THE EFFECTS OF GAUGING STATION CONTROL STRUCTURES ON NATIVE FISH MIGRATION IN FRESHWATER STREAMS OF SOUTH WEST AUSTRALIA

Environmental Protection Authority
Perth, Western Australia
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1. INTRODUCTION

Gauging stations are water monitoring installations on watercourses where the accurate measurement of stream flow, and water quality is undertaken. Some gauging stations incorporate control structures which regulate part of the stream flow, thereby possibly restricting the movement of aquatic fauna. These gauging station control structures will be referred to in this document as 'gauging structures'. Gauging structures are among the many natural and man made restrictions on streams in the south west of WA.

No specific research has been undertaken to date in the south west of WA on the effect of gauging structures on migratory freshwater fish. However, research in south eastern Australia and personal observations by various people in the south west indicate that some gauging structures can present a physical barrier which is not negotiable by migratory fish.

This report reviews the available information on this matter and identifies research required to determine the possible effects of gauging structures on the movement of migratory freshwater fish.

2. GAUGING STATION CONTROL STRUCTURES

2.1 THE NEED FOR GAUGING STATIONS

The Water Authority of Western Australia is responsible for the assessment, planning and management of the use and conservation of the State's water resources for the continuing benefit of the community. The Water Authority of Western Australia is therefore the major operator of gauging stations in Western Australia, however some are also operated directly by private or government organisations, including the Environmental Protection Authority, for specific projects, usually of comparatively short term duration.

Water resource information provided by gauging structures provides information which is used for a range of studies. In the south west of WA specific research on streams and catchment areas involve investigations relating to quantifying salinity increase associated with land clearance, turbidity monitoring resulting from activities such as mining, and monitoring of nutrient losses for agriculture. Information is also used to aid water resource management, floodplain management, water supply design and operation, road and rail design and resolution of land use conflicts. The establishment of gauging stations forms part of an overall programme for the State.

A major review of gauging stations was carried out in 1982 and documented in 'The Hydrometric Network for Western Australia'. This document has been supplemented by a report entitled 'Surface Water Resources Assessment in Western Australia - a Strategy for the Future', recently released by the Western Australian Water Resources Council (November 1986). This report includes a recommendation stating that the network of water resources assessment and special purpose gauging stations be expanded by approximately 200 stations within the next 15-20 years. However, the primary need for network expansion is not in the south west and it is anticipated that most of the new gauging stations will be constructed elsewhere in the State. The majority of the proposed stations will not involve the construction of a major control structure.

2.2 GAUGING STRUCTURE CHARACTERISTICS

Several different types of gauging structures are utilised. These are installed at sites where a stable relationship between stream depth and stream volume either exists naturally or can be economically constructed and maintained. When a natural control, such as a rock bar is available, the relationship between stream depth and streamflow is defined by direct measurement using a current meter. If a natural control is not available a control structure with a predetermined relationship, often in the form of a weir, may be constructed. No practical, economical technology presently exists for continuously directly measuring streamflow at unstable sites.

Factors important for the determination of the type of gauging structure include:

- the degree of accuracy required. Research catchments require a high degree of accuracy;
- the size of catchment area;
- the downstream site conditions (eg whether forested or cleared land);
- the silt and debris load;
- the range of annual water flow; and
- the nature and stability of the banks and channel.

River height, and frequently water salinity and temperature are continuously recorded by instruments housed adjacent to the stream. Many gauging stations are also equipped with automatic water samplers to support a manual water sampling programme for key water quality parameters, eg total dissolved solids, turbidity, sediment, colour and nutrients. All data collected by the Water Authority is available to other government departments and to members of the public.

