BACKGROUND AND CONTEXT

- Upstream Thinking aims to improve water quality through catchment interventions tackling a number of sources of point source and diffuse pollution issues in 11 catchments across Devon and Cornwall.
- The University of Exeter has been monitoring water quality at catchment scale in a number of test catchments to assess the impact of catchment interventions.
- Water quality problems encountered within catchments include: colour, dissolved organic carbon, turbidity (or sediment pollution), nutrient inputs to reservoirs causing eutrophication, taste and odour compounds, and pesticides.

Understanding and reducing water pollution

The input of contaminants to freshwater resulting from land use, agriculture and wastewater treatment has an impact on the ecology and the health of the waterbody, but also on the production of drinking water, as pollution has to be removed before water is fit for human consumption. This is especially important in South West England, where most drinking water is sourced from surface waters (i.e. rivers and reservoirs). Two different types of pollution are generally considered:

- **Point source pollution:** this type of pollution occurs as contaminants are directly discharged to a body of water in a specific location. These sources of contaminants can include sewage, leaking pipes, farmyard effluents, slurry pits or septic tanks, or accidental spillage of waste into waters; they tend to have the worst impact in summer conditions when the river level is low with less dilution potential.
- **Diffuse pollution:** diffuse pollution happens as a result of the increased overland and subsurface flow occurring from rainfall falling on agricultural land (Figure 1). In its journey to the river system, this flow of water will wash contaminants (e.g. soil, nutrients, herbicides or pesticides) from farmland; this is especially a problem on land that is steep and farmed intensively, right up to stream and riverbanks.

Figure 1 Examples of poor soil management: cattle poaching in Cornwall (top) and dirty water runoff onto the road in the Fowey catchment (bottom); photos by CWT (top) and Giles Rickard, WRT (bottom).

The main pollutants from agriculture are nutrients (phosphate and nitrate in particular), chemicals (e.g. pesticides), faecal bacteria and pathogens from livestock, and soil or sediment from erosion. A number of activities have been identified as causing pollution. For instance, the poor management of slurry and manure can lead to increased leaching of nutrients, whilst the lack of vegetation or barriers in fields can cause sediment loss and water runoff that will enter streams directly.

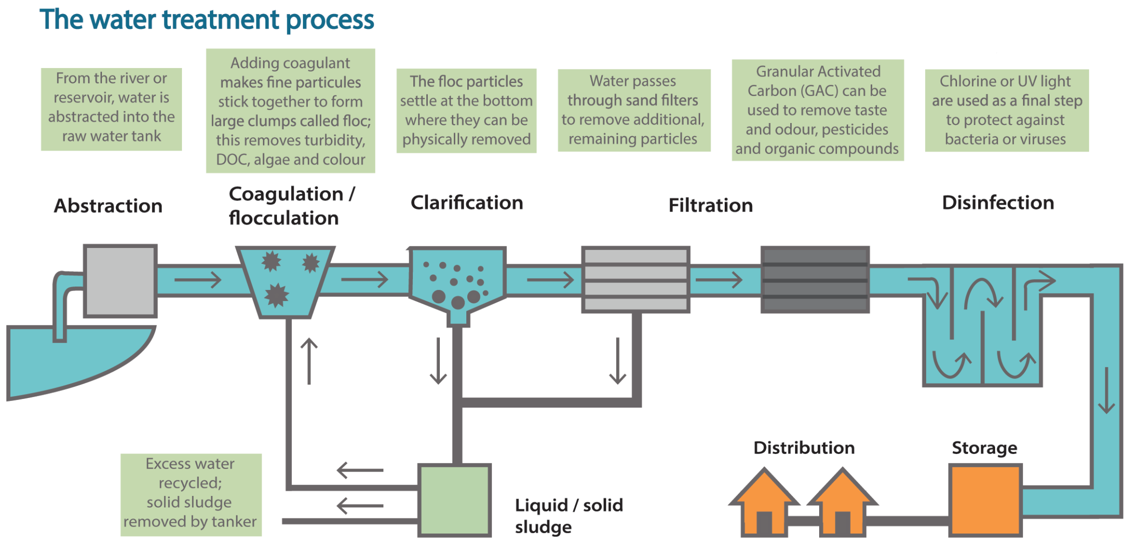
In addition to affecting the ecology and the health of waterbodies, water pollution has a major impact on the production of drinking water. The removal of contamination at water treatment works (WTWs) (Figure 2) is necessary to make water safe for drinking and meet health regulations. The process traditionally involves a number of steps, such as coagulation/flocculation and filtration (Figure 3), which use chemicals and produce waste. The efficiency and cost of production is therefore highly dependent on the quality of the raw water abstracted from rivers. Additionally, high levels of contaminants can lead to a temporary WTW shutdown, when removal is impossible. Such events are expensive and put pressure on the supply network, but can also trigger fines and penalties from either the Drinking Water Inspectorate (DWI) or the regulator OfWat.

