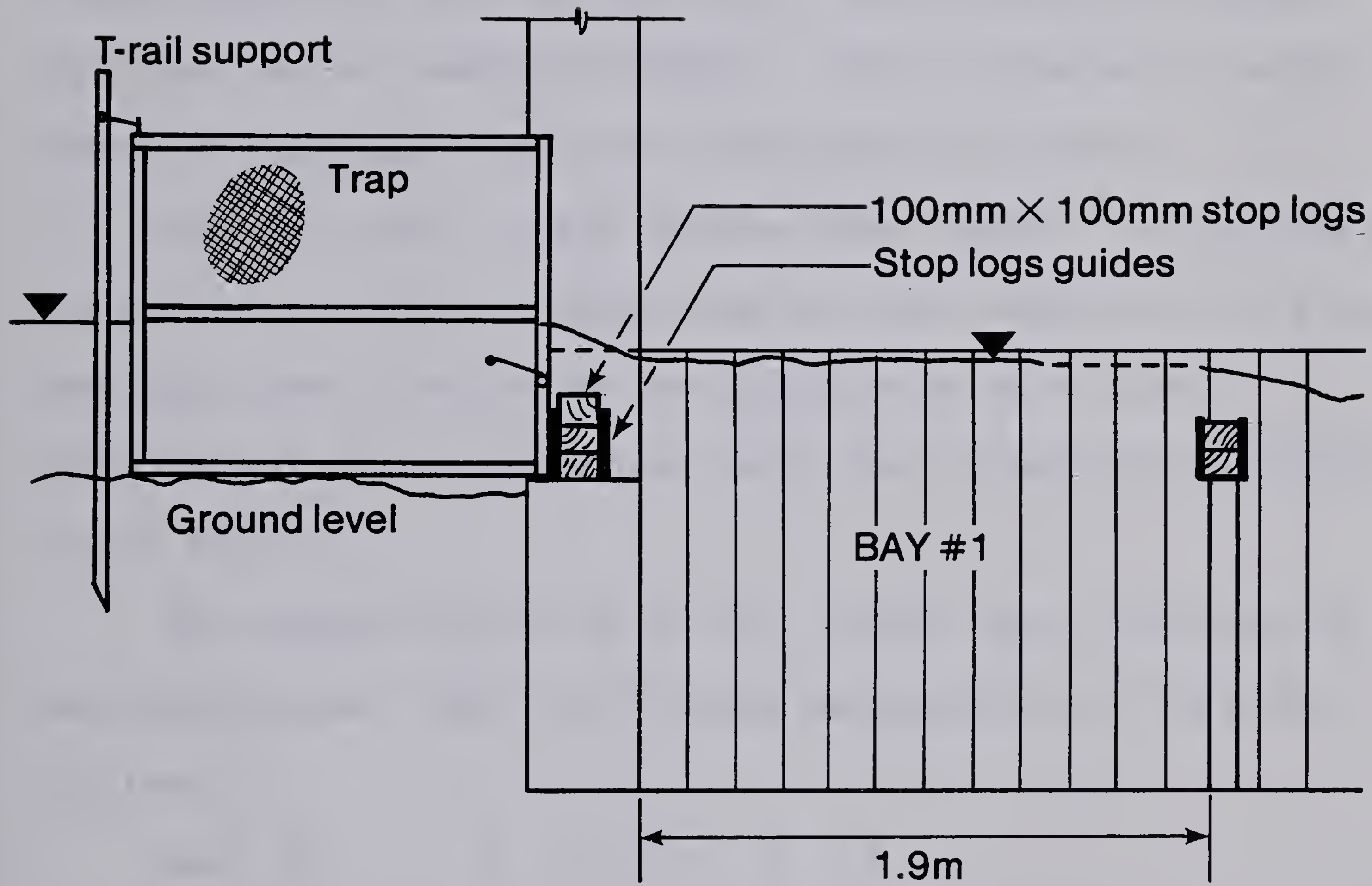


Fig. 32 Placement of the ladder trap at the Steele Lake site, cross section.

the ladder. Consequently, greatly different flow characteristics and velocities were produced in the first two bays, than through the rest of the ladder.

The existence of a beaver dam, located upstream of the ladder, produced a slight ponding effect on the area of water between the stabilization weir and this dam. As a result, the flood gate (located at the north end of the stabilization weir, in Fig. 30) was utilized to lower upstream water levels slightly. This produced a second means of manipulating flows through the ladder.

Upon arrival at the Steele Lake ladder, it was decided to utilize the existing set up of the ladder as the first manipulation. Two other manipulations were later established and these three were then alternated randomly until May 17.

The upper six weirs of the ladder were involved in the manipulations. The first three manipulations were as follows:

man. #1; 3 - 2 - 2 - 2 - 2 - 2

man. #2; 2 - 1 - 1 - 1 - 1 - 1

man. #3; 1 - 0 - 0 - 0 - 0 - 0

Where each digit refers to the number of stop logs placed on top of the steel sheet weir. The first digit (on the left) refers to the first or uppermost weir in the ladder. (The seventh weir was always submerged by downstream water levels and therefore was not manipulated).

Once a familiarity with the peculiarities of the ladder was established, four new manipulations were implemented:

man. #4; 3 - 2 - 1 - 1 - 1 - 1 (flood gate open 25%).

man. #5; 3 - 2 - 1 - 1 - 1 - 1 (flood gate closed).

man. #6; 2 - 1 - 0 - 0 -0 - 0 (flood gate open 25%).

man. #7; 2 - 1 - 0 - 0 - 0 - 0 (flood gate closed).

The short length of the stop log guides (over the first weir) and constant elevation of the first three weirs, greatly restricted the number of manipulations that could be done, while still maintaining a sequential head drop through the ladder.

Most of the remaining sets involved these four manipulations (Table C.16), however, three other manipulations were tried during the latter stages of the project:

man. #8; 3.5 - 2 - 1 - 1 - 1 - 1 (flood gate open 25%). The 3.5 logs over the first weir refer to two 100 mm x 100 mm logs and one 150 mm x 100 mm log.

man. #9; involved placing the ladder trap in the third bay of the ladder. Flow through the ladder was dampened by damming the top end of the ladder with planks. This was done in order to establish smaller heads and a free flow over the weir.

man. #10; was set only once (set 48, Table C.16). A restricted route of ascent was set up over the second

weir, (Plate 6). This orifice forced an ascending fish to pass through the water column of the nappe in order to ascend to the next bay. The orifice was 210 mm in height, with a mean water velocity of 1.6 m/s.

The pattern of the stop log manipulations used followed a randomized design. Due to the amount of work and time involved in each manipulation change, no attempt was made to maintain a particular head level. The length of time that each set lasted was dependent on the number of fish caught. Each time a change in stop logs was made (some manipulations occurred twice in a row due to the randomized design) a new set was designated. Initially, only 1 - 2 hour sets were used. Later, the set time was extended to 5 hours.

5.2.2.5 Velocity measurements

All velocity measurements were taken using either the Price model AA current meter, or the Cushing model 611-P water current meter converter. The Price meter was used to directly measure velocities within the nappe. Velocities were taken in two locations at each weir:

(1) directly over the weir, approximately half way down in the water column.

(2) downstream in the nappe as close as possible to the point where the nappe merged with the water level in the next bay.

Plate 6 A photograph of the makeshift orifice which was placed over weir #2 during manipulation #10.

In conjunction with these velocity measurements, head levels were taken for each weir as described. Head levels for the first weir were established by installing a T-rail post about 3.0 m upstream of the ladder and calibrated to the top elevation of the fishladder. Water levels over the first weir were then taken in relation to this point.

Velocities using the Price meter were done only on the first four sets (and occasionally on other sets) in order to establish a correlation between measured head and velocity.

Table C.23 outlines these sets, giving the head at each weir and the corresponding velocities over the weir and in the lower end of the nappe. The regression analysis allows an approximation of the velocity in the lower portion of the nappe (applicable to the lower four weirs of the ladder only) to be calculated from the head over the weir by the equation:

$$Y = 0.0065(X) + 1.4 \qquad (8)$$

where:

X = head over the weir (mm)

Y = velocity (m/s)

$r = 0.88$

Mean velocity over the weir can be approximated from the head by the regression equation:

$$Y = 0.0033(X) + 0.78 \qquad (9)$$

where:

X = head (mm)

Y = velocity (m/s)

r = 0.88

Water velocities in the nappe of the two upper weirs were generally only half that measured at the lower four weirs. Consequently, in order to maintain consistency in the head/velocity relationship, only the lower four weirs were considered (since the most critical velocities for the fish were at these sites).

5.2.2.6 Velocity profiles and discharge

In order to contrast the differences in velocities which occur at various points in a step and pool ladder, complete profiles were carried out on manipulations 1 - 8.

The Cushing current meter was utilized in this case for measurement of velocities. During each profile, velocities were taken throughout the ladder in the following pattern:

(1) over each weir - The wading rod was placed directly over the weir (just touching its surface). Five separate readings were taken at 30 cm intervals across the weir.

(2) within the nappe after each weir - The wading rod was rested against the downstream edge of the weir and set at about a 45° angle into the flow of the nappe. Five readings at 30 cm intervals across the flow were done.

(3) two or more equally spaced positions into the bay,

downstream of each weir - The wading rod was held in the flow vertically. Five readings at 30 cm intervals were taken across each position. As well, the rod was moved vertically down in the bay at 30 cm intervals (the depth attained varied, depending on debris, etc.).

By utilizing equations (3) and (6), discharges were calculated for most of the sets, in terms of flow over the main weir and flow through the ladder itself.

5.2.2.7 Fish sampling

All fish captured were sized by fork length, sexed, and tagged. Every second or third fish was also weighed, and a scale sample removed for aging.

After each set, the upstream ladder trap was removed (if it contained fish) and carried to the shore area where fish were more easily netted out for handling. Once all fish were sampled and returned to the water, the trap was then placed back in its ladder position, designating the start of the next set. Stop logs were arranged for a different manipulation if necessary.

5.2.2.8 Physical/chemical measurements

Water temperature, conductivity, and dissolved oxygen readings were taken immediately upstream of the ladder and at the fishladder entrance, in the morning and evening of each day.

5.3 Data Analysis

5.3.1 General

All statistical analyses were carried out using the "Minitab" statistical computing package (Ryan et al., 1976 & Ryan et al, 1981) which runs interactively with the University of Alberta MTS (Michigan Terminal System) computing system.

All raw field data were initially arranged according to tag number (see Appendix A) for both the Driedmeat and Steele Lake sites.

5.3.1.1 Length/weight correlation

The logarithms of fish length were plotted against the logarithms of the corresponding weights (using those individuals that had both length and weight recorded). Regression coefficients were calculated for each plot.

Length/weight correlations were plotted for each of the following data sets:

(a) Driedmeat Lake counting fence (pike and white sucker)

(b) Combined data of the Steele Lake ladder trap (pike only)

5.3.1.2 Frequency polygons & histograms

In order to provide a visual representation of the relative numbers of fish, or numbers within a length grouping, frequency polygons and histograms were generated

(such as Figs. 34 & 48).

5.3.1.3 Sex and age

Sex ratio and age range for each species as a whole were ascertained using those individuals where sex and/or age had been determined. In the case of Driedmeat Lake, this involved combining the appropriate data of all three study sites. For Steele Lake, all appropriate ladder trap data were used.

5.3.2 Site specific analysis

Observations at Silver Creek, Gwynne culvert and Steele Lake sites required an examination of the effects of the water velocities on the swimming abilities of the fish involved.

Fish length was utilized as the dependent variable in the analysis. The size range of the fish tended to demonstrate less fluctuation than fish numbers at any one time.

Two different statistical designs were used; the one-way ANOVA (completely randomized design), and the CHI-SQUARE for independance (Spatz & Johnson, 1976; Miller & Freund, 1977; and Khazanie, 1979).

In using the one-way ANOVA, mean fish length was calculated for each flow rate involved. The flow rates were then compared using the null hypothesis that the mean length of fish captured at each flow rate was the same, or that:

$U_1 = U_2 = U_3$, etc. (U=mean)

The application of the ANOVA rests on three major assumptions; normality, homoscedasticity and random sampling. Therefore use of the ANOVA depended on the data from each study site conforming to these three assumptions.

Normality was tested by conversion of the length data to their equivalent probit scores (Ryan et al. 1981). These two sets of scores were then plotted against each other and correlated (Fig. B1, A-C). The higher the correlation the more consistent are the data with a normal distribution.

Standard deviation values were calculated for the mean population length at each velocity to insure that the amount of variation around the mean was similar for each population in the analysis (homoscedastiity).

The use of random sampling was implicit in the design of the experiments since each fish downstream of a particular flow regime had equal opportunity to attempt the flow.

The chi-square is a measure of the deviation of "observed" data from the model or "expected" case, based on probability. Again, fish length was used here as the event (or dependent variable). The range of lengths which occurred were divided into equal sized categories. The frequency of occurrence (total number) of a particular size group at a particular flow rate was determined, and expected values calculated.

5.3.2.1 Silver Creek

All fish captured in the Silver Creek trap were white sucker, subsequently all analysis dealt with this species. Data obtained using the shorter, 61 cm. chute, were treated separately from the long chute results.

To compare the mean length of suckers captured under each of the flow conditions through the short chute the one-way ANOVA was used.

Due to the small numbers of fish captured during the use of the long chute, no further breakdown of the data was done to compare the different velocities. However, a one-way ANOVA was performed on the mean length of sucker passing through the short chute as opposed to the longer chute.

5.3.2.2 Gwynne culvert

All fish captured in the Gwynne culvert trap were pike, therefore all analysis dealt with this species. A one-way ANOVA was used to test if the mean length of pike passing through the culvert differed during each set of the culvert (i.e. as a result of the decreasing velocities).

In order to determine whether size class might be a factor, the range of lengths of the fish were divided into 3 groups. These classes were then examined against the four flow rates in a chi-square test for independence.

5.3.2.3 Steele Lake

Since insufficient numbers of white sucker were captured during manipulations at the Steele Lake ladder, all statistical analysis involved only pike.

The application of the one-way ANOVA and chi-square to the Steele Lake data was somewhat more involved. Since the analyses used were based on lengths and not numbers of fish captured, all sets which resulted in no fish were not utilized. Further, in order to better quantify the analysis, only those sets which contained more than 5 pike were used.

The velocity categories used were grouped in the following manner:

(a) The range of mean head levels (using the lower 4 weirs to compute each mean) which occurred, were plotted against the corresponding set numbers (Fig. 33).

The mean, as opposed to the maximum head value was utilized for two reasons. First, the turbulent nature of the flow through the ladder resulted in small, constant changes in head levels across the width of the weir. Thus, velocities across the width of the weir varied from moment to moment. Second, the position of ascent over the weir was not consistent for either the pike or sucker.

(b) The range of head levels was then divided into four equal classes from lowest to highest.

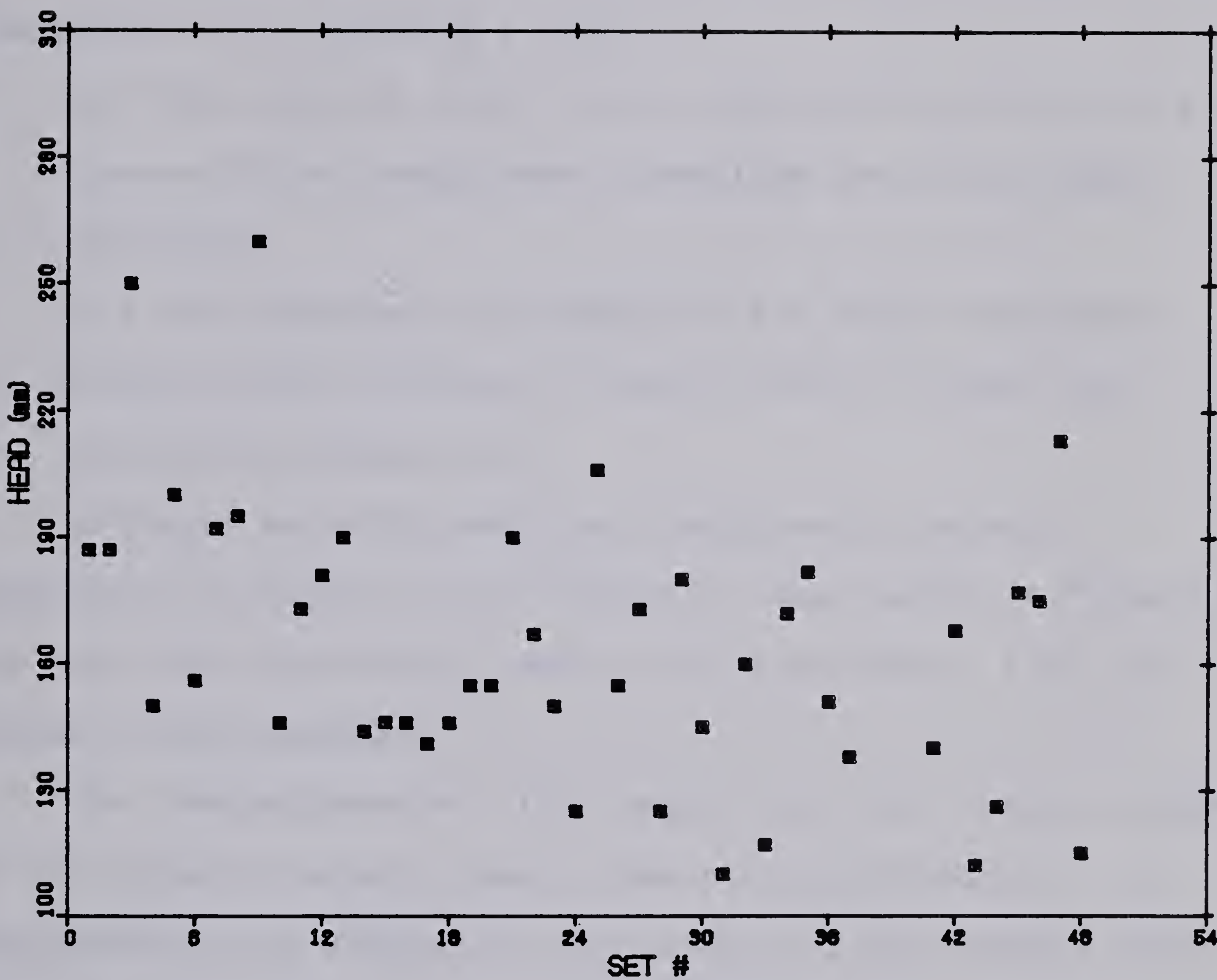


Fig. 33 Mean head level at each set of the Steele Lake fishladder.

(c) These head level classes were then converted to velocity equivalents (in m/s) using equation (8). In this way each set was then assigned to a velocity category (as outlined in Table B.5).

In the case of the chi-square tests, size classes were grouped by the following method:

(a) The range of pike lengths which occurred over the course of the study were classified into four equal divisions.

(b) The frequency of lengths within each group were then totaled according to each velocity class (as outlined in Table B.6).

Although velocity and fish length were the main variables of concern to the analysis, the factor of "time of day" was also considered, due to its involvement with fish migration and movement.

The independence of fish length from this factor needed to be tested to ensure that it was not contributing significantly to changes in the range of fish lengths which might be available to ascend the ladder at the various velocities.

The chi-square test for independence was used to test length class with time of day.

Once this independence was established, an evaluation of the variability of lengths among sets within the same velocity grouping were done, by perfoming an ANOVA on the sets with each velocity group (using mean pike lengths) and

calculating the 95% confidence intervals for the means. This was needed to establish if significance in mean size existed among sets within the same velocity class (also a test of homoscedasticity).

Once it was established that the data did conform to the assumptions involved in the ANOVA and chi-square, these two test were carried out.

The one-way ANOVA was used to compare mean length of fish captured at each of the four velocity settings.

The chi-square for independence was used to test for a relationship between size class and velocity class (using the classes described).

Finally, a one-way ANOVA on lengths for velocity classes 2, 3 & 4, during the time period of 1500 - 2100. was carried out. This was done for three reasons:

(1) The numbers of fish involved varied less than in the overall ANOVA.

(2) Any biases which might have resulted due to time periods was eliminated.

(3) As a check on the results of the overall ANOVA.

6. Results & Discussion

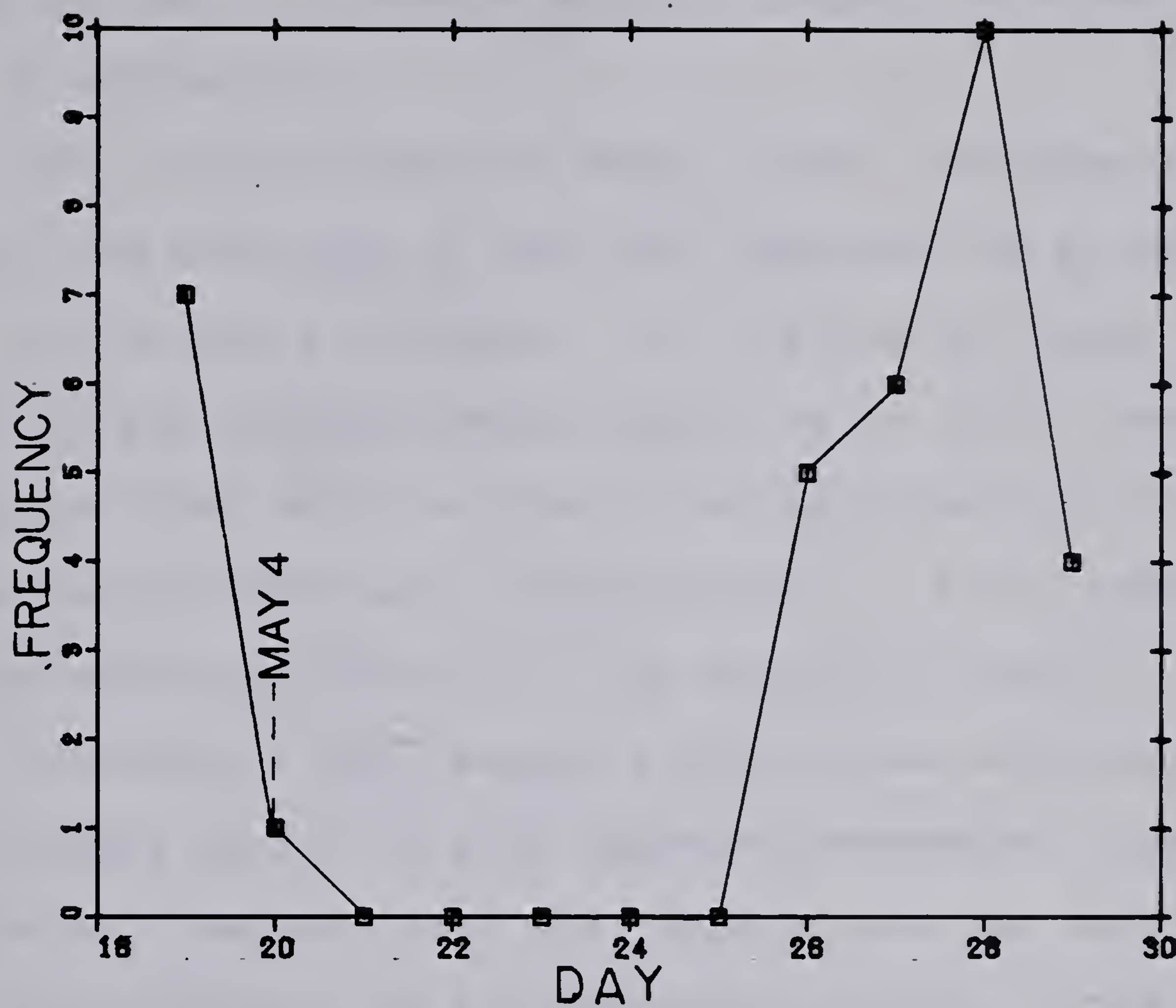
6.1 Driedmeat Lake migration

The migration of northern pike and white sucker into Driedmeat Lake from the lower end of the Battle River appeared to take place despite the inoperative nature of the fishladder. Fish of both species moved into the lake by skirting the slower moving shoreline areas at either end of the stabilization weir (as evidenced by counting fence, seining and observational results). Although movement in the main stream may have occurred, it would appear unlikely due to the extreme turbulence and velocity of the water moving downstream of the weir.

The results indicate rather erratic movements of pike into the Lake. From Table C.5 it appears that migration into the lake began sometime between April 26 and April 30. The counting fence results suggest that this initial movement trailed off between May 4 and May 9, then resumed to the end of the study period (Fig. 34).

White sucker were notably absent from all seine hauls, and did not make any noticeable appearance in the counting fence until May 8, at which time a fairly large movement appeared to take place. The migration of sucker seemed to be much more extensive than that of the pike (Fig. 35).

The migration of suckers also occurred in two peaks (the second of which was still occurring at the end of the



counting fence & chute fence for each day of operation.

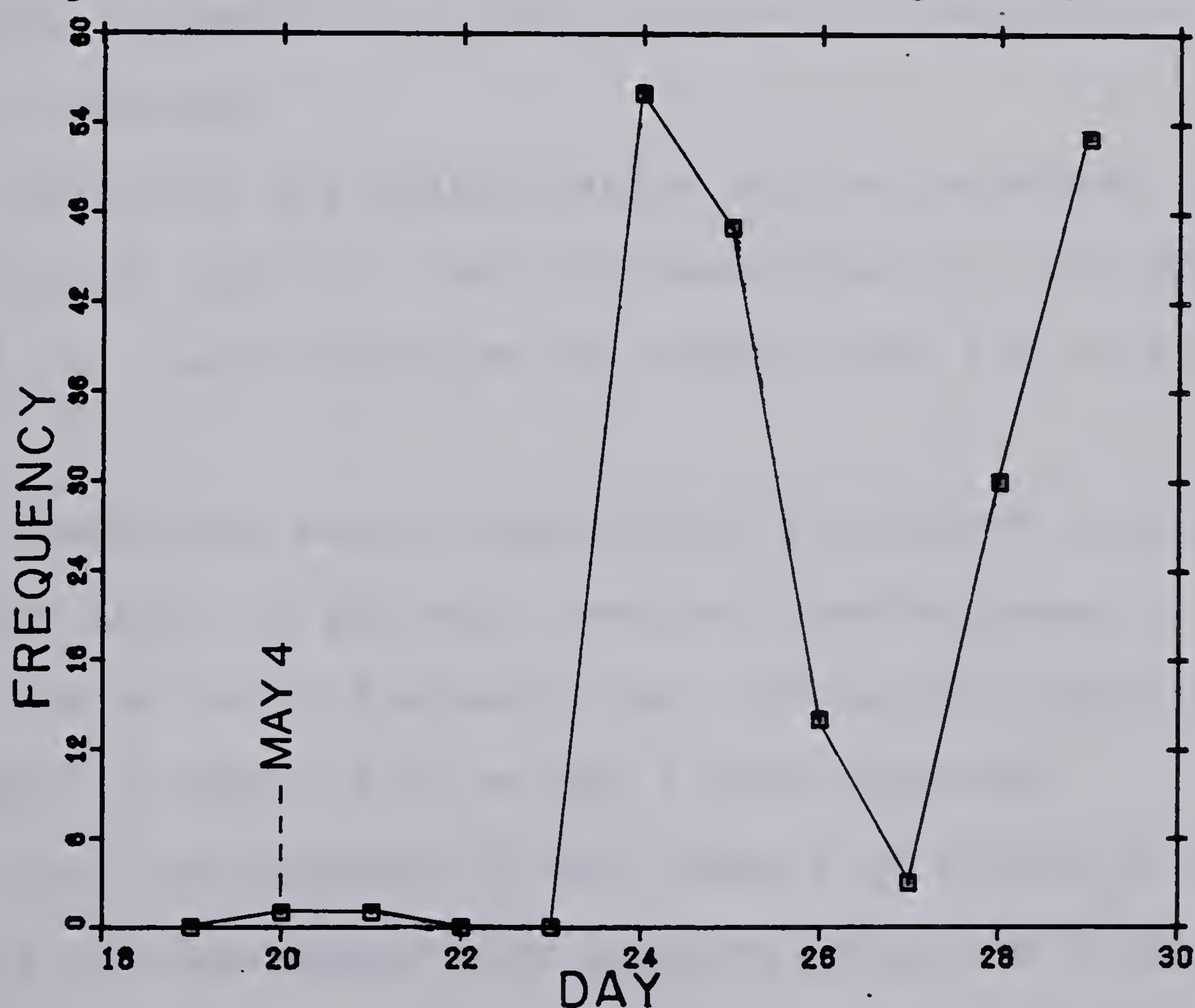
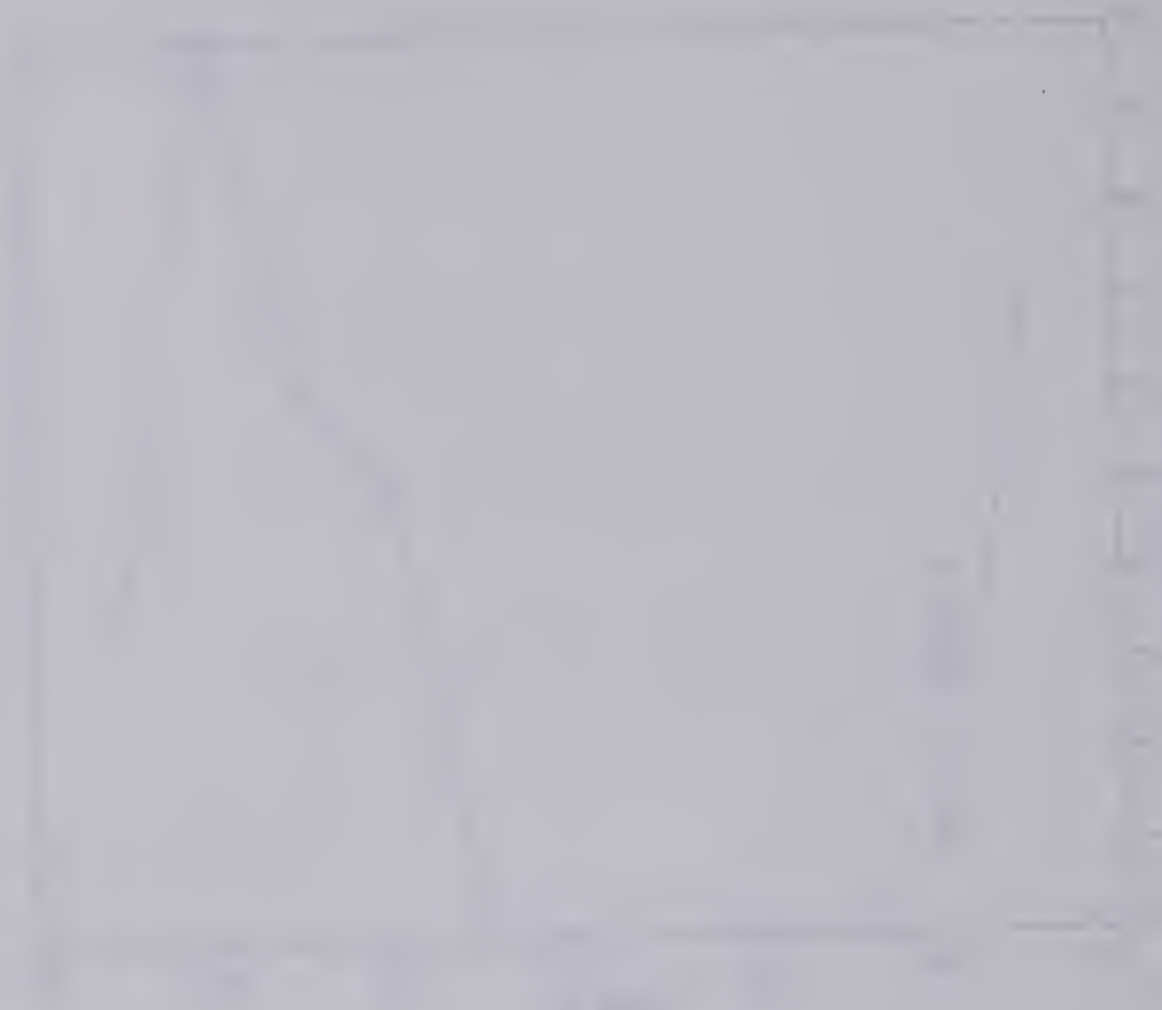


Fig. 35 Frequency polygon of white sucker captured at the counting fence.



study period). A notable drop in numbers occurred between May 10 and May 12.

The two year study of Rhude (1980) indicates that the timing and magnitude of the pike spawning run at Driedmeat Lake can be quite variable. In 1978 the run began around April 19 and sometime before April 14 in 1977. Rhude indicates that both the time of spring break-up (rising water levels) and water temperature (7 - 8° C) appeared to be the governing factors in the migration times.

Koshinsky (1979) suggests that stream discharge may be the primary factor in pike spawning movements. Koshinsky indicates, however, that low temperatures can exert a "negative effect on pike spawning migration". The migration of sucker appears to be more related to temperature rather than discharge.

Flow over the stabilization weir at Driedmeat did not begin until April 21, but increased sharply from then until May 5 to a peak discharge of greater than 215 m^3/s (Fig. 36).

Downstream water temperatures fluctuated considerably between April 15 and May 5 before climbing steadily (Fig. 37). Prior to this steady rise, two earlier peaks of 5° C on April 21 and 7.7° C on May 2 were observed.

Little difference in the numbers or timing of male vs. female pike movements were apparent (Figs. 38 & 39). The initial movement of the pike may be associated with the sudden discharge over the weir, while the second peak could

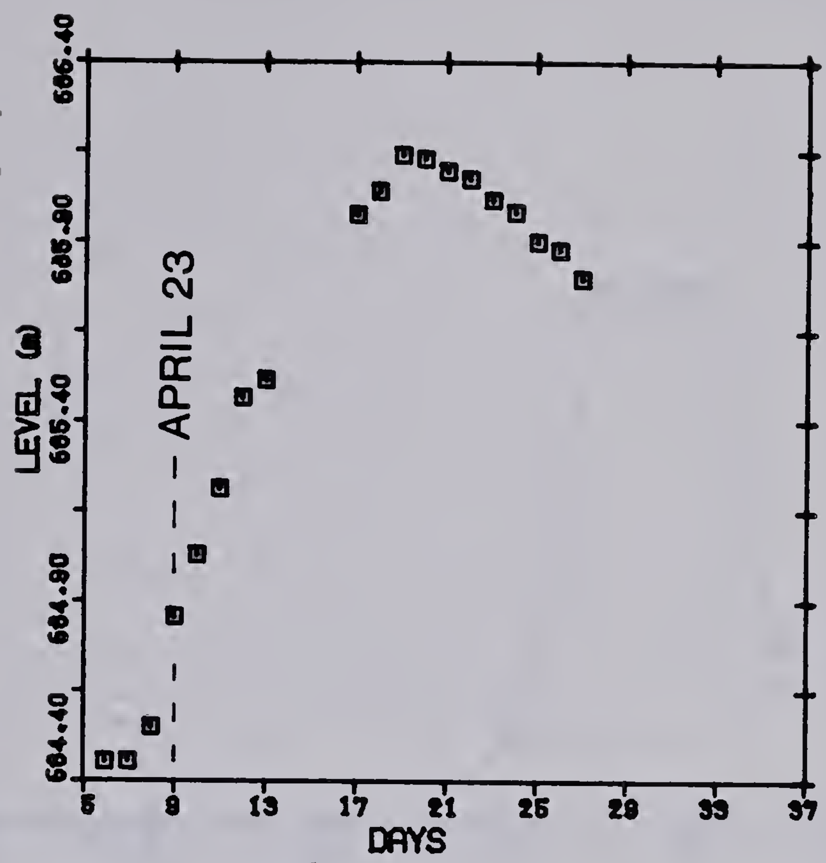


Fig. 36 Geodetic water level changes downstream of the Driedmeat stabilization weir.

