



## Briefing Paper

### River and Groundwater Abstraction

Water is essential for all life forms; it makes up approximately 60 to 70%, by weight, of all living organisms, is essential for photosynthesis and controls biodiversity distribution on the planet. Water covers approximately 71% of the earth surface, yet 97% is saline water in the oceans. Of the 3% of freshwater, about 69% is trapped in icecaps, 30% in groundwater and only 1% is readily available in surface waters such as rivers and lakes (Gleick, 1996). The demand for freshwater for both human and environmental needs, therefore can result in conflicts.

River flow is the result of rainfall and is measured in units of volume / time. It is often referred to as discharge. The interaction of discharge/flow with the shape of a river channel creates water velocity patterns. Rivers do not have single, uniformed flows. Instead, river flows vary through time in response to changing rainfall, mediated by underlying geology: more porous rocks allow greater storage of water in aquifers (underground or groundwater reserves) and lead to smoother, more damped flow patterns through time. Flow also depends on landscape and land use, something humans do influence. The timing and intensity of high and low flow events can have important effects on aquatic biodiversity (Poff *et al.* 1997; Brown and Ford, 2002). Human activities, such as the direct removal of water from rivers and aquifers (abstraction), and impoundment (construction of dams for various purposes), have greatly modified the natural flow regimes of many rivers (Ward and Stanford, 1983, 1995; Poff *et al.*, 1997). It is estimated approximately 60% of the world's rivers have been diverted, and many of the rivers, including the Colorado, Ganges, Murray and Yellow, no longer reach the sea (Naiman *et al.*, 2002).

Abstraction is the permanent or temporary removal of water from rivers, canals, lakes, reservoirs or aquifers. Data from 2005 showed 57,757 megalitres of water per day was abstracted from surface and ground waters in England and Wales, of which approximately 52% was used in electricity production and 30% in public water supply. The remaining amount was utilised by agriculture, fish farming, mineral washing and other industries (Defra Abstraction Statistics, 2005).

Over-abstraction can be destructive to resident river flora and fauna, and animals with a migratory lifestyle. Human water management activities are threatening our freshwater systems (Giles *et al.*, 1991; Wood and Petts, 1994). The restoration and preservation of native stream biota requires the rehabilitation of natural flow regimes (Stanford *et al.*, 1996; Poff *et al.*, 1997). Yet, it is predicted that by 2025, 40% of the world's population will be facing water poverty (Naiman *et al.*, 2002). The challenge is how we balance these needs.

#### Potential Impacts of Water Abstraction

Hydrological variability within rivers and streams is widely recognised as one of the primary factors influencing the distribution of aquatic flora and fauna (Townsend *et al.*, 1997). Unnaturally low flows and altered flow regimes caused by water abstraction can have damaging impacts on river systems, and their associated biota (Wright and Berrie, 1987; Giles *et al.*, 1991; Wood and Petts, 1994; McKay and King, 2006). The biological communities living in flowing water conditions are adapted to natural flow regimes combined with natural channel morphology, for example via their body shape, metabolism and feeding behaviours (Statzner *et al.* 1988). Hence changes in discharge can have major impacts on these communities.

Over-abstraction of river systems can cause:

- Hydrological and hydraulic changes. A reduction in discharge alters the width, depths, velocity patterns and shear stresses within the system (Armitage and Petts, 1992). This can modify the distribution and availability of in-stream habitat, which can have detrimental effects on invertebrates and fish populations (Wood *et al.*, 1999). Altered flow regimes have also been linked to invasion of non-native species (Baltz and Moyle, 1993; Brown and Moyle, 1997; Brown and Ford, 2002). Velocity is a significant factor affecting the distribution and assemblage of lotic invertebrates (Statzner *et al.*, 1988), by influencing their respiration, feeding biology and behavioural characteristics (Petts, 2008).
- Shifts in invertebrate assemblages (Armitage, 1987). For example, reduced abundance of filter-feeding invertebrates such as caddisflies, and a reduction of stoneflies and heptageniid mayflies, which favour clean stones and well-oxygenated water (Extence *et al.*, 1999), and an increase in taxa associated with low velocity including chironomids and molluscs (Jowett and Duncan, 1990). Some macroinvertebrates are able to survive short episodes of low flow, providing adequate refugia are available. However, prolonged artificially low flow conditions can lead to invertebrate mortality (Armitage and Petts, 1992). The Salmon and Trout Association (S&TA) River Fly Life Abundance survey data from 2002 clearly correlates low flow with decreasing fly abundance (Hayes, 2007).
- Water quality changes. An artificial reduction in flow reduces dilution of effluent which is returned to rivers (Armitage and Petts, 1992). This will increase the concentration of any pollutants when compared to the situation without an artificial flow reduction.
- Sediment deposition. Periodic high flows (spates or freshets) are important for maintaining in-stream habitats by flushing fine sediment out of the system (Reiser *et al.*, 1989; Old and Acreman 2006). The highest flows also play a role in maintaining channel carrying capacity and form. Similarly, artificially low flows can result in fine sediment being deposited in the channel. This can clog interstitial spaces in the substrate, thus reducing available fish spawning habitat (Carling and McCahon, 1987; Crisp, 1989) and invertebrate refugia (Wood and Armitage, 1999; Milan *et al.*, 2000).
- Temperature changes. Artificially low flows may increase water temperatures, by allowing heat and ambient air temperature to impact the water (Webb *et al.*, 2003). Increases in water temperature will affect the river fauna and flora (Richardson *et al.*, 1994). Temperature has a direct effect on metabolic processes, while increased temperature increases biochemical reaction rates and can cause wide fluctuations in dissolved oxygen levels. Temperatures over 22°C will have serious negative effects on salmonids (Elliott, 1994).
- Disruption to migratory passages. Low flows can impede the migration of salmonids and limit the distribution of spawning fish (Stevens, 1999; Environment Agency, 2004; Old and Acreman 2006). The upper reaches of river catchments are often very important for juvenile salmonid production; however these areas may not be accessible to upward migrating fish at low flows. A reduction in fisheries production may jeopardise angling participation, resulting in the loss of social and economic benefits to local communities (Willis and Garrod, 1999) and onward investment in river management and conservation projects.
- Reduced growth of aquatic flora (Franklin *et al.* 2008; Wilby *et al.* 1998; Herne and Armitage, 1997). Low flows can inhibit the growth of certain aquatic plants, such as *Ranunculus*. Reduced *Ranunculus* growth can have significant knock-on effects for invertebrates and fish.
- Reduced connectivity with floodplains and riparian margins. Functioning floodplains have a major influence on in-channel processes, for example by providing inputs of nutrients and refugia and breeding habitat, essential to the life cycles of many riverine species (Bunn and Arthington, 2002).