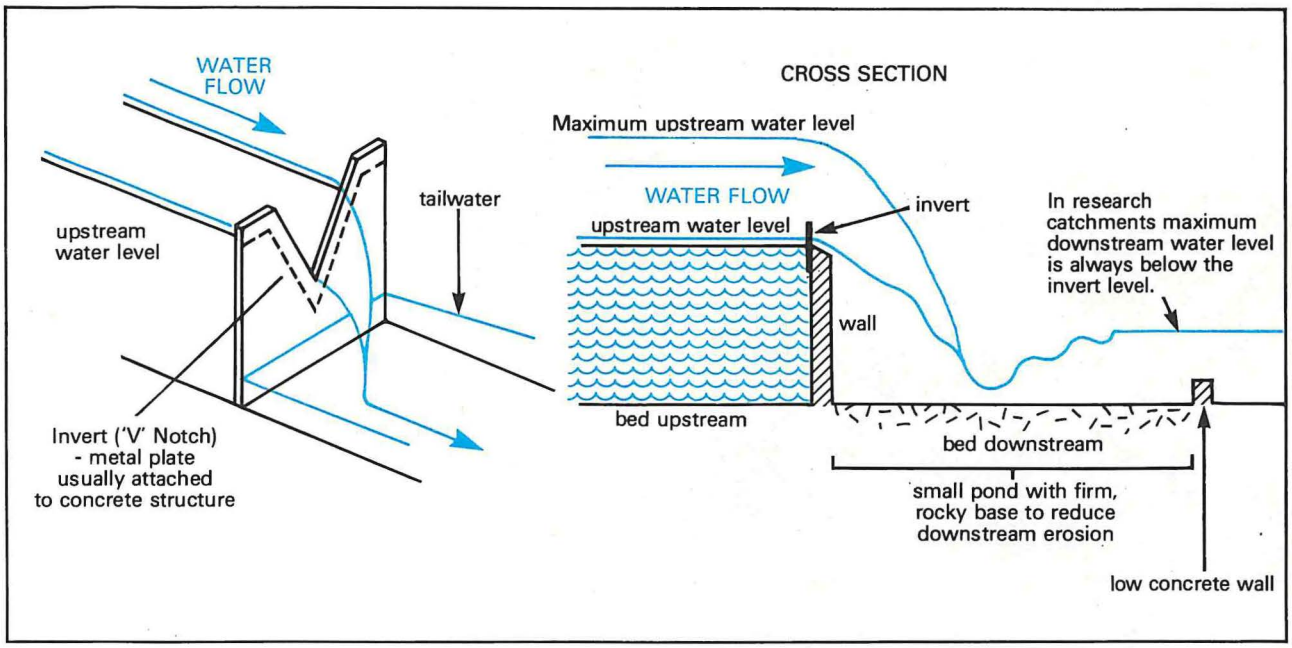
The two main types of control structures utilised by the Water Authority are illustrated in Figure 1.

2.2.1 NARROW OR SHARP CRESTED WEIRS

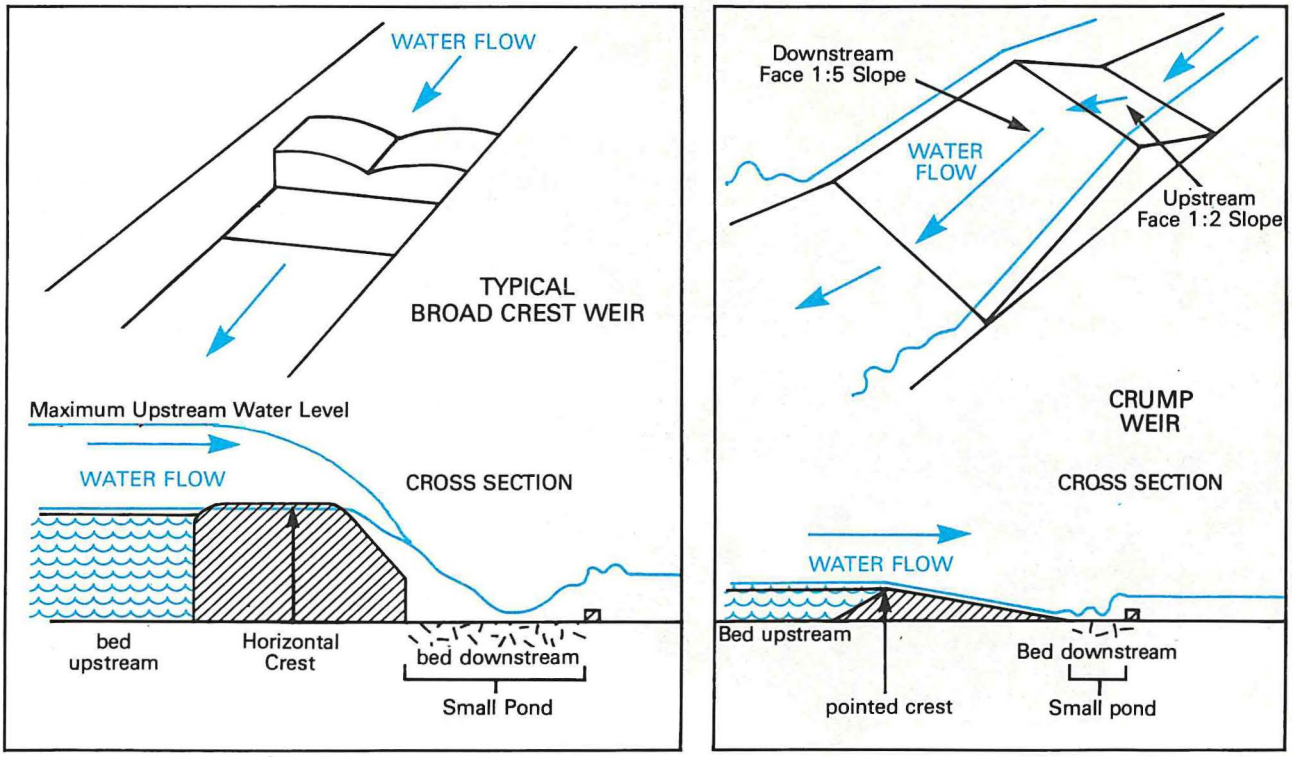
These are generally used to monitor small stream flows. Their 'invert', or base of 'v' notch is sufficiently above the water level downstream (tailwater) of the weir to give an accurate, stable discharge relationship for the required range of flows. These weirs obtain accurate measurements and are usually designed so as never to 'drown out', ie be completely submerged by water. Photographs 3.1 and 3.2 illustrate an example of this type of weir. This includes the characteristic 'V' notch through which water flows and is accurately measured.