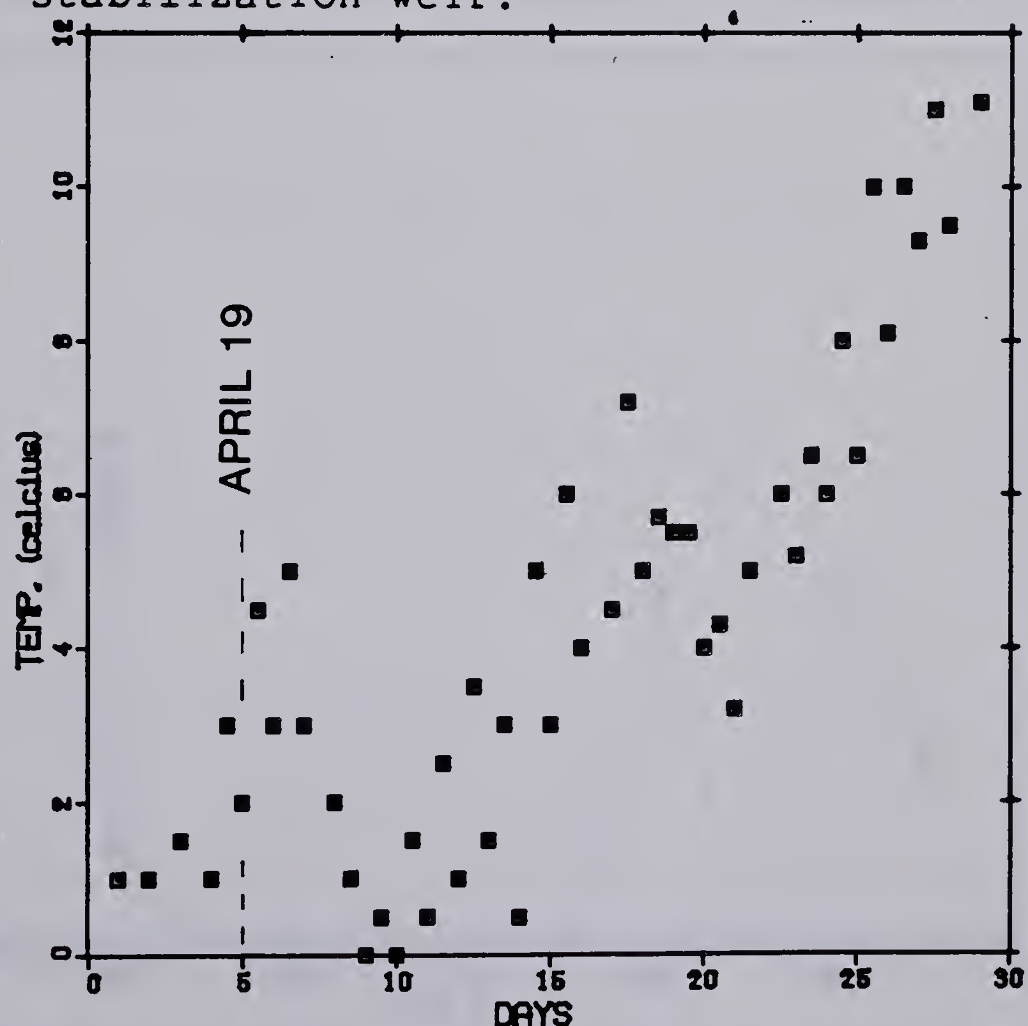


Fig. 37 Plot of downstream water temperature vs days, at Driedmeat weir.

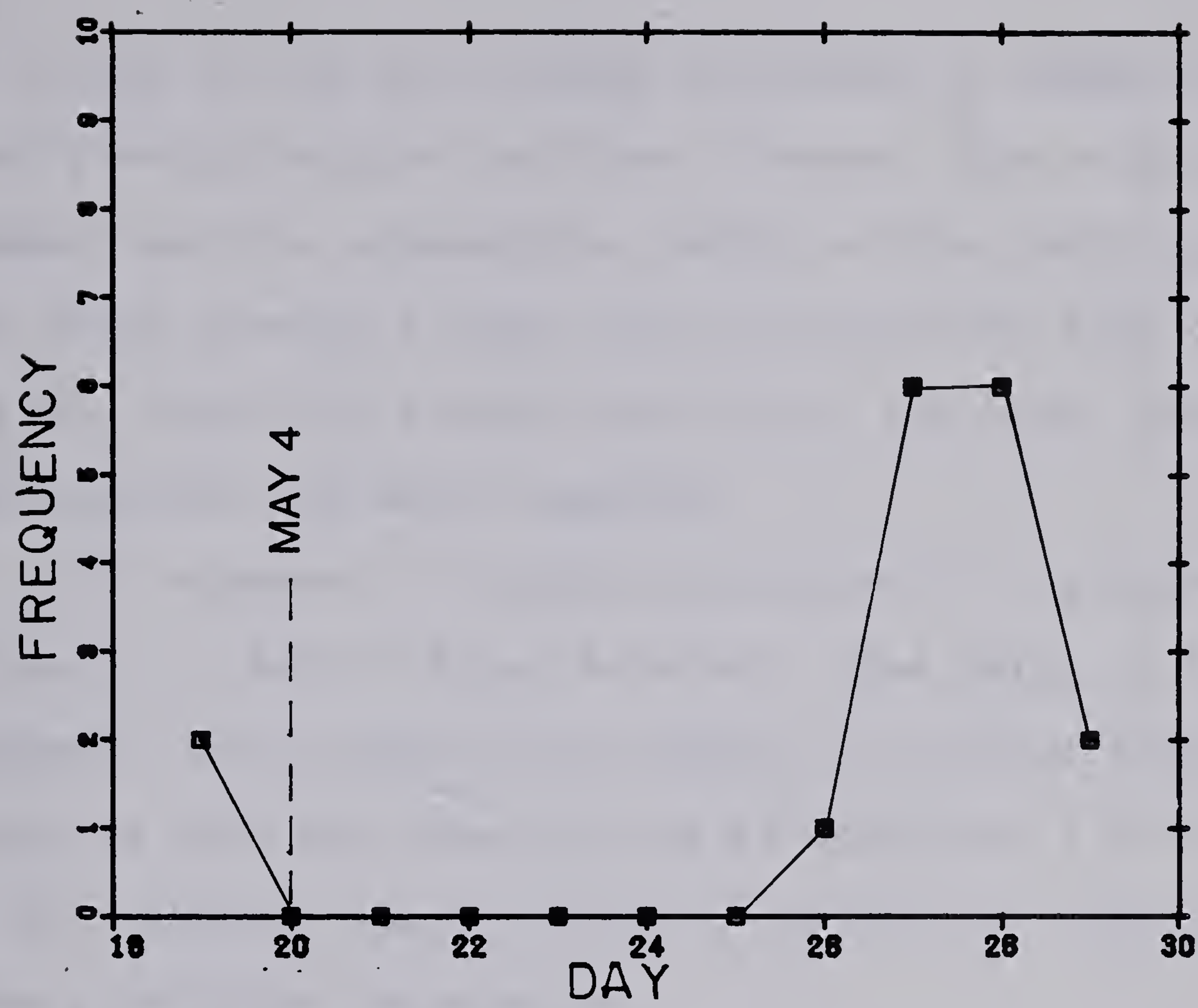


Fig. 38 Frequency polygon of male pike captured at the counting and chute fences, located at Driedmeat weir.

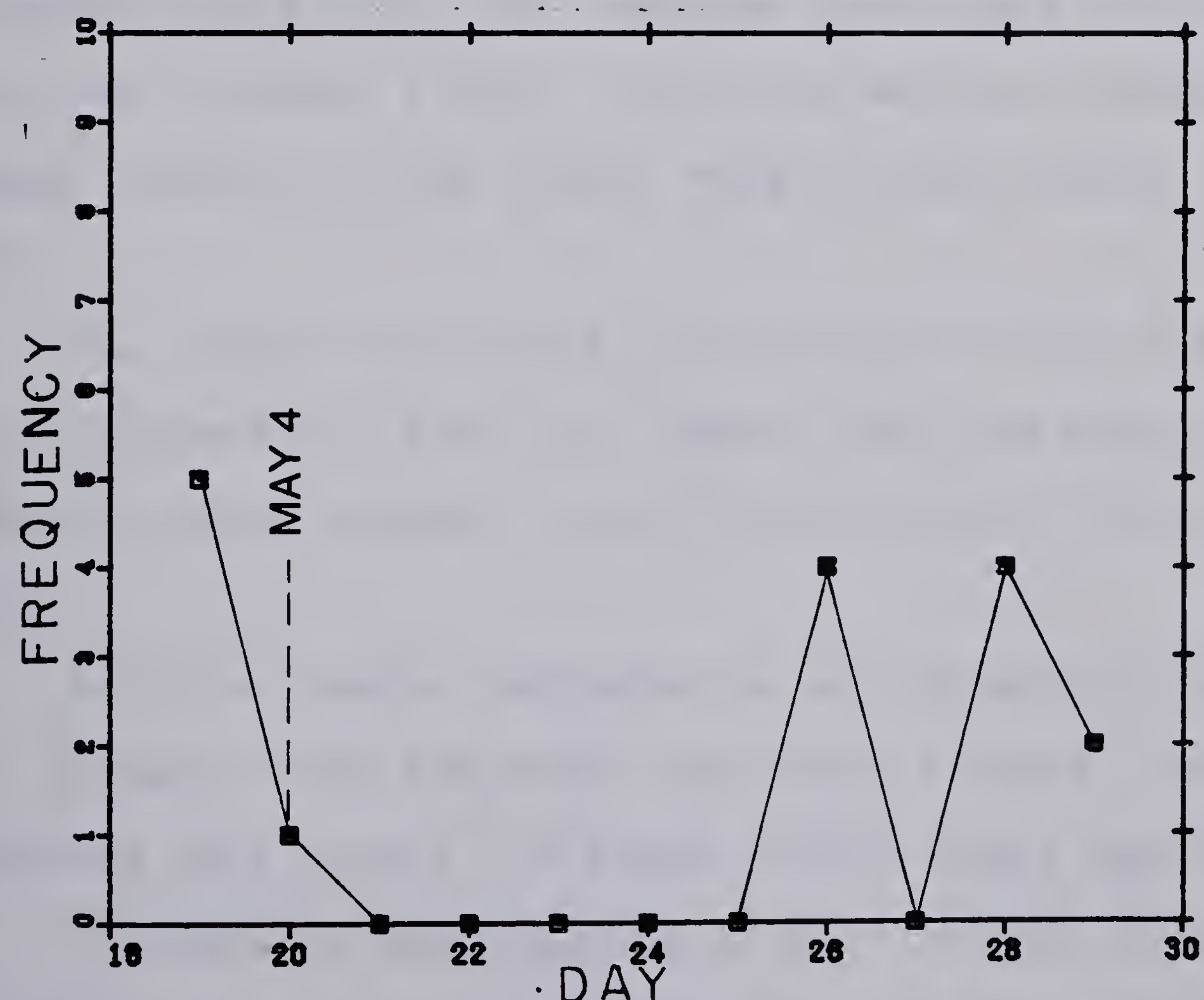
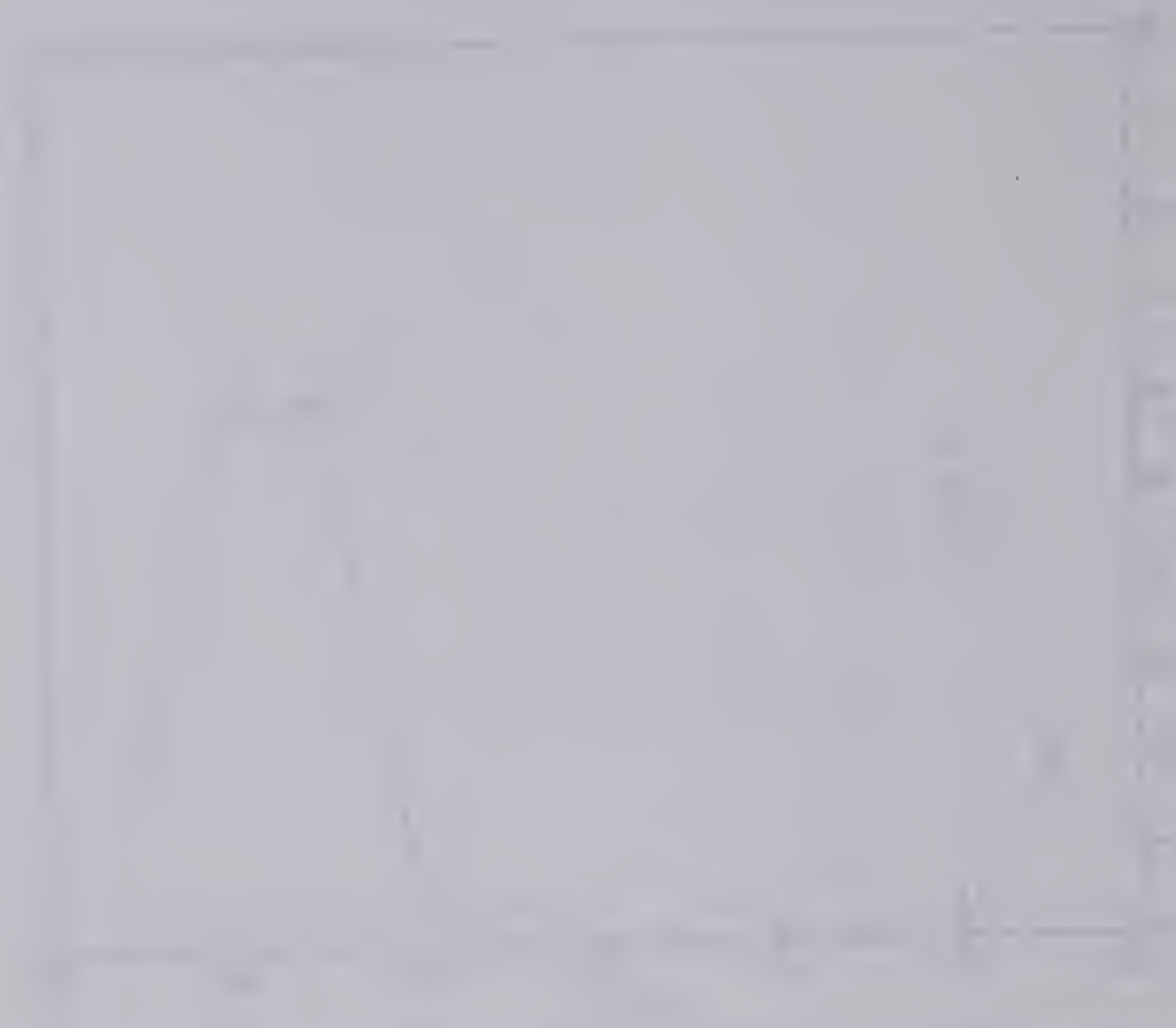


Fig. 39 Frequency polygon of female pike captured at the counting and chute fences, located at Driedmeat weir.



be linked to the more steady increases in temperature. No real conclusions can be drawn, however, due to the lack of numbers and the subsampling nature of the counting fence. The fence covered a small area on the north side of the lake outlet, thus only a small portion of the total numbers of each species was being sampled.

The movement of suckers consisted of a greater number of males, 1.6/1.0 (Figs. 40 & 41). The delay of their movement until temperatures began to increase more steadily complies with the observations of Koshinsky (1979) and Geen, et al. (1966). Again, however, insufficient data exists to draw a definite correlation.

The length vs. weight relationship obtained on pike at Driedmeat Lake (Fig. 42) compares favourably with that outlined by Rhude (1980). Both the male and female pike appear similar in the length weight relationship (Figs 44 & 45).

The length vs. weight relationship of the white sucker is illustrated in Fig. 43. Again, both the males and females appear similar in this relationship (Figs. 46 & 47).

Aging by scales indicated an age range for the pike of 2 - 6 years, with the modal age being 4 years. White sucker captured were from 2 - 5 years, with a modal age of 3 years.

A frequency distribution of pike lengths at the Driedmeat counting fence (Fig. 48) approximates closely those distributions given by Rhude (1980). Lengths ranged

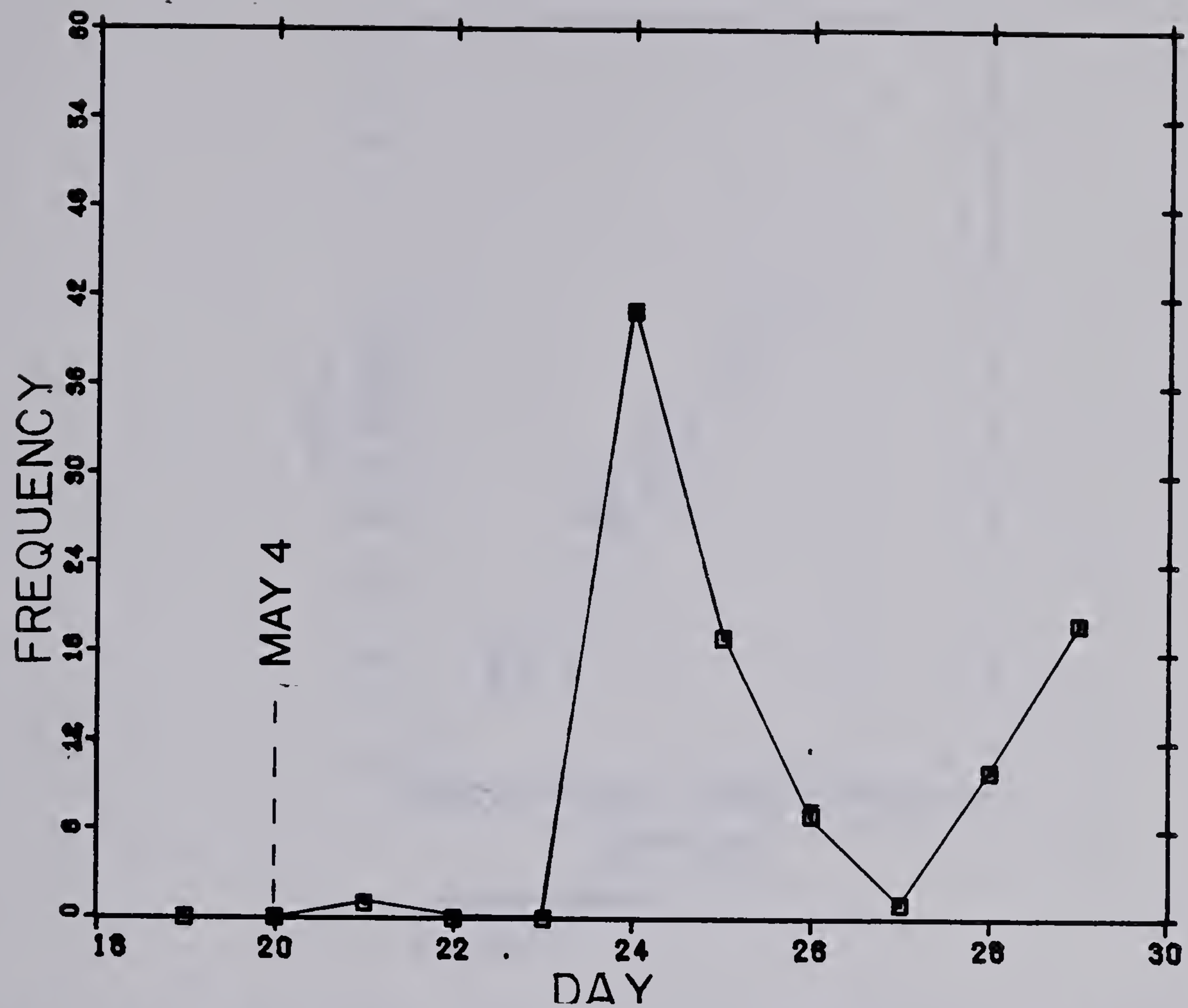


Fig. 40 Frequency polygon of male white sucker captured at the counting fence, located at Driedmeat weir.

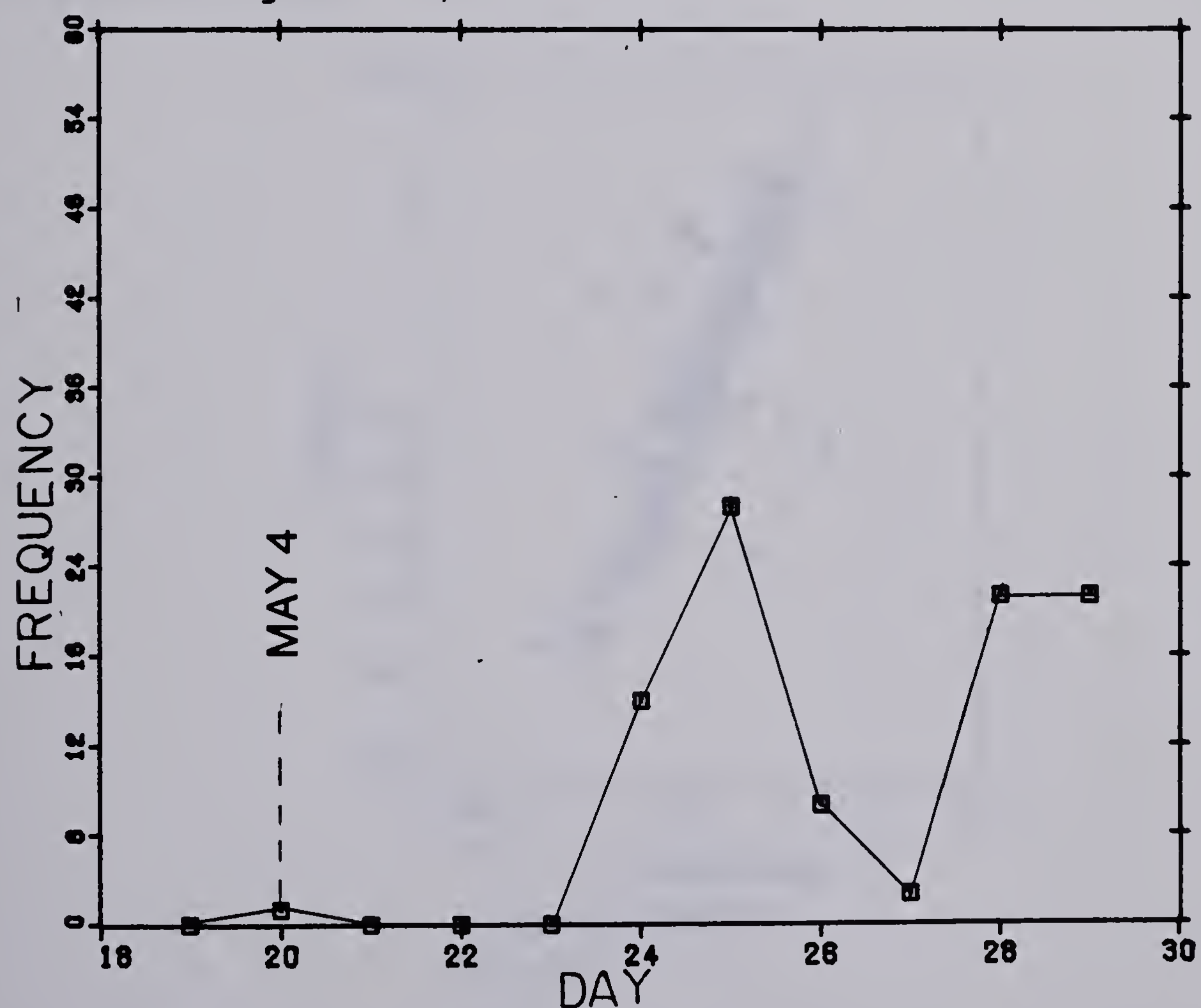
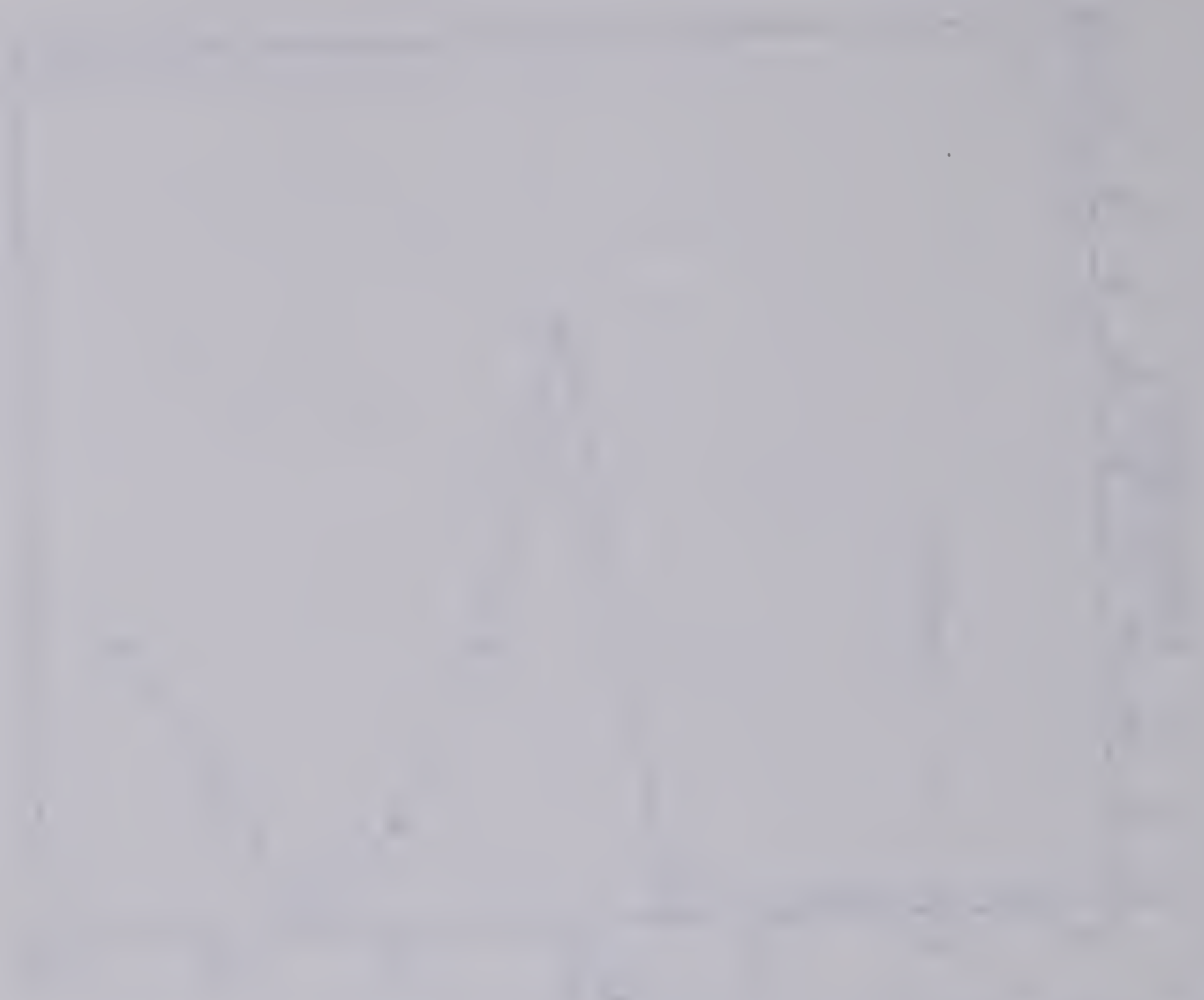
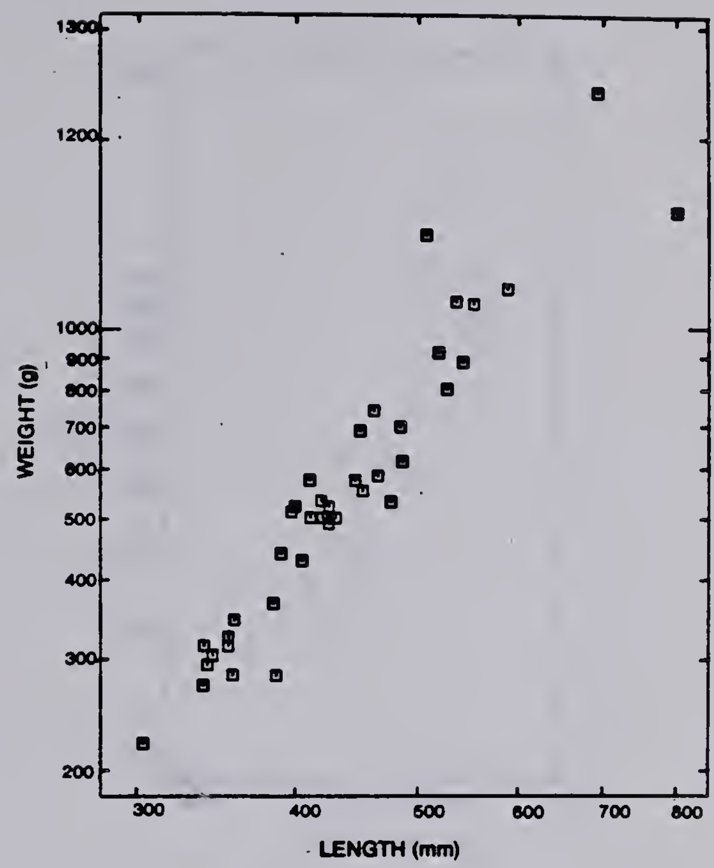


Fig. 41 Frequency polygon of female white sucker captured at the counting fence, located at Driedmeat weir.

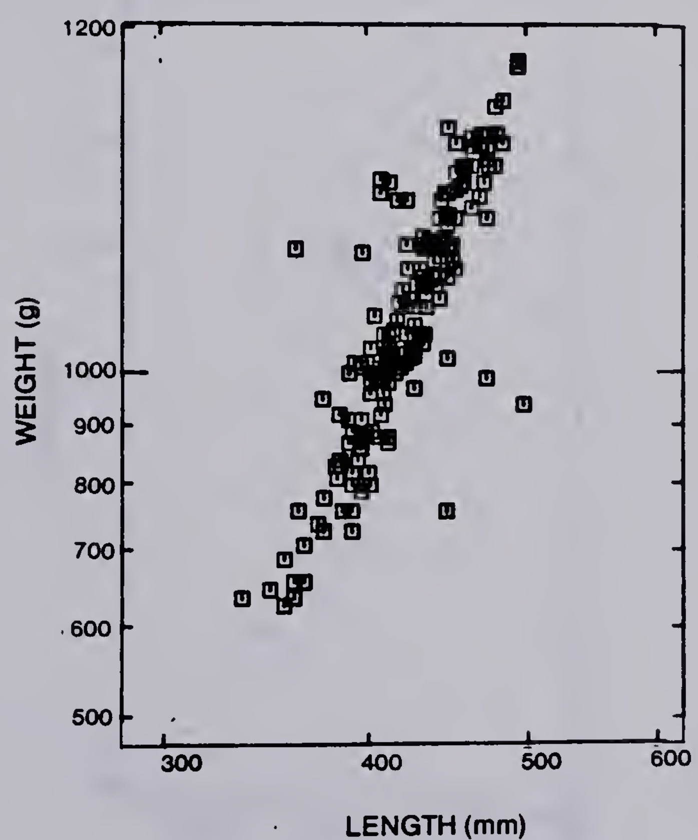




$Y = 10^{-3.30 + 2.29 (\mathrm{LOG}\ X)}$

$r^2 = 75.8\%$

Fig. 42 A log-log length vs. weight plot of pike captured at Driedmeat Lake.



$Y = 10^{-4.23 + 2.77 (\mathrm{LOG}\ X)}$

$r^2 = 71.5\%$

Fig. 43 A log-log length vs. weight plot of white suckers captured at Driedmeat Lake.

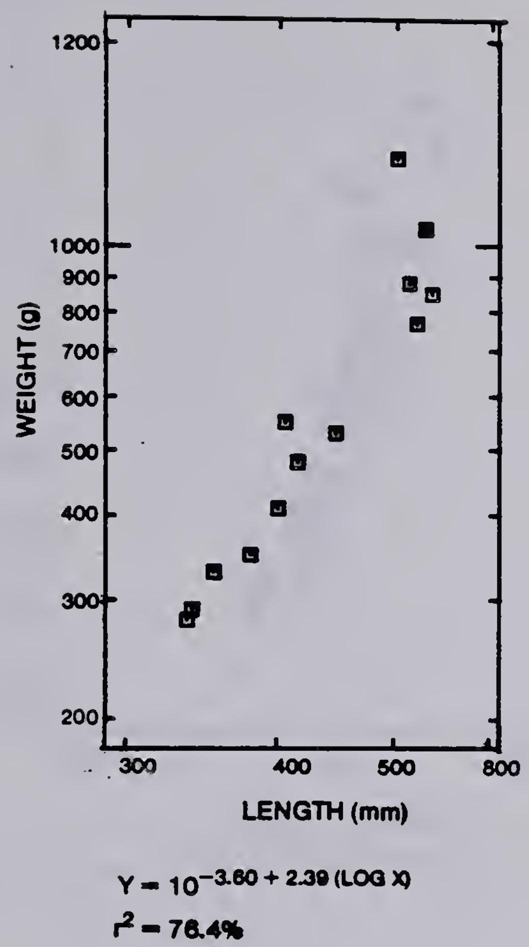


Fig. 44 A log-log length vs. weight plot of male pike captured at Driedmeat Lake.

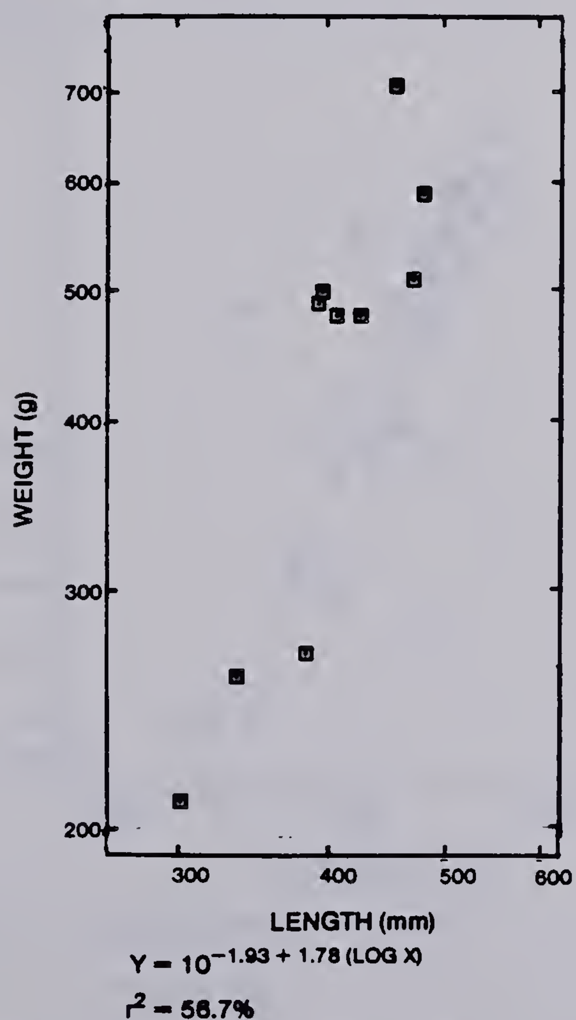
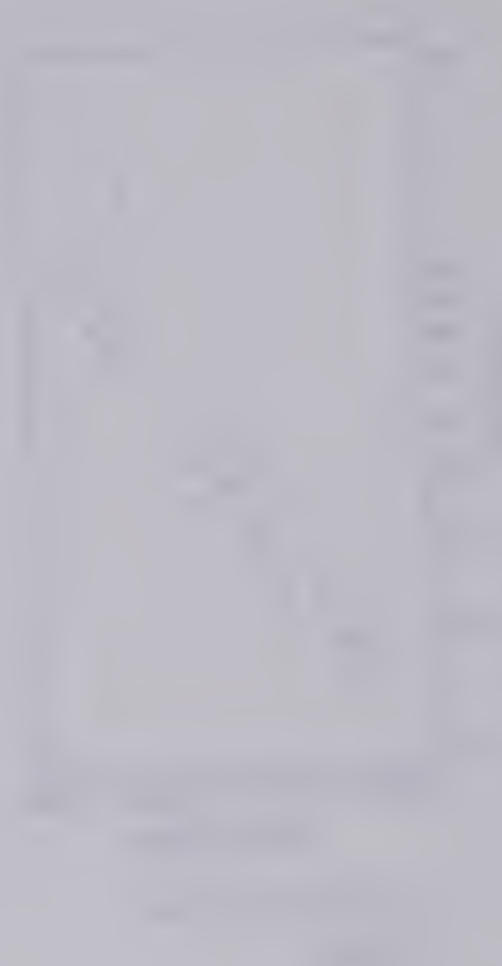


Fig. 45 A log-log length vs. weight plot of female pike captured at Driedmeat Lake.



