An Experimental Facility to Generate Artificial Up and Downwelling Zones

John Davy-Bowker

Freshwater Biological Association, River Laboratory, East Stoke, Wareham, Dorset, BH20 6BB, England

Introduction

Studies of the ecological consequences of hyporheic exchange processes have been constrained by the practical difficulties of coupling measurements of flows of water in and out of the streambed with the collection of quantitative biological samples (Davy-Bowker *et al*. 2006). Measuring up and downwelling flows using piezometers or seepage meters is often inaccurate in the coarse substrate of running waters and usually disturbs the substrate so as to make representative biological sampling impossible. An experimental facility is presented (Figs. 1, 2) to artificially generate replicated up and downwelling zones in a natural streambed within treatment pots that can be extracted as biological sample units.

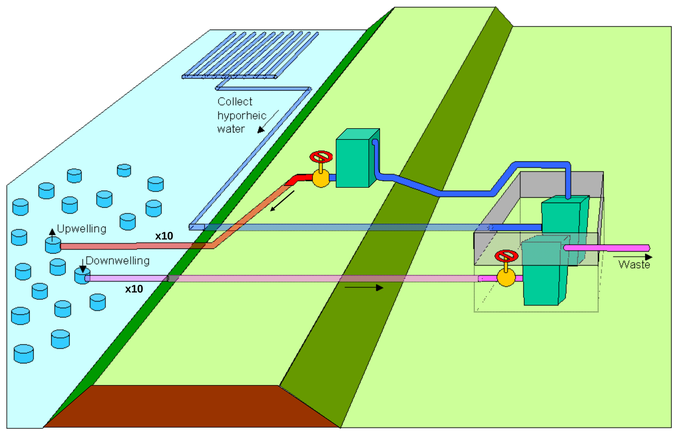

Fig 1. Schematic diagram of experimental structure showing directions of water movement

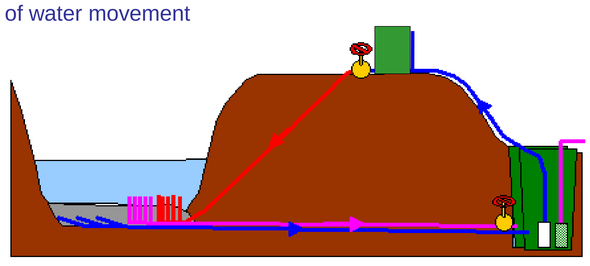

Fig 2. Cross section diagram showing directions of water movement

Study Site

This new facility is located in Dorset, England, on the Mill Stream (Fig 3a), a side channel of a 4th order chalk stream, the River Frome.

Fig 3. a) Study site on the Mill Stream, Dorset, England; b) Excavation of a sub-streambed depth trench through the stream bank

Design & Construction

The facility is designed to create 10 independent downwelling and 10 upwelling treatments with water movement through each treatment being gravity-fed and controlled by valves. For gravity-driven water movement to occur, the depth at which the water carriage pipes are installed is critical (Fig 3b). For downwellings the water pipes fall as water is carried away from the treatment pots via flow control valves to a collection reservoir (Fig. 6b). For upwellings an excess volume of natural hyporheic water is collected by a large under gravel manifold (Fig. 5). This is pumped up to a header tank on the bank and then released through flow control valves into the base of the treatment pots.

Fig 4. a) 20,000 hyporheic water collection holes; b) wrapping collection pipes in capillary matting; c)one of ten 30cm deep x10m length streambed trenches for hyporheic water collection pipes

The hyporheic collection manifold comprises 10x10m length, 2cm diameters pipes, drilled with a total of 20,000 2mm water collection holes (Fig 4a). These pipes were wrapped in capillary matting (Fig. 4b) to prevent the penetration of sand, and buried 30cm below the streambed (Fig. 4c).The collection pipes were united into a single pipe (Fig. 5) to drain into a collection reservoir outside the stream (Fig. 7a).

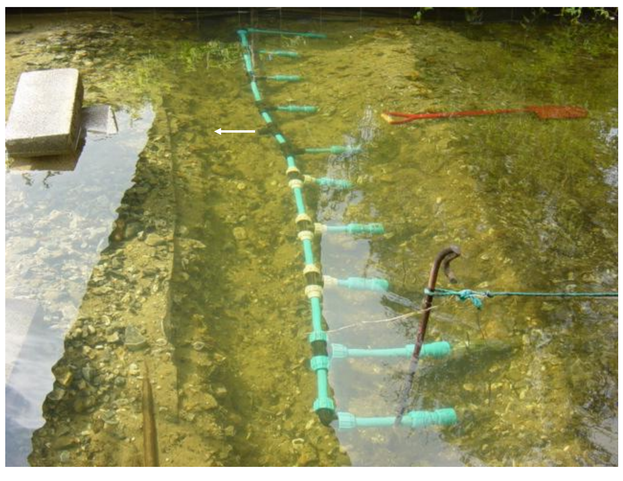

Fig 5. Hyporheic water collection manifold (30cm depth below gravel) prior to connection to a single through-riverbank pipe (arrow) and burial

Two collection reservoirs were installed in a deep reinforced concrete chamber adjacent to the stream (Fig 6a), one to collect and measure the flow of downwelling water (Fig 6b) and one to gather the hyporheic water from the collection manifold prior to pumping to the header tank to provide upwelling water. The whole facility is controlled by 20 independent valves (one for each treatment pot), and 2 large pumps to move bulk volumes to water up to the header tank and away as waste. Fig. 7b)

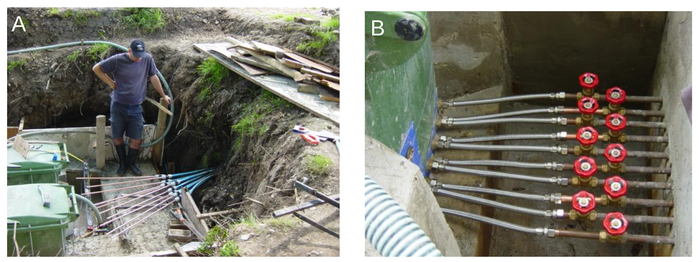

Fig 6. a) Connecting and concreting in downwelling pipes; b) downwelling pipes, flow control values and a collection reservoir

Research Questions

We plan to use this new facility to carry out a series of collaborative studies:

- Studies of links between vertical hydraulic exchange and the community structure of macroinvertebrates, meiofauna and phytobenthos
- Studies of the importance of up and downwellings for macrophyte (*Ranunculus* sp.) establishment and growth
- Examination of the importance of up and downwellings for Salmonid fish egg survival
- Studies of chemical transformations within the hyporheic zone and the effects of residence time
- Studies of the influence of up and downwelling flows on hyporheic zone microbial processes

Ref: Davy-Bowker J., Sweeting W., Wright N., Clarke R.T. & Arnott, S. (2006). The distribution of benthic and hyporheic macroinvertebrates from the heads and tails of riffles. Hydrobiologia. 563: 109–123.

Fig. 7a) Completed collection reservoirs with main pumps installed; b) reinforced concrete chamber housing collection reservoirs and pumps