2.2.2 LONG BASED WEIRS (INCLUDING FLUMES AND 'CRUMP WEIRS')

These have a broad base without a sharp invert plate and are often used to monitor rivers with a large water flow or when the site is susceptable to variable outside influences. This type of weir has a lower degree of accuracy than sharp crested weirs, and may be used for large and small rivers. These structures are usually seasonally 'drowned out' thereby



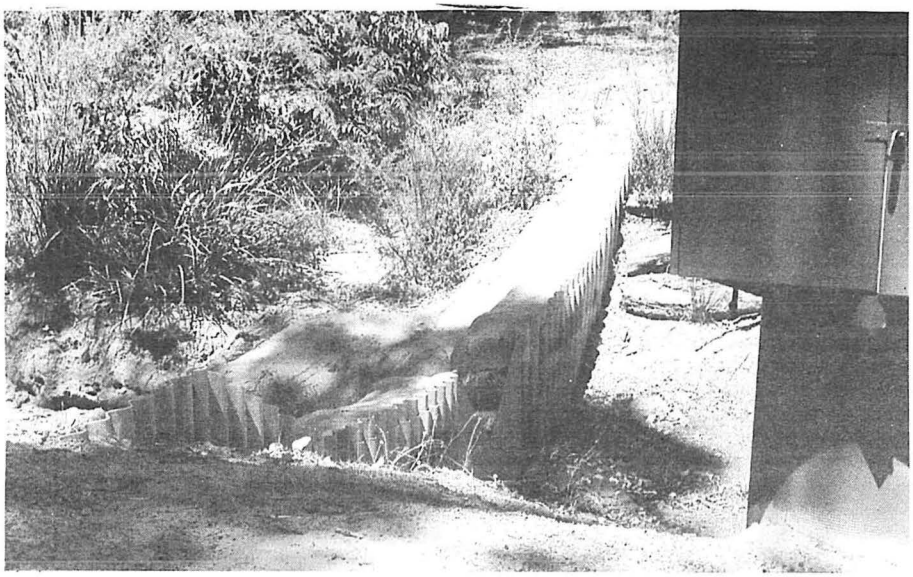
1.1. SHARP CREST WEIR



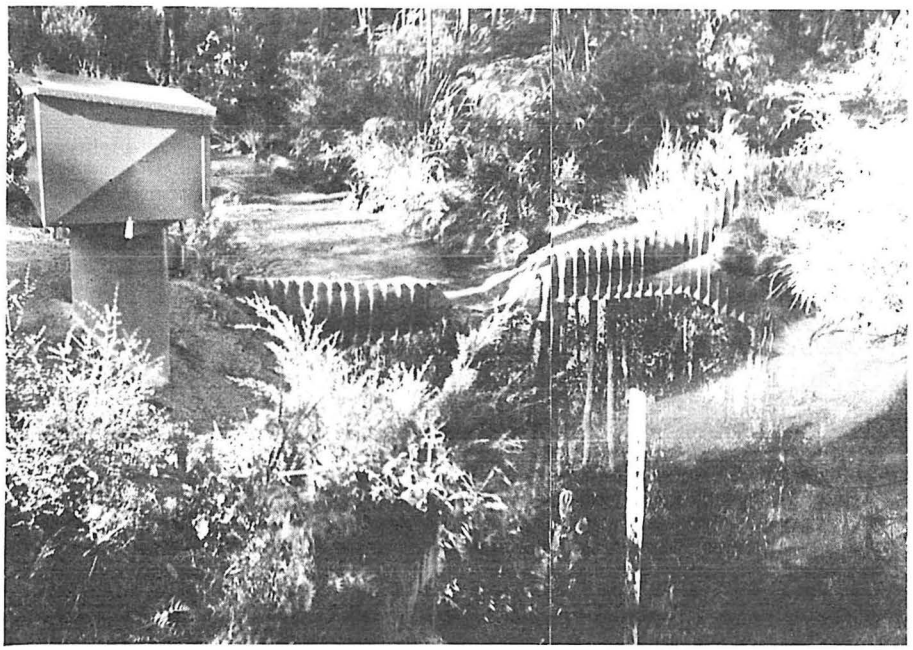
1.2 LONG BASED WEIRS

Figure 1. Diagram illustrating the two main types of gauging station control structures used in South West Australia.

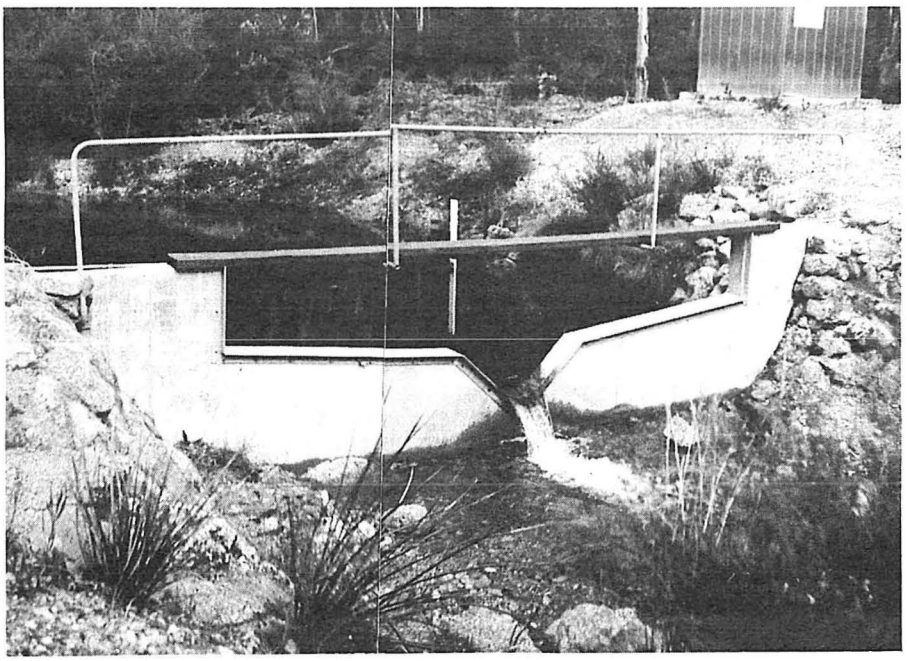
1. Temporary Control Structure, Scar Brook, Harris River, incorporating a sharp crested weir plate (G.12028). This structure has recently been removed by the Water Authority.