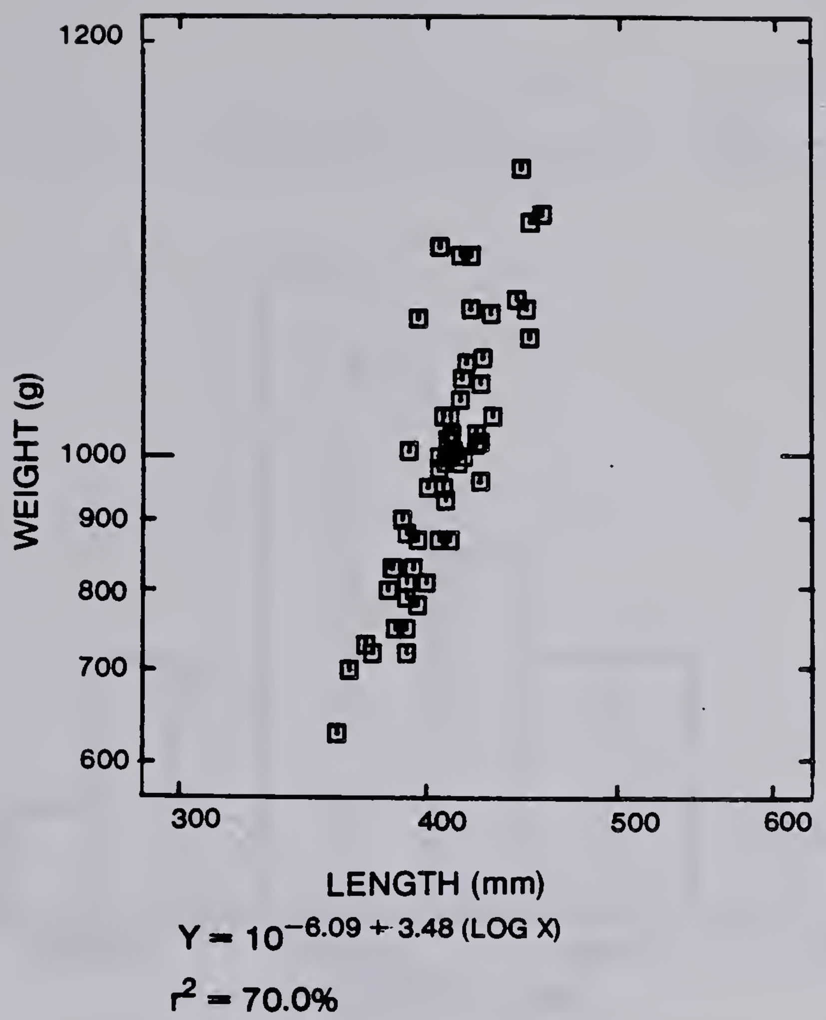


Fig. 46 A log-log length vs. weight plot of male white sucker captured at Driedmeat Lake.

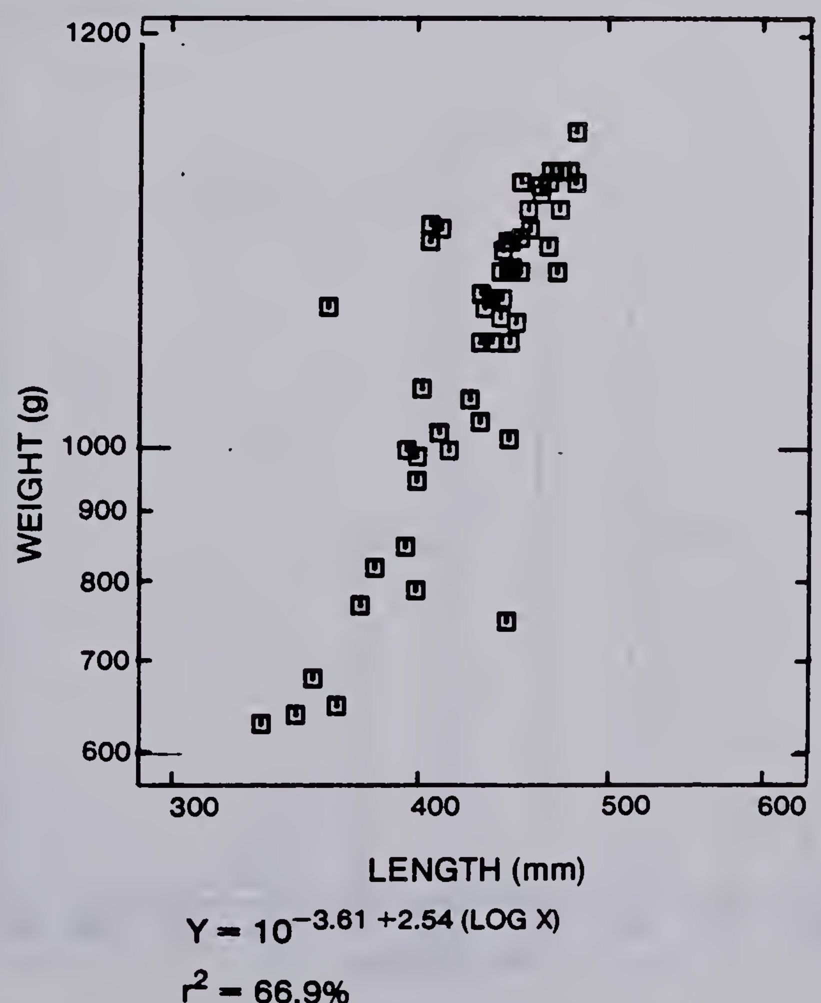


Fig. 47 A log-log length vs. weight plot of female white sucker captured at Driedmeat Lake.

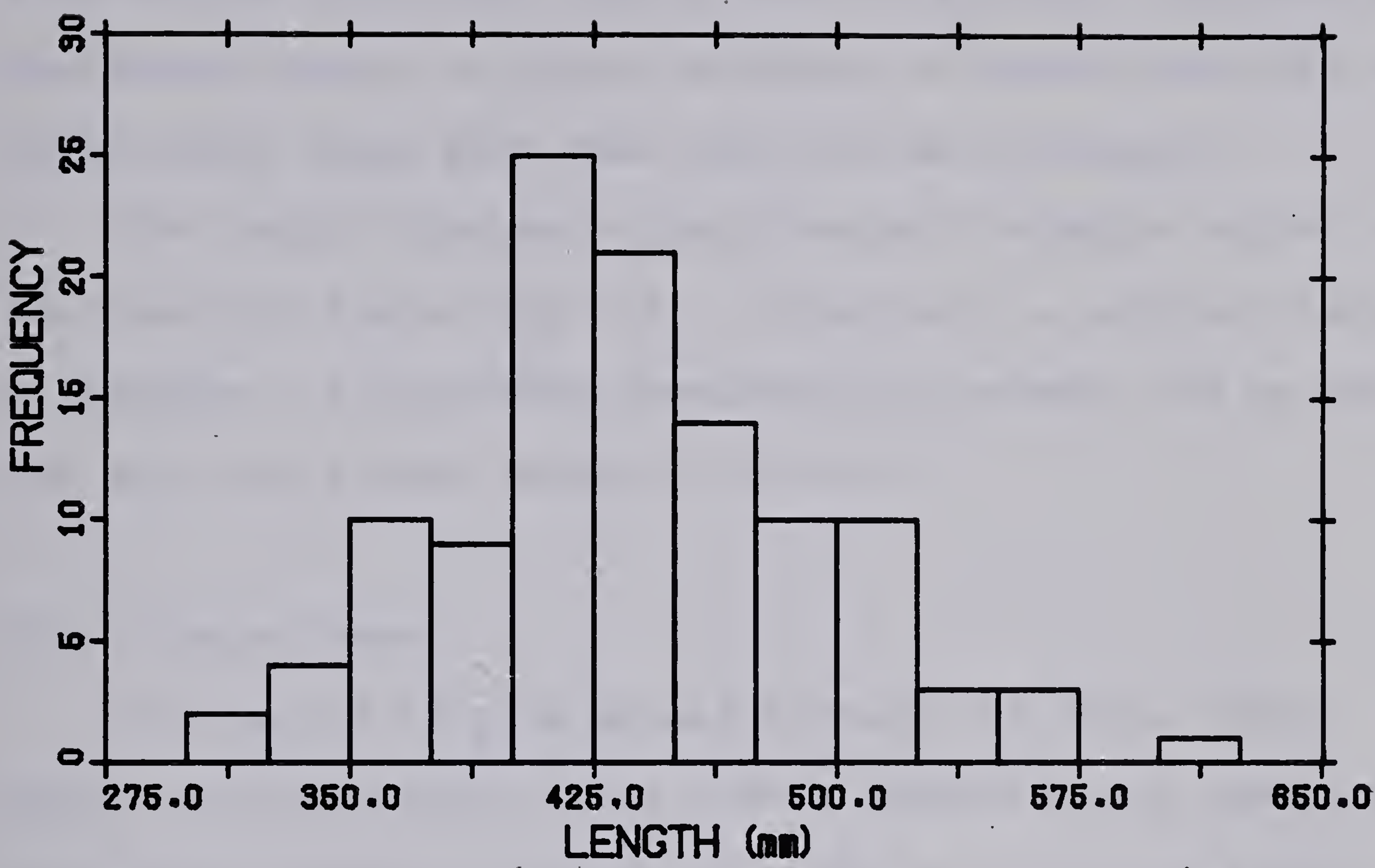


Fig. 48 Length frequency histogram of Driedmeat pike.

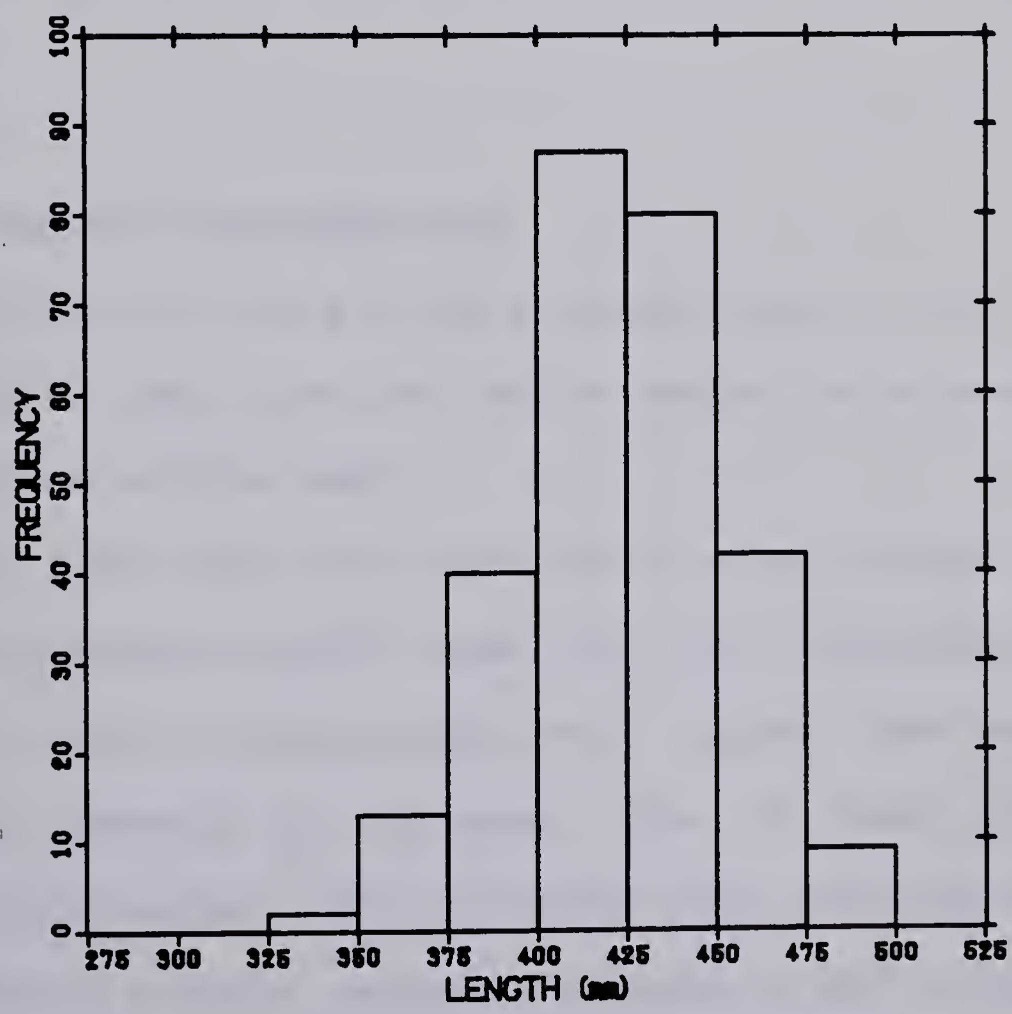


Fig. 49 Length frequency histogram of Driedmeat white sucker.

from 300 mm to 625 mm, with a mean of 430 mm. Although a percentage cannot be given, evidence of sexual maturity was found among those pike less than 400 mm in length.

The length frequency distribution for white sucker at the counting fence (Fig. 49), illustrates a narrower range of lengths. All suckers captured were between 300 mm and 500 mm, with a mean length of 430 mm.

6.1.1 Chute fence

A total of 19 pike passed through the chute fence during its operation (Table C.6). These results indicate that pike ranging in length from 300 mm to 425 mm passed through the 5.0 m long chute against a mean velocity of 0.8 m/s.

6.1.2 General observations

Prior to flow over the stabilization weir, large numbers of dead pike and white sucker were observed downstream of the weir.

As flow over the stabilization weir began, many pike were observed to spill over the weir and swim downstream. Twenty three of these pike were tagged (see tag numbers 103 - 1025, appendix A), however, none of these animals were later recaptured. All of these pike were extremely lethargic in their swimming movements and in handling, probably as a result of the low temperature and low dissolved oxygen conditions which prevailed at that time.

Overnight observations at the counting fence suggest that the majority of pike movement occurred between 1800 and 0300 hours. The movement of white sucker appeared to be more generalized over the entire 24 hour period.

6.1.3 Physical/chemical measurements

Measurements of temperature, conductivity, and dissolved oxygen indicated differences upstream and downstream of the stabilization weir (Tables C.17 & C.18).

Temperatures upstream of the weir were generally 1 - 2° C warmer, probably due to a warming of the pooled water. Temperatures ranged from 0° C to 12° C during the study period.

Conductivity during the month of May has been recorded at Ponoka (on the Battle River) at 491 micromhos/cm, this corresponding to a flow of 14.4 m^3/s (H.S.S., 1979; W.Q.D., 1975). Specific conductance during this study ranged from a low of 195 micromhos/cm to a high of 350 micromhos/cm. Flows were considerably higher however, and conductance generally declined as water level increased. Conductivity levels upstream and downstream of the weir were slightly different during the same period, but no continuous trend was observed.

Dissolved oxygen levels at the stabilization weir have, in the past been extremely low during ice cover (Lowe, 1982, person. comm.). A dissolved oxygen level of 1.0 mg/L was recorded by Rhude (1980) in March of 1979. Dissolved oxygen

during this study ranged from a low of 2.2 mg/L (when ice cover still existed) and increased to a high of 14.8 mg/L at 4.5° C (during high water conditions). Again, upstream and downstream concentrations generally differed, but no consistent trend was apparent.

6.2 Silver Creek

The ANOVA indicates no significant difference (5% level) in the mean length of white sucker moving through the smaller, 61 cm, chute at the different velocity settings (Table B.1). Analysis of mean length of sucker moving through the short vs. long chutes also produced no significant difference (5% level)(Table B.2).

The data indicate that white suckers in the size range of 35 - 47 cm are capable of moving up to 2.5 m against a velocity of up to 1.4 m/s.

Several of the suckers which moved up the long chute were timed in their ascent (manually). Times ranged between 2.5 and 4 seconds. If the mean time of 3.2 seconds is used together with the maximum water velocity of 1.4 m/s, this indicates an average speed of about 2.2 m/s. This observation compares favorably with the sustained and burst speed estimates given by Bell (1973) of 1.7 and 3.0 m/s respectively.

The suckers moved through the chute in a side to side fashion, to achieve a zig-zag path of ascent. The width

setting of the chute (ranging from 23 to 60 cm) appeared to have no effect on the ability of the suckers to swim through it.

The length frequency distribution of suckers moving through the two chutes at Silver Creek (Fig. 50) does not differ markedly from the distribution found for suckers captured at the counting fence (Fig. 43).

6.2.1 Other observations

Although pike were no longer moving up Silver Creek by the time the chute trap was set up, observations on pike were made upon first investigation of the site (May 3). Dipnetting revealed that pike were accumulating in the pool below the outfall of the elevated culvert (Plate 6). These pike were in the range of 32 - 50 cm in length (with a mean of 37 cm). Three pike were observed to jump out of the water immediately in front of the culvert (presumably in an attempt to overcome the outfall). Bell (1973) used the following formula to calculate exit velocity for a jumping fish:

$$V = (2gh)^{0.5} \qquad (10)$$

Where:

V = exit velocity in m/s

g = acceleration due to gravity (9.81 m/s)

h = height of the jump above the water surface (m)

If the angle of the exit is taken into account, the actual exit velocity can be calculated from the secant of

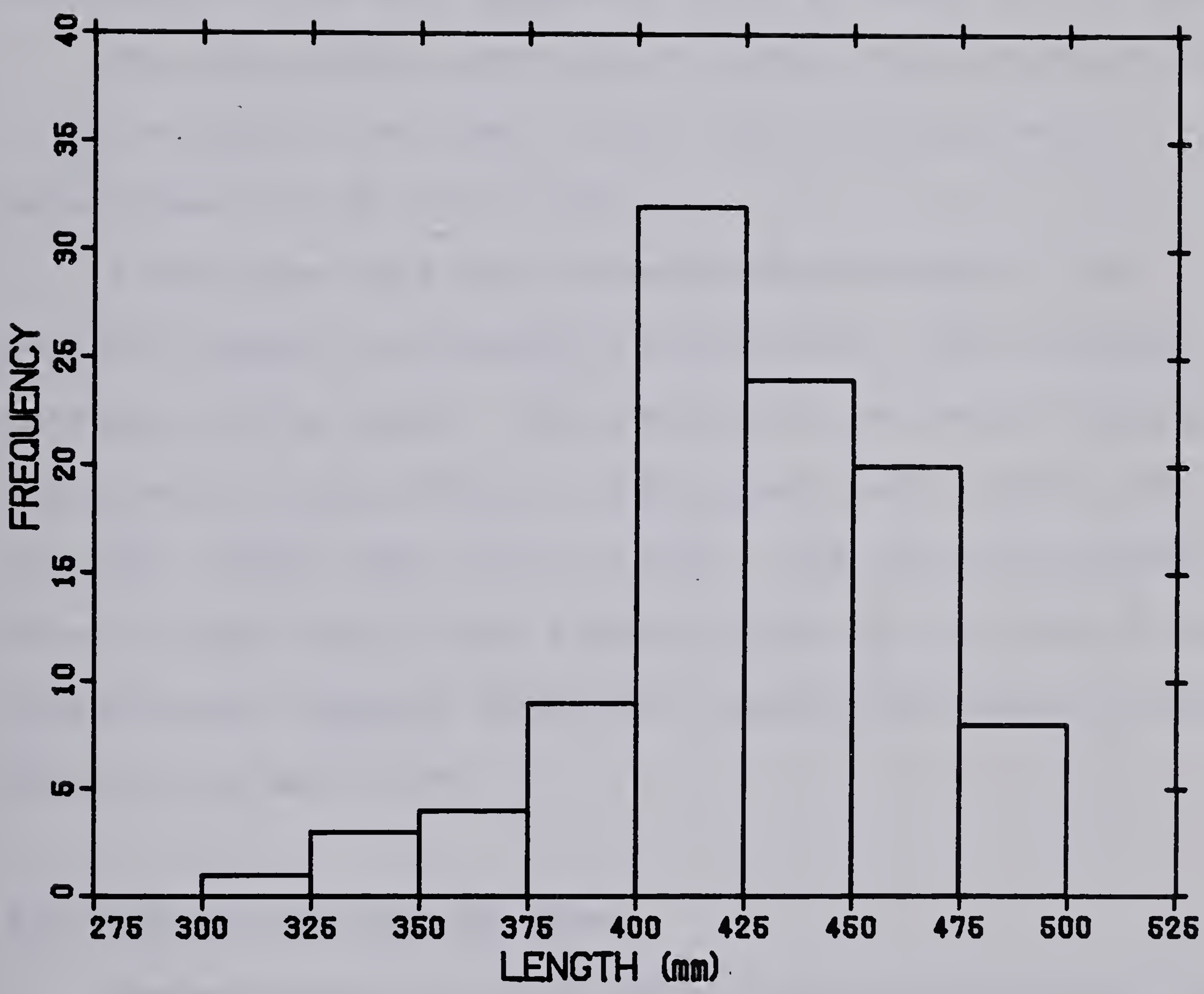


Fig. 50 Length frequency histogram of white sucker captured Silver Creek.

the angle times the value obtained by equation (10). However, the angle of the exit in these observations could not be properly estimated. Therefore, only equation (10) was used in calculating these velocities. It should be noted that the actual exit velocities would be higher, since the angle of the exit appeared to be at least 30° or more.

The three pike observed attained a maximum height of 75 - 100 cm during the jump. This would indicate exit velocities of 3.8 to 4.4 m/s.

A few pike were also observed downstream of the culvert, moving up through the shallower, fast flowing, portions of the creek. The pattern of movement contrasted with that of the suckers by being much more rapid, and straight rather than side to side. The pike also tended to move through weedy areas along the bottom or close to the stream bank, whenever possible, whereas the suckers remained more in the main flow.

6.2.2 Physical/chemical data

Temperatures in Silver Creek fluctuated between 5 and 13° C. during the study period. Conductivity ranged from 395 to 620 micromhos/cm, increasing as water levels in the creek dropped. Dissolved oxygen fluctuated between 10.6 and 16.8 mg/L. A summary of these three parameters for Silver Creek is outlined in Table C.9. None of these parameters appeared to be a contributing factor to the number of fish captured (i.e. moving up the creek).

6.3 Gwynne washout

Both the pike and white sucker favoured the higher velocity zones (B & C) as a route of ascent over the road washout. Both of these zones also exhibited greater water depth (in the high velocity zone) than the two side zones, A or D (Fig. 28).

Pike moving through zone B during observation period 2 (Table C.11) were timed (manually) in their ascent through the high velocity zone up onto the road. Times ranged between 1 and 3 seconds for a distance of about 2.4 m. If an average time of 2 seconds is used, this would indicate an overall average swimming velocity of 3.3 m/s for these pike (ranging in length from 30 - 45 cm).

The white suckers exhibited much more difficulty in overcoming the incline. However, this appeared to be almost exclusively due to the shallow water conditions. The much wider girth of the suckers resulted in several instances where an animal became stranded momentarily on weeds or gravel.

Two suckers were observed to move up the incline in an unimpeded manner. The timing was much slower than that of the pike (between 3 and 4 seconds) indicating an overall average swimming speed of 2.7 m/s, for specimens of 30 - 35 cm in length.

The pattern of movement for the two species was similar to the patterns observed at Silver Creek. The pike darted over the incline in a straight line, with rapid tail

fluctuations at a minimum of amplitude. The white sucker exhibited much larger amplitude tail movements at a slower speed, they moved in the characteristic side to side pattern.

6.4 Gwynne culvert

The ANOVA indicates no significant difference (5% level) in mean length of the pike moving through the culvert at the differing water velocities. As well, the frequency of different lengths is independent of the different velocities (5% level), as shown by the chi square analysis (Tables B.3 & B.4).

None of the pike captured in the culvert trap (Table C.13) were actually observed to enter the culvert, consequently, no timings were done on the duration of passage.

Due to the lack of a more extensive velocity profile on the water column in the culvert, little can be said on the swimming performance required of the pike as they moved through the culvert. The situation was complicated further by the entrapment of debris due to a sag half way along the length of the culvert. A steady, uninterrupted flow appeared to exist, however, and pike between 38 and 51 cm passed through the 12.4 m culvert.

The work of Katapodis, et al. (1978) indicated that the lowest velocities within a corrugated culvert appear along

the bottom, and that these bottom velocities do not vary to any great extent along the wetted perimeter. Observations of pike at Silver Creek and Gwynne washout, indicate that they tend to move in the zones of lowest velocity if confronted with a choice of higher and lower velocities. Thus the downstream velocities given in Table C.12 are an indicator, at least, of the minimum velocities against which these fish swam during their passage.

It is interesting that the length frequency distribution of pike moving through the culvert (Fig. 51) is skewed to the right. If the length frequency distribution found at the counting fence is assumed to be available downstream of the culvert, it would suggest that only those pike in the upper half of the distribution were moving through the culvert.

6.5 Steele Lake

6.5.1 Pike

Upon arrival at the Steele Lake site, it was found that the migration of pike into the lake was in progress. Indications were (Table C.16) that the run was at its peak or just beginning its downswing at the time set #1 was initiated.

No manipulation used in the ladder during the study resulted in an obstruction to pike or white sucker passage.

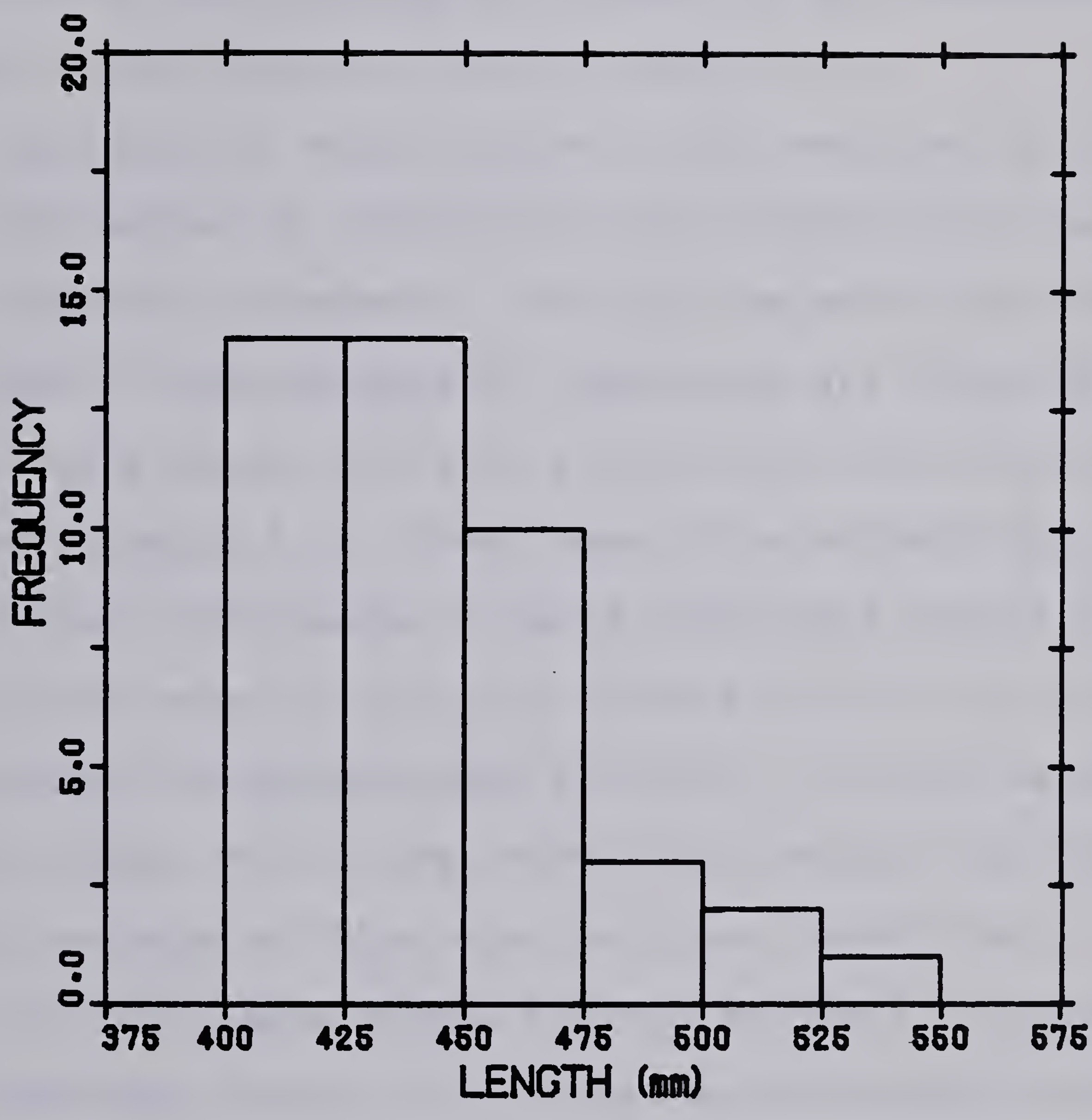


Fig. 51 Length frequency histogram of pike captured at the Gwynne culvert site.

Although a trend toward increasing length with increasing water velocity is apparent from the mean lengths given in Table B.5, the ANOVA indicates that no significant differences existed (5% level). The chi-square analysis indicates the frequency of the different lengths of pike observed to pass through the ladder to be independent (5% level) of the velocity setting (Table B.6).

This lack of significance is at least partially due to the high degree of variability of lengths within each of the four velocity groupings. When all the sets that were utilized in the analysis of velocities are compared by ANOVA, as a whole, still no significant differences are apparent (Table B.7). Even when it is evident that no significant differences existed among sets within a particular velocity grouping (Tables B.8 to B.10). If any significant difference were to occur, it would be expected at the higher velocities, since both smaller and larger fish should be able to negotiate the lower velocities.

It is at these higher velocities where the greatest data shortage occurs. Only three sets occurred within the fourth (highest) velocity grouping (Table C.16) and only one of these resulted in the capture of fish. Also, from Table C.16 it is apparent that the majority of the sets within the lowest velocity group occurred once pike numbers had decreased substantially. Only two sets were utilized in the lowest velocity group. The majority of the results occur within the second and third velocity groupings. Analysis by

chi-square for independence indicates that the range of pike lengths was not independent of time of day ($P < .05$), (Table B.12). This significance, however, may be a result of the fact that the greatest number of pike appeared to move during 1500 to 0300.

Table B.13 demonstrates that the various flow rates did not occur during each time of day, in fact, many of the sets were run between 1800 and 0600. This anomaly is strictly a result of the fact that most maintenance and errand activities for the project had to be conducted during normal working hours (i.e. 0600 to 1800).

The large differences in the number of sets (and consequently fish numbers) involved in each velocity class may have created a bias in the analysis. However, the lack of significance in each velocity group would be independent of this bias. Also, the ANOVA done on velocity groups V2 - V4 (at 1501 - 2100) also indicates a lack of significance (5% level) (Table B.11). In this case, fish numbers were about the same for each grouping. The confidence intervals about the means followed a pattern similar to that of the overall ANOVA.

6.5.1.1 Patterns of weir ascent

The route of ascent over each weir varied from individual to individual, although three general patterns recurred, these were:

(1) ascent through the flow in the centre region of the weir. The pike would usually surface just at the point where the nappe entered the lower pool, and would immediately swim through the flow without hesitation (Plate 7).

(2) ascent at either end of the weir. The pike generally surfaced as in (1), however, it would then move across the bay before darting over the weir close to the side wall of the ladder. In this case, the pike usually was partially emerged as it moved over the weir.

(3) ascent by jumping over the weir. The pike generally emerged in a leaping motion toward and over the weir. The point of emergence from the lower pool varied from just in front of the nappe, to as far as 30 cm back from the nappe. It appeared that it was usually the smaller pike which jumped. Clearance over the top of the nappe, during a successful jump, ranged from partial submergence to as much as 30 - 40 cm.

Patterns of movement similar to these were also described by Watters (1980) in his work on the Gregoire Lake step and pool ladder.

When a pike ascended a weir in the manner described in 1 or 2, the motions of the tail and body appeared quite similar to those described by Weihs (1973) for the rapid start. The initial stroke of the tail was usually large in amplitude, however, stage 3 oscillations (as the fish moved

Plate 7 A northern pike shown swimming over the #1 weir and into the ladder trap.

over the weir) were much smaller in amplitude and too rapid for the eye to follow consistently. The initial high amplitude stroke (in the case of the larger pike) was generally sufficient to lift the animal through the nappe. The shorter, faster strokes were then used to carry it across the weir and into the next pool. Generally, the time required to ascend a weir was 1 second or less, although this varied with the size of the pike.

Variation also existed in the overall pattern of movement through the ladder. Several pike were observed to move quickly through 2 or 3 bays in a row before resting. These multiple weir ascents were accomplished in 3 to 5 s (depending on the number of bays ascended) with the animal remaining in the upper portion of the bay as it moved from one weir to the next. Most pike, however, moved through the ladder more slowly, stopping to rest (presumably) in each pool before attempting the next weir. Since most observations on movements were done when pike numbers were greatest, several pike were constantly moving in and out of resting pools at any one time, thus no indication of resting times could be summized.

6.5.1.2 Other observations

During the heavier periods of movement (May 14 - 16) large numbers of pike were observed to congregate in front of the stabilization weir, at the point of the hydraulic jump. Many of these pike were seen to leap at the cascade

of water created by the hydraulic jump, sometimes landing heavily against the steel of the stabilization weir or outside of the ladder. These leaps appeared to range between 50 and 75 cm, indicating an exit velocity of 3.1 to 3.8 m/s by equation (10). One pike (estimated at 40 - 50 cm in length) observed jumping in the ladder, hit the bottom of a walking plank laid across the top of the ladder. The distance from the water surface to the plank was 65 cm, indicating an exit velocity of at least 3.6 m/s.

Another pike (estimated at 50 cm in length) was observed to swim into the flow over the first weir, and maintain its postion there for at least 10 seconds (counted manually) before continuing over into the trap. The velocity over the weir was measured as 1.20 m/s.

No previous monitoring work has been done on the fish population of Steele Lake (Zelt, 1982, person. comm.). The length vs. weight relationship outlined in Fig. 52, however, is similar to that obtained for Driedmeat Lake. The length of pike captured at Steele Lake ranged from 380 to 660 mm, with a mean of 535 mm (substantially different from Driedmeat Lake). The majority of pike captured fell in the range of 450 to 580 mm (Fig. 53).

Sexual condition was assessed for 557 of the pike captured in the ladder trap. Of these, 466 were male and 91 female (or a ratio of about 5/1). Length/weight relationships for each sex are presented in Figures 54 and 55.

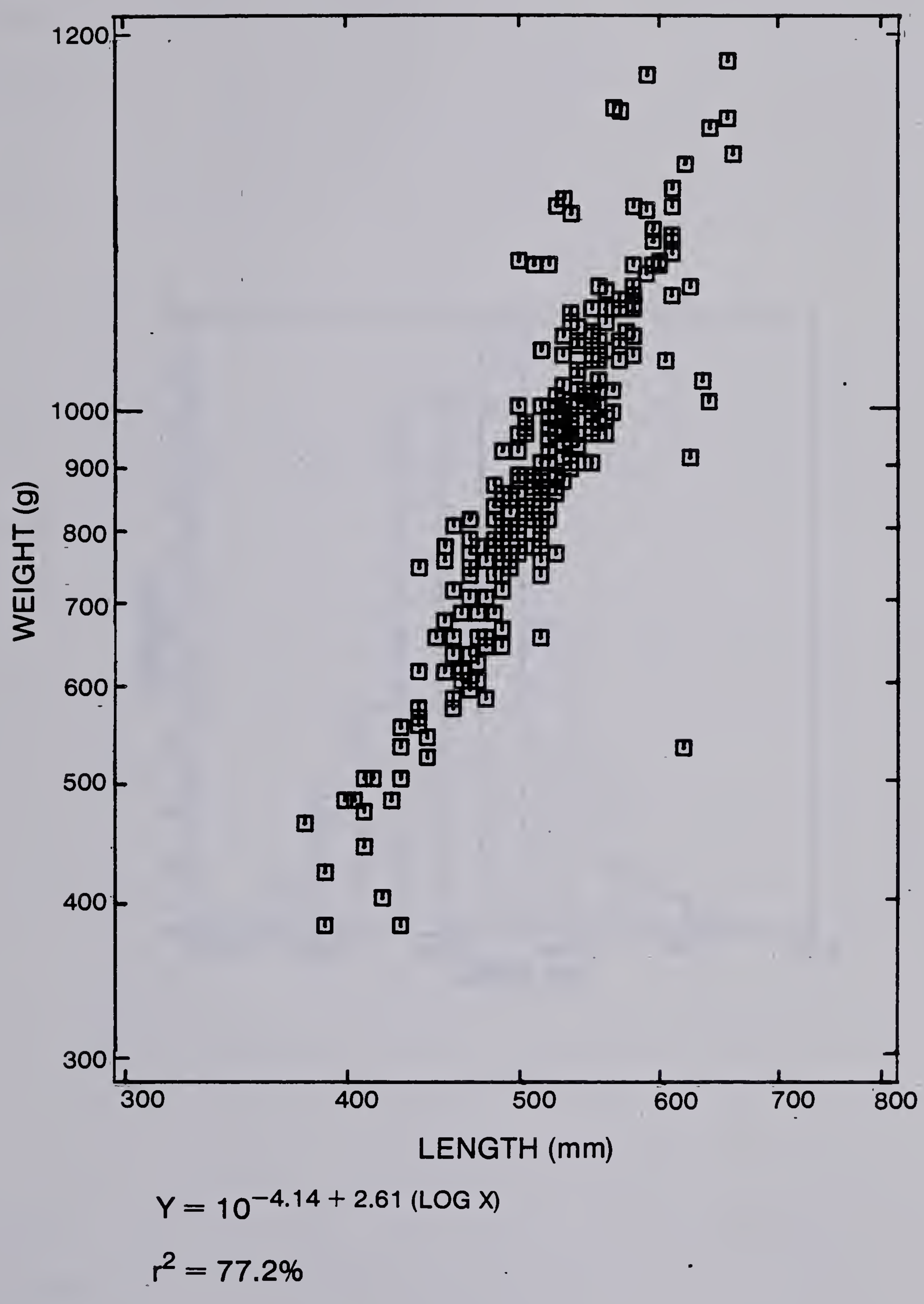


Fig. 52 A log-log length vs. weight plot of pike captured at Steele Lake.