These mechanisms of impact are reasonably well known and the science of Environmental Flows is young, but developing rapidly (Acreman and Dunbar, 2004). However, it can still be very difficult to diagnose the ecological impacts of low flows in any particular situation. There are several reasons for this, but particularly important are:

- the availability of sufficient hydrological data, on historical flows and actual water use (for many abstractions only licensed amounts are available);

- the availability of sufficient ecological data, as variability in natural systems is often high even without human impacts. Furthermore, introductions and stocking can confound hydroecological relationships;
- the presence of additional stressors such as historical channel modification and water quality impacts. Impacts tend to go together and a river ecosystem will respond to an integration of the impacts; hence separating impacts caused by an individual stressor (such as abstraction) alone can be difficult.

Some of the most acute problems with over-abstraction have been found in chalk stream systems, where naturally up to 95% of the flow is derived from underground aquifers (Owen, 1991). The catchments of chalk streams provide underground reservoirs of generally high quality groundwater which can be abstracted for public supply. Under natural conditions chalk streams provide a stable environment with flow and temperature changing only gradually through time (Berrie, 1992). This, along with the natural water chemistry, makes the English chalk stream one of the most morphologically diverse and productive riverine habitats (Mantle and Mantle, 1992; Bowes *et al.*, 2005). They support populations of fish, including important salmonid fisheries (Mann, 1971) and aquatic invertebrates (Wright, 1992). Low flow periods, which are artificially lower for longer, can change the physical and biological attributes of these waterbodies. Abstraction for public water supply and industry has dramatically reduced the flow in many chalk streams and, in some cases, completely dried up sections of these important rivers, particularly during dry summers, when public demand is at its highest. This also has an economic impact to local communities, resulting from the inability to fish or undergo other recreational activities (Willis and Garrod, 1999).

### **Current Management**

The Environment Agency is responsible for managing water systems and abstraction licenses in England and Wales. Its duties stem from the 1963 Water Resources Act, and they are required to balance the licensing of water abstraction for the needs of water users with the needs of the environment. Historically this was undertaken on a piecemeal basis, with many local precedents and "rules of thumb". A general principle was the protection of the lowest flows, commonly those experienced naturally only 5% of the time, through the use of "hands off flows"; specific flow criteria at which abstraction had to cease or be significantly reduced.

In May 1997, the Government held a Water Summit with all key stakeholders, to review the Water Resources Act abstraction licensing system. This resulted in the 1999 publication of 'Taking Water Responsibly', which announced changes to the water abstraction licensing system in England and Wales. The legislative changes were realised in the 2003 Water Act, which included (Defra, 2008):

- Time limits for all new abstraction licences
- Facility to revoke abstraction licences causing serious environmental damage without compensation
- Greater flexibility to raise or lower licensing thresholds
- Deregulation of small and environmentally insignificant abstractions
- Licensing extended to abstractors of significant quantities presently outside the licensing system
- Water company drought plans and water resource management plans to become a statutory requirement.

The non legislative changes included;

### **Catchment Abstraction Management Strategies (CAMS)**

CAMS were developed as a response to the requirements of 'Taking Water Responsibly' and to provide a consistent mechanism for managing water use through catchment planning and licensing. The Resource Assessment and Management (RAM) framework within CAMS provides information on water availability at a catchment scale (Dunbar *et al.*, 2004). This assessment is based on the requirements of river ecosystems and other water users. CAMS were designed to provide the information necessary for the review of existing time-limited licences and for the assessment of new time-limited licenses.