1.1 Weir during summer (February 1987)

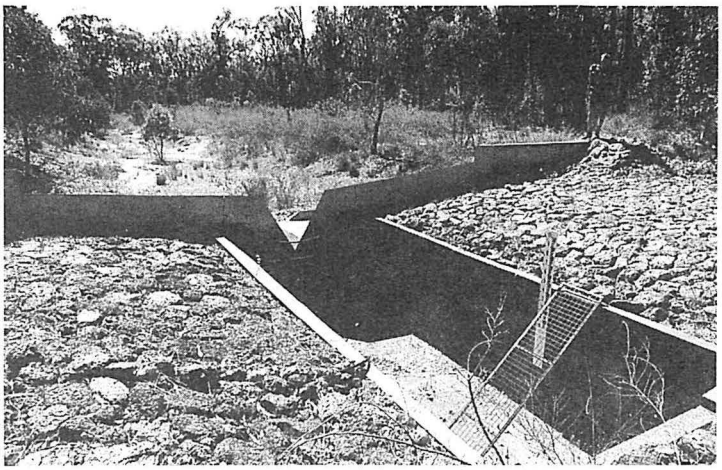


1.2 Weir during winter - control structure is sometimes drowned out, though this is infrequent.



2. Narrow Crest Weir, Mt William, Samson Brook. It is unlikely that fish could negotiate this weir during low flows.

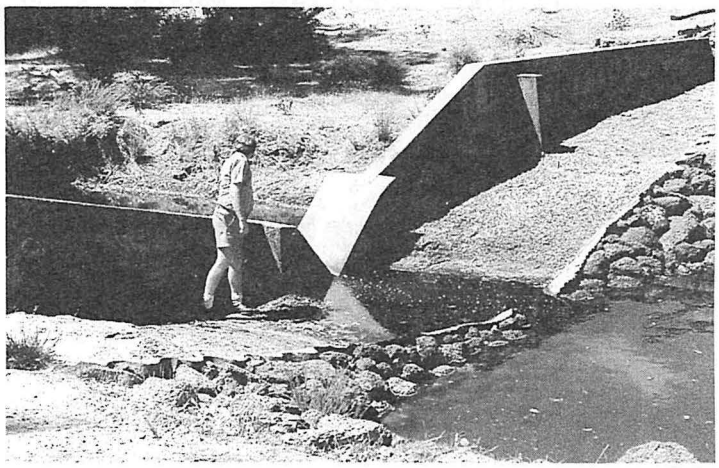
3. Sharp Crested Weir, Ernies Catchment, Bingham River (G 12008).



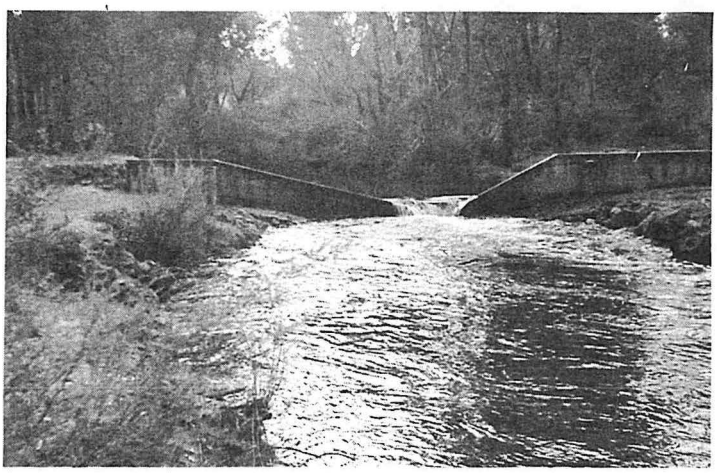
3.1 Upstream of weir. Immediate vicinity has been cleared to increase monitoring accuracy.

3.2 Downstream of weir. This weir has been designed to never drown out and obviously fish could never bypass the control structure.