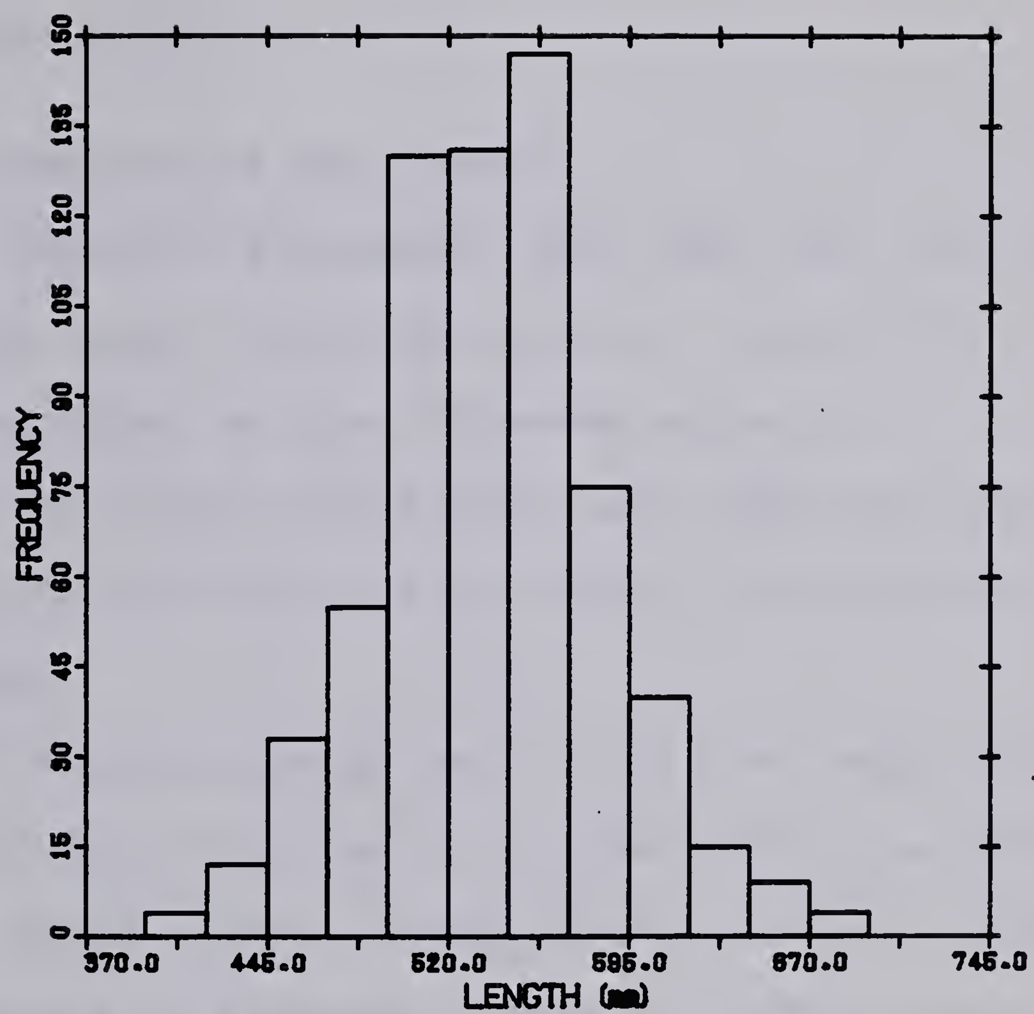


Fig. 53 Length frequency histogram of pike captured at Steele Lake.

Of the 466 males, 4 were assessed as ripe, 381 as still expressing and 81 as spent. Of the 91 females, 0 were assessed as ripe, 4 as still expressing and 87 as spent. Ages of the pike ranged from 2 to 8 years (using both scales and cleithra) with the modal ages being 4 and 5 years.

6.5.2 White sucker

6.5.2.1 Patterns of weir ascent

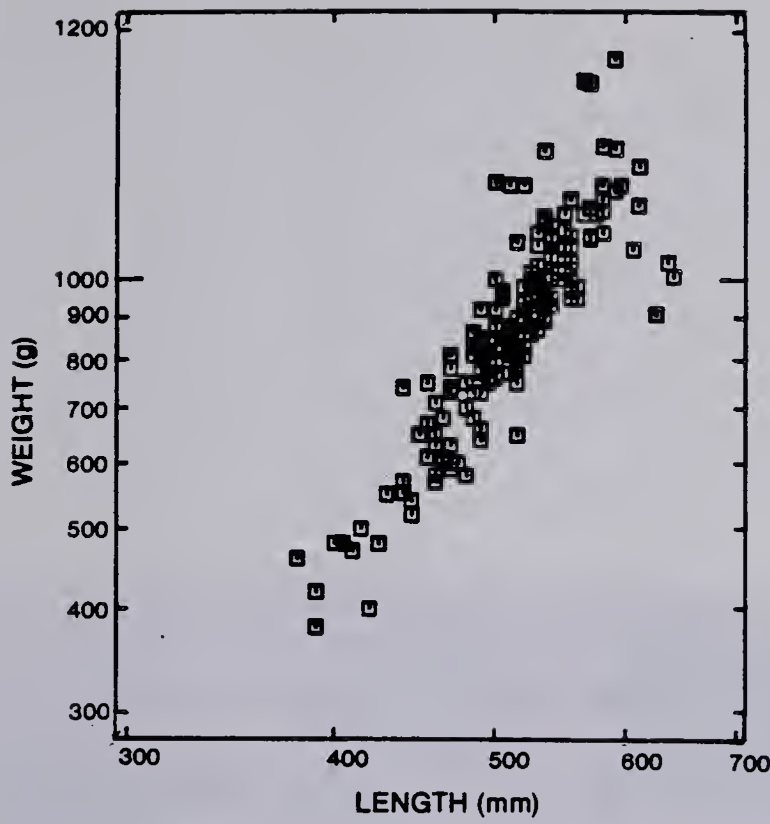
The pattern of movement over each weir was much more homogenous among the white suckers. Generally, this pattern can be described by the following sequence:

(1) The sucker would move back and forth just under the surface in front and/or behind the bottom of the nappe.

(2) When an attempt at the flow was made, the sucker would initially meet the flow head on as did the pike, but would quickly begin moving laterally across the nappe as it ascended (Plate 8). This lateral movement would sometimes occur in both directions, with the fish first moving to one side and then switching directions.

As a result of this lateral motion, the overall ascent lasted from 2 to 5 s. No sucker was ever observed to attempt to move over two weirs successively without a rest.

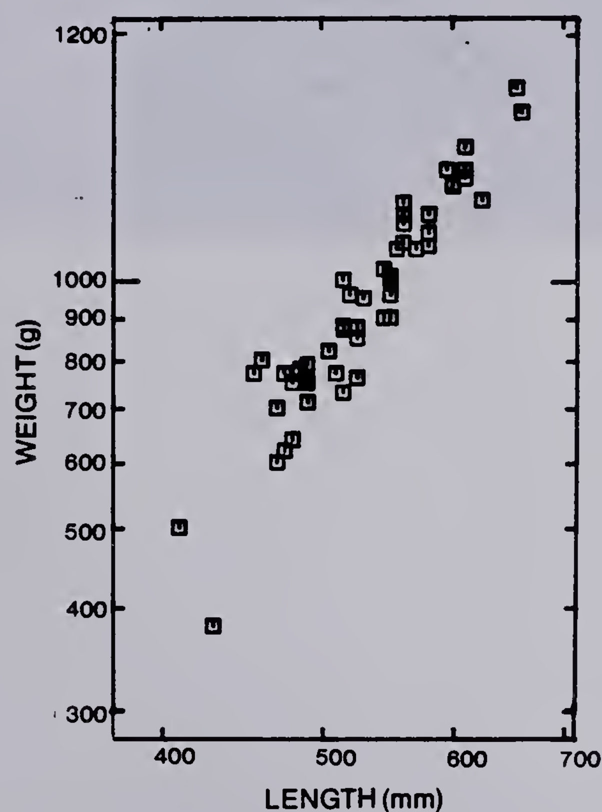
The motions of the tail and body were similar to that of the pike for the initial stroke. However, subsequent stage 3 oscillations continued to be of a large amplitude



$Y = 10^{-4.26 + 2.65 (LOG X)}$

$r^2 = 88.3\%$

Fig. 54 A log-log length vs. weight plot of male pike captured at Steele Lake.



$Y = 10^{-3.88 + 2.56 (LOG X)}$

$r^2 = 70.5\%$

Fig. 55 A log-log length vs. weight plot of female pike captured at Steele Lake.

Plate 8 A white sucker shown swimming over the #1 weir and into the ladder trap at Steele Lake.

stroke (Plate 9). For the suckers, the initial stroke never carried the animal as far into the nappe as with the pike. Resting times between ascents varied from 5 to 15 minutes.

Sexual condition was assessed for 51 white suckers captured in the ladder trap. Of these, 31 were male and 20 were female (a ratio of about 1.5/1). Of the 31 males, 29 were ripe, 1 still expressing and 1 spent. Of the 20 females, 0 were ripe, 0 were still expressing, 3 were assessed as spent, and 17 were considered to be still in a non-ovulating state.

As with the pike, it appeared that the white suckers were capable of ascending the fishladder under all the velocity conditions produced. The length of suckers captured ranged from 350 mm to 540 mm, with a mean of 415 mm. The suckers, however, appeared to undergo greater stress than pike in their ascent of the ladder.

6.5.3 Physical/chemical data

Ice break up occurred on Steele Lake about May 11 or 12 (Yanicki, 1982, person. comm.). Upon arrival at the site on May 14, water temperatures were already 11° C. Temperature increased slightly until May 19, and then stabalized in the 13 - 16° C range for the remainder of the study. Temperatures upstream and downstream of the weir varied little (Tables C.19 & C.20).

Specific conductance fluctuated little, remaining between 185 and 210 micromhos/cm throughout. Upstream and

Plate 9 A white sucker shown moving through the orifice set up of manipulation #10 at Steele Lake.

downstream values varied little.

Dissolved oxygen remained fairly consistent throughout, ranging from 9.3 to 14.5 mg/L. Again, little difference was observed between upstream and downstream values.

6.5.4 Velocity profiles and discharge

The profiles provided in Figs. C.1 - C.4 indicate a submerged condition of the weirs throughout the study. Consequently, a streaming flow was characteristic to all eight of these manipulations, with only minimal velocities in the lower layers of each bay, and little energy dissipation between weirs. This streaming flow appeared to predominate even at head levels as low as 15 cm. This is in contrast to the head levels given by Pretious, et al. (1957, cited in Clay, 1961) of 30 cm or less for plunging flow and greater than 35 cm for streaming flow.

Although such authors as Jens (1973) advise against the streaming flow, submerged weir condition, it did not appear to affect the ability of either the pike or sucker to successfully ascend the ladder. As well, at the lower head levels (in the ladder) the velocity of the attraction water leaving the ladder was sharply decreased (Figs. C.1 - C.4, and Plate 10A & B) although insufficient data are available to determine if this was a factor in the ability of the fish to find the ladder.

No profiles were done on manipulations 9 & 10, however, observations were noted. Flows during manipulation 9 were

Plate 10 Entrance of Steele Lake ladder during set #20 (above) and set #47 (below).

reduced considerably (Table C.16) and a free flow of the nappe established. However, very few fish were captured during these sets.

Manipulation 10 was similar in its flow characteristics to manipulations 1 through 8. The main difference being in the installment of the orifice over the number 2 weir. Both pike and white sucker were observed to swim through this orifice, against the 1.6 m/s (mean velocity) flow.

From Plate 11 it can be seen that the fishladder at Steele Lake is a structure of substantial size in comparison with the stabilization weir as a whole. The width of the ladder is, in fact, 22% of the width of the main weir. Consequently, discharge through the ladder often equaled or exceeded the discharge over the adjacent weir (Table C.15), depending on the number of stop logs placed on top of the first weir, and the level of the lake itself.

6.6 Tag Recaptures

All tagged fish recaptured by anglers are summarized in Tables C.21 & C.22 (Sloman, 1982).

At both the Driedmeat and Steele Lake locations, no fish died during tagging operations and all appeared to recover quickly once released. The recapture data indicate that some of the pike, at least, survived the tagging operation in the longer term.

Plate 11 Steele Lake stabilization weir and fishladder, looking upstream.

6.6.1 Driedmeat Lake

Several of the pike tagged at the Gwynne culvert site subsequently moved upstream into Pipestone Creek, where they were caught below the Coal Lake spillway.

6.6.2 Steele Lake

Tagging results suggest that most of the pike tagged at the ladder moved into the lake for the duration of the summer. One recapture, however, (tag# 10454) was caught about 1 month later in the Pembina River, approximately 80 km (by water) from the weir site.

7. Summary and Conclusions

The flood conditions which took place at Driedmeat Lake rendered the step and pool fishladder inoperable. However, due to the extent of the flooding, both pike and white sucker were able to migrate up into the lake by moving around the weir.

Except for the delay in the migrations, biological data (such as length vs. weight relationships) are in agreement with the work of Rhude (1980). The extent of the white sucker movement appeared to be greater than that of the pike.

Due to the inoperative nature of the fishladder at Driedmeat, alternative performance studies on pike and white sucker were conducted.

The performance of white sucker was assessed at Silver Creek by directing the fish to swim through a "venturi-like" chute device, which was monitored for water velocity. Pike movements were monitored here as well, including observations on jumping ability.

Both pike and white sucker were observed to swim through a wide range of velocities at a road washout near the town of Gwynne. Pike were also found to pass through a 12 m long road culvert at this same location.

Observations on pike swimming performance at the various sites involved in the study, support the high burst speed capabilities suspected of this species. At no time was a flow produced which totally blocked the passage of

pike or white sucker. Although observations indicate the ability of white sucker to navigate all flows that were produced, the burst speed performance of this species appears to be inferior to that of the pike.

The high initial acceleration of pike during a darting movement (Weihs, 1973 & Webb, 1980) would appear to be the key to their success in short distance, short duration sprints against high water velocities. The use of quick, low amplitude tail movements after initial acceleration allows the pike to maximize the advantage of its torpedo shape during sprint movements.

This high initial acceleration appears most evident in the jumping ability of the pike, demonstrating exit velocities of 3.1 to 4.4 m/s for pike of 300 to 500 mm in length. The observation at the Gwynne washout of pike to move at 3.3 m/s over a distance of 2.4 m indicates that this level of performance is sustainable for at least 1 to 2 seconds and distances of 2 to 3 m.

From these observations of pike performance at the Driedmeat study sites, it would be expected that the pike should perform reasonably well in a step and pool fish ladder situation, where burst levels of swimming activity are required for only very short distances (less than 1.0 m). In fact, this is what was observed at the Steele Lake ladder, where the pike were able to overcome, without apparent stress, critical nappe velocities within the ladder of up to 3.0 m/s. The lack of significance in mean length

of pike at the different velocities demonstrates that pike of 350 mm in length and greater are capable of moving through the ladder under the flow conditions which existed.

The streaming flow conditions which did exist in the ladder seemed to have little effect on the ability of the pike (or sucker) to move through the full length of the ladder. In fact, several pike were observed to quickly move over two or three weirs in a row (2 to 3 m) without stopping. During these extended maneuvres, the pike remained in the upper (higher velocity) zones of the bays. This indicates a probable speed of 1.5 to 2.0 m/s.

The movement of both the pike and sucker through the ladder appeared to be unimpeded by the presence of light (i.e. lack of a covering over the ladder) or even the presence of the investigators overhead, observing their movements. Table B.12 indicates that the largest number of pike were captured during the latter half of the day (1500 - 0300) demonstrating an apparent preference in diel movements. Koshinsky (1979) however, found no, "consistent diel migratory behavior", in Lac la Ronge pike, although his comparison was strictly between times of darkness and times of light. Hildebrand (1980) on the other hand indicates that, "it is generally assumed that fish do not move actively during darkness.". The most preferred hours of movement at Steele Lake included both daylight and darkness. Interestingly, a similar pattern of movement was observed at the Driedmeat counting fence. Pike appeared to

move most actively between 1800 and 0300 hours.

Summary of all observations on pike swimming performance would indicate that this species (for individuals 400 mm and longer) is capable of swimming at speeds of 2.5 to 3.0 m/s over distances of 2 to 3 m (more or less) depending on water velocity. In the case of very short term bursts of speed (such as jumping or moving through the nappe over a weir) pike appear to be capable of attaining velocities as high as 4.0 m/s or more, depending on fish length.

These data support the findings of Bainbridge (1958), Gray (1957) and others, that burst speed swimming is a short duration activity. Bainbridge (1960) concluded that fish can generally maintain a burst speed performance of 10 lengths/s for up to 1 s, and 5 lengths/s for up to 10 s. Hildebrand (1980) indicates 8 lengths/s as a burst speed criterion. The regression (Fig 13) on the burst speed performance data summarized by Beamish (1978) also indicates a burst speed capability of 10 lengths/s, although times were not specified.

In this study, exit speeds of jumping pike, as well as observations at the Steele Lake ladder, indicate that pike lie in this range of 8 to 10 lengths/s for periods of 1 s or less. Longer term performance is less clear, although one 50 cm pike was observed to maintain a speed of 1.2 m/s for 10 s at Steele Lake.

Such swimming performance has implications when considering the use of other fishladders such as the denil, for the passage of pike. Depending on the velocity of the water moving through the denil, the ability of the pike to maneuvre the ladder will depend on its length. For example, these data suggest that a 30 cm pike may be capable of moving 3 to 4 m against velocities of 1 to 2 m/s. Thus, it may be necessary to provide resting pools in the denil every 4 or 5 m depending on the water velocities which can exist in the ladder.

As indicated, the burst speed capability of the white sucker appeared to be inferior to that of the pike. At the Steele Lake ladder for instance, a greater number of sucker (on a proportional basis) were observed to fail in attempts at moving over a weir, than with the pike. At the higher velocities, it appeared that the inability of the suckers to attain the same high initial acceleration of the pike, was a major reason for their poorer performance in moving up through the nappe.

The lack of other biological data for pike at Steele Lake is important in terms of the high mean length of pike captured at the fishladder (535 mm). The mean length of pike captured in other Alberta lakes by such techniques as angling, tends to lie between 400 and 500 mm (Mackay, 1982, person. comm.). If the actual mean length of pike in Steele Lake lies in this range, the results obtained for the fishway may indicate a size bias for larger pike.

The depressed movement of pike through the Fawcett Lake step and pool ladder observed by Minchau (1980) may have been a function of either flow characteristics or the downstream tagging operation carried out on approaching pike. The data of this study suggest that the velocities throughout the Fawcett ladder, as recorded by Minchau, should have been within the performance capability of pike. Also, the velocity profiles of Minchau suggest a streaming flow pattern, as was the case at Steele Lake. At Steele Lake, this type of flow seemed to exhibit little observable effect on the performance of the fish. It appears that the prior tagging of the pike, before ascent of the ladder, may have affected their performance.

Of 50 pike captured (between May 23 and 26) in the Steele Lake ladder trap, tagged, and released downstream, only 3 were subsequently recaptured again in the ladder trap. However, for 37 white sucker, tagged, and released downstream (during the same period) 8 were recaptured again in the ladder trap. One of these was recaptured twice, the first time within 12 hours of release.

Finally, although both pike and sucker were able to navigate the step and pool fishladder at Steele Lake, two factors need to be considered for the interpretation of this success.

First, it is unclear as to what percentage of the pike which were attempting to move into the lake, actually found the ladder entrance. It is clear that many individuals were

delayed (and possibly injured) at the hydraulic jump of the weir.

Second, the step and pool ladder remained operational throughout the study only because of the constant maintenance provided. Without the maintenance the ladder could have easily become inoperable due to debris build-up or a sudden drop in water levels or if spring runoff were below average.

8. Recommendations

All recommendations given will apply mainly to the Steele Lake fishladder, since it was the only ladder which was functioning during the investigation of the two sites.

The inadequacy of the step and pool fishladder to handle fluctuations in water levels and remain operable without monitoring throughout the fish run, was apparent at Steele Lake. A substantial amount of maintenance was required throughout the monitoring period to ensure that the ladder remained functional. Observations indicate that a large number of pike actually missed the ladder entrance in their upstream approach, and may have wasted excessive time at the hydraulic jump (possibly injuring themselves) before finding the entrance.

Even though the Steele Lake ladder did pass fish during this study, there are some changes that could be implemented, which I believe would improve it's efficiency.

(1) The entrance to the ladder should be moved upstream so as to lie more in line with the crest of the spillway created by the hydraulic jump. The exact distance of relocation will depend on the average and maximum heads which can be expected according to hydrographic records. This should ensure that the majority of fish will find the ladder entrance more easily.

(2) The exit of the ladder should be moved further back from the stabilization weir, so as to prevent the

possibility of fish being swept back downstream once they emerge from the ladder. If (1) above were implemented, this would automatically result in the relocation of the exit further upstream.

(3) A trash rack should be included in the design. This would assist in preventing debris buildup in the ladder.

(4) Easier access should be provided to the fishway for monitoring purposes. This would include a walkway from the shore area out to the structure, as well as a covering over the fishway (preferably panels of steel grating).

(5) Provisions should be made for monitoring fish movement. This could be done through the use of a resting bay just prior to the exit of the ladder. Provisions for a portable trap should also be considered for periods when water clarity is reduced.

Since no assessment could be done on fish passage through the Driedmeat ladder, few specific suggestions can be made in this regard. However, it is apparent that this ladder is also very sensitive to water level changes (because of its step and pool design).

The use of stop logs to make up the weirs of the ladder demonstrated specific flaws. It was found that as ice breakup occurred, and ice flows moved downstream, several of these flows moved through the ladder. As the flows moved through the ladder, they would strike the top logs of the

weirs, eventually jarring loose the wedges which held the logs in place. This in turn permitted the logs to float up and escape from the ladder. This problem could be solved by installation of a trash deflector upstream of the ladder.

The flood level conditions which occurred at Driedmeat demonstrate what can happen when the top elevation of the fishladder is only 30 cm above that of the stabilization weir. Fortunately, in the case of Driedmeat, the contours of the land at the edges of the outlet are shallow enough to permit access (for the fish) around the weir at high flows.

Finally, the migration of pike into Steele Lake provides an excellent opportunity for in situ studies on pike (and white sucker) swimming performance, for the following reasons.

(1) The migration is quite extensive (it appears that during the peak movement, at least 60 pike were moving through the ladder every hour).

(2) The combination of the fishladder and stabilization weir appear to regulate water levels quite well. French Creek, immediately downstream of the weir, remained fairly shallow and reasonably clear throughout the migration.

(3) The site is located within a provincial park, and has good access by vehicle.

Due to the shallow nature of the creek, the site would be appropriate for the installation of an in situ monitoring device to measure fish swimming performance. The device

could be designed similar to the Driedmeat chute fence (Fig. 24). Fish moving upstream would be led into the chute by downstream wings. Water velocities within the chute could be controlled by the funnelling effect of the upstream (plywood) fence, as well as the width setting of the chute. One or more water pumps could also be used to increase velocities moving through the chute.

This site would also provide a good opportunity to study the performance of pike in a denil or vertical slot fishway, if the present step and pool were replaced, as recommended.

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Appendix A

A.1 Driedmeat Lake Data

A list of all relevant fish data collected at the Driedmeat study sites is provided. These sites include:

(1) Driedmeat counting fences

(2) seining results

(3) Silver Creek

(4) Gwynne culvert

The data are arranged according to tag number, with eight parameters listed for each specimen. These parameters are defined as follows:

(1) Tag - The fluorescent red (Dept. of Environment) tags are given the prefix "10", followed by the relevant digits of the tag.

(eg.) 10153 corresponds to tag #B000153.

The white (Dept. of Fish and Wildlife) tags are given the prefix "20" followed by the relevant digits of the tag.

(eg.) 202250 corresponds to tag #R02250.

(2) Species - The number "1" refers to northern pike (*Esox lucius*).

The number "2" refers to white sucker (*Catastomus commersonii*).

(3) Location - "1" refers to the Driedmeat stabilization weir, #1 counting fence and chute fence.
"2" refers to downstream of the Driedmeat stabilization weir (eg. seine hauls).
"3" refers to Silver Creek
"4" refers to Gwynne culvert.

(4) Sex - A two digit number. The first number defines sex:

1 = male
2 = female
3 = unknown

The second number defines sexual condition:

0 = unknown
1 = ripe
2 = Expressing
3 = partial express (probably spent)
4 = spent
5 = non-ovulating

For example, 14; refers to a male, spent.

(5) Time - Refers to the time of release on the 24 hour clock.

(6) Date - Refers to the date of the tagging. The date is listed in the order of; day/month/year, with each category seperated by the digit "0".

(eg.) 3004082 designates the 30th day of the 4th month of the year 1982.

(7) Length - The length of the fish in millimeters.

(8) Weight - The weight of the fish in grams.

Note: In cases where data are missing or none was taken a series of *'s are given.

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
101.	1.	736.	2104082.	2.	30.	*****	*****
102.	1.	737.	2104082.	2.	30.	*****	*****
103.	1.	1805.	2104082.	2.	30.	*****	*****
104.	1.	1824.	2104082.	2.	30.	*****	*****
105.	1.	1831.	2104082.	2.	30.	*****	*****
106.	1.	1834.	2104082.	2.	30.	*****	*****
107.	1.	1840.	2104082.	2.	30.	*****	*****
108.	1.	1847.	2104082.	2.	30.	*****	*****
109.	1.	1855.	2104082.	2.	30.	*****	*****
1010.	1.	1858.	2104082.	2.	30.	*****	*****
1011.	1.	1902.	2104082.	2.	30.	*****	*****
1012.	1.	1905.	2104082.	2.	30.	*****	*****
1013.	1.	1907.	2104082.	2.	30.	*****	*****
1015.	1.	935.	1005082.	1.	24.	382.	270.
1016.	1.	1913.	2104082.	2.	30.	*****	*****
1017.	1.	1915.	2104082.	2.	30.	*****	*****
1018.	1.	1920.	2104082.	2.	30.	*****	*****
1019.	1.	1921.	2104082.	2.	30.	*****	*****
1020.	1.	1926.	2104082.	2.	30.	*****	*****
1021.	1.	1931.	2104082.	2.	30.	*****	*****
1022.	1.	1934.	2104082.	2.	30.	*****	*****
1023.	1.	1937.	2104082.	2.	30.	*****	*****
1024.	1.	1938.	2104082.	2.	30.	*****	*****
1025.	1.	1940.	2104082.	2.	30.	*****	*****
1054.	1.	2034.	3004082.	2.	24.	*****	*****
1055.	1.	2137.	3004082.	2.	30.	*****	*****
1056.	1.	2131.	105082.	2.	30.	*****	*****
1056.	1.	2131.	105082.	2.	30.	*****	*****
1057.	1.	2035.	3004082.	2.	12.	*****	*****
1058.	1.	2036.	3004082.	2.	21.	*****	*****
1059.	2.	925.	105082.	1.	12.	413.	*****
1060.	1.	2036.	3004082.	2.	30.	*****	*****
1061.	1.	2037.	3004082.	2.	11.	*****	*****
1062.	1.	2052.	3004082.	2.	21.	*****	*****
1063.	2.	925.	105082.	1.	11.	415.	*****
1064.	1.	2053.	3004082.	2.	30.	*****	*****
1065.	1.	2053.	3004082.	2.	30.	*****	*****
1066.	1.	2136.	3004082.	2.	11.	*****	*****
1067.	1.	2053.	3004082.	2.	21.	*****	*****
1068.	1.	820.	305082.	1.	21.	484.	*****
1069.	1.	2104.	3004082.	2.	30.	*****	*****
1070.	1.	2130.	3004082.	2.	30.	*****	*****
1071.	1.	2130.	3004082.	2.	12.	*****	*****
1073.	1.	2135.	3004082.	2.	12.	*****	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
1074.	1.	2135.	3004082.	2.	30.	*****	*****
1075.	1.	2131.	3004082.	2.	21.	*****	*****
1076.	1.	2101.	105082.	2.	30.	*****	*****
1077.	1.	2102.	105082.	2.	12.	*****	*****
1079.	1.	2100.	105082.	2.	12.	*****	*****
1080.	1.	2101.	105082.	2.	12.	*****	*****
1081.	1.	2102.	105082.	2.	30.	*****	*****
1082.	1.	2101.	105082.	2.	12.	*****	*****
1083.	1.	2100.	105082.	2.	12.	*****	*****
1084.	1.	820.	305082.	1.	21.	370.	*****
1084.	1.	800.	305082.	1.	30.	*****	*****
1085.	1.	800.	205082.	2.	30.	*****	*****
1086.	1.	820.	305082.	1.	30.	380.	*****
1086.	1.	800.	305082.	1.	30.	*****	*****
1087.	1.	800.	305082.	2.	30.	*****	*****
1088.	1.	2125.	105082.	2.	12.	*****	*****
1089.	1.	820.	305082.	1.	30.	327.	*****
1089.	1.	800.	305082.	1.	30.	*****	*****
1090.	1.	2125.	105082.	2.	22.	*****	*****
1091.	1.	800.	205082.	2.	30.	*****	*****
1092.	1.	820.	305082.	1.	30.	360.	*****
1093.	1.	2140.	205082.	2.	11.	*****	*****
1094.	1.	820.	305082.	1.	21.	472.	*****
1095.	1.	2144.	205082.	2.	22.	*****	*****
1096.	1.	2144.	205082.	2.	12.	*****	*****
1097.	1.	820.	305082.	1.	21.	474.	*****
1098.	1.	2145.	205082.	2.	12.	*****	*****
1099.	1.	820.	305082.	1.	12.	350.	*****
10100.	1.	2145.	205082.	2.	30.	*****	*****
10101.	1.	820.	305082.	1.	21.	387.	*****
10102.	1.	820.	305082.	1.	12.	312.	*****
10103.	1.	1230.	305082.	3.	21.	320.	*****
10104.	2.	1259.	305082.	3.	30.	530.	*****
10105.	1.	1303.	305082.	3.	21.	390.	*****
10106.	2.	1321.	805082.	3.	11.	460.	*****
10106.	2.	1310.	305082.	3.	11.	460.	*****
10107.	2.	1307.	805082.	3.	21.	*****	*****
10107.	2.	1327.	305082.	3.	20.	365.	*****
10108.	1.	1345.	305082.	3.	12.	330.	*****
10109.	1.	1353.	305082.	3.	12.	375.	*****
10110.	1.	1347.	305082.	3.	12.	340.	*****
10111.	1.	900.	405082.	1.	21.	385.	*****
10112.	1.	1430.	305082.	3.	12.	353.	*****
10114.	1.	900.	405082.	1.	21.	497.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10115.	1.	900.	405082.	1.	12.	370.	*****
10117.	1.	900.	405082.	1.	21.	370.	*****
10118.	2.	925.	1005082.	1.	11.	374.	940.
10119.	1.	900.	405082.	1.	30.	370.	*****
10120.	1.	900.	405082.	1.	30.	307.	*****
10121.	1.	900.	405082.	1.	12.	450.	*****
10122.	1.	900.	405082.	1.	21.	470.	*****
10123.	2.	925.	1005082.	1.	25.	424.	*****
10126.	1.	910.	505082.	1.	21.	464.	*****
10127.	1.	910.	505082.	1.	12.	482.	*****
10128.	1.	910.	505082.	1.	21.	380.	*****
10129.	1.	910.	505082.	1.	21.	490.	*****
10130.	2.	925.	1005082.	1.	25.	410.	1040.
10131.	1.	1032.	605082.	3.	30.	290.	*****
10132.	2.	840.	805082.	1.	20.	432.	1130.
10133.	2.	840.	805082.	1.	24.	460.	*****
10134.	2.	1100.	1305082.	1.	11.	400.	990.
10135.	1.	840.	805082.	1.	24.	682.	2280.
10136.	2.	840.	805082.	1.	13.	388.	860.
10137.	2.	1317.	805082.	3.	25.	385.	*****
10138.	2.	1315.	805082.	3.	20.	425.	*****
10139.	2.	1317.	805082.	3.	11.	380.	*****
10140.	2.	1315.	805082.	3.	21.	425.	*****
10141.	2.	1314.	805082.	3.	11.	425.	*****
10142.	2.	1315.	805082.	3.	11.	310.	*****
10143.	2.	1314.	805082.	3.	11.	410.	*****
10144.	2.	1314.	805082.	3.	11.	400.	*****
10145.	2.	1321.	805082.	3.	11.	420.	*****
10146.	2.	1321.	805082.	3.	21.	475.	*****
10147.	2.	925.	1005082.	1.	25.	400.	970.
10149.	1.	1532.	805082.	4.	30.	441.	*****
10150.	1.	1543.	805082.	4.	13.	420.	*****
10151.	1.	1936.	605082.	4.	30.	470.	*****
10152.	1.	1932.	605082.	4.	21.	515.	*****
10153.	1.	1935.	605082.	4.	30.	415.	*****
10154.	1.	1936.	605082.	4.	30.	440.	*****
10155.	1.	1933.	605082.	4.	11.	425.	*****
10156.	1.	1934.	605082.	4.	12.	460.	*****
10157.	1.	1936.	605082.	4.	11.	400.	*****
10158.	1.	1934.	605082.	4.	22.	435.	*****
10159.	1.	1532.	805082.	4.	****	*****	*****
10161.	1.	923.	705082.	4.	11.	465.	*****
10162.	2.	925.	1005082.	1.	10.	469.	*****
10163.	1.	922.	705082.	4.	12.	400.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10164.	1.	934.	705082.	4.	12.	390.	*****
10165.	1.	924.	705082.	4.	30.	445.	*****
10166.	2.	925.	1005082.	1.	11.	408.	*****
10167.	1.	925.	705082.	4.	30.	430.	*****
10168.	1.	921.	705082.	4.	12.	405.	*****
10169.	1.	924.	705082.	4.	30.	425.	*****
10170.	1.	921.	705082.	4.	22.	450.	*****
10171.	1.	930.	705082.	4.	30.	415.	*****
10172.	1.	930.	705082.	4.	30.	420.	*****
10173.	1.	932.	705082.	4.	11.	390.	*****
10173.	1.	2115.	705082.	4.	12.	385.	*****
10174.	1.	933.	705082.	4.	30.	400.	*****
10175.	1.	932.	705082.	4.	30.	397.	*****
10176.	1.	930.	705082.	4.	21.	397.	*****
10177.	1.	931.	705082.	4.	30.	480.	*****
10178.	2.	925.	1005082.	1.	25.	388.	990.
10179.	1.	929.	705082.	4.	30.	450.	*****
10180.	1.	935.	705082.	4.	12.	390.	*****
10181.	1.	934.	705082.	4.	12.	390.	*****
10182.	1.	2115.	705082.	4.	12.	390.	*****
10183.	1.	2115.	705082.	4.	12.	440.	*****
10184.	1.	2100.	705082.	4.	12.	400.	*****
10185.	2.	925.	1005082.	1.	25.	448.	1240.
10186.	1.	2115.	705082.	4.	12.	415.	*****
10187.	1.	2100.	705082.	4.	21.	430.	*****
10188.	2.	925.	1005082.	1.	25.	410.	1030.
10189.	1.	2100.	705082.	4.	12.	390.	*****
10190.	1.	1534.	805082.	4.	13.	498.	*****
10191.	2.	925.	1005082.	1.	25.	421.	*****
10192.	1.	1534.	805082.	4.	13.	418.	*****
10193.	1.	1534.	805082.	4.	13.	422.	*****
10194.	2.	925.	1005082.	1.	11.	391.	1010.
10195.	1.	1534.	805082.	4.	13.	412.	*****
10196.	1.	1532.	805082.	4.	13.	418.	*****
10197.	1.	1532.	805082.	4.	13.	408.	*****
10198.	1.	1532.	805082.	4.	24.	399.	*****
10199.	1.	1532.	805082.	4.	13.	432.	*****
10203.	1.	2110.	805082.	4.	24.	424.	*****
10204.	2.	2150.	805082.	3.	30.	410.	*****
10206.	2.	2150.	805082.	3.	20.	430.	*****
10207.	2.	1010.	905082.	1.	25.	440.	1250.
10208.	2.	1010.	905082.	1.	25.	430.	1050.
10209.	2.	1010.	905082.	1.	25.	455.	*****
10210.	2.	1010.	905082.	1.	25.	425.	1090.