The first formal cycle of CAMS commenced in 2001, and concluded in March 2008. A review of the first cycle of the CAMS process has been undertaken (the Managing Water Abstraction Interim update (Environment Agency, 2008)). With the implementation of the Water Framework Directive, CAMS will no longer be produced on their own cyclical programme, but will feed into the WFD River Basin Planning process. Research undertaken to set abstraction limits to achieve 'Good Ecological Status' under WFD (Acreman *et al.*, 2008a) has now been included within revisions to the RAM framework. Appropriate managed flow releases from reservoirs have been investigated (Acreman *et al.*, 2008b) but have proved difficult to define simple rules, as each reservoir is unique, site specific studies are usually required.

### **Restoring Sustainable Abstraction (RSA) Programme**

The RSA Programme was set up by the Environment Agency in 1999 to identify sites which may be at risk from abstraction, and to prioritise how to resolve the conflicts in these areas, including sites classified under the European Habitats Directive, and designated as Sites of Specific Scientific Interest (SSSI). It is a successor to the Alleviation of Low Flows (ALF) programme, which during the 1990s targeted 40 rivers believed to be suffering most because of artificially low flows. An ongoing review is taking place (Environment Agency, 2008) to identify environmental damage still occurring as a result of abstraction, focusing on sites designated under the Habitats and Birds Directives.

Since April 2004 all new abstraction licenses must incorporate a time limit; meaning a start and expiry date. The Environment Agency has the power, under existing legalisation, to vary or revoke abstraction licenses causing environmental damage, however, in many circumstances, such as permanent licences, this requires compensation to be paid to the licence holder. With most existing abstraction licenses being permanent (Environment Agency, 2005), the need for compensation is preventing progress to remove the damaging abstractions. For example, eight years of consultation on how to alleviate over-abstraction of the Rivers Brennand and Whitendale in the upper Ribble catchment, which results in important salmonid spawning and nursery areas being reduced to pools in the drier months, has ended in no changes to the current abstraction licences, because no funds are available to compensate water companies for taking less water.

There is also concern over the effectiveness of the CAMS process in aquifer-fed catchments such as the Bourne Rivulet, where the Environment Agency are still allowing high levels of winter abstraction in the Test & Itchen CAMS. This is deemed acceptable because of high seasonal rainfall, but continuing abstraction during these winter months is jeopardising replenishment of the aquifer, with potential to impact the ecology of the Bourne Rivulet.

Despite the conservation of aquatic biodiversity and ecosystem health being embedded in current policies, there seems to be little political will to prioritise it. Environmental protection tends to favour small scale site protection or rehabilitation. However, structural river restoration will provide very little environmental benefit if other key stressors on the system are not removed. The conservation of running water systems requires the restoration of the underlying processes that support the biota. Restoring natural flow regimes is fundamental to improving aquatic habitats, and increasing biodiversity. Restoring flow regimes should not be considered in isolation, but linked with water quality and morphology targets.

One approach to incorporate environmental flows into water resource management is using ecologically acceptable flow regimes (EAFR). EAFR uses 1) environmental flows to assess short-term and local operational rules, 2) ecologically acceptable hydrographs to manage inter-annual flows and 3) ecologically acceptable flow duration curves. This approach considers the hydrological variables, such as flow magnitude, timing, frequency and duration, in order to meet ecological targets.

### **Action Required**

The S&TA believes that WFD compliance will be compromised if further action is not taken to address damaging abstractions through altering their licenses. This could lead to the EU initiating legal infraction proceedings against the UK Government.

S&TA seeks:

- Action to make all existing licences time limited, and to remove the requirement to provide compensation to the licence holder if the abstraction is causing environmental damage.
- An urgent review of the CAMS process to 1) make allowances for inadequacies in historical flow data in assessing future flows and water availability, 2) take full account of the necessary dilution requirements needed to reduce the impact of consented discharges and diffuse pollution and 3) to enforce the Precautionary Principle where limited data exist.
- The Government to quantify the effectiveness of the Restoring Sustainable Abstraction Programme.
- Action to create more natural flow regimes and river and stream morphologies in order to buffer the ecological impacts of climate change.
- Sufficient funding for monitoring, so the impacts of abstraction can be separated from other stressors to provide clear evidence of the environmental damage caused by abstractions, and research to distinguish human impacts on flow regimes from the effects on climate change.

## Conclusions

River flows help create and maintain in-river morphology, riparian zones and floodplains, and create habitat for their fauna and flora. Flows help sustain water quality by flushing nutrients, contaminants and sediments (thus protecting spawning gravels) from the fluvial system. The magnitude, timing, frequency and duration of high and low flow events are critical to all elements of the river biota.

Increasing human populations and escalating demand on freshwater resources, coupled with mounting concerns about environmental change, higher the need to protect, maintain and restore natural riverine flows. Action is required now to create more natural running water systems in order to improve ecosystem health and provide resilience to climate change.

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