Today, throughout the country, **catchment management** has been used as a way to effectively address pollution; a number of practical methods are now widely employed as effective remedies. The overall aim of such an approach is to use sustainable measures by working with farmers and land owners to reduce diffuse and point source pollution to water, improve wildlife and natural habitats, and positively impact on the treatment of water and its cost.

This approach is guided by a number of drivers and regulations, such as the EU Water Framework Directive (WFD) that requires water bodies to meet 'good' ecological status, or the Nitrates Directive to reduce the impact of nitrogen fertilisers on the environment. For the water industry, this has translated into legal requirements set out for South West Water by the Drinking Water Inspectorate and the Environment Agency.

Figure 2 Mayflower WTW in 2019, providing drinking water for the Plymouth area; photo by South West Water.

Figure 3 The different steps of water treatment used to remove contaminants and produce safe drinking water.



Upstream Thinking

Upstream Thinking is an award winning catchment management scheme set up by **South West Water** (SWW). Using natural landscape-scale solutions and on-farm mitigation measures, the project aims to work with farmers, landowners and project partners to mitigate the impact of farming activities on river ecosystems in the lowlands, and therefore on the production of drinking water. In the uplands, the actions are focused on restoring large peatland areas on Exmoor and Dartmoor through the Mires project[1].

Since the second phase of the project starting in 2015, **Cornwall Wildlife Trust** (CWT), **Devon Wildlife Trust** (DWT), **Exmoor National Park** (ENPA), the **Farming and Wildlife Advisory Group** (FWAG) and **Westcountry Rivers Trust** (WRT) have been engaging with land owners in 11 catchments (Figure 4) to identify challenges and opportunities within the farm business. Discussion with farm advisors will generally lead to the recommendation of costed interventions available through a number of funding streams.

Supporting and encouraging farmers to adopt active management practices, as laid out in the farm plans, is a key ambition of Upstream Thinking. Between 2015 and 2020, project partners have collectively established 864 integrated farm management plans and allocated capital grants to a value of £10.5m through SWW funding and £15.4m through match funding, bringing the total investment in catchment management in the south west region to £25.9m.