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10211.	2.	1010.	905082.	1.	25.	430.	*****
10212.	2.	1010.	905082.	1.	25.	480.	1570.
10213.	2.	1010.	905082.	1.	25.	450.	1570.
10214.	2.	1010.	905082.	1.	25.	430.	*****
10215.	2.	1010.	905082.	1.	20.	460.	1380.
10216.	2.	1010.	905082.	1.	12.	405.	870.
10217.	2.	1010.	905082.	1.	20.	445.	1270.
10218.	2.	1045.	905082.	1.	25.	480.	*****
10218.	2.	1010.	905082.	1.	25.	450.	1350.
10219.	2.	1010.	905082.	1.	12.	425.	1025.
10220.	2.	1010.	905082.	1.	12.	410.	*****
10221.	2.	1010.	905082.	1.	12.	425.	1130.
10223.	2.	1010.	905082.	1.	25.	410.	*****
10224.	2.	1010.	905082.	1.	12.	390.	810.
10225.	2.	1010.	905082.	1.	12.	435.	*****
10226.	2.	1010.	905082.	1.	25.	395.	850.
10227.	2.	1010.	905082.	1.	25.	480.	*****
10228.	2.	1040.	905082.	1.	25.	455.	*****
10229.	2.	1040.	905082.	1.	25.	410.	1450.
10230.	2.	1040.	905082.	1.	11.	390.	720.
10231.	2.	1040.	905082.	1.	25.	420.	*****
10232.	2.	1040.	905082.	1.	25.	460.	*****
10233.	2.	1040.	905082.	1.	12.	405.	1420.
10234.	2.	1040.	905082.	1.	25.	465.	1410.
10235.	2.	1040.	905082.	1.	11.	410.	1070.
10236.	2.	1040.	905082.	1.	12.	415.	1400.
10237.	2.	1040.	905082.	1.	25.	450.	*****
10238.	2.	1040.	905082.	1.	25.	445.	*****
10239.	2.	1040.	905082.	1.	25.	405.	1460.
10240.	2.	1040.	905082.	1.	12.	425.	*****
10241.	2.	1040.	905082.	1.	30.	360.	650.
10242.	2.	1045.	905082.	1.	15.	445.	1620.
10243.	2.	1045.	905082.	1.	25.	445.	750.
10244.	2.	1045.	905082.	1.	30.	355.	620.
10245.	2.	1045.	905082.	1.	25.	445.	*****
10246.	2.	1045.	905082.	1.	25.	400.	790.
10247.	2.	1045.	905082.	1.	25.	430.	*****
10248.	2.	1045.	905082.	1.	11.	420.	*****
10249.	2.	1045.	905082.	1.	25.	430.	*****
10250.	2.	1045.	905082.	1.	12.	385.	750.
10251.	2.	1045.	905082.	1.	12.	395.	780.
10252.	2.	925.	1005082.	1.	11.	390.	880.
10253.	2.	1045.	905082.	1.	25.	445.	1200.
10254.	1.	935.	1005082.	1.	13.	512.	880.

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10255.	2.	925.	1005082.	1.	25.	407.	*****
10256.	2.	1045.	905082.	1.	25.	455.	1450.
10257.	2.	1045.	905082.	1.	12.	440.	*****
10258.	2.	1045.	905082.	1.	12.	410.	870.
10259.	2.	1045.	905082.	1.	12.	365.	700.
10260.	2.	1207.	905082.	3.	11.	435.	*****
10261.	2.	1208.	905082.	3.	21.	435.	*****
10262.	2.	925.	1005082.	1.	11.	418.	1170.
10263.	2.	1209.	905082.	3.	21.	450.	*****
10264.	2.	1207.	905082.	3.	21.	440.	*****
10265.	2.	1930.	905082.	1.	11.	390.	790.
10266.	2.	2028.	905082.	3.	25.	410.	*****
10267.	2.	1100.	1305082.	1.	12.	420.	1280.
10268.	2.	2027.	905082.	3.	25.	405.	*****
10269.	2.	2027.	905082.	3.	25.	410.	*****
10270.	2.	2026.	905082.	3.	25.	410.	*****
10271.	1.	905.	1005082.	1.	21.	395.	500.
10272.	1.	905.	1005082.	1.	34.	459.	560.
10273.	1.	905.	1005082.	1.	24.	470.	510.
10274.	1.	905.	1005082.	1.	34.	478.	670.
10275.	1.	905.	1005082.	1.	24.	480.	590.
10276.	2.	925.	1005082.	1.	25.	450.	*****
10277.	2.	925.	1005082.	1.	12.	399.	810.
10279.	2.	925.	1005082.	1.	25.	445.	1420.
10281.	2.	925.	1005082.	1.	25.	471.	1500.
10282.	2.	925.	1005082.	1.	12.	414.	990.
10283.	2.	925.	1005082.	1.	15.	375.	720.
10285.	2.	2120.	1005082.	1.	30.	450.	*****
10286.	1.	1000.	1105082.	1.	12.	400.	410.
10288.	1.	1000.	1105082.	1.	14.	520.	770.
10289.	2.	1130.	1005082.	3.	11.	415.	*****
10289.	1.	1000.	1105082.	1.	34.	385.	420.
10290.	1.	1000.	1105082.	1.	34.	440.	550.
10291.	1.	1000.	1105082.	1.	34.	420.	500.
10292.	1.	1000.	1105082.	1.	12.	415.	480.
10293.	1.	1000.	1105082.	1.	12.	405.	550.
10295.	1.	1000.	1105082.	1.	34.	545.	1050.
10296.	1.	1000.	1105082.	1.	30.	420.	470.
10297.	1.	1000.	1105082.	1.	12.	535.	850.
10298.	2.	1000.	1105082.	1.	12.	420.	1400.
10299.	1.	1000.	1105082.	1.	12.	380.	350.
10300.	2.	1000.	1105082.	1.	25.	470.	1350.
10301.	2.	1000.	1105082.	1.	25.	405.	1420.
10303.	2.	1108.	1105082.	3.	11.	450.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10306.	2.	1.	1205082.	10.	25.	434.	*****
10307.	2.	930.	1205082.	1.	25.	365.	650.
10310.	2.	1.	1205082.	1.	25.	467.	*****
10311.	2.	1.	1205082.	1.	25.	365.	*****
10313.	2.	930.	1205082.	1.	11.	400.	950.
10314.	2.	930.	1205082.	1.	24.	355.	680.
10314.	2.	1100.	1205082.	1.	12.	401.	*****
10315.	2.	1.	1205082.	1.	25.	468.	*****
10316.	2.	930.	1205082.	1.	25.	375.	770.
10317.	2.	330.	1205082.	1.	25.	434.	*****
10318.	2.	1.	1205082.	1.	25.	407.	*****
10319.	2.	930.	1205082.	1.	25.	400.	990.
10320.	2.	1.	1205082.	1.	15.	414.	*****
10321.	2.	1.	1205082.	1.	25.	428.	*****
10322.	2.	330.	1205082.	1.	25.	430.	*****
10323.	2.	930.	1205082.	1.	11.	395.	1260.
10324.	2.	930.	1205082.	1.	25.	445.	1020.
10325.	2.	930.	1205082.	1.	25.	415.	1000.
10326.	1.	1000.	1205082.	1.	30.	353.	270.
10327.	1.	1000.	1205082.	1.	30.	335.	300.
10329.	1.	1000.	1205082.	1.	12.	790.	1474.
10330.	1.	1000.	1205082.	1.	21.	335.	260.
10332.	1.	1000.	1205082.	1.	13.	446.	530.
10333.	1.	930.	1305082.	1.	25.	455.	710.
10334.	2.	930.	1205082.	1.	11.	360.	630.
10335.	2.	930.	1305082.	1.	25.	360.	1270.
10336.	2.	1025.	1305082.	1.	11.	412.	1010.
10337.	2.	930.	1205082.	1.	11.	425.	960.
10338.	2.	700.	1205082.	1.	11.	410.	*****
10339.	2.	700.	1205082.	1.	11.	440.	*****
10340.	2.	700.	1205082.	1.	20.	440.	*****
10341.	2.	700.	1205082.	1.	24.	470.	*****
10342.	2.	930.	1205082.	1.	25.	430.	1200.
10343.	2.	700.	1205082.	1.	11.	440.	*****
10345.	1.	930.	1205082.	1.	11.	500.	1350.
10346.	1.	930.	1205082.	1.	34.	580.	1110.
10347.	2.	330.	1205082.	1.	25.	447.	*****
10348.	2.	1100.	1205082.	1.	11.	424.	*****
10349.	2.	330.	1205082.	1.	25.	462.	*****
10350.	2.	930.	1205082.	1.	25.	465.	1570.
10351.	1.	1000.	1205082.	1.	12.	354.	330.
10352.	2.	1025.	1305082.	1.	11.	425.	*****
10353.	2.	1005.	1305082.	1.	25.	402.	1110.
10354.	2.	1005.	1305082.	1.	25.	461.	1540.

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
10355.	2.	1005.	1305082.	1.	25.	435.	1290.
10356.	2.	1005.	1305082.	1.	25.	441.	1290.
10358.	2.	1005.	1305082.	1.	25.	460.	1560.
10359.	2.	1005.	1305082.	1.	11.	388.	900.
10360.	2.	1005.	1305082.	1.	12.	431.	1070.
10361.	2.	1005.	1305082.	1.	11.	430.	1270.
10362.	2.	1005.	1305082.	1.	25.	395.	1000.
10363.	2.	1018.	1305082.	1.	11.	426.	1180.
10364.	2.	1005.	1305082.	1.	25.	381.	820.
10365.	2.	1005.	1305082.	1.	11.	390.	750.
10366.	2.	1018.	1305082.	1.	25.	480.	1710.
10367.	2.	1018.	1305082.	1.	25.	450.	*****
10368.	2.	1018.	1305082.	1.	25.	434.	*****
10369.	2.	1018.	1305082.	1.	12.	443.	1300.
10370.	2.	1018.	1305082.	1.	25.	454.	1500.
10371.	2.	1018.	1305082.	1.	25.	415.	*****
10372.	2.	1018.	1305082.	1.	12.	408.	*****
10373.	2.	1018.	1305082.	1.	25.	468.	*****
10374.	2.	1018.	1305082.	1.	25.	450.	1430.
10375.	2.	1018.	1305082.	1.	12.	416.	1140.
10376.	1.	1100.	1305082.	1.	12.	528.	1060.
10377.	1.	1100.	1305082.	1.	30.	444.	660.
10378.	2.	1100.	1305082.	1.	25.	470.	*****
10379.	2.	1100.	1305082.	1.	11.	407.	1070.
10380.	2.	1100.	1305082.	1.	11.	450.	1480.
10381.	2.	1100.	1305082.	1.	25.	460.	*****
10382.	2.	1100.	1305082.	1.	25.	471.	1600.
10383.	2.	1100.	1305082.	1.	14.	448.	1280.
10384.	2.	1100.	1305082.	1.	12.	410.	1000.
10386.	2.	1100.	1305082.	1.	11.	415.	1100.
10387.	2.	1100.	1305082.	1.	25.	446.	1360.
10389.	2.	1100.	1305082.	1.	11.	427.	*****
10390.	2.	1100.	1305082.	1.	12.	400.	*****
10391.	2.	1100.	1305082.	1.	11.	424.	*****
10392.	2.	1100.	1305082.	1.	25.	443.	1420.
10393.	2.	1100.	1305082.	1.	25.	418.	*****
10394.	1.	1110.	1305082.	1.	34.	350.	300.
10395.	1.	1110.	1305082.	1.	21.	425.	480.
10396.	1.	1110.	1305082.	1.	30.	350.	310.
30212.	1.	1005.	1305082.	1.	12.	324.	910.
201146.	2.	1.	1205082.	1.	10.	*****	*****
202210.	2.	2254.	705082.	3.	21.	470.	*****
202250.	2.	900.	405082.	1.	25.	467.	*****
202251.	2.	1759.	405082.	3.	30.	410.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
202252.	2.	1758.	405082.	3.	11.	425.	*****
202253.	2.	1800.	405082.	3.	11.	455.	*****
202254.	2.	1800.	405082.	3.	11.	425.	*****
202254.	2.	2254.	705082.	3.	10.	425.	*****
202255.	2.	810.	705082.	1.	10.	406.	910.
202256.	2.	1803.	405082.	3.	21.	476.	*****
202257.	2.	1805.	405082.	3.	11.	225.	*****
202258.	2.	1805.	405082.	3.	21.	445.	*****
202260.	2.	910.	505082.	1.	12.	417.	*****
202261.	2.	810.	705082.	1.	20.	446.	1270.
202262.	2.	1054.	505082.	3.	11.	417.	*****
202263.	2.	1051.	705082.	3.	20.	470.	*****
202264.	2.	1055.	505082.	3.	10.	387.	*****
202265.	2.	1031.	605082.	3.	11.	400.	*****
202266.	2.	1055.	505082.	3.	10.	415.	*****
202267.	2.	1055.	505082.	3.	20.	454.	*****
202268.	2.	1055.	505082.	3.	20.	482.	*****
202269.	2.	1054.	505082.	3.	20.	444.	*****
202271.	2.	1055.	505082.	3.	10.	432.	*****
202272.	2.	1053.	705082.	3.	11.	420.	*****
202273.	2.	810.	705082.	1.	20.	384.	820.
202274.	2.	1054.	505082.	3.	12.	428.	*****
202275.	2.	810.	705082.	1.	10.	394.	850.
202276.	2.	1056.	505082.	3.	10.	402.	*****
202277.	2.	1056.	505082.	3.	10.	424.	*****
202278.	2.	1056.	505082.	3.	20.	404.	*****
202279.	2.	1103.	505082.	3.	20.	434.	*****
202280.	2.	1103.	505082.	3.	10.	386.	*****
202281.	2.	1104.	505082.	3.	20.	474.	*****
202282.	2.	1107.	505082.	3.	10.	432.	*****
202283.	2.	810.	705082.	1.	10.	432.	1180.
202284.	2.	755.	705082.	1.	10.	450.	1350.
202285.	2.	1106.	505082.	3.	10.	400.	*****
202286.	2.	1106.	505082.	3.	10.	444.	*****
202287.	2.	1106.	505082.	3.	10.	444.	*****
202288.	2.	1106.	505082.	3.	20.	470.	*****
202289.	2.	1107.	505082.	3.	10.	438.	*****
202290.	2.	1109.	505082.	3.	10.	418.	*****
202291.	2.	1051.	705082.	3.	21.	485.	*****
202291.	2.	1107.	505082.	3.	20.	468.	*****
202292.	2.	1109.	505082.	3.	20.	430.	*****
202293.	2.	1109.	505082.	3.	20.	452.	*****
202294.	2.	1109.	505082.	3.	10.	426.	*****
202295.	2.	2055.	505082.	3.	24.	490.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
202296.	2.	1052.	705082.	3.	11.	415.	*****
202297.	2.	1052.	705082.	3.	20.	470.	*****
202298.	2.	2254.	705082.	3.	24.	490.	*****
202299.	2.	1053.	705082.	3.	20.	475.	*****
202300.	2.	2000.	605082.	3.	20.	420.	*****
202301.	2.	755.	705082.	1.	20.	437.	1240.
202302.	2.	2000.	605082.	3.	10.	443.	*****
202303.	2.	755.	705082.	1.	10.	419.	1030.
202304.	2.	2000.	605082.	3.	10.	433.	*****
202305.	2.	2000.	605082.	3.	20.	455.	*****
202306.	2.	810.	705082.	1.	10.	432.	1180.
202307.	2.	755.	705082.	1.	20.	398.	1010.
202308.	2.	2000.	605082.	3.	20.	447.	*****
202309.	2.	2235.	705082.	3.	20.	420.	*****
202310.	2.	2000.	605082.	3.	20.	464.	*****
202311.	2.	2000.	605082.	3.	10.	362.	*****
202311.	2.	1314.	805082.	3.	****	*****	*****
202313.	2.	755.	705082.	1.	20.	495.	930.
202314.	2.	2000.	605082.	3.	20.	339.	*****
202315.	2.	2000.	605082.	3.	10.	334.	*****
202316.	2.	733.	705082.	1.	20.	410.	970.
202317.	2.	720.	705082.	1.	20.	464.	*****
202318.	2.	739.	705082.	1.	20.	430.	*****
202319.	2.	733.	705082.	1.	20.	453.	1440.
202320.	2.	733.	705082.	1.	20.	460.	1590.
202321.	2.	720.	705082.	1.	10.	420.	*****
202322.	2.	720.	705082.	1.	20.	440.	*****
202323.	2.	720.	705082.	1.	20.	444.	*****
202324.	2.	720.	705082.	1.	10.	398.	*****
202325.	2.	720.	705082.	1.	20.	432.	*****
202326.	2.	720.	705082.	1.	10.	429.	*****
202327.	2.	739.	705082.	1.	20.	432.	1160.
202328.	2.	720.	705082.	1.	20.	461.	*****
202329.	2.	739.	705082.	1.	10.	428.	1220.
202330.	2.	720.	705082.	1.	20.	451.	*****
202331.	2.	720.	705082.	1.	10.	418.	*****
202332.	2.	755.	705082.	1.	10.	401.	880.
202333.	2.	755.	705082.	1.	10.	422.	1150.
202334.	2.	720.	705082.	1.	10.	404.	*****
202335.	2.	720.	705082.	1.	20.	428.	*****
202337.	2.	733.	705082.	1.	20.	420.	1070.
202338.	2.	720.	705082.	1.	10.	402.	*****
202339.	2.	755.	705082.	1.	10.	408.	1000.
202340.	2.	2235.	705082.	3.	20.	420.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
202341.	2.	733.	705082.	1.	20.	468.	1450.
202342.	2.	739.	705082.	1.	20.	438.	1180.
202343.	2.	733.	705082.	1.	20.	444.	1360.
202344.	2.	733.	705082.	1.	20.	383.	910.
202345.	2.	720.	705082.	1.	10.	400.	*****
202346.	2.	739.	705082.	1.	20.	421.	1220.
202347.	2.	739.	705082.	1.	10.	413.	1080.
202348.	2.	720.	705082.	1.	10.	407.	*****
202351.	2.	1054.	705082.	3.	10.	425.	*****
202352.	2.	1055.	705082.	3.	21.	450.	*****
202353.	2.	1054.	705082.	3.	10.	425.	*****
202354.	2.	1900.	705082.	1.	20.	475.	1690.
202355.	2.	1900.	705082.	1.	10.	470.	1550.
202357.	2.	1900.	705082.	1.	20.	430.	1280.
202358.	2.	1900.	705082.	1.	10.	420.	1010.
202360.	2.	1900.	705082.	1.	10.	400.	970.
202361.	2.	1900.	705082.	1.	10.	410.	860.
202362.	2.	1900.	705082.	1.	20.	410.	1040.
202364.	2.	1925.	705082.	1.	10.	445.	1330.
202365.	2.	840.	805082.	1.	14.	403.	*****
202366.	2.	1925.	705082.	1.	10.	420.	1030.
202368.	2.	1925.	705082.	1.	20.	455.	1500.
202369.	2.	1925.	705082.	1.	10.	430.	1180.
202370.	2.	1925.	705082.	1.	20.	470.	1600.
202371.	2.	1920.	705082.	1.	10.	425.	1060.
202372.	2.	1925.	705082.	1.	20.	440.	1200.
202373.	2.	3500.	705082.	3.	10.	455.	*****
202374.	2.	1925.	705082.	1.	10.	445.	1235.
202377.	2.	1920.	705082.	1.	20.	440.	1150.
202378.	2.	1920.	705082.	1.	20.	410.	1050.
202379.	2.	2235.	705082.	3.	20.	445.	*****
202380.	2.	1925.	705082.	1.	10.	395.	900.
202381.	2.	1925.	705082.	1.	20.	470.	1520.
202382.	2.	1925.	705082.	1.	20.	475.	1500.
202383.	2.	1925.	705082.	1.	20.	490.	1850.
202384.	2.	1925.	705082.	1.	20.	460.	1500.
202385.	2.	1925.	705082.	1.	20.	490.	1830.
202386.	2.	2235.	705082.	3.	20.	420.	*****
202387.	2.	1925.	705082.	1.	10.	430.	1070.
202388.	2.	1925.	705082.	1.	10.	420.	1130.
202400.	2.	840.	805082.	1.	11.	418.	*****
202401.	2.	840.	805082.	1.	24.	441.	1400.
202402.	2.	840.	805082.	1.	20.	400.	1040.
202403.	2.	840.	805082.	1.	11.	411.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
202404.	2.	840.	805082.	1.	11.	423.	1040.
202405.	2.	840.	805082.	1.	11.	405.	*****
202406.	2.	840.	805082.	1.	14.	438.	*****
202407.	2.	840.	805082.	1.	11.	418.	*****
202408.	2.	840.	805082.	1.	24.	454.	*****
202409.	2.	840.	805082.	1.	14.	407.	950.
202410.	2.	840.	805082.	1.	13.	392.	*****
202411.	2.	840.	805082.	1.	13.	430.	*****
202412.	2.	840.	805082.	1.	14.	428.	*****
202413.	2.	840.	805082.	1.	13.	382.	800.
202414.	2.	840.	805082.	1.	11.	372.	730.
202416.	2.	840.	805082.	1.	13.	405.	1000.
202418.	2.	840.	805082.	1.	24.	468.	*****
202420.	2.	925.	1005082.	1.	11.	402.	*****
202422.	2.	840.	805082.	1.	14.	392.	*****
202450.	2.	840.	805082.	1.	14.	417.	1000.
202452.	2.	815.	805082.	1.	24.	440.	1350.
202453.	2.	840.	805082.	1.	14.	400.	*****
202454.	2.	815.	805082.	1.	14.	393.	830.
202455.	2.	840.	805082.	1.	3.	362.	750.
202456.	2.	815.	805082.	1.	24.	400.	950.
202457.	2.	815.	805082.	1.	24.	410.	1030.
202458.	2.	815.	805082.	1.	14.	456.	1500.
202459.	2.	815.	805082.	1.	14.	410.	*****
202460.	2.	810.	805082.	1.	20.	470.	980.
202461.	2.	840.	805082.	1.	24.	435.	*****
202462.	2.	810.	805082.	1.	12.	384.	830.
202463.	2.	815.	805082.	1.	14.	408.	930.
202464.	2.	810.	805082.	1.	10.	405.	870.
202466.	2.	815.	805082.	1.	14.	411.	1040.
202467.	2.	810.	805082.	1.	25.	444.	1360.
202468.	2.	815.	805082.	1.	25.	436.	1200.
202469.	2.	810.	805082.	1.	25.	432.	1270.
202470.	2.	815.	805082.	1.	11.	409.	1030.
202471.	2.	810.	805082.	1.	25.	476.	1600.
202471.	2.	810.	805082.	1.	25.	476.	1600.
202472.	2.	810.	805082.	1.	12.	423.	1020.
202473.	2.	810.	805082.	1.	14.	405.	980.
202474.	2.	840.	805082.	1.	11.	444.	*****
202475.	2.	815.	805082.	1.	24.	430.	1300.
202476.	2.	815.	805082.	1.	25.	466.	1600.
202477.	2.	2300.	705082.	3.	24.	470.	*****
202477.	2.	1307.	805082.	3.	****	*****	*****
202478.	2.	2300.	705082.	3.	24.	410.	*****

TAG	SPECIES	TIME	DATE	LOCATION	SEX	LENGTH	WEIGHT
202479.	2.	2300.	705082.	3.	21.	455.	*****
202480.	2.	1307.	805082.	3.	****	*****	*****
202480.	2.	2300.	705082.	3.	21.	425.	*****
202481.	2.	2300.	705082.	3.	24.	440.	*****
202482.	2.	2300.	705082.	3.	21.	455.	*****
202483.	2.	1108.	1105082.	3.	21.	480.	*****
202484.	2.	2300.	705082.	3.	11.	365.	*****
202485.	2.	2245.	705082.	3.	30.	330.	*****
202485.	2.	2150.	805082.	3.	****	*****	*****
202486.	2.	2300.	705082.	3.	21.	445.	*****
202488.	2.	2300.	705082.	3.	11.	375.	*****
202489.	2.	840.	805082.	1.	11.	450.	1220.
202491.	2.	2254.	705082.	3.	24.	485.	*****
202492.	2.	840.	805082.	1.	12.	383.	830.
202493.	2.	2300.	705082.	3.	24.	485.	*****
202494.	2.	2254.	705082.	3.	10.	415.	*****
202496.	2.	2235.	705082.	3.	21.	395.	*****
202497.	2.	2235.	705082.	3.	11.	400.	*****
202498.	2.	2254.	705082.	3.	24.	460.	*****
202499.	2.	840.	805082.	1.	24.	462.	*****
*******	1.	1000.	1205082.	1.	24.	406.	480.
*******	2.	930.	1205082.	1.	24.	348.	640.
*******	1.	1000.	1205082.	1.	30.	414.	510.
*******	1.	1000.	1205082.	1.	13.	337.	280.
*******	2.	1025.	1305082.	1.	11.	408.	990.
*******	2.	1025.	1305082.	1.	11.	395.	870.
*******	2.	1100.	1305082.	1.	25.	334.	630.
*******	1.	900.	405082.	1.	21.	494.	*****
*******	1.	1000.	1205082.	1.	14.	340.	290.
*******	1.	1000.	1205082.	1.	25.	392.	490.
*******	1.	1000.	1205082.	1.	21.	300.	210.

A.2 Steele Lake Data

A list of all relevant fish data collected at the Steele Lake fishladder is provided.

The data are arranged according to tag number, with ten parameters listed for each specimen. These parameters are defined as follows:

(1) Tag - See previous definition.

(2) Species - See previous definition.

(3) Location - Refers to the area of release. A release upstream of the weir is designated by "5", a release downstream of the weir is designated by "6".

(4) Time - See previous definition.

(5) Sex - See previous definition.

(6) Set - Refers to the set number of the ladder, as defined in the methods.

(7) Manipulation - Refers to the manipulation used for that set, as outlined in the methods.

(8) Data - See previous definition.

(9) Length - See previous definition.

(10) Weight - See previous definition.