4. Narrow Crest Weir, Tallanalla Road, Harris River (G 12017)

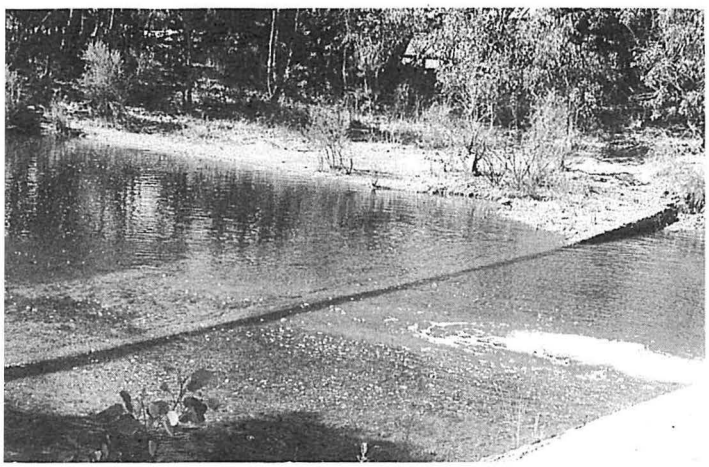


4.1 Weir during summer (February, 1987)

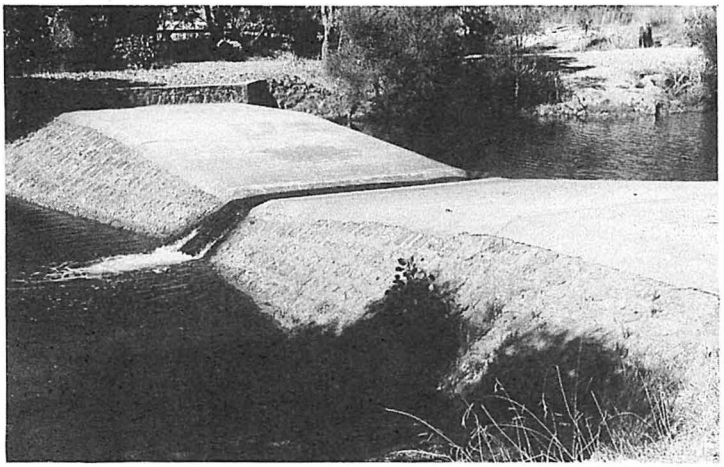


4.2 Weir during winter. Minnows may be able to negotiate this structure although this is not known.

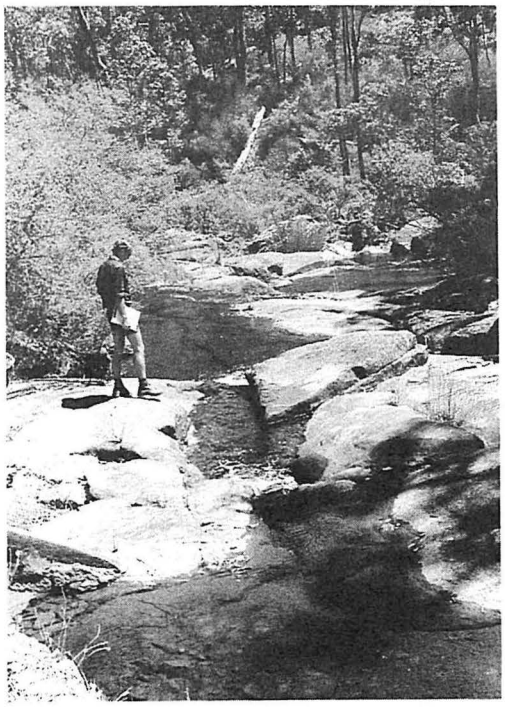
5. Broad Crested Weir, Collie South Branch, Collie River (G 12034).



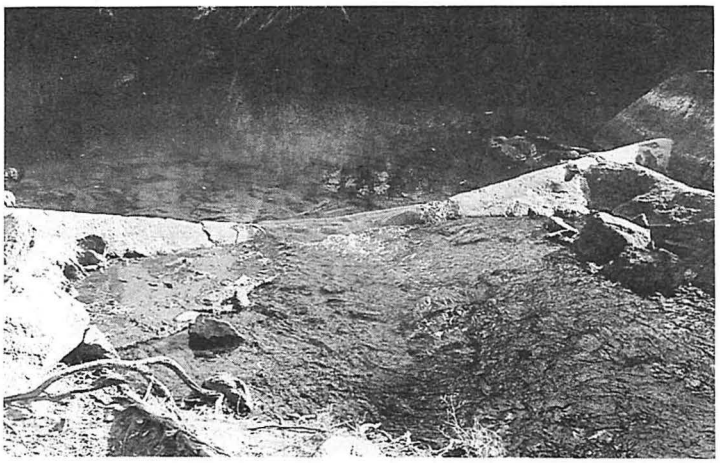
5.1 Weir during summer (February, 1987). River flows permanently and minnows have been located upstream and downstream of structure.



5.2 Downstream of weir. The low cement wall (in centre of photograph) creates a 'small pool' at the base of the weir to reduce downstream erosion.



7. Natural Control, Falls Brook (G 13008). Local geology has formed a natural constriction hence a control structure is not necessary.



6. Natural Control, Mungalup Tower, Collie (G. 12002). A small cement ridge has been built on the rocky stream bed to stabilise the section and so aid water flow monitoring.

presenting only a temporary obstacle to the upstream migration of fish. Photograph 5 illustrates an example of this type of weir.

At locations where the local geology creates a natural restriction in the water course the construction of a gauging structure may not be necessary (see Photographs 6 and 7).

3. POTENTIAL IMPACT OF GAUGING STRUCTURES ON FISH MOVEMENT

3.1 RESEARCH BACKGROUND

Extensive research on the effect of barriers in freshwater streams on migratory aquatic fauna has been undertaken in Europe, however research on Australian freshwater fishes is poorly documented and the ecological significance of obstructing fish passage through inland drainage systems has seldom been examined.

Northern Hemisphere research has almost exclusively been in relation to Salmonid fish species which migrate throughout large permanent streams. It is known that Australian freshwater fish are generally slower moving and smaller in size, and inhabit streams with much greater seasonal fluctuation in water level. It is also known that few Australian freshwater fish leap. However, Northern Hemisphere research can aid in understanding factors which trigger fish migration, and factors required for fish to successfully negotiate natural or artificial restrictions.

