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Restoration of a gauging weir to aid fish passage

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Abstract

This paper presents a case study of restoration of a flow gauging station namely Pontneddfechan located in South West Wales, UK. The weir was found to be affected by significant deterioration due to prolonged use and also created obstacles to fish migrating upstream. The main objective of this paper is to examine the hydraulic conditions of the weir considering the opportunities for fish passage while still retaining the accuracy of flow measurement. A one-dimensional hydrodynamic model called ISIS was used to estimate hydraulic parameters under different flow conditions. Results indicated that the weir did not fulfil the fishery requirements in the original condition. The stilling basin was modified as a way of improving the fish pass. While the modified weir was favourable for strong swimmers like salmon and trout, it was not adequate for weaker swimmers such as coarse fish. A rock ramp structure has been designed and assessed to aid fish passage across the weir.

Keywords: Crump weir; Fish passage; Gauging weir; Hydraulic modelling; Hydrometry

1. Background

Hydrometric structures such as weirs and flumes dominate the hydrometric network in the UK because they offer a number of advantages over other available gauging methods. They provide a relatively accurate and reliable means of measuring flow on a continuous basis with minimal calibration and little day-to-day maintenance (Zaidman et al., 2005). Crump and Flat V weirs are the most common flow gauging structures in the UK (Environment Agency, 2010a). While these gauging weirs are important assets for water resources management, such types of intrusive structural barriers create problems for migrant fish species and result in direct influence on the stream habitat conditions, particularly riverine fish populations (Fjeldstad et al., 2011; Mouton et al., 2007; Poulet, 2007; Turnpenny et al., 2002; Mills, 1989). Obstructions created by in-channel structures result in changes in flow regimes (Armstrong et al., 2003), and can impact upon fisheries by changing wetted perimeter (habitat availability), velocity, flow depth and the ability of fish to undertake upstream and downstream migration (Solomon et al., 1999; Clough and Turnpenny, 2001).

Upstream fish pass structures are an integral and growing component of projects designed to restore river connectivity and thus facilitate the upstream or downstream migration of fish (Bunt et al., 2011; FAO, 2002). The effectiveness of different types of fish pass structures has been extensively studied over the past few decades (eg. Beach, 1984; Yagci, 2010; Rhodes and Servais, 2008; Kim, 2001). However, reconciling fish passage at gauging weirs has become an important issue as many weirs are affected by significant deterioration due to prolonged use leading to reduced confidence in the accuracy of flow measurement data. The rehabilitation of a weir provides the opportunity to improve upon the original design and to include fish passage measures that may not have been considered originally (Rickard et al., 2003).

As part of its strategic policy of monitoring the environment and managing flood risk and water resources, Environment

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Agency Wales considered restoration options for some existing gauging weirs in South West Wales which were in poor condition. Restoration of the weirs was necessary to improve the hydrometric data quality as well as offer the opportunity to enhance fish passage, thereby improving access to upstream habitats. In this context, the aim of this study was to examine the hydraulic conditions of a gauging weir considering the opportunities for fish passage whilst still retaining the required accuracy for flow measurement.

2. Location and characteristics of the gauging weir

Pontneddfechan Gauging Station is located northeast of Glynneath on a steep reach of the River Mellte (catchment area circa 66 km^2), approximately 1.6 km upstream of its confluence with the River Neath (Fig. 1). The weir has been in continuous use for over 40 years as important assets for water resources and flood risk management and provides flow data for the National River Flow Archive held by the Centre for Ecology and Hydrology (http://www.ceh.ac.uk/). The weir is also used to calibrate high flow estimates for local development control (Flood Consequences Assessments) and strategic flood risk planning such as Catchment Flood Management Plans (CFMP's). In addition, the data are used for various purposes such as resource assessment for abstraction licensing, water resources strategic planning together with Water Framework Directive, Habitats Directive and Drought Management Planning (Halcrow, 2007).