Note: In cases where data are missing or no data was taken, a series of *'s are given.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10159.	1.	5.	2330.	24.	30.	8.	2205082.	525.	*****
10398.	1.	5.	1526.	1.	3.	3.	1505082.	500.	880.
10400.	1.	5.	2245.	12.	1.	1.	1405082.	487.	*****
10426.	1.	5.	2245.	34.	1.	1.	1405082.	630.	*****
10427.	1.	5.	2245.	12.	1.	1.	1405082.	530.	*****
10428.	1.	5.	2245.	12.	1.	1.	1405082.	485.	*****
10430.	1.	5.	2245.	12.	1.	1.	1405082.	550.	*****
10431.	1.	5.	2245.	12.	1.	1.	1405082.	495.	*****
10432.	1.	5.	2245.	12.	1.	1.	1405082.	405.	*****
10434.	1.	5.	2245.	12.	1.	1.	1405082.	485.	*****
10435.	1.	5.	2245.	12.	1.	1.	1405082.	530.	*****
10436.	1.	5.	2245.	12.	1.	1.	1405082.	570.	*****
10437.	1.	5.	2245.	12.	1.	1.	1405082.	510.	*****
10438.	1.	5.	2245.	12.	1.	1.	1405082.	445.	*****
10439.	1.	5.	2245.	12.	1.	1.	1405082.	540.	*****
10440.	1.	5.	2245.	34.	1.	1.	1405082.	600.	*****
10441.	1.	5.	2245.	34.	1.	1.	1405082.	520.	*****
10442.	1.	5.	2245.	12.	1.	1.	1405082.	505.	*****
10443.	1.	5.	2245.	12.	1.	1.	1405082.	590.	*****
10444.	1.	5.	2245.	12.	1.	1.	1405082.	430.	*****
10445.	1.	5.	2245.	12.	1.	1.	1405082.	495.	*****
10446.	1.	5.	2245.	12.	1.	1.	1405082.	570.	*****
10447.	1.	5.	2245.	12.	1.	1.	1405082.	525.	*****
10448.	1.	5.	2245.	12.	1.	1.	1405082.	570.	*****
10449.	1.	5.	2245.	12.	1.	1.	1405082.	470.	*****
10451.	1.	5.	2245.	12.	1.	1.	1405082.	500.	*****
10452.	1.	5.	2245.	34.	1.	1.	1405082.	465.	*****
10453.	1.	5.	2245.	22.	1.	1.	1405082.	460.	*****
10454.	1.	5.	2245.	12.	1.	1.	1405082.	575.	*****
10455.	1.	5.	2245.	34.	1.	1.	1405082.	485.	*****
10456.	1.	5.	2245.	34.	1.	1.	1405082.	585.	*****
10457.	1.	5.	2245.	34.	1.	1.	1405082.	635.	*****
10458.	1.	5.	2245.	12.	1.	1.	1405082.	525.	*****
10459.	1.	5.	2245.	12.	1.	1.	1405082.	535.	*****
10460.	1.	5.	2245.	12.	1.	1.	1405082.	510.	*****
10461.	1.	5.	2245.	12.	1.	1.	1405082.	495.	*****
10462.	1.	5.	2245.	12.	1.	1.	1405082.	495.	*****
10463.	1.	5.	2245.	34.	1.	1.	1405082.	565.	*****
10464.	1.	5.	2245.	12.	1.	1.	1405082.	490.	*****
10465.	1.	5.	2245.	12.	1.	1.	1405082.	510.	*****
10466.	1.	5.	2245.	12.	1.	1.	1405082.	555.	*****
10467.	1.	5.	2245.	12.	1.	1.	1405082.	500.	*****
10468.	1.	5.	2245.	12.	1.	1.	1405082.	570.	*****
10469.	1.	5.	2245.	12.	1.	1.	1405082.	555.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10470.	1.	5.	2245.	12.	1.	1.	1405082.	540.	*****
10471.	1.	5.	2245.	12.	1.	1.	1405082.	525.	*****
10472.	1.	5.	2245.	12.	1.	1.	1405082.	480.	*****
10473.	1.	5.	2245.	34.	1.	1.	1405082.	650.	*****
10474.	1.	5.	2245.	12.	1.	1.	1405082.	540.	*****
10475.	1.	5.	2245.	34.	1.	1.	1405082.	560.	*****
10476.	1.	5.	2245.	12.	1.	1.	1405082.	441.	*****
10477.	1.	5.	2245.	12.	1.	1.	1405082.	538.	*****
10478.	1.	5.	2245.	12.	1.	1.	1405082.	512.	*****
10479.	1.	5.	2245.	12.	1.	1.	1405082.	500.	*****
10480.	1.	5.	2245.	12.	1.	1.	1405082.	517.	*****
10480.	1.	5.	2245.	22.	1.	1.	1405082.	424.	*****
10481.	1.	5.	2245.	12.	1.	1.	1405082.	510.	*****
10482.	1.	5.	2245.	12.	1.	1.	1405082.	600.	*****
10483.	1.	5.	2245.	12.	1.	1.	1405082.	594.	*****
10484.	1.	5.	2245.	12.	1.	1.	1405082.	490.	*****
10485.	1.	5.	2245.	12.	1.	1.	1405082.	441.	*****
10486.	1.	5.	2245.	12.	1.	1.	1405082.	564.	*****
10487.	1.	5.	2245.	12.	1.	1.	1405082.	538.	*****
10488.	1.	5.	2245.	12.	1.	1.	1405082.	556.	*****
10489.	1.	5.	2245.	12.	1.	1.	1405082.	458.	*****
10490.	1.	5.	2245.	12.	1.	1.	1405082.	515.	*****
10491.	1.	5.	2245.	12.	1.	1.	1405082.	541.	*****
10492.	1.	5.	2245.	34.	1.	1.	1405082.	500.	*****
10493.	1.	5.	2245.	12.	1.	1.	1405082.	498.	*****
10494.	1.	5.	2245.	12.	1.	1.	1405082.	545.	*****
10495.	1.	5.	2245.	12.	1.	1.	1405082.	525.	*****
10496.	1.	5.	2245.	12.	1.	1.	1405082.	510.	*****
10497.	1.	5.	2245.	12.	1.	1.	1405082.	535.	*****
10498.	1.	5.	2245.	12.	1.	1.	1405082.	495.	*****
10499.	1.	5.	2245.	12.	1.	1.	1405082.	470.	*****
10500.	1.	5.	2245.	12.	1.	1.	1405082.	525.	*****
10501.	1.	5.	1253.	12.	2.	2.	1505082.	590.	1280.
10502.	1.	5.	1253.	12.	2.	2.	1505082.	530.	*****
10503.	1.	5.	1317.	12.	2.	2.	1505082.	530.	950.
10504.	1.	5.	1248.	34.	2.	2.	1505082.	595.	*****
10505.	1.	5.	1248.	12.	2.	2.	1505082.	510.	*****
10506.	1.	5.	1248.	12.	2.	2.	1505082.	520.	940.
10507.	1.	5.	1253.	12.	2.	2.	1505082.	485.	*****
10508.	1.	5.	1248.	12.	2.	2.	1505082.	625.	910.
10509.	1.	5.	1310.	12.	2.	2.	1505082.	560.	*****
10510.	1.	5.	1248.	12.	2.	2.	1505082.	575.	1200.
10511.	1.	5.	1257.	12.	2.	2.	1505082.	445.	*****
10512.	1.	5.	1257.	34.	2.	2.	1505082.	640.	1680.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10513.	1.	5.	1257.	12.	2.	2.	1505082.	495.	750.
10514.	1.	5.	1257.	12.	2.	2.	1505082.	535.	*****
10515.	1.	5.	1253.	12.	2.	2.	1505082.	505.	970.
10516.	1.	5.	1317.	12.	2.	2.	1505082.	555.	1000.
10517.	1.	5.	1317.	34.	34.	2.	2.	440.	*****
10519.	1.	5.	1317.	12.	2.	2.	1505082.	520.	*****
10520.	1.	5.	1317.	34.	2.	2.	1505082.	470.	*****
10521.	1.	5.	1310.	12.	2.	2.	1505082.	525.	860.
10522.	1.	5.	1310.	12.	2.	2.	1505082.	555.	*****
10523.	1.	5.	1310.	12.	2.	2.	1505082.	600.	*****
10524.	1.	5.	1310.	34.	2.	2.	1505082.	475.	680.
10525.	1.	5.	1317.	12.	2.	2.	1505082.	520.	900.
10526.	1.	5.	1547.	12.	3.	3.	1505082.	530.	1000.
10527.	1.	5.	1310.	12.	2.	2.	1505082.	540.	930.
10528.	1.	5.	1541.	12.	3.	3.	1505082.	570.	1730.
10529.	1.	5.	1324.	12.	2.	2.	1505082.	525.	1000.
10530.	1.	5.	1324.	34.	2.	2.	1505082.	605.	*****
10531.	1.	5.	1324.	14.	2.	2.	1505082.	420.	*****
10532.	1.	5.	1317.	12.	2.	2.	1505082.	495.	*****
10533.	1.	5.	1317.	14.	2.	2.	1505082.	515.	1110.
10534.	1.	5.	1520.	34.	3.	3.	1505082.	575.	*****
10535.	1.	5.	1520.	12.	3.	3.	1505082.	555.	1030.
10536.	1.	5.	1520.	34.	3.	3.	1505082.	450.	*****
10537.	1.	5.	1520.	12.	3.	3.	1505082.	530.	870.
10538.	1.	5.	1520.	34.	3.	3.	1505082.	565.	*****
10539.	1.	5.	1520.	34.	3.	3.	1505082.	620.	1570.
10540.	1.	5.	1526.	34.	3.	3.	1505082.	565.	1030.
10541.	1.	5.	1547.	12.	3.	3.	1505082.	550.	*****
10542.	1.	5.	1533.	12.	3.	3.	1505082.	490.	920.
10543.	1.	5.	1526.	34.	3.	3.	1505082.	595.	1390.
10544.	1.	5.	1533.	12.	3.	3.	1505082.	540.	*****
10545.	1.	5.	1531.	34.	3.	3.	1505082.	580.	1230.
10546.	1.	5.	1526.	12.	3.	3.	1505082.	560.	*****
10547.	1.	5.	1533.	12.	3.	3.	1505082.	505.	*****
10548.	1.	5.	1531.	34.	3.	3.	1505082.	585.	*****
10549.	1.	5.	1526.	12.	3.	3.	1505082.	535.	*****
10550.	1.	5.	1526.	12.	3.	3.	1505082.	545.	1020.
10551.	1.	5.	1533.	12.	3.	3.	1505082.	440.	570.
10552.	1.	5.	1547.	12.	3.	3.	1505082.	530.	1000.
10553.	1.	5.	1541.	12.	3.	3.	1505082.	485.	*****
10554.	1.	5.	1825.	34.	4.	1.	1505082.	510.	*****
10555.	1.	5.	1827.	12.	4.	1.	150582.	580.	*****
10556.	1.	5.	1845.	12.	4.	1.	1505082.	470.	810.
10557.	1.	5.	1845.	12.	4.	1.	1505082.	530.	980.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10558.	1.	5.	1825.	12.	4.	1.	1505082.	560.	*****
10559.	1.	5.	1825.	22.	4.	1.	1505082.	580.	1200.
10560.	1.	5.	1825.	12.	4.	1.	1505082.	545.	*****
10561.	1.	5.	1845.	34.	4.	1.	1505082.	535.	*****
10562.	1.	5.	1827.	34.	4.	1.	1505082.	500.	870.
10563.	1.	5.	1825.	12.	4.	1.	1505082.	565.	1200.
10564.	1.	5.	1833.	12.	4.	1.	1505082.	520.	1300.
10565.	1.	5.	1845.	34.	4.	1.	1505082.	540.	1030.
10566.	1.	5.	1833.	12.	4.	1.	1505082.	525.	1000.
10568.	1.	5.	1833.	12.	4.	1.	1505082.	530.	*****
10569.	1.	5.	1837.	34.	4.	1.	1505082.	510.	*****
10570.	1.	5.	1837.	12.	4.	1.	1505082.	525.	*****
10571.	1.	5.	1837.	14.	4.	1.	1505082.	540.	1000.
10572.	1.	5.	1837.	12.	4.	1.	1505082.	500.	1310.
10573.	1.	5.	1833.	12.	4.	1.	1505082.	520.	*****
10574.	1.	5.	1833.	12.	4.	1.	1505082.	580.	1300.
10575.	1.	5.	1837.	12.	4.	1.	1505082.	545.	*****
10576.	1.	5.	1845.	14.	4.	1.	1505082.	490.	*****
10577.	1.	5.	1845.	12.	4.	1.	1505082.	550.	*****
10578.	1.	5.	1845.	34.	4.	1.	1505082.	485.	810.
10579.	1.	5.	2153.	12.	5.	2.	1505082.	510.	*****
10580.	1.	5.	1856.	12.	4.	1.	1505082.	535.	*****
10581.	1.	5.	1856.	12.	4.	1.	1505082.	535.	1010.
10582.	1.	5.	1856.	12.	4.	1.	1505082.	545.	*****
10583.	1.	5.	1853.	12.	4.	1.	1505082.	500.	870.
10584.	1.	5.	1853.	12.	4.	1.	1505082.	465.	*****
10585.	1.	5.	1853.	12.	4.	1.	1505082.	465.	*****
10586.	1.	5.	1853.	12.	4.	1.	1505082.	495.	800.
10587.	1.	5.	1853.	12.	4.	1.	1505082.	535.	*****
10588.	1.	5.	1856.	34.	4.	1.	1505082.	525.	950.
10589.	1.	5.	1900.	22.	4.	1.	1505082.	455.	770.
10590.	1.	5.	1905.	12.	4.	1.	1505082.	500.	*****
10591.	1.	5.	1900.	34.	4.	1.	1505082.	480.	*****
10592.	1.	5.	1856.	12.	4.	1.	1505082.	510.	880.
10593.	1.	5.	1900.	12.	4.	1.	1505082.	560.	*****
10594.	1.	5.	1900.	12.	4.	1.	1505082.	470.	740.
10595.	1.	5.	1914.	12.	4.	1.	1505082.	600.	*****
10596.	1.	5.	2103.	24.	18.	5.	1905082.	485.	770.
10597.	1.	5.	1905.	12.	4.	1.	1505082.	555.	1100.
10598.	1.	5.	1905.	12.	4.	1.	1505082.	520.	900.
10599.	1.	5.	1905.	34.	4.	1.	1505082.	550.	950.
10600.	1.	5.	1905.	12.	4.	1.	1505082.	515.	*****
10601.	1.	5.	2122.	34.	5.	2.	1505082.	520.	*****
10602.	1.	5.	2122.	12.	5.	2.	1505082.	490.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10603.	1.	5.	2122.	12.	5.	2.	1505082.	510.	860.
10604.	1.	5.	2122.	12.	5.	2.	1505082.	640.	1010.
10605.	1.	5.	2126.	12.	5.	2.	1505082.	510.	830.
10606.	1.	5.	2122.	34.	5.	2.	1505082.	530.	*****
10607.	1.	5.	2122.	12.	5.	2.	1505082.	490.	*****
10608.	1.	5.	2117.	12.	5.	2.	1505082.	480.	*****
10609.	1.	5.	2126.	12.	5.	2.	1505082.	490.	840.
10610.	1.	5.	2117.	12.	5.	2.	1505082.	545.	*****
10611.	1.	5.	2117.	34.	5.	2.	1505082.	610.	1500.
10612.	1.	5.	2126.	12.	5.	2.	1505082.	545.	*****
10613.	1.	5.	2126.	34.	5.	2.	1505082.	485.	*****
10614.	1.	5.	2117.	12.	5.	2.	1505082.	500.	*****
10615.	1.	5.	2117.	12.	5.	2.	1505082.	510.	870.
10616.	1.	5.	2117.	12.	5.	2.	1505082.	535.	*****
10617.	1.	5.	1917.	12.	4.	1.	1505082.	550.	1090.
10618.	1.	5.	2153.	34.	5.	2.	1505082.	530.	1470.
10619.	1.	5.	1917.	12.	4.	1.	1505082.	520.	*****
10620.	1.	5.	1917.	12.	4.	1.	1505082.	540.	1060.
10621.	1.	5.	1914.	12.	4.	1.	1505082.	460.	630.
10622.	1.	5.	1914.	12.	4.	1.	1505082.	535.	1430.
10623.	1.	5.	1914.	12.	4.	1.	1505082.	550.	*****
10624.	1.	5.	1914.	12.	4.	1.	1505082.	540.	*****
10625.	1.	5.	2156.	12.	5.	2.	1505082.	490.	*****
10626.	1.	5.	2153.	34.	5.	2.	1505082.	485.	*****
10627.	1.	5.	2153.	34.	5.	2.	1505082.	515.	*****
10628.	1.	5.	2148.	34.	5.	2.	1505082.	580.	*****
10629.	1.	5.	2148.	12.	5.	2.	1505082.	550.	*****
10630.	1.	5.	2148.	12.	5.	2.	1505082.	475.	*****
10631.	1.	5.	2148.	12.	5.	2.	1505082.	590.	1850.
10632.	1.	5.	2148.	12.	5.	2.	1505082.	480.	*****
10633.	1.	5.	2142.	34.	5.	2.	1505082.	430.	500.
10634.	1.	5.	2156.	12.	5.	2.	1505082.	540.	1120.
10635.	1.	5.	2156.	12.	5.	2.	1505082.	550.	*****
10636.	2.	5.	2143.	25.	5.	2.	1505082.	540.	1750.
10637.	1.	5.	2142.	12.	5.	2.	1505082.	500.	*****
10638.	1.	5.	2142.	12.	5.	2.	1505082.	540.	*****
10639.	1.	5.	2142.	12.	5.	2.	1505082.	550.	1020.
10640.	1.	5.	2142.	34.	5.	2.	1505082.	540.	*****
10642.	1.	5.	2153.	12.	5.	2.	1505082.	550.	1100.
10643.	1.	5.	2136.	12.	5.	2.	1505082.	570.	*****
10644.	1.	5.	2136.	12.	5.	2.	1505082.	530.	980.
10645.	1.	5.	2230.	34.	5.	2.	1505082.	545.	*****
10645.	1.	5.	2136.	12.	5.	2.	1505082.	490.	*****
10646.	1.	5.	2230.	12.	5.	2.	1505082.	450.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10647.	1.	5.	2136.	12.	5.	2.	1505082.	490.	*****
10648.	1.	5.	2136.	12.	5.	2.	1505082.	500.	*****
10649.	1.	5.	2136.	12.	5.	2.	1505082.	550.	1150.
10650.	1.	5.	2136.	12.	5.	2.	1505082.	490.	*****
10651.	1.	5.	2224.	12.	5.	2.	1505082.	485.	*****
10652.	1.	5.	2224.	12.	5.	2.	1505082.	495.	840.
10653.	1.	5.	2230.	12.	5.	2.	1505082.	525.	*****
10654.	1.	5.	2224.	12.	5.	2.	1505082.	480.	*****
10655.	1.	5.	2224.	12.	5.	2.	1505082.	580.	1140.
10656.	2.	5.	2230.	25.	5.	2.	1505082.	350.	560.
10657.	1.	5.	2224.	12.	5.	2.	1505082.	555.	*****
10658.	1.	5.	2215.	12.	5.	2.	1505082.	555.	*****
10659.	1.	5.	2224.	12.	5.	2.	1505082.	510.	*****
10660.	1.	5.	2215.	12.	5.	2.	1505082.	485.	*****
10661.	1.	5.	2212.	12.	5.	2.	1505082.	520.	900.
10662.	1.	5.	2215.	12.	5.	2.	1505082.	530.	980.
10663.	1.	5.	2212.	12.	5.	2.	1505082.	640.	*****
10664.	1.	5.	2212.	34.	5.	2.	1505082.	590.	*****
10665.	1.	5.	2215.	12.	5.	2.	1505082.	560.	*****
10667.	1.	5.	2207.	12.	5.	2.	1505082.	530.	1140.
10668.	1.	5.	2207.	12.	5.	2.	1505082.	510.	*****
10668.	1.	5.	2212.	14.	5.	2.	1505082.	545.	*****
10669.	1.	5.	2207.	12.	5.	2.	1505082.	490.	*****
10670.	1.	5.	2207.	12.	5.	2.	1505082.	550.	1000.
10671.	1.	5.	2207.	34.	5.	2.	1505082.	570.	*****
10672.	1.	5.	2207.	12.	5.	2.	1505082.	535.	1000.
10673.	1.	5.	2207.	12.	5.	2.	1505082.	545.	*****
10674.	1.	5.	2224.	12.	5.	2.	1505082.	470.	730.
10675.	1.	5.	2156.	12.	5.	2.	1505082.	550.	*****
10676.	1.	5.	2230.	12.	5.	2.	1505082.	440.	552.
10677.	1.	5.	1623.	12.	6.	1.	1605082.	565.	*****
10678.	1.	5.	1619.	12.	6.	1.	1605082.	495.	*****
10679.	1.	5.	1623.	12.	6.	1.	1605082.	535.	970.
10680.	1.	5.	1619.	12.	6.	1.	1605082.	505.	830.
10681.	1.	5.	1645.	14.	6.	1.	1605082.	620.	*****
10682.	1.	5.	1619.	34.	6.	1.	1605082.	550.	1140.
10683.	1.	5.	1619.	34.	6.	1.	1605082.	530.	1000.
10684.	1.	5.	1619.	34.	6.	1.	1606082.	585.	*****
10685.	1.	5.	1627.	12.	6.	1.	1605082.	540.	*****
10686.	1.	5.	1627.	12.	6.	1.	1605082.	550.	*****
10687.	1.	5.	1627.	12.	6.	1.	1605082.	535.	900.
10688.	1.	5.	1627.	12.	6.	1.	1605082.	480.	*****
10689.	1.	5.	1627.	12.	6.	1.	1605082.	550.	1200.
10690.	1.	5.	2035.	13.	7.	4.	1605082.	530.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10691.	1.	5.	1634.	12.	6.	1.	1605082.	535.	*****
10692.	1.	5.	1634.	14.	6.	1.	1605082.	545.	*****
10693.	1.	5.	1634.	12.	6.	1.	1605082.	510.	1300.
10694.	1.	5.	1634.	12.	6.	1.	1605082.	455.	610.
10695.	1.	5.	1635.	12.	6.	1.	1605082.	525.	*****
10696.	1.	5.	1635.	34.	6.	1.	1605082.	495.	740.
10697.	1.	5.	1634.	12.	6.	1.	1605082.	515.	800.
10698.	1.	5.	1645.	12.	6.	1.	1605082.	490.	770.
10699.	1.	5.	1645.	12.	6.	1.	1605082.	560.	*****
10700.	1.	5.	1645.	12.	6.	1.	1605082.	520.	920.
10701.	1.	5.	2109.	24.	18.	5.	1905082.	570.	1090.
10702.	1.	5.	2021.	13.	7.	4.	1605082.	480.	*****
10703.	1.	5.	1648.	12.	6.	1.	1605082.	485.	680.
10704.	1.	5.	1645.	12.	6.	1.	1605082.	540.	930.
10705.	1.	5.	1650.	12.	6.	1.	1605082.	500.	760.
10706.	1.	5.	1650.	34.	6.	1.	1605082.	480.	650.
10707.	1.	5.	1650.	34.	6.	1.	1605082.	500.	*****
10709.	1.	5.	1648.	12.	6.	1.	1605082.	490.	*****
10709.	1.	5.	1648.	14.	6.	1.	1605082.	540.	*****
10710.	1.	5.	2007.	12.	7.	4.	1605082.	550.	1090.
10711.	1.	5.	2007.	13.	7.	4.	1605082.	530.	*****
10712.	1.	5.	2016.	13.	7.	4.	1605082.	500.	800.
10713.	1.	5.	2007.	14.	7.	4.	1605082.	580.	*****
10714.	1.	5.	2007.	12.	7.	4.	1605082.	505.	820.
10715.	1.	5.	2016.	24.	7.	4.	1605082.	540.	*****
10716.	1.	5.	2007.	12.	7.	4.	1605082.	550.	*****
10717.	1.	5.	2016.	24.	7.	4.	1605082.	550.	*****
10718.	1.	5.	2007.	13.	7.	4.	1605082.	565.	*****
10719.	1.	5.	2010.	13.	7.	4.	1605082.	525.	1000.
10720.	1.	5.	2010.	12.	7.	4.	1605082.	445.	*****
10721.	1.	5.	2010.	13.	7.	4.	1605082.	550.	*****
10722.	1.	5.	2007.	12.	7.	4.	1605082.	500.	*****
10723.	1.	5.	2021.	13.	7.	4.	1605082.	540.	*****
10724.	1.	5.	2016.	12.	7.	4.	1605082.	530.	990.
10725.	1.	5.	2016.	13.	7.	4.	1605082.	470.	*****
10726.	1.	5.	2021.	12.	7.	4.	1605082.	500.	880.
10727.	1.	5.	2021.	14.	7.	4.	1605082.	520.	900.
10728.	1.	5.	2021.	24.	7.	4.	1605082.	515.	1000.
10729.	1.	5.	2021.	34.	7.	4.	1605082.	540.	*****
10730.	1.	5.	2035.	13.	7.	4.	1605082.	510.	*****
10731.	1.	5.	2028.	14.	7.	4.	1605082.	545.	*****
10732.	1.	5.	2028.	12.	7.	4.	1605082.	555.	1250.
10735.	1.	5.	2028.	13.	7.	4.	1605082.	480.	*****
10737.	1.	5.	2031.	12.	7.	4.	1605082.	485.	730.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10738.	1.	5.	2031.	12.	7.	4.	1605082.	460.	*****
10739.	1.	5.	2031.	12.	7.	4.	1605082.	575.	*****
10740.	1.	5.	2031.	13.	7.	4.	1605082.	535.	*****
10741.	1.	5.	2031.	13.	7.	4.	1605082.	440.	*****
10742.	1.	5.	2031.	13.	7.	4.	1605082.	505.	770.
10743.	1.	5.	2035.	12.	7.	4.	1605082.	535.	890.
10744.	1.	5.	2035.	12.	7.	4.	1605082.	535.	960.
10745.	1.	5.	2035.	34.	7.	4.	1605082.	500.	*****
10746.	1.	5.	2035.	14.	7.	4.	1605082.	555.	*****
10747.	1.	5.	2035.	13.	7.	4.	1605082.	505.	*****
10748.	1.	5.	2035.	12.	7.	4.	1605082.	525.	*****
10749.	1.	5.	2035.	12.	7.	4.	1605082.	505.	950.
10750.	1.	5.	2035.	12.	7.	4.	1605082.	535.	*****
10751.	1.	5.	2035.	13.	7.	4.	1605082.	500.	*****
10752.	1.	5.	2050.	12.	7.	4.	1605082.	575.	*****
10753.	1.	5.	2041.	12.	7.	4.	1605082.	460.	650.
10754.	1.	5.	2050.	13.	7.	4.	1605082.	505.	*****
10755.	1.	5.	2050.	13.	7.	4.	1605082.	470.	780.
10756.	1.	5.	2100.	12.	7.	4.	1605082.	500.	920.
10757.	1.	5.	2243.	12.	8.	2.	1605082.	580.	*****
10758.	1.	5.	2050.	12.	7.	4.	1605082.	450.	*****
10759.	1.	5.	2050.	12.	7.	4.	1605082.	520.	*****
10760.	1.	5.	2050.	13.	7.	4.	1605082.	580.	1210.
10761.	1.	5.	2053.	34.	7.	4.	1605082.	500.	*****
10762.	1.	5.	2243.	34.	8.	2.	1605082.	475.	*****
10763.	1.	5.	2053.	13.	7.	4.	1605082.	515.	*****
10764.	1.	5.	2053.	34.	7.	4.	1605082.	540.	*****
10765.	1.	5.	2247.	13.	11.	5.	1705082.	485.	*****
10767.	1.	5.	2053.	13.	7.	4.	1605082.	530.	1000.
10768.	1.	5.	2053.	12.	7.	4.	1605082.	570.	1120.
10769.	1.	5.	2053.	34.	7.	4.	1605082.	430.	*****
10770.	1.	5.	2100.	12.	7.	4.	1605082.	500.	*****
10771.	1.	5.	2100.	12.	7.	4.	1605082.	510.	*****
10772.	1.	5.	2100.	13.	7.	4.	1605082.	380.	460.
10773.	1.	5.	2057.	13.	7.	4.	1605082.	440.	*****
10774.	1.	5.	2057.	13.	7.	4.	1605082.	530.	*****
10775.	1.	5.	2057.	13.	7.	4.	1605082.	540.	1010.
10776.	1.	5.	2300.	13.	8.	2.	1605082.	530.	960.
10777.	1.	5.	2300.	12.	8.	2.	1605082.	490.	800.
10778.	1.	5.	2243.	34.	8.	2.	1605082.	505.	*****
10779.	1.	5.	2243.	34.	8.	2.	1605082.	525.	1450.
10780.	1.	5.	2249.	13.	8.	2.	1605082.	540.	1130.
10781.	1.	5.	2249.	12.	8.	2.	1605082.	455.	*****
10781.	1.	5.	2253.	13.	8.	2.	1605082.	560.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10782.	1.	5.	2249.	12.	8.	2.	1605082.	580.	*****
10783.	1.	5.	2300.	34.	8.	2.	1605082.	500.	950.
10784.	1.	5.	2249.	12.	8.	2.	1605082.	485.	*****
10785.	1.	5.	2249.	13.	8.	2.	1605082.	455.	*****
10788.	1.	5.	2253.	12.	8.	2.	1605082.	515.	788.
10789.	1.	5.	2249.	12.	8.	2.	1605082.	485.	810.
10789.	1.	5.	2249.	12.	8.	2.	1605082.	485.	*****
10789.	1.	5.	2253.	34.	8.	2.	1605082.	515.	*****
10790.	1.	5.	2253.	13.	8.	2.	1605082.	515.	900.
10792.	1.	5.	2300.	13.	8.	2.	1605082.	520.	*****
10793.	1.	5.	2247.	13.	11.	5.	1705082.	555.	*****
10794.	1.	5.	2300.	12.	8.	2.	1605082.	535.	*****
10795.	1.	5.	2300.	34.	8.	2.	1605082.	480.	*****
10796.	1.	5.	2257.	34.	8.	2.	1605082.	474.	*****
10797.	1.	5.	2300.	13.	8.	2.	1605082.	630.	*****
10798.	1.	5.	2257.	12.	8.	2.	1605082.	505.	960.
10799.	1.	5.	2257.	34.	8.	2.	1605082.	610.	*****
10800.	1.	5.	2257.	13.	8.	2.	1605082.	515.	*****
10801.	1.	5.	1723.	13.	13.	7.	1805082.	525.	950.
10802.	1.	5.	2300.	13.	8.	2.	1605082.	530.	*****
10803.	1.	5.	2300.	13.	8.	2.	1605082.	550.	*****
10804.	1.	5.	1915.	13.	10.	4.	1705082.	535.	*****
10805.	1.	5.	1915.	13.	10.	4.	1705082.	570.	1220.
10806.	1.	5.	1920.	13.	10.	4.	1705082.	500.	1000.
10807.	1.	5.	1915.	13.	10.	4.	1705082.	535.	1170.
10808.	1.	5.	1915.	13.	10.	4.	1705082.	484.	*****
10809.	1.	5.	2247.	13.	11.	5.	1705082.	560.	*****
10810.	1.	5.	1915.	13.	10.	4.	1705082.	495.	820.
10811.	1.	5.	1920.	12.	10.	4.	1705082.	550.	*****
10812.	1.	5.	1920.	34.	10.	4.	1705082.	560.	*****
10813.	1.	5.	1920.	13.	10.	4.	1705082.	550.	1030.
10814.	1.	5.	1920.	14.	10.	4.	1705082.	480.	*****
10815.	1.	5.	1920.	13.	10.	4.	1705082.	530.	*****
10816.	1.	5.	1920.	12.	10.	4.	1705082.	450.	650.
10817.	1.	5.	1920.	12.	10.	4.	1705082.	520.	*****
10818.	1.	5.	2247.	13.	11.	5.	1705082.	505.	820.
10819.	1.	5.	1920.	13.	10.	4.	1705082.	530.	930.
10820.	1.	5.	2241.	34.	11.	5.	1705082.	640.	1680.
10821.	1.	5.	2241.	13.	11.	5.	1705082.	465.	680.
10822.	1.	5.	2241.	34.	11.	5.	1705082.	565.	990.
10823.	1.	5.	2247.	34.	11.	5.	1705082.	575.	1150.
10824.	1.	5.	2241.	12.	11.	5.	1705082.	445.	*****
10825.	1.	5.	2241.	13.	11.	5.	1705082.	505.	*****
10826.	1.	5.	424.	14.	15.	5.	1905082.	465.	*****

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10827.	1.	5.	2103.	34.	18.	5.	1905082.	485.	*****
10828.	1.	5.	424.	13.	15.	5.	1905082.	495.	790.
10829.	1.	5.	424.	24.	15.	5.	1905082.	540.	*****
10830.	1.	5.	424.	14.	15.	5.	1905082.	530.	910.
10831.	1.	5.	935.	12.	16.	5.	1905082.	525.	1020.
10832.	1.	5.	2109.	12.	18.	5.	1905082.	515.	850.
10833.	1.	5.	2103.	24.	18.	5.	1905082.	620.	*****
10834.	2.	5.	431.	25.	15.	5.	1905082.	440.	1020.
10835.	1.	5.	2103.	13.	18.	5.	1905082.	415.	500.
10836.	1.	5.	2103.	13.	18.	5.	1905082.	520.	860.
10837.	1.	5.	424.	12.	15.	5.	1905082.	560.	*****
10838.	1.	5.	424.	12.	15.	5.	1905082.	525.	950.
10839.	1.	5.	2203.	34.	23.	5.	2005082.	570.	1200.
10840.	1.	5.	2109.	12.	18.	5.	1905082.	470.	*****
10841.	1.	5.	2109.	12.	18.	5.	1905082.	541.	*****
10846.	1.	5.	233.	12.	19.	8.	2005082.	500.	850.
10847.	1.	5.	233.	13.	19.	8.	2005082.	530.	*****
10848.	1.	5.	233.	24.	19.	8.	2005082.	610.	1330.
10849.	1.	5.	233.	13.	19.	8.	2005082.	480.	750.
10850.	1.	5.	233.	24.	19.	8.	2005082.	500.	*****
10851.	1.	5.	2254.	34.	11.	5.	1705082.	465.	*****
10852.	1.	5.	1723.	14.	13.	7.	1805082.	390.	380.
10853.	1.	5.	2247.	12.	11.	5.	1705082.	555.	1130.
10854.	1.	5.	2254.	12.	11.	5.	1705082.	525.	*****
10855.	1.	5.	2345.	14.	14.	14.	4.	550.	*****
10856.	1.	5.	935.	13.	16.	5.	1905082.	420.	400.
10857.	1.	5.	2254.	13.	11.	5.	1705082.	530.	*****
10858.	1.	5.	2254.	34.	11.	5.	1705082.	515.	840.
10859.	1.	5.	2254.	13.	11.	5.	1705082.	555.	1050.
10860.	1.	5.	1246.	13.	12.	6.	1805082.	480.	580.
10861.	1.	5.	1725.	24.	13.	7.	1805082.	550.	990.
10862.	1.	5.	1246.	13.	12.	6.	1805082.	525.	960.
10863.	1.	5.	1246.	13.	12.	6.	1805082.	485.	863.
10864.	1.	5.	1246.	13.	12.	6.	1805082.	470.	630.
10865.	1.	5.	1711.	24.	13.	7.	1805082.	525.	760.
10866.	1.	5.	1711.	34.	13.	7.	1805082.	575.	*****
10867.	1.	5.	1711.	24.	13.	7.	1805082.	580.	1100.
10868.	1.	5.	1711.	13.	13.	7.	1805082.	525.	*****
10869.	2.	5.	1715.	25.	13.	7.	1805082.	419.	1420.
10870.	1.	5.	1715.	14.	13.	7.	1805082.	540.	*****
10871.	1.	5.	1715.	14.	13.	7.	1805082.	515.	*****
10872.	1.	5.	1715.	13.	13.	7.	1805082.	565.	1740.
10873.	1.	5.	1725.	14.	13.	7.	1805082.	505.	*****
10874.	1.	5.	1711.	13.	13.	7.	1805082.	495.	760.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10875.	1.	5.	1715.	13.	13.	7.	1805082.	520.	*****
10876.	1.	5.	1723.	14.	13.	7.	1805082.	530.	*****
10877.	1.	5.	2345.	14.	14.	4.	1805082.	490.	780.
10878.	1.	5.	1725.	13.	13.	7.	1805082.	530.	1000.
10879.	1.	5.	1732.	14.	13.	7.	1805082.	490.	*****
10880.	1.	5.	1732.	2.	13.	7.	1805082.	405.	*****
10881.	1.	5.	1736.	12.	13.	7.	1805082.	540.	1000.
10882.	1.	5.	1736.	2.	13.	7.	1805082.	460.	*****
10883.	1.	5.	1732.	13.	13.	7.	1805082.	525.	980.
10884.	1.	5.	935.	24.	16.	5.	1905082.	560.	1170.
10885.	1.	5.	1732.	24.	13.	7.	1805082.	610.	1450.
10886.	1.	5.	1736.	2.	13.	7.	1805082.	655.	1900.
10889.	1.	5.	2345.	24.	14.	4.	1805082.	505.	820.
10889.	1.	5.	1741.	13.	13.	7.	1805082.	530.	1040.
10890.	1.	5.	1741.	14.	13.	7.	1805082.	495.	*****
10891.	1.	5.	2345.	13.	14.	4.	1805082.	525.	*****
10892.	1.	5.	1741.	13.	13.	7.	1805082.	530.	*****
10893.	1.	5.	1743.	12.	13.	7.	1805082.	460.	630.
10894.	1.	5.	1743.	2.	13.	7.	1805082.	540.	*****
10895.	1.	5.	1748.	13.	13.	7.	1805082.	500.	*****
10896.	1.	5.	1748.	34.	13.	7.	1805082.	440.	560.
10897.	1.	5.	1748.	13.	13.	7.	1805082.	535.	1010.
10897.	1.	5.	1741.	14.	13.	7.	1805082.	510.	770.
10898.	1.	5.	1748.	34.	13.	7.	1805082.	555.	*****
10899.	1.	5.	1752.	24.	13.	7.	1805082.	485.	780.
10900.	1.	5.	1752.	13.	13.	7.	1805082.	490.	*****
10901.	1.	5.	239.	24.	19.	8.	2005082.	520.	*****
10902.	1.	5.	239.	24.	19.	8.	2005082.	460.	800.
10903.	1.	5.	233.	24.	19.	8.	2005082.	490.	*****
10904.	1.	5.	239.	13.	19.	8.	2005082.	475.	600.
10905.	1.	5.	239.	34.	19.	8.	2005082.	470.	*****
10906.	1.	5.	239.	34.	19.	8.	2005082.	430.	530.
10907.	1.	5.	2203.	24.	23.	5.	2005082.	660.	1600.
10908.	2.	5.	2205.	25.	23.	5.	2005082.	495.	1280.
10909.	1.	5.	239.	13.	19.	8.	2005082.	410.	470.
10910.	1.	5.	239.	34.	19.	8.	2005082.	570.	*****
10911.	1.	5.	239.	13.	19.	8.	2005082.	525.	980.
10912.	1.	5.	850.	13.	20.	8.	2005082.	520.	*****
10913.	1.	5.	850.	24.	20.	8.	2005082.	480.	640.
10914.	1.	5.	850.	13.	20.	8.	2005082.	515.	750.
10915.	1.	5.	850.	13.	20.	8.	2005082.	535.	940.
10916.	1.	5.	850.	24.	20.	8.	2005082.	530.	*****
10917.	1.	5.	855.	14.	20.	8.	2005082.	525.	880.
10918.	2.	5.	855.	25.	20.	8.	2005082.	420.	910.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10919.	2.	5.	855.	25.	20.	8.	2005082.	485.	1320.
10920.	1.	5.	855.	14.	20.	8.	2005082.	520.	980.
10921.	1.	5.	855.	13.	20.	8.	2005082.	505.	*****
10922.	1.	5.	855.	24.	20.	8.	2005082.	580.	*****
10923.	1.	5.	855.	34.	20.	8.	2005082.	410.	440.
10924.	1.	5.	855.	24.	20.	8.	2005082.	515.	*****
10925.	1.	5.	2203.	12.	23.	5.	2005082.	635.	1050.
10926.	1.	5.	315.	13.	24.	4.	2105082.	500.	*****
10927.	1.	5.	315.	13.	24.	4.	2105082.	390.	420.
10928.	1.	5.	315.	13.	24.	4.	2105082.	580.	1450.
10929.	1.	5.	315.	13.	24.	4.	2105082.	500.	790.
10930.	1.	5.	2330.	24.	30.	8.	2205082.	515.	880.
10931.	1.	5.	315.	13.	24.	4.	2105082.	540.	1160.
10932.	1.	5.	315.	34.	24.	4.	2105082.	480.	640.
10933.	1.	5.	135.	13.	26.	7.	2205082.	595.	1300.
10934.	1.	5.	135.	14.	26.	7.	2205082.	455.	*****
10935.	1.	5.	135.	13.	26.	7.	2205082.	555.	970.
10936.	1.	5.	135.	34.	26.	7.	2205082.	490.	710.
10937.	1.	5.	135.	14.	26.	7.	2205082.	450.	*****
10938.	2.	5.	135.	25.	26.	7.	2205082.	400.	910.
10939.	1.	5.	135.	13.	26.	7.	2205082.	490.	*****
10940.	1.	5.	715.	24.	27.	6.	2205082.	600.	1310.
10941.	2.	5.	137.	25.	26.	7.	2205082.	425.	910.
10942.	2.	5.	137.	25.	26.	7.	2205082.	395.	*****
10943.	1.	5.	137.	34.	26.	7.	2205082.	490.	800.
10944.	2.	5.	137.	25.	26.	7.	2205082.	395.	*****
10945.	1.	5.	710.	13.	27.	6.	2205082.	510.	*****
10946.	1.	5.	710.	13.	27.	6.	2205082.	525.	*****
10948.	1.	5.	710.	24.	27.	6.	2205082.	580.	1140.
10949.	1.	5.	710.	14.	27.	6.	2205082.	535.	*****
10950.	1.	5.	710.	24.	27.	6.	2205082.	545.	900.
10951.	1.	5.	710.	13.	27.	6.	2205082.	540.	950.
10952.	1.	5.	2330.	24.	30.	8.	2205082.	550.	1010.
10953.	1.	5.	710.	13.	27.	6.	2205082.	520.	*****
10954.	1.	5.	710.	13.	27.	6.	2205082.	565.	*****
10955.	1.	5.	715.	14.	27.	6.	2205082.	430.	550.
10956.	1.	5.	715.	14.	27.	6.	2205082.	500.	*****
10957.	2.	5.	715.	25.	27.	6.	2205082.	355.	*****
10958.	2.	5.	715.	25.	27.	6.	2205082.	445.	970.
10959.	1.	5.	2343.	14.	30.	8.	2205082.	580.	*****
10960.	2.	5.	715.	25.	27.	6.	2205082.	410.	890.
10961.	1.	5.	1806.	24.	29.	7.	2205082.	510.	*****
10962.	2.	5.	1806.	25.	29.	7.	2205082.	435.	*****
10963.	1.	5.	1755.	13.	29.	7.	2205082.	455.	670.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
10965.	1.	5.	1755.	13.	29.	7.	2205082.	525.	*****
10966.	1.	5.	1801.	14.	29.	7.	2205082.	485.	*****
10967.	1.	5.	1755.	24.	29.	7.	2205082.	550.	900.
10968.	1.	5.	1801.	13.	29.	7.	2205082.	575.	*****
10969.	1.	5.	1801.	13.	29.	7.	2205082.	455.	750.
10970.	1.	5.	1801.	24.	29.	7.	2205082.	520.	960.
10971.	2.	5.	1801.	11.	29.	7.	2205082.	435.	840.
10972.	2.	5.	1806.	11.	29.	7.	2205082.	435.	950.
10973.	2.	5.	1801.	11.	29.	7.	2205082.	390.	*****
10974.	2.	5.	1806.	13.	29.	7.	2205082.	540.	*****
10975.	1.	5.	1806.	14.	29.	7.	2205082.	535.	1190.
10976.	1.	5.	2245.	12.	1.	1.	1405082.	545.	*****
10978.	1.	5.	2245.	34.	1.	1.	1405082.	525.	*****
10979.	1.	5.	2245.	34.	1.	1.	1405082.	575.	*****
10980.	1.	5.	2245.	12.	1.	1.	1405082.	580.	*****
10981.	1.	5.	2245.	12.	1.	1.	1405082.	530.	*****
10982.	1.	5.	2245.	12.	1.	1.	1405082.	485.	*****
10982.	1.	5.	2245.	12.	1.	1.	1405082.	575.	*****
10983.	1.	5.	2245.	12.	1.	1.	1405082.	500.	*****
10984.	1.	5.	2245.	12.	1.	1.	1405082.	515.	*****
10985.	1.	5.	2245.	12.	1.	1.	1405082.	540.	*****
10986.	1.	5.	2245.	12.	1.	1.	1405082.	560.	*****
10987.	1.	5.	2245.	12.	1.	1.	1405082.	520.	*****
10988.	1.	5.	2245.	12.	1.	1.	1405082.	440.	*****
10989.	1.	5.	2245.	12.	1.	1.	1405082.	575.	*****
10990.	1.	5.	2245.	34.	1.	1.	1405082.	600.	*****
10991.	1.	5.	2245.	12.	1.	1.	1405082.	440.	*****
10992.	1.	5.	2245.	34.	1.	1.	1405082.	590.	*****
10993.	1.	5.	2245.	12.	1.	1.	1405082.	565.	*****
10994.	1.	5.	2245.	12.	1.	1.	1405082.	530.	*****
10995.	1.	5.	2245.	12.	1.	1.	1405082.	540.	*****
10997.	1.	5.	2245.	34.	1.	1.	1405082.	550.	*****
10998.	1.	5.	2245.	12.	1.	1.	1405082.	520.	*****
10999.	1.	5.	2245.	12.	1.	1.	1405082.	500.	*****
101001.	1.	5.	1806.	14.	29.	7.	2205082.	530.	1100.
101002.	2.	5.	1806.	11.	29.	7.	2205082.	405.	850.
101003.	1.	5.	2355.	14.	30.	8.	2205082.	440.	740.
101004.	1.	5.	2330.	24.	30.	8.	2205082.	535.	*****
101005.	1.	6.	13.	14.	30.	8.	2305082.	610.	1375.
101006.	1.	6.	530.	24.	31.	4.	2305082.	520.	*****
101007.	1.	5.	2343.	14.	30.	8.	2205082.	485.	*****
101008.	1.	5.	2343.	24.	30.	8.	2205082.	560.	1110.
101010.	1.	5.	2355.	14.	30.	8.	2205082.	580.	*****
101011.	1.	5.	2343.	24.	30.	8.	2205082.	475.	770.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
101012.	1.	5.	2343.	24.	30.	8.	2205082.	485.	*****
101013.	1.	5.	2355.	14.	30.	8.	2205082.	465.	610.
101014.	1.	5.	2355.	14.	30.	8.	2205082.	400.	480.
101015.	1.	5.	2355.	24.	30.	8.	2205082.	460.	*****
101016.	1.	5.	2355.	24.	30.	8.	2205082.	655.	1710.
101017.	1.	5.	2355.	14.	30.	8.	2205082.	425.	*****
101018.	1.	5.	2355.	24.	30.	8.	2205082.	480.	*****
101019.	1.	5.	2355.	14.	30.	8.	2205082.	535.	*****
101020.	1.	6.	13.	24.	30.	8.	2305082.	480.	750.
101021.	1.	5.	2355.	24.	30.	8.	2205082.	480.	*****
101022.	1.	6.	534.	24.	31.	4.	2305082.	550.	1000.
101023.	1.	6.	13.	24.	30.	8.	2305082.	430.	*****
101024.	1.	6.	530.	14.	31.	4.	2305082.	530.	1000.
101025.	1.	5.	2355.	24.	30.	8.	2205082.	410.	500.
101026.	1.	6.	530.	14.	31.	4.	2305082.	465.	680.
101027.	1.	6.	536.	24.	31.	4.	2305082.	485.	*****
101028.	1.	6.	534.	14.	31.	4.	2305082.	445.	*****
101029.	1.	6.	534.	24.	31.	4.	2305082.	600.	1300.
101030.	1.	6.	1410.	14.	0.	0.	2305082.	490.	*****
101031.	1.	6.	320.	24.	35.	7.	2405082.	455.	*****
101032.	1.	6.	310.	24.	35.	7.	2405082.	545.	1030.
101032.	1.	6.	1410.	14.	0.	0.	2305082.	550.	*****
101033.	1.	6.	1410.	24.	0.	0.	2305082.	565.	*****
101034.	1.	6.	1410.	14.	0.	0.	2305082.	460.	*****
101035.	1.	6.	1410.	24.	0.	0.	2305082.	440.	*****
101036.	1.	6.	320.	24.	35.	7.	2405082.	520.	*****
101039.	1.	6.	1626.	24.	33.	8.	2305082.	525.	850.
101040.	1.	6.	1626.	24.	33.	8.	2305082.	525.	875.
101041.	1.	6.	1626.	13.	33.	8.	2305082.	480.	700.
101042.	1.	6.	1626.	14.	33.	8.	2305082.	490.	850.
101043.	2.	6.	325.	21.	35.	7.	2405082.	420.	1050.
101044.	1.	6.	320.	24.	35.	7.	2405082.	490.	790.
101045.	2.	6.	330.	11.	35.	7.	2405082.	375.	800.
101045.	2.	6.	230.	11.	43.	8.	2605082.	380.	*****
101046.	2.	6.	2205.	11.	34.	6.	2305082.	380.	725.
101047.	2.	6.	2205.	11.	34.	6.	2305082.	400.	1025.
101048.	2.	6.	2205.	25.	34.	6.	2305082.	445.	1150.
101050.	1.	6.	2205.	24.	34.	6.	2305082.	560.	1240.
101051.	2.	6.	330.	21.	35.	7.	2405082.	420.	*****
101052.	1.	6.	1540.	14.	37.	4.	2405082.	605.	1090.
101053.	2.	6.	330.	11.	35.	7.	2405082.	425.	*****
101054.	2.	6.	330.	21.	35.	7.	2405082.	420.	*****
101055.	2.	6.	330.	11.	35.	7.	2405082.	400.	840.
101056.	2.	6.	330.	11.	35.	7.	2405082.	450.	1140.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
101057.	2.	6.	330.	11.	35.	7.	2405082.	355.	*****
101058.	1.	6.	1058.	24.	36.	6.	2405082.	470.	700.
101059.	1.	6.	342.	24.	35.	7.	2405082.	510.	*****
101060.	2.	6.	1545.	*****	37.	4.	2405082.	415.	800.
101061.	1.	6.	342.	24.	35.	7.	2405082.	560.	1200.
101062.	1.	6.	342.	14.	35.	7.	2405082.	580.	1250.
101063.	1.	6.	342.	14.	35.	7.	2405082.	590.	*****
101064.	1.	6.	342.	14.	35.	7.	2405082.	530.	1000.
101065.	1.	6.	342.	24.	35.	7.	2405082.	510.	*****
101066.	2.	6.	352.	11.	35.	7.	2405082.	390.	*****
101068.	2.	6.	352.	11.	35.	7.	2405082.	415.	850.
101069.	1.	6.	1545.	24.	37.	4.	2405082.	520.	*****
101070.	2.	6.	352.	11.	35.	7.	2405082.	380.	*****
101071.	2.	6.	352.	11.	35.	7.	2405082.	405.	925.
101073.	2.	6.	352.	11.	35.	7.	2405082.	430.	925.
101074.	2.	6.	352.	11.	35.	7.	2405082.	405.	*****
101076.	2.	6.	1545.	*****	37.	4.	2405082.	410.	800.
101077.	1.	6.	2110.	14.	38.	9.	2405082.	560.	950.
101078.	1.	6.	2315.	13.	39.	9.	2405082.	520.	810.
101079.	1.	6.	2315.	13.	39.	9.	2405082.	490.	800.
101080.	1.	6.	2315.	24.	39.	9.	2405082.	610.	1360.
101081.	1.	6.	2315.	24.	39.	9.	2405082.	595.	1360.
101082.	1.	6.	1435.	24.	41.	4.	2505082.	490.	760.
101083.	2.	6.	720.	11.	40.	9.	2505082.	405.	820.
101084.	2.	6.	720.	11.	40.	9.	25.	390.	600.
101085.	1.	6.	1435.	14.	41.	4.	2505082.	425.	480.
101086.	1.	6.	2027.	13.	42.	7.	2505082.	460.	710.
101087.	2.	6.	2027.	11.	42.	7.	2505082.	425.	960.
101088.	2.	6.	2027.	11.	42.	7.	2505082.	360.	580.
101089.	1.	6.	217.	24.	43.	8.	2605082.	555.	1090.
101090.	2.	6.	2027.	11.	42.	7.	2505082.	360.	585.
101091.	1.	6.	217.	14.	43.	8.	2605082.	485.	830.
101092.	2.	6.	235.	11.	43.	8.	2605082.	385.	790.
101093.	1.	6.	217.	34.	43.	8.	2605082.	470.	760.
101094.	1.	6.	217.	24.	43.	8.	2605082.	525.	*****
101095.	2.	6.	226.	11.	43.	8.	2605082.	415.	*****
101096.	1.	6.	217.	24.	43.	8.	2605082.	555.	*****
101097.	1.	6.	217.	24.	43.	8.	2605082.	625.	1250.
101098.	1.	6.	217.	24.	43.	8.	2605082.	575.	*****
101099.	2.	6.	226.	11.	43.	8.	2605082.	435.	860.
101100.	1.	6.	226.	34.	43.	8.	2605082.	440.	610.
101101.	2.	6.	226.	11.	43.	8.	2605082.	465.	1200.
101102.	1.	6.	748.	34.	44.	5.	2605082.	475.	650.
101103.	2.	6.	748.	11.	44.	5.	2605082.	360.	550.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
101104.	1.	6.	1600.	14.	47.	34.	2605082.	405.	480.
101105.	1.	6.	805.	14.	48.	10.	2705082.	530.	*****
101106.	1.	6.	805.	24.	48.	10.	2705082.	510.	*****
101107.	1.	6.	805.	24.	48.	10.	2705082.	490.	710.
101108.	1.	6.	805.	14.	48.	10.	2705082.	490.	730.
101109.	1.	6.	805.	14.	48.	10.	2705082.	510.	810.
101110.	1.	6.	815.	24.	48.	10.	2705082.	475.	*****
101111.	1.	6.	815.	24.	48.	10.	2705082.	495.	*****
101112.	1.	6.	810.	14.	48.	10.	2705082.	515.	810.
101113.	1.	6.	810.	24.	48.	10.	2705082.	500.	*****
101114.	1.	6.	810.	24.	48.	10.	2705082.	490.	750.
101115.	2.	6.	815.	14.	48.	10.	2705082.	430.	970.
101116.	2.	6.	818.	1.	48.	10.	2705082.	385.	*****
101117.	2.	6.	818.	11.	48.	10.	2705082.	465.	*****
101118.	1.	6.	805.	24.	48.	10.	2705082.	500.	*****
101119.	1.	6.	815.	24.	48.	10.	2705082.	515.	870.
*******	1.	6.	2315.	14.	39.	9.	2405082.	620.	530.
*******	1.	6.	1058.	24.	36.	6.	2405082.	505.	820.
*******	1.	6.	1058.	14.	36.	6.	2405082.	610.	1230.
*******	1.	5.	2355.	24.	30.	8.	2205082.	450.	*****
*******	1.	5.	2355.	11.	30.	8.	2205082.	505.	820.
*******	1.	5.	815.	14.	25.	5.	2105082.	560.	980.
*******	1.	5.	1257.	14.	2.	2.	1505082.	445.	520.
*******	1.	5.	1613.	*****	0.	6.	1.	10989.	*****
*******	1.	5.	1920.	11.	10.	4.	1705082.	445.	540.
*******	1.	5.	1920.	14.	10.	4.	1705082.	550.	1200.
*******	1.	5.	1920.	11.	10.	4.	1705082.	590.	1440.
*******	1.	5.	1246.	14.	12.	6.	1805082.	555.	950.
*******	1.	5.	1249.	24.	12.	6.	1805082.	515.	730.
*******	1.	5.	1250.	11.	12.	6.	1805082.	570.	1130.
*******	1.	5.	1752.	14.	13.	7.	1805082.	465.	610.
*******	1.	5.	1752.	14.	13.	7.	1805082.	470.	590.
*******	1.	5.	1758.	24.	13.	7.	1805082.	470.	600.
*******	1.	5.	1758.	14.	13.	7.	1805082.	520.	830.
*******	1.	5.	1755.	14.	29.	7.	2205082.	540.	1070.
*******	1.	5.	1758.	14.	13.	7.	1805082.	460.	580.
*******	1.	5.	935.	14.	16.	5.	1905082.	490.	660.
*******	1.	5.	1530.	14.	17.	4.	1905082.	465.	600.
*******	1.	5.	1230.	14.	28.	6.	2205082.	515.	780.
*******	1.	5.	2103.	24.	18.	5.	1905082.	430.	380.
*******	2.	5.	2109.	25.	18.	5.	1905082.	430.	1030.
*******	1.	5.	239.	14.	19.	8.	2005082.	515.	650.
*******	1.	5.	240.	24.	19.	8.	2005082.	530.	950.
*******	1.	5.	240.	14.	19.	8.	2005082.	560.	980.