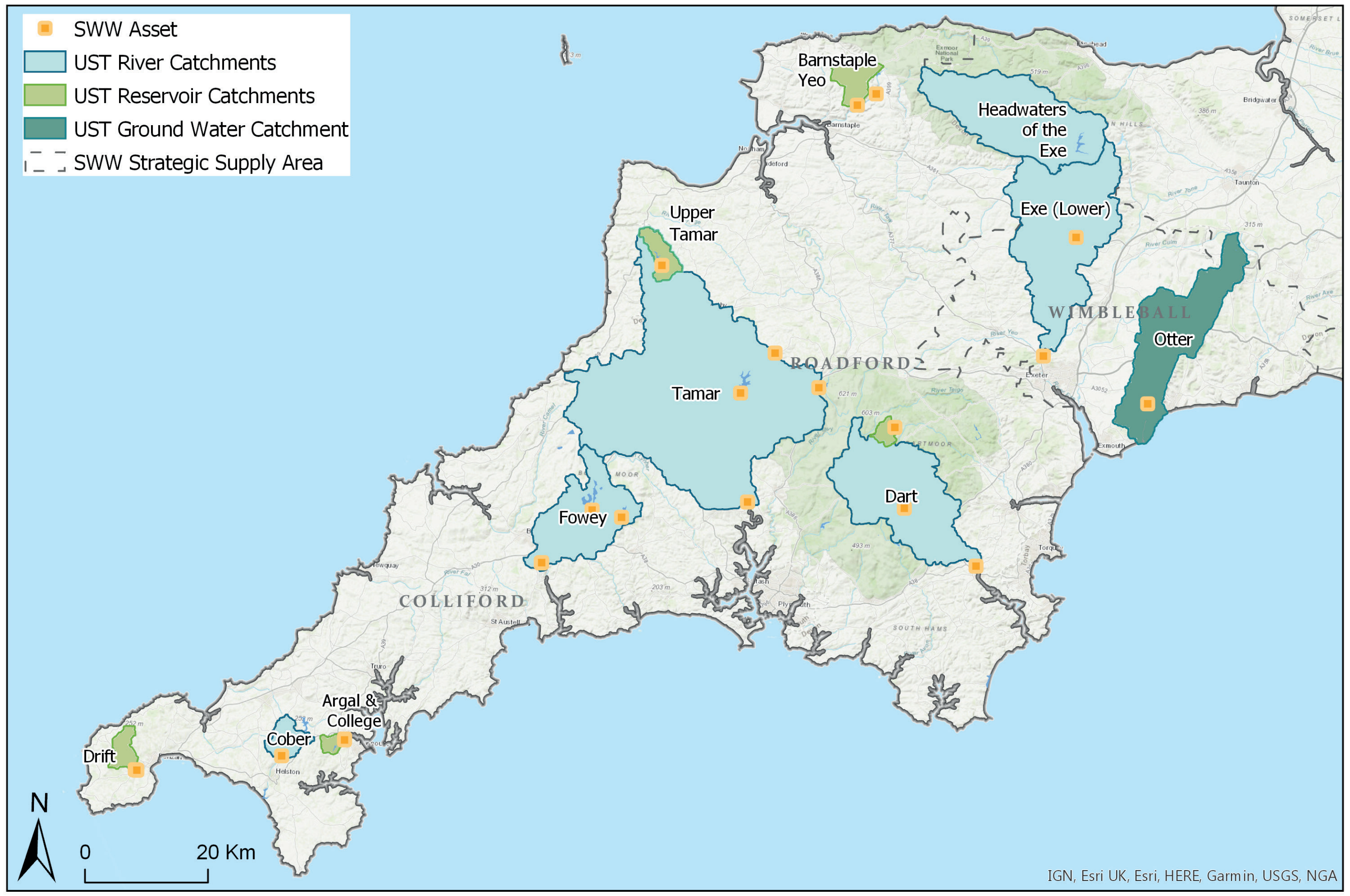


Figure 4 Upstream Thinking catchments and SWW assets (i.e. drinking water treatment works and abstraction points) within the supply areas in the Southwest region; this map also highlights the type of water supply to the water treatment works, i.e. reservoir, river or groundwater.

Understanding change

Overall, Upstream Thinking has delivered demonstrable environmental benefits, such as mire[1,2] or culm grassland[3] habitat restoration or improvement of local biodiversity and water body ecological status. However, whilst the change occurring as a result of the interventions can be identified on a site-by-site basis, the case has yet to be made for significant changes in water quality at large catchment scale where benefits may reduce the costs of water treatment. As a result, a monitoring programme has been set up by the **University of Exeter** (UoE) to address this need and to evaluate the impact of interventions delivered under the second phase of the project (2015-2020) in the target catchments. Additionally, UoE has also been monitoring water quality for the Headwaters of the Exe project (HotE) delivered by ENPA as part of the Upstream Thinking programme.

Within the catchments included in Upstream Thinking (Figure 4), this report focuses on results obtained during the second phase of the project (2015-2020) in a number of test catchments that are representative of the different types of water sources used for drinking water production in the south west region:

- **River catchments:** River Exe (Headwaters of the Exe and Lower Exe), River Fowey and River Cober;
- **Reservoir catchments:** Drift, Argal and Upper Tamar Lake.

The work presented here classifies and maps some of the in-catchment interventions delivered by project partners to reduce water pollution, identifies change (both observed and modelled) for a number of parameters in each catchment, and highlights some of the physical processes that may have occurred.

The mid-Devon hills; photo by DWT.

The main water quality issues affecting catchments in the south west are the following:

Colour in drinking water comes from organic compounds, including dissolved organic carbon, and metal ions (e.g. manganese) leaching from the environment. Colour is therefore largely dependent on agricultural practices and driven by the accelerated drainage of the land. Colour is removed by coagulation and flocculation (Figure 3). Left untreated, excess colour can cause unsightly drinking water and can exceed regulatory standards. The limit for colour in drinking water at the consumer's tap[4] is 20 mg L^{-1}.

Dissolved organic carbon (DOC) is a term defining a range of compounds causing discolouration of water. It originates from peatlands and other organic-rich soils, or excess application of manures and slurries to the land. DOC has an ability to bind to heavy metals, and gives water a tea colour that has to be removed by coagulation. At the catchment scale, DOC in water is an issue because it represents a loss of carbon from a long-term store, and therefore has a negative impact on global mitigation of climate change. It is a particular problem for the water industry as it is costly to remove and its improper removal can react with chlorine and cause the formation of carcinogenic compounds (e.g. trihalomethanes) in drinking water. There is no regulatory concentration in drinking water specifically for DOC.