Pontneddfechan Gauging Station consists of a flat V-shaped Crump weir approximately 15 m wide and 16 m long (Fig. 2, Table 1). A Crump weir is a gauging weir with triangular cross-section, typically with a 1:2 upslope and 1:5 downslope face and is suitable for measuring flow in low and high flow conditions. Crump weirs are used as measuring structures in open channels and have the advantage that the coefficient of discharge is predictable and that they operate over a wide modular limit. A diving survey, undertaken in 2007 to assess the condition of the weir, concluded that significant erosion had occurred across the weir's crest, stilling basin and sill which were made of reinforced concrete. Significant undercutting of the sill toe had also occurred, compromising the structure's integrity (Halcrow, 2007).

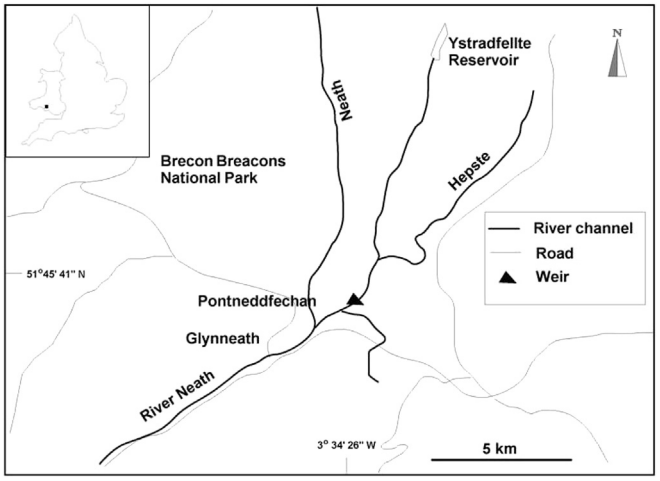

Fig. 1. Location map.

3. Methodology

3.1. Fish passage requirements and design criteria

The Environment Agency Fish Pass Manual (Environment Agency, 2010b) stipulates that refurbished gauging station weirs should be modified to ensure the guideline parameters are adhered to, e.g. reduced afflux, improved approach conditions, or that a fish pass is constructed to form a compound gauging and fish pass structure. The design guidelines developed by the Environment Agency Joint Hydrometry and Fisheries Fish Passage Group (Environment Agency, 2010b) are useful for assessing the fisheries requirements of a gauging weir and are adopted in this study. This study considers mainly two factors which are directly relevant to the passage of fish: the head difference between the crest level and downstream tail water level, and the velocity of the flow. The head difference governs the height that fish will be required to ascend. The velocity of flow governs the swimming speed that a fish must be able to maintain to be able to pass over a structure.

The high velocities and thin flows created at Flat V weirs can be very problematic as fish are often attracted by the noisy turbulence of the hydraulic jump, which they then have to overcome before negotiating the long downstream face of the weir (Zaidman et al., 2005). In the design of any fish pass facility, it is important to consider the swimming capability of the fish. There are generally three levels of speed. "Cruising" is the speed that can be maintained for a long period of time (hours). "Sustained" speed can be maintained for minutes. "Burst" speed is the maximum speed that can be maintained by a fish for less than 20 s. The burst and sustained swimming performance of fish governs their ability to ascend weirs and fish passes and it varies between species and between individuals of the same species (Clough and Turnpenny, 2001).

The fish pass must be designed in such a way that the water depths that fish need for ascending are respected and that the permissible flow velocities are not exceeded for the design flow conditions. Three design criteria have been considered in this study which relates to the position of weir crest level, flow velocity in the stilling basin and the depth of flow. In accordance with the design guidelines of the Environment Agency Joint Hydrometry and Fisheries Fish Passage Group, the following criteria have been used (see Fig. 2 for notations):

(1) The maximum difference between the crest level and the downstream tail water level (h) should be less than 0.3 m for a Flat V weir.
(2) The mean approach velocity in the stilling basin (v) should not be greater than 0.7 m/s for migratory salmon (including trout) or 0.3 m/s for coarse fish.
(3) The minimum flow depth (d) in the stilling basin should be 300 mm.