It is known that many native Australian fish are 'potamodromous' ie they migrate within inland river systems. These travels may be related to the fact that water is continually moving in one direction, and to oppose the continual downstream motion, many fish tend to migrate upstream to spawn. Fish are most susceptible to downstream displacement in their early stages as eggs or larvae (Harris, 1985) as obviously at that stage of their life cycle they are not able to swim and so oppose the current. It appears then that fish passage upstream is required to allow some fish species to complete their life cycles and to avoid gradual downstream displacement.

Factors which are thought to trigger fish migration include:

- flooding - is thought to provide the stimulus for major biological events, in particular migration and breeding;
- water, noise and turbulence - presumed to be associated with floods (Beach, 1984);
- temperature and dissolved oxygen levels in water; and
- water temperature.

Factors thought to contribute to restricting fish movement include:

- height of obstacle;
- water velocity;
- size of fish; and
- length and depth of water approach before an obstacle.

3.2 NATIVE FISH SPECIES WHICH MAY BE AFFECTED BY GAUGING STRUCTURES

Native fish species which may be affected by the presence of gauging structures in the south west of Western Australia include:

. Western Minnow (Galaxias occidentalis)

These are lean fish which can jump up to 30 centimetres and can negotiate low weirs. They have been known to migrate upstream over distances of several kilometres to river headwaters, where they spawn after the first winter rains, and have been observed gathering in large numbers downstream of gauging structures during winter.

. Nightfish (Bostockia porosa) and Western Pygmy Perch (Edelia vittata)

These are fatter, more sluggish fish which are not known to migrate over large distances. Although they are not thought to be severely restricted by gauging structures, the restriction of small scale high frequency movement may still be significant.

3.3 POTENTIAL IMPACTS

Gauging station control structures can restrict the passage of fish as they are designed to restrict water flow. In Western Australia the seasonal flow of water in inland streams and rivers is highly variable and most gauging stations, with the exception of sharp crested research weirs, tend to partially drown out during periods of heavy rainfall. Long based gauging weirs have a relatively small drop which may therefore present less of an obstruction to the movement of fish. However, most weirs prevent fish movement upstream for long periods of time during dry periods, therefore restricting migration and/or isolating upstream and downstream populations. Once a sharp crested weir is constructed it is almost impossible for fish to recolonise the area upstream.

Large numbers of fish, especially minnows, have been observed gathering downstream of gauging structures in south west rivers, in particular in the Collie area (Ed Riley, Pers Comm). Two theories have been suggested to explain this. Either the fish are attracted to the highly oxygenated water from the flow cascading over the structure, or alternatively the fish are physically prevented from passing it. Fish congregating at these locations provide easy prey for exotic fish species, predatory birds such as heron, and recreational fishing people.

Restriction in fish distribution may lead to a quantitative reduction in the overall size of fish populations.

Other potential impacts include:

. Delay in spawning time

Fish such as minnows like to move upstream after the first winter rains. These rains may create sufficient flow to drown out a control structure however, as previously mentioned, some gauging structures are designed so as never to drown out. This condition could have a natural equivalent during periods of drought, however the effect of delayed seasonal migration is not known.

- Physical damage to adult fish as they swim upstream and downstream of gauging structures.

- Juvenile fish and fish larvae are not affected when moving downstream as they are buoyant and float near the surface. Attempts by adult minnows to overcome gauging structures can result in damage to the fish (Luke Penn, Pers Comm.).

- Subtle changes to water temperature and dissolved oxygen levels which affect fish migration ie low temperatures or low levels of oxygen may affect fishes swimming performance, thereby altering fish migration behaviour (Harris, 1985). However, there is no definitive evidence for this.

Some fish act as vectors for other aquatic organisms eg freshwater mussels (Williams 1980). These organisms are dependent on the fish to transport them upstream and so repopulate the upper reaches. Restricting fish movement can therefore restrict the distribution of other aquatic fauna. This is considered to be an indirect, though significant effect.

The creation of relatively large pools of water could be viewed in some cases as beneficial to some aquatic organisms. This would generally apply as a result of the creation of deeper water, giving greater protection, reduced water temperature and increased food supply.

4. WATER AUTHORITY OF WESTERN AUSTRALIA POSITION

The Water Authority believes it should be responsive in its attitude to environmental issues, however, the question of gauging station control structures should be viewed in the context of the overall industry and community usage of a water course. Any concern regarding fish passage should address all man-made constrictions anywhere in the water course and not just specific structures.