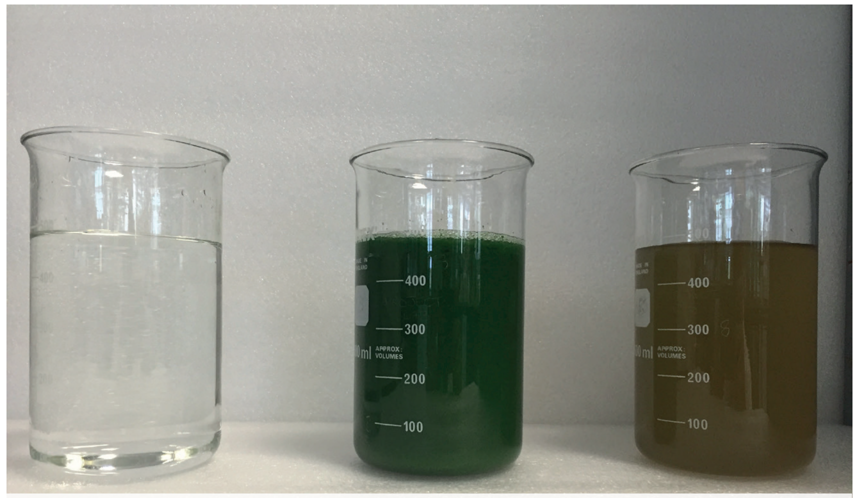
Suspended sediment (SS) refers to particles over 2 µm present in water, made out of inorganic (e.g. clay, silt and soil particles) and organic (e.g. algae, bacteria) material. SS is measured by weighing the mass of sediment present in a set volume of water.

Turbidity is closely related to SS. It is defined as a measure of the transparency of the water in the presence of particles in suspension, such as organic waste material, soil, sediment, algae or bacteria. Turbidity mostly originates from erosion of soil and agricultural material, and has detrimental impacts on the ecosystem, including blocking light penetration and clogging the gills of fish. In drinking water, the main issue with turbidity is caused by its aesthetic impact; in the treatment process, it is removed by coagulation and filtration. However, the process is unable to treat raw water with turbidity values above 20 NTU, whilst **legal requirements** limit concentrations at consumer's taps to 4 NTU.

Nutrients (i.e. forms of nitrogen or phosphorus) are essential for plant growth. In surface waters, they originate from fertilisers, runoff from manure or sewage and/or sediment input from point source or diffuse pollution. At high concentrations, they promote algal growth and have toxic effects on aquatic organisms. These excess nutrients, such as **Soluble Reactive Phosphorus** (SRP) and **nitrate** (NO_3), can lead to **eutrophication**, likely to promote algal blooms (see below). Nitrate can be removed from raw water by ion exchange. **Ammonium** (NH_4) concentrations over 2 mg L^{-1} in raw water lead to treatment interruptions.

A feeder stream to the Drift reservoir; photo by Emilie Grand-Clement.

BACKGROUND AND CONTEXT



Water quality issues encountered in streams and reservoirs in the South West: high suspended sediment loading from a stream after a rainfall event (right), acute blue-green algal bloom in reservoir (middle) compared with drinking water after the treatment process (left); photo by Paul Henderson.

Blue-green algal (i.e. cyanobacteria) blooms are a recurrent problem in drinking water reservoirs. Blooms form as a result of the rapid and extensive multiplication of cyanobacteria. They are driven by high concentrations of nutrients in the reservoir and by environmental factors (i.e. warm and still conditions). They are problematic for the ecology of the resevoir (e.g. oxygen depletion, prevention of light penetration), cause discolouration of the water, produce harmful cyanotoxins, and release taste and odour compounds as they die-back. Cyanobacteria are removed from raw water through coagulation, flocculation and clarification, followed by various stages of filtration. However, along with other phytoplankton species, the sheer volume to be removed can cause issues during the filtration of water. There is no statutory limit for algae concentrations in drinking water.

Taste and odour compounds, such as geosmin and 2-Methylisoborneol (MIB), originate from algae die-back and from soil bacteria. These compounds give the water a musty taste and smell and are removed through granular activated carbon (Figure 3).

Pesticides originating from both domestic and agricultural usage are a significant issue in most catchments[5]. They present an issue for non-target species (including humans), habitats and ecosystems. The UK drinking water quality regulations specify standards in drinking water of 100 ng L^{-1} (equivalent to 0.1 µg L^{-1}) per compound, or 500 ng L^{-1} (equivalent to 0.5 µg L^{-1}) for total pesticides. Pesticides are removed by activated carbon. **Metaldehyde** is a type of pesticide found in slug pellets and widely used in a number of catchments. It is of particular concern for drinking water production because its degradation in water is particularly slow, making it "semi-permanent" in aquatic ecosystems[6], but also because its removal from water using conventional treatment processes is difficult and therefore costly[7].

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