TAG	SPECIES	LOC.	TIME	SEX	SET	MAN.	DATE	LENGTH	WEIGHT
*******	1.	5.	855.	24.	20.	8.	2005082.	550.	960.
*******	1.	5.	1420.	14.	21.	7.	2005082.	490.	640.
*******	1.	5.	315.	14.	24.	4.	2105082.	460.	570.
*******	1.	5.	315.	24.	24.	4.	2105082.	510.	770.
*******	1.	5.	315.	24.	24.	4.	2105082.	475.	620.

Appendix B

The following tables are a summary of the statistical tests carried out on the Driedmeat and Steele Lake data. Each table is discussed or referred to in the body of the text.

Note that for these tables the following terms are defined:

DF = degrees of freedom for each factor

SS = sums of squares

MS = mean square

F = statistical F-value for ANOVA

F(0.5) = required F-value for significance at the 5% level

N = number used in analysis

Sd = standard deviation

Table B.1 Summary table of ANOVA and confidence intervals for settings of the 61 cm chute at Silver Creek.

VARIANCE DUE TO	DF	SS	MS	F	F(.05)
Velocities	5	17251	3450	1.91	2.30
Error	82	147857	1803		
Total	87	165108			

SET #	MEAN VELOCITY (m/s)	MEAN LENGTH (mm)	N	Sd	95% CONFIDENCE INTERVAL
1	0.9	408.7	7	83.9	$346.5 < \bar{X} < 470.85$
2	1.2	434.4	26	27.7	$423.7 < \bar{X} < 445.1$
3	1.2	410.8	9	51.4	$393.6 < \bar{X} < 427.9$
4	1.5	448.3	9	27.4	$430.4 < \bar{X} < 466.2$
5	0.7	430.4	23	40.4	$413.8 < \bar{X} < 446.9$
6	0.9	404.8	14	42.3	$382.6 < \bar{X} < 426.9$

∴ the mean lengths of white sucker passing through the 61 m chute at the various velocity settings were not significantly different (P>.05).

Table B.2 Summary table of ANOVA and confidence intervals for 61 cm vs 2.4 m chute data at Silver Creek.

Variance Due to	DF	SS	MS	F	F.05
Chute Length	1	123	123	0.07	3.96
Error	101	180792	1790		
Total	102	180915			

Chute Length (m)	Mean Sucker Length (mm)	Mean Velocity (m/s)	N	Sd	95% Confidence Interval
0.67	425.3	1.1	89	43.4	$416.2 < \bar{x} < 434.4$
2.4	422.1	1.0	14	34.0	$404.0 < \bar{x} < 440.0$

∴ The mean lengths of white sucker passing through the two chutes were not significantly different from each other (P>.05).

Table B.3 Summary table of ANOVA and confidence intervals for Gwynne culvert data.

VARIANCE DUE TO	DF	SS	MS	F	F(.05)
Velocity	3	6071	2024	2.41	2.85
Error	41	32719	839		
Total	44	38790			

VELOCITY	MEAN LENGTH	Sd	95% CONFIDENCE INTERVAL
0.8	44.50	36.3	$419.8 < \bar{X} < 470.2$
0.7	418.8	28.6	$405.6 < \bar{X} < 432.1$
0.5	407.1	21.6	$391.0 < \bar{X} < 423.1$
0.3	426.8	27.6	$409.7 < \bar{X} < 443.9$

$\therefore$ the mean lengths of pike passing through the culvert at the different velocities were not significantly different (P>.05).

Table B.4 Chi Square analysis for Gwynne culvert data.

		VELOCITY (m/s)				
		0.8	0.7	0.5	0.3	Totals
	380 - 420	4 (5.0)	12 (11.3)	5 (4.4)	7 (6.3)	28
SIZE CLASS (mm)	421 - 460	4 (5.4)	5 (2.1)	2 (3.0)	3 14	14
	461 - 510	1 (0.6)	1 (1.3)	0 (0.5)	1 (0.7)	3
TOTALS		9	18	7	11	45

Expected values in brackets

Total chisquare = 3.46 Degrees of freedom = 6

$\chi^2(.05) = 12.59$

$\therefore$ the range of lengths of pike passing through the culvert was independent of the velocity setting (P>.05).

Table B.5 Summary table of ANOVA and confidence intervals for the different velocity groups of the Steele Lake data.

Variance Due To	DF	SS	MS	F	F.05
Velocity	3	11109	3703	1.79	2.62
Error	566	1170367	2068		
Total	569	1181475			

Velocity (m/s)	Mean Pike Length (mm)	N	Sd	95% Confidence Interval
2.00-2.25	509.7	17	58.0	$482.1 < \bar{x} < 537.3$
2.26-2.50	518.4	197	44.2	$511.8 < \bar{x} < 524.2$
2.51-2.75	521.4	333	45.6	$516.5 < \bar{x} < 526.3$
2.75-3.00	539.1	23	44.7	$520.8 < \bar{x} < 557.4$

∴ the mean length of pike passing through the ladder under the different velocity setting did not differ significantly (P>.05).

Table B.6 Chi square analysis for pike length and velocity group, Steele Lake data.

		Velocity Class 2.0 to 2.25	2.26 to 2.50	2.51 to 2.75	2.76 to 3.00	TOTALS
Size Class (mm)	380-450	3 (3.1)	16 (1.42)	26 (28.1)	2 (1.7)	47
	451-520	26 (18.2)	85 (83.8)	163 (165.9)	4 (10.0)	278
	521-590	11 (18.4)	82 (84.4)	172 (167.1)	15 (10.1)	280
	591-660	2 (2.3)	10 (10.6)	21 (20.9)	2 (1.3)	35
TOTALS		42	193	382	23	640

Expected values in brackets
Total chi-square = 1.350
χ^2 (.05) = 16.92

Degrees of Freedom = 9

Table B.7 Summary table of ANOVA and confidence intervals for all sets used in the velocity analysis, Steele Lake data.

VARIANCE DUE TO	DF	SS	MS	F	F.05
Sets	19	33352	2779	1.31	1.67
Error	526	992230	2116		
Total	545	1025582			

Set #	Mean Pike Length (mm)	Mean Velocity (m/s)	N	Sd	95% Confidence Interval
24	492.8	2.21	9	52.9	$428.2 < \bar{x} < 527.4$
43	528.8	2.13	8	61.0	$486.5 < \bar{x} < 571.1$
4	524.4	2.37	51	33.6	$515.1 < \bar{x} < 533.6$
6	524.2	2.41	30	35.0	$512.7 < \bar{x} < 535.6$
10	522.0	2.35	17	40.9	$502.5 < \bar{x} < 541.4$
14	527.8	2.34	16	49.8	$503.4 < \bar{x} < 552.2$
19	504.4	2.40	17	50.0	$484.0 < \bar{x} < 523.9$
18	515.4	2.35	12	41.1	$485.5 < \bar{x} < 545.3$
15	503.6	2.35	7	52.9	$464.4 < \bar{x} < 542.8$
20	531.8	2.40	11	45.1	$505.1 < \bar{x} < 558.4$
26	516.4	2.40	11	37.8	$494.1 < \bar{x} < 538.7$
30	500.6	2.34	26	64.0	$474.9 < \bar{x} < 526.3$
1	524.6	2.61	97	47.6	$515.1 < \bar{x} < 534.1$
2	530.2	2.61	30	53.5	$511.0 < \bar{x} < 549.3$
5	524.3	2.70	68	41.7	$514.3 < \bar{x} < 534.2$
7	513.9	2.65	61	40.4	$504.3 < \bar{x} < 523.5$
8	519.4	2.66	28	43.2	$503.3 < \bar{x} < 535.4$
18	513.1	2.35	39	50.7	$497.1 < \bar{x} < 529.1$
35	529.0	2.58	10	41.3	$503.4 < \bar{x} < 554.6$
3	539.1	3.02	23	44.7	$520.8 < \bar{x} < 557.4$

∴ The mean lengths of pike captured at all sets used in the velocity analysis are not significantly different (5% level).

Table B.8 Summary table of ANOVA and confidence intervals for velocity group #1, Steele Lake data.

Variance Due To	DF	SS	MS	F	F.05
Sets	1	5481	5481	1.70	4.54
Error	15	48393	3226		
Total	16	53874			

Set #	Mean Velocity (m/s)	Mean Pike Length (mm)	N	Sd	95% Confidence Interval
24	2.21	492.8	9	52.9	428.2 < $\bar{x}$ < 527.4
43	2.13	528.8	8	61.0	486.5 < $\bar{x}$ < 571.1

∴ the mean lengths of pike captured during the sets used for velocity group #1 were not significantly different (P>.05).

Table B.9 Summary table of ANOVA and confidence intervals for velocity group #2, Steele Lake data.

Variance Due To	DF	SS	MS	F	F.05
Sets	9	19398	2155	1.11	1.92
Error	187	363899	1946		
Total	196	383297			

Set #	Mean Velocity (m/s)	Mean Pike Length (mm)	N	Sd	95% Confidence Interval
4	2.37	524.4	51	33.6	515.1 < $\bar{x}$ < 533.6
6	2.41	524.2	30	35.0	512.7 < $\bar{x}$ < 535.6
10	2.35	522.0	17	40.9	502.5 < $\bar{x}$ < 541.4
14	2.34	527.8	16	49.8	503.4 < $\bar{x}$ < 552.2
19	2.40	504.4	17	50.0	484.0 < $\bar{x}$ < 523.9
18	2.35	515.4	12	41.1	485.5 < $\bar{x}$ < 545.3
15	2.35	503.6	7	52.9	464.4 < $\bar{x}$ < 542.8
20	2.40	531.8	11	45.1	505.1 < $\bar{x}$ < 558.4
26	2.40	516.4	11	37.8	494.1 < $\bar{x}$ < 538.7
30	2.34	500.6	26	64.0	474.9 < $\bar{x}$ < 525.2

∴ the mean lengths of pike captured during the sets used for velocity group #2 were not significantly different (P>.05).

Table B.10 Summary table of ANOVA and confidence intervals for velocity group #3, Steele Lake data.

Variance Due To	DF	SS	MS	F	F.05
Sets	6	10735	1789	0.86	2.14
Error	326	678539	2081		
Total	332	689274			

Set #	Mean Velocity (m/s)	Mean Pike Length (mm)	N	Sd	95% Confidence Interval
1	2.61	524.6	97	47.6	515.1 < x̄ < 534.1
2	2.61	530.2	30	53.5	511.0 < x̄ < 549.3
5	2.70	524.3	68	41.7	514.3 < x̄ < 534.2
7	2.65	513.9	61	40.4	504.3 < x̄ < 523.5
8	2.66	519.4	28	43.2	503.3 < x̄ < 535.4
18	2.35	513.1	39	50.7	497.1 < x̄ < 529.1
35	2.58	529.0	10	41.3	503.4 < x̄ < 554.6

∴ the mean lengths of pike captured during the sets used for velocity group #3 were not significantly different (P>.05).

Table B.11 Summary table of ANOVA and confidence intervals for V2, V3, & V4 during 1501 - 2100, Steele Lake data.

Variance Due To	DF	SS	MS	F	F.05
Velocity	2	3406	1703	0.85	3.11
Error	84	168142	2002		
Total	86	171548			

Velocity (m/s)	Mean Pike Length (mm)	N	Sd	95% Confidence Interval
2.26-2.50	523.4	34	35.3	511.5 < x̄ < 535.3
2.51-2.75	530.2	30	53.5	511.0 < x̄ < 549.4
2.76-3.00	539.1	23	44.7	520.0 < x̄ < 557.4

∴ the mean lengths of pike moving through the ladder during 1501-2100 at flow rates V2, V3 & V4 were not significantly different (P>.05).

Table B.12 Chi square analysis for pike length and time of day, Steele Lake data.

		Time of Day (hrs)				
		0301 to 0900	0901 to 1500	1501 to 2100	2101 to 0300	TOTALS
Size Class (mm)	380-450	4 (5.2)	7 (4.0)	14 (18.1)	24 (21.7)	49
	451-520	37 (29.9)	23 (23.4)	98 (104.3)	125 (125.5)	283
	521-590	26 (29.9)	18 (23.4)	122 (104.3)	117 (125.5)	283
	591-660	2 (4.1)	6 (3.2)	7 (14.4)	24 (17.3)	39
TOTALS		69	54	241	290	654

Expected values in brackets
Total chi-square = 20.85
χ^2 (.05) = 16.92

Degress of Freedom = 9

$\therefore$ the range of the different lengths of pike passing through the ladder was independent of the velocity setting (P<.05).

Table B.13 Chi square analysis for time of day and velocity group, Steele Lake data.

		Velocity (m/s)				
		2.0 to 2.25	2.26 to 2.50	2.51 to 2.75	2.76 to 3.00	TOTALS
Time of Day (hrs)	0301 to 0900	29 (4.5)	18 (20.8)	22 (41.2)	0 (2.5)	
	0901 to 1500	1 (3.2)	9 (14.8)	39 (29.2)	0 (1.8)	49
	1501 to 2100	4 (15.6)	100 (71.8)	111 (142.1)	23 (8.6)	238
	2101 to 0300	8 (18.6)	66 (85.6)	210 (169.5)	0 (10.2)	284
TOTALS		42	193	382	23	640

Expected values in brackets
Total chi-square 234.2
χ^2 (.05) = 16.92

Degrees of Freedom = 9

$\therefore$ the range of velocity settings implemented at the ladder were not independent of time of day (P<.05).

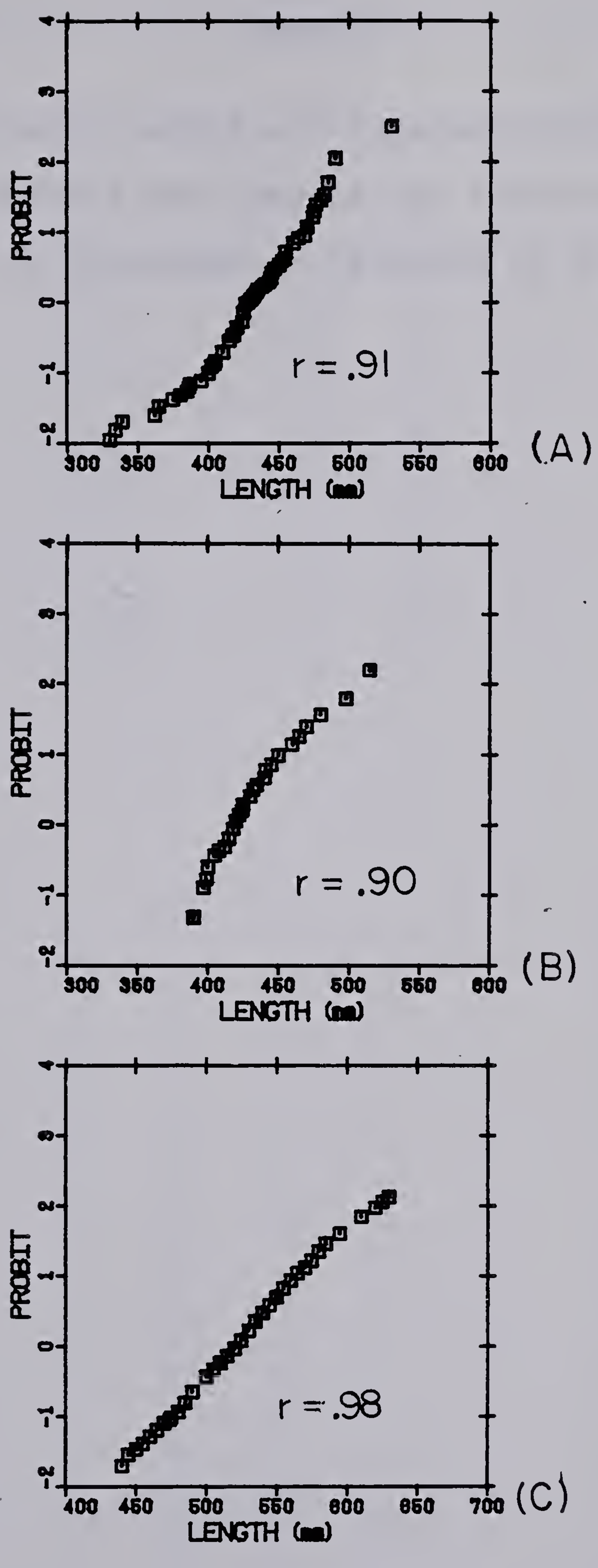

Fig. B.1 Plot of raw length scores vs equivalent probit scores for Silver Creek sucker (A), Gwynne culvert pike (B), and Steele Lake pike (C).

Appendix C

The following tables and figures provide a summary of procedure schedules and results for the various study sites. Each is discussed or referred to in the body of the text.

Table C.1 A list of fish destructively sampled at Driedmeat Lake.

SPECIES	DATE & (LOCATION)	WEIGHT (g)	LENGTH (mm)	SEX	SCALE AGE
P	12-05-82-(1)	210	300	21	2
P	12-05-82-(1)	280	337	12	3
P	12-05-82-(1)	400	378	24	3
P	07-05082-(4)	600	485	24	4
P	08-05-82-(4)	490	430	14	4
P	12-05-82-(1)	480	405	24	3
P	01-05-82-(2)	160	390	21	2
P	12-05-82-(1)	450	380	24	4
P	07-05-82-(1)	780	520	12	6
S	13-05-82-(1)	630	334	25	3
S	12-05-82-(1)	420	323	14	3
S	13-05082-(1)	-	444	24	3
S	07-05-82-(1)	820	384	25	3
S	07-05-82-(1)	1180	432	11	5
S	07-05-82-(3)	1130	420	25	4
S	08-05-82-(1)	1350	440	24	4
S	08-05-82-(1)	1040	411	14	5
S	12-05-82-(1)	640	348	24	2
S	09-05-82-(3)	900	435	21	4

Table C.2 A list of fish destructively sampled at Steele Lake.

SPECIES	SET #	WEIGHT (g)	LENGTH (mm)	SEX	CLEITHRA AGE	SCALE AGE
P	13	610	465	14	3	4
P	10	540	445	11	-	4
P	2	520	445	14	2	3
P	12	730	515	24	4	4
P	13	590	470	14	-	4
P	24	570	470	14	3	4
P	21	640	490	14	5	4
P	13	600	470	24	3	4
P	19	650	515	14	7	4
P	13	830	520	14	6	5
P	20	960	550	24	4	5
P	19	950	530	24	4	5
P	16	660	490	14	3	4
P	13	580	460	14	3	4
P	12	950	555	14	6	5
P	18	380	430	24	3	4
P	10	1200	558	14	6	4
P	10	1440	590	11	6	5
P	12	1130	570	11	7	5
P	17	600	465	14	3	4
P	24	770	510	24	5	4
P	39	620	530	14	5	5
P	25	980	560	14	5	4
P	19	1500	550	11	5	4
P	24	620	475	24	3	4
P	36	780	500	14	5	4
P	36	1230	610	24	6	6
P	30	820	505	11	3	4
P	29	1070	540	14	5	5
P	28	780	515	14	5	5
S	5	560	350	25	-	3
S	15	1750	540	25	-	5
S	27	1280	495	25	-	3
S	29	730	375	11	-	4
S	37	750	380	11	-	4

Table C.3 Schedule of operation of the fyke net at Driedmeat Lake

DATE	TIME	RESULTS
18-04-82	1800	fyke net installed
19-04-82	0730	net empty
19-04-82	1800	net empty
20-04-82	0830	net empty
20-04-82	1800	net empty
21-04-82	0700	2 pike (tag #s: 101, 102 1 w. sucker 960 mm length)
22-04-82	0800	net empty
22-04-82	1800	net empty
23-04-82	0830	net empty
23-04-82	0900	fyke removed

Table C.4 Schedule of operation of the ladder trap at Driedmeat Lake.

DATE	TIME	RESULTS
17-04-82	600	ladder trap installed
18-04-82	0700	trap empty
18-04-82	1400	trap empty
19-04-82		trap out for repair
20-04-82	0800	trap empty
20-04-82	1400	trap empty
20-04-82	2000	trap empty
21-04-82	0800	trap empty
21-04-82	1400	trap empty
21-04-82	2000	trap empty
22-04-82	0830	trap empty
23-04-82		trap removed

Table C.5 Schedule of seine hauls conducted downstream of the Driedmeat fishladder.

DATE	LOCATION & NO. OF HAULS	CATCH
21-04-82	A-2	empty
22-04-82	A-2	empty
23-04-82	A-2	empty
24-04-82	A-2	empty
25-04-82	C-2	empty
26-04-82	B-3	1 pike
26-04-82	B-3	1 pike
27-04-82	B-3	empty
28-04-82	B-1	2 pike
28-04-82	B-1	1 pike
28-04-82	B-1	1 pike
29-04-82	B-2	1 pike
30-04-82	B-2	3 pike
30-04-82	C-2	5 pike
30-04-82	D-2	5 pike
30-04-82	C-2	7 pike
01-05-82	C-2	7 pike
01-05-82	D-2	3 pike
01-05-82	C-2	1 pike
02-05-82	C-1	2 pike
02-05-82	B-1	1 pike
02-05-82	C-1	1 pike
02-05-82	B-2	5 pike
04-05-82	C-1	empty
04-05-82	D-1	empty
04-05-82	C-1	empty
04-05-82	C-1	empty
04-05-82	C-1	empty
04-05-82	B-1	empty
13-05-82	C-1	1 pike

Total fish captured = 48

Table C.6 Summary of results for the chute fence.

Date	# Caught	Mean Length (mm)	Length range (mm)
11-05-82	6	407.5	385-420
12-04-82	10	362.0	300-414
13-05-82	3	375.0	350-425
14-05-82	-	-	-

Table C.7 Geodetic water levels recorded upstream and downstream of the Driedmeat Stabilization weir.

DATE	UPSTREAM LEVEL (m)	DOWNSTREAM LEVEL (m)
20-04-82	684.454	683.780
21-04-82	684.546	683.768
22-04-82	684.550	683.810
23-04-82	684.858	684.430
24-04-82	685.029	684.783
25-04-82	685.213	684.993
26-04-82	685.408	685.253
27-04-82	685.467	685.320
28-04-82	685.516	685.413
29-04-82	Staff Gauges out	
30-04-82	Staff Gauges out	
01-05-82	Staff gauges out	
02-05-82	685.975	685.975
03-05-82	686.040	686.053
04-05-82	686.100	686.100
05-05-82	686.140	686.140
06-05-82	686.130	686.130
07-05-82	686.096	686.090
08-05-82	686.074	686.065
09-05-82	686.016	686.008
10-05-82	685.982	686.980
11-06-82	685.900	685.885
12-05-82	685.878	685.860
13-05-82	685.798	685.780

Note: The top elevation of the stabilization weir is 684.756 m.

Table C.8 Schedule of operations at Silver Creek.

SET #	WIDTH OF CHUTE (cm)	# CAPTURED	VELOCITIES (m/s) A	B	C	TIME & DATE
*1	40	7	0.5	1.0	1.2	1830-04-05-82
*2	35	26	0.8	1.3	1.5	2050-05-05-82
*3	35	9	0.8	1.3	1.5	1030-06-05-82
*4	23	9	1.0	1.8	1.8	2100-06-05-82
*5	60	23	0.7	0.7	0.7	1030-07-05-82
*6	30	14	0.6	1.0	1.0	2200-07-05-82
*7	30	1	0.6	1.0	1.0	1300-08-05-82
**8	30	3	0.7	0.9	1.5	2100-08-05-82
**9	30	4	0.8	1.1	1.2	1200-09-05-82
**10	30	1	0.8	1.4	1.4	2015-09-05-82
**11	46	1	0.8	1.0	1.2	1130-10-05-82
**12	15	5	0.7	0.8	1.0	1115-11-05-82
		operations terminated				

Note: * = 61 cm chute
** = 2.5 m chute

Table C.9 Physical/chemical data for Silver Creek.

Date	Temperature (°C)	Conductance (μmhos/cm)	Dissolved Oxygen (mg/L)
03-05-82	13	405	16.0
04-05-82	8.8	395	16.0
05-05-82	5.5	395	15.5
06-05-82	5.0	400	16.0
07-05-82	6.2	540	16.8
08-05-82	9.0	550	15.0
09-05-82	7.3	550	13.6
10-05-82	8.0	500	11.6
11-05-82	11.2	620	10.6

Table C.10 Schedule of operations at the Gwynne washout.

OBSERVATION PERIOD	DATE	ZONE	MEAN VELOCITY (m/s) CRITICAL ZONE
1	30-04-82	A	1.6
		B	2.1
		C	2.4
		D	1.9
2	01-05-82	A	1.5
		B	2.1
		C	2.1
		D	1.5
3	02-05-82	A	1.5
		B	2.1
		C	2.1
		D	1.5

Table C.11 Observations on fish movement at the Gwynne washout.

OBSERVATION PERIOD	ZONE	SPECIES	# SUCCESSFUL	# FAILED	SIZE RANGE (cm)
1	A	P	-	-	-
		S	-	2	(30-35)
	B	P	3	-	(40-50)
		S	20	15	(30-35)
	C	P	-	-	-
		S	7	1	(30-35)
	D	P	3	-	(35-45)
		S	2	1	(30-35)
2	A	P	-	-	-
		S	-	-	-
	B	P	5	1	(30-45)
		S	2	1	(30-45)
	C	P	-	-	-
		S	-	-	-
	D	P	-	-	-
		S	-	-	-
3	A	P	-	-	-
		S	-	-	-
	B	P	2	-	(35-45)
		S	-	-	-
	C	P	-	-	-
		S	-	-	-
	D	P	-	-	-
		S	-	-	-

Table C.12 Schedule of sets at Gwynne culvert.

SET #	DATE	UPSTREAM VELOCITY (m/s)	DOWNSTREAM VELOCITY (m/s)	WATER LEVEL IN CULVERT (m)
1	2100-06-05-82	1.3	0.8	0.430
2	0930-07-05-82	1.2	0.7	0.410
3	2100-07-05-82	0.9	0.5	0.380
4	1500-08-05-82	0.6	0.3	0.280
5	2110-08-05-82	0.4	0.2	0.260

Table C.13 Results of the Gwynne culvert sets.