Gauging structures designed by the Water Authority take into consideration two primary factors, accuracy and stability. The primary constraints are considered to be economic and environmental considerations. Natural control gauging stations are preferred as they are obviously cheaper to construct and maintain, however they are often not capable of producing sufficiently accurate data over the full range of flow conditions. Small streams, because of their extremely rapid water level change in response to rainfall, can only be gauged by the use of precalibrated structures. Sharp crested weirs are therefore often the only means to obtain accurate information. These are usually installed in catchments of 20 sq km^2 or less, on creeks which are characterised by intermittent flows at locations where they are representative of similar catchments in the vicinity.

The Water Authority recognises that its control structures, particularly sharp crested weirs, have the potential to interfere with fish migration and distribution. The possibility of incorporating a 'shute' or 'ramp' to existing sharp crested weirs has been considered, however, in order to obtain accurate measurements, water must free fall from the notch to the river bed. The greater the water flow, the bigger the drop and ramps would be unsuitable. The introduction of 'Parshall Flumes' is not considered a practical gauging weir alternative as they induce high water velocities, provide inaccurate information during low flow conditions,and would have to be large and therefore uneconomical.

Broad crested weirs are the most commonly installed gauging control structures, and are designed to drown out during periods of high rainfall. Fish appear to have no trouble passing these during winter months.

The Authority has initiated a number of studies of aquatic fauna in south west streams, which includes assessing the potential impact of gauging stations on aquatic fauna (Davis et al 1987a) and 1987b), and is currently reviewing the need for several temporary gauging weir structures. This has led to the closure and removal of three temporary structures on the Harris River catchment. Others no longer required will also be closed and removed.

The design of any new Water Authority gauging control structures will address the requirements of fish passage. This will include allowing fish passage in most years, or not reducing the existing potential for fish passage in the water course. In general terms, with the exception of small catchments (necessitating sharp crested weirs) natural or minimal constriction or utilising other artificial constrictions eg bridges, is preferred.

5. CURRENT RESEARCH

Additional research is required to determine what effect gauging station control structures do actually have on migratory native fish in the south west.

Studies are currently being undertaken at:

- University of Western Australia through the Aquatic Research Laboratory (Zoology Department) on the aquatic biota of selected rivers in the northern jarrah forest, funded by the Water Authority of Western Australia. Studies undertaken at North Dandalup Pipehead Dam indicate that fish populations differ in size upstream and downstream of the dam.

- Murdoch University through the School of Environmental and Life Sciences on aquatic biota (mainly invertebrates) in the Lower Serpentine River, Dirk Brook (Davis et al 1987a) and 1987b) and Big Brook. This research is also funded by the Water Authority of Western Australia.

The studies at Serpentine and Dirk Brook have been designed primarily to provide a baseline from which the effect of the proposed new water supply pipehead dams can be determined. However, the studies will also provide additional information on the effect of existing gauging structures on the aquatic biota of these streams.The study on Big Brook has been initiated to determine the effect of the newly constructed dam on fish species inhabiting Big Brook. However, it will also investigate the effect of an existing gauging structure on Lefroy Brook.

- University of Adelaide on the 'Hydrological and Ecological Effect of Small Weirs', by Dr. Keith Walker. This project is still at the planning stage and is due to commence in July 1987, to extend over a three year period.

Extensive research has also been undertaken by Dr John Harris on fish migration in New South Wales. He has been involved in research on the effect of gauging stations on native fish and believes weirs are a significant problem throughout Australian rivers. Luke Penn (Murdoch University) believes that gauging weirs could represent a potential problem to fish distribution in the long term. In particular, additional obstructions such

as gauging weirs could prevent migration (and thus minimise distribution) to new habitats in wet years following several years of drought. Native fish species in the south west of Western Australia are particularly vulnerable to these effects.

6. CONCLUSION

While the Environmental Protection Authority recognises that gauging station control structures are only one of several different types of artificial barriers which may prevent fish migration, research is required to assess the possible impact of gauging structures on native migratory fish. Further information is also required to further define the biology of the native fish species inhabiting the streams of the southwest, and to determine the seasonal triggers and flow conditions which stimulate fish movement. An objective assessment of the possible impact of gauging structures can then be made and the design of new structures modified to ameliorate any adverse effects.

Research addressing these objectives has been initiated by the Water Authority of Western Australia in conjunction with the Zoology Department, University of Western Australia and the School of Biological Sciences, Murdoch University.

7. REFERENCES

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