SET #	SPECIES	# CAPTURED	LENGTH RANGE (cm)	MEAN SIZE (cm)
1	P	9	40-51	44
2	P	18	39-46	42
3	P	7	38-44	41
4	P	11	40-44	42
5	P	1	42	42

Table C.14 Schedule of seining operations, Steele Lake site.

DATE	LOCATION & # OF HAULS	CATCH SPECIES	SEX	LENGTH (mm)	TAG #
19-05-82	A - 1	-	-	-	-
19-05-82	B - 2	-	-	-	-
21-05-82	B - 2	-	-	-	-
23-05-82	B - 2	-	--	-	
23-05-82	B - 3	P	14	550	B001032
		P	14	490	B001030
		P	34	565	B001033
		P	34	440	B001035
		P	14	460	B001034
		Pr	?	235	B001037
24-05-82	B - 2	P	34	445	B001072
		P	34	550	B001067
	B - 3	-	-	-	-
		(6 pike & 2 w. sucker observed)			

P = pike
Pr = perch (*Perca flavescens*)
Sex = defined in Appendix A

Table C.15 Summary of discharge estimates for the Steele Lake stabilization weir and fishladder.

Set #	Discharge Over Weir (m^3/s)	Discharge Through Fishladder (m^3/s)
11	0.79	0.44
12	0.52	0.54
13	0.75	0.59
14	0.46	0.29
17	0.47	0.32
19	0.83	0.17
21	0.84	0.63
23	0.70	0.30
24	0.52	0.25
26	0.55	0.39
28	0.31	0.20
29	0.44	0.45
31	0.55	0.18
32	0.63	0.55
33	0.34	0.12
34	0.22	0.39
35	0.52	0.49
36	0.34	0.44
37	0.51	0.18
38	0.48	0.04
39	0.48	0.04
40	0.48	0.48
41	0.55	0.26
42	0.44	0.46
43	0.41	0.14
44	0.40	0.18
45	0.48	0.25
46	0.37	0.42
47	0.34	0.70

Table C.16 Schedule of manipulations on the Steele Lake step & pool fishladder.

TIME & DATE	SET #	MAN. #	MEAN NAPPE VELOCITY (M/S)	LENGTH OF SET (hrs)	MEAN WEIR HEAD (mm)	NUMBER OF FISH CAPTURED
2215-14-0582	1	1	2.61	1.5	187	97
1230-15-05-82	2	2	2.61	1.5	187	30
1510-15-05-82	3	3	3.02	1.5	250	23
1810-15-05-82	4	1	2.37	1.2	150	52
2110-15-05-82	5	2	2.70	1.3	200	71
1600-16-05-82	6	1	2.41	1.2	156	31
2000-16-05-82	7	3	2.65	2.5	192	65
2230-16-05-82	8	2	2.66	1.5	195	28
0950-17-05-82	9	3	3.09	1.0	260	0
1630-17-05-82	10	4	2.35	2.5	146	20
2215-17-05-82	11	5	2.52	2.0	173	17
1240-18-05-82	12	6	2.58	5.0	181	7
1700-18-05-82	13	7	2.63	5.0	190	40
2340-18-05-82	14	4	2.34	5.0	144	18
0415-19-05-82	15	5	2.35	5.0	146	8
0930-19-05-82	16	5	2.35	5.0	146	5
1515-19-05-82	17	4	2.32	5.0	141	1
2100-19-05-82	18	5	2.35	5.8	146	14
0220-20-05-82	19	8	2.40	5.0	155	18
0850-20-05-82	20	8	2.40	6.2	155	14
1410-20-05-82	21	7	2.63	2.6	190	2
1700-20-05-82	22	6	2.48	3.0	167	0
2200-20-05-82	23	5	2.37	5.0	150	4
0300-21-05-82	24	4	2.21	5.0	125	9
0800-21-05-82	25	5	2.74	5.0	206	3
0115-22-05-82	26	7	2.40	5.0	155	11
0700-22-05-82	27	6	2.62	5.0	173	15
1230-22-05-82	28	5	2.21	5.0	125	1
1620-22-05-82	29	7	2.57	3.4	180	17
2330-22-05-82	30	8	2.34	5.0	145	25
0530-23-05-82	31	4	2.11	5.0	110	7
1100-23-05-82	32	7	2.44	5.0	160	0
1620-23-05-82	33	8	2.16	5.0	117	4
2145-23-03-82	34	6	2.52	5.0	172	6
0300-24-05-82	35	7	2.58	5.0	182	24
0930-24-05-82	36	6	2.38	5.0	151	1
1530-24-05-82	37	4	2.30	5.0	138	8
2100-24-05-82	38	9	-	5.0	80	2
2300-24-05-82	39	9	-	2.0	80	4
0715-25-05-82	40	9	-	7.0	80	2
1430-25-05-82	41	4	2.31	7.0	140	2
2020-25-05-82	42	7	2.49	5.4	168	6
0205-26-05-82	43	8	2.13	5.0	112	15
0745-26-05-82	44	5	2.22	5.0	126	2
1000-26-05-82	45	1	2.55	1.5	177	0
1140-26-05-82	46	2	2.54	1.5	175	0
1545-26-05-82	47	3	2.78	4.0	213	1
0200-27-05-82	48	10	2.15	4.0	115	18

Table C.17 Physical/chemical data recorded upstream of the Driedmeat stabilization weir.

DATE	TEMP (celcius)	CONDUCTANCE (μmhos/cm)	DISSOLVED OXYGEN (mg/L)
16-14-82	1.0	340	2.2
17-04-82	1.0	350	2.6
18-04-82	1.5	250	3.6
19-04-82 (A.M.)	1.0	240	3.6
19-04-82 (P.M.)	3.0	255	3.8
20-04-82 (A.M.)	2.0	200	4.1
20-04-82 (P.M.)	4.5	250	4.2
21-04-82 (A.M.)	3.0	240	3.9
21-04-82 (P.M.)	5.0	230	4.3
22-04-82 (A.M.)	3.0	280	6.8
23-04-82 (A.M.)	2.0	345	-
23-04-82 (P.M.)	1.0	300	10.0
24-04-82 (A.M.)	0.0	320	12.2
24-04-82 (P.M.)	0.5	320	12.0
24-04-82 (A.M.)	0.0	320	8.8
25-04-82 (P.M.)	1.5	320	11.0
26-04-82 (A.M.)	0.5	270	11.4
26-04-82 (P.M.)	2.5	295	13.0
27-04-82 (A.M.)	1.0	250	10.0
27-04-82 (P.M.)	3.5	250	-
28-04-82 (A.M.)	1.5	225	-
28-04-82 (P.M.)	3.0	220	-
29-04-82 (A.M.)	0.5	195	-
29-04-82 (P.M.)	5.0	220	13.2
30-04-82 (A.M.)	3.0	200	11.2
30-04-82 (P.M.)	6.0	210	9.4
01-05-82 (A.M.)	4.0	200	9.8
02-05-82 (A.M.)	4.5	195	9.5
02-05-82 (P.M.)	7.2	200	9.6
03-05-82 (A.M.)	5.0	200	9.8
03-05-82 (P.M.)	5.7	200	10.4
04-05-82 (A.M.)	5.5	200	12.2
04-05-82 (P.M.)	5.5	210	12.5
05-05-82 (A.M.)	4.0	205	13.8
05-05-82 (P.M.)	4.3	200	14.8
06-05-82 (A.M.)	3.2	190	14.0
06-05-82 (P.M.)	5.0	185	14.8
07-05-82 (P.M.)	6.0	200	14.2
08-05-82 (A.M.)	5.2	210	12.4
08-05-82 (P.M.)	6.5	225	12.2
09-05-82 (A.M.)	6.0	220	11.6
09-05-82 (P.M.)	8.0	225	11.8
10-05-82 (A.M.)	6.5	225	9.2
10-05-82 (P.M.)	10.5	235	12.2
11-05-82 (A.M.)	8.2	235	9.9
11-05-82 (P.M.)	10.0	230	12.2
12-05-82 (A.M.)	9.3	250	11.6
12-05-82 (P.M.)	11.0	250	13.8
13-05-82 (A.M.)	9.5	250	11.8
14-05-82 (A.M.)	11.1	250	14.4

Table C.18 Physical/chemical data recorded downstream of the Driedmeat stabiziation weir.

DATE	TEMP. (celcius)	CONDUCTANCE (μmhos/cm)	DISSOLVED OXYGEN (mg/L)
17-04-82	1.5	340	3.1
18-04-82	1.5	245	3.9
19-04-82 (A.M.)	1.0	235	4.0
19-04-82 (P.M.)	3.0	260	4.0
20-04-82 (A.M.)	2.0	230	4.1
20-04-82 (P.M.)	4.5	240	4.5
21-04-82 (A.M.)	3.0	245	4.5
21-04-82 (P.M.)	5.0	230	4.7
22-04-82 (A.M.)	3.0	290	7.2
23-04-82 (A.M.)	1.5	345	8.1
23-04-82 (P.M.)	1.0	335	11.1
24-04-82 (A.M.)	0.0	340	13.2
24-04-82 (P.M.)	1.0	340	13.6
25-04-82 (A.M.)	0.0	340	12.4
25-04-82 (P.M.)	1.0	280	12.5
26-04-82 (A.M.)	0.5	300	8.3
26-04-82 (P.M.)	2.0	305	10.3
27-04-82 (A.M.)	0.5	250	10.5
27-04-82 (P.M.)	2.5	225	-
28-04-82 (A.M.)	0.0	205	-
28-04-82 (P.M.)	1.5	215	-
29-04-82 (A.M.)	0.0	195	-
29-04-82 (P.M.)	3.0	200	11.4
30-04-82 (A.M.)	3.0	200	11.4
30-04-82 (P.M.)	6.0	210	9.4
01-05-82 (A.M.)	2.5	190	9.4
02-05-82 (A.M.)	3.5	190	9.0
02-05-82 (P.M.)	7.7	210	7.4
03-05-82 (A.M.)	5.0	195	10.0
03-05-82 (P.M.)	6.0	200	11.2
04-05-82 (A.M.)	5.0	200	10.5
04-05-82 (P.M.)	5.5	215	12.5
05-05-82 (A.M.)	3.5	195	14.0
05-05-82 (P.M.)	3.0	195	14.2
06-05-82 (A.M.)	3.0	195	14.6
06-05-82 (P.M.)	4.5	185	14.8
07-05-82 (P.M.)	6.0	200	14.0
08-05-82 (A.M.)	4.8	210	12.1
08-05-82 (P.M.)	6.0	220	12.5
09-05-82 (A.M.)	5.0	220	12.0
09-05-82 (P.M.)	7.5	220	11.4
10-05-82 (A.M.)	6.1	225	9.5
10-05-82 (P.M.)	9.2	240	10.5
11-05-82 (A.M.)	8.3	235	10.4
11-05-82 (P.M.)	12.0	250	12.5
12-05-82 (A.M.)	9.5	255	11.2
12-05-82 (P.M.)	12.0	260	13.4
13-05-82 (A.M.)	9.0	250	11.2
14-05-82 (A.M.)	9.1	250	12.2

Table C.19 Physical/chemical data recorded at Steele Lake, upstream of the weir.

DATE	TEMP. (celcius)	CONDUCTANCE (μmhos/cm)	DISSOLVED OXYGEN (mg/L)
14-05-82 (P.M.)	11.2	185	12.6
15-05-82 (P.M.)	12.0	190	11.8
16-05-82 (P.M.)	12.0	195	11.2
17-05-82 (A.M.)	10.0	190	11.6
18-05-82 (A.M.)	12.7	190	11.2
18-05-82 (P.M.)	12.6	190	10.6
19-05-82 (A.M.)	12.0	185	13.2
19-05-82 (P.M.)	15.0	200	13.8
20-05-82 (A.M.)	13.0	195	12.2
20-05-82 (P.M.)	16.0	210	11.4
21-05-82 (A.M.)	14.0	200	9.8
21-05-82 (P.M.)	16.2	210	11.4
22-05-82 (A.M.)	14.0	200	10.0
22-05-82 (P.M.)	15.2	210	10.2
23-05-82 (A.M.)	14.6	200	9.2
23-05-82 (P.M.)	15.5	200	10.2
24-05-82 (A.M.)	16.2	210	10.7
25-05-82 (A.M.)	14.0	205	9.4
25-05-82 (P.M.)	13.5	200	10.0
26-05-82 (A.M.)	13.5	195	9.3
26-05-82 (P.M.)	14.5	195	14.5

Table C.20 Physical/chemical data recorded at Steele Lake, downstream of the weir.

DATE	TEMP. (celcius)	CONDUCTANCE (μmhos/cm)	DISSOLVED OXYGEN (mg/L)
14-05-82 (P.M.)	11.2	190	11.8
15-05-82 (P.M.)	12.3	180	12.6
16-05-82 (P.M.)	12.0	195	12.4
17-05-82 (A.M.)	10.5	190	11.4
18-05-82 (A.M.)	12.2	195	11.0
18-05-82 (P.M.)	12.0	200	10.4
19-05-82 (A.M.)	11.5	190	13.0
19-05-82 (P.M.)	14.1	200	12.8
20-05-82 (A.M.)	12.6	190	11.6
20-05-82 (P.M.)	15.0	200	11.2
21-05-82 (A.M.)	13.5	200	10.4
21-05-82 (P.M.)	16.0	215	11.4
22-05-82 (A.M.)	13.7	207	10.1
22-05-82 (P.M.)	15.0	210	10.2
23-05-82 (A.M.)	14.0	200	9.8
23-05-82 (P.M.)	15.2	205	10.8
24-05-82 (P.M.)	15.7	210	10.6
25-05-82 (A.M.)	14.0	200	9.2
25-05-82 (P.M.)	14.0	200	9.8
26-05-82 (A.M.)	14.0	190	10.0
26-05-82 (P.M.)	14.0	200	9.0

Table C.21 Tag returns for Driedmeat Lake.

Tag #	Loc. Released	Date	Loc. Caught	Date
10275	Driedmeat Weir	10-05-82	Edberg Bridge	05-07-82
10376	Driedmeat Weir	13-05-82	Edberg Bridge	05-08-82
10346	Driedmeat Weir	12-05-82	West end of Lake	10-06-82
1054	DriedmentWeir	30-04-82	Lake @ Gravel Rd.	29-05-82
10187	Gwynn Culvert	07-05-82	d/s of Coal Lake	26-05-82
10224	Driedmeat Weir	09-05-82	d/s of Coal Lake	02-06-82
10156	Gwynn Culvert	06-05-82	d/s of Coal Lake	22-05-82
10151	Gwynn Culvert	06-05-82	d/s of Coal Lake	13-05-82
10114	Driedmeat Weir	04-05-82	Driedmeat Lake	13-06-82

Table C.22 Tag returns for Steele Lake.

Tag #	Loc. Released	Date	Loc. Caught	Date
10538	U/S of Ladder	15-05-82	Steele Lake	03-09-82
10723	U/S of Ladder	16-05-82	Steele Lake	04-09-82
10633	U/S of Ladder	15-05-82	Steele Lake	30-06-82
10740	U/S of Ladder	16-05-82	Steele Lake	19-08-82
10778	U/S of Ladder	16-05-82	Steele Lake	10-07-82
10747	U/S of Ladder	16-05-82	Steele Lake	22-08-82
10655	U/S of Ladder	15-05-82	Steele Lake	17-08-82
10906	U/S of Ladder	20-05-82	Steele Lake	28-07-82
10578	U/S of Ladder	15-05-82	Steele Lake	12-07-82
10606	U/S of Ladder	15-05-82	Steele Lake	11-07-82
10902	U/S of Ladder	20-05-82	Steele Lake	08-07-82
10627	U/S of Ladder	15-05-82	Steele Lake	08-07-82
10966	U/S of Ladder	14-05-82	Steele Lake	30-05-82
10612	U/S of Ladder	15-05-82	Steele Lake	19-06-82
10683	U/S of Ladder	16-05-82	Steele Lake	28-06-82
10874	U/S of Ladder	18-05-82	Steele Lake	24-06-82
10984	U/S of Ladder	14-05-82	Steele Lake	03-06-82
10859	U/S of Ladder	17-05-82	Steele Lake	22-05-82
10881	U/S of Ladder	18-05-82	Steele Lake	12-06-82
101100	U/S of Ladder	26-05-82	Steele Lake	01-06-82
10451	U/S of Ladder	14-05-82	Steele Lake	13-06-82
10858	U/S of Ladder	17-05-82	Steele Lake	14-06-82
10454	U/S of Ladder	14-05-82	NE14-62-1-W5 (Pembina River)	18-06-82

Table C.23 Hydraulic data used in establishing regression equations (8) and (9) for head level and velocity.

A list of the lead and velocity data used to establish equation (8).

HEAD OVER WEIR (mm)	*VELOCITY AT THE BOTTOM OF THE NAPPE (m/s)
250	2.93
250	3.14
250	2.93
250	3.14
155	2.26
160	2.47
140	2.26
145	2.35
190	2.47
195	2.68
195	2.53
230	2.68
195	2.86
190	2.77
190	2.77
190	2.83

A list of the head and velocity data used to establish equation (9).

HEAD OVER WEIR (mm)	*VELOCITY ACROSS THE TOP OF THE WEIR (m/s)
160	1.25
155	1.28
150	1.22
165	1.34
155	1.37
165	1.37
180	1.34
150	1.31
160	1.25
145	1.31
145	1.37
135	1.10
130	1.19
80	1.00
250	1.52
200	1.46
150	1.34
125	1.16
100	1.07

* Note: (1) Velocities taken using the Price model "A" current meter at 0.5 head depth.

(2) The relationship does not include the top two weirs of the ladder.

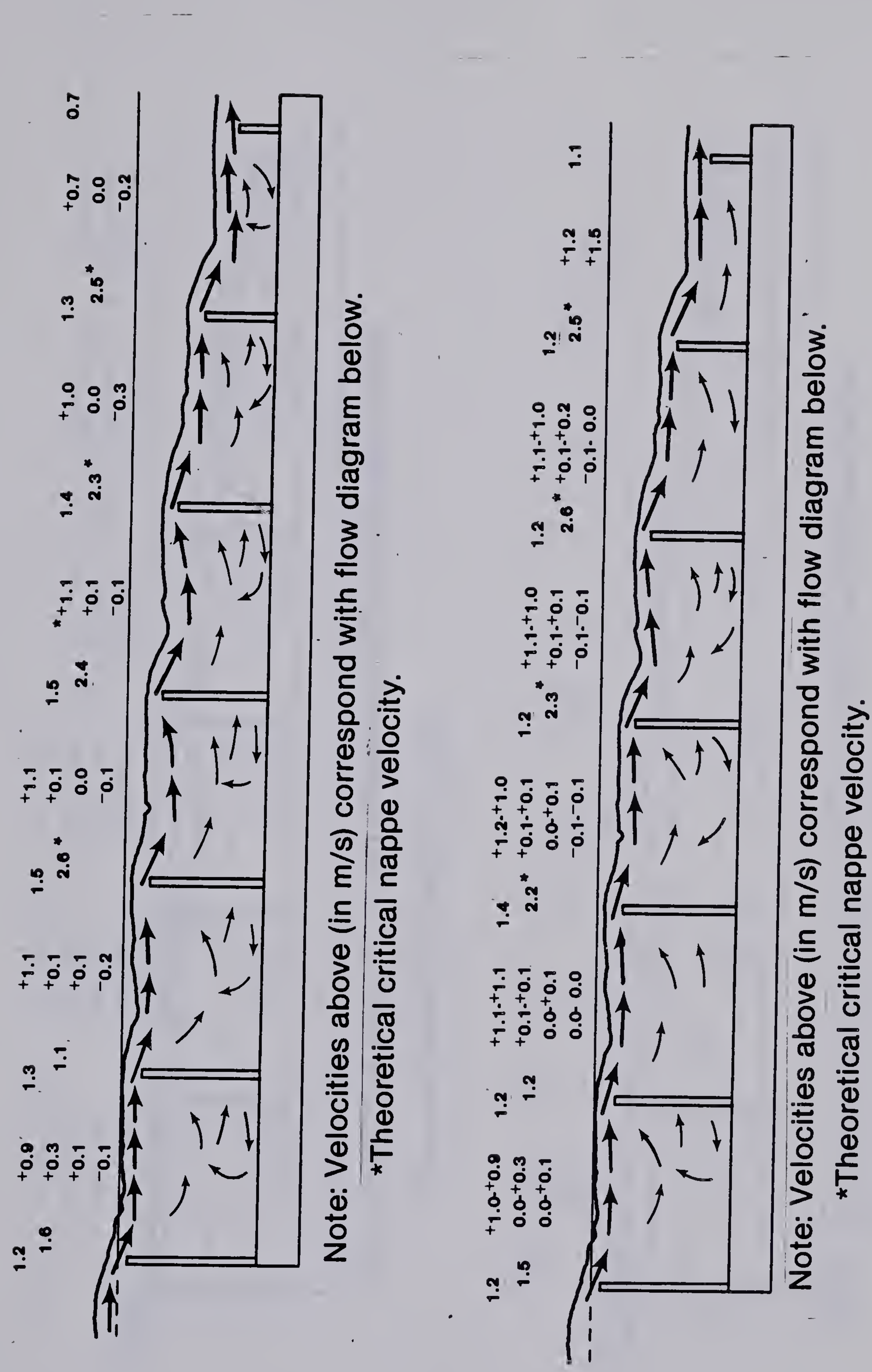

Fig. C.1 Velocity profiles of manipulation #1, set #45 (right); manipulation #2, set #46 (left).

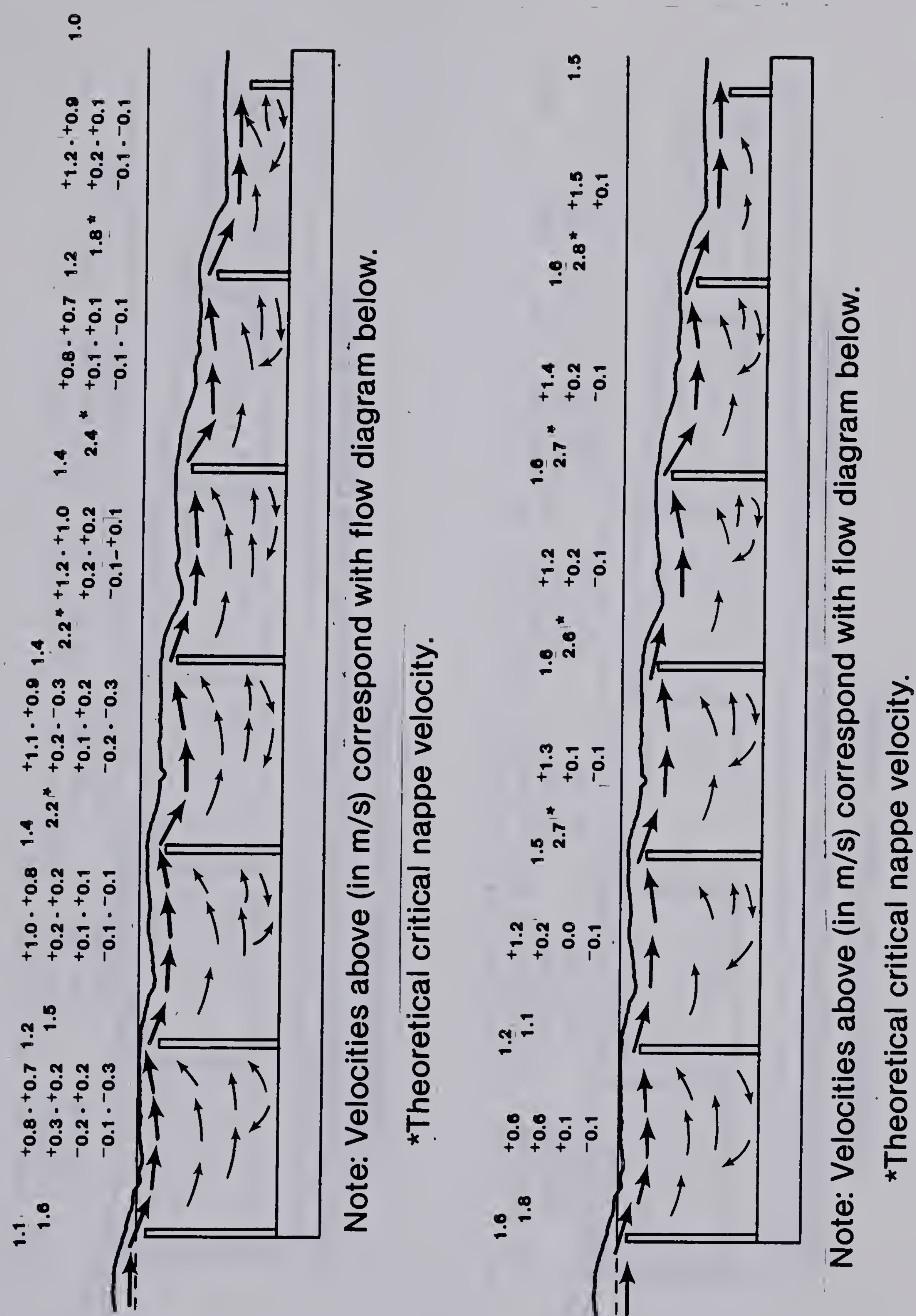

Fig. C.2 Velocity profiles of manipulation #3, set #47 (right); manipulation #4, set #17 (left).

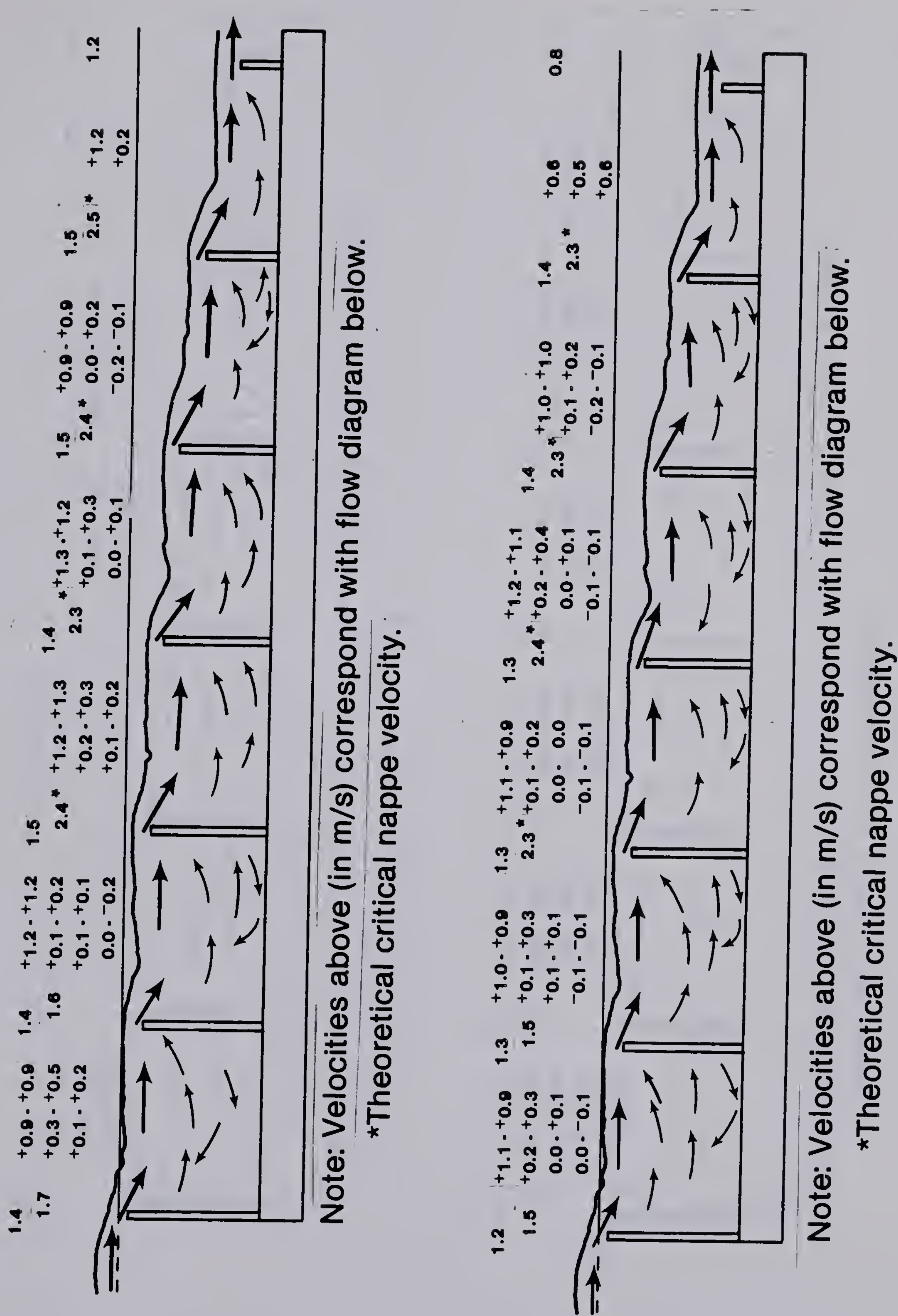

Fig. C.3 Velocity profiles of manipulation #5, set #23 (right); manipulation #6 set #22 (left).

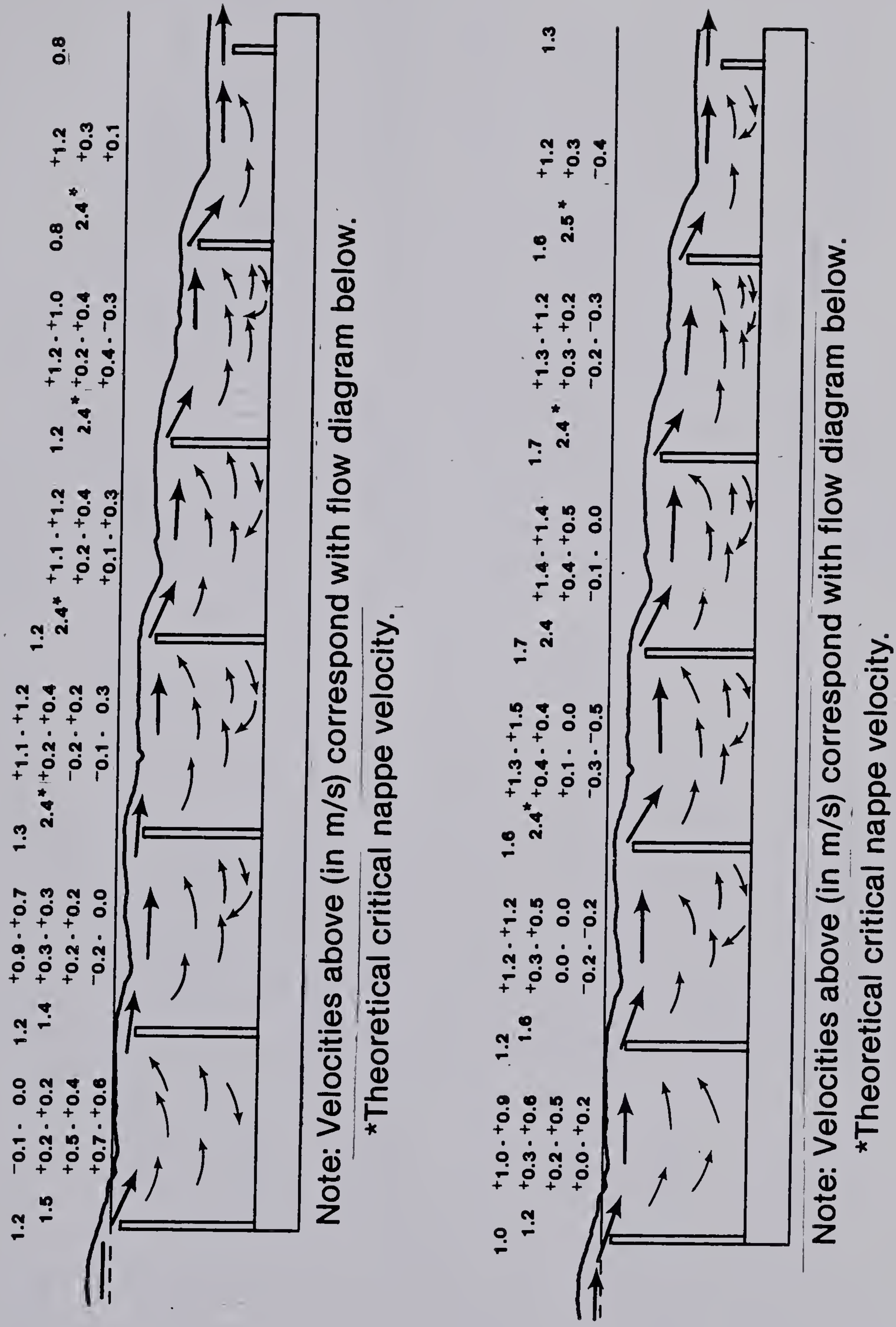

Fig. C.4 Velocity profiles of manipulation #7, set #21 (right); manipulation #8, set #19 (left).

Appendix D

Table D.1 A list of existing and proposed fishladder facilities in the province of Alberta. From Alberta Fish & Wildlife, 1982.

NAME	LOCATION	DESCRIPTION	DATE	SUCCESS	COMMENTS
BEAVERLODGE RIVER	71-10-W6	Stabilization weir, denil 2 fishway proposed	-	-	weir was built without ladder. (Grayling, pike, sucker)
BELLY RIVER	09-23-W4	Stabilization weir, with modified vertical slot fishway. (8 pools, concrete)	1977	not known	no monitoring work done to present
BOLLOQUE LAKE	64-25-W4	Stabilization weir, with step & pool ladder, (3 pools, steel sheet pile)	1978	appears to be unsuccessful	no study done to date (pike)
CARSELAND WEIR	21-2-5-W4	Stabilization weir, with modified vertical slot, dimensions vary		appears to operate properly when flows are adequate	no study to date (trout)
CROSS LAKE	65-25-W4	Stabilization weir, with step & pool ladder, (6 pools, steel sheet pile)	1974	appears to pass mature pike, and sucker	1 study (present paper) (pike, sucker, perch)
DRIEDMEAT LAKE	45-2-W4	Stabilization weir, with step & pool ladder, (8 pools, steel sheet pile and timber logs)	1975	partially operational	1 study (Rhude, 1980) (pike, sucker)
FAWCETT LAKE	73-26-W4	Stabilization weir, with step & pool ladder (10 pools, steel sheet pile with timber logs). Converted to Denil 2 in 1982.	1979	success variable previous to denil present denil 2 appears to pass most species	(Minchau, 1979) (Halsted, 1982 in prep.) (pike, sucker)
GROGOIRE LAKE	86-8-W4	Stabilization wier, with step & pool ladder, (4 pools steel sheet pile)	1974	success variable depending on flows	1 study (Watters, 1980) (pike, sucker, walleye)

NAME	LOCATION	DESCRIPTION	DATE	SUCCESS	COMMENTS
HANGINGSTONE RIVER	89-9-W4	Stabilization weir, with step & pool ladder, (5 pools, steel sheet pile with timber logs)	1979	success unknown	no study done
LESSER SLAVE LAKE	73-6-W5	Stabilization weir with fishladder proposed.	1983		Experimental Denil 2 fishway to be tested.
LETHRIDGE IRRIGATION DISTRICT	8-23-W4	Proposed weirs with ladders			
MANATOKA LAKE	63-7-W4	Proposed weir and ladder			
MIST CREEK	18-7-W5	Proposed weir and ladder			
NOTIKEWIN RIVER	95-20-W5	Submerged weir with notch, (not a true ladder)		appears to pass some fish	no study done (pike, sucker)
PEACE-ATHABASCA DELTA	114-9-W4	Proposed weir with ladder			experiment Denil 2 and vertical slot to be tested (1983).
RIVIERE DES ROCHE	115-9-W4	Fishway cut out of rock (not a true ladder)	1975	passes some goldeye, largely unsuccessful	no study done (pike, grayling, goldeye)
SALINE CREEK	88-9-W4	Proposed baffle system for a culvert			
SNIPE CREEK	73-20-W5	Submerge weir with notch, (not a true fishladder)	1973	appears to pass some fish	no study done (pike)

NAME	LOCATION	DESCRIPTION	DATE	SUCCESS	COMMENTS
STURGEON CREEK	71-21-W5	Stabilization weir, was step and pool, now modified vertical slot (4 pools, concrete)	1969	success unknown	no study done (pike & whitefish)
SWAN RIVER	67-10-W5	Stabilization weir, with denil steeppass ladder	1979	largely unsuccessful	no study done (grayling)
UTIKUMA RIVER	83-7-W5	Submerged weir with notch, (not a true fishladder)	1969	appears to pass some fish	no study done (pike, sucker)
WEST PRAIRIE RIVER	75-17-W5	Stabilization weir, with step & pool ladder, however ladder non-operational as yet